Step 1 of 3

1.4.1e

Refer to circuit diagram in Figure E4.1 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_-}{2\text{ k}} = \frac{v_o - v_-}{12\text{ k}}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Substitute 12 V for v_- in the expression.

$$\frac{v_-}{2\text{ k}} = \frac{v_o - v_-}{12\text{ k}}$$

$$\frac{12}{2} = \frac{v_o - 12}{12}$$

$$v_o - 12 = 72$$

$$v_o = 84\text{ V}$$

Step 3 of 3

Write the expression for the current I_o:

$$I_o = \frac{V_o}{10\text{k}}$$

Substitute 84 V for V_o in the equation.

$$\begin{aligned} I_o &= \frac{V_o}{10\text{ k}} \\ &= \frac{84\text{ V}}{10\text{ k}} \\ &= 8.4\text{ mA} \end{aligned}$$

Therefore, the current I_o is $\boxed{8.4\text{ mA}}$.

Step 1 of 2

1.4.1fe

Refer to Figure 4PFE-1 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$I_1 + I_2 = I_3$$

$$\frac{4 - v_-}{4} + \frac{-2 - v_-}{12} = \frac{v_- - V_o}{R_2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute 0 for v_- and $-3\,\text{V}$ for V_o in the equation.

$$\frac{4 - v_-}{4} + \frac{-2 - v_-}{12} = \frac{v_- - V_o}{R_2}$$

$$\frac{4 - 0}{4} + \frac{-2 - 0}{12} = \frac{0 - (-3)}{R_2}$$

$$\frac{3}{R_2} = 1 - \frac{1}{6}$$

$$R_2 = 3.6\,\text{k}\Omega$$

Hence, the value of resistance R_2 is $3.6\,\text{k}\Omega$.

Therefore, the correct option is $\boxed{\text{c}}$.

Step 1 of 3

1.4.1p

Refer to waveform shown in Figure P4.1 in the textbook.

The value of gain (A_o) is 15.

It is known that, for an amplifier the output voltage is,

$$v_o = A_o v_{in}$$

Calculate the output voltage at $t = 0$.

$$\begin{aligned} v_o &= 15(0\text{ mV}) \\ &= 0\text{ V} \end{aligned}$$

Calculate the output voltage at $t = 0.5^+$.

$$\begin{aligned} v_o &= 15(50\text{ mV}) \\ &= 750\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 0.5^-$.

$$\begin{aligned} v_o &= 15(-100\text{ mV}) \\ &= -1500\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1^+$.

$$\begin{aligned} v_o &= 15(0) \\ &= 0\text{ V} \end{aligned}$$

Step 2 of 3

Calculate the output voltage at $t = 1^-$.

$$\begin{aligned} v_o &= 15(-150\text{ mV}) \\ &= -2250\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1.5^+$.

$$\begin{aligned} v_o &= 15(50\text{ mV}) \\ &= 750\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1.5^-$.

$$\begin{aligned} v_o &= 15(0\text{ mV}) \\ &= 0\text{ V} \end{aligned}$$

Calculate the output voltage at $t = 2$.

$$\begin{aligned} v_o &= 15(0) \\ &= 0\text{ V} \end{aligned}$$

Step 3 of 3

The output waveform is shown in Figure 1.

Figure 1

Therefore, the output waveform for the amplifier is shown in Figure 1.

Refer to circuit diagram in Figure E4.2 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Substitute the values V_S for v_- in the expression.

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

$$\frac{V_S}{R_1} = \frac{V_o - V_S}{R_2}$$

$$\frac{V_o}{R_2} = V_S\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

Therefore, the gain of the op-amp is $\boxed{1 + \frac{R_2}{R_1}}$.

Step 1 of 3

1.4.2FE

Refer to Figure 4PFE-2 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the first op-amp.

$$I_1 + I_2 = I_3$$

$$\frac{2-v_-}{6} + \frac{-1-v_-}{12} = \frac{v_- - v_x}{18}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute the values $v_- = 0$ in the expression.

$$\frac{2-v_-}{6} + \frac{-1-v_-}{12} = \frac{v_- - v_x}{18}$$

$$\frac{2-0}{6} + \frac{-1-0}{12} = \frac{0-v_x}{18}$$

$$\frac{v_x}{18} = \frac{1}{12} - \frac{2}{6}$$

$$v_x = -4.5\,\text{V}$$

Step 3 of 3

Write the node equation at the inverting terminal of the second op-amp.

$$I_4 + I_5 = I_6$$

$$\frac{v_x - v_-}{6} + \frac{3-v_-}{12} = \frac{v_- - V_o}{36}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute the values $v_- = 0$ and $v_x = -4.5\,\text{V}$ in the expression.

$$\frac{v_x - v_-}{6} + \frac{3-v_-}{12} = \frac{v_- - V_o}{36}$$

$$\frac{-4.5-0}{6} + \frac{3-0}{12} = \frac{0-V_o}{36}$$

$$\frac{V_o}{36} = \frac{4.5}{6} - \frac{3}{12}$$

$$V_o = 18\,\text{V}$$

Hence, the output voltage V_o is $18\,\text{V}$.

Therefore, the correct option is $\boxed{b}$.

Step 1 of 2

1.4.2P

Consider the waveform shown in textbook Figure P4.2. The waveform is the output of an amplifier with gain -5. We know that $v_{in} = \frac{v_o}{A_o}$

Where $A_0 = -5$

The output voltage values from the waveform with respect to time instants are

$v_0 = 0, 4, 12, 12, 12, 8, 0$ at $t = 0$ to 6 respectively

$v_0 = -8$ at $t = 6^-$

And

$v_0 = -12, -6, 0$ at $t = 7$ to 9 respectively

From the output voltage values, we can find the voltage values from the above equation.

Therefore at

$t = 0$

$v_{in} = \frac{0}{-5}$

$= 0$ V

$t = 1$

$v_{in} = \frac{4}{-5}$

$= -0.8$ V

$t = 2$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 3$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 4$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 5$

$v_{in} = \frac{8}{5}$

$= 1.6$ V

$t = 6^+$

$v_{in} = 0$ V

$t = 6^-$

$v_{in} = \frac{-8}{-5}$

$= 1.6$ V

$t = 7$

$v_{in} = \frac{-12}{-5}$

$= 2.4$ V

$t = 8$

$v_{in} = \frac{-6}{-5}$

$= 1.2$ V

$t = 9$

$v_{in} = 0$ V

Step 2 of 2

From the above voltage values, the input waveform is

Figure 1

Therefore the input waveform for the given amplifier is as shown in Figure 1.

Step 1 of 4

1.4.3E

Refer to circuit diagram in Figure E4.3 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 4

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_- - 0}{1} = \frac{V_o - v_-}{100}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Substitute 1 mV for v_- in the expression.

$$\frac{v_- - 0}{1} = \frac{V_o - v_-}{100}$$

$$\frac{V_S}{R_1} = \frac{V_o - V_S}{R_2}$$

$$\frac{V_o}{R_2} = V_S\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

Step 3 of 4

Calculate the gain of the op-amp circuit by substitute $1\text{ k}\Omega$ for R_1 and $100\text{ k}\Omega$ for R_2 in the equation.

$$\begin{aligned}\frac{V_o}{V_S} &= 1 + \frac{R_2}{R_1}\\ &= 1 + \frac{100\text{ k}\Omega}{1\text{ k}\Omega}\\ &= 1 + 100\\ &= 101\end{aligned}$$

Therefore, the gain of the op-amp is $\boxed{101}$.

Step 4 of 4

Write the expression for the gain of the op-amp circuit.

$$\frac{V_o}{V_S} = 101$$

Calculate the output voltage of the op-amp by substitute 1 mV for V_S in the equation.

$$\begin{aligned}\frac{V_o}{V_S} &= 101\\ V_o &= (101)V_S\\ &= (101)(1\text{ mV})\\ &= 0.101\text{ V}\end{aligned}$$

Therefore, the output voltage of the op-amp is $\boxed{0.101\text{ V}}$.

Step 1 of 2

1.4e

Consider the circuit given in Figure E1.4 (a) in the text book having voltage $V_s = 4\text{ V}$.

Calculate the power *P* supplied by the dependent source $10V_s$ having current I_o as follows:

$$\begin{aligned} P &= (10V_s)(-I_o) \\ &= (10)(4\text{ V})(-2\text{ A}) \\ &= (40)(-2) \\ &= -80\text{ W} \end{aligned}$$

Therefore, the power supplied by the dependent source in the Figure E1.4 (a) is $\boxed{80\text{ W}}$.

Step 2 of 2

Consider the circuit given in Figure E1.4 (b) in the text book having current $I_s = 4\text{ A}$

Calculate the power *P* supplied by the dependent source $4I_s$ as follows:

$$\begin{aligned} P &= (10\text{ V})(-4I_s) \\ &= (10\text{ V})(4)(-4\text{ A}) \\ &= (10)(4)(-4) \\ &= -160\text{ W} \end{aligned}$$

Therefore, the power supplied by the dependent source in the Figure E1.4 (b) is $\boxed{160\text{ W}}$.

Step 1 of 2

1.4p

Consider that a battery having voltage, $V = 12\ \text{V}$ delivers the energy, (Δw) of $100\ \text{J}$ in a time period, (dt) of 5 seconds.

(a)

Calculate the amount of charge, (q) delivered.

$$\begin{aligned} dq &= \frac{dw}{V} \\ &= \frac{100\ \text{J}}{12\ \text{V}} \\ &= \frac{100}{12} \\ &= 8.33\ \text{C} \end{aligned}$$

Therefore, the amount of delivered charge is $\boxed{8.33\ \text{C}}$.

Step 2 of 2

(b)

Calculate the value of current (i) produced.

$$\begin{aligned} i &= \frac{dq}{dt} \\ &= \frac{8.33\ \text{C}}{5\ \text{s}} \\ &= \frac{8.33}{5} \\ &= 1.67\ \text{A} \end{aligned}$$

Therefore, the value of current produced is $\boxed{1.67\ \text{A}}$.

Step 1 of 3

1.5e

Consider the circuit of Figure E1.5 given in the text book.

Calculate the power $(P_{24\text{ V}})$ absorbed or supplied by the voltage source having voltage $V = 24\text{ V}$ and current $I_x = 4\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_{24\text{ V}} &= (V)(-I_x) \\ &= (24\text{ V})(-4\text{ A}) \\ &= (24)(-4) \\ &= -96\text{ W} \end{aligned}$$

Therefore, the sign of power is negative and so the 24 V voltage source supplies a power of $\boxed{96\text{ W}}$.

Step 2 of 3

Calculate the power (P_1) that is absorbed or supplied by element '1' having voltage $V = 8\text{ V}$ and current $I_x = 4\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_1 &= (V)(I_x) \\ &= (8\text{ V})(4\text{ A}) \\ &= (8)(4) \\ &= 32\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element '1' absorbs the power of $\boxed{32\text{ W}}$.

Step 3 of 3

Calculate the power P_{4I_x} that is absorbed or supplied by the $4I_x$ dependent source having voltage $V = 4I_x$ and current $I_x = 4\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_{4I_x} &= (4I_x)(I_x) \\ &= (4)(4\text{ A})(4\text{ A}) \\ &= (4)(4)(4) \\ &= 64\text{ W} \end{aligned}$$

Therefore, the sign of power is positive so the $4I_x$ dependent source absorbs the power of $\boxed{64\text{ W}}$.

1.5p

Consider that the current, (i) in a conductor is $1.5\ \text{A}$ and the time interval, (dt) is 1.5 minutes.

Calculate the value of charge, (q).

$$\begin{aligned} q &= i(dt) \\ &= (1.5\ \text{A})(1.5 \times 60\ \text{s}) \\ &= (1.5)(1.5)(60) \\ &= 135\ \text{C} \end{aligned}$$

Therefore, the charge passing through any point in the conductor is $\boxed{135\ \text{C}}$.

Step 1 of 5

1.6e

Consider the circuit of Figure E1.6 given in the text book.

Calculate the power $(P_{24\text{ V}})$ that is absorbed or supplied by the voltage source having voltage $V = 24\text{ V}$ and current $I_x = 1.5\text{ A}$ by using sign convection of power as follows:

$$\begin{aligned} P_{24\text{ V}} &= (V)(-I_x) \\ &= (24\text{ V})(-1.5\text{ A}) \\ &= (24)(-1.5) \\ &= -36\text{ W} \end{aligned}$$

Therefore the sign of power is negative and so the 24 V voltage source supplies a power of $\boxed{36\text{ W}}$.

Step 2 of 5

Calculate the power P_{2I_x} that is absorbed or supplied by the dependent source having voltage $V = 2I_x$ and current $I_x = 1.5\text{ A}$ by using sign convection of power as follows:

$$\begin{aligned} P_{2I_x} &= V(-I_x) \\ &= (2I_x)(-I_x) \\ &= (2)(1.5\text{ A})(-1.5\text{ A}) \\ &= -4.5\text{ W} \end{aligned}$$

Therefore the sign of power is negative and so the $2I_x$ dependent source supplies a power of $\boxed{4.5\text{ W}}$.

Step 3 of 5

Calculate the power (P_1) that is absorbed or supplied by element '1' having voltage $V = 6\text{ V}$ and current $I_x = 1.5\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_1 &= V(I_x) \\ &= (6\text{ V})(1.5\text{ A}) \\ &= (6)(1.5) \\ &= 9\text{ W} \end{aligned}$$

Therefore the sign of power is positive and so the element '1' absorbs the power of $\boxed{9\text{ W}}$.

Step 4 of 5

Calculate the power $(P_{12\text{ V}})$ that is absorbed or supplied by voltage source having voltage $V = 12\text{ V}$ and current $I_x = 1.5\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_{12\text{ V}} &= V(I_x) \\ &= (12\text{ V})(1.5\text{ A}) \\ &= (12)(1.5) \\ &= 18\text{ W} \end{aligned}$$

Therefore the sign of power is positive and so the 12 V voltage source absorbs the power of $\boxed{18\text{ W}}$.

Step 5 of 5

Calculate the power (P_2) that is absorbed or supplied by element '2' having voltage $V = 9\text{ V}$ and current $I_x = 1.5\text{ A}$ by using passive sign convection as follows:

$$\begin{aligned} P_2 &= V(I_x) \\ &= (9\text{ V})(1.5\text{ A}) \\ &= (9)(1.5) \\ &= 13.5\text{ W} \end{aligned}$$

Therefore the sign of power is positive and so the element '2' absorbs the power of $\boxed{13.5\text{ W}}$.

1.6p

Consider that the charge, (q) of $60\ \mathrm{C}$ is passing through an electric conductor in time period, (dt) of 30 seconds.

Calculate the value of current, (i) passing in the conductor.

$$
\begin{aligned}
i &= \frac{q}{dt} \\
&= \frac{60\ \mathrm{C}}{30\ \mathrm{s}} \\
&= \frac{60}{30} \\
&= 2\ \mathrm{A}
\end{aligned}
$$

Therefore, the current passing in the conductor is $\boxed{2\ \mathrm{A}}$.

Step 1 of 7

1.7e

Consider the circuit in Figure E1.7 given in the text book.

First calculate all the values of power absorbed or supplied by each element in the network by using the sign convention for power.

Calculate the power (P_1) absorbed or supplied by element '1' in the circuit having voltage $V = 25\text{ V}$ and current $I = 1\text{ A}$ as follows:

$$\begin{aligned} P_1 &= VI \\ &= (25\text{ V})(1\text{ A}) \\ &= (25)(1) \\ &= 25\text{ W} \end{aligned}$$

Step 2 of 7

Calculate the power $(P_{5\text{ A}})$ absorbed or supplied by 5 A current source in the circuit having voltage $V = 25\text{ V}$ and current $I = 5\text{ A}$ as follows:

$$\begin{aligned} P_{5\text{ A}} &= V(-I) \\ &= (25\text{ V})(-5\text{ A}) \\ &= (25)(-5) \\ &= -125\text{ W} \end{aligned}$$

Step 3 of 7

Calculate the power (P_{I_x}) absorbed or supplied by I_x current source in the circuit having voltage $V = 10\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P_{I_x} &= V(-I) \\ &= (10\text{ V})(-I_x) \\ &= -10I_x \end{aligned}$$

Step 4 of 7

Calculate the power (P_2) absorbed or supplied by element '2' in the circuit having voltage $V = 15\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P_2 &= V(-I) \\ &= (15\text{ V})(-I_x) \\ &= -15I_x \end{aligned}$$

Step 5 of 7

Calculate the power (P_3) absorbed or supplied by element '3' in the circuit having voltage $V = 15\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_3 &= VI \\ &= (15\text{ V})(2\text{ A}) \\ &= (15)(2) \\ &= 30\text{ W} \end{aligned}$$

Step 6 of 7

Calculate the power $(P_{10\text{ V}})$ absorbed or supplied by 10 V voltage source in the circuit having voltage $V = 10\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{10\text{ V}} &= VI \\ &= (10\text{ V})(2\text{ A}) \\ &= (10)(2) \\ &= 20\text{ W} \end{aligned}$$

Step 7 of 7

According to Tellegen's theorem sum of the power absorbed or supplied by all the elements in the network is equal to zero as follows:

$$\begin{aligned} &25\text{ W} - 125\text{ W} - 10I_x - 15I_x + 30\text{ W} + 20\text{ W} = 0 \\ &75 - 125 - 25I_x = 0 \\ &25I_x = -50 \\ &I_x = -2\text{ A} \end{aligned}$$

Therefore, by using Tellegen's theorem, the value of I_x is $\boxed{-2\text{ A}}$.

1.7p

Calculate the charge, (q) produced by a battery having current, $i = 12\ \text{A}$ within a time interval (dt) of one hour.

$$
\begin{aligned}
q &= idt \\
&= (12\ \text{A})(60\ \text{min}) \\
&= (12\ \text{A})(60 \times 60\ \text{s}) \\
&= 43.2\ \text{kC}
\end{aligned}
$$

Therefore, the charge produced is $\boxed{43.2\ \text{kC}}$.

Step 1 of 3

1.8e

Consider the circuit given in Figure E1.8 in the text book.

Calculate the energy w delivered to the box by using equation 1.4 given in the textbook as follows:

$$\begin{aligned} w &= \int_{t_1}^{t_2} p(t)\,dt \\ &= \int_{0}^{250\text{ ms}} 2.5e^{-4t}\,dt \\ &= 2.5\int_{0}^{0.25} e^{-4t} \\ &= (2.5)\left(\left.\frac{e^{-4t}}{-4}\right|_{0}^{0.25}\right) \end{aligned}$$

Further simplification is as follows:

$$\begin{aligned} w &= (2.5)\left(\frac{e^{-4(0.25)}}{-4} - \frac{e^{-4(0)}}{-4}\right) \\ &= (2.5)(-0.092 + 0.25) \\ &= (2.5)(0.158) \\ &= 395\text{ mJ} \end{aligned}$$

Therefore, the energy delivered to the box is $\boxed{395\text{ mJ}}$.

Step 2 of 3

Calculate the value of current $i(t)$ in the circuit by using equation 1.3 given in the textbook as follows:

$$\begin{aligned} i(t) &= \frac{p(t)}{v(t)} \\ &= \frac{2.5e^{-4t}\text{ W}}{50e^{-t}\text{ V}} \\ &= \frac{2.5}{50}e^{(-4t+t)} \\ &= 50e^{-3t}\text{ mA} \end{aligned}$$

Step 3 of 3

Calculate the value of charge $(q(t))$ delivered to the box in time interval $0 < t < 250\text{ ms}$ as follows:

$$\begin{aligned} q(t) &= \int_{t_0}^{t_1} i(t)\,dt \\ &= \int_{0}^{0.25} \left(50e^{-3t}\text{ mA}\right)dt \\ &= 0.05\int_{0}^{0.25} e^{-3t}\,dt \\ &= (0.05)\left(\left.\frac{e^{-3t}}{-3}\right|_{0}^{0.25}\right) \end{aligned}$$

Further simplification is as follows:

$$\begin{aligned} q(t) &= (0.05)\left(\frac{e^{-3(0.25)}}{-3} + \frac{e^{-3(0)}}{(-3)}\right) \\ &= -0.00787 + 0.0166 \\ &= 0.0088 \\ &= 8.8\text{ mC} \end{aligned}$$

Therefore the charge delivered to the box is $\boxed{8.8\text{ mC}}$.

Step 1 of 1

1.8p

Consider Figure P1.8 in the textbook.

Consider that the charge, (q) of $5\ \mathrm{C}$ passes through the element from point A to B. Therefore, the equation becomes as $V_1 = \frac{-w}{q}$.

Calculate the voltage, (V_1) for which the energy, (w) absorbed by the element is $120\ \mathrm{J}$.

$$\begin{aligned} V_1 &= \frac{-w}{q} \\ &= \frac{-120\ \mathrm{J}}{5\ \mathrm{C}} \\ &= \frac{-120}{5} \\ &= -24\ \mathrm{V} \end{aligned}$$

Therefore, the voltage across the element is $\boxed{-24\ \mathrm{V}}$.

Step 1 of 5

1.9e

Refer to Figure E1.9 in the textbook for electrical circuit and energy waveform.

The value of source voltage is, 10 V

Write the mathematical expressions for energy waveform.

$$w(t)=\begin{cases}2.5t & 0\le t\le 2\\ 0 & 2\le t\le 4\\ -2.5t+15 & 4\le t\le 6\\ 0 & 6\le t\le 7\\ -2.5t+17.5 & 7\le t\le 8\\ 0 & 8\le t\le 10\\ 1.25t-15 & 10\le t\le 12\end{cases}$$

Write the expression for current in terms of voltage and energy.

$$i(t)=\frac{1}{v}\frac{dw(t)}{dt}$$

Determine the current for $0\le t\le 2$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(2.5t)}{dt}\\&=\frac{1}{10}(2.5)\\&=0.25\text{ A}\end{aligned}$$

Determine the current for $2\le t\le 4$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(0)}{dt}\\&=\frac{1}{10}(0)\\&=0\text{ A}\end{aligned}$$

Determine the current for $4\le t\le 6$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(-2.5t+15)}{dt}\\&=\frac{1}{10}(-2.5)\\&=-0.25\text{ A}\end{aligned}$$

Step 2 of 5

Determine the current for $6\le t\le 7$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(0)}{dt}\\&=\frac{1}{10}(0)\\&=0\text{ A}\end{aligned}$$

Determine the current for $7\le t\le 8$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(-2.5t+17.5)}{dt}\\&=\frac{1}{10}(-2.5)\\&=-0.25\text{ A}\end{aligned}$$

Determine the current for $8\le t\le 10$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(0)}{dt}\\&=\frac{1}{10}(0)\\&=0\text{ A}\end{aligned}$$

Determine the current for $10\le t\le 12$.

$$\begin{aligned}i(t)&=\frac{1}{10}\frac{d(1.25t-15)}{dt}\\&=\frac{1}{10}(1.25)\\&=0.125\text{ A}\end{aligned}$$

Step 3 of 5

Draw the current waveform, $i(t)$.

Step 4 of 5

Therefore, the current entering into the BOX over the period is can be mathematically defined as:

$$\boxed{i(t)=\begin{cases}0.25\text{ A} & 0\le t\le 2\\ 0\text{ A} & 2\le t\le 4\\ -0.25\text{ A} & 4\le t\le 6\\ 0\text{ A} & 6\le t\le 7\\ -0.25\text{ A} & 7\le t\le 8\\ 0\text{ A} & 8\le t\le 10\\ 0.125\text{ A} & 10\le t\le 12\end{cases}}.$$

Step 5 of 5

Calculate the charge that enters the BOX between 0 and 12 seconds.

$$\begin{aligned}q(t)&=\int_{t_1}^{t_2}i(t)dt\\&=\int_0^2 0.25dt+\int_4^6(-0.25)dt+\int_7^8(-0.25)dt+\int_{10}^{12}(0.125)dt\\&=0.25(2-0)-0.25(6-4)-0.25(8-7)+0.125(12-10)\\&=0.5-0.5-0.25+0.25\\&=0\text{ C}\end{aligned}$$

Therefore, the charge enters the BOX between 0 and 12 seconds is $\boxed{0\text{ C}}$.

Step 1 of 3

1.9p

Refer to Figure P1.9 in the textbook for the wave form of the current.

The relation between current $i(t)$ and the charge $q(t)$ that enters the element is, $i(t)=\frac{dq(t)}{dt}$

The equation for current $i(t)$ in the interval $10 \le t \le 20\,\text{sec}$ is,

$i(t)=mt+c$ ..... (1)

Here,

m is the slope of the line

c is a constant

The slope m of the current waveform $i(t)$ between two time intervals t_2 and t_1 is calculate as follows:

$$m=\frac{i(t_2)-i(t_1)}{t_2-t_1}$$

Here,

$i(t_2)$ is the value of current $i(t)$ at time t_2

$i(t_1)$ is the value of current $i(t)$ at time t_1

Step 2 of 3

The current $i(t)$ in the interval $0 \le t \le 10\,\text{sec}$ is from Figure P1.9 is a constant value of 10 mA . Thus, current $i(t)$ in the interval $0 \le t \le 10\,\text{sec}$ is,

$$i(t)=10\times10^{-3}\text{ mA}$$

Calculate the slope of the current waveform $i(t)$ in the interval $10 \le t \le 20\,\text{sec}$.

$$\begin{aligned} m&=\frac{i(20)-i(10)}{20-10}\\ &=\frac{0-10\times10^{-3}}{20-10}\\ &=-10^{-3}\end{aligned}$$

Substitute the value of slope m and $i(t)$ at time $t=10$ sec in equation (1) to find constant.

$$\begin{aligned} i(10)&=-10^{-3}t+c\\ 0.01&=-0.01+c\\ c&=0.02\end{aligned}$$

Step 3 of 3

Write the equation for current $i(t)$ in the interval $10 \le t \le 20\,\text{sec}$ is,

$$i(t)=-10^{-3}t+0.02$$

Determine the charge $q(t)$ that enters the box in the interval $0 \le t \le 20\text{ sec}$.

$$\begin{aligned} q(t)&=\int_0^{10} i(t)dt+\int_{10}^{20} i(t)dt\\ &=\int_0^{10}\left(10\times10^{-3}\right)dt+\int_{10}^{20}\left(-10^{-3}t+0.02\right)dt\\ &=\left(10\times10^{-3}\right)[t]_0^{10}-\left(10^{-3}\right)\left[\frac{t^2}{2}\right]_{10}^{20}+(0.02)[t]_{10}^{20}\\ &=\left(10\times10^{-3}\right)[10-0]-\left(10^{-3}\right)\left[\frac{20^2-10^2}{2}\right]+(0.02)[20-10]\end{aligned}$$

$$\begin{aligned} &=0.1-0.15+0.2\\ &=0.15\text{ C}\\ &=150\text{ mC}\end{aligned}$$

Therefore, the charge that enters the box in the interval $0 \le t \le 20\text{ s}$ is $\boxed{150\text{ mC}}$.

1.10p

Calculate the current, $i(t)$ having charge, $q(t) = -30e^{-4t}\ \text{mC}$.

$$\begin{aligned} i(t) &= \frac{dq(t)}{dt} \\ &= \frac{d}{dt}\left(-30e^{-4t}\ \text{mC}\right) \\ &= (-30)(-4)\left(e^{-4t}\right) \\ &= 120e^{-4t}\text{mA} \end{aligned}$$

Calculate the energy, (w) having voltage, $v = 120e^{-2t}\ \text{V}$.

$$\begin{aligned} w &= \int_{t_1}^{t_2} vidt \\ &= \int_0^{50\text{ m}} \left(120e^{-2t}\ \text{V}\right)\left(120e^{-4t}\ \text{mA}\right)dt \\ &= (120)\left(120\times10^{-3}\right)\left(\int_0^{50} e^{-6t}dt\right) \\ &= 14.4\left(\left.\frac{e^{-6t}}{-6}\right|_0^{50\text{ m}}\right) \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} w &= (14.4)\left(\frac{e^{-6(50\text{ m})}}{-6} - \frac{e^{-6(0)}}{(-6)}\right) \\ &= (14.4)(-0.1234 + 0.166) \\ &= (14.4)(0.04319) \\ &= 622\ \text{mJ} \end{aligned}$$

Therefore, the energy delivered to the element is $\boxed{622\ \text{mJ}}$.

Step 1 of 3

Calculate the current, $i(t)$.

$$\begin{aligned} i(t) &= \frac{dq(t)}{dt} \\ &= \frac{d}{dt}\left(-12e^{-2t}\ \text{mC}\right) \\ &= (-12)(-2)\left(e^{-2t}\right)\left(10^{3}\right) \\ &= 24e^{-2t}\ \text{mA} \end{aligned}$$

Therefore, the current in the element is $\boxed{24e^{-2t}\ \text{mA}}$.

Step 2 of 3

Calculate the energy, (w) .

$$\begin{aligned} w &= \int_{0}^{100\ \text{m}} \left(2.4e^{-3t}\ \text{W}\right)dt \\ &= 2.4\left(\left.\frac{e^{-3t}}{-3}\right|_{0}^{100\ \text{m}}\right) \\ &= \frac{2.4}{-3}e^{-3(100\ \text{m})} - e^{-3(0)} \\ &= 207.34\ \text{mJ} \end{aligned}$$

Therefore, the energy delivered to the element is $\boxed{207.34\ \text{mJ}}$.

Step 3 of 3

Calculate the voltage, (v) across the element.

$$\begin{aligned} v(t) &= \frac{p(t)}{i(t)} \\ &= \frac{2.4e^{-3t}\ \text{W}}{2.4e^{-2t}\ \text{mA}} \\ &= \left(\frac{1}{10}\right)\left(e^{-3t+2t}\right)\left(10^{3}\right) \\ &= 100e^{-t}\ \text{V} \end{aligned}$$

Therefore, the voltage across the element is $\boxed{100e^{-t}\ \text{V}}$.

1.12p

Calculate the value of energy (w) by referring equation 1.4 given in the text book having voltage $v = 12e^{-2t}\ \text{V}$ and current $i = 2e^{-2t}\ \text{A}$ as follows:

$$
\begin{aligned}
w &= \int_{t_1}^{t_2} vi\,dt \\
&= \int_{0}^{1.5} \left(12e^{-2t}\ \text{V}\right)\left(2e^{-2t}\ \text{A}\right) dt \\
&= 24\int_{0}^{1.5} e^{-4t}\,dt \\
&= 24\left(\left.\frac{e^{-4t}}{-4}\right|_{0}^{1.5}\right)
\end{aligned}
$$

Further simplification is as follows:

$$
\begin{aligned}
w &= \left(\frac{24}{-4}\right)\left(e^{-4(1.5)} - e^{-4(0)}\right) \\
&= (-6)\left(\left(2.478\times10^{-3}\right) - 1\right) \\
&= (-6)(-0.9975) \\
&= 5.98\ \text{J}
\end{aligned}
$$

Therefore, the energy absorbed by the element is $\boxed{5.98\ \text{J}}$.

Step 1 of 2

1.13p

Calculate the current (i) from the equation 1.3 in the text book having power $p = 2e^{-2t}\ \mathrm{W}$ and voltage $v = 4e^{-t}\ \mathrm{V}$ as follows:

$$\begin{aligned} i &= \frac{p}{v} \\ &= \frac{2e^{-2t}\ \mathrm{W}}{4e^{-t}\ \mathrm{V}} \\ &= 0.5e^{-2t+t} \\ &= 0.5e^{-t}\ \mathrm{A} \end{aligned}$$

Step 2 of 2

Calculate the amount of charge $q(t)$ that enters the box between the time interval $0.1\ \mathrm{s}$ and $0.4\ \mathrm{s}$ from equation 1.1 in the text book having current i as follows:

$$\begin{aligned} q(t) &= \int_{0.1}^{0.4} \left(0.5e^{-t}\right) dt \\ &= (0.5)\left(\left. \frac{e^{-t}}{-1} \right|_{0.1}^{0.4} \right) \\ &= (-0.5)\left(e^{-0.4} - e^{-0.1}\right) \\ &= 0.1172\ \mathrm{C} \end{aligned}$$

Therefore, the charge that enters into the box is $\boxed{0.1172\ \mathrm{C}}$.

1.14p

Calculate the energy (w) absorbed by the box by referring equation 1.4 in the text book having power $p = 0.1e^{-4t}\ \mathrm{W}$ as follows:

$$
\begin{aligned}
w &= \int_{t_1}^{t_2} p\,dt \\
&= \int_0^{\infty} \left(0.1e^{-4t}\ \mathrm{W}\right) dt \\
&= (0.1)\left(\left.\frac{e^{-4t}}{-4}\right|_0^{\infty}\right) \\
&= (-0.25)\left(e^{-4(\infty)} - e^{-4(0)}\right)
\end{aligned}
$$

Further simplification is as follows:

$$
\begin{aligned}
w &= -0.25\left(e^{-\infty} - e^{0}\right) \\
&= (-0.025)(-1) \\
&= 0.025\ \mathrm{J}
\end{aligned}
$$

Therefore the energy absorbed by the box is $\boxed{0.025\ \mathrm{J}}$.

Step 1 of 3

1.17p

Refer to Figure P1.17 in the text book.

Calculate the expression for current through the circuit.

$$w(t)=\int_{t_1}^{t_2} v(t)i(t)\,dt$$

$$v(t)i(t)=\frac{dw(t)}{dt}$$

$$i(t)=\frac{1}{v(t)}\frac{dw(t)}{dt}$$

Here $\frac{dw(t)}{dt}$ indicates the slope of the waveform.

Calculate the slopes at every instant of $w(t)$.

$$\frac{dw(t)}{dt}=\begin{cases}\frac{5-0}{2-0} & 0\le t\le 2\\ 0 & 2\le t\le 4\\ \frac{0-5}{6-4} & 4\le t\le 6\\ 0 & 6\le t\le 7\\ \frac{-2.5-0}{8-7} & 7\le t\le 8\\ 0 & 8\le t\le 10\\ \frac{0-(-2.5)}{12-10} & 10\le t\le 12\end{cases}$$

$$=\begin{cases}2.5 & 0<t<2\\ 0 & 2<t<4\\ -2.5 & 4<t<6\\ 0 & 6<t<7\\ -2.5 & 7<t<8\\ 0 & 8<t<10\\ 1.25 & 10<t<12\end{cases}$$

Step 2 of 3

Draw the waveform for $\frac{dw(t)}{dt}$.

Figure 1

Step 3 of 3

Consider the expression for $i(t)$.

$$i(t)=\frac{1}{v(t)}\frac{dw(t)}{dt}$$

Calculate the current through the circuit.

$$i(t)=\begin{cases}0.25\text{ A} & 0<t<2\\ 0\text{ A} & 2<t<4\\ -0.25\text{ A} & 4<t<6\\ 0\text{ A} & 6<t<7\\ -0.25\text{ A} & 7<t<8\\ 0\text{ A} & 8<t<10\\ 0.125\text{ A} & 10<t<12\end{cases}$$

Calculate the charge that enters the BOX between 0 and 12 seconds.

$$\begin{aligned}q(t)&=\int_0^{12} i(t)\,dt\\ &=\int_0^2 0.25\,dt+\int_4^6(-0.25)\,dt+\int_7^8(-0.25)\,dt+\int_{10}^{12}(0.125)\,dt\\ &=0.25(2-0)-0.25(6-4)-0.25(8-7)+0.125(12-10)\\ &=0\text{ C}\end{aligned}$$

Thus, the charge that enters the BOX between 0 and 12 seconds is $\boxed{0\text{ C}}$.

Step 1 of 4

1.20p

Consider the circuit given in Figure P1.20 in the text book.

(a)

Calculate the power (P) absorbed or supplied by the element in the circuit having voltage $V_1 = 9\ \text{V}$ and current $I = 2\ \text{A}$ as follows:

$$\begin{aligned} P &= V_1 I \\ &= (9\ \text{V})(2\ \text{A}) \\ &= (9)(2) \\ &= 18\ \text{W} \end{aligned}$$

Therefore, the sign of power is positive and so the element absorbs the power of $\boxed{18\ \text{W}}$.

Step 2 of 4

(b)

Calculate the power (P) absorbed or supplied by the element in the circuit having voltage $V_1 = 9\ \text{V}$ and current $I = -3\ \text{A}$ as follows:

$$\begin{aligned} P &= V_1 I \\ &= (9\ \text{V})(-3\ \text{A}) \\ &= (9)(-3) \\ &= -27\ \text{W} \end{aligned}$$

Therefore, the sign of power is negative and so the element supplies the power of $\boxed{27\ \text{W}}$

Step 3 of 4

(c)

Calculate the power (P) absorbed or supplied by the element in the circuit having voltage $V_1 = -12\ \text{V}$ and current $I = 2\ \text{A}$ as follows:

$$\begin{aligned} P &= V_1 I \\ &= (-12\ \text{V})(2\ \text{A}) \\ &= (-12)(2) \\ &= -24\ \text{W} \end{aligned}$$

Therefore the sign of power is negative and so the element supplies the power of $\boxed{24\ \text{W}}$.

Step 4 of 4

(d)

Calculate the power (P) absorbed or supplied by the element in the circuit having voltage $V_1 = -12\ \text{V}$ and current $I = -3\ \text{A}$ as follows:

$$\begin{aligned} P &= V_1 I \\ &= (-12\ \text{V})(-3\ \text{A}) \\ &= (-12)(-3) \\ &= 36\ \text{W} \end{aligned}$$

Therefore the sign power is positive and so the element absorbs the power of $\boxed{36\ \text{W}}$.

Step 1 of 2

1.21p

Consider the circuit shown in Figure P1.21 in the text book.

Now consider the Figure 1 to calculate the power absorbed by element A as follows:

Figure 1

Step 2 of 2

Calculate the power (P) absorbed by element A by using passive sign convention as follows:

$$\begin{aligned} P &= VI \\ &= (15\text{ V})(-3\text{ A}) \\ &= -45\text{ W} \end{aligned}$$

Therefore, power absorbed by element A is $\boxed{-45\text{ W}}$.

Step 1 of 2

1.22p

Consider the circuit shown in Figure P1.22 in the text book.

Now consider to Figure 1 to calculate the power supplied by element A as follows:

Figure 1

Step 2 of 2

Calculate the power (P) supplied by element A as follows:

$$\begin{aligned} P &= VI \\ &= (20\text{ V})(-2\text{ A}) \\ &= (20)(-2) \\ &= -40\text{ W} \end{aligned}$$

Therefore, the power supplied by element A is $\boxed{40\text{ W}}$.

1.24p

Consider the circuit shown in Figure P1.24 in the text book.

Calculate value of current I_x in the considered circuit having power P supplied by element B by using the formula $P = VI$.

Substitute $P = -60\ \text{W}$, $V = 24\ \text{V}$, $I = I_x$ from the considered circuit and solve for current I_x .

$$-60\ \text{W} = (24\ \text{V})(I_x)$$

$$\begin{aligned} I_x &= \frac{-60\ \text{W}}{24\ \text{V}} \\ &= -2.5\ \text{A} \end{aligned}$$

Therefore, the value of current I_x is $\boxed{-2.5\ \text{A}}$.

1.26p

Consider the circuit shown in Figure P1.25 in the text book.

The element B in the considered circuit supplies $72\ \mathrm{W}$ of power and so the absorbed power P is $-72\ \mathrm{W}$.

Calculate value of voltage V_A in the considered circuit having power P by using the formula $P = VI$.

Substitute $P = -72\ \mathrm{W}$, $V = V_A$, $I = 3\ \mathrm{A}$ from the considered circuit and solve for voltage V_A.

$$-72\ \mathrm{W} = (V_A)(3\ \mathrm{A})$$

$$\begin{aligned} V_A &= \frac{-72\ \mathrm{W}}{3\ \mathrm{A}} \\ &= -24\ \mathrm{V} \end{aligned}$$

Therefore, the value of voltage V_A is $\boxed{-24\ \mathrm{V}}$.

Step 1 of 6

(a)

Consider the circuit given in Figure P1.27 (a) in the text book.

The sign of power P_1 is positive and so the current I flowing in the circuit is shown in figure 1.

Figure 1

Step 2 of 6

Calculate value of current I in Figure 1 having power P_1 by using the formula $P = VI$.

Substitute $P = 36\text{ W}$, $V = 12\text{ V}$ from element 1 in Figure 1 and solve for current I.

$$\begin{aligned} I &= \frac{P_1}{V_1} \\ &= \frac{36\text{ W}}{12\text{ V}} \\ &= 3\text{ A} \end{aligned}$$

Step 3 of 6

Now calculate the power absorbed or supplied by element 2 in figure 1 by using the formula $P = VI$.

Substitute $V = 6\text{ V}$, $I = 3\text{ A}$ from element 2 in Figure 1 and solve for power P.

$$\begin{aligned} P &= V_2 I \\ &= (6\text{ V})(3\text{ A}) \\ &= (6)(3) \\ &= 18\text{ W} \end{aligned}$$

Therefore, the sign of power P_2 is positive and so the element 2 in Figure 1 is absorbing the power of $\boxed{18\text{ W}}$.

Step 4 of 6

(b)

Consider the circuit given in Figure P1.27 (b) in the text book.

The sign of power P_2 is negative and so the current I flowing in the circuit is shown in figure 2.

Figure 2

Step 5 of 6

Calculate value of current I in Figure 2 having power P_2 by using the formula $P = VI$.

Substitute $P = -48\text{ W}$, $V = -24\text{ V}$ from element 2 in Figure 2 and solve for current I.

$$\begin{aligned} I &= \frac{P_2}{V_2} \\ &= \frac{-48\text{ W}}{-24\text{ V}} \\ &= 2\text{ A} \end{aligned}$$

Step 6 of 6

Now calculate the power absorbed or supplied by element 1 in figure 2 by using the formula $P = VI$.

Substitute $V = 6\text{ V}$, $I = 2\text{ A}$ from element 1 in Figure 2 and solve for power P.

$$\begin{aligned} P &= V_1 I \\ &= (6\text{ V})(2\text{ A}) \\ &= (6)(2) \\ &= 12\text{ W} \end{aligned}$$

Therefore, the sign of power P is positive and so the element 1 in Figure 2 is absorbing the power of $\boxed{12\text{ W}}$.

Step 1 of 3

1.28p

Consider the circuit given in Figure P1.28 in the text book.

In the considered circuit the element 1 supplies $24\ \mathrm{W}$ of power and so the current I flowing in the circuit is shown in Figure 1.

Figure 1

Step 2 of 3

Calculate value of current I in Figure 1 having power P by using the formula $P = VI$.

Substitute $P = 24\ \mathrm{W}$, $V = 3\ \mathrm{V}$ from element 1 in Figure 1 and solve for current I .

$$\begin{aligned} I &= \frac{P_1}{V_1} \\ &= \frac{24\ \mathrm{W}}{3\ \mathrm{V}} \\ &= 8\ \mathrm{A} \end{aligned}$$

Step 3 of 3

Now calculate the power absorbed or supplied by element 2 in figure 1 by using the formula $P = VI$.

Substitute $V = 6\ \mathrm{V}$, $I = 8\ \mathrm{A}$ from element 2 in Figure 1 and solve for power P .

$$\begin{aligned} P &= V_2 I \\ &= (6\ \mathrm{V})(8\ \mathrm{A}) \\ &= (6)(8) \\ &= 48\ \mathrm{W} \end{aligned}$$

Therefore, the sign of power P is positive and so the element 2 absorbs power of $\boxed{48\ \mathrm{W}}$.

Step 1 of 4

1.29p

Consider the circuit given in Figure P1.29 in the text book.

The element 2 absorbs $32\ \text{W}$ of power and so the current I flowing in the circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Calculate value of current I in Figure 1 having power P_2 by using the formula $P = VI$.

Substitute $P = 32\ \text{W}$, $V = 8\ \text{V}$ from element 2 in Figure 1 and solve for current I.

$$\begin{aligned} P_2 &= V_2 I \\ I &= \frac{P_2}{V_2} \\ &= \frac{32\ \text{W}}{8\ \text{V}} \\ &= 4\ \text{A} \end{aligned}$$

Step 3 of 4

Now calculate the power absorbed or supplied by element **1** in figure 1 by using the formula $P = VI$.

Substitute $P = P_1$, $V = -4\ \text{V}$, $I = 4\ \text{A}$ from element 1 in Figure 1 and solve for power P_1.

$$\begin{aligned} P_1 &= V_1 I \\ &= (-4\ \text{V})(4\ \text{A}) \\ &= (-4)(4) \\ &= -16\ \text{W} \end{aligned}$$

Therefore, the sign of power (P_1) is negative and so the element 1 supplies power of $\boxed{16\ \text{W}}$.

Step 4 of 4

Now calculate the power absorbed or supplied by element 3 in figure 1 by using the formula $P = VI$.

Substitute $P = P_3$, $V = 12\ \text{V}$, $I = 4\ \text{A}$ from element 3 in Figure 1 and solve for power P_3.

$$\begin{aligned} P_3 &= V_3 I \\ &= (12\ \text{V})(4\ \text{A}) \\ &= (12)(4) \\ &= 48\ \text{W} \end{aligned}$$

Therefore, the sign of power (P_3) is positive and so the element 3 absorbs the power of $\boxed{48\ \text{W}}$.

Step 1 of 1

1.30p

Consider the circuit given in Figure P1.30 in the text book.

The current flowing in the circuit through element 2 is also I_s .

Calculate value of current I_s in the considered circuit having power P by using the formula $I = \frac{P}{V}$.

Substitute $P = 7\ \text{W}$, $V = 2\ \text{V}$ from element 2 in considered circuit and solve for current I_s .

$$\begin{aligned} I_s &= \frac{P}{V} \\ &= \frac{7\ \text{W}}{2\ \text{V}} \\ &= \frac{7}{2} \\ &= 3.5\ \text{A} \end{aligned}$$

Therefore, the value of current I_s is $\boxed{3.5\ \text{A}}$.

Step 1 of 6

(a)

Consider the circuit shown in Figure P1.31 (a) in the text book having current flow of $I = 2\text{ A}$.

Calculate the power absorbed or supplied by 2 A current source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{2\text{ A}}$, $V = -20\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power $P_{2\text{ A}}$.

$$\begin{aligned} P_{2\text{ A}} &= (-20\text{ V})(2\text{ A}) \\ &= (-20)(2) \\ &= -40\text{ W} \end{aligned}$$

Therefore, the sign of power $(P_{2\text{ A}})$ is negative and so the 2 A current source supplies the power of $\boxed{40\text{ W}}$.

Step 2 of 6

Calculate the power absorbed or supplied by element 1 in the considered circuit by using the formula $P = VI$.

Substitute $P = P_1$, $V = 6\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power P_1.

$$\begin{aligned} P_1 &= (6\text{ V})(2\text{ A}) \\ &= (6)(2) \\ &= 12\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element 1 absorbs the power of $\boxed{12\text{ W}}$.

Step 3 of 6

Calculate the power absorbed or supplied by 14 V voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{14\text{ V}}$, $V = 14\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power $P_{14\text{ V}}$.

$$\begin{aligned} P_{14\text{ V}} &= (14\text{ V})(2\text{ A}) \\ &= (14)(2) \\ &= 28\text{ W} \end{aligned}$$

Therefore, the sign of power $P_{14\text{ V}}$ is positive and so the 14 V voltage source absorbs the power of $\boxed{28\text{ W}}$.

Step 4 of 6

(b)

Consider the circuit shown in Figure P1.31 (b) in the text book having current flow of $I = 4\text{ A}$.

Calculate the power absorbed or supplied by 4 A current source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{4\text{ A}}$, $V = -16\text{ V}$, $I = 4\text{ A}$ from the considered circuit and solve for power $P_{4\text{ A}}$.

$$\begin{aligned} P_{4\text{ A}} &= (-16\text{ V})(4\text{ A}) \\ &= (-16)(4) \\ &= -64\text{ W} \end{aligned}$$

Therefore, the sign of power $P_{4\text{ A}}$ is negative and so the 4 A current source supplies the power of $\boxed{64\text{ W}}$.

Step 5 of 6

Calculate the power absorbed or supplied by element 1 in the considered circuit by using the formula $P = VI$.

Substitute $P = P_1$, $V = 8\text{ V}$, $I = 4\text{ A}$ from the considered circuit and solve for power P_1.

$$\begin{aligned} P_1 &= (8\text{ V})(4\text{ A}) \\ &= (8)(4) \\ &= 32\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element 1 absorbs the power of $\boxed{32\text{ W}}$.

Step 6 of 6

Calculate the power absorbed or supplied by $2I_x$ dependent voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{2I_x}$, $V = 2I_x$, $I = 4\text{ A}$ from the considered circuit and solve for power P_{2I_x}.

$$\begin{aligned} P_{2I_x} &= (2I_x)(4\text{ A}) \\ &= (2)(4\text{ A})(4\text{ A}) \\ &= 32\text{ W} \end{aligned}$$

Therefore, the sign of power P_{2I_x} is positive and so the dependent voltage source absorbs the power of

Step 1 of 7

1.32p

(a)

Consider the circuit shown in Figure P1.32 (a) in the text book having current I_x flow of 2 A.

Calculate the power absorbed or supplied by 12 V voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{12\text{ V}}$, $V = -12\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power $P_{12\text{ V}}$.

$$P = V(I_x)$$

$$\begin{aligned} P_{12\text{ V}} &= (-12\text{ V})(2\text{ A}) \\ &= (-12)(2) \\ &= -24\text{ W} \end{aligned}$$

Therefore, the sign of power $(P_{12\text{ V}})$ is negative and so the 12 V voltage source supplies the power of $\boxed{24\text{ W}}$.

Step 2 of 7

Calculate the power absorbed or supplied by element 1 in the considered circuit by using the formula $P = VI$.

Substitute $P = P_1$, $V = 8\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power P_1.

$$P = VI_x$$

$$\begin{aligned} P_1 &= (8\text{ V})(2\text{ A}) \\ &= (8)(2) \\ &= 16\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element 1 absorbs the power of $\boxed{16\text{ W}}$.

Step 3 of 7

Calculate the power absorbed or supplied by $2I_x$ dependent voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{2I_x}$, $V = 2I_x$, $I = 2\text{ A}$ from the considered circuit and solve for power P_{2I_x}.

$$P = VI_x$$

$$\begin{aligned} P_{2I_x} &= (2I_x)(2\text{ A}) \\ &= (2)(2)(2) \\ &= 8\text{ W} \end{aligned}$$

Therefore, the sign of power (P_{2I_x}) is positive and so the $2I_x$ dependent voltage source absorbs the power of $\boxed{8\text{ W}}$.

Step 4 of 7

(b)

Consider the circuit shown in Figure P1.31 (b) in the text book having current I_x flow of 2 A.

Calculate the power absorbed or supplied by $4I_x$ dependent voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{4I_x}$, $V = -4I_x$, $I = 2\text{ A}$ from the considered circuit and solve for power P_{4I_x}.

$$P = V(I_x)$$

$$\begin{aligned} P_{4I_x} &= (-4I_x)(2\text{ A}) \\ &= (-4)(2)(2) \\ &= -16\text{ W} \end{aligned}$$

Therefore, the sign of power P_{4I_x} is negative and so the $4I_x$ voltage dependent source supplies the power of $\boxed{16\text{ W}}$.

Step 5 of 7

Calculate the power absorbed or supplied by 24 V voltage source in the considered circuit by using the formula $P = VI$.

Substitute $P = P_{24\text{ V}}$, $V = -24\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power $P_{24\text{ V}}$.

$$P = V(I_x)$$

$$\begin{aligned} P_{24\text{ V}} &= (-24\text{ V})(2\text{ A}) \\ &= (-24)(2) \\ &= -48\text{ W} \end{aligned}$$

Therefore, the sign of power $P_{24\text{ V}}$ is negative and so the 24 V voltage source supplies the power of $\boxed{48\text{ W}}$.

Step 6 of 7

Calculate the power absorbed or supplied by element 1 in the considered circuit by using the formula $P = VI$.

Substitute $P = P_1$, $V = 20\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power P_1.

$$P = VI_x$$

$$\begin{aligned} P_1 &= (20\text{ V})(2\text{ A}) \\ &= (20)(2) \\ &= 40\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element 1 absorbs the power of $\boxed{40\text{ W}}$.

Step 7 of 7

Calculate the power absorbed or supplied by element 2 in the considered circuit by using the formula $P = VI$.

Substitute $P = P_2$, $V = 12\text{ V}$, $I = 2\text{ A}$ from the considered circuit and solve for power P_2.

$$P = VI_x$$

$$\begin{aligned} P_2 &= (12\text{ V})(2\text{ A}) \\ &= (12)(2) \\ &= 24\text{ W} \end{aligned}$$

Therefore, the sign of power is positive and so the element 2 absorbs the power of $\boxed{24\text{ W}}$.

Step 1 of 2

1.33p

Refer to Figure P1.33 in the text book.

If the notation of the power is positive, it indicates that the power is absorbing otherwise power is delivering. Current entering from positive terminal gives absorbing power.

Calculate the power delivered by the independent source.

$$\begin{aligned} P_{36\text{ V}} &= (36)(I_x) \\ &= (36)(4) \\ &= 144\text{ W} \end{aligned}$$

Calculate the power delivered by the dependent source.

$$\begin{aligned} P_{I_x} &= (2)(I_x) \\ &= (2)(4) \\ &= 8\text{ W} \end{aligned}$$

Calculate the total power supplied.

$$\begin{aligned} P_{del} &= P_{36\text{ V}} + P_{I_x} \\ &= 144\text{ W} + 8\text{ W} \\ &= 152\text{ W} \end{aligned}$$

Thus, the power supplied by the sources is $\boxed{152\text{ W}}$.

Step 2 of 2

Calculate the power absorbed by the element 1.

$$\begin{aligned} P_1 &= (12)(4) \\ &= 48\text{ W} \end{aligned}$$

Calculate the power absorbed by the element 2.

$$\begin{aligned} P_2 &= (24)(2) \\ &= 48\text{ W} \end{aligned}$$

Calculate the power absorbed by the element 3.

$$\begin{aligned} P_3 &= (28)(2) \\ &= 56\text{ W} \end{aligned}$$

Calculate the power absorbed by the elements.

$$\begin{aligned} P_{abs} &= P_1 + P_2 + P_3 \\ &= 48\text{ W} + 48\text{ W} + 56\text{ W} \\ &= 152\text{ W} \end{aligned}$$

Thus, the power absorbed by the elements is $\boxed{152\text{ W}}$.

Hence, the power supplied by the sources is same as power absorbed by the elements.

Step 1 of 6

1.34p

Consider the circuit shown in Figure P1.34 in the text book.

The current (I) flowing in the circuit is $2\ \mathrm{A}$.

Calculate the power $(P_{12\ \mathrm{V}})$ absorbed or supplied by $12\ \mathrm{V}$ voltage source having voltage $V = 12\ \mathrm{V}$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{12\ \mathrm{V}} &= (12\ \mathrm{V})(-2\ \mathrm{A}) \\ &= (12)(-2) \\ &= -24\ \mathrm{W} \end{aligned}$$

Step 2 of 6

Calculate the power (P_1) absorbed or supplied by element 1 having voltage $V = 4\ \mathrm{V}$ as follows:

$$\begin{aligned} P &= VI \\ P_1 &= (4\ \mathrm{V})(2\ \mathrm{A}) \\ &= (4)(2) \\ &= 8\ \mathrm{W} \end{aligned}$$

Step 3 of 6

Calculate the power (P_{2V_x}) absorbed or supplied by the dependent voltage source having voltage $V = 2V_x$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{2V_x} &= (2V_x)(-2\ \mathrm{A}) \\ &= (2V_x)(-2) \\ &= -4V_x\ \mathrm{W} \end{aligned}$$

Step 4 of 6

Calculate the power (P_2) absorbed or supplied by element 2 having voltage $V = V_x$ as follows:

$$\begin{aligned} P &= VI \\ P_2 &= (V_x)(2\ \mathrm{A}) \\ &= (V_x)(2) \\ &= 2V_x\ \mathrm{W} \end{aligned}$$

Step 5 of 6

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of V_x as follows:

$$\begin{aligned} P_{12\ \mathrm{V}} + P_{2V_x} &= P_1 + P_2 \\ 24 + 4V_x &= 8 + 2V_x \\ 2V_x &= -16 \\ V_x &= -8\ \mathrm{V} \end{aligned}$$

Step 6 of 6

Calculate the value of power (P_2) absorbed or supplied by element 2 in the circuit as follows:

$$\begin{aligned} P_2 &= V_x I \\ &= (-8\ \mathrm{V})(2\ \mathrm{A}) \\ &= (-8)(2) \\ &= -16\ \mathrm{W} \end{aligned}$$

Therefore, the sign of power (P_2) is negative and so the element 2 supplies the power of $\boxed{16\ \mathrm{W}}$.

Step 1 of 6

1.35p

Consider the circuit shown in Figure P1.35 in the text book.

Calculate the power $(P_{36\text{ V}})$ absorbed or supplied by 36 V voltage source having voltage $V = 36\text{ V}$ and current $I = I_x$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{36\text{ V}} &= (36\text{ V})(-I_x\text{ A}) \\ &= (36)(-I_x) \\ &= -36I_x\text{ W} \end{aligned}$$

Step 2 of 6

Calculate the power (P_1) absorbed or supplied by element 1 having voltage $V = 12\text{ V}$ and current $I = I_x$ as follows:

$$P = VI$$

$$\begin{aligned} P_1 &= (12\text{ V})(I_x\text{ A}) \\ &= (12)(I_x) \\ &= 12I_x\text{ W} \end{aligned}$$

Step 3 of 6

Calculate the power (P_2) absorbed or supplied by element 2 having voltage $V = 24\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$P = VI$$

$$\begin{aligned} P_2 &= (24\text{ V})(2\text{ A}) \\ &= (24)(2) \\ &= 48\text{ W} \end{aligned}$$

Step 4 of 6

Calculate the power (P_{1I_x}) absorbed or supplied by the dependent voltage source having voltage $V = 1I_x$ and current $I = 2\text{ A}$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{1I_x} &= (1I_x)(-2\text{ A}) \\ &= (1I_x)(-2) \\ &= -2I_x\text{ W} \end{aligned}$$

Step 5 of 6

Calculate the power (P_3) absorbed or supplied by element 3 having voltage $V = 28\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$P = VI$$

$$\begin{aligned} P_3 &= (28\text{ V})(2\text{ A}) \\ &= (28)(2) \\ &= 56\text{ W} \end{aligned}$$

Step 6 of 6

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$P_{36\text{ V}} + P_{1I_x} = P_1 + P_2 + P_3$$

$$36I_x + 2I_x = 12I_x + 48 + 56$$

$$26I_x = 104$$

$$I_x = 4\text{ A}$$

Therefore, the value of I_x is $\boxed{4\text{ A}}$.

Step 1 of 7

1.36p

Consider the circuit shown in Figure P1.36 in the text book.

Calculate the power $(P_{36\text{ V}})$ absorbed or supplied by 36 V voltage source having voltage $V = 36\text{ V}$ and current $I = I_x$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{36\text{ V}} &= (36\text{ V})(-I_x\text{ A}) \\ &= (36)(-I_x) \\ &= -36I_x\text{ W} \end{aligned}$$

Step 2 of 7

Calculate the power (P_1) absorbed or supplied by element 1 having voltage $V = 12\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P &= VI \\ P_1 &= (12\text{ V})(I_x\text{ A}) \\ &= (12)(I_x) \\ &= 12I_x\text{ W} \end{aligned}$$

Step 3 of 7

Calculate the power (P_{2I_x}) absorbed or supplied by the dependent current source having voltage $V = 24\text{ V}$ and current $I = 2I_x\text{ A}$ as follows:

$$P = VI$$

$$\begin{aligned} P_{2I_x} &= (24\text{ V})(2I_x\text{ A}) \\ &= (24)(2I_x) \\ &= 48I_x\text{ W} \end{aligned}$$

Step 4 of 7

Calculate the power (P_2) absorbed or supplied by element 2 having voltage $V = 8\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_2 &= (8\text{ V})(-2\text{ A}) \\ &= (8)(-2) \\ &= -16\text{ W} \end{aligned}$$

Step 5 of 7

Calculate the power (P_3) absorbed or supplied by element 3 having voltage $V = 16\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_3 &= (16\text{ V})(-2\text{ A}) \\ &= (16)(-2) \\ &= -32\text{ W} \end{aligned}$$

Step 6 of 7

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$\begin{aligned} P_{36\text{ V}} + P_2 + P_3 &= P_1 + P_{2I_x} \\ 36I_x + 16 + 32 &= 12I_x + 48I_x \\ 24I_x &= 48 \\ I_x &= 2\text{ A} \end{aligned}$$

Step 7 of 7

Calculate the value of power (P_1) absorbed or supplied by element 1 in the circuit as follows:

$$\begin{aligned} P_1 &= VI_x \\ &= (12\text{ V})(2\text{ A}) \\ &= (12)(2) \\ &= 24\text{ W} \end{aligned}$$

Therefore, the sign of power (P_1) is positive and so the element 1 absorbs the power of $\boxed{24\text{ W}}$.

Step 1 of 7

1.37p

Consider the circuit shown in Figure P1.37 in the text book.

Calculate the power $(P_{18\text{ V}})$ absorbed or supplied by 18 V voltage source having voltage $V = 18\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{18\text{ V}} &= (18\text{ V})(-I_x\text{ A}) \\ &= (18)(-I_x) \\ &= -18I_x\text{ W} \end{aligned}$$

Step 2 of 7

Calculate the power (P_1) absorbed or supplied by element 1 having voltage $V = 6\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P &= VI \\ P_1 &= (6\text{ V})(I_x\text{ A}) \\ &= (6)(I_x) \\ &= 6I_x\text{ W} \end{aligned}$$

Step 3 of 7

Calculate the power $(P_{24\text{ V}})$ absorbed or supplied by voltage source having voltage $V = 24\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{24\text{ V}} &= (24\text{ V})(-2\text{ A}) \\ &= (24)(-2) \\ &= -48\text{ W} \end{aligned}$$

Step 4 of 7

Calculate the power (P_2) absorbed or supplied by element 2 having voltage $V = 4\text{ V}$ and current $I = 2I_x\text{ A}$ as follows:

$$\begin{aligned} P &= VI \\ P_2 &= (4\text{ V})(2I_x\text{ A}) \\ &= (4)(2I_x) \\ &= 8I_x\text{ W} \end{aligned}$$

Step 5 of 7

Calculate the power (P_{2I_x}) absorbed or supplied by the dependent current source having voltage $V = 20\text{ V}$ and current $I = 2I_x\text{ A}$ as follows:

$$\begin{aligned} P &= VI \\ P_{2I_x} &= (20\text{ V})(2I_x\text{ A}) \\ &= (20)(2I_x) \\ &= 40I_x\text{ W} \end{aligned}$$

Step 6 of 7

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$\begin{aligned} P_{18\text{ V}} + P_{24\text{ V}} &= P_1 + P_2 + P_{2I_x} \\ 18I_x + 48 &= 6I_x + 8I_x + 40I_x \\ 36I_x &= 48 \\ I_x &= 1.33\text{ A} \end{aligned}$$

Step 7 of 7

Calculate the value of power (P_1) absorbed or supplied by element 1 in the circuit as follows:

$$\begin{aligned} P_1 &= VI_x \\ &= (6\text{ V})(1.33\text{ A}) \\ &= (6)(1.33) \\ &= 8\text{ W} \end{aligned}$$

Therefore, the sign of power (P_1) is positive and so the element 1 absorbs the power of $\boxed{8\text{ W}}$.

Step 1 of 9

1.38p

Consider the circuit shown in Figure P1.38 in the text book.

Calculate the power $(P_{12\,\mathrm{V}})$ absorbed or supplied by $12\ \mathrm{V}$ voltage source having voltage $V = 12\ \mathrm{V}$ and current $I = 2\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{12\,\mathrm{V}} &= (12\ \mathrm{V})(-2\ \mathrm{A}) \\ &= (2)(-2) \\ &= -24\ \mathrm{W} \end{aligned}$$

Step 2 of 9

Calculate the power (P_1) absorbed or supplied by element 1 having voltage $V = 4\ \mathrm{V}$ and current $I = 2\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_1 &= (4\ \mathrm{V})(2\ \mathrm{A}) \\ &= (4)(2) \\ &= 8\ \mathrm{W} \end{aligned}$$

Step 3 of 9

Calculate the power (P_{2V_x}) absorbed or supplied by the dependent voltage source having voltage $V = 2V_x$ and current $I = 2\ \mathrm{A}$ as follows:

$$P = V(-I)$$

$$\begin{aligned} P_{2V_x} &= (2V_x)(-2\ \mathrm{A}) \\ &= (2V_x)(-2) \\ &= -4V_x\ \mathrm{W} \end{aligned}$$

Step 4 of 9

Calculate the power $(P_{12\,\mathrm{V}})$ absorbed or supplied by element 1 having voltage $V = 12\ \mathrm{V}$ and current $I = 4\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{12\,\mathrm{V}} &= (12\ \mathrm{V})(-4\ \mathrm{A}) \\ &= (12)(-4) \\ &= -48\ \mathrm{W} \end{aligned}$$

Step 5 of 9

Calculate the power (P_2) absorbed or supplied by element 2 having voltage $V = 16\ \mathrm{V}$ and current $I = 2\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_2 &= (16\ \mathrm{V})(2\ \mathrm{A}) \\ &= (16)(2) \\ &= 32\ \mathrm{W} \end{aligned}$$

Step 6 of 9

Calculate the power (P_3) absorbed or supplied by element 3 having voltage $V = V_x$ and current $I = 2\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_3 &= (V_x)(2\ \mathrm{A}) \\ &= (V_x)(2) \\ &= 2V_x\ \mathrm{W} \end{aligned}$$

Step 7 of 9

Calculate the power (P_4) absorbed or supplied by element 4 having voltage $V = 20\ \mathrm{V}$ and current $I = 2\ \mathrm{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_4 &= (20\ \mathrm{V})(2\ \mathrm{A}) \\ &= (20)(2) \\ &= 40\ \mathrm{W} \end{aligned}$$

Step 8 of 9

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of V_x as follows:

$$\begin{aligned} P_{12\,\mathrm{V}} + P_{2V_x} + P_{12\,\mathrm{V}} &= P_1 + P_2 + P_3 + P_4 \\ 24 + 4V_x + 48 &= 8 + 32 + 2V_x + 40 \\ 2V_x &= 8 \\ V_x &= 4\ \mathrm{V} \end{aligned}$$

Step 9 of 9

Calculate the value of power (P_3) absorbed or supplied by element 3 in the circuit as follows:

$$\begin{aligned} P_3 &= V_x I \\ &= (4\ \mathrm{V})(2\ \mathrm{A}) \\ &= (4)(2) \\ &= 8\ \mathrm{W} \end{aligned}$$

Therefore, the sign of power (P_3) is positive and so the element 3 absorbs the power of $\boxed{8\ \mathrm{W}}$.

Step 1 of 8

1.39p

Consider the circuit shown in Figure P1.39 in the text book.

Calculate the power $\left(P_{4I_x}\right)$ absorbed or supplied by the dependent current source having voltage $V = 12\ \text{V}$ and current $I = 4I_x\ \text{A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{4I_x} &= (12\ \text{V})(-4I_x\ \text{A}) \\ &= (12)(-4I_x) \\ &= -48I_x\ \text{W} \end{aligned}$$

Step 2 of 8

Calculate the power $\left(P_1\right)$ absorbed or supplied by element 1 having voltage $V = 4\ \text{V}$ and current $I = 4I_x\ \text{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_1 &= (4\ \text{V})(4I_x\ \text{A}) \\ &= (4)(4I_x) \\ &= 16I_x\ \text{W} \end{aligned}$$

Step 3 of 8

Calculate the power $\left(P_2\right)$ absorbed or supplied by element 2 having voltage $V = 8\ \text{V}$ and current $I = 4\ \text{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_2 &= (8\ \text{V})(4\ \text{A}) \\ &= (8)(4) \\ &= 32\ \text{W} \end{aligned}$$

Step 4 of 8

Calculate the power $\left(P_{12\text{ V}}\right)$ absorbed or supplied by $12\ \text{V}$ voltage source having voltage $V = 12\ \text{V}$ and current $I = 4\ \text{A}$ as follows:

$$\begin{aligned} P &= V(-I) \\ P_{12\text{ V}} &= (12\ \text{V})(-4\ \text{A}) \\ &= (12)(-4) \\ &= -48\ \text{W} \end{aligned}$$

Step 5 of 8

Calculate the power $\left(P_3\right)$ absorbed or supplied by element 3 having voltage $V = 20\ \text{V}$ and current $I = 2\ \text{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_3 &= (20\ \text{V})(2\ \text{A}) \\ &= (20)(2) \\ &= 40\ \text{W} \end{aligned}$$

Step 6 of 8

Calculate the power $\left(P_4\right)$ absorbed or supplied by element 4 having voltage $V = 20\ \text{V}$ and current $I = I_x\ \text{A}$ as follows:

$$\begin{aligned} P &= VI \\ P_4 &= (20\ \text{V})(I_x\ \text{A}) \\ &= (20)(I_x) \\ &= 20I_x\ \text{W} \end{aligned}$$

Step 7 of 8

In the considered circuit the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$\begin{aligned} P_{4I_x} + P_{12\text{ V}} &= P_1 + P_2 + P_3 + P_4 \\ 48I_x + 48 &= 16I_x + 32 + 40 + 20I_x \\ 12I_x &= 24 \\ I_x &= 2\ \text{A} \end{aligned}$$

Step 8 of 8

Calculate the value of power $\left(P_1\right)$ absorbed or supplied by element 1 in the circuit as follows:

$$\begin{aligned} P_1 &= V(4I_x) \\ &= (4\ \text{V})(4)(2\ \text{A}) \\ &= (4)(4)(2) \\ &= 32\ \text{W} \end{aligned}$$

Therefore, the sign of power $\left(P_1\right)$ is positive and so the element 1 absorbs the power of $\boxed{32\ \text{W}}$.

Step 1 of 7

1.40p

Consider the circuit in Figure P1.40 given in the text book.

First calculate all the values of power absorbed or supplied by each element in the network by using the sign convention for power.

Calculate the power $(P_{9\text{ V}})$ absorbed or supplied by 9 V voltage source in the circuit having voltage $V = 9\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{9\text{ V}} &= VI \\ &= (9\text{ V})(2\text{ A}) \\ &= (9)(2) \\ &= 18\text{ W} \end{aligned}$$

Step 2 of 7

Calculate the power (P_1) absorbed or supplied by element '1' in the circuit having voltage $V = 12\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_1 &= VI \\ &= (12\text{ V})(2\text{ A}) \\ &= (12)(2) \\ &= 24\text{ W} \end{aligned}$$

Step 3 of 7

Calculate the power $(P_{24\text{ V}})$ absorbed or supplied by 24 V voltage source in the circuit having voltage $V = 24\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{24\text{ V}} &= V(-I) \\ &= (24\text{ V})(-2\text{ A}) \\ &= (24)(-2) \\ &= -48\text{ W} \end{aligned}$$

Step 4 of 7

Calculate the power (P_2) absorbed or supplied by element '2' in the circuit having voltage $V = V_x$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_2 &= VI \\ &= (V_x)(2\text{ A}) \\ &= 2V_x \end{aligned}$$

Step 5 of 7

Calculate the power (P_3) absorbed or supplied by element '3' in the circuit having voltage $V = 16\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_3 &= VI \\ &= (16\text{ V})(2\text{ A}) \\ &= (16)(2) \\ &= 32\text{ W} \end{aligned}$$

Step 6 of 7

Calculate the power $(P_{12\text{ V}})$ absorbed or supplied by 12 V voltage source in the circuit having voltage $V = 12\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{12\text{ V}} &= V(-I) \\ &= (12\text{ V})(-2\text{ A}) \\ &= (12)(-2) \\ &= -24\text{ W} \end{aligned}$$

Step 7 of 7

According to Tellegen's theorem the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of V_x as follows:

$$\begin{aligned} P_{24\text{ V}} + P_{12\text{ V}} &= P_{9\text{ V}} + P_1 + P_2 + P_3 \\ 48 + 24 &= 18 + 24 + 2V_x + 32 \\ 2V_x &= -2 \\ V_x &= -1\text{ V} \end{aligned}$$

Therefore, by using Tellegen's theorem, the value of V_x is $\boxed{-1\text{ V}}$.

Step 1 of 8

1.41p

Consider the circuit in Figure P1.41 given in the text book.

First calculate all the values of power absorbed or supplied by each element in the network by using the sign convention for power.

Calculate the power $(P_{24\text{ V}})$ absorbed or supplied by 24 V voltage source in the circuit having voltage $V = 24\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{24\text{ V}} &= V(-I) \\ &= (24\text{ V})(-2\text{ A}) \\ &= (24)(-2) \\ &= -48\text{ W} \end{aligned}$$

Step 2 of 8

Calculate the power $(P_{4\text{ V}})$ absorbed or supplied by 4 V voltage source in the circuit having voltage $V = 4\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{4\text{ V}} &= VI \\ &= (4\text{ V})(2\text{ A}) \\ &= (4)(2) \\ &= 8\text{ W} \end{aligned}$$

Step 3 of 8

Calculate the power $(P_{8\text{ V}})$ absorbed or supplied by 8 V voltage source in the circuit having voltage $V = 8\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{8\text{ V}} &= VI \\ &= (8\text{ V})(2\text{ A}) \\ &= (8)(2) \\ &= 16\text{ W} \end{aligned}$$

Step 4 of 8

Calculate the power $(P_{2\text{ A}})$ absorbed or supplied by 2 A current source in the circuit having voltage $V = 12\text{ V}$ and current $I = 2\text{ A}$ as follows:

$$\begin{aligned} P_{2\text{ A}} &= V(-I) \\ &= (12\text{ V})(-2\text{ A}) \\ &= (12)(-2) \\ &= -24\text{ W} \end{aligned}$$

Step 5 of 8

Calculate the power $(P_{18\text{ V}})$ absorbed or supplied by 18 V voltage source in the circuit having voltage $V = 18\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P_{18\text{ V}} &= VI \\ &= (18\text{ V})(I_x) \\ &= (18)(I_x) \\ &= 18I_x\text{ W} \end{aligned}$$

Step 6 of 8

Calculate the power $(P_{12\text{ V}})$ absorbed or supplied by 12 V voltage source in the circuit having voltage $V = 12\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P_{12\text{ V}} &= V(-I) \\ &= (12\text{ V})(-I_x) \\ &= (12)(-I_x) \\ &= -12I_x\text{ W} \end{aligned}$$

Step 7 of 8

Calculate the power $(P_{6\text{ V}})$ absorbed or supplied by 6 V voltage source in the circuit having voltage $V = 6\text{ V}$ and current $I = I_x$ as follows:

$$\begin{aligned} P_{6\text{ V}} &= VI \\ &= (6\text{ V})(I_x) \\ &= (6)(I_x) \\ &= 6I_x\text{ W} \end{aligned}$$

Step 8 of 8

According to Tellegen's theorem the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$\begin{aligned} P_{24\text{ V}} + P_{2\text{ A}} + P_{12\text{ V}} &= P_{4\text{ V}} + P_{8\text{ V}} + P_{18\text{ V}} + P_{6\text{ V}} \\ 48 + 24 + 12I_x &= 8 + 16 + 18I_x + 6I_x \\ 12I_x &= 48 \\ I_x &= 4\text{ A} \end{aligned}$$

Therefore, by using Tellegen's theorem, the value of I_x is $\boxed{4\text{ A}}$.

Step 1 of 7

1.42p

Consider the circuit in Figure P1.42 given in the text book.

First calculate all the values of power absorbed or supplied by each element in the network by using the sign convention for power.

Calculate the power $(P_{10\,V})$ absorbed or supplied by $10\ V$ voltage source in the circuit having voltage $V = 10\ V$ and current $I = 3\ A$ as follows:

$$\begin{aligned} P_{10\,V} &= VI \\ &= (10\ V)(3\ A) \\ &= (10)(3) \\ &= 30\ W \end{aligned}$$

Step 2 of 7

Calculate the power $(P_{6\,V})$ absorbed or supplied by $6\ V$ voltage source in the circuit having voltage $V = 6\ V$ and current $I = 3\ A$ as follows:

$$\begin{aligned} P_{6\,V} &= VI \\ &= (6\ V)(3\ A) \\ &= (6)(3) \\ &= 18\ W \end{aligned}$$

Step 3 of 7

Calculate the power $(P_{9\,A})$ absorbed or supplied by $9\ A$ current source in the circuit having voltage $V = 16\ V$ and current $I = 9\ A$ as follows:

$$\begin{aligned} P_{9\,A} &= V(-I) \\ &= (16\ V)(-9\ A) \\ &= (16)(-9) \\ &= -144\ W \end{aligned}$$

Step 4 of 7

Calculate the power (P_{V_S}) absorbed or supplied by V_S voltage source in the circuit having voltage $V = V_S$ and current $I = 6\ A$ as follows:

$$\begin{aligned} (P_{V_S}) &= VI \\ &= (V_S)(6\ A) \\ &= (V_S)(6) \\ &= 6V_S\ W \end{aligned}$$

Step 5 of 7

Calculate the power $(P_{8\,V})$ absorbed or supplied by $8\ V$ voltage source in the circuit having voltage $V = 8\ V$ and current $I = 6\ A$ as follows:

$$\begin{aligned} P_{8\,V} &= VI \\ &= (8\ V)(6\ A) \\ &= (8)(6) \\ &= 48\ W \end{aligned}$$

Step 6 of 7

According to Tellegen's theorem the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of I_x as follows:

$$\begin{aligned} P_{9\,A} &= P_{10\,V} + P_{6\,V} + P_{V_S} + P_{8\,V} \\ 144 &= 30 + 18 + 6V_S + 48 \\ 6V_S &= 144 - 96 \\ V_S &= 8\ V \end{aligned}$$

Step 7 of 7

Calculate the value of power (P_{V_S}) absorbed or supplied by voltage source V_S in the circuit having voltage $V_S = 8\ V$ and current $I = 6\ A$ as follows:

$$\begin{aligned} P_{V_S} &= V_S I \\ &= (8\ V)(6\ A) \\ &= (8)(6) \\ &= 48\ W \end{aligned}$$

Therefore, the sign of power (P_{V_S}) is positive and so the voltage source V_S absorbs the power of $\boxed{48\ W}$

1.43p

Consider the circuit given in Figure P1.26 in the text book.

Calculate value of current I_x in the considered circuit having power P supplied by element B by using the formula $P = VI$.

Substitute $P = 72\ \text{W}$, $V = 18\ \text{V}$, $I = I_x$ from the considered circuit and solve for current I_x .

$$72\ \text{W} = (18\ \text{V})(I_x)$$

$$\begin{aligned} I_x &= \frac{72\ \text{W}}{18\ \text{V}} \\ &= 4\ \text{A} \end{aligned}$$

Therefore, the value of current I_x is $\boxed{4\ \text{A}}$.

1.44p

Consider the circuit shown in Figure P1.23 in the text book. The value of current I flowing in the considered circuit is shown in Figure 1.

Figure 1

Calculate value of voltage V_x in Figure 1 having power P by using the formula $P = VI$.

Substitute $P = 30\ \text{W}$, $V = V_x$, $I = -2\ \text{A}$ from the considered circuit and solve for voltage V_x .

$$30\ \text{W} = (V_x)(-2\ \text{A})$$

$$\begin{aligned} V_x &= \frac{30\ \text{W}}{-2\ \text{A}} \\ &= -15\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_x across the element A is $\boxed{-15\ \text{V}}$.

Step 1 of 9

1.45p

Consider the circuit in Figure P1.45 in the text book.

First calculate all the values of power absorbed or supplied by each element in the network by using the sign convention for power.

Calculate the power $(P_{40\,V})$ absorbed or supplied by $40\ V$ voltage source in the circuit having voltage $V = 40\ V$ and current $I = 5\ A$ as follows:

$$\begin{aligned} P_{40\,V} &= V(-I) \\ &= (40\ V)(-5\ A) \\ &= (40)(-5) \\ &= -200\ W \end{aligned}$$

Therefore, the sign of power is negative and so the power supplied by $40\ V$ voltage source is $\boxed{200\ W}$.

Step 2 of 9

Calculate the power $(P_{15\,V})$ absorbed or supplied by $15\ V$ voltage source in the circuit having voltage $V = 15\ V$ and current $I = 1\ A$ as follows:

$$\begin{aligned} P_{15\,V} &= VI \\ &= (15\ V)(1\ A) \\ &= (15)(1) \\ &= 15\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by $15\ V$ voltage source is $\boxed{15\ W}$.

Step 3 of 9

Calculate the power $(P_{4\,A})$ absorbed or supplied by $4\ A$ current source in the circuit having voltage $V = 30\ V$ and current $I = 4\ A$ as follows:

$$\begin{aligned} P_{4\,A} &= VI \\ &= (30\ V)(4\ A) \\ &= (30)(4) \\ &= 120\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by $4\ A$ current source is $\boxed{120\ W}$.

Step 4 of 9

Calculate the power (P_1) absorbed or supplied by element '1' in the circuit having voltage $V = 5\ V$ and current $I = 5\ A$ as follows:

$$\begin{aligned} P_1 &= VI \\ &= (5\ V)(5\ A) \\ &= (5)(5) \\ &= 25\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by element '1' is $\boxed{25\ W}$.

Step 5 of 9

Calculate the power (P_2) absorbed or supplied by element '2' in the circuit having voltage $V = 5\ V$ and current $I = 1\ A$ as follows:

$$\begin{aligned} P_2 &= VI \\ &= (5\ V)(1\ A) \\ &= (5)(1) \\ &= 5\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by element '2' is $\boxed{5\ W}$.

Step 6 of 9

Calculate the power (P_3) absorbed or supplied by element '3' in the circuit having voltage $V = 10\ V$ and current $I = 4\ A$ as follows:

$$\begin{aligned} P_3 &= VI \\ &= (10\ V)(4\ A) \\ &= (10)(4) \\ &= 40\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by element '3' is $\boxed{40\ W}$.

Step 7 of 9

Calculate the power (P_4) absorbed or supplied by element '4' in the circuit having voltage $V = 5\ V$ and current $I = -3\ A$ as follows:

$$\begin{aligned} P_4 &= V(-I) \\ &= (5\ V)(-3\ A) \\ &= (5)(-3) \\ &= -15\ W \end{aligned}$$

Therefore, the sign of power is negative and so the power supplied by element '4' is $\boxed{15\ W}$.

Step 8 of 9

Calculate the power (P_5) absorbed or supplied by element '5' in the circuit having voltage $V = 10\ V$ and current $I = 1\ A$ as follows:

$$\begin{aligned} P_5 &= VI \\ &= (10\ V)(1\ A) \\ &= (10)(1) \\ &= 10\ W \end{aligned}$$

Therefore, the sign of power is positive and so the power absorbed by element '5' is $\boxed{10\ W}$.

Step 9 of 9

According to Tellegen's theorem the sum of supplied powers must be equal to the sum of absorbed powers.

Verify Tellegen's theorem as follows:

$$\begin{aligned} P_{40\,V} + P_4 &= P_{15\,V} + P_1 + P_2 + P_3 + P_5 \\ 200 + 15 &= 25 + 5 + 40 + 10 + 120 + 15 \\ 215 &= 215 \end{aligned}$$

Therefore, the supplied power is equal to the absorbed power and so Tellegen's theorem is verified.

Step 1 of 1

1.46p

Consider the circuit diagram in Figure P1.46 in the text book.

Let the power supplied by element '5' be P_5 . According to Tellegen's theorem the sum of supplied powers must be equal to the sum of absorbed powers.

Calculate the value of P_5 as follows:

$$50\text{ W} + 25\text{ W} + P_5 = 40\text{ W} + 15\text{ W}$$
$$50 + 25 + P_5 = 40 + 15$$
$$75 + P_5 = 55$$
$$P_5 = -20$$

Therefore, the power supplied by element '5' is $\boxed{-20\text{ Watts}}$.

Step 1 of 10

2.7fe

Consider the circuit shown in Figure 2PFE-7 in the text book.

Calculate the equivalent resistance R_{p1} of resistors $3\ \text{k}\Omega$ and $6\ \text{k}\Omega$ connected in parallel in the considered circuit by using the formula $R = \frac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_{p1}$, $R_x = 3\ \text{k}\Omega$, $R_y = 6\ \text{k}\Omega$ considered circuit and solve for R_{p1}.

$$\begin{aligned} R_{p1} &= \frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{3\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= \frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{9\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Step 2 of 10

The circuit is reduced as shown in Figure 1.

Figure 1

Step 3 of 10

Calculate the equivalent resistance R_{s1} of resistors R_3, R_4, R_{p1} connected in series in Figure 1 by using the formula $R = R_x + R_y + R_z$.

Substitute $R = R_{s1}$, $R_x = 4\ \text{k}\Omega$, $R_y = 12\ \text{k}\Omega$, $R_z = R_{p1}$ from Figure 1 and solve for R_{s1}.

$$\begin{aligned} R_{s1} &= 4\ \text{k}\Omega + 12\ \text{k}\Omega + R_{p1} \\ &= 4\ \text{k}\Omega + 12\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 18\ \text{k}\Omega \end{aligned}$$

Step 4 of 10

Calculate the equivalent resistance R_{s2} of resistors R_1, R_2 connected in series in Figure 1 by using the formula $R = R_x + R_y$.

Substitute $R = R_{s2}$, $R_x = 6\ \text{k}\Omega$, $R_y = 3\ \text{k}\Omega$ from Figure 1 and solve for R_{s2}.

$$\begin{aligned} R_{s2} &= 6\ \text{k}\Omega + 3\ \text{k}\Omega \\ &= 9\ \text{k}\Omega \end{aligned}$$

Step 5 of 10

Calculate the equivalent resistance R_{p2} of resistors R_{s1} and R_{s2} connected in parallel in Figure 1 by using the formula $R = \frac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_{p2}$, $R_x = 18\ \text{k}\Omega$, $R_y = 9\ \text{k}\Omega$ and solve for R_{p2}.

$$\begin{aligned} R_{p2} &= \frac{(R_{s1})(R_{s2})}{R_{s1} + R_{s2}} \\ &= \frac{(18\ \text{k}\Omega)(9\ \text{k}\Omega)}{18\ \text{k}\Omega + 9\ \text{k}\Omega} \\ &= \frac{(18\ \text{k}\Omega)(9\ \text{k}\Omega)}{27\ \text{k}\Omega} \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 6 of 10

The circuit is reduced as shown in Figure 2.

Step 7 of 10

Figure 2

Step 8 of 10

Calculate the value of current I_s in the circuit of Figure 2 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_s$, $V = -12\ \text{V}$, $R = 6\ \text{k}\Omega + 6\ \text{k}\Omega$ from Figure 2 and solve for current I_s.

$$\begin{aligned} I_s &= \frac{V}{R} \\ &= \frac{-12\ \text{V}}{6\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= \frac{-12\ \text{V}}{12\ \text{k}\Omega} \\ &= -1\ \text{mA} \end{aligned}$$

Step 9 of 10

Calculate the current I_x in Figure 1 by using the current division formula $I_x = \left(\frac{R_y}{R_x + R_y}\right) I$.

Substitute $I = I_s$, $R_x = R_3 + R_4 + R_{p1}$, $R_y = R_2 + R_1$ from Figure 1 and solve for current I_x.

$$\begin{aligned} I_x &= \left(\frac{R_1 + R_2}{(R_3 + R_4 + R_{p1}) + (R_1 + R_2)}\right) I_s \\ &= \left(\frac{6\ \text{k}\Omega + 3\ \text{k}\Omega}{(4\ \text{k}\Omega + 12\ \text{k}\Omega + 2\ \text{k}\Omega) + (3\ \text{k}\Omega + 6\ \text{k}\Omega)}\right)(-1\ \text{mA}) \\ &= \left(\frac{9\ \text{k}\Omega}{27\ \text{k}\Omega}\right)(-1\ \text{mA}) \\ &= -0.33\ \text{mA} \end{aligned}$$

Step 10 of 10

Calculate the value of current I_0 in Figure 2PFE -7 in the text book by using current division rule $I_0 = \left(\frac{R_y}{R_s + R_y}\right) I$.

Substitute $I = I_s$, $R_x = 3\ \text{k}\Omega$, $R_y = 6\ \text{k}\Omega$ from Figure 2PFE-7 in the text book and solve for I_0.

$$\begin{aligned} I_0 &= \left(\frac{6\ \text{k}\Omega}{6\ \text{k}\Omega + 3\ \text{k}\Omega}\right)(-0.33\ \text{mA}) \\ &= \left(\frac{6\ \text{k}\Omega}{9\ \text{k}\Omega}\right)(-0.33\ \text{mA}) \\ &= (0.667)(-0.33\ \text{mA}) \\ &= -0.22\ \text{mA} \end{aligned}$$

Therefore, the value of current I_0 is $-0.22\ \text{mA}$ and the correct option is $\boxed{d}$.

Step 1 of 2

2.7p

The voltage across any branch is distributed among the network elements connected in series in the branch. If a number of components are connected in parallel, the voltages across all the components are same.

The current in a branch remains same even though it passes through the network elements connected in the branch. When a number of components are connected in parallel, the current divides itself depending on the branch impedances.

Refer to Figure P2.7a in the textbook.

In the past, the lights were connected in series. In series connection, the current remains the same, and the voltage is equally distributed. The lights will not have a voltage equivalent to the source voltage. The voltage across the each light depends upon the number of lights connected serially. If the number of lights connected is increased, the lights would decrease their intensity and would become dimmer.

Step 2 of 2

Refer to Figure P2.7b in the textbook.

Now, the lights are connected in parallel. In parallel connection, the voltage remains same, and the current is equally distributed. The voltage across all the lights is the same. Even though the number of lights connected is increased in parallel, the voltage across each bulb is same and all the lights will glow with equal intensity (intensity would not decrease).

Another reason for this change is, in Figure P2.7a if a light gets damaged or if the connection of a light is cut, then, all the lights would stop glowing. This would not be in the case of Fig P2.7b because, if one bulb is damaged, the remaining would not be effected as they are connected across the same terminals (parallel).

Therefore, the reason for this change is in Figure P2.7b, the lights glow with more brightness as compared to those connected in Figure P2.7a for the same voltage applied across the input terminals.

Step 1 of 4

2.8e

Consider the circuit shown in Figure E2.8 in the text book.

Consider the circuit shown in Figure 1 to calculate V_{ad} which is redrawn from Figure E2.8 as follows:

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to the path afeda to calculate voltage V_{ad} as follows:

$$V_{ad} = 6\text{ V} + 8\text{ V} + 12\text{ V}$$
$$= 26\text{ V}$$

Therefore, the value of V_{ad} is $\boxed{26\text{ V}}$.

Step 3 of 4

Consider the circuit shown in Figure 2 to calculate V_{eb} which is re drawn from figure E2.8 as follows:

Figure 2

Step 4 of 4

Apply Kirchhoff's voltage law to the path bcdeb to calculate voltage V_{eb} as follows:

$$V_{eb} = 12\text{ V} - 6\text{ V} + 4\text{ V}$$
$$= 10\text{ V}$$

Therefore, the value of V_{eb} is $\boxed{10\text{ V}}$.

Step 1 of 3

2.8fe

Consider the circuit shown in Figure 2PFE-8 in the text book.

Calculate the equivalent resistance of resistors connected in series by using the formula $R = R_x + R_y$.

Substitute $R = R_{S1}$, $R_x = 3\ \text{k}\Omega$, $R_y = 1\ \text{k}\Omega$ and solve for R_{S1}.

$$\begin{aligned} R_{S1} &= 3\ \text{k}\Omega + 1\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Calculate the equivalent resistance of resistors connected in series by using the formula $R = R_x + R_y$.

Substitute $R = R_{S2}$, $R_x = 2\ \text{k}\Omega$, $R_y = 6\ \text{k}\Omega$ and solve for R_{S2}.

$$\begin{aligned} R_{S2} &= 2\ \text{k}\Omega + 6\ \text{k}\Omega \\ &= 8\ \text{k}\Omega \end{aligned}$$

Calculate the equivalent resistance of resistors connected in parallel by using the formula $R = \dfrac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_{P1}$, $R_x = 6\ \text{k}\Omega$, $R_y = 12\ \text{k}\Omega$ and solve for R_{P1}.

$$\begin{aligned} R_{P1} &= \frac{(6\ \text{k}\Omega)(12\ \text{k}\Omega)}{6\ \text{k}\Omega + 12\ \text{k}\Omega} \\ &= \frac{(6\ \text{k}\Omega)(12\ \text{k}\Omega)}{18\ \text{k}\Omega} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 2 of 3

The considered circuit is reduced as shown in Figure 1.

Figure 1

Calculate the value of current I_o flowing through R_{S2} by using the current division formula

$$I_x = \left(\frac{R_y}{R_x + R_y}\right) I.$$

Substitute $I_x = I_o$, $R_y = R_{S1}$, $R_x = R_{S2} + R_{P1}$, $I = 24\ \text{mA}$ from Figure 1 and solve for current I_o.

$$\begin{aligned} I_o &= \left(\frac{R_{S1}}{(R_{S2} + R_{P1}) + R_{S1}}\right)(24\ \text{mA}) \\ &= \left(\frac{4\ \text{k}\Omega}{(8\ \text{k}\Omega + 4\ \text{k}\Omega) + 4\ \text{k}\Omega}\right)(24\ \text{mA}) \\ &= (0.25)(24\ \text{mA}) \\ &= 6\ \text{mA} \end{aligned}$$

Step 3 of 3

The same current I_o is flowing through $6\ \text{k}\Omega$ resistor having V_o by using the Ohm's law $V = IR$.

Substitute $V = V_o$, $I = 6\ \text{mA}$, $R = 6\ \text{k}\Omega$ and solve for voltage V_o.

$$\begin{aligned} V_o &= (6\ \text{mA})(6\ \text{k}\Omega) \\ &= 36\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the considered circuit is $36\ \text{V}$ and so the correct answer is option $\boxed{\text{c}}$.

Step 1 of 3

Refer to Figure P2.8 in the text book.

Determine the value of current, I_1 in the network

Apply Kirchhoff's voltage law at node-A in the network.

$$5+4+I_1=2+8$$
$$9+I_1=10$$
$$I_1=1\text{ A}$$

Thus, the value of current, I_1 is $\boxed{1\text{ A}}$.

Step 2 of 3

Determine the value of current, I_2 in the network

Apply Kirchhoff's voltage law at node-B in the network.

$$3=6+I_2+I_1$$
$$I_1+I_2=-3$$

Substitute 1 A for I_1 in the equation.

$$1+I_2=-3$$
$$I_2=-4\text{ A}$$

Thus, the value of current, I_2 is $\boxed{-4\text{ A}}$.

Step 3 of 3

Determine the value of current, I_3 in the network.

Apply Kirchhoff's voltage law at node-C in the network.

$$I_2+8=I_3+4$$
$$I_3=I_2+4$$

Substitute -4 A for I_2 in the equation.

$$I_3=-4+4$$
$$I_3=0\text{ A}$$

Thus, the value of current, I_3 is $\boxed{0\text{ A}}$.

Step 1 of 2

2.9e

Consider the circuit shown in Figure E2.9 in the text book.

Apply Kirchhoff's voltage law to the loop abcda to calculate voltage $\left(V_{R_1}\right)$ across resistor R_1 as follows:

$$V_{R_1} + V_{R_2} + 10V_{R_1} - 12\text{ V} = 0$$
$$11V_{R_1} = 12 - V_{R_2}$$
$$11V_{R_1} = 12 - 1\text{ V}$$
$$V_{R_1} = 1\text{ V}$$

Step 2 of 2

Now apply Kirchhoff's voltage law to the loop bcdb to calculate voltage $\left(V_{bd}\right)$ as follows:

$$V_{R_2} + 10V_{R_1} - V_{bd} = 0$$

$$\begin{aligned} V_{bd} &= V_{R_2} + 10V_{R_1} \\ &= 1\text{ V} + 10(1\text{ V}) \\ &= 11\text{ V} \end{aligned}$$

Therefore, the value of V_{bd} is $\boxed{11\text{ V}}$.

Step 1 of 2

2.9fe

Consider the circuit shown in Figure 2PFE-9 in the text book.

The node voltage for the considered circuit is shown in Figure 1.

Figure 1

Apply Kirchhoff's current law at the node V_1 in Figure 1 and solve.

$$2+\frac{V_1}{2}-4+\frac{V_1}{1+3}=0$$
$$\frac{4(2)}{4}+\frac{2V_1}{4}-\frac{4(4)}{4}+\frac{V_1}{4}=0$$
$$2V_1+V_1=16-8$$
$$V_1=2.67\text{ V}$$

Step 2 of 2

Calculate the value of voltage V_o in Figure 1 by using voltage division formula $V_x=\left(\frac{R_x}{R_x+R_y}\right)V$.

Substitute $V_x=V_o$, $R_x=3\,\Omega$, $R_y=1\,\Omega$, $V=2.67\text{ V}$ from Figure 1 and solve for V_o.

$$\begin{aligned}V_o&=\left(\frac{3\,\Omega}{3\,\Omega+1\,\Omega}\right)(2.67\text{ V})\\&=\left(\frac{3}{4}\right)(2.67)\\&=(0.75)(2.67)\\&=2\text{ V}\end{aligned}$$

Therefore, the value of voltage V_o in the circuit is 2 V and so the correct answer is option $\boxed{a}$.

Step 1 of 3

2.9p

Consider the circuit shown in Figure P2.10 in the text book. The nodes and current flow directions in the branches of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

Let I_2 be the current flowing through the resistor in between the nodes A and B.

Apply Kirchhoff's current law at node B and calculate the value of I_2.

$$\begin{aligned} I_2 &= 6\text{ mA} + 4\text{ mA} \\ &= 10\text{ mA} \end{aligned}$$

Step 3 of 3

Apply Kirchhoff's current law at node A and calculate the value of I_1.

$$\begin{aligned} I_1 + I_2 &= 20\text{ mA} \\ I_1 &= 20\text{ mA} - I_2 \\ &= 20\text{ mA} - 10\text{ mA} \\ &= 10\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{10\text{ mA}}$.

Step 1 of 3

2.10e

Consider the circuit shown in Figure E2.10 in the text book.

Apply Kirchhoff's voltage law to the circuit and calculate current (I) value as follows:

$$(80\ \text{k}\Omega)(I)+12\ \text{V}+(40\ \text{k}\Omega)(I)-6\ \text{V}=0$$
$$(80\times10^3+40\times10^3)(I)=-12+6$$
$$I=\frac{-6}{120\times10^3}$$
$$I=-0.05\ \text{mA}$$

Therefore, the value of current (I) flowing in the circuit is $\boxed{-0.05\ \text{mA}}$.

Step 2 of 3

Calculate the voltage (V) across $40\ \text{k}\Omega$ resistor as follows:

$$\begin{aligned}V&=IR\\&=(-0.05\ \text{mA})(40\ \text{k}\Omega)\\&=(-0.05\times10^{-3})(40\times10^3)\\&=-2\ \text{V}\end{aligned}$$

Step 3 of 3

Now apply the Kirchhoff's law to the loop bcdb to calculate voltage V_{bd} as follows:

$$\begin{aligned}V_{bd}&=12\ \text{V}-2\ \text{V}\\&=10\ \text{V}\end{aligned}$$

Therefore the value of voltage, V_{bd} is $\boxed{10\ \text{V}}$.

Step 1 of 5

2.10fe

Refer to figure 2PFE-10, Replace the series combination of resistors 8Ω and 2Ω resistor with their equivalent resistance given by

$$R_{eq} = 8 + 2$$
$$R_{eq} = 10\Omega$$

Figure 1

Step 2 of 5

Replace the series combination of resistors 10Ω and 10Ω resistor with their equivalent resistance given by

$$R_{eq} = \frac{10 \times 10}{20}$$
$$R_{eq} = 5\Omega$$

Figure 2

Step 3 of 5

Replace the series combination of resistors 1Ω and 5Ω resistor with their equivalent resistance given by

$$R_{eq} = 1 + 5$$
$$R_{eq} = 6\Omega$$

Figure 3

Step 4 of 5

Equivalent resistance of the circuit R_{eq} is given by

$$R_{eq} = 1 + \frac{(6 \times 3)}{6 + 3}$$
$$R_{eq} = 3\Omega$$

Total current I_T delivered by the 12 V source is given by

$$I_T = \frac{12}{3}$$
$$I_T = 4\text{ A}$$

Figure 4

Step 5 of 5

Apply current division rule between 3 ohms and 6 ohms resistors to find I_x

$$I_x = I_T\left(\frac{6}{6+3}\right)$$
$$I_x = 4\left(\frac{6}{6+3}\right)$$

Thus, the current I_x is $\boxed{2.66\text{A}}$.

2.10p

Consider the circuit shown in Figure P2.11 in the text book.

Apply Kirchhoff's current law at the top node in the considered circuit and solve for current I_1 .

$$\begin{aligned} I_1 &= 6\text{ mA} + 2\text{ mA} \\ &= 8\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{8\text{ mA}}$.

Step 1 of 5

2.11e

Consider the circuit shown in Figure 1 as follows:

Figure 1

Step 2 of 5

Let I be the current flowing in the circuit. Apply Kirchhoff's voltage law to the loop ada to calculate current I flowing in the circuit as follows:

$$-I(20\text{ k}\Omega) = V_{ad}$$
$$I(20\times10^3) = 3\text{ V}$$
$$I = -0.15\text{ mA}$$

Step 3 of 5

Calculate the voltage (V_1) across $25\text{ k}\Omega$ resistor as follows:

$$\begin{aligned} V_1 &= (-0.15\text{ mA})(25\text{ k}\Omega) \\ &= (-0.15\times10^{-3})(25\times10^3) \\ &= -3.75\text{ V} \end{aligned}$$

Step 4 of 5

Calculate the voltage (V_2) across $15\text{ k}\Omega$ resistor as follows:

$$\begin{aligned} V_2 &= (-0.15\text{ mA})(15\text{ k}\Omega) \\ &= (-0.15\times10^{-3})(15\times10^3) \\ &= -2.25\text{ V} \end{aligned}$$

Step 5 of 5

Now, apply Kirchhoff's voltage law to loop abcda to calculate V_S as follows:

$$V_{ad} = V_S + V_1 + V_2$$

$$\begin{aligned} V_S &= V_{ad} - V_1 - V_2 \\ &= 3\text{ V} - (-3.75\text{ V}) - (-2.25\text{ V}) \\ &= 9\text{ V} \end{aligned}$$

Therefore, the value of V_S is $\boxed{9\text{ V}}$.

2.11p

Consider the circuit shown in Figure P2.13 in the text book. The nodes and current flow directions in the branches of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node 'b' in Figure 1 and solve for current I_2.

$$I_2 + 12\text{ mA} = 4\text{ mA}$$

$$\begin{aligned} I_2 &= 4\text{ mA} - 12\text{ mA} \\ &= -8\text{ mA} \end{aligned}$$

Apply Kirchhoff's current law at node 'a' in Figure 1 and solve for current I_1.

$$I_1 + I_2 = 2\text{ mA}$$

$$I_1 - 8\text{ mA} = 2\text{ mA}$$

$$\begin{aligned} I_1 &= 2\text{ mA} + 8\text{ mA} \\ &= 10\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{10\text{ mA}}$.

Step 1 of 3

2.12e

Consider the circuit shown in Figure E2.12 given in the text book.

Calculate the value of I_1 passing through $R_1 = 40\ \text{k}\Omega$ by using the current division formula given in equation 2.19 in the text book having $I = 16\ \text{mA}$ and $R_2 = 120\ \text{k}\Omega$ as follows:

$$\begin{aligned} I_1 &= \left(\frac{R_2}{R_1 + R_2}\right)(I) \\ &= \left(\frac{120\ \text{k}\Omega}{40\ \text{k}\Omega + 120\ \text{k}\Omega}\right)(16\ \text{mA}) \\ &= (0.75)(16 \times 10^{-3}) \\ &= 12\ \text{mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{12\ \text{mA}}$.

Step 2 of 3

Calculate the value of I_2 passing through $R_2 = 120\ \text{k}\Omega$ by using the current division formula given in equation 2.20 in the text book having $I = 16\ \text{mA}$ and $R_1 = 40\ \text{k}\Omega$ as follows:

$$\begin{aligned} I_2 &= \left(\frac{R_1}{R_1 + R_2}\right)(I) \\ &= \left(\frac{40\ \text{k}\Omega}{40\ \text{k}\Omega + 120\ \text{k}\Omega}\right)(16\ \text{mA}) \\ &= (0.25)(16 \times 10^{-3}) \\ &= 4\ \text{mA} \end{aligned}$$

The current leaving from the bottom node of $16\ \text{mA}$ should equal to the current entering in $40\ \text{k}\Omega$ resistor and $120\ \text{k}\Omega$ resistor. So the sign of current I_2 should be negative to enter into $120\ \text{k}\Omega$.

Therefore, the value of current I_2 is $\boxed{-4\ \text{mA}}$.

Step 3 of 3

Calculate the power $(P_{40\ \text{k}\Omega})$ absorbed by $R_1 = 40\ \text{k}\Omega$ as follows:

$$\begin{aligned} P_{40\ \text{k}\Omega} &= (I_1^2)(R_1) \\ &= (12\ \text{mA})^2 (40\ \text{k}\Omega) \\ &= (144 \times 10^{-3})(40) \\ &= 5.76\ \text{W} \end{aligned}$$

Therefore, the power absorbed by $40\ \text{k}\Omega$ resistor is $\boxed{5.76\ \text{W}}$.

Step 1 of 4

2.12p

Consider the circuit shown in Figure P2.16 in the text book. The nodes and current flow directions in the branches of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Let 'a', 'b', 'c' be the nodes as shown in Figure 1. Let the current I_a flowing in the circuit between the nodes 'a' and 'b'.

Apply Kirchhoff's current law at node 'a' and calculate the value of current I_a.

$$I_a + 4\text{ mA} = 5\text{ mA} \quad \begin{aligned} I_a &= 5\text{ mA} - 4\text{ mA} \\ &= 1\text{ mA} \end{aligned}$$

Step 3 of 4

Apply Kirchhoff's current law at node 'b' and calculate the value of current I_1.

$$I_1 + I_a + 3\text{ mA} = 2\text{ mA}$$
$$I_1 + 1\text{ mA} + 3\text{ mA} = 2\text{ mA}$$

$$\begin{aligned} I_1 &= 2\text{ mA} - 4\text{ mA} \\ &= -2\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{-2\text{ mA}}$.

Step 4 of 4

Apply Kirchhoff's current law at node 'c' and calculate current I_o as follows:

$$\begin{aligned} I_o &= I_1 + 5\text{ mA} \\ &= -2\text{ mA} + 5\text{ mA} \\ &= 3\text{ mA} \end{aligned}$$

Therefore, the value of current I_o is $\boxed{3\text{ mA}}$.

Step 1 of 5

2.13e

Consider the circuit shown in figure E2.13 in the text book.

Calculate the total resistance (R_1) value of $4\ \text{k}\Omega$ and $12\ \text{k}\Omega$ resistors that are connected in parallel.

$$\begin{aligned} R_1 &= \left(\frac{1}{4\ \text{k}\Omega} + \frac{1}{12\ \text{k}\Omega}\right)^{-1} \\ &= \left(\left(2.5\times10^{-4}\right) + \left(8.33\times10^{-5}\right)\right)^{-1} \\ &= \frac{1}{\left(3.233\times10^{-4}\right)} \\ &= 3\ \text{k}\Omega \end{aligned}$$

Step 2 of 5

Add the current sources algebraically and find the value of resultant current (I).

$$\begin{aligned} I &= 6\ \text{mA} - 4\ \text{mA} \\ &= 2\ \text{mA} \end{aligned}$$

Step 3 of 5

Thus, the circuit of Figure E2.13 is reduced as follows:

Figure 1

Step 4 of 5

From Figure 1 the circuit (I_2) is flowing through the resistor $R_2 = 6\ \text{k}\Omega$.

Apply current division rule of equation 2.20 in the text book calculate the value of I_2.

$$\begin{aligned} I_2 &= -\left(\frac{R_1}{R_1 + R_2}\right)(I) \\ &= \left(\frac{3\ \text{m}\Omega}{3\ \text{m}\Omega + 6\ \text{m}\Omega}\right)(2\ \text{mA}) \\ &= \left(\frac{3\times10^3}{\left(3\times10^3\right) + \left(6\times10^3\right)}\right)\left(2\times10^{-3}\right) \\ &= -0.667\ \text{mA} \end{aligned}$$

Step 5 of 5

Calculate the value of power (P) absorbed by resistor (R_2) of $6\ \text{k}\Omega$.

$$\begin{aligned} P &= I_2^2 R_2 \\ &= (-0.667\ \text{mA})^2 (6\ \text{k}\Omega) \\ &= \left(-0.667\times10^{-3}\right)^2 \left(6\times10^3\right) \\ &= 2.67\ \text{mW} \end{aligned}$$

Therefore, the power absorbed $6\ \text{k}\Omega$ by resistor is $\boxed{2.67\ \text{mW}}$.

Step 1 of 2

2.13p

Refer to Figure P2.18 in the textbook.

Represent the nodes and redraw the circuit.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node 'a' and calculate the value of current, I_x.

$$I_x + 3\text{ mA} = 12\text{ mA}$$

$$\begin{aligned} I_x &= 12\text{ mA} - 3\text{ mA} \\ &= 9\text{ mA} \end{aligned}$$

Therefore, the value of current, I_x is, $\boxed{9\text{ mA}}$.

Apply Kirchhoff's current law at node 'b' and calculate the value of current, I_z.

$$I_z + 4\text{ mA} = 2\text{ mA}$$

$$\begin{aligned} I_z &= 2\text{ mA} - 4\text{ mA} \\ &= -2\text{ mA} \end{aligned}$$

Therefore, the value of current, I_z is, $\boxed{-2\text{ mA}}$.

Apply Kirchhoff's current law at node 'c' and calculate the value of current, I_y.

$$I_y + I_z + 12\text{ mA} = 0$$

$$I_y - 2\text{ mA} + 12\text{ mA} = 0 \qquad (\text{since, } I_z = -2\text{ mA})$$

$$I_y + 10\text{ mA} = 0$$

$$I_y = -10\text{ mA}$$

Therefore, the value of current, I_y is, $\boxed{-10\text{ mA}}$.

Step 1 of 4

2.14e

Refer to Figure E2.14 in the text book.

Calculate the equivalent resistance (R_1) of resistors $3\ \text{k}\Omega$ and $6\ \text{k}\Omega$ connected in series as follows:

$$\begin{aligned} R_1 &= 3\ \text{k}\Omega + 6\ \text{k}\Omega \\ &= 9\ \text{k}\Omega \end{aligned}$$

Step 2 of 4

The resistor R_1 is in parallel to $18\ \text{k}\Omega$ resistance. Calculate the equivalent resistor (R_2) as follows:

$$\begin{aligned} R_2 &= R_1 \| 18\ \text{k}\Omega \\ &= \frac{(R_1)(18\ \text{k}\Omega)}{R_1 + 18\ \text{k}\Omega} \\ &= \frac{(9\ \text{k}\Omega)(18\ \text{k}\Omega)}{9\ \text{k}\Omega + 18\ \text{k}\Omega} \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 3 of 4

Now, the circuit is reduced to as shown in Figure 1.

Figure 1

Step 4 of 4

Calculate the total equivalent resistance (R_{AB}) of circuit in Figure **1** as follows:

$$\begin{aligned} R_{AB} &= 6\ \text{k}\Omega + R_2 + 10\ \text{k}\Omega \\ &= 6\ \text{k}\Omega + 6\ \text{k}\Omega + 10\ \text{k}\Omega \\ &= 22\ \text{k}\Omega \end{aligned}$$

Therefore, the equivalent resistance at the terminals A-B in the network is $\boxed{22\ \text{k}\Omega}$.

Step 1 of 2

2.14p

Step 2 of 2

Applying KCL at node a,

$I_x + 10\text{m} - 5I_x - 2\text{m} = 0$

$8\text{m} - 4I_x = 0$

$4I_x = 8\text{m}$

$\boxed{I_x = 2\text{ mA}}$

Step 1 of 6

2.15e

Refer to Figure E2.15 in the text book.

Calculate the equivalent resistance (R_1) of resistors $4\ \text{k}\Omega$ and $8\ \text{k}\Omega$ that are connected in series as follows:

$$\begin{aligned} R_1 &= 4\ \text{k}\Omega + 8\ \text{k}\Omega \\ &= 12\ \text{k}\Omega \end{aligned}$$

Step 2 of 6

The resistance $R_1 = 12\ \text{k}\Omega$ is in parallel to $12\ \text{k}\Omega$ resistor and $3\ \text{k}\Omega$ resistor.

Calculate the equivalent resistance (R_2) by as follows:

$$\begin{aligned} R_2 &= \left(\frac{1}{12\ \text{k}\Omega} + \frac{1}{12\ \text{k}\Omega} + \frac{1}{3\ \text{k}\Omega}\right)^{-1} \\ &= \left(\left(83.33\times10^{-6}\right) + \left(83.33\times10^{-6}\right) + \left(333.3\times10^{-6}\right)\right)^{-1} \\ &= \left(4.99\times10^{-4}\right)^{-1} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Step 3 of 6

Now the circuit is reduced as shown in Figure 1.

Figure 1

Step 4 of 6

Calculate the equivalent resistance (R_3) of resistors $4\ \text{k}\Omega$ and R_2 that are connected in series in Figure 1.

$$\begin{aligned} R_3 &= 4\ \text{k}\Omega + R_2 \\ &= 4\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 5 of 6

Now, the circuit is reduced as shown in Figure 2.

Figure 2

Step 6 of 6

Calculate the total equivalent resistance (R_{AB}) from Figure 2 for resistors $6\ \text{k}\Omega$ and R_3 connected in parallel as follows:

$$\begin{aligned} R_{AB} &= 6 \parallel R_3 \\ &= \frac{(6\ \text{k}\Omega)(6\ \text{k}\Omega)}{6\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= \frac{\left(6\times10^3\right)\left(6\times10^3\right)}{\left(6\times10^3\right)+\left(6\times10^3\right)} \\ &= 3\ \text{k}\Omega \end{aligned}$$

Therefore, the value of equivalent resistance at terminals *A-B* in the circuit is $\boxed{3\ \text{k}\Omega}$.

2.15p

Consider the circuit shown in Figure P2.14 in the text book.

According Kirchhoff's current law the currents flowing at any node is equal to currents leaving from the same node.

Apply Kirchhoff's current law to the considered circuit and solve for current I_x value.

$$2I_x - 4\text{ mA} + 12\text{ mA} - I_x - 3I_x = 0$$

$$-2I_x = -8\text{ mA}$$

$$2I_x = 8\text{ mA}$$

$$I_x = 4\text{ mA}$$

Therefore, the value of current I_x is $\boxed{4\text{ mA}}$.

Step 1 of 10

2.16e

Refer to Figure E2.16 in the text book.

Calculate the equivalent resistance (R_1) of resistors $2\ \text{k}\Omega$, $2\ \text{k}\Omega$ and $2\ \text{k}\Omega$ that are connected in series as follows:

$$\begin{aligned} R_1 &= 2\ \text{k}\Omega + 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 2 of 10

The resistor $R_1 = 6\ \text{k}\Omega$ is in parallel to $6\ \text{k}\Omega$ resistor. Calculate the equivalent resistance (R_2) as follows:

$$\begin{aligned} R_2 &= \left(\frac{1}{6\ \text{k}\Omega} + \frac{1}{6\ \text{k}\Omega}\right)^{-1} \\ &= \frac{(6\ \text{k}\Omega)(6\ \text{k}\Omega)}{6\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= \frac{(6\times10^3)(6\times10^3)}{(6\times10^3)+(6\times10^3)} \\ &= 3\ \text{k}\Omega \end{aligned}$$

Step 3 of 10

Now, the circuit is reduced as shown in Figure 1.

Figure 1

Step 4 of 10

Calculate the equivalent resistance (R_3) of resistors $3\ \text{k}\Omega$ and $R_2 = 3\ \text{k}\Omega$ that are connected in series in Figure 1.

$$\begin{aligned} R_3 &= 3\ \text{k}\Omega + R_2 \\ &= 3\ \text{k}\Omega + 3\ \text{k}\Omega \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 5 of 10

Now the resistor $R_3 = 6\ \text{k}\Omega$ and $12\ \text{k}\Omega$ are in parallel connection. Calculate the equivalent resistance (R_4) as follows:

$$\begin{aligned} R_4 &= \left(\frac{1}{12\ \text{k}\Omega} + \frac{1}{6\ \text{k}\Omega}\right)^{-1} \\ &= \frac{(6\ \text{k}\Omega)(12\ \text{k}\Omega)}{12\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= \frac{(6\times10^3)(12\times10^3)}{(12\times10^3)+(6\times10^3)} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 6 of 10

Now, the circuit is reduced as shown in Figure 2.

Figure 2

Step 7 of 10

Calculate the equivalent resistance (R_5) of resistors $4\ \text{k}\Omega$ and $R_4 = 4\ \text{k}\Omega$ that are connected in series in Figure 2.

$$\begin{aligned} R_5 &= 4\ \text{k}\Omega + R_4 \\ &= 4\ \text{k}\Omega + 4\ \text{k}\Omega \\ &= 8\ \text{k}\Omega \end{aligned}$$

Step 8 of 10

Now the resistor R_5 and $8\ \text{k}\Omega$ are in parallel connection. Calculate the equivalent resistance (R_6) as follows:

$$\begin{aligned} R_6 &= 8\ \text{k}\Omega \parallel R_5 \\ &= \frac{(8\ \text{k}\Omega)(8\ \text{k}\Omega)}{8\ \text{k}\Omega + 8\ \text{k}\Omega} \\ &= \frac{(8\times10^3)(8\times10^3)}{(8\times10^3)+(8\times10^3)} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 9 of 10

Now, the circuit is reduced as shown in Figure 3.

Figure 3

Step 10 of 10

Calculate the total equivalent resistance (R_{AB}) from Figure 3 for the series resistors of $4\ \text{k}\Omega$, R_6 and $4\ \text{k}\Omega$ by using equation 2.25 in the text book as follows:

$$\begin{aligned} R_{AB} &= 4\ \text{k}\Omega + R_6 + 4\ \text{k}\Omega \\ &= 4\ \text{k}\Omega + 4\ \text{k}\Omega + 4\ \text{k}\Omega \\ &= 12\ \text{k}\Omega \end{aligned}$$

Therefore, the value of R_{AB} is $\boxed{12\ \text{k}\Omega}$.

Step 1 of 2

2.16p

Consider the circuit shown in Figure P2.17 in the text book. The nodes for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node 'a' in Figure 1 and calculate the value of current I_x .

$$\begin{aligned} I_x &= 4\text{ mA} + 2\text{ mA} \\ &= 6\text{ mA} \end{aligned}$$

Apply Kirchhoff's current law at node 'b' in Figure 1 and calculate the value of current I_1 .

$$I_1 + 2I_x = 4\text{ mA}$$
$$I_1 + (2)(6\text{ mA}) = 4\text{ mA}$$

$$\begin{aligned} I_1 &= 4\text{ mA} - 12\text{ mA} \\ &= -8\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{-8\text{ mA}}$.

2.17p

Refer to Figure P2.23 in the textbook.

The voltage, V_{bc} between the nodes b and c is, 6 V. The voltage, V_{cd} between the nodes c and d is 2 V.

Calculate the voltage, V_{bd} between the nodes b and d.

$$\begin{aligned} V_{bd} &= V_{bc} + V_{cd} \\ &= 6\text{ V} + 2\text{ V} \\ &= 8\text{ V} \end{aligned}$$

Therefore, the value of voltage, V_{bd} is, $\boxed{8\text{ V}}$.

Step 1 of 6

2.18e

Refer to Figure E2.18 in the textbook for the circuit.

Redraw the circuit by representing currents in the circuit as shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the value of voltage across the resistor R_1 as follows:

$$\begin{aligned} V_1 &= I_1 R_1 \\ &= (0.1\text{ mA})(60\text{ k}\Omega) \\ &= (0.1\times10^{-3})(60\times10^{3}) \\ &= 6\text{ V} \end{aligned}$$

Step 3 of 6

Therefore, the voltage V_2 across the resistor R_2 is also equal to 6 V because the voltage is same across the branches in parallel circuit.

Now, calculate the current I_2 in Figure 1 as follows:

$$\begin{aligned} I_2 &= \frac{V_2}{R_2} \\ &= \frac{6\text{ V}}{120\text{ k}\Omega} \\ &= 0.05\text{ mA} \end{aligned}$$

Step 4 of 6

Apply Kirchhoff's current law and calculate the current I .

$$\begin{aligned} I &= I_1 + I_2 \\ &= 0.1\text{ mA} + 0.05\text{ mA} \\ &= 0.15\text{ mA} \end{aligned}$$

Step 5 of 6

Now, calculate the voltage (V) across resistor (R) .

$$\begin{aligned} V &= IR \\ &= (0.15\text{ mA})(20\text{ k}\Omega) \\ &= (0.15\times10^{-3})(20\times10^{3}) \\ &= 3\text{ V} \end{aligned}$$

Step 6 of 6

Apply Kirchhoff's voltage law around the loop formed by V_s , V and V_1 as follows:

$$\begin{aligned} V + V_1 - V_s &= 0 \\ 3\text{ V} + 6\text{ V} - V_s &= 0 \\ 9\text{ V} - V_s &= 0 \\ V_s &= 9\text{ V} \end{aligned}$$

Therefore, the value of V_s in the circuit is $\boxed{9\text{ V}}$.

Step 1 of 2

Refer to Figure P2.20 in the textbook.

Represent the nodes and redraw the circuit.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node 'a' and calculate the value of current, I_x .

$$2I_x + 4\text{ mA} = 6\text{ mA} + 6\text{ mA}$$
$$2I_x = 12\text{ mA} - 4\text{ mA}$$

$$I_x = \frac{8\text{ mA}}{2}$$
$$= 4\text{ mA}$$

Apply Kirchhoff's current law at node 'b' and calculate the value of current, I_1 .

$$I_1 + I_x + 6\text{ mA} = 0$$
$$I_1 + 4\text{ mA} + 6\text{ mA} = 0 \quad (\text{since, } I_x = 4\text{ mA})$$
$$I_1 + 10\text{ mA} = 0$$
$$I_1 = -10\text{ mA}$$

Therefore, the value of current, I_1 is, $\boxed{-10\text{ mA}}$.

Step 1 of 6

2.19e

Refer to Figure E2.19 in the textbook for the circuit.

Redraw the circuit by representing currents in the circuit as shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the current (I_2) from Figure 1 having voltage $V = 3\text{ V}$ and resistance $R_3 = 30\text{ k}\Omega$ as follows:

$$\begin{aligned} I_2 &= \frac{V}{R_3} \\ &= \frac{3\text{ V}}{30\text{ k}\Omega} \\ &= 0.1\text{ mA} \end{aligned}$$

Step 3 of 6

Calculate the voltage V_2 across the resistor $R_2 = 90\text{ k}\Omega$ having current $I_2 = 0.1\text{ mA}$ in Figure 1 as follows:

$$\begin{aligned} V_2 &= I_2 R_2 \\ &= (0.1\text{ mA})(90\text{ k}\Omega) \\ &= (0.1\times10^{-3})(90\times10^{3}) \\ &= 9\text{ V} \end{aligned}$$

Step 4 of 6

The voltage V_1 across resistor R_1 is equal to the sum of V_2 and V as follows:

$$\begin{aligned} V_1 &= V_2 + V \\ &= 9\text{ V} + 3\text{ V} \\ &= 12\text{ V} \end{aligned}$$

Step 5 of 6

Calculate current (I_1) through resistor $R_1 = 60\text{ k}\Omega$ as follows:

$$\begin{aligned} I_1 &= \frac{V_1}{R_1} \\ &= \frac{12\text{ V}}{60\text{ k}\Omega} \\ &= 0.2\text{ mA} \end{aligned}$$

Step 6 of 6

Calculate the value of current I_S by applying Kirchhoff's current law as follows:

$$\begin{aligned} I_S &= I_1 + I_2 \\ &= 0.2\text{ mA} + 0.1\text{ mA} \\ &= 0.3\text{ mA} \end{aligned}$$

Therefore, the value of current I_S is $\boxed{0.3\text{ mA}}$.

Step 1 of 3

Refer to Figure P2.21 in the textbook.

Represent the nodes and redraw the circuit.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law at node 'a'.

$$I_3 + 4\text{ mA} + 2I_x = 0$$
$$I_3 = -(2I_x + 4\text{ mA})$$

Apply Kirchhoff's current law at node 'b' and calculate the value of current, I_x.

$$I_3 + I_x = 12\text{ mA}$$

Substitute the expression for I_3.

$$-2I_x - 4\text{ mA} + I_x = 12\text{ mA}$$
$$-I_x = 12\text{ mA} + 4\text{ mA}$$
$$I_x = -16\text{ mA}$$

Apply Kirchhoff's current law at node 'c' and calculate the value of current, I_1.

$$\begin{aligned} I_1 &= 2I_x + 2I_x \\ &= 4I_x \\ &= 4(-16\text{ mA}) \quad (\text{since, } I_x = -16\text{ mA}) \\ &= -64\text{ mA} \end{aligned}$$

Therefore, the value of current, I_1 is, $\boxed{-64\text{ mA}}$.

Step 3 of 3

Apply Kirchhoff's current law at node 'd' and calculate the value of current, I_2.

$$I_2 + 12\text{ mA} = 2I_x$$
$$I_2 + 12\text{ mA} = 2(-16\text{ mA}) \qquad (\text{since, } I_x = -16\text{ mA})$$

$$\begin{aligned} I_2 &= -32\text{ mA} - 12\text{ mA} \\ &= -44\text{ mA} \end{aligned}$$

Therefore, the value of current, I_2 is, $\boxed{-44\text{ mA}}$.

Substitute the value of I_x in the equation of I_3.

$$\begin{aligned} I_3 &= -(2I_x + 4\text{ mA}) \\ &= -[2(-16\text{ mA}) + 4\text{ mA}] \\ &= -(-32\text{ mA} + 4\text{ mA}) \\ &= -(-28\text{ mA}) \end{aligned}$$

$$I_3 = 28\text{ mA}$$

Therefore, the value of current, I_3 is, $\boxed{28\text{ mA}}$.

Step 1 of 4

2.20e

Refer to Figure E2.20 in the textbook for the circuit.

Redraw the circuit by representing current and voltage in the circuit as shown in Figure 1.

Figure 1

Step 2 of 4

Calculate the current (I) passing through the resistor R connected in parallel across the current sources of 25 mA and 15 mA as follows:

$$\begin{aligned} I_R &= 25\text{ mA} - 15\text{ mA} \\ &= 10\text{ mA} \end{aligned}$$

Step 3 of 4

Calculate the voltage V across the resistor R as follows:

$$\begin{aligned} V &= I_R R \\ &= (10\text{ mA})(6\text{ k}\Omega) \\ &= (10\times10^{-3})(6\times10^{3}) \\ &= 60\text{ V} \end{aligned}$$

Step 4 of 4

Calculate voltage V_1 across the resistor R_1 by using voltage division formula as follows:

$$\begin{aligned} V_1 &= \left(\frac{R_1}{R_1+R_2+R}\right)(V) \\ &= \left(\frac{3\text{ k}\Omega}{3\text{ k}\Omega+6\text{ k}\Omega+6\text{ k}\Omega}\right)(60\text{ V}) \\ &= \left(\frac{3\times10^{3}}{15\times10^{3}}\right)(60) \\ &= 12\text{ V} \end{aligned}$$

Therefore, the value of voltage V_1 is $\boxed{12\text{ V}}$.

Step 1 of 2

2.20p

Refer to Figure P2.25 in the textbook.

Represent the voltages, V_{fb} and V_{ec} and redraw the circuit.

Figure 1

Step 2 of 2

Apply Kirchhoff's voltage law around the loop $fgabf$ and calculate the value of voltage, V_{fb} .

$$\begin{aligned} V_{fb} &= 2\text{ V} + 2\text{ V} - 12\text{ V} \\ &= 4\text{ V} - 12\text{ V} \\ &= -8\text{ V} \end{aligned}$$

Therefore, the value of voltage, V_{fb} is, $\boxed{-8\text{ V}}$.

Apply Kirchhoff's voltage law around the loop $edce$ and calculate the value of voltage, V_{ec} .

$$\begin{aligned} V_{ec} &= -3\text{ V} - 3\text{ V} \\ &= -6\text{ V} \end{aligned}$$

Therefore, the value of voltage, V_{ec} is, $\boxed{-6\text{ V}}$.

Step 1 of 3

Refer to Figure E2.21 in the textbook for the circuit.

Redraw the circuit by representing current I_1 as shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of current I_1 by using current division formula as follows:

$$
\begin{aligned}
I_1 &= \left(\frac{R_4}{R_3+(R_1 \parallel R_2)+R_4}\right)(-I) \\
&= \left(\frac{R_4}{R_3+\left(\frac{R_1R_2}{R_2+R_1}\right)+R_4}\right)(-I) \\
&= \left(\frac{12\ \text{k}\Omega}{4\ \text{k}\Omega+\left(\frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{6\ \text{k}\Omega+3\ \text{k}\Omega}\right)+12\ \text{k}\Omega}\right)(-9\ \text{mA}) \\
&= \left(\frac{12\ \text{k}\Omega}{4\ \text{k}\Omega+(2\ \text{k}\Omega)+12\ \text{k}\Omega}\right)(-9\ \text{mA})
\end{aligned}
$$

Simplify further.

$$
\begin{aligned}
I_1 &= \left(\frac{12\times10^3}{18\times10^3}\right)\left(-9\times10^{-3}\right) \\
&= -6\ \text{mA}
\end{aligned}
$$

Step 3 of 3

Calculate the current I_0 by using current division formula in Figure 1.

$$
\begin{aligned}
I_0 &= I_1\left(\frac{R_2}{R_1+R_2}\right) \\
&= (-6\ \text{mA})\left(\frac{6\ \text{k}\Omega}{3\ \text{k}\Omega+6\ \text{k}\Omega}\right) \\
&= \left(-6\times10^{-3}\right)\left(\frac{2}{3}\right) \\
&= -4\ \text{mA}
\end{aligned}
$$

Therefore, the value of current I_0 is $\boxed{-4\ \text{mA}}$.

Step 1 of 11

2.21p

Refer to Figure P2.27 in the text book for the circuit diagram.

Identify the voltages in the circuit diagram.

$V_{dg} = 16\ \text{V}$,

$V_{gh} = 12\ \text{V}$,

$V_{hi} = -4\ \text{V}$,

$V_{if} = -14\ \text{V}$,

$V_{fc} = -20\ \text{V}$,

$V_{cb} = 12\ \text{V}$ and

$V_{ba} = -8\ \text{V}$.

Step 2 of 11

Consider the expression for the value of the voltage V_{da} (outer loop).

$$V_{da} = V_{dg} + V_{gh} + V_{hi} + V_{if} + V_{fc} + V_{cb} + V_{ba}$$

Substitute $16\ \text{V}$ for V_{dg}, $12\ \text{V}$ for V_{gh}, $-4\ \text{V}$ for V_{hi}, $-14\ \text{V}$ for V_{if}, $-20\ \text{V}$ for V_{fc}, $12\ \text{V}$ for V_{cb} and $-8\ \text{V}$ for V_{ba}.

$$\begin{aligned} V_{da} &= 16 + 12 - 4 - 14 - 20 + 12 - 8 \\ &= -6\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{da} is, $\boxed{-6\ \text{V}}$.

Step 3 of 11

Consider the expression for the value of the voltage V_{bh}.

$$V_{bh} = V_{bc} + V_{cf} + V_{fi} + V_{ih}$$

Substitute $4\ \text{V}$ for V_{ih}, $14\ \text{V}$ for V_{fi}, $20\ \text{V}$ for V_{cf} and $-12\ \text{V}$ for V_{bc}.

$$\begin{aligned} V_{bh} &= -12 + 20 + 14 + 4 \\ &= 26\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{bh} is, $\boxed{26\ \text{V}}$.

Step 4 of 11

Consider the expression for the value of the voltage V_{gc}.

$$V_{gc} = V_{gh} + V_{hi} + V_{if} + V_{fc}$$

Substitute $12\ \text{V}$ for V_{gh}, $-4\ \text{V}$ for V_{hi}, $-14\ \text{V}$ for V_{if} and $-20\ \text{V}$ for V_{fc}.

$$\begin{aligned} V_{gc} &= 12 - 4 - 14 - 20 \\ &= -26\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{gc} is, $\boxed{-26\ \text{V}}$.

Step 5 of 11

Consider the expression for the value of the voltage V_{di}.

$$V_{di} = V_{dg} + V_{gh} + V_{hi}$$

Substitute $16\ \text{V}$ for V_{dg}, $12\ \text{V}$ for V_{gh} and $-4\ \text{V}$ for V_{hi}.

$$\begin{aligned} V_{di} &= 16 + 12 - 4 \\ &= 24\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{di} is, $\boxed{24\ \text{V}}$.

Step 6 of 11

Consider the expression for the value of the voltage V_{fa}.

$$V_{fa} = V_{fc} + V_{cb} + V_{ba}$$

Substitute $-20\ \text{V}$ for V_{fc}, $12\ \text{V}$ for V_{cb} and $-8\ \text{V}$ for V_{ba}.

$$\begin{aligned} V_{fa} &= -20 + 12 - 8 \\ &= -16\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{fa} is, $\boxed{-16\ \text{V}}$.

Step 7 of 11

Consider the expression for the value of the voltage V_{ac}.

$$V_{ac} = V_{ab} + V_{bc}$$

Substitute $-12\ \text{V}$ for V_{bc} and $8\ \text{V}$ for V_{ab}.

$$\begin{aligned} V_{ac} &= 8 - 12 \\ &= -4\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{ac} is, $\boxed{-4\ \text{V}}$.

Step 8 of 11

Consider the expression for the value of the voltage V_{ai}.

$$V_{ai} = V_{ab} + V_{bc} + V_{cf} + V_{fi}$$

Substitute $8\ \text{V}$ for V_{ab}, $14\ \text{V}$ for V_{fi}, $20\ \text{V}$ for V_{cf} and $-12\ \text{V}$ for V_{bc}.

$$\begin{aligned} V_{ai} &= 8 - 12 + 20 + 14 \\ &= 30\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{ai} is, $\boxed{30\ \text{V}}$.

Step 9 of 11

Consider the expression for the value of the voltage V_{hf}.

$$V_{hf} = V_{hi} + V_{if}$$

Substitute $-4\ \text{V}$ for V_{hi} and $-14\ \text{V}$ for V_{if}.

$$\begin{aligned} V_{hf} &= -4 - 14 \\ &= -8\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{hf} is, $\boxed{-18\ \text{V}}$.

Step 10 of 11

Consider the expression for the value of the voltage V_{fb}.

$$V_{fb} = V_{fc} + V_{cb}$$

Substitute $-20\ \text{V}$ for V_{fc} and $12\ \text{V}$ for V_{cb}.

$$\begin{aligned} V_{fb} &= -20 + 12 \\ &= -8\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{fb} is, $\boxed{-18\ \text{V}}$.

Step 11 of 11

Consider the expression for the value of the voltage V_{dc}.

$$V_{dc} = V_{da} - V_{ca}$$

Substitute $-6\ \text{V}$ for V_{da} and $4\ \text{V}$ for V_{ca}.

$$\begin{aligned} V_{dc} &= -6 - 4 \\ &= -10\ \text{V} \end{aligned}$$

Therefore, the value of the voltage V_{dc} is, $\boxed{-10\ \text{V}}$.

Step 1 of 3

2.22e

Refer to the circuit shown in Figure 2PFE-2 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

Let the current I_1 flowing through the $4\ \mathrm{A}$ source.

$$I_1 = 4\ \mathrm{A}$$

Apply Kirchhoff's voltage law to the outer loop of the circuit and solve.

$$10(I_1 + I_2) + 5(I_1 + I_2) + 15I_2 + 10I_2 = 0$$
$$15I_1 + 15I_2 + 15I_2 + 10I_2 = 0$$
$$(15)(4) + 40I_2 = 0$$
$$60 + 40I_2 = 0$$

Simplify the expression further.

$$40I_2 = -60$$

$$\begin{aligned} I_2 &= \frac{-60}{40} \\ &= -1.5\ \mathrm{A} \end{aligned}$$

Step 3 of 3

Now, apply Kirchhoff's voltage law to the loop formed by nodes a, b and V_{ab} in Figure 1 and solve.

$$\begin{aligned} V_{ab} &= (I_1 + I_2)5 + I_2(15) \\ &= (4 - 1.5)(5) + (-1.5)(15) \\ &= 12.5 - 22.5 \\ &= -10\ \mathrm{V} \end{aligned}$$

Therefore, the value of voltage V_{ab} in the circuit is $-10\ \mathrm{V}$ and so the correct answer is option $\boxed{\mathrm{d}}$.

Step 1 of 2

Refer to Figure P2.22 in the text book.

Determine the value of voltage V_{BE}.

Apply Kirchhoff's voltage law in the path BEDCB.

$$V_{BE} + 4 - 24 + 12 = 0$$
$$V_{BE} - 8 = 0$$
$$V_{BE} = 8\ \text{V}$$

Thus, the value of voltage, V_{BE} is $\boxed{8\ \text{V}}$.

Step 2 of 2

Determine the value of voltage V_{DA}.

Apply Kirchhoff's voltage law in the path DABCD.

$$V_{DA} - 6 - 12 + 24 = 0$$
$$V_{DA} + 6 = 0$$
$$V_{DA} = -6\ \text{V}$$

Thus, the value of voltage, V_{DA} is $\boxed{-6\ \text{V}}$.

Step 1 of 4

2.23e

Refer to figure E2.23 in the textbook.

Identify the nodes a and b. Consider V_a and V_b as voltages at node a and b .

Figure 1

Apply Kirchhoff current law at node a .

$$\frac{V_a}{4000}+\frac{V_a-V_b}{10000}+\frac{V_a}{6000}+\frac{V_a}{12000}=0$$

$$V_a\left(\frac{1}{4}+\frac{1}{10}+\frac{1}{6}+\frac{1}{12}\right)=\frac{V_b}{10}$$

$$V_a\left(\frac{15+6+10+5}{60}\right)=\frac{V_b}{10}$$

$$V_b=6V_a \text{ ..... (1)}$$

Step 2 of 4

Apply Kirchhoff current law at node b.

$$\frac{V_b}{4000}+\frac{V_b-V_a}{10000}=-\frac{20}{1000}$$

$$-V_a\left(\frac{1}{10000}\right)+V_b\left(\frac{1}{4000}+\frac{1}{10000}\right)=-\frac{20}{1000}$$

$$\frac{-V_a(2)+V_b(7)}{20}=-20$$

$$-V_a(2)+V_b(7)=-400 \text{ ..... (2)}$$

Step 3 of 4

Substitute equation (1) in equation (2) to find V_a .

$$-V_a(2)+(6V_a)(7)=-400$$

$$40V_a=-400$$

$$V_a=-10\text{ V} \text{ ..... (3)}$$

Substitute equation (3) in equation (1) to find V_b .

$$\begin{aligned}V_b&=6V_a\\&=(6)(-10)\\&=-60\text{ V}\end{aligned}$$

Thus, Nodal voltages V_a and V_b are:

$$V_a=-10\text{ V}$$
$$V_b=-60\text{ V}$$

Step 4 of 4

From the figure E2.23 relation between V_a, V_1 and V_b, V_0 is,

$$V_a=-V_1$$
$$V_b=V_0$$

Thus, V_1 and V_0 is,

$$V_1=10\text{V}$$
$$V_0=-60\text{V}$$

Step 1 of 3

2.23p

Consider the circuit given in Figure P2.28 in the text book.

Figure 1

Step 2 of 3

Apply Kirchhoff's voltage law to the loop 1 shown in Figure 1 and calculate V_x as follows:

$$-6\text{ V} - 12\text{ V} + V_x - 4\text{ V} = 0$$
$$V_x - 22\text{ V} = 0$$
$$V_x = 22\text{ V}$$

Therefore the value of V_x is $\boxed{22\text{ V}}$.

Step 3 of 3

Apply Kirchhoff's voltage law to the loop 2 shown in Figure 1 and calculate V_y as follows:

$$-6\text{ V} - V_y + 12\text{ V} = 0$$
$$-V_y + 6\text{ V} = 0$$
$$V_y = 6\text{ V}$$

Therefore the value of V_y is $\boxed{6\text{ V}}$.

Step 1 of 5

(a)

Consider the circuit shown in Figure 1 as follows:

Figure 1

Step 2 of 5

Calculate the value of current I_1 by using Kirchhoff's current law at node 'a' as follows:

$$\begin{aligned} 4\text{ mA} + I_1 &= 10\text{ mA} \\ I_1 &= 10\text{ mA} - 4\text{ mA} \\ &= 6\text{ mA} \end{aligned}$$

Therefore, the value of current, I_1 is $\boxed{6\text{ mA}}$.

Step 3 of 5

(b)

Consider the circuit shown in Figure 2 as follows:

Figure 2

Step 4 of 5

Apply Kirchhoff's current law at node 'a' as follows:

$I_1 = I_2 + 3\text{ mA}$ ..... (1)

Apply Kirchhoff's current law at node 'b' as follows:

$$\begin{aligned} I_1 + 4\text{ mA} &= 12\text{ mA} \\ I_1 &= 12\text{ mA} - 4\text{mA} \\ &= 8\text{ mA} \end{aligned}$$

Therefore, the value of current, I_1 is $\boxed{8\text{ mA}}$.

Step 5 of 5

Now substitute the value of I_1 in equation (1) and solve for I_2 as follows:

$$\begin{aligned} I_2 + 3\text{mA} &= 8\text{mA} \\ I_2 &= 8\text{mA} - 3\text{mA} \\ &= 5\text{ mA} \end{aligned}$$

Therefore, the value of current, I_2 is $\boxed{5\text{ mA}}$.

Step 1 of 3

2.24p

The given circuit is,

Step 2 of 3

Given $V_x = 2V$

Therefore voltage across the dependent source is

$V_{bc} = 3V_x$

$V_{bc} = 3 \times 2$

$V_{bc} = 6\,\text{V}$

Step 3 of 3

For finding V_{ac} we can apply KVL across the closed loop 'cabc'

$V_{ac} - 4 - 3V_x = 0$

$V_{ac} = 4 + 3V_x$

$V_{ac} = 4 + 6$

$V_{ac} = 10$

$\boxed{V_{ac} = 10\text{V}}$

Step 1 of 4

2.25e

Refer to Figure E2.25 in the text book.

Draw the modified circuit with the nodes *a*, *b* and *c* is as shown in Figure 1.

Figure 1

Step 2 of 4

Refer to Figure 2.35 for delta and wye resistance networks in the text book.

Apply Wye to delta transformation between nodes a, b and c.

Determine the resistance between nodes *a* and *c*.

$$R_1 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

Substitute $12\ \text{k}\Omega$ for R_a, $12\ \text{k}\Omega$ for R_b and $12\ \text{k}\Omega$ for R_c in the equation.

$$\begin{aligned} R_1 &= \frac{(12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k})}{12\ \text{k}} \\ &= 12\ \text{k} + 12\ \text{k} + 12\ \text{k} \\ &= 36\ \text{k}\Omega \end{aligned}$$

Determine the resistance between nodes *a* and *b*.

$$R_2 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

Substitute $12\ \text{k}\Omega$ for R_a, $12\ \text{k}\Omega$ for R_b and $12\ \text{k}\Omega$ for R_c in the equation.

$$\begin{aligned} R_2 &= \frac{(12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k})}{12\ \text{k}} \\ &= 12\ \text{k} + 12\ \text{k} + 12\ \text{k} \\ &= 36\ \text{k}\Omega \end{aligned}$$

Determine the resistance between nodes *b* and *c*.

$$R_3 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

Substitute $12\ \text{k}\Omega$ for R_a, $12\ \text{k}\Omega$ for R_b and $12\ \text{k}\Omega$ for R_c in the equation.

$$\begin{aligned} R_3 &= \frac{(12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k}) + (12\ \text{k})(12\ \text{k})}{12\ \text{k}} \\ &= 12\ \text{k} + 12\ \text{k} + 12\ \text{k} \\ &= 36\ \text{k}\Omega \end{aligned}$$

Step 3 of 4

The modified circuit diagram is shown in Figure 2.

Figure 2

In Figure 2, the $36\ \text{k}\Omega$ and $12\ \text{k}\Omega$ resistors are in parallel.

$$\begin{aligned} R &= (36\ \text{k}) \| (12\ \text{k}) \\ &= \frac{(36\ \text{k})(12\ \text{k})}{36\ \text{k} + 12\ \text{k}} \\ &= 9\ \text{k}\Omega \end{aligned}$$

The modified circuit diagram is shown in Figure 3.

Figure 3

Step 4 of 4

Apply current division rule to find the value of current, I_2.

$$\begin{aligned} I_2 &= \left(4 \times 10^{-3}\right)\left(\frac{36\ \text{k}}{36\ \text{k} + 9\ \text{k} + 9\ \text{k}}\right) \\ &= \frac{8}{3}\ \text{mA} \end{aligned}$$

Determine the value of voltage across the $9\ \text{k}\Omega$ resistor in Figure 3.

$$\begin{aligned} V_0 &= (I_2)(9\ \text{k}) \\ &= \left(\frac{8}{3} \times 10^{-3}\right)\left(9 \times 10^{3}\right) \\ &= 24\ \text{V} \end{aligned}$$

Thus, the value of output voltage, V_0 is $\boxed{24\ \text{V}}$.

Step 1 of 3

2.25p

Step 2 of 3

Applying KVL around loop $adea$,

$$V_{ad} + V_{de} + V_{ea} = 0$$
$$V_{ad} = -V_{de} - V_{ea}$$
$$V_{ad} = V_{ed} + V_{ae}$$
$$V_{ad} = V_{ed} + 4V_x$$
$$V_{ad} = 1 + 4(2)$$
$$V_{ad} = 9$$

Hence $\boxed{V_{ad} = 9 \text{ V}}$

Step 3 of 3

Applying KVL around loop $ceabc$,

$$V_{ce} + V_{ea} + V_{ab} + V_{bc} = 0$$
$$V_{ce} = -V_{ea} - V_{ab} - V_{bc}$$
$$V_{ce} = V_{ae} + V_{ba} + V_{cb}$$
$$V_{ce} = 4V_x + V_{ba} + V_{cb}$$
$$V_{ce} = 4(2) + 1 + 2$$
$$V_{ce} = 11$$

Hence $\boxed{V_{ce} = 11 \text{ V}}$

Step 1 of 2

2.27e

Consider the circuit shown in Figure E2.27 in the text book.

Calculate the value of voltage V_A across the resistor in the circuit by using Ohm's law $V = IR$.

Substitute $V = V_A$, $R = 4\ \text{k}\Omega$ and solve for V_A .

$$V_A = I(4\ \text{k}\Omega)$$

Apply Kirchhoff's voltage law to the circuit and solve for current I .

$$-6 + V_A - 2V_A + 8\text{k}I = 0$$
$$-6 - V_A + 8\text{k}I = 0$$
$$-4\text{k}I + 8\text{k}I = 6$$
$$I = \frac{6}{4\text{k}}\ \text{A}$$

Step 2 of 2

Calculate the value of voltage V_o in the circuit by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = \frac{6}{4\text{k}}\ \text{A}$, $R = 8\ \text{k}\Omega$ and solve for voltage V_o .

$$\begin{aligned} V_o &= \left(\frac{6\ \text{A}}{4\text{k}}\right)(8\ \text{k}\Omega) \\ &= (6\ \text{A})(2\ \Omega) \\ &= 12\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{12\ \text{V}}$.

Step 1 of 7

2.27p

Refer to Figure E2.26 in the text book.

Draw the modified circuit with the nodes a, b and c is as shown in Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 2.35 for delta and wye resistance networks in the text book.

Apply delta to wye transformation between nodes a, b and c. Let,

$$R_1 = 18\ \Omega$$
$$R_2 = 18\ \Omega$$
$$R_3 = 18\ \Omega$$

Determine the value of resistance, R_a.

$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

Substitute $18\ \Omega$ for R_1, $18\ \Omega$ for R_2 and $18\ \Omega$ for R_3 in the equation.

$$R_a = \frac{(18)(18)}{18+18+18}$$
$$= 6\ \Omega$$

Step 3 of 7

Determine the value of resistance, R_b.

$$R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

Substitute $18\ \Omega$ for R_1, $18\ \Omega$ for R_2 and $18\ \Omega$ for R_3 in the equation.

$$R_b = \frac{(18)(18)}{18+18+18}$$
$$= 6\ \Omega$$

Determine the value of resistance, R_c.

$$R_c = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

Substitute $18\ \Omega$ for R_1, $18\ \Omega$ for R_2 and $18\ \Omega$ for R_3 in the equation.

$$R_c = \frac{(18)(18)}{18+18+18}$$
$$= 6\ \Omega$$

Step 4 of 7

The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 7

In Figure 2, the resistors $12\ \Omega$ and 6Ω are in series. Thus the equivalent resistance is,

$$R = 12 + 6$$
$$= 18\ \Omega$$

In Figure 2, the resistors $6\ \Omega$ and 6Ω are in series. Thus, the equivalent resistance is,

$$R = 6 + 6$$
$$= 12\ \Omega$$

Step 6 of 7

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 7

Apply current division rule to calculate the value of current I_1.

$$I_1 = -I_3$$
$$= -(3)\left(\frac{12}{12+18}\right)$$
$$= -1.2\ \text{A}$$

Thus, the value of current, I_1 is $\boxed{-1.2\ \text{A}}$.

Step 1 of 3

2.28e

Refer to Figure E2.28 in the textbook.

Voltage across $6\ \text{k}\Omega$ resistor is V_s . Thus, Voltage at the top node is V_s .

Draw the modified circuit diagram.

Figure 1

Step 2 of 3

Apply Kirchhoff Current Law at top node for the circuit shown in figure 1

$$-\frac{V_0}{2000}+\frac{V_s}{6000}+\frac{V_s}{3000}-2\times10^{-3}=0$$

$$V_s\left(\frac{1}{6000}+\frac{1}{3000}\right)-V_0\left(\frac{1}{2000}\right)=2\times10^{-3}$$

$$V_s\left(\frac{1}{2000}\right)-V_0\left(\frac{1}{2000}\right)=2\times10^{-3}$$

$V_s-V_0=4$ ..... (1)

Node voltage V_s appears across series combination of $1\ \text{k}\Omega$ and $2\ \text{k}\Omega$ resistors. Apply voltage division rule in the branch to find V_0

$$V_0=V_s\left(\frac{2\ \text{k}}{1\ \text{k}+2\ \text{k}}\right)$$

$V_0=\frac{2}{3}V_s$ ..... (2)

Step 3 of 3

Substitute equation (2) in equation (1) to find V_s .

$$V_s-\frac{2}{3}V_s=4$$

$$\frac{V_s}{3}=4$$

$$V_s=12\ \text{V}$$

Substitute V_s in equation (2) to find V_0 .

$V_0=\frac{2}{3}\times12\ \text{V}$ Therefore, the output voltage, V_0 is $\boxed{8\ \text{V}}$.

$=8\ \text{V}$

Step 1 of 2

2.28p

Consider the circuit of Figure P2.31 given in text book.

Let I be the current flowing in the circuit and $V_o = 2V_A$, also $V_x = 4I$.

Therefore from the circuit the voltage V_A is given as follows:

$$V_A = 2I + 2V_A$$
$$V_A = -2I$$

Apply Kirchhoff's voltage law to the circuit and solve for current I as follows:

$$12 + V_x - 4V_x + 2I + 2V_A = 0$$
$$12 - 3V_x + V_A = 0$$
$$12 - 3(4I) + (-2I) = 0$$
$$I = 0.857 \text{ A}$$

Step 2 of 2

Calculate the value of voltage V_A as follows:

$$\begin{aligned} V_A &= -2I \\ &= (-2)(0.857 \text{ A}) \\ &= (-2)(0.857) \\ &= -1.714 \text{ V} \end{aligned}$$

Calculate the value of voltage V_o as follows:

$$\begin{aligned} V_o &= 2V_A \\ &= (2)(-1.714) \\ &= -3.428 \text{ V} \end{aligned}$$

Therefore the value of voltage V_o is $\boxed{-3.428 \text{ V}}$.

Step 1 of 2

2.29e

Consider the circuit shown in Figure E2.29 in the text book.

Let I be the current flowing in the circuit in clockwise direction.

Now, the value of V_x in the circuit is $5\text{k}I$.

Apply Kirchhoff's voltage law to the considered circuit and solve for current I .

$$-12+10\text{k}I+2V_x+5\text{k}I+36+V_x=0$$
$$15\text{k}I+3V_x=-36+12$$
$$15\text{k}I+3(5\text{k}I)=-24$$
$$15\text{k}I+15\text{k}I=-24$$

Simplify the expression further.

$$30\text{k}I=-24$$
$$I=\frac{-24}{30\text{k}}\ \text{A}$$

Step 2 of 2

Calculate the value of voltage V_x .

$$\begin{aligned}V_x&=(5\ \text{k}\Omega)I\\&=(5\ \text{k}\Omega)\left(\frac{-24}{30\text{k}}\ \text{A}\right)\\&=-4\ \text{V}\end{aligned}$$

Calculate the value of voltage V_A by using Kirchhoff's voltage law.

$$\begin{aligned}V_A&=2V_x+(5\ \text{k}\Omega)I\\&=(2)(-4\ \text{V})+(5\ \text{k}\Omega)\left(\frac{-24}{30\ \text{k}}\right)\\&=-8\ \text{V}+(-4\ \text{V})\\&=-12\ \text{V}\end{aligned}$$

Therefore, the value of voltage V_A in the circuit is $\boxed{-12\ \text{V}}$.

Step 1 of 2

2.29p

Consider the circuit shown in Figure P2.34 given in the text book.

Apply Kirchhoff's voltage law to the loop formed by $12\ \text{V}$ voltage source, $4\ \text{V}$ voltage source, V_x and calculate the value of V_x as follows:

$$-12\ \text{V}+4\ \text{V}+V_x=0$$
$$V_x-8\ \text{V}=0$$
$$V_x=8\ \text{V}$$

Apply Kirchhoff's voltage law to the loop formed by voltage V_1, $4V_x$ dependent current source, $4\ \text{V}$ voltage source and calculate the value of V_1 as follows:

$$-V_1-4V_x-4\ \text{V}=0$$
$$V_1+4(8\ \text{V})-4\ \text{V}=0$$
$$V_1+32-4=0$$
$$V_1=-28\ \text{V}$$

Therefore the value of V_1 is $\boxed{-28\ \text{V}}$.

Step 2 of 2

Apply Kirchhoff's voltage law to the loop formed by $4V_x$ dependent current source, $6\ \text{V}$ voltage source, voltage V_2 and calculate the value of V_2 as follows:

$$4V_x+6\ \text{V}+V_2=0$$
$$4(8\ \text{V})+6\ \text{V}+V_2=0$$
$$32+6\ \text{V}+V_2=0$$
$$V_2=-38\ \text{V}$$

Therefore the value of V_2 is $\boxed{-38\ \text{V}}$.

Apply Kirchhoff's voltage law to the loop formed by voltages V_x, V_2, V_3 and calculate the value of V_3 as follows:

$$-V_2+V_3-V_x=0$$
$$V_3=V_x+V_2$$
$$=8\ \text{V}-38\ \text{V}$$
$$=-30\ \text{V}$$

Therefore the value of V_3 is $\boxed{-30\ \text{V}}$.

Step 1 of 2

2.30e

Consider the circuit shown in Figure E2.30 in the text book.

Let I be the current flowing in the circuit in clockwise direction.

Now, the value of voltage V_x in the circuit is $(-I)(8\text{ k}\Omega)$.

Apply Kirchhoff's voltage law to the circuit and solve for current I.

$$-0.5V_x + 4\text{k}I + 18 - V_x - 50 + 8\text{k}I = 0$$
$$-1.5V_x + 12\text{k}I = 50 - 18$$
$$-(1.5)(-8\text{k}I) + 12\text{k}I = 32$$
$$12\text{k}I + 12\text{k}I = 32$$

Simplify the expression further.

$$24\text{k}I = 32$$
$$I = \frac{32}{24\text{ k}}\text{ A}$$

Step 2 of 2

Calculate the value of voltage V_x in the circuit.

$$\begin{aligned} V_x &= (-I)(8\text{ k}\Omega) \\ &= \left(\frac{-32}{24\text{k}}\right)(8\text{ k}\Omega) \\ &= \frac{-32}{3}\text{ V} \end{aligned}$$

Now, apply Kirchhoff's voltage law to the right hand side loop in the considered circuit and solve for V_1.

$$\begin{aligned} V_1 &= 18 - V_x - 50 + 8\text{k}I \\ &= -32 - \left(\frac{-32}{3}\right) + (8\text{k})\left(\frac{32}{24\text{k}}\right) \\ &= -32 + \frac{32}{3} + \frac{32}{3} \\ &= \frac{-(3)(32) + 32 + 32}{3} \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} V_1 &= \frac{-96 + 64}{3} \\ &= \frac{-32}{3}\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{\frac{-32}{3}\text{ V}}$.

Step 1 of 2

2.30p

Step 2 of 2

Given $V_0 = 3\,\text{V}$ in the circuit diagram,

By Voltage Division rule,

$$V_0 = V_s \frac{9\text{k}}{(9\text{k}+12\text{k})}$$

Hence,

$$V_S = V_0 \frac{(9\text{k}+12\text{k})}{9\text{k}}$$

$$V_S = (3)\left(\frac{21\text{k}}{9\text{k}}\right)$$

$$V_S = 7\text{V}$$

Hence $\boxed{V_S = 7\ \text{V}}$

Step 1 of 4

2.31e

Refer to Figure E2.31 in the textbook.

Consider Voltage at top node as *V*. Replace the parallel combination of two resistors $5\ \text{k}\Omega$ and $10\ \text{k}\Omega$ connected in parallel with their equivalent resistance.

$$\begin{aligned}(5\ \text{k} \| 10\ \text{k}) &= \frac{5\text{k}\times 10\text{k}}{5\text{k}+10\text{k}} \\ &= \frac{50\text{k}}{15} \\ &= \frac{10}{3}\text{k}\Omega \\ &= 3.33\ \text{k}\Omega\end{aligned}$$

Step 2 of 4

Draw the modified circuit diagram.

Figure 1

Step 3 of 4

Apply Kirchhoff current law at top node.

$$-10\times 10^{-3} - 2I_x + \frac{V}{2000} + 3\times 10^{-3} + \frac{V}{3333} = 0$$

$$V\left[\frac{1}{2000} + \frac{1}{3333}\right] = \left(7\times 10^{-3}\right) + 2I_x \quad \text{..... (1)}$$

In the Figure 1, the current I_x flows from reference node to top node. Equation for current I_x flowing in the 3.33 k Resistor is,

$$I_x = \frac{0-V}{3333}$$

$$I_x = -\frac{V}{3333} \quad \text{..... (2)}$$

Step 4 of 4

Substitute equation (2) in equation (1) to find voltage at top node *V*.

$$V\left[\frac{1}{2000} + \frac{1}{3333}\right] = \left(7\times 10^{-3}\right) + 2\left(-\frac{V}{3333}\right)$$

$$V\left[\frac{1}{2000} + \frac{1}{3333} + \frac{2}{3333}\right] = 7\times 10^{-3}$$

$$V\left[1.4\times 10^{-3}\right] = 7\times 10^{-3}$$

$$V = 5\ \text{V}$$

Substitute $5\ \text{V}$ for *V* in equation (2) to find current I_x.

$$\begin{aligned}I_x &= -\frac{5}{3333} \\ &= -0.0015 \\ &= -1.5\ \text{mA}\end{aligned}$$

Thus, the value of current I_x is $\boxed{-1.5\ \text{mA}}$.

Step 1 of 5

2.31p

The given circuit is,

Step 2 of 5

Let I be the current in the loop,

Step 3 of 5

Applying KVL around loop $abcdefga$,

$$V_{ab}+V_{bc}+V_{cd}+V_{de}+V_{ef}+V_{fg}+V_{ga}=0$$

$$I(4\text{k})+6+I(3\text{k})+I(3\text{k})+I(6\text{k})+I(2\text{k})-12=0$$

$$I(4\text{k}+6\text{k}+3\text{k}+3\text{k}+2\text{k})=12-6$$

$$I=\frac{6}{18\text{k}}$$

$$I=\frac{1}{3}\ \text{mA}$$

Step 4 of 5

Therefore power by 12V source is,

$$P_{12\text{V}}=-VI$$

$$P_{12\text{V}}=-(12)\left(\frac{1}{3}\text{m}\right)$$

$$P_{12\text{V}}=-4\text{m}$$

Since the power is negative, the power supplied by the 12 V source is 4mW.

$$\boxed{P_{12\text{V}}=4\text{mW}(\text{supplied})}$$

Step 5 of 5

Therefore power by 6V source is,

$$P_{6\text{V}}=VI$$

$$P_{6\text{V}}=(6)\left(\frac{1}{3}\text{m}\right)$$

$$P_{6\text{V}}=2\text{m}$$

Since the power is positive, the power absorbed by the 6 V source is 2mW.

$$\boxed{P_{6\text{V}}=-2\text{mW}(\text{supplied})}$$

2.32e

Consider the circuit shown in Figure E2.32 in the text book.

The voltage across every branch in the circuit is equal to V_o . So, the value of current I_x in the circuit is,

$$I_x = \frac{V_o}{4\ \text{k}\Omega}$$

Now, apply Kirchhoff's current law at the top node of the considered circuit and solve for voltage V_o .

$$I_x - 6\text{m} + \frac{V_o}{6\text{k}} - 0.5I_x + \frac{V_o}{12\text{k}} = 0$$

$$0.5I_x + \frac{2V_o + V_o}{12\text{k}} = 6\text{m}$$

$$(0.5)\left(\frac{V_o}{4\text{k}}\right) + \frac{3V_o}{12\text{k}} = 6\text{m}$$

$$\frac{(3)(0.5)(V_o)}{12\text{k}} + \frac{3V_o}{12\text{k}} = 6\text{m}$$

Simplify the expression further.

$$1.5V_o + 3V_o = (6\text{m})(12\text{k})$$

$$4.5V_o = 72$$

$$V_o = \frac{72}{4.5}$$

$$V_o = 16\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{16\ \text{V}}$.

Step 1 of 3

2.32p

Refer to Figure P2.33 in text book.

The power absorbed by 10V source is $2.5\,\text{mW}$, that is current is entering through the positive terminal.

$$P = VI$$

$$I = \frac{P}{V}$$

$$= \frac{2.5\times10^{-3}}{10}$$

$$= 0.25\text{ mA}$$

Draw the circuit diagram with current, I .

Figure 1

Step 2 of 3

Apply Kirchhoff's voltage law for left side loop.

$$10+(5\text{k})(I)-20+(2\text{k})(I)-V_{ba}=0$$

$$(7\text{k})(I)-10-V_{ba}=0$$

$$(7\text{k})(0.25\text{ m})-10-V_{ba}=0$$

$$1.75-10-V_{ba}=0$$

$$-8.25-V_{ba}=0$$

$$V_{ba}=-8.25\text{ V}$$

Therefore, the voltage, V_{ba} is $\boxed{-8.25\text{ V}}$.

Step 3 of 3

Calculate the voltage across $10\text{ k}\Omega$ resistor.

$$V_x = -(10\text{k})(I)$$

$$= -(10\text{k})(0.25\text{m})$$

$$= -2.5\text{ V}$$

Calculate the power absorbed by the dependent voltage source.

$$P_{2V_x} = -(2V_x)(I)$$

Substitute -2.5 V for V_x and 0.25 mA for I .

$$P_{2V_x} = -(2(-2.5))(0.25\text{m})$$

$$= 1.25\text{ mW}$$

Therefore, the power absorbed by the dependent voltage source, P_{2V_x} is $\boxed{1.25\text{ mW}}$.

Step 1 of 7

Refer to Figure E2.33 in the text book.

Given power supplied by the 3-A current source is $12\ \text{W}$.

The given circuit with voltage notations is as shown below,

Step 2 of 7

Figure 1

Step 3 of 7

The power supplied by the 3-A current source is,

$$P_{3\text{-A}} = V_1 \times 3$$
$$12 = V_1 \times 3$$
$$V_1 = \frac{12}{3}$$
$$V_1 = 4\ \text{V}$$

Using Ohm's law,

$$V_2 = 3 \times 4$$
$$= 12\ \text{V}$$

Step 4 of 7

From above circuit,

The voltage across $5\ \Omega$ resistor is $10\ \text{V}$

i.e., $V_4 = 10\ \text{V}$

From Ohm's law,

$$I_4 = \frac{V_4}{5}$$
$$= \frac{10}{5}$$
$$I_4 = 2\ \text{A}$$

Step 5 of 7

Applying KVL in the top loop yields,

$$-V_1 + V_2 - V_3 = 0$$
$$-4 + 12 - V_3 = 0$$
$$8 - V_3 = 0$$
$$V_3 = 8\ \text{V}$$

Now,

$$I_3 = \frac{V_3}{4}$$
$$= \frac{8}{4}$$
$$I_3 = 2\ \text{A}$$

Step 6 of 7

Applying Kirchhoff's current Law at the node **1**, we get

$$-3 - I_3 + I_4 - I_V = 0$$
$$-3 - 2 + 2 - I_V = 0$$
$$-3 - I_V = 0$$
$$I_V = -3\ \text{A}$$

Now, the power supplied by the 10-V source is,

$$P_{10\text{-V}} = 10 \times I_V$$
$$P_{10\text{-V}} = 10 \times (-3)$$

Therefore, the power delivered by the voltage source 10 V is $\boxed{-30\ \text{W}}$.

Step 7 of 7

Applying KVL in the bottom center loop.

$$-V_1 + V_3 + V_4 = 0$$
$$-V_1 + 8 + 10 = 0$$
$$-V_1 + 18 = 0$$
$$V_1 = 18\ \text{V}$$

Determine the current I_1 .

$$I_1 = \frac{V_1}{6}$$
$$= \frac{18}{6}$$
$$I_1 = 3\ \text{A}$$

Applying Kirchhoff's current Law at the node 2, we get

$$-I_S + I_1 + I_3 + 3 = 0$$
$$-I_S + 3 + 2 + 3 = 0$$
$$-I_S + 8 = 0$$
$$I_S = 8\ \text{A}$$

Use Ohm's law.

$$V_5 = I_S \times 3$$
$$= 8 \times 3$$
$$V_5 = 24\ \text{V}$$

Applying Kirchhoff's Voltage Law in the bottom left loop, we get

$$-V_S + V_5 + V_1 = 0$$
$$-V_S + 24 + 18 = 0$$
$$-V_S + 42 = 0$$

Therefore, the value of V_S is $\boxed{42\ \text{V}}$.

2.33p

Consider the circuit shown in Figure P2.37 in the text book.

Let I be the current flowing in the circuit.

Apply Kirchhoff's voltage law in the circuit and calculate current I as follows:

$$-12\text{ V}+(3\text{ k}\Omega)(I)+(1\text{ k}\Omega)(I)+4\text{ V}=0$$

$$(4\times10^{3})(I)=8$$

$$\begin{aligned} I &= \frac{8}{4\times10^{3}} \\ &= 2\text{ mA} \end{aligned}$$

Let V_{bd} be the voltage across the nodes b and d in the circuit.

Apply Kirchhoff's voltage law to the loop formed by b c d b and calculate the value of voltage V_{bd} as follows:

$$\begin{aligned} V_{bd} &= (1\text{ k}\Omega)(I)+4\text{ V} \\ &= (1\times10^{3})(2\times10^{-3})+4 \\ &= 2+4 \\ &= 6\text{ V} \end{aligned}$$

Therefore the value of voltage V_{bd} is $\boxed{6\text{ V}}$.

Step 1 of 2

2.34p

Consider the circuit shown in Figure P2.41 in the text book.

Let the current I flowing in the circuit in clockwise direction. So, by Ohm's law the value of voltage V_x is $-(10\text{k})(I)$.

Apply Kirchhoff's voltage law to the circuit and solve for V_x.

$$-25 - V_x + 5\text{k}I + \frac{V_x}{4} = 0$$

$$-25 - (-10\text{k}I) + 5\text{k}I + \frac{-10\text{k}I}{4} = 0$$

$$-25 + I\left((10\times10^3) + (5\times10^3) - \frac{(10\times10^3)}{4}\right) = 0$$

$$-25 + I(12.5\times10^3) = 0$$

Simplify the expression further.

$$I(12.5\times10^3) = 25$$

$$\begin{aligned} I &= \frac{25}{12.5\times10^3} \\ &= 2\text{ mA} \end{aligned}$$

Step 2 of 2

Apply Kirchhoff's voltage law to the left hand loop in Figure P2.41 in the text book formed by 25 V, V_x, V_1.

Calculate the value of voltage, V_1.

$$V_1 - 25\text{ V} - V_x = 0$$

$$V_1 - 25 - (-10\text{k}I) = 0$$

$$\begin{aligned} V_1 &= 25 - \left((10\times10^3)(2\times10^{-3})\right) \\ &= 5\text{ V} \end{aligned}$$

Therefore, the value of voltage V_1 is $\boxed{5\text{ V}}$.

Step 1 of 2

2.35p

Consider the circuit shown in Figure P2.44 in the text book.

Apply Kirchhoff's voltage law to the circuit and calculate the value of current I_x .

$$6kI_x - 20 + 4kI_x + 60 + 10kI_x + 2kI_x + 10kI_x = 0$$
$$32kI_x + 40 = 0$$
$$I_x = \frac{-40}{32 \times 10^3}$$
$$I_x = -1.25 \text{ mA}$$

Step 2 of 2

Calculate the power (P) absorbed by dependent source having voltage $V = 2000I_x$ and current, $I_x = -1.25 \text{ mA}$.

$$\begin{aligned} P &= VI_x \\ &= (2000I_x)(I_x) \\ &= (2000)(-1.25 \times 10^{-3})(-1.25 \times 10^{-3}) \\ &= 3.125 \text{ mW} \end{aligned}$$

Therefore, the value of power absorbed by dependent source is $\boxed{3.125 \text{ mW}}$.

Step 1 of 3

2.36p

Refer to Figure P2.36 in the text book.

Determine the value of voltage V_X.

Apply Kirchhoff's voltage law in the path ABCDEFA.

$$V_{AB} - V_X + V_{CD} + V_{DE} - 36 + V_{FA} = 0$$
$$(I \times 2) - V_X + (I \times 2) + (I \times 3) - 36 + (I \times 1) = 0$$

Substitute $3\ \text{A}$ for I in the equation.

$$(3 \times 2) - V_X + (3 \times 2) + (3 \times 3) - 36 + (3 \times 1) = 0$$
$$6 - V_X + 6 + 9 - 36 + 3 = 0$$
$$-V_X - 12 = 0$$
$$V_X = -12\ \text{V}$$

Thus, the value of voltage, V_X is $\boxed{-12\ \text{V}}$.

Step 2 of 3

Determine the value of voltage V_{AE}.

Apply Kirchhoff's voltage law in the path AEFA.

$$V_{AE} - 36 + V_{FA} = 0$$
$$V_{AE} - 36 + (I \times 1) = 0$$

Substitute $3\ \text{A}$ for I in the equation.

$$V_{AE} - 36 + (3 \times 1) = 0$$
$$V_{AE} - 36 + 3 = 0$$
$$V_{AE} = 33\ \text{V}$$

Thus, the value of voltage, V_{AE} is $\boxed{33\ \text{V}}$.

Step 3 of 3

Determine the value of voltage V_{BD}.

Apply Kirchhoff's voltage law in the path BCDB.

$$-V_{BD} - V_X + V_{CD} = 0$$
$$-V_{BD} - V_X + (I \times 2) = 0$$

Substitute $3\ \text{A}$ for I and $-12\ \text{V}$ for V_X in the equation.

$$-V_{BD} - (-12) + (3 \times 2) = 0$$
$$-V_{BD} + 12 + 6 = 0$$
$$V_{BD} = 18\ \text{V}$$

Thus, the value of voltage, V_{BD} is $\boxed{18\ \text{V}}$.

Step 1 of 3

2.37p

Refer to Figure P2.37 in the text book.

Redraw the network by representing loop current in Figure P2.37 as shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of current flowing in the network.

Apply Kirchhoff's voltage law in the path BAEB.

$$V_{BA} + V_{AE} + V_{EB} = 0$$
$$(I)(1\times10^3) + (I)(2\times10^3) + V_{EB} = 0$$

Substitute $6\ \text{V}$ for V_{EB} in the equation.

$$I(3\times10^3) + 6 = 0$$
$$I = -\frac{6}{(3\times10^3)}$$
$$I = -2\ \text{mA}$$

Step 3 of 3

Calculate the value of voltage V_S.

Apply Kirchhoff's voltage law in the path CBEDCB.

$$-V_S + V_{CB} - V_{EB} + V_{ED} = 0$$
$$-V_S + (I)(4\times10^3) - V_{EB} + (I)(3\times10^3) = 0$$

Substitute $6\ \text{V}$ for V_{EB} and $-2\ \text{mA}$ for I in the equation.

$$-V_S + (-2\times10^{-3})(4\times10^3) - 6 + (-2\times10^{-3})(3\times10^3) = 0$$
$$-V_S - 8 - 6 - 6 = 0$$
$$V_S = -20\ \text{V}$$

Thus, the value of voltage, V_S is $\boxed{-20\ \text{V}}$.

Step 1 of 3

2.38p

Refer to Figure P2.38 in the text book.

Redraw the network by representing loop current in Figure P2.38 as shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of current flowing in the network.

Apply Kirchhoff's voltage law in the path BCDEB.

$$V_{BC} + 12 + V_{DE} - V_{BE} = 0$$
$$(I)(2\times10^3) + 12 + (I)(1\times10^3) - V_{BE} = 0$$

Substitute $18\ \text{V}$ for V_{BE} in the equation.

$$(I)(3\times10^3) + 12 - 18 = 0$$
$$I = \frac{6}{3\times10^3}$$
$$I = 2\ \text{mA}$$

Step 3 of 3

Calculate the value of voltage V_S.

Apply Kirchhoff's voltage law in the path ABEA.

$$-V_S + V_{AB} + V_{BE} = 0$$
$$-V_S + (I)(3\times10^3) + V_{BE} = 0$$

Substitute $18\ \text{V}$ for V_{BE} and $2\ \text{mA}$ for I in the equation.

$$-V_S + (2\times10^{-3})(3\times10^3) + 18 = 0$$
$$-V_S + 6 + 18 = 0$$
$$V_S = 24\ \text{V}$$

Thus, the value of voltage, V_S is $\boxed{24\ \text{V}}$.

Step 1 of 3

2.39p

Refer to Figure P2.39 in the text book.

Redraw the network by representing loop current and nodes in Figure P2.39 as shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of current flowing in the network shown in Figure 1.

Apply Kirchhoff's voltage law in the path BCDEB.

$$V_{BC} + 12 + V_{DE} - 4 = 0$$
$$(I)(1) + 12 + (I)(1) - 4 = 0$$
$$2I + 8 = 0$$
$$I = -4 \text{ A}$$

Step 3 of 3

Calculate the value of voltage V_A.

Apply Kirchhoff's voltage law in the path ABEFA.

$$V_{AB} + 4 - V_A + V_{FA} = 0$$
$$(I)(2) + 4 - V_A + (I)(2) = 0$$

Substitute -4 A for I in the equation.

$$(-4)(2) + 4 - V_A + (-4)(2) = 0$$
$$-8 + 4 - V_A - 8 = 0$$
$$V_A = -12 \text{ V}$$

Thus, the value of voltage in the network, V_A is $\boxed{-12 \text{ V}}$.

Step 1 of 4

2.40p

Refer to Figure P2.40 in the text book.

Redraw the network by representing loop current in Figure P2.40 as shown in Figure 1.

Figure 1

Step 2 of 4

Calculate the value of current flowing in the network shown in Figure 1.

The power absorbed by the $12\ \text{V}$ voltage source in the network is,

$$P_{12\,\text{V}} = 36\ \text{W}$$
$$(12)(I) = 36$$
$$I = \frac{36}{12}$$
$$I = 3\ \text{A}$$

Step 3 of 4

Calculate the value of voltage V_o.

Apply Kirchhoff's voltage law to the network shown in Figure 1.

$$-V_o - 24 + (I)(1) + (I)(1) + 12 = 0$$

Substitute $3\ \text{A}$ for I in the equation.

$$-V_o - 24 + (3)(1) + (3)(1) + 12 = 0$$
$$-V_o - 24 + 3 + 3 + 12 = 0$$
$$V_o = -6\ \text{V}$$

Thus, the value of voltage in the network, V_o is $\boxed{-6\ \text{V}}$.

Step 4 of 4

Calculate the value of unknown resistance.

$$V_o = -(I)(R)$$

Substitute $3\ \text{A}$ for I and $-6\ \text{V}$ for V_o in the equation.

$$-6 = -(3)(R)$$
$$R = \frac{6}{3}$$
$$R = 2\ \Omega$$

Thus, the value of unknown resistance in the network, R is $\boxed{2\ \Omega}$.

Step 1 of 3

Refer to Figure P2.41 in the text book.

Calculate the value of current flowing in the network.

$$V_x = (I)(2)$$

Substitute $-12\ \text{V}$ for V_x in the equation.

$$-12 = (I)(2)$$
$$I = -\frac{12}{2}$$
$$I = -6\ \text{A}$$

Step 2 of 3

Calculate the value of voltage V_S.

Apply Kirchhoff's voltage law to the network shown in Figure P2.41.

$$(I)(1) + V_S + V_x + (I)(1) - 4 = 0$$

Substitute $-6\ \text{A}$ for I and $-12\ \text{V}$ for V_x in the equation.

$$(-6)(1) + V_S - 12 + (-6)(1) - 4 = 0$$
$$-6 + V_S - 12 - 6 - 4 = 0$$
$$V_S = 28\ \text{V}$$

Thus, the value of voltage in the network, V_S is $\boxed{28\ \text{V}}$.

Step 3 of 3

Calculate the value of voltage V_{BA}.

$$V_{BA} = -(I)(1)$$

Substitute $-6\ \text{A}$ for I in the equation.

$$V_{BA} = -(-6)(1)$$
$$= 6\ \text{V}$$

Thus, the value of voltage in the network, V_{BA} is $\boxed{6\ \text{V}}$.

2.42p

Figure 1

Let I be the current in the loop as shown in figure 1.
Resistors $2k\Omega, 6k\Omega$ are in series.
Replace with $R_{eq1} = 8k\Omega$ between nodes a and c.
Also resistors $3k\Omega, 3k\Omega$ are in series.
Replace with $R_{eq2} = 6k\Omega$ between nodes e and c as shown in figure 2.

Figure 2

By Ohm's Law,
$V_{ac} = I(8k)$
Since $V_{ac} = V_x$,
$V_x = I(8k)$ ..... (1)

Applying KVL around loop $acefga$,
$V_{ac} + V_{ce} + V_{ef} + V_{fg} + V_{ga} = 0$
$I(8k) + I(6k) + 1.5V_x + I(4k) + 12 = 0$
$I(18k) + 1.5(I(8k)) = -12$ (from (1))
$I(18k + 12k) = -12$
$I = \frac{-12}{30k}$
$I = -0.4$ mA
$V_x = (-0.4 \text{ m})(8k)$ (from (1))
$V_x = -3.2$ V

Power absorbed by the dependent source is,
$P_{absDep} = (1.5V_x)(I)$
$P_{absDep} = (1.5(-3.2))(-0.4\text{m})$
$P_{absDep} = 1.92$ mW
Hence $\boxed{P_{absDep} = 1.92 \text{ mW}}$

Step 1 of 4

2.44p

Refer to Figure P2.43 in the text book.

Redraw the network by representing nodes in Figure P2.43 as shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to the network shown in Figure 1.

$$-12+(I)(2)+2V_A+24+(I)(4)+(I)(2)=0$$

$8I+2V_A+12=0$ ..... (1)

Apply Kirchhoff's voltage law in the path-abfa.

$$(I)(2)+V_A-12=0$$

$V_A=12-2I$ ..... (2)

Calculate the value of current flowing in the network.

$$8I+2(12-2I)+12=0$$
$$8I+24-4I+12=0$$
$$4I=-36$$
$$I=-9\text{ A}$$

Step 3 of 4

Calculate the value of voltage V_A.

Substitute -9 A for I in equation (2).

$$\begin{aligned}V_A&=12-2(-9)\\&=12+18\\&=30\text{ V}\end{aligned}$$

Thus, the value of voltage in the network, V_A is $\boxed{30\text{ V}}$.

Step 4 of 4

Calculate the value of voltage V_o.

Apply Kirchhoff's voltage law in the path-befb.

$$-V_A-V_o+(I)(2)=0$$

Substitute 30 V for V_A and -9 A for I in the equation.

$$-30-V_o+(-9)(2)=0$$
$$-V_o-48=0$$
$$V_o=-48\text{ V}$$

Thus, the value of voltage in the network, V_o is $\boxed{-48\text{ V}}$.

Step 1 of 2

2.45p

Refer to Figure P2.45 in the textbook for the circuit.

Apply Kirchhoff's current law to the circuit.

$$-12-2V_a+\left(4\times10^3\right)I+\left(2\times10^3\right)I-4V_b=0$$

$$-2V_a+\left(6\times10^3\right)I-4V_b=12 \text{ ..... (1)}$$

From the circuit, the voltage V_a is,

$$V_a=-\left(2\times10^3\right)I$$

From the circuit, the voltage V_b is,

$$V_b=\left(4\times10^3\right)I$$

Step 2 of 2

Substitute $-\left(2\times10^3\right)I$ for V_a and $\left(4\times10^3\right)I$ for V_b in equation (1).

$$-2\left[-\left(2\times10^3\right)I\right]+\left(6\times10^3\right)I-4\left[\left(4\times10^3\right)I\right]=12$$

$$\left(4\times10^3\right)I+\left(6\times10^3\right)I-\left(16\times10^3\right)I=12$$

$$-\left(6\times10^3\right)I=12$$

$$I=-\frac{12}{6\times10^3}$$

$$I=-2\text{ mA}$$

The power absorbed or supplied by the 12-V source is,

$$\begin{aligned}P_{12\text{-V}}&=(12)I\\&=(12)\left(-2\times10^{-3}\right)\\&=-24\text{ mW}\end{aligned}$$

Since the power obtained is negative, the power is absorbed by the 12-V source.

Therefore, the power absorbed by the 12-V source is $\boxed{24\text{ mW}}$.

Step 1 of 2

2.46p

Refer to Figure P2.46 in the textbook for the circuit.

Apply Kirchhoff's voltage law to the circuit.

$$-2V_x + \left(1\times10^3\right)I - 6 + \left(1\times10^3\right)I + \left(2\times10^3\right)I = 0$$

$$-2V_x + \left(4\times10^3\right)I = 6 \quad \text{..... (1)}$$

From the circuit, the voltage V_x is,

$$V_x = 6 - \left(1\times10^3\right)I$$

Step 2 of 2

Substitute $6-\left(1\times10^3\right)I$ for V_x in equation (1).

$$-2\left[6-\left(1\times10^3\right)I\right] + \left(4\times10^3\right)I = 6$$

$$-12 + \left(2\times10^3\right)I + \left(4\times10^3\right)I = 6$$

$$\left(6\times10^3\right)I = 18$$

$$I = \frac{18}{6\times10^3}$$

$$I = 3\text{ mA}$$

From the circuit, the voltage V_o is,

$$\begin{aligned} V_o &= \left(2\times10^3\right)I \\ &= \left(2\times10^3\right)\left(3\times10^{-3}\right) \\ &= 6\text{ V} \end{aligned}$$

Therefore, the voltage, V_o is $\boxed{6\text{ V}}$.

Step 1 of 3

2.47p

Refer to Figure P2.47 in the textbook.

Calculate the equivalent resistance R_a of resistors connected in parallel by using the formula $R_a = \frac{R_2 R_3}{R_2 + R_3}$.

Substitute $R_2 = 6\ \text{k}\Omega$, $R_3 = 3\ \text{k}\Omega$ from Figure P2.47 in the text book and solve for R_a.

$$\begin{aligned} R_a &= \frac{(6\ \text{k}\Omega)(3\ \text{k}\Omega)}{(6\ \text{k}\Omega)+(3\ \text{k}\Omega)} \\ &= \frac{(6\ \text{k}\Omega)(3\ \text{k}\Omega)}{9\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Step 2 of 3

The circuit is reduced as shown in figure 1.

Figure 1

Step 3 of 3

Calculate the value of current I_o by using current division formula $I_o = \left(\frac{R_2}{R_1 + R_2}\right) I$.

Substitute $I = 12\ \text{mA}$, $R_1 = 2\ \text{k}\Omega$, $R_2 = R_a$ from figure 1 and solve for current I_o.

$$\begin{aligned} I_o &= \left(\frac{R_a}{2\ \text{k}\Omega + R_a}\right)(12\ \text{mA}) \\ &= \left(\frac{2\ \text{k}\Omega}{2\ \text{k}\Omega + 2\ \text{k}\Omega}\right)(12\ \text{mA}) \\ &= \left(\frac{2\ \text{k}\Omega}{4\ \text{k}\Omega}\right)(12\ \text{mA}) \\ &= 6\ \text{mA} \end{aligned}$$

Therefore, the value of current I_o is $\boxed{6\ \text{mA}}$.

Step 1 of 3

2.48p

Refer to Figure P2.48 in the textbook.

Calculate the equivalent resistance R_a of resistors connected in parallel by using the formula,

$$R_a = \frac{R_2 R_3}{R_2 + R_3}.$$

Substitute $R_2 = 6\ \text{k}\Omega$, $R_3 = 12\ \text{k}\Omega$ from Figure P2.48 in the text book and solve for R_a.

$$\begin{aligned} R_a &= \frac{(6\ \text{k}\Omega)(12\ \text{k}\Omega)}{(6\ \text{k}\Omega)+(12\ \text{k}\Omega)} \\ &= \frac{(6\ \text{k}\Omega)(12\ \text{k}\Omega)}{18\ \text{k}\Omega} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 2 of 3

The circuit is reduced as shown in figure 1.

Figure 1

Step 3 of 3

Calculate the value of current I_o by using current division formula having current $I = -12\ \text{mA}$, $R_1 = 12\ \text{k}\Omega$, $R_2 = R_a$ from figure 1 and solve for current I_o.

$$\begin{aligned} I_o &= \left(\frac{R_2}{R_1 + R_2}\right) I \\ &= \left(\frac{4\ \text{k}\Omega}{12\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(-12\ \text{mA}) \\ &= \left(\frac{4\ \text{k}\Omega}{16\ \text{k}\Omega}\right)(-12\ \text{mA}) \\ &= -3\ \text{mA} \end{aligned}$$

Therefore, the value of current I_o is $\boxed{-3\ \text{mA}}$.

Step 1 of 4

2.50p

Refer to circuit in Figure P2.49 in the text book.

Calculate the equivalent resistance $\left(R_{eq}\right)$ of the resistors connected in parallel in the circuit.

$$\begin{aligned} R_{eq} &= \left(\frac{1}{1\ \text{k}\Omega}+\frac{1}{2\ \text{k}\Omega}+\frac{1}{5\ \text{k}\Omega}\right)^{-1} \\ &= \left(1\ \text{m}\Omega+0.5\ \text{m}\Omega+0.2\ \text{m}\Omega\right)^{-1} \\ &= \left(1.7\times10^{-3}\right)^{-1} \\ &= 588.23\ \Omega \end{aligned}$$

Calculate the equivalent current source I_{eq} value.

$$\begin{aligned} I_{eq} &= 4\ \text{mA}-2\ \text{mA} \\ &= 2\ \text{mA} \end{aligned}$$

Step 2 of 4

The reduced circuit is shown in Figure **1**.

Figure 1

Step 3 of 4

Calculate the voltage V from Figure 1.

$$\begin{aligned} V &= I_{eq}R_{eq} \\ &= \left(2\ \text{mA}\right)\left(588.23\ \Omega\right) \\ &= 1.176\ \text{V} \end{aligned}$$

The voltage V is same across the branches in the circuit of Figure P2.49 in the text book.

Now, calculate the power supplied by source $I_1 = 4\ \text{mA}$.

$$\begin{aligned} P_{4\ \text{mA}} &= VI \\ &= \left(1.176\ \text{V}\right)\left(4\ \text{mA}\right) \\ &= \left(1.176\right)\left(4\times10^{-3}\right) \\ &= 4.704\ \text{mW} \end{aligned}$$

Therefore, the sign power is positive and so the source absorbs the power of $\boxed{4.704\ \text{mW}}$.

Step 4 of 4

Calculate the power supplied by source $I_2 = -2\ \text{mA}$.

$$\begin{aligned} P_{2\ \text{mA}} &= V\left(-I\right) \\ &= \left(1.176\ \text{V}\right)\left(-2\ \text{mA}\right) \\ &= \left(1.176\ \text{V}\right)\left(-2\times10^{-3}\ \text{A}\right) \\ &= -2.352\ \text{mW} \end{aligned}$$

Therefore the sign of power is negative and so the source supplies the power of $\boxed{2.352\ \text{mW}}$.

Step 1 of 2

2.51p

Refer to Figure P2.51 in the textbook for the circuit.

Apply Kirchhoff's current law to the circuit.

$$\frac{V_S}{(1\times10^3)+(1\times10^3)}+\frac{V_S}{(1\times10^3)}-2\times10^{-3}-\frac{2V_X}{10^3}=0$$

$$\frac{V_S}{2\times10^3}+\frac{V_S}{1\times10^3}-\frac{2V_X}{10^3}=2\times10^{-3}$$

$$\frac{V_S+2V_S-4V_X}{2\times10^3}=2\times10^{-3}$$

$$3V_S-4V_X=4 \text{ ..... (1)}$$

From the circuit, the voltage V_X is,

$$V_X=\left(\frac{V_S}{2\times10^3}\right)(1\times10^3)$$

$$=\frac{V_S}{2}$$

Step 2 of 2

Substitute $\frac{V_S}{2}$ for V_X in equation (1).

$$3V_S-4\left(\frac{V_S}{2}\right)=4$$

$$3V_S-2V_S=4$$

$$V_S=4\text{ V}$$

Therefore, the voltage, V_S is $\boxed{4\text{ V}}$.

Step 1 of 3

2.52p

Refer to Figure P2.52 in the textbook for the circuit.

Redraw the circuit by representing node voltage V_A as shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law to the circuit in Figure 1.

$$\frac{V_A}{(2\times10^3)+(1\times10^3)}+\frac{V_A}{(6\times10^3)}+\frac{2V_X}{10^3}-\frac{12}{10^3}=0$$

$$\frac{V_A}{3\times10^3}+\frac{V_A}{6\times10^3}+\frac{2V_X}{10^3}=12\times10^{-3}$$

$$\frac{2V_A+V_A+12V_X}{6\times10^3}=12\times10^{-3}$$

$3V_A+12V_X=72$ ..... (1)

From the circuit, the voltage V_X is,

$$V_X=\left(\frac{V_A}{3\times10^3}\right)(2\times10^3)$$
$$=\frac{2V_A}{3}$$

Step 3 of 3

Substitute $\frac{2V_A}{3}$ for V_X in equation (1).

$$3V_A+12\left(\frac{2V_A}{3}\right)=72$$
$$3V_A+8V_A=72$$
$$11V_A=72$$
$$V_A=\frac{72}{11}$$

The current I_o is,

$$I_o=\frac{V_A}{6\times10^3}$$
$$=\frac{\left(\frac{72}{11}\right)}{6\times10^3}$$
$$=1.091\text{ mA}$$

Therefore, the current I_o is $\boxed{1.091\text{ mA}}$.

Step 1 of 6

2.53p

Refer to Figure P2.53 in the textbook.

From Figure P2.53 in the textbook, the $1\ \text{k}\Omega$ resistor and $1\ \text{k}\Omega$ resistor are in series. The equivalent is in parallel with $1\ \text{k}\Omega$ resistor. Determine the equivalent resistor.

$$\begin{aligned} R_{eq} &= (1\ \text{k}\Omega + 1\ \text{k}\Omega) \| 1\ \text{k}\Omega \\ &= 2\ \text{k}\Omega \| 1\ \text{k}\Omega \\ &= \frac{(2\ \text{k}\Omega)(1\ \text{k}\Omega)}{2\ \text{k}\Omega + 1\ \text{k}\Omega} \\ &= \frac{2}{3}\ \text{k}\Omega \end{aligned}$$

Step 2 of 6

Re-draw the circuit diagram:

Figure 1

Step 3 of 6

From Figure 1, apply Kirchhoff's current law and determine the value of current I.

$$6\ \text{mA} + \frac{2V_x}{\text{k}} = I + 2\ \text{mA}$$

$$I = 4\ \text{mA} + 2V_x\ \text{mA}$$

Determine the value of voltage across $\frac{2}{3}\ \text{k}\Omega$ resistor.

$$V = I\left(\frac{2}{3}\ \text{k}\Omega\right)$$

Substitute $4\ \text{mA} + 2V_x\ \text{mA}$ for I in the equation.

$$V = (4\ \text{mA} + 2V_x\ \text{mA})\left(\frac{2}{3}\ \text{k}\Omega\right)$$

$$V = \frac{8}{3} + \frac{4}{3}V_x \quad \text{..... (1)}$$

Step 4 of 6

From Figure P2.53, determine the value of current in $1\ \text{k}\Omega$ resistor.

$$I_{1\ \text{k}\Omega} = \frac{V_x}{1\ \text{k}\Omega}$$

Determine the value of total node voltage, V.

$$\begin{aligned} V &= \left(\frac{V_x}{1\ \text{k}\Omega}\right)(1\ \text{k}\Omega + 1\ \text{k}\Omega) \\ &= 2V_x \end{aligned}$$

$$V_x = \frac{V}{2}$$

Step 5 of 6

Substitute $\frac{V}{2}$ for V_x in equation (1).

$$\begin{aligned} V &= \frac{8}{3} + \left(\frac{4}{3}\right)\left(\frac{V}{2}\right) \\ &= \frac{8}{3} + \frac{2V}{3} \end{aligned}$$

$$\frac{1}{3}V = \frac{8}{3}$$

$$\begin{aligned} V &= \left(\frac{8}{3}\right)(3) \\ &= 8\ \text{V} \end{aligned}$$

Step 6 of 6

Determine the value of current, I_0.

$$\begin{aligned} I_0 &= \frac{V}{1\ \text{k}\Omega} \\ &= \frac{8}{1\ \text{k}\Omega} \\ &= 8\ \text{mA} \end{aligned}$$

Therefore, the value of current, I_0 is $\boxed{8\ \text{mA}}$.

Step 1 of 4

2.54p

Refer to Figure P2.54 in the textbook.

Determine the current in $3\ \Omega$ resistor.

$$I_{3\Omega} = \frac{V_x}{3}$$

From Figure P2.54 in the textbook, the $2\ \Omega$ resistor and $2\ \Omega$ resistor are in parallel. Determine the equivalent resistance.

$$\begin{aligned} R_{eq} &= \frac{(2\ \Omega)(2\ \Omega)}{2\ \Omega + 2\ \Omega} \\ &= \frac{4}{4} \\ &= 1\ \Omega \end{aligned}$$

The resistors $1\ \Omega$ and $3\ \Omega$ are in series.

Determine the total resistance.

$$\begin{aligned} R_T &= 1 + 3 \\ &= 4\ \Omega \end{aligned}$$

Step 2 of 4

Re-draw the circuit diagram:

Figure 1

Step 3 of 4

From Figure 1, determine the value of current I .

$$\begin{aligned} I &= \frac{V_0}{1} \\ &= V_0 \end{aligned}$$

From Figure 1, apply Kirchhoff's current law and determine the current in $1\ \Omega$ resistor.

$$I + \frac{V_x}{2} + \frac{V_x}{3} = 2$$

$$I + \frac{5V_x}{6} = 2$$

Substitute V_0 for I in the equation.

$$V_0 + \frac{5V_x}{6} = 2 \text{ ..... (1)}$$

Step 4 of 4

From Figure 1, determine the voltage across $4\ \Omega$ resistor.

$$V_0 = \left(\frac{V_x}{3}\right)(4)$$

$$V_x = \frac{3}{4}V_0$$

Substitute $\frac{3}{4}V_0$ for V_x in equation (1).

$$V_0 + \frac{5\left(\frac{3}{4}V_0\right)}{6} = 2$$

$$V_0 + \frac{5}{8}V_0 = 2$$

$$13V_0 = 16$$

$$\begin{aligned} V_0 &= \frac{16}{13} \\ &= 1.231\ \text{V} \end{aligned}$$

Therefore, the value of voltage, V_0 is $\boxed{1.231\ \text{V}}$.

Step 1 of 4

2.55p

Refer to Figure P2.55 in the textbook.

From Figure P2.55, the voltage across $3\ \text{k}\Omega$ resistor and $6\ \text{k}\Omega$ resistor are equal.

$$V_{3\ \text{k}\Omega} = V_{6\ \text{k}\Omega}$$
$$I_x(3\ \text{k}\Omega) = I_{6\ \text{k}\Omega}(6\ \text{k}\Omega)$$

$$\begin{aligned} I_{6\ \text{k}\Omega} &= \frac{I_x(3\ \text{k}\Omega)}{(6\ \text{k}\Omega)} \\ &= \frac{I_x}{2} \end{aligned}$$

Step 2 of 4

Determine the value of current in $4\ \text{k}\Omega$ resistance.

$$\begin{aligned} I_{4\ \text{k}\Omega} &= I_{6\ \text{k}\Omega} + I_x \\ &= \frac{I_x}{2} + I_x \\ &= \frac{3I_x}{2} \end{aligned}$$

Apply current division rule.

$$6\ \text{mA} = \frac{3I_x}{2} + I_0 + 2I_x$$

$$6\ \text{mA} = \frac{7I_x}{2} + I_0 \quad \text{..... (1)}$$

Step 3 of 4

From Figure P2.55, the resistors $3\ \text{k}\Omega$ and $6\ \text{k}\Omega$ resistor are in parallel.

Determine the equivalent resistance.

$$\begin{aligned} R_{eq} &= 3\ \text{k}\Omega \parallel 6\ \text{k}\Omega \\ &= \frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{3\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

The equivalent resistance $2\ \text{k}\Omega$ and $4\ \text{k}\Omega$ resistor are in series.

Determine the total resistance.

$$\begin{aligned} R_T &= 2\ \text{k}\Omega + 4\ \text{k}\Omega \\ &= 6\ \text{k}\Omega \end{aligned}$$

Re-draw the circuit diagram.

Figure 1

Step 4 of 4

From Figure 1, the voltage across resistance R_T is equal to voltage across $3\ \text{k}\Omega$ resistance.

$$(I_{4\ \text{k}\Omega})(R_T) = I_0(3\ \text{k}\Omega)$$
$$\left(\frac{3I_x}{2}\right)(6\ \text{k}\Omega) = I_0(3\ \text{k}\Omega)$$

$$\begin{aligned} I_x &= I_0\left(\frac{6}{(3)(6)}\right) \\ &= \frac{I_0}{3} \end{aligned}$$

Substitute $\frac{I_0}{3}$ for I_x in equation (1).

$$6\ \text{mA} = \frac{7\left(\frac{I_0}{3}\right)}{2} + I_0$$

$$6\ \text{mA} = \frac{7(I_0)}{6} + I_0$$

$$36\ \text{mA} = 13I_0$$

$$\begin{aligned} I_0 &= \frac{36\ \text{mA}}{13} \\ &= 2.769\ \text{mA} \end{aligned}$$

Therefore, the value of current, I_0 is $\boxed{2.769\ \text{mA}}$.

Step 1 of 3

2.56p

Refer to circuit in Figure P2.51 in the textbook.

The circuit with current directions is shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the current I_1 in Figure 1 by using current division formula.

$$I_1 = \left(\frac{R_4}{\left(R_3 + \frac{R_1R_2}{R_1+R_2}\right)+R_4}\right)I$$

$$= \left(\frac{6\ \text{k}\Omega}{\left(3\ \text{k}\Omega + \frac{(4\ \text{k}\Omega)(12\ \text{k}\Omega)}{4\ \text{k}\Omega + 12\ \text{k}\Omega}\right)+6\ \text{k}\Omega}\right)(12\ \text{mA})$$

$$= \left(\frac{6\ \text{k}\Omega}{(3\ \text{k}\Omega + 3\ \text{k}\Omega)+6\ \text{k}\Omega}\right)(12\ \text{mA})$$

$$= \left(\frac{6\ \text{k}\Omega}{12\ \text{k}\Omega}\right)(12\ \text{mA})$$

Further simplification:

$$I_1 = \left(\frac{6\times10^3}{12\times10^3}\right)\left(12\times10^{-3}\right)$$

$$= (0.5)\left(12\times10^{-3}\right)$$

$$= 6\ \text{mA}$$

Step 3 of 3

Calculate the value of current I_o in Figure 1 by using current division formula.

$$I_o = \left(\frac{R_2}{R_1+R_2}\right)I_1$$

$$= \left(\frac{12\ \text{k}\Omega}{4\ \text{k}\Omega + 12\ \text{k}\Omega}\right)(6\ \text{mA})$$

$$= \left(\frac{12\times10^3}{\left(4\times10^3\right)+\left(12\times10^3\right)}\right)\left(6\times10^{-3}\right)$$

$$= 4.5\ \text{mA}$$

Therefore the value of current I_o is $\boxed{4.5\ \text{mA}}$.

Step 1 of 3

2.57p

Refer to circuit in Figure P2.52 in the textbook.

The circuit with current directions is shown in Figure 1.

Figure 1

Step 2 of 3

Let the current flowing through $4\ \Omega$ resistor be I_x and voltage across $6\ \Omega$ resistor be V_1.

Calculate the value of V_x in terms of V_1.

$$\begin{aligned} V_x &= 4I_x \\ &= 4\left(\frac{V_1}{8+4}\right) \\ &= \frac{V_1}{3} \end{aligned}$$

Apply Kirchhoff's current law and solve for voltage V_1.

$$\begin{aligned} 5\text{ A} &= I_o + I_x + 3V_x \\ &= \frac{V_1}{6000} + \frac{V_1}{8+4} + 3\left(\frac{V_1}{3}\right) \\ &= \frac{V_1}{6000} + \frac{V_1}{12} + V_1 \\ &= 1.0835V_1 \end{aligned}$$

$$V_1 = 4.615\text{ V}$$

Step 3 of 3

Calculate the value of voltage I_o.

$$V_1 = (6\text{ k}\Omega)I_o$$

$$\begin{aligned} I_o &= \frac{V_1}{6\text{ k}\Omega} \\ &= \frac{4.615\text{ V}}{6\text{ k}\Omega} \\ &= 0.769\text{ mA} \end{aligned}$$

Therefore the value of current I_o is $\boxed{0.769\text{ mA}}$.

Step 1 of 2

2.58p

Refer to circuit shown in Figure P2.53 in the text book.

The voltage across any branch is equal to V_1 as it is parallel circuit.

The value of current I_x is $\frac{V_1}{6\ \text{k}\Omega}$.

Apply Kirchhoff's current law to the circuit and calculate the value of voltage V_1.

$$I_x + 3I_x + 3\ \text{mA} + \frac{V_1}{2\ \text{k}\Omega} + I_L - 6\ \text{mA} = 0$$

$$\frac{V_1}{6\ \text{k}\Omega} + \frac{3V_1}{6\ \text{k}\Omega} + 3\ \text{mA} + \frac{V_1}{2\ \text{k}\Omega} + \frac{V_1}{3\ \text{k}\Omega} - 6\ \text{mA} = 0$$

$$V_1\left(\frac{1}{6\ \text{k}\Omega} + \frac{3}{6\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega} + \frac{1}{3\ \text{k}\Omega}\right) = 6\ \text{mA} - 3\ \text{mA}$$

$$V_1\left(\frac{1+3+3+2}{6\ \text{k}\Omega}\right) = 3\ \text{mA}$$

Further simplification:

$$V_1\left(\frac{9}{6\ \text{k}\Omega}\right) = 3\ \text{mA}$$

$$V_1 = \left(3\times10^{-3}\right)\left(\frac{6\times10^3}{9}\right)$$
$$= 2\ \text{V}$$

Step 2 of 2

Calculate the value of current I_L.

$$I_L = \frac{V_1}{3\ \text{k}\Omega}$$
$$= \frac{2\ \text{V}}{3\times10^3}$$
$$= 0.667\ \text{mA}$$

Therefore the value of current I_L is $\boxed{0.667\ \text{mA}}$.

Step 1 of 7

2.59p

Consider the circuit shown in Figure P2.56 in the text book.

Reduce the considered circuit starting from opposite end of the network terminals.

Calculate the equivalent resistance R_1 of resistors connected in parallel by using the formula $R = \frac{R_a R_b}{R_a + R_b}$.

Substitute $R = R_1$, $R_a = 3\ \text{k}\Omega$, $R_b = 6\ \text{k}\Omega$ from Figure P2.56 in the text book and solve for R_1.

$$\begin{aligned} R_1 &= 3\ \text{k}\Omega \| 6\ \text{k}\Omega \\ &= \frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{(3\ \text{k}\Omega)+(6\ \text{k}\Omega)} \\ &= \frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{9\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Step 2 of 7

The resistance R_1 is in series to $2\ \text{k}\Omega$ resistance and is shown in Figure 1.

Step 3 of 7

Figure 1

Step 4 of 7

Calculate the equivalent resistance R_2 of two resistors connected in series by using the formula $R = R_a + R_b$.

Substitute $R = R_2$, $R_a = 2\ \text{k}\Omega$, $R_b = R_1$ from Figure 1 and solve for R_2.

$$\begin{aligned} R_2 &= 2\ \text{k}\Omega + R_1 \\ &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 5 of 7

Now the resistor R_2 is in parallel to $4\ \text{k}\Omega$ resistor.

Calculate the equivalent resistance R_3 of resistors connected in parallel by using the formula $R = \frac{R_a R_b}{R_a + R_b}$.

Substitute $R = R_3$, $R_a = R_2$, $R_b = 4\ \text{k}\Omega$ from Figure 1 and solve for R_3.

$$\begin{aligned} R_3 &= R_2 \| 4\ \text{k}\Omega \\ &= \frac{(R_2)(4\ \text{k}\Omega)}{(R_2)+(4\ \text{k}\Omega)} \\ &= \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega)}{(4\ \text{k}\Omega)+(4\ \text{k}\Omega)} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Step 6 of 7

Now the circuit is reduced as shown in Figure 2.

Figure 2

Step 7 of 7

Calculate the equivalent resistance R_{AB} for the resistors connected in series by using the formula $R = R_a + R_b$.

Substitute $R = R_{AB}$, $R_a = R_3$, $R_b = 1\ \text{k}\Omega$ from Figure 2 and solve for R_{AB}.

$$\begin{aligned} R_{AB} &= R_3 + 1\ \text{k}\Omega \\ &= 2\ \text{k}\Omega + 1\ \text{k}\Omega \\ &= 3\ \text{k}\Omega \end{aligned}$$

Therefore, the value of equivalent resistance R_{AB} in the network is $\boxed{3\ \text{k}\Omega}$.

Step 1 of 4

Consider the circuit shown in Figure 1 as follows:

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law for the loop a e d a and calculate the value of V_1 as follows:

$$4\text{ V}+6\text{ V}-V_1=0$$
$$V_1=10\text{ V}$$

Therefore the value of V_1 is $\boxed{10\text{ V}}$.

Step 3 of 4

Apply Kirchhoff's voltage law for the loop a e b a and calculate the value of V_x as follows:

$$4\text{ V}-6\text{ V}+V_x=0$$
$$V_x=6\text{ V}-4\text{ V}$$
$$=2\text{ V}$$

Apply Kirchhoff's voltage law for the loop b e c b and calculate the value of V_2 as follows:

$$6\text{ V}-V_2-2V_x=0$$
$$6\text{ V}-V_2-2(2\text{ V})=0$$
$$-V_2=-6\text{ V}+4\text{ V}$$
$$V_2=2\text{ V}$$

Therefore the value of V_2 is $\boxed{2\text{ V}}$.

Step 4 of 4

Apply Kirchhoff's voltage law for the loop e c d e and calculate the value of V_3 as follows:

$$-V_2+V_3-6\text{ V}=0$$
$$-2\text{ V}+V_3-6\text{ V}=0$$
$$V_3-8\text{ V}=0$$
$$V_3=8\text{ V}$$

Therefore the value of V_3 is $\boxed{8\text{ V}}$.

Step 1 of 7

2.61p

Consider the circuit shown in Figure P2.55 in the text book.

Starting from opposite end of network terminals the circuit is reduced.

Calculate the equivalent resistance R_1 of two resistors connected in series by using the formula $R = R_a + R_b$.

Substitute R_1 for R, $2\ \text{k}\Omega$ for R_a, $2\ \text{k}\Omega$ for R_b in the equation and solve for R_1.

$$\begin{aligned} R_1 &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Now the resistor R_1 is in parallel to $4\ \text{k}\Omega$ resistance.

Step 2 of 7

Calculate the equivalent resistance R_2 of resistors connected in parallel by using the formula $R = \dfrac{R_a R_b}{R_a + R_b}$.

Substitute R_2 for R, R_1 for R_a, $4\ \text{k}\Omega$ for R_b in the equation and solve for R_2.

$$\begin{aligned} R_2 &= R_1 \parallel 4\ \text{k}\Omega \\ &= \frac{(R_1)(4\ \text{k}\Omega)}{R_1 + 4\ \text{k}\Omega} \\ &= \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega)}{4\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Now the circuit is reduced as shown in Figure 1 as follows:

Figure 1

Step 3 of 7

Now from Figure 1 the resistors $2\ \text{k}\Omega$ and R_2 are in series.

Calculate the equivalent resistance R_3 for the resistors connected in series by using the formula $R = R_a + R_b$.

Substitute R_3 for R, $2\ \text{k}\Omega$ for R_a, R_2 for R_b in the equation and solve for R_3.

$$\begin{aligned} R_3 &= 2\ \text{k}\Omega + R_2 \\ &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

The resistance R_3 is in parallel to the $12\ \text{k}\Omega$ resistor.

Step 4 of 7

The resistance R_3 is in parallel to the $12\ \text{k}\Omega$ resistor.

Calculate the equivalent resistance R_4 of resistors connected in parallel by using the formula $R = \dfrac{R_a R_b}{R_a + R_b}$.

Substitute R_4 for R, R_3 for R_a, $12\ \text{k}\Omega$ for R_b in the equation and solve for R_4.

$$\begin{aligned} R_4 &= R_3 \parallel 12\ \text{k}\Omega \\ &= \frac{(R_3)(12\ \text{k}\Omega)}{R_3 + 12\ \text{k}\Omega} \\ &= \frac{(4\ \text{k}\Omega)(12\ \text{k}\Omega)}{4\ \text{k}\Omega + 12\ \text{k}\Omega} \\ &= 3\ \text{k}\Omega \end{aligned}$$

Step 5 of 7

The circuit is reduced as shown in Figure 2.

Step 6 of 7

Figure 2

Step 7 of 7

Calculate the equivalent resistance R_{AB} for the resistors connected in series by using the formula $R = R_a + R_b$.

Substitute R_{AB} for R, $9\ \text{k}\Omega$ for R_a, R_4 for R_b in the equation and solve for R_{AB}.

$$\begin{aligned} R_{AB} &= 9\ \text{k}\Omega + R_4 \\ &= 9\ \text{k}\Omega + 3\ \text{k}\Omega \\ &= 12\ \text{k}\Omega \end{aligned}$$

Therefore, the value of equivalent resistance R_{AB} is $\boxed{12\ \text{k}\Omega}$.

Step 1 of 8

Figure 1

Step 2 of 8

Resistors R_2 and R_3 are in series.

Replace with $R_{e1} = R_3 + R_2$ between nodes d and c.

$R_{e1} = 4\text{k} + 8\text{k}$

$R_{e1} = 12\text{k}\Omega$

Step 3 of 8

Figure 2

Step 4 of 8

Resistors R_{e1}, R_4, R_5 and R_6 are in parallel.

Replace with $R_{e2} = R_{e1} \parallel R_4 \parallel R_5 \parallel R_6$ between nodes d and b.

$$R_{e2} = \frac{1}{\left(\frac{1}{12\text{k}} + \frac{1}{4\text{k}} + \frac{1}{3\text{k}} + \frac{1}{3\text{k}}\right)}$$

$$R_{e2} = \frac{1}{\left(\frac{1+3+4+4}{12\text{k}}\right)}$$

$$R_{e2} = \frac{12}{12}\text{k}$$

$$R_{e2} = 1\text{k}\Omega$$

Step 5 of 8

Figure 3

Step 6 of 8

Resistors R_{e2} and R_1 are in series.

Replace with $R_{e3} = R_1 + R_{e2}$ between nodes a and b.

$R_{e3} = 5\text{k} + 1\text{k}$

$R_{e3} = 6\text{k}\Omega$

Step 7 of 8

Figure 4

Step 8 of 8

Resistors R_{e3} and R_7 are in parallel.

Replace with $R_{ab} = R_7 \parallel R_{e3}$ between nodes a and b.

$$R_{AB} = \frac{6\text{k} \times 6\text{k}}{6\text{k} + 6\text{k}}$$

$$R_{AB} = \frac{36\text{k}}{12}$$

$$R_{AB} = 3\text{k}\Omega$$

Hence $\boxed{R_{AB} = 3\text{ k}\Omega}$

Step 1 of 6

Figure 1

Step 2 of 6

Resistors R_2 and R_3 are in parallel.

Replace with $R_{e1} = R_3 \parallel R_2$ between nodes d and c.

$$R_{e1} = \frac{6k \times 12k}{6k + 12k}$$

$$R_{e1} = \frac{72k}{18}$$

$$R_{e1} = 4k\Omega$$

Step 3 of 6

Figure 2

Step 4 of 6

Resistors R_{e1} and R_1 are in series.

Replace with $R_{e2} = R_{e1} + R_1$ between nodes a and b.

$$R_{e2} = 2k + 4k$$

$$R_{e2} = 6k\Omega$$

Step 5 of 6

Figure 3

Step 6 of 6

Therefore

$$R_{AB} = R_{e2} \parallel R_5 \parallel R_4$$

$$R_{AB} = \frac{1}{\left(\frac{1}{6k} + \frac{1}{12k} + \frac{1}{4k}\right)}$$

$$R_{AB} = \frac{1}{\left(\frac{2+1+3}{12k}\right)}$$

$$R_{AB} = \frac{12k}{6}$$

$$R_{AB} = 2k\Omega$$

Hence $\boxed{R_{AB} = 2\,k\Omega}$

Step 1 of 4

2.64p

Redrawing the circuit

Step 2 of 4

See $2k\Omega$ is in parallel with a short circuit i.e. $R = 0$

$$R_y = \frac{2k \times 0}{2k + 0} = 0$$

Step 3 of 4

Step 4 of 4

Now the three $6k\Omega$ are in parallel:

$$R_{AB} = \frac{6k \times 6k \times 6k}{6k \times 6k + 6k \times 6k + 6k \times 6k}$$

$$\boxed{R_{AB} = 2k\Omega}$$

Step 1 of 8

Figure 1

Step 2 of 8

Resistors (R_1, R_2) , (R_3, R_4) , (R_5, R_6) and (R_7, R_8) are in series respectively.

Replace with $R_{e1} = R_1 + R_2, R_{e2} = R_3 + R_4, R_{e3} = R_5 + R_6, R_{e4} = R_7 + R_8$ respectively.

$R_{e1} = 2\text{k} + 2\text{k}$

$R_{e1} = 4\text{k}\Omega$

$R_{e2} = 2\text{k} + 2\text{k}$

$R_{e2} = 4\text{k}\Omega$

$R_{e3} = 2\text{k} + 2\text{k}$

$R_{e3} = 4\text{k}\Omega$

$R_{e4} = 2\text{k} + 2\text{k}$

$R_{e4} = 4\text{k}\Omega$

Step 3 of 8

Figure 2

Step 4 of 8

Resistors (R_{e1}, R_9) and (R_{e2}, R_{10}) are in parallel respectively.

Replace with $R_{e6} = R_{e1} \parallel R_9, R_{e5} = R_{e2} \parallel R_{10}$ respectively .

$$R_{e6} = \frac{(4\text{k})(4\text{k})}{4\text{k} + 4\text{k}}$$

$$R_{e6} = \frac{16\text{k}}{8}$$

$R_{e6} = 2\text{k}\Omega$

$$R_{e5} = \frac{(4\text{k})(4\text{k})}{4\text{k} + 4\text{k}}$$

$$R_{e5} = \frac{16\text{k}}{8}$$

$R_{e5} = 2\text{k}\Omega$

Step 5 of 8

Figure 3

Step 6 of 8

Resistors (R_{e5}, R_{e3}) and (R_{e6}, R_{e4}) are in series respectively.

Replace with $R_{e8} = R_{e5} + R_{e3}, R_{e7} = R_{e6} + R_{e4}$ respectively .

$R_{e8} = 2\text{k} + 4\text{k}$

$R_{e8} = 6\text{k}\Omega$

$R_{e7} = 2\text{k} + 4\text{k}$

$R_{e7} = 6\text{k}\Omega$

Step 7 of 8

Figure 4

Step 8 of 8

Therefore

$R_{AB} = R_{e8} \parallel R_{e7}$

$$R_{AB} = \frac{(6\text{k})(6\text{k})}{6\text{k} + 6\text{k}}$$

$$R_{AB} = \frac{36\text{k}}{12}$$

Hence $\boxed{R_{AB} = 3\text{ k}\Omega}$

Step 1 of 3

2.66p

Refer to Figure P2.44 in the textbook for the circuit.

Redraw the circuit by representing loop current in the circuit as shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law to the circuit.

$$-12+\left(1\times10^3\right)I+2V_x+\left(2\times10^3\right)I+\left(3\times10^3\right)I=0$$

$$\left(6\times10^3\right)I+2V_x=12 \text{ ..... (1)}$$

From the circuit, the voltage V_x is,

$$V_x=\left(2\times10^3\right)I \text{ ..... (2)}$$

Substitute $\left(2\times10^3\right)I$ for V_x in equation (1).

$$\left(6\times10^3\right)I+2\left[\left(2\times10^3\right)I\right]=12$$

$$\left(10\times10^3\right)I=12$$

$$I=\frac{12}{10\times10^3}$$

$$=1.2\text{ mA}$$

Substitute 1.2 mA for I in the equation (2).

$$V_x=\left(2\times10^3\right)\left(1.2\times10^{-3}\right)$$

$$=2.4\text{ V}$$

Step 3 of 3

From the circuit, the voltage V_o is,

$$V_o=\left(1\times10^3\right)I+2V_x$$

Substitute 1.2 mA for I and 2.4 V for V_x in the equation.

$$V_o=\left(1\times10^3\right)\left(1.2\times10^{-3}\right)+2\left(2.4\right)$$

$$=1.2+4.8$$

$$=6\text{ V}$$

Therefore, the value of V_o is $\boxed{6\text{ V}}$.

The power absorbed by $2\text{ k}\Omega$ resistor is,

$$P_{2\text{ k}\Omega}=I^2\left(2\times10^3\right)$$

$$=\left(1.2\times10^{-3}\right)^2\left(2\times10^3\right)$$

$$=2.88\text{ mW}$$

Therefore, the power absorbed by $2\text{ k}\Omega$ resistor is $\boxed{2.88\text{ mW}}$.

Step 1 of 5

2.67p

Refer to circuit in Figure P2.50 in the textbook.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Let the current I flowing in the circuit through the node 'a' as shown in Figure 1.

Reduce the circuit by calculating the equivalent resistance and equivalent current values.

Calculate the equivalent resistance R_{eq} of Figure 1 having resistors R_1, R_2, R_3 connected in parallel.

$$\begin{aligned} R_{eq} &= \left(\frac{1}{4\text{ k}\Omega}+\frac{1}{1\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}\right)^{-1} \\ &= \left(0.25\text{ m}\Omega+1\text{ m}\Omega+0.5\text{ m}\Omega\right)^{-1} \\ &= \left(1.75\times10^{-3}\right)^{-1} \\ &= 571\ \Omega \end{aligned}$$

Calculate the equivalent current source I_{eq} of Figure 1 as follows:

$$\begin{aligned} I_{eq} &= -7\text{ mA}+3\text{ mA} \\ &= -4\text{ mA} \end{aligned}$$

Step 3 of 5

The circuit of Figure 1 is reduced as shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the value of current I by using current division rule.

$$\begin{aligned} I &= \left(\frac{R_{eq}}{R_{eq}+R_4}\right)\left(I_{eq}\right) \\ &= \left(\frac{571}{571+\left(5\times10^3\right)}\right)\left(-4\times10^{-3}\right) \\ &= \left(0.1025\right)\left(-4\times10^{-3}\right) \\ &= -0.41\text{ mA} \end{aligned}$$

Step 5 of 5

Apply Kirchhoff's current law at node 'a' in Figure 1 and calculate the value of current I_A.

$$3\text{ mA}+I_A = I$$

$$\begin{aligned} I_A &= I-3\text{ mA} \\ &= -0.41-3\text{ mA} \\ &= -3.41\text{ mA} \end{aligned}$$

Therefore the value of current I_A is $\boxed{-3.41\text{ mA}}$.

Step 1 of 4

2.68p

(a)

Consider the circuit shown in Figure E2.1 (a) in the text book, having voltage $V = 12\ \text{V}$ and resistance, $R = 40\ \text{k}\Omega$.

Calculate the current (I) by using equation 2.1 in the text book as follows:

$$\begin{aligned} V &= IR \\ I &= \frac{V}{R} \\ &= \frac{12\ \text{V}}{40\ \text{k}\Omega} \\ &= 0.3\ \text{mA} \end{aligned}$$

Therefore, the value of current, I is $\boxed{0.3\ \text{mA}}$.

Step 2 of 4

Calculate the power (P) absorbed by resistor by using equation 2.2 given in the text book as follows:

$$\begin{aligned} P &= VI \\ &= (12\ \text{V})(0.3\ \text{mA}) \\ &= (12)(0.3\times10^{-3}) \\ &= 3.6\ \text{mW} \end{aligned}$$

Therefore, the value of power absorbed by the resistor is $\boxed{3.6\ \text{mW}}$.

Step 3 of 4

(b)

Consider the circuit shown in Figure E2.1 (b) in the text book, having current $I = 0.6\ \text{mA}$ and resistance, $R = 6\ \text{k}\Omega$.

Calculate the value of voltage (V_s) across the current source by using equation 2.1 in the text book as follows:

$$\begin{aligned} V &= IR \\ V_s &= (0.6\ \text{mA})(6\ \text{k}\Omega) \\ &= (0.6\times10^{-3})(6\times10^{3}) \\ &= 3.6\ \text{V} \end{aligned}$$

Therefore, the value of voltage is $\boxed{3.6\ \text{V}}$.

Step 4 of 4

Calculate the value of power (P) supplied by the source by using equation 2.2 given in the text book as follows:

$$\begin{aligned} P &= V_s I \\ &= (3.6\ \text{V})(0.6\ \text{mA}) \\ &= (3.6)(0.6\times10^{-3}) \\ &= 2.16\ \text{mW} \end{aligned}$$

Therefore, the value of power supplied by the source is $\boxed{2.16\ \text{mW}}$.

2.69p

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

Ask an expert

2.70p

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

Ask an expert

Step 1 of 6

2.73p

Consider the circuit shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the equivalent resistance R_a of resistors $6\ \text{k}\Omega$ and $(8\ \text{k}\Omega + 4\ \text{k}\Omega)$ connected in parallel.

$$\begin{aligned} R_a &= 6\ \text{k}\Omega \,\|\, (8\ \text{k}\Omega + 4\ \text{k}\Omega) \\ &= \frac{(6\ \text{k}\Omega)(8\ \text{k}\Omega + 4\ \text{k}\Omega)}{6\ \text{k}\Omega + 8\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= \frac{(6\times10^3)(12\times10^3)}{18\times10^3} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 3 of 6

Now the circuit is reduced as shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the current I flowing in the circuit of Figure 2 having voltage $V = 12\ \text{V}$ and resistance $R = 2\ \text{k}\Omega + R_a$.

$$\begin{aligned} I &= \frac{V}{R} \\ &= \frac{12\ \text{V}}{2\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 2\ \text{mA} \end{aligned}$$

Step 5 of 6

Now calculate the value of current I_1 in Figure 1 by using current division formula.

$$\begin{aligned} I_1 &= \left(\frac{R_2 + R_3}{R_1 + R_2 + R_3}\right) I \\ &= \left(\frac{(8\ \text{k}\Omega + 4\ \text{k}\Omega)}{(6\ \text{k}\Omega) + (8\ \text{k}\Omega + 4\ \text{k}\Omega)}\right)(2\ \text{mA}) \\ &= 1.33\ \text{mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{1.33\ \text{mA}}$.

Step 6 of 6

Apply Kirchhoff's current law to node '*a*' in Figure **1** and calculate the value of current I_2.

$$\begin{aligned} I &= I_1 + I_2 \\ I_2 &= I - I_1 \\ &= 2\ \text{mA} - 1.33\ \text{mA} \\ &= 0.667\ \text{mA} \end{aligned}$$

Calculate the value of voltage V_o in Figure 1 having current I_2 and resistance $R_3 = 4\ \text{k}\Omega$.

$$\begin{aligned} V_o &= I_2 R_3 \\ &= (0.667\ \text{mA})(4\ \text{k}\Omega) \\ &= (0.667\times10^{-3})(4\times10^3) \\ &= 2.67\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o is $\boxed{2.67\ \text{V}}$.

Step 1 of 3

2.74p

Consider the circuit shown in Figure P2.68 in the text book.

Calculate the value of current I_1 having voltage $V = 6\ \text{V}$ and resistance $R_1 = 12\ \text{k}\Omega$ by using Ohm's law.

$$\begin{aligned} I_1 &= \frac{V}{R_1} \\ &= \frac{6\ \text{V}}{12\ \text{k}\Omega} \\ &= \frac{6}{12\times10^3} \\ &= 0.5\ \text{mA} \end{aligned}$$

Therefore, the value of current I_1 is $\boxed{0.5\ \text{mA}}$.

Step 2 of 3

Let I_2 be the current flowing through $2\ \text{k}\Omega$ and $4\ \text{k}\Omega$ resistors.

Calculate the value of current I_2 having voltage $V = 6\ \text{V}$ and resistance $R_1 = 2\ \text{k}\Omega + 4\ \text{k}\Omega$ by using Ohm's law.

$$\begin{aligned} I_2 &= \frac{V}{R_2} \\ &= \frac{6\ \text{V}}{2\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= \frac{6}{6\times10^3} \\ &= 1\ \text{mA} \end{aligned}$$

Step 3 of 3

Calculate the value of voltage V_o across $4\ \text{k}\Omega$ resistor.

$$\begin{aligned} V_0 &= I_2(4\ \text{k}\Omega) \\ &= (1\ \text{mA})(4\ \text{k}\Omega) \\ &= (1\times10^{-3})(4\times10^3) \\ &= 4\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o is $\boxed{4\ \text{V}}$.

Step 1 of 5

2.76p

Consider the circuit given in Figure 1.

Figure 1

Step 2 of 5

Calculate the equivalent R_a of resistors $R_1 = 12\ \text{k}\Omega$ and $R_2 = 12\ \text{k}\Omega$ connected in parallel.

$$\begin{aligned} R_a &= R_1 \parallel R_2 \\ &= \frac{(R_1)(R_2)}{R_1 + R_2} \\ &= \frac{(12\ \text{k}\Omega)(12\ \text{k}\Omega)}{12\ \text{k}\Omega + 12\ \text{k}\Omega} \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 3 of 5

The resistor R_a is in series with R_3.

Calculate the equivalent R_b of resistors $R_a = 6\ \text{k}\Omega$ and $R_3 = 6\ \text{k}\Omega$ connected in series.

$$\begin{aligned} R_b &= R_a + R_3 \\ &= 6\ \text{k}\Omega + 6\ \text{k}\Omega \\ &= 12\ \text{k}\Omega \end{aligned}$$

Step 4 of 5

Now the circuit is reduced as shown in Figure 2.

Figure 2

Step 5 of 5

Calculate the current I_o in Figure 2 by using current division rule.

$$\begin{aligned} I_o &= \left(\frac{R_b}{R_4 + R_b}\right) I \\ &= \left(\frac{12\ \text{k}\Omega}{12\ \text{k}\Omega + 12\ \text{k}\Omega}\right)(12\ \text{mA}) \\ &= \left(\frac{12 \times 10^3}{24 \times 10^3}\right)(12 \times 10^{-3}) \\ &= 6\ \text{mA} \end{aligned}$$

Therefore, the value of current I_o in the network is $\boxed{6\ \text{mA}}$.

Step 1 of 6

Refer to Figure P2.78 in the textbook.

In Figure P2.78, the series combination of $6\ \Omega$ and $4\ \Omega$ resistors connected in parallel with $10\ \Omega$ resistor. Calculate their equivalent resistance.

$$\begin{aligned} R_{eq1} &= (6+4)\|(10) \\ &= (10)\|(10) \\ &= \frac{(10)(10)}{10+10} \\ &= 5\ \Omega \end{aligned}$$

Draw the reduced diagram as shown in Figure 1.

Figure 1

Step 2 of 6

In Figure 1, the series combination of $3\ \Omega$ and $5\ \Omega$ resistors connected in parallel with $8\ \Omega$ resistor. Calculate their equivalent resistance.

$$\begin{aligned} R_{eq2} &= (3+5)\|(8) \\ &= (8)\|(8) \\ &= \frac{(8)(8)}{8+8} \\ &= 4\ \Omega \end{aligned}$$

Draw the reduced circuit diagram of Figure 1.

Figure 2

Step 3 of 6

Calculate the current flowing in the circuit shown in Figure 2.

$$\begin{aligned} i_1 &= \frac{24}{5+4+3} \\ &= \frac{24}{12} \\ &= 2\ \text{A} \end{aligned}$$

Calculate the current i_2 in Figure 1 using current division rule.

$$\begin{aligned} i_2 &= i_1\left(\frac{8}{8+5+3}\right) \\ &= (2)\left(\frac{8}{16}\right) \\ &= 1\ \text{A} \end{aligned}$$

Step 4 of 6

Draw the Figure P2.78 in the textbook with current notations.

Figure 3

Step 5 of 6

Calculate the current, i_5 using current division rule.

$$\begin{aligned} i_5 &= i_2\left(\frac{10}{10+6+4}\right)i_5 \\ &= (1)\left(\frac{10}{20}\right) \\ &= 0.5\ \text{A} \end{aligned}$$

Step 6 of 6

Calculate the voltage V_1 in Figure 3.

$$\begin{aligned} V_1 &= 4i_5 + 3i_2 \\ &= 4(0.5) + 3(1) \\ &= 5\ \text{V} \end{aligned}$$

Therefore, the voltage, V_1 is $\boxed{5\ \text{V}}$.

Step 1 of 5

2.79p

Step 2 of 5

Given 5A current source supplies 50W

Hence

$P = VI$

$50 = V_{5A}(5)$

$V_{5A} = 10\text{V}$

Since this current flows through 4Ω

$V_{4\Omega} = (4)(5)$

$V_{4\Omega} = 20\text{V}$

By applying KVL to DCD loop we can write

$-V_{CD} - V_{4\Omega} + V_{5A} = 0$

$V_{CD} = -V_{4\Omega} + V_{5A}$

$V_{CD} = -20 + 10$

$V_{CD} = -10\text{V}$

Step 3 of 5

Since 5V source and 2Ω are in parallel, the voltage across 2Ω

$V_{AB} = 5\text{V}$

By applying KVL to loop ACDBA

$-V_{AB} + V_{AC} + V_{CD} = 0$

$V_{AC} = V_{AB} - V_{CD}$

$V_{AC} = 5 - (-10)$

$V_{AC} = 15\text{V}$

Step 4 of 5

Applying KCL at node C

$\frac{V_{CA}}{4} + I + \frac{V_{CD}}{2} - 5 = 0$

$I = 5 - \frac{V_{CD}}{2} - \frac{V_{CA}}{4}$

$I = 5 - \left(\frac{-10}{2}\right) - \left(\frac{-15}{4}\right)$

$I = 10 + \frac{15}{4}$

$I = \frac{55}{4}\text{A}$

Step 5 of 5

Therefore voltage across 2Ω is

$V_{2\Omega} = (2\Omega)(I)$

$V_{2\Omega} = 2 \times \frac{55}{4}$

$V_{2\Omega} = \frac{55}{2}\text{V}$

Since V_{AC} and the elements 2Ω, V_x are parallel

$V_{AC} - V_x + V_{2\Omega} = 0$

$V_x = V_{AC} + V_{2\Omega}$

$V_x = 15 + \frac{55}{2}$

$\boxed{V_x = \frac{85}{2}\text{V}}$

Step 1 of 8

Consider the circuit given in Figure 1.

Step 2 of 8

Figure 1

Step 3 of 8

Calculate the equivalent resistance R_a of resistors $(R_1 + R_2) = (4\ \text{k}\Omega + 12\ \text{k}\Omega)$ and $R_3 = 16\ \text{k}\Omega$ connected in parallel.

$$\begin{aligned} R_a &= (R_1 + R_2) \parallel R_3 \\ &= \frac{(R_1 + R_2)(R_3)}{R_1 + R_2 + R_3} \\ &= \frac{(4\ \text{k}\Omega + 12\ \text{k}\Omega)(16\ \text{k}\Omega)}{4\ \text{k}\Omega + 12\ \text{k}\Omega + 16\ \text{k}\Omega} \\ &= 8\ \text{k}\Omega \end{aligned}$$

Step 4 of 8

Now the circuit is reduced as shown in Figure 2.

Figure 2

Step 5 of 8

Calculate the equivalent resistance R_b of resistors $(R_a + R_4)$ and $R_6 = 6\ \text{k}\Omega$ connected in parallel in Figure 2.

$$\begin{aligned} R_b &= (R_a + R_4) \parallel R_6 \\ &= \frac{(R_a + R_4)(R_6)}{R_a + R_4 + R_6} \\ &= \frac{(8\ \text{k}\Omega + 4\ \text{k}\Omega)(6\ \text{k}\Omega)}{8\ \text{k}\Omega + 4\ \text{k}\Omega + 6\ \text{k}\Omega} \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 6 of 8

Now the circuit is reduced as shown in Figure 3.

Figure 3

Step 7 of 8

Calculate the value of current I flowing in the circuit in Figure 3.

$$\begin{aligned} I &= \frac{-V}{R_b + R_5} \\ &= \frac{-12\ \text{V}}{4\ \text{k}\Omega + 2\ \text{k}\Omega} \\ &= \frac{-12\ \text{V}}{6\ \text{k}\Omega} \\ &= -2\ \text{mA} \end{aligned}$$

Step 8 of 8

Calculate the value of current I_o by using current division formula $I_a = \left(\frac{R_x}{R_x + R_y}\right) I$ in Figure 2.

Substitute $R_x = R_a + R_4$, $R_y = R_6$, $I = -2\ \text{mA}$ and solve for I_o.

$$\begin{aligned} I_o &= \left(\frac{R_a + R_4}{R_a + R_4 + R_6}\right) I \\ &= \left(\frac{8\ \text{k}\Omega + 4\ \text{k}\Omega}{8\ \text{k}\Omega + 4\ \text{k}\Omega + 6\ \text{k}\Omega}\right)(-2\text{mA}) \\ &= \left(\frac{12\ \text{k}\Omega}{18\ \text{k}\Omega}\right)(-2\text{mA}) \\ &= -1.33\ \text{mA} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{-1.33\ \text{mA}}$.

Step 1 of 5

2.82p

Consider the circuit shown in Figure P2.73 in the text book.

Calculate the value of equivalent current source I by summing up algebraically.

$$\begin{aligned} I &= -30\text{ mA} + 18\text{ mA} \\ &= -12\text{ mA} \end{aligned}$$

Step 2 of 5

The current sources in the circuit are reduced as shown in Figure1.

Step 3 of 5

Figure 1

Step 4 of 5

Calculate the value of current I_o by using current division formula $I_o = \left(\frac{R_x}{R_x + R_y}\right) I$ in Figure 1.

Substitute $R_x = R_1$, $R_y = R_2 + R_3$, $I = -12\text{ mA}$ and solve for I_o in Figure 1.

$$\begin{aligned} I_o &= \left(\frac{R_1}{R_1 + (R_2 + R_3)}\right) I \\ &= \left(\frac{3\text{ k}\Omega}{3\text{ k}\Omega + (5\text{ k}\Omega + 1\text{ k}\Omega)}\right)(-12\text{ mA}) \\ &= \left(\frac{3\text{ k}\Omega}{9\text{ k}\Omega}\right)(-12\text{ mA}) \\ &= -4\text{ mA} \end{aligned}$$

Step 5 of 5

Calculate the value of voltage V_o by using Ohm's law $V = IR$ in Figure 1.

Substitute $V = V_o$, $I = I_o$, $R = R_3$ and solve for V_o .

$$\begin{aligned} V_o &= I_o R_3 \\ &= (-4\text{ mA})(1\text{ k}\Omega) \\ &= -4\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o is $\boxed{-4\text{ V}}$.

Step 1 of 4

2.84p

Refer to the resistive circuit shown in Figure P2.84 in the textbook.

The middle part of the circuit forms a bridge circuit. Draw the circuit diagram designating with bridge circuit.

Figure 1

Step 2 of 4

Since all the values of all resistors in the bridge are same, the bridge circuit becomes balanced. At this condition, the potential at point *A* is equal to the potential at point *B*. Hence, no current is flowing through $6\,\Omega$ resistor connected between the points *A* and *B*.

So, $6\,\Omega$ resistor can be taken out from the circuit.

Re-draw the modified circuit diagram.

Figure 2

Step 3 of 4

In the right side of the circuit shown in Figure 2, two $6\,\Omega$ resistors are connected in series and this series combination is connected in parallel with another $6\,\Omega$ resistor. Determine its equivalent resistance.

$$\Rightarrow (6+6)\|6$$
$$\Rightarrow 12\|6$$
$$\Rightarrow \frac{(12)(6)}{(12)+(6)}$$
$$\Rightarrow 4\,\Omega$$

Re-draw the modified circuit diagram.

Figure 3

Step 4 of 4

Apply current division principle to calculate the value of I_o .

$$I_o = \left(\frac{4}{6+6+4}\right)I_s$$
$$= \left(\frac{4}{16}\right)(6)$$
$$= 1.5\text{ A}$$

Therefore, the value of current I_o in the circuit is $\boxed{1.5\text{ A}}$.

Step 1 of 4

2.90p

Refer to the circuit diagram shown in Figure P2.90 in the textbook.

In the left side of the circuit, the two resistors $7\ \text{k}\Omega$ and $1\ \text{k}\Omega$ are connected in series. Calculate its equivalent resistance.

$$\Rightarrow 7\ \text{k}\Omega + 1\ \text{k}\Omega$$
$$\Rightarrow 8\ \text{k}\Omega$$

Similarly, in the right side of the circuit, the two resistors $2\ \text{k}\Omega$ and $5\ \text{k}\Omega$ are connected in series. Calculate its equivalent resistance.

$$\Rightarrow 2\ \text{k}\Omega + 5\ \text{k}\Omega$$
$$\Rightarrow 7\ \text{k}\Omega$$

Draw the modified circuit diagram.

Figure 1

Step 2 of 4

In the Figure 1, two $8\ \text{k}\Omega$ resistors are connected in parallel. Calculate its equivalent resistance.

$$\Rightarrow (8\ \text{k}\Omega) \| (8\ \text{k}\Omega)$$
$$\Rightarrow \frac{(8\ \text{k}\Omega)(8\ \text{k}\Omega)}{(8\ \text{k}\Omega)+(8\ \text{k}\Omega)}$$
$$\Rightarrow 4\ \text{k}\Omega$$

It is given that, the voltage across $4\ \text{k}\Omega$ resistor is, $-14\ \text{V}$. Find the current flowing through it.

$$\begin{aligned} I_1 &= \frac{V_1}{4\times10^3} \\ &= \frac{-14}{4\times10^3} \\ &= -3.5\ \text{mA} \end{aligned}$$

Step 3 of 4

Draw the modified circuit diagram.

Figure 2

Step 4 of 4

Calculate the voltage drop, V_2 .

$$\begin{aligned} V_2 &= (4\times10^3)I_1 \\ &= (4\times10^3)(-3.5\times10^{-3}) \\ &= -14\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law around the left side of the circuit.

$$V_2 + V_1 + V_S = 0$$

$$\begin{aligned} V_S &= -V_1 - V_2 \\ &= -(-14) - (-14) \\ &= 14 + 14 \\ &= 28\ \text{V} \end{aligned}$$

Therefore, the value of source voltage, V_S is $\boxed{28\ \text{V}}$.

Step 1 of 6

2.92p

Refer to Figure P2.92 in the text book.

Consider nodal voltages as V_1, V_2 and V_3 for nodes 1, 2 and 3 respectively as shown in Figure 1.

Figure 1

Step 2 of 6

From Figure 1, the value of voltage V_3 is,

$$V_3 = 4\text{ V}$$

The difference between nodal voltages of node 3 and node 1 is,

$$V_3 - V_1 = 12$$

Substitute 4 V for V_3 in the equation.

$$4 - V_1 = 12$$
$$V_1 = -8\text{ V}$$

Step 3 of 6

Draw the modified circuit of Figure 1 with direction of currents I_1 and I_2.

Figure 2

Step 4 of 6

Calculate the value of current I_1 in Figure 2.

$$I_1 = \frac{0 - V_1}{2}$$

Substitute -8 V for V_1 in the equation.

$$I_1 = \frac{0-(-8)}{2}$$
$$= 4\text{ A}$$

Step 5 of 6

Calculate the value of current I_2 in Figure 2.

$$I_2 = \frac{V_3 - 0}{2}$$

Substitute 4 V for V_3 in the equation.

$$I_2 = \frac{4-0}{2}$$
$$= 2\text{ A}$$

Step 6 of 6

Apply Kirchhoff's Current Law at ground node in Figure 2.

$$I_2 = I_1 + I_A$$

Substitute 4 A for I_1 and 2 A and I_2 in the equation.

$$2 = 4 + I_A$$
$$I_A = -2\text{ A}$$

Thus, the value of current, I_A is $\boxed{-2\text{ A}}$.

Step 1 of 5

2.93p

Consider the Figure P2.87 from the text book.

Assume the value of the unknown resistor to be R .

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Calculate the value of current I_1 .

$$I_1 = \frac{5}{R}\ \text{A}$$

Therefore, the value of the current I_1 is $\frac{5}{R}$ A .

Step 3 of 5

Calculate the value of the equivalent resistance R_{eq} .

$$\begin{aligned} R_{eq} &= R + (6\,\text{k} \| 3\,\text{k}) \\ &= R + \frac{(6\,\text{k})(3\,\text{k})}{6\,\text{k} + 3\,\text{k}} \\ &= R + \frac{(6\,\text{k})(3\,\text{k})}{9\,\text{k}} \\ &= R + 2\,\text{k} \end{aligned}$$

Therefore, the value of the equivalent resistance is $R + 2\ \text{k}\Omega$.

Step 4 of 5

Consider the simplified circuit diagram shown in Figure 2.

Figure 2

Step 5 of 5

Consider the expression for the current I_1 using current division rule.

$$I_1 = I_s\left(\frac{4\,\text{k}}{4\,\text{k} + R + 2\,\text{k}}\right)$$

Substitute $\frac{5}{R}$ for I_1 .

$$\begin{aligned} \frac{5}{R} &= I_s\left(\frac{4\,\text{k}}{4\,\text{k} + R + 2\,\text{k}}\right) \\ \frac{5}{R} &= I_s\left(\frac{4\,\text{k}}{6\,\text{k} + R}\right) \\ I_s &= \left(\frac{6\,\text{k} + R}{4\,\text{k}}\right)\left(\frac{5}{R}\right) \\ I_s &= \frac{30\,\text{k} + 5R}{(4\,\text{k})R} \\ I_s &= \frac{30\,\text{k}}{(4\,\text{k})R} + \frac{5R}{(4\,\text{k})R} \\ &= \left(\frac{7.5}{R} + 1.25\,\text{m}\right)\text{A} \end{aligned}$$

Therefore, the value of the current I_s is $\boxed{\left(\frac{7.5}{R} + 1.25\,\text{m}\right)\text{A}}$.

Step 1 of 6

2.94p

Consider the circuit shown in Figure P2.89 in the text book.

The current direction flowing in each branch of the network is shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the current I_o, by using the Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_o$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for current I_o.

$$\begin{aligned} I_o &= \frac{V_o}{R} \\ &= \frac{4\ \text{V}}{1\ \text{k}\Omega} \\ &= 4\ \text{mA} \end{aligned}$$

Step 3 of 6

Apply Kirchhoff's current law at node '*a*' and solve for I_1.

$$I_o + I_1 = 2\ \text{m}$$

$$\begin{aligned} I_1 &= 2\text{m} - I_o \\ &= 2\ \text{m} - 4\ \text{mA} \\ &= -2\ \text{mA} \end{aligned}$$

Step 4 of 6

Apply Kirchhoff's voltage law to the right hand side loop in Figure 1 and calculate the value of current I_2.

$$12\ \text{k}I_2 - 4 - 2\ \text{k}I_o + 3\ \text{k}I_1 - 6 = 0$$

$$12\ \text{k}I_2 - 10 - (2\ \text{k})(4\ \text{mA}) + (3\ \text{k})(-2\ \text{mA}) = 0$$

$$12\ \text{k}I_2 = 10 + 8 + 6$$

$$I_2 = 2\text{mA}$$

Step 5 of 6

Apply Kirchhoff's current law at node '*b*' and solve for I_s.

$$I_s + I_1 = I_2$$

$$\begin{aligned} I_s &= I_2 - I_1 \\ &= 2\ \text{mA} - (-2\ \text{mA}) \\ &= 4\text{mA} \end{aligned}$$

Step 6 of 6

Apply Kirchhoff's voltage law to the left hand side loop in Figure 1 and solve for voltage V_S.

$$-V_S + 12\ \text{k}I_2 + 3\ \text{k}I_2 = 0$$

$$\begin{aligned} V_S &= (12\ \text{k})(2\ \text{mA}) + (3\ \text{k})(4\ \text{mA}) \\ &= 24 + 12 \\ &= 36\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_S is $\boxed{36\ \text{V}}$.

Step 1 of 3

2.95p

Refer to circuit shown in Figure P2.84 in the text book.

Calculate the value of voltage V_I by using following formula.

$$P = V_I I$$

Substitute $0\ \mathrm{W}$ for P, $3\ \mathrm{A}$ for I in the equation to solve for V_I.

$$0 = V_I(3\ \mathrm{A})$$

$$\begin{aligned} V_I &= \frac{0}{3\ \mathrm{A}} \\ &= 0\ \mathrm{V} \end{aligned}$$

Step 2 of 3

Consider the circuit shown in Figure 1.

Figure 1

Step 3 of 3

Apply Kirchhoff's current law at node 'a' in Figure **1** and calculate the value of V_S.

$$\frac{18}{2+3} + 3 + \frac{V_S}{8+6} = 0$$

$$\frac{18}{5} + 3 + \frac{V_S}{14} = 0$$

$$\frac{V_S}{14} = -6.6$$

$$V_S = -92.4\ \mathrm{V}$$

Therefore, the value of source voltage V_S is $\boxed{-92.4\ \mathrm{V}}$.

Step 1 of 5

2.96p

Refer to Figure P2.85 shown in the text book, let the currents flowing in each branch is as shown in Figure 1.

Figure 1

Step 2 of 5

The $V_o = 6\ \text{V}$ voltage is same across any parallel branch in the circuit.

Calculate the value of current I_o by using Ohm's law.

$$\begin{aligned} I_o &= \frac{V_o}{R} \\ &= \frac{6\ \text{V}}{2\ \text{k}\Omega} \\ &= 3\ \text{mA} \end{aligned}$$

Step 3 of 5

Calculate the value of current I_1 by using Ohm's law.

$$\begin{aligned} I_1 &= \frac{V}{R} \\ &= \frac{6\ \text{V}}{1\ \text{k}\Omega + 2\ \text{k}\Omega} \\ &= \frac{6\ \text{V}}{3\ \text{k}\Omega} \\ &= 2\ \text{mA} \end{aligned}$$

Step 4 of 5

Apply Kirchhoff's current law at node '*a*' and calculate the value of current I_2 from Figure 1.

$$\begin{aligned} I_2 &= I_o + I_1 \\ &= 3\ \text{mA} + 2\ \text{mA} \\ &= 5\ \text{mA} \end{aligned}$$

Apply Kirchhoff's voltage law to the middle loop in Figure 1 formed by V_3, $3\ \text{k}I_2$, V_o and solve for V_3.

$$-V_3 + 3\ \text{k}I_2 + V_o = 0$$

$$\begin{aligned} V_3 &= (3\ \text{k})(5\ \text{mA}) + 6\ \text{V} \\ &= 15\ \text{V} + 6\ \text{V} \\ &= 21\ \text{V} \end{aligned}$$

Step 5 of 5

Calculate the value of current I_3 by using Ohm's law.

$$\begin{aligned} I_3 &= \frac{V_3}{R} \\ &= \frac{21\ \text{V}}{7\ \text{k}\Omega} \\ &= 3\ \text{mA} \end{aligned}$$

Apply Kirchhoff's current law at node '*b*' in Figure 1 and solve for I_S.

$$\begin{aligned} I_S &= I_2 + I_3 \\ &= 5\ \text{mA} + 3\ \text{mA} \\ &= 8\ \text{mA} \end{aligned}$$

Therefore, the value of current I_S is $\boxed{8\ \text{mA}}$.

Step 1 of 4

2.97p

Refer to circuit diagram in Figure P2.86 in the textbook.

Consider the circuit shown in Figure 1 that represents the current direction and voltages across resistors.

Step 2 of 4

Figure 1

Step 3 of 4

The value of V_a is $0\ \text{V}$ and so by using Ohm's law the value of I_a is also $0\ \text{A}$.

Apply Kirchhoff's current law at node '*a*' in Figure 1.

$$\begin{aligned} I_1 &= I_a + I_2 \\ &= 0 + I_2 \\ &= I_2 \end{aligned}$$

Calculate the current I_1 by using Ohm's law.

$$\begin{aligned} I_1 &= \frac{V}{R} \\ &= \frac{V_1}{2} \end{aligned}$$

Step 4 of 4

The voltage across $4\ \Omega$ is V_3 which is equals to $8\ \text{V}$ and voltage V_4 is equals to $(8\ \text{V} - V_1)$ from Figure 1.

Calculate the current I_2 by applying Kirchhoff's current law at node '*b*' and solve for I_2 .

$$\begin{aligned} I_2 &= \frac{V_3}{4} + \frac{V_4}{2} \\ &= \frac{8\ \text{V}}{4} + \frac{8\ \text{V} - V_1}{2} \\ &= 2 + 4 - \frac{V_1}{2} \\ &= 6 - \frac{V_1}{2} \end{aligned}$$

Substitute I_2 for I_1 in the equaiton and solve for V_1 .

$$\frac{V_1}{2} = 6 - \frac{V_1}{2}$$

$$\frac{V_1}{2} + \frac{V_1}{2} = 6$$

$$\frac{2V_1}{2} = 6$$

$$V_1 = 6\ \text{V}$$

Therefore, the value of voltage V_1 is $\boxed{6\ \text{V}}$.

2.99p

Figure 1

Step 2 of 11

Given Power supplied by the 2 A source is,

$P_{sup2} = 40$ W ....(1)

Also from figure 1,

$V_{ad} = 5$ V ....(2)

Hence ,

$P_{sup2} = (V_{cb})(2)$

$40 = V_{cb}(2)$

$V_{cb} = 20$ V ....(3)

Step 3 of 11

Let current in different branches be I_1, I_2, I_3, I_4, I_5 as shown in figure 1.

By Ohm's Law,

$V_{ab} = (2)(5)$

$V_{ab} = 10$ V ....(4)

Step 4 of 11

By KVL around loop $abca$,

$V_{ab} + V_{bc} + V_{ca} = 0$

$-V_{ca} = 10 - 20$ ....(from (3) and (4))

$V_{ac} = -10$ V ....(5)

Step 5 of 11

By Ohm's Law,

$V_{ac} = I_3(10)$

$-10 = I_3(10)$ ....(from (5))

$I_3 = -1$ A ....(6)

Step 6 of 11

By KVL around loop $acda$,

$V_{ac} + V_{cd} + V_{da} = 0$

$-10 + V_{cd} - 5 = 0$ ....(from (2) and (5))

$V_{cd} = 15$ V ....(7)

Step 7 of 11

By Ohm's Law,

$V_{cd} = I_5(5)$

$15 = I_5(5)$ ....(from (7))

$I_5 = 3$ A ....(8)

Step 8 of 11

By KCL at node c ,

$-I_4 - I_5 + I_3 + 2 = 0$

$I_4 = -I_5 + I_3 + 2$

$I_4 = -3 - 1 + 2$ ....(from (6) and (8))

$I_4 = -2$ A ....(9)

Step 9 of 11

By KVL around loop $cedc$,

$V_{ce} + V_{ed} + V_{dc} = 0$

$I_4(5) + V_S - (15) = 0$ ....(from (7))

$(-2)(5) + V_S - 15 = 0$ ....(from (9))

$V_S = 25$ V ....(8)

Hence $\boxed{V_S = 25 \text{ V}}$

Step 10 of 11

By KCL at node a ,

$-I_1 - I_2 - I_3 - 2 = 0$

$I_1 = -I_2 - I_3 - 2$

$I_1 = -\frac{V_{ad}}{5} - (-1) - 2$

$I_1 = -\frac{5}{5} + 1 - 2$ ....(from (6) and (2))

$I_1 = -2$ A ....(10)

Step 11 of 11

Therefore the power absorbed by the 5 V source is,

$P_{abs5} = (5)I_1$

$P_{abs5} = 5(-2)$ ....(from (10))

$P_{abs5} = -10$ W

Hence $\boxed{P_{abs5} = -10 \text{ W}}$

Step 1 of 6

Given circuit,

Step 2 of 6

Given,

40V source absorbing power is 80W

$P = VI$

$I = \frac{P}{V}$

$I = \frac{80}{40}$

$I = 2\text{A}$

Step 3 of 6

Therefore the circuit will be,

Step 4 of 6

The KCL equation at node V_1 is

$\frac{V_1}{30} + \frac{V_1 - V_x}{6} + \frac{V_1 - V_2}{5} + 3 = 0$

$\frac{V_1}{30} + \frac{V_1}{6} + \frac{V_1}{5} - \frac{V_x}{6} - \frac{V_2}{5} + 3 = 0$ ..... (1)

The KCL equation at node V_2 is

$\frac{V_2 - V_1}{5} + \frac{V_2 - 40}{10} - 3 - 5 = 0$

$-\frac{V_1}{5} + \frac{V_2}{5} + \frac{V_2}{10} = 8 + 4$

$-\frac{V_1}{5} + \frac{V_2}{5} + \frac{V_2}{10} = 12$ ..... (2)

Step 5 of 6

From the circuit,

$\frac{V_2 - 40}{10} = I$

$\frac{V_2 - 40}{10} = 2$

$V_2 - 40 = 20$

$V_2 = 60\text{V}$

Substitute V_2 value in equation (2)

$-\frac{V_1}{5} + \frac{60}{5} + \frac{60}{10} = 12$

$-\frac{V_1}{5} + 12 + 6 = 12$

$-\frac{V_1}{5} = -6$

$V_1 = 30\text{V}$

Step 6 of 6

Substitute V_1 and V_2 values in equation (1)

$\frac{30}{30} + \frac{30}{6} + \frac{30}{5} - \frac{V_x}{6} - \frac{60}{5} + 3 = 0$

$1 + 5 + 6 - \frac{V_x}{6} - 12 + 3 = 0$

$\frac{V_x}{6} = 3$

$\boxed{V_x = 18\text{V}}$

Step 1 of 8

Consider the circuit shown in Figure P2.94 in the text book.

The nodes and current flowing directions in each branch of considered circuit are shown in Figure 1.

Step 2 of 8

Figure 1

Step 3 of 8

Calculate the value of current I_1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $V = 4\ \text{V}$, $I = I_1$, $R = 2\ \Omega$ from Figure 1 and solve for I_1.

$$\begin{aligned} I_1 &= \frac{V}{R} \\ &= \frac{4\ \text{V}}{2\ \Omega} \\ &= 2\ \text{A} \end{aligned}$$

Step 4 of 8

Apply Kirchhoff's voltage law to the right hand side loop in Figure 1 formed by V_2, $6\ \text{V}$ source, $4\ \text{V}$, V_1 and solve for I_2.

$$\begin{aligned} V_2 + 6 - 4 - V_1 &= 0 \\ 3I_2 + 2 - 4I_1 &= 0 \\ 3I_2 &= (4)(2\ \text{A}) - 2 \\ I_2 &= 2\ \text{A} \end{aligned}$$

Step 5 of 8

Apply Kirchhoff's current law at node '*a*' in figure 1 and solve for current I_3.

$$\begin{aligned} I_3 &= I_2 + 2\ \text{A} \\ &= 2\ \text{A} + 2\ \text{A} \\ &= 4\ \text{A} \end{aligned}$$

Step 6 of 8

From figure 1 the voltage V_5 across $2\ \Omega$ resistor is equal to $6\ \text{V}$ because voltage in parallel branches is equal.

Calculate the value of current I_5 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_5$, $V = V_5$, $R = 2\ \Omega$ from Figure 1 and solve for I_5.

$$\begin{aligned} I_5 &= \frac{V_5}{R} \\ &= \frac{6\ \text{V}}{2\ \Omega} \\ &= 3\ \text{A} \end{aligned}$$

Step 7 of 8

Apply Kirchhoff's current law at node '*d*' in figure 1 and solve for current I_6.

$$I_3 + I_6 + I_1 = 0$$

$$\begin{aligned} I_6 &= -I_1 - I_3 \\ &= -2\ \text{A} - 4\ \text{A} \\ &= -6\ \text{A} \end{aligned}$$

Step 8 of 8

Apply Kirchhoff's current law at node '*b*' in figure 1 and solve for current I_A.

$$I_A + I_6 = I_5$$

$$\begin{aligned} I_A &= I_5 - I_6 \\ &= 3\ \text{A} - (-6\ \text{A}) \\ &= 9\ \text{A} \end{aligned}$$

Therefore, the value of current I_A in the network is $\boxed{9\ \text{A}}$.

Step 1 of 12

Consider the circuit shown in Figure P2.99 in the text book.

The voltage and current flow directions in each branch for the considered circuit is indicated in Figure 1.

Step 2 of 12

Figure 1

Step 3 of 12

Calculate the voltage V_1 by using Ohm's law $V = IR$.

Substitute $V = V_1$, $I = I_o$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for V_1 .

$$\begin{aligned} V_1 &= I_o R \\ &= (2\ \text{mA})(1\ \text{k}\Omega) \\ &= 2\ \text{V} \end{aligned}$$

Step 4 of 12

Apply Kirchhoff's voltage law to the loop formed by voltages V_1 , $6\ \text{V}$ source, V_2 in Figure 1 and solve for V_2 .

$$-V_1 - 6\ \text{V} + V_2 = 0$$

$$\begin{aligned} V_2 &= V_1 + 6\ \text{V} \\ &= 2\ \text{V} + 6\ \text{V} \\ &= 8\ \text{V} \end{aligned}$$

Step 5 of 12

Calculate the value of current I_2 by using Ohm's law $I = \frac{V}{R}$ in Figure 1.

Substitute $I = I_2$, $V = 8\ \text{V}$, $R = 2\ \text{k}\Omega$ from Figure 1 and solve for I_2 .

$$\begin{aligned} I_2 &= \frac{V}{R} \\ &= \frac{8\ \text{V}}{2\ \text{k}\Omega} \\ &= 4\ \text{mA} \end{aligned}$$

Step 6 of 12

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve for current I_5 .

$$\begin{aligned} I_5 &= I_o + I_2 \\ &= 2\ \text{mA} + 4\ \text{mA} \\ &= 6\ \text{mA} \end{aligned}$$

Step 7 of 12

Calculate the voltage V_5 in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_5$, $I = 6\ \text{mA}$, $R = 2\ \text{k}\Omega$ from Figure 1 and solve for V_5 .

$$\begin{aligned} V_5 &= IR \\ &= (6\ \text{mA})(2\ \text{k}\Omega) \\ &= 12\ \text{V} \end{aligned}$$

Step 8 of 12

Apply Kirchhoff's voltage law to the voltage loop formed by V_1 , V_5 , V_3 , $6\ \text{V}$ source in Figure 1 and solve for V_3 .

$$V_1 + V_5 - V_3 + 6\ \text{V} = 0$$

$$\begin{aligned} V_3 &= V_1 + V_5 + 6\ \text{V} \\ &= 2\ \text{V} + 12\ \text{V} + 6\ \text{V} \\ &= 20\ \text{V} \end{aligned}$$

Step 9 of 12

Calculate the value of current I_3 by using Ohm's law $I = \frac{V}{R}$ in Figure 1.

Substitute $I = I_3$, $V = 20\ \text{V}$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for I_3 .

$$\begin{aligned} I_3 &= \frac{V}{R} \\ &= \frac{20\ \text{V}}{1\ \text{k}\Omega} \\ &= 20\ \text{mA} \end{aligned}$$

Step 10 of 12

Apply Kirchhoff's current law at node 'b' in Figure 1 and calculate the current I_4 .

$$\begin{aligned} I_4 &= I_3 + I_5 \\ &= 20\ \text{mA} + 6\ \text{mA} \\ &= 26\ \text{mA} \end{aligned}$$

Step 11 of 12

Calculate the voltage V_4 in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_4$, $I = 26\ \text{mA}$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for V_4 .

$$\begin{aligned} V_4 &= IR \\ &= (26\ \text{mA})(1\ \text{k}\Omega) \\ &= 26\ \text{V} \end{aligned}$$

Step 12 of 12

Apply Kirchhoff's voltage law to the loop formed by voltages V_A , V_3 , V_4 in Figure 1 and solve for V_A .

$$V_A + V_3 + V_4 = 0$$

$$\begin{aligned} V_A &= -V_3 - V_4 \\ &= -20\ \text{V} - 26\ \text{V} \\ &= -46\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_A is $\boxed{-46\ \text{V}}$.

Step 1 of 10

2.103p

Consider the circuit shown in Figure P2.96 in the text book.

The voltages and current flow direction for each branch in the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 10

The 5 A current source supplies 50 W of power.

Calculate the power P across 5 A source by using formula $P = VI$.

Substitute power $P = 50\text{ W}$, $V = V_s$, $I = 5\text{ A}$ from Figure 1 and solve for V_s.

$$50\text{ W} = V_s(5\text{ A})$$
$$V_s = \frac{50\text{ W}}{5\text{ A}}$$
$$= 10\text{ V}$$

Step 3 of 10

Calculate the voltage V_5 by using Ohm's law $V = IR$ in Figure 1.

Substitute $V = V_5$, $I = 5\text{ A}$, $R = 4\ \Omega$ from Figure 1 and solve for V_5.

$$V_5 = (5\text{ A})(4\ \Omega)$$
$$= 20\text{ V}$$

Step 4 of 10

Apply Kirchhoff's voltage law to the loop formed by *d c f e d* and solve for voltage V_4.

$$V_5 + V_4 - V_s = 0$$
$$V_4 = V_s - V_5$$
$$= 10\text{ V} - 20\text{ V}$$
$$= -10\text{ V}$$

Step 5 of 10

Calculate the value of current I_4 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_4$, $V = V_4$, $R = 2\ \Omega$ from Figure 1 and solve for I_4.

$$I_4 = \frac{V_4}{R}$$
$$= \frac{-10\text{ V}}{2\ \Omega}$$
$$= -5\text{ A}$$

Step 6 of 10

Apply Kirchhoff's voltage law to the loop formed by *a b c f g h a* in Figure 1 and solve for voltage V_2.

$$-5 + V_2 + V_4 = 0$$
$$V_2 = 5 - V_4$$
$$= 5\text{ V} - (-10\text{ V})$$
$$= 15\text{ V}$$

Step 7 of 10

Calculate the value of current I_2 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_2$, $V = 15\text{ V}$, $R = 4\ \Omega$ from Figure 1 and solve for I_2.

$$I_2 = \frac{V}{R}$$
$$= \frac{15\text{ V}}{4\ \Omega}$$
$$= 3.75\text{ V}$$

Step 8 of 10

Apply Kirchhoff' current law at node '*c*' in Figure 1 and solve for current I_3.

$$I_3 + I_4 = I_2 + I_5$$
$$I_3 = I_2 + I_5 - I_4$$
$$= 3.75\text{ A} + 5\text{ A} - (-5\text{ A})$$
$$= 13.75\text{ A}$$

Step 9 of 10

Calculate the voltage V_3 in Figure 1 by using Ohm's law $V = IR$ in Figure 1.

Substitute $V = V_3$, $I = 13.75\text{ A}$, $R = 2\ \Omega$ from Figure 1 and solve for V_3.

$$V_3 = (13.75\text{ A})(2\ \Omega)$$
$$= 27.5\text{ V}$$

Step 10 of 10

Apply Kirchhoff's voltage law to the loop formed by j l b c j in Figure 1 and solve for voltage V_x.

$$-V_x + V_3 + V_2 = 0$$
$$V_x = V_2 + V_3$$
$$= 15\text{ V} + 27.5\text{ V}$$
$$= 42.5\text{ V}$$

Therefore, the value of voltage V_x is $\boxed{42.5\text{ V}}$.

Step 1 of 10

2.104p

Consider the circuit shown in Figure P2.98 in the text book.

The voltages and current flow direction in each branch for the considered circuit is indicated in Figure 1.

Figure 1

Step 2 of 10

Calculate the voltage V_4 in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_4$, $I = 2\text{ mA}$, $R = 2\text{ k}\Omega$ from Figure 1 and solve for V_4.

$$\begin{aligned} V_4 &= (2\text{ mA})(2\text{ k}\Omega) \\ &= 4\text{ V} \end{aligned}$$

Step 3 of 10

Apply Kirchhoff's voltage law to the loop formed by voltages V_3, 6 V source, V_4 in Figure 1 and solve for V_3.

$$V_3 - V_4 - 6\text{ V} = 0$$

$$\begin{aligned} V_3 &= V_4 + 6\text{ V} \\ &= 4\text{ V} + 6\text{ V} \\ &= 10\text{ V} \end{aligned}$$

Step 4 of 10

Calculate the value of current I_3 in figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_3$, $V = 10\text{ V}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for I_3.

$$\begin{aligned} I_3 &= \frac{V}{R} \\ &= \frac{10\text{ V}}{1\text{ k}\Omega} \\ &= 10\text{ mA} \end{aligned}$$

Step 5 of 10

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve for I_5.

$$\begin{aligned} I_5 &= I_3 + I_o \\ &= 10\text{ mA} + 2\text{ mA} \\ &= 12\text{ mA} \end{aligned}$$

Step 6 of 10

Apply Kirchhoff's voltage law to the loop formed by V_1, 6 V source, 6 V source in Figure 1 and solve for V_1.

$$V_1 - 6\text{ V} - 6\text{ V} = 0$$

$$\begin{aligned} V_1 &= 6\text{ V} + 6\text{ V} \\ &= 12\text{ V} \end{aligned}$$

Step 7 of 10

Calculate the value of current I_1 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_1$, $V = 12\text{ V}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for I_1.

$$\begin{aligned} I_1 &= \frac{V}{R} \\ &= \frac{12\text{ V}}{1\text{ k}\Omega} \\ &= 12\text{ mA} \end{aligned}$$

Step 8 of 10

Apply Kirchhoff's voltage law to the outer loop formed by voltages 6 V source, V_3, V_5, V_2 in Figure 1 and solve for V_2.

$$6\text{ V} + V_3 + V_5 - V_2 = 0$$

$$\begin{aligned} V_2 &= 6\text{ V} + 10\text{ V} + 1\text{ k}I_5 \\ &= 16\text{ V} + (12\text{ mA})(1\text{ k}) \\ &= 28\text{ V} \end{aligned}$$

Step 9 of 10

Calculate the value of current I_2 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_2$, $V = 28\text{ V}$, $R = 2\text{ k}\Omega$ from Figure 1 and solve for I_2.

$$\begin{aligned} I_2 &= \frac{V}{R} \\ &= \frac{28\text{ V}}{2\text{ k}\Omega} \\ &= 14\text{ mA} \end{aligned}$$

Step 10 of 10

Apply Kirchhoff's current law at node '*b*' in Figure 1 and solve for I_A.

$$I_A + I_2 + I_5 = 0$$

$$\begin{aligned} I_A &= -I_2 - I_5 \\ &= -14\text{ mA} - 12\text{ mA} \\ &= -26\text{ mA} \end{aligned}$$

Therefore, the value of current I_A is $\boxed{-26\text{ mA}}$.

Step 1 of 13

Consider the circuit shown in Figure P2.100 in the text book.

The nodes, voltages and current flow direction for each branch in the considered circuit is indicated and shown in Figure 1.

Step 2 of 13

Figure 1

Step 3 of 13

Calculate the value of current I_o in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = 4\text{ V}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for I_o.

$$\begin{aligned} I_o &= \frac{V}{R} \\ &= \frac{4\text{ V}}{1\text{ k}\Omega} \\ &= 4\text{ mA} \end{aligned}$$

Step 4 of 13

Apply Kirchhoff's voltage law to the loop formed by nodes *d e h i d* in Figure 1 and solve for voltage V_3.

$$-12\text{ V} + V_3 - V_o = 0$$

$$\begin{aligned} V_3 &= V_o + 12\text{ V} \\ &= 4\text{ V} + 12\text{ V} \\ &= 16\text{ V} \end{aligned}$$

Step 5 of 13

Calculate the value of current I_3 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_3$, $V = 16\text{ V}$, $R = 2\text{ k}\Omega$ from Figure 1 and solve for I_3.

$$\begin{aligned} I_3 &= \frac{V}{R} \\ &= \frac{16\text{ V}}{2\text{ k}\Omega} \\ &= 8\text{ mA} \end{aligned}$$

Step 6 of 13

Apply Kirchhoff's current law at node '*h*' in Figure 1 and solve for current I_5.

$$\begin{aligned} I_5 &= I_3 + I_o \\ &= 8\text{ mA} + 4\text{ mA} \\ &= 12\text{ mA} \end{aligned}$$

Step 7 of 13

Apply Kirchhoff's voltage law to the loop formed by nodes *f e h g h* in Figure 1 and solve for V_2.

$$V_2 + V_3 - 6\text{ V} = 0$$

$$\begin{aligned} V_2 &= 6\text{ V} - V_3 \\ &= 6\text{ V} - 16\text{ V} \\ &= -10\text{ V} \end{aligned}$$

Step 8 of 13

Calculate the value of current I_2 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_2$, $V = -10\text{ V}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for I_2.

$$\begin{aligned} I_2 &= \frac{V}{R} \\ &= \frac{-10\text{ V}}{1\text{ k}\Omega} \\ &= -10\text{ mA} \end{aligned}$$

Step 9 of 13

Apply Kirchhoff's current law at node '*f*' in Figure 1 and solve for current I_1.

$$I_1 + I_2 = I_5$$

$$\begin{aligned} I_1 &= I_5 - I_2 \\ &= 12\text{ mA} - (-10\text{ mA}) \\ &= 22\text{ mA} \end{aligned}$$

Step 10 of 13

Calculate the voltage V_1 in Figure 1 by using Ohm's law $V = IR$.
Substitute $V = V_1$, $I = 22\text{ mA}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for V_1.

$$\begin{aligned} V_1 &= (22\text{ mA})(1\text{ k}\Omega) \\ &= 22\text{ V} \end{aligned}$$

Step 11 of 13

Apply Kirchhoff's voltage law to the loop formed by nodes *a b c d i h g f a* in Figure 1 and solve for voltage V_4.

$$V_4 + V_o - 6\text{ V} + V_1 = 0$$

$$\begin{aligned} V_4 &= 6\text{ V} - V_o - V_1 \\ &= 6\text{ V} - 4\text{ V} - 22\text{ V} \\ &= -20\text{ V} \end{aligned}$$

Step 12 of 13

Calculate the value of current I_4 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_4$, $V = -20\text{ V}$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for I_4.

$$\begin{aligned} I_4 &= \frac{V}{R} \\ &= \frac{-20\text{ V}}{1\text{ k}\Omega} \\ &= -20\text{ mA} \end{aligned}$$

Step 13 of 13

Apply Kirchhoff's current law at node '*b*' in Figure 1 and solve for current I_A.

$$I_A + I_4 = I_1$$

$$\begin{aligned} I_A &= I_1 - I_4 \\ &= 22\text{ mA} - (-20\text{ mA}) \\ &= 42\text{ mA} \end{aligned}$$

Therefore, the value of current I_A is $\boxed{42\text{ mA}}$.

Step 1 of 9

Consider the circuit shown in Figure P2.101 in the text book.

The nodes, voltages and current flow direction in each branch for the considered circuit is shown in Figure 1.

Step 2 of 9

Figure 1

Step 3 of 9

Calculate the voltage V_s having power supplied by 5 A source is 60 W by using the formula $P = VI$.

Substitute $P = 60\text{ W}$, $V = V_s$, $I = 5\text{ A}$ from Figure 1 and solve for V_s.

$$\begin{aligned} P &= V_s I \\ V_s &= \frac{P}{I} \\ &= \frac{60\text{ W}}{5\text{ A}} \\ &= 12\text{ V} \end{aligned}$$

Step 4 of 9

Calculate the current I_3 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_3$, $V = 12\text{ V}$, $R = 2\,\Omega$ from Figure 1 and calculate the value of I_3.

$$\begin{aligned} I_3 &= \frac{V}{R} \\ &= \frac{12\text{ V}}{2\,\Omega} \\ &= 6\text{ A} \end{aligned}$$

Step 5 of 9

Apply Kirchhoff's voltage law to the loop formed by 5 V source, V_s, V_2 in Figure 1 and solve for voltage V_2.

$$V_2 + 5\text{ V} - V_s = 0$$

$$\begin{aligned} V_2 &= V_s - 5\text{ V} \\ &= 12\text{ V} - 5\text{ V} \\ &= 7\text{ V} \end{aligned}$$

Step 6 of 9

Calculate the current I_2 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_2$, $V = 7\text{ V}$, $R = 4\,\Omega$ from Figure 1 and calculate the value of I_2.

$$\begin{aligned} I_2 &= \frac{V}{R} \\ &= \frac{7\text{ V}}{4\,\Omega} \\ &= 1.75\text{ A} \end{aligned}$$

Step 7 of 9

Apply Kirchhoff's current law at node 'a' in Figure 1 and solve for current I_4.

$$I_4 + I_2 + I_3 = 5\text{ A}$$

$$\begin{aligned} I_4 &= 5\text{ A} - I_2 - I_3 \\ &= 5\text{ A} - 1.75\text{ A} - 6\text{ A} \\ &= -2.75\text{ A} \end{aligned}$$

Step 8 of 9

Apply Kirchhoff's current law at node 'b' in Figure 1 and solve for current I_1.

$$\begin{aligned} I_1 &= 3\text{ A} + I_4 \\ &= 3\text{ A} + (-2.75\text{ A}) \\ &= 0.75\text{ A} \end{aligned}$$

Step 9 of 9

Apply Kirchhoff's voltage law to the loop formed by voltages V_x, V_z, V_2, V_y in Figure 1 and solve for voltage V_x.

$$-V_x + V_z - V_2 + V_y = 0$$

$$\begin{aligned} V_x &= 1I_1 - 7\text{ V} + 1I_1 \\ &= 0.75\text{ V} - 7\text{ V} + 0.75\text{ V} \\ &= -5.5\text{ V} \end{aligned}$$

Therefore, the value of voltage V_x is $\boxed{-5.5\text{ V}}$.

Step 1 of 7

2.108p

Consider the circuit shown in Figure P2.106 in the text book.

The nodes, voltages and current flow directions for the considered circuit is shown in Figure 1.

Step 2 of 7

Figure 1

Step 3 of 7

Calculate the voltage V_s across the 3 A source in Figure 1 by using the formula $V = \frac{P}{I}$.

Substitute $P = 20\text{ W}$, $V = V_s$, $I = 3\text{ A}$ from Figure 1 and solve for voltage V_s.

$$\begin{aligned} V_s &= \frac{P}{I} \\ &= \frac{20\text{ W}}{3\text{ A}} \\ &= 6.67\text{ V} \end{aligned}$$

Step 4 of 7

Apply Kirchhoff's current law at node 'A' and solve for I_x from Figure 1.

$$I_x + I_1 = 3\text{ A}$$

$$I_x = 3 - I_1 \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the loop formed by the nodes A C B A in Figure 1 and solve.

$$\begin{aligned} V_s &= 1I_x + 2I_3 \\ 6.67 &= (3 - I_1) + 2I_3 \\ 6.67 - 3 &= -I_1 + 2I_3 \end{aligned}$$

$$-I_1 + 2I_3 = 3.67 \quad \text{..... (2)}$$

Step 5 of 7

Apply Kirchhoff's current law at node 'B' and solve for I_2.

$$\begin{aligned} I_2 + I_3 &= 3\text{ A} \\ I_2 &= 3\text{ A} - I_3 \end{aligned}$$

Apply Kirchhoff's voltage law to the loop formed by nodes A B D A and solve.

$$\begin{aligned} 2I_1 + 2I_2 &= V_s \\ 2I_1 + 2(3 - I_3) &= 6.67 \\ 2I_1 - 2I_3 &= 6.67 - 6 \end{aligned}$$

$$I_1 - I_3 = 0.335 \quad \text{..... (3)}$$

Step 6 of 7

Substitute the value of $I_1 = 0.335 + I_3$ from equation (3) in (2) and solve for I_3.

$$\begin{aligned} -(0.335 + I_3) + 2I_3 &= 3.67 \\ -I_3 + 2I_3 &= 3.67 + 0.335 \\ I_3 &= 4\text{ A} \end{aligned}$$

Substitute $I_3 = 4\text{ A}$ in equation (3) and solve for I_1.

$$\begin{aligned} I_1 &= 0.335 + 4\text{ A} \\ &= 4.335\text{ A} \end{aligned}$$

Substitute $I_1 = 4.335\text{ A}$ in equation (1) and solve for I_x.

$$\begin{aligned} I_x &= 3\text{ A} - 4.335\text{ A} \\ &= -1.335\text{ A} \end{aligned}$$

Step 7 of 7

Apply Kirchhoff's current law at node 'C' in Figure 1 and solve for g.

$$I_x = I_3 + gI_x$$

$$\begin{aligned} g &= \frac{I_x - I_3}{I_x} \\ &= \frac{-1.335\text{ A} - 4\text{ A}}{-1.335\text{ A}} \\ &= 4 \end{aligned}$$

Therefore, the value of 'g' in the network is $\boxed{4}$.

Step 1 of 5

2.113p

Refer to the circuit diagram shown in Figure P2.113 in the textbook.

From the data, the voltage across $4\ \Omega$ resistor is $24\ \text{V}$.

Find the current flowing through $4\ \Omega$ resistor using Ohms law.

$$\begin{aligned} I_{4\Omega} &= \frac{V_o}{4} \\ &= \frac{24}{4} \\ &= 6\ \text{A} \end{aligned}$$

Draw the circuit diagram depicted with branch currents and voltages.

Figure 1

Step 2 of 5

The circuit diagram in Figure 4 is representing with four loops namely 1, 2, 3 and 4 and four nodes *A*, *B*, *C* and *D*. The currents through each branch and voltage across each branch are marked as per their respective component values.

Apply Kirchhoff's current law at node *B*.

$$2 = I_{4\Omega} + I_{2\Omega}$$

$$\begin{aligned} I_{2\Omega} &= 2 - I_{4\Omega} \\ &= 2 - 6 \\ &= -4\ \text{A} \end{aligned}$$

Calculate the voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} V_{2\Omega} &= 2I_{2\Omega} \\ &= 2(-4) \\ &= -8\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law in loop 2.

$$-12 - V_{2\Omega} + V_{2A} = 0$$

$$\begin{aligned} V_{2A} &= V_{2\Omega} + 12 \\ &= -8 + 12 \\ &= 4\ \text{V} \end{aligned}$$

Step 3 of 5

Apply Kirchhoff's voltage law in loop 4.

$$-V_{5\Omega} - V_{2A} + 24 = 0$$

$$\begin{aligned} V_{5\Omega} &= 24 - V_{2A} \\ &= 24 - 4 \\ &= 20\ \text{V} \end{aligned}$$

Calculate the current through $5\ \Omega$ resistor.

$$\begin{aligned} I_{5\Omega} &= \frac{V_{5\Omega}}{5} \\ &= \frac{20}{5} \\ &= 4\ \text{A} \end{aligned}$$

Apply Kirchhoff's voltage law in loop 3.

$$-16 - V_{I_s} + V_{5\Omega} = 0$$

$$\begin{aligned} V_{I_s} &= V_{5\Omega} - 16 \\ &= 20 - 16 \\ &= 4\ \text{V} \end{aligned}$$

Step 4 of 5

Apply Kirchhoff's voltage law in loop 1.

$$V_{4\Omega} + 12 + V_{I_s} = 0$$

$$\begin{aligned} V_{4\Omega} &= -12 - V_{I_s} \\ &= -12 - 4 \\ &= -16\ \text{V} \end{aligned}$$

Find the current through $4\ \Omega$ resistor using Ohms law.

$$\begin{aligned} I_{4\Omega} &= \frac{V_{4\Omega}}{4} \\ &= \frac{-16}{4} \\ &= -4\ \text{A} \end{aligned}$$

Step 5 of 5

Apply Kirchhoff's current law at node *C*.

$$I_{4\Omega} + I_{12V} + I_{2\Omega} = 0$$

$$\begin{aligned} I_{12V} &= -I_{4\Omega} - I_{2\Omega} \\ &= -(-4) - (-4) \\ &= 4 + 4 \\ &= 8\ \text{A} \end{aligned}$$

Finally, apply Kirchhoff's current law at node *A*.

$$\begin{aligned} I_S &= I_{5\Omega} + 2 + I_{12V} \\ &= 4 + 2 + 8 \\ &= 14\ \text{A} \end{aligned}$$

Therefore, the value of source current, I_s is $\boxed{14\ \text{A}}$.

Step 1 of 5

2.114p

Refer to the circuit diagram shown in Figure P2.114 in the textbook.

From the circuit, it is clear that, the voltage across right most $1\ \text{k}\Omega$ is 8 V.

Determine the current flowing through it.

$$\begin{aligned} I_1 &= \frac{8}{1\times10^3} \\ &= 8\ \text{mA} \end{aligned}$$

Draw the circuit diagram.

Figure 1

Step 2 of 5

The circuit diagram in Figure 1 is representing with three loops namely 1, 2 and 3 and two nodes *A* and *B*. The currents through each branch and voltage across each branch are depicted as shown in the figure.

Determine the voltage drop V_1.

$$\begin{aligned} V_1 &= \left(1\times10^3\right)I_1 \\ &= \left(1\times10^3\right)\left(8\times10^{-3}\right) \\ &= 8\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law around the loop 3.

$$-V_X + V_1 + 8 = 0$$

$$\begin{aligned} V_X &= V_1 + 8 \\ &= 8 + 8 \\ &= 16\ \text{V} \end{aligned}$$

Calculate the value of current I_2.

$$\begin{aligned} I_2 &= \frac{V_X}{1\times10^3} \\ &= \frac{16}{1\times10^3} \\ &= 16\ \text{mA} \end{aligned}$$

Step 3 of 5

Apply Kirchhoff's current law at node *B*.

$$\begin{aligned} I_S &= I_1 + I_2 \\ &= 8\ \text{mA} + 16\ \text{mA} \\ &= 24\ \text{mA} \end{aligned}$$

Apply Kirchhoff's current law at node *A*.

$$\frac{V_A - 2V_X}{1\times10^3} + \frac{V_A}{1\times10^3} + I_S = 0$$

$$V_A\left(\frac{1}{1\times10^3} + \frac{1}{1\times10^3}\right) = \frac{2(16)}{1\times10^3} - 24\times10^{-3}$$

$$2\times10^{-3}V_A = 8\times10^{-3}$$

$$V_A = 4\ \text{V}$$

Step 4 of 5

Calculate the value of current, I_3.

$$\begin{aligned} I_3 &= \frac{V_A}{1\times10^3} \\ &= \frac{4}{1\times10^3} \\ &= 4\ \text{mA} \end{aligned}$$

Determine the voltage drop V_2.

$$\begin{aligned} V_2 &= \left(1\times10^3\right)I_3 \\ &= \left(1\times10^3\right)\left(4\times10^{-3}\right) \\ &= 4\ \text{V} \end{aligned}$$

Step 5 of 5

Apply Kirchhoff's voltage law around the loop 2.

$$-V_2 - V_S + V_X = 0$$

$$\begin{aligned} V_S &= V_X - V_2 \\ &= 16 - 4 \\ &= 12\ \text{V} \end{aligned}$$

Therefore, the value of source voltage, V_S is $\boxed{12\ \text{V}}$.

Step 1 of 7

Remove the current source from the circuit and draw the equivalent circuit.

Figure 1

Step 2 of 7

Convert the delta network into star network.

Figure 2

Find the value of the resistance R_Y ass shown in Figure 2.

$$\begin{aligned} R_Y &= \frac{(12\text{ k}\Omega)(12\text{ k}\Omega)}{12\text{ k}\Omega+12\text{ k}\Omega+12\text{ k}\Omega} \\ &= \frac{(12\text{ k}\Omega)(12\text{ k}\Omega)}{36\text{ k}\Omega} \\ &= \frac{12\text{ k}\Omega}{3} \\ &= 4\text{ k}\Omega \end{aligned}$$

Step 3 of 7

Replace the delta- network as shown in Figure 1 with its equivalent star-network.

Figure 3

Step 4 of 7

Determine the equivalent resistance R as shown in Figure 3.

$$\begin{aligned} R &= \left((12\text{ k}\Omega+R_Y)\|(4\text{ k}\Omega+R_Y)\right)+R_Y \\ &= \left((12\text{ k}\Omega+4\text{ k}\Omega)\|(4\text{ k}\Omega+4\text{ k}\Omega)\right)+4\text{ k}\Omega \\ &= \frac{16}{3}\text{ k}\Omega+4\text{ k}\Omega \\ &= \frac{28}{3}\text{ k}\Omega \end{aligned}$$

Step 5 of 7

Draw the equivalent circuit.

Figure 4

Step 6 of 7

Use Ohm's law to find the value of the voltage V_1 as shown in Figure 4.

$$\begin{aligned} V_1 &= (6\text{ mA})\left(\frac{28}{3}\text{ k}\Omega\right) \\ &= (6)\left(\frac{28}{3}\right) \\ &= 56\text{ V} \end{aligned}$$

Step 7 of 7

Find the power supplied by the $6-\text{mA}$ source.

$$\begin{aligned} P_{6\text{ mA}} &= (V_1)(6\text{ mA}) \\ &= (56)(6\text{ mA}) \\ &= 336\text{ mW} \end{aligned}$$

Thus, the power supplied by the $6-\text{mA}$ source is $\boxed{336\text{ mW}}$.

Step 1 of 2

2.116p

Consider the circuit shown in Figure P2.111 in the text book.

Apply Kirchhoff's voltage law to the circuit and solve for current I_s .

$$-12+3\text{k}I_s-2000I_s+5\text{k}I_s=0$$
$$8\text{k}I_s-2\text{k}I_s=12$$
$$6\text{k}I_s=12$$
$$I_s=2\text{ mA}$$

Step 2 of 2

Calculate the voltage V_o across $5\text{ k}\Omega$ resistor by using Ohm's law $V=IR$.

Substitute $V=V_o$, $I=2\text{ mA}$, $R=5\text{ k}\Omega$ and solve for voltage V_o .

$$\begin{aligned}V&=(2\text{ mA})(5\text{ k}\Omega)\\&=10\text{ V}\end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{10\text{ V}}$.

Step 1 of 3

2.117p

Consider the circuit shown in Figure P2.112 in the text book.

Calculate the voltage V_o across $4\ \text{k}\Omega$ resistor in the circuit by using Ohm's law $V = IR$.

Substitute $V = V_o$, $R = 4\ \text{k}\Omega$ and solve for V_o .

$$V_o = I(4\ \text{k}\Omega)$$

Step 2 of 3

Apply Kirchhoff's voltage law to the circuit and substitute $V_o = 4\text{k}I$ solve for current I .

$$-24 + 2\text{k}I + 2V_o + V_o = 0$$
$$-24 + 2\text{k}I + 2(4\text{k}I) + 4\text{k}I = 0$$
$$14\text{k}I = 24$$
$$I = 1.714\ \text{mA}$$

Step 3 of 3

Calculate the voltage V_o across $4\ \text{k}\Omega$ resistor by using Ohm's law $V = IR$.

Substitute $V = V_o$, $R = 4\ \text{k}\Omega$, $I = 1.714\ \text{mA}$ and solve for V_o .

$$\begin{aligned} V_o &= (1.714\ \text{mA})(4\ \text{k}\Omega) \\ &= 6.86\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the network is $\boxed{6.86\ \text{V}}$.

2.118p

Figure 1

Let current in different branches be I_1, I_2, I_3, I_4 as shown in figure 1.

By Ohm's Law,

$V_{bc} = I_1(4)$

$V_{bc} = I_2(6)$

$V_{bc} = I_3(12)$

$\therefore I_2 = I_1\left(\frac{4}{6}\right)$

$I_2 = \frac{2}{3}I_1$ ....(1)

$\therefore I_3 = I_1\left(\frac{4}{12}\right)$

$I_3 = \frac{1}{3}I_1$ ....(2)

By KCL at node b,

$I_4 - I_1 - I_2 + 3I_2 - I_3 + 4.5 = 0$

$I_4 - I_1 + 2I_2 - I_3 + 4.5 = 0$

$I_4 - I_1 + 2\left(\frac{2}{3}\right)I_1 - \left(\frac{1}{3}\right)I_1 + 4.5 = 0$ ....(from (1) and (2))

$I_4 - I_1 + \frac{3}{3}I_1 + 4.5 = 0$

$I_4 = -4.5$ A ....(3)

By KVL around loop $abca$,

$V_{ab} + V_{bc} + V_{ca} = 0$

$I_4(8) + I_1(4) - 60 = 0$

$(-4.5)(8) + I_1(4) = 60$ ....(from (3))

$I_1(4) = 60 + 36$

$I_1 = 24$ A ....(4)

Hence $\boxed{I_1 = 24 \text{ A}}$

Step 1 of 4

2.119p

Figure 1

Step 2 of 4

Let current in different branches be I_1, I_b, I_O as shown in figure 1.

By Ohm's Law,

$V_{bc} = I_1(4\text{k})$

$V_{bc} = I_0(400)$

$\therefore\ I_1 = I_0\left(\frac{400}{4000}\right)$

$I_1 = \frac{1}{10} I_0$ ....(1)

Step 3 of 4

By KVL around loop $dacd$,

$V_{da} + V_{ac} + V_{cd} = 0$

$I_b R_S + I_b R_a - V_S = 0$

$I_b(1000) + I_b(250) - 250\text{m} = 0$

$I_b(1250) = 250\text{m}$

$I_b = \frac{250}{1250}\text{m}$

$I_b = 0.2\ \text{mA}$ ....(2)

Step 4 of 4

By KCL at node b,

$-100I_b - I_1 - I_0 = 0$

$-100(0.2\text{m}) - \frac{1}{10} I_0 - I_0 = 0$ ....(from (1) and (2))

$\frac{11}{10} I_0 = -20\text{m}$

$I_0 = -\frac{200}{11}\ \text{mA}$ ....(3)

Hence $\boxed{I_0 = -18.18\ \text{mA}}$

Step 1 of 4

2.120p

Consider the circuit shown in Figure P2.114 in the text book.

The voltage across any parallel branch in the considered circuit is V_o.

Calculate the current I_o in figure by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_o$, $R = (2\ \Omega + 1\ \Omega)$ from the considered figure and solve for I_o.

$$\begin{aligned} I_o &= \frac{V_o}{2\ \Omega + 1\ \Omega} \\ &= \frac{V_o}{3\ \Omega} \end{aligned}$$

Step 2 of 4

Calculate the voltage V_x across $1\ \Omega$ resistor in the considered circuit by using Ohm's law $V = IR$.

Substitute $V = V_x$, $I = I_o$, $R = 1\ \Omega$ from the considered figure and solve for V_x.

$$\begin{aligned} V_x &= I_o(1\ \Omega) \\ &= \frac{V_o}{3\ \Omega}(1\ \Omega) \\ &= \frac{V_o}{3} \end{aligned}$$

Step 3 of 4

Apply Kirchhoff's current law at top node in the considered circuit and solve for voltage V_o.

$$\begin{aligned} 4\ \text{A} + 2V_x &= I_o + 2\ \text{A} \\ 4\ \text{A} + 2\left(\frac{V_o}{3\ \Omega}\right) &= \left(\frac{V_o}{3\ \Omega}\right) + 2\ \text{A} \\ \frac{2V_o - V_o}{3} &= 2\ \text{A} - 4\ \text{A} \\ V_o &= -6\ \text{A} \end{aligned}$$

Step 4 of 4

Calculate the value of current I_o.

$$\begin{aligned} I_o &= \frac{V_o}{3\ \Omega} \\ &= \frac{-6\ \text{A}}{3\ \Omega} \\ &= -2\ \text{A} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{-2\ \text{A}}$.

Step 1 of 2

2.121p

Consider the circuit shown in Figure P2.115 in the text book.

The voltage across the parallel branches in the circuit is V_o.

Calculate the current I_y flowing in the circuit by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_y$, $V = V_o$, $R = 2\ \Omega$ from the circuit and solve for I_y.

$$I_y = \frac{V_o}{2\ \Omega}$$

Calculate the voltage V_x across $1\ \Omega$ resistor in the circuit by using voltage division rule

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V.$$

Substitute $R_x = 1\ \Omega$, $R_y = 2\ \Omega$, $V = V_o$ from the circuit and solve for voltage V_x.

$$\begin{aligned} V_x &= \left(\frac{1\ \Omega}{1\ \Omega + 2\ \Omega}\right)V_o \\ &= \frac{V_o}{3} \end{aligned}$$

Step 2 of 2

Apply Kirchhoff's current law at top node in the considered circuit and solve for voltage V_o.

$$6\text{ A} + \frac{V_x}{2} = 2I_y + \frac{V_o}{2+1} + I_y$$

$$6\text{ A} + \frac{1}{2}\left(\frac{V_o}{3}\right) = 2\left(\frac{V_o}{2}\right) + \frac{V_o}{3} + \frac{V_o}{2}$$

$$6\text{ A} = \frac{6V_o + 2V_o + 3V_o}{6} - \frac{V_o}{6}$$

$$\frac{11V_o - V_o}{6} = 6\text{ A}$$

Simplify the expression further.

$$\frac{10V_o}{6} = 6\text{ A}$$

$$\begin{aligned} V_o &= 6\left(\frac{6}{10}\right) \\ &= \frac{36}{10} \\ &= 3.6\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{3.6\text{ V}}$.

Step 1 of 3

2.122p

Refer to circuit shown in Figure P2.120 in the text book.

Let the voltage across the resistor $500\ \Omega$ in the circuit be V_b.

Calculate the equivalent resistance R_1 of resistors $5\ \text{k}\Omega$ and $500\ \Omega$ connected in parallel in the circuit by using the following formula.

$$R = \frac{R_x R_y}{R_x + R_y}$$

Substitute $5\ \text{k}\Omega$ for R_x, $500\ \Omega$ for R_y in the equation to solve for R_1.

$$\begin{aligned} R_1 &= \frac{(5\ \text{k}\Omega)(500\ \Omega)}{5\ \text{k}\Omega + 500\ \Omega} \\ &= \frac{(5\ \text{k}\Omega)(500\ \Omega)}{5.5\ \text{k}\Omega} \\ &= 454.54\ \Omega \end{aligned}$$

Step 2 of 3

Calculate the voltage V_b across R_1 by using voltage division rule.

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V$$

Substitute $454.54\ \Omega$ for R_x, $100\ \Omega$ for R_y, $250\ \text{mV}$ for V in the equation to solve for V_b.

$$\begin{aligned} V_b &= \left(\frac{454.54\ \Omega}{454.54\ \Omega + 100\ \Omega}\right)(250\ \text{mV}) \\ &= (0.8196)(250\ \text{mV}) \\ &= 0.205\ \text{V} \end{aligned}$$

Now, calculate the current I_b through $500\ \Omega$ resistor in the Figure P2.120 in the text book by using Ohm's law.

$$I = \frac{V}{R}$$

Substitute $500\ \Omega$ for R in the equation to solve for I_b.

$$\begin{aligned} I_b &= \frac{V_b}{R} \\ &= \frac{0.205\ \text{V}}{500\ \Omega} \\ &= 410\ \mu\text{A} \end{aligned}$$

Step 3 of 3

Calculate the voltage V_o across $300\ \Omega$ resistor in the considered circuit by using voltage division rule.

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V$$

Substitute $300\ \Omega$ for R_x, $4\ \text{k}\Omega$ for R_y, $-4\times10^5 I_b$ for V in the equation to solve for V_o.

$$\begin{aligned} V_o &= \left(\frac{300\ \Omega}{300\ \Omega + 4\ \text{k}\Omega}\right)\left(-4\times10^5 I_b\right) \\ &= \left(\frac{300}{4300}\right)\left(-4\times10^5\right)\left(410\times10^{-6}\right) \\ &= -11.44\ \text{V} \end{aligned}$$

Calculate the amplifier gain by using the formula.

$$G = \frac{V_o}{V_s}$$

Substitute $-11.44\ \text{V}$ for V_o, $250\ \text{mV}$ for V_s and solve for gain G.

$$\begin{aligned} G &= \frac{-11.44\ \text{V}}{250\ \text{mV}} \\ &= -45.76 \end{aligned}$$

Therefore, the value of amplifier gain is $\boxed{-45.76}$.

Step 1 of 6

2.123p

Consider the circuit shown in Figure P2.116 in the text book.

Calculate the equivalent resistance R_a of resistors $6\,\Omega$ and $3\,\Omega$ connected in parallel by using the formula $R = \frac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_a$, $R_x = 6\,\Omega$, $R_y = 3\,\Omega$ from the considered circuit and solve for R_a.

$$\begin{aligned} R_a &= \frac{(6\,\Omega)(3\,\Omega)}{6\,\Omega + 3\,\Omega} \\ &= \frac{(6\,\Omega)(3\,\Omega)}{9\,\Omega} \\ &= 2\,\Omega \end{aligned}$$

Step 2 of 6

The circuit is reduced as shown in Figure 1.

Figure 1

Step 3 of 6

Calculate the voltage V_a across $R_a = 2\,\Omega$ in Figure 1 by using voltage division rule $V_a = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_a = V_a$, $R_x = 2\,\Omega$, $R_y = 6\,\Omega \| 3\,\Omega$, $V = V_o$ from Figure 1 and solve for V_o.

$$\begin{aligned} V_a &= \left(\frac{2\,\Omega}{2 + (6\|3)}\right)(V_o) \\ &= \left(\frac{2\,\Omega}{2\,\Omega + 2\,\Omega}\right)(V_o) \\ &= \left(\frac{2\,\Omega}{4\,\Omega}\right)(V_o) \\ &= \frac{V_o}{2} \end{aligned}$$

Step 4 of 6

Apply Kirchhoff's voltage law to the middle loop in Figure 1 and solve for I_x.

$$\begin{aligned} 3I_x + V_a - V_o &= 0 \\ 3I_x + \frac{V_o}{2} - V_o &= 0 \\ 3I_x &= \frac{V_o}{2} \\ I_x &= \frac{V_o}{6} \end{aligned}$$

Step 5 of 6

Apply Kirchhoff's current law to the circuit in Figure 1 and solve for voltage V_o.

$$\begin{aligned} 4\text{ A} + 2I_x &= \frac{V_o}{2\,\Omega + 2\,\Omega} + \frac{V_o}{1\,\Omega + 2\,\Omega} \\ 4 + 2\left(\frac{V_o}{6}\right) &= \frac{V_o}{4} + \frac{V_o}{3} \\ 4 &= \frac{V_o}{4} + \frac{V_o}{3} - \frac{V_o}{3} \\ V_o &= 16\text{ V} \end{aligned}$$

Step 6 of 6

Calculate the voltage V_x across $2\,\Omega$ resistor in Figure 1 by using voltage division rule $V_o = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_a = V_x$, $R_x = 2\,\Omega$, $R_y = 1\,\Omega$, $V = 16\text{ V}$ from Figure 1 and solve for voltage V_x.

$$\begin{aligned} V_x &= \left(\frac{2\,\Omega}{2\,\Omega + 1\,\Omega}\right)(16\text{ V}) \\ &= \left(\frac{2}{3}\right)(16) \\ &= \frac{32}{3} \\ &= 10.67\text{ V} \end{aligned}$$

Therefore, the value of voltage V_x in the network is $\boxed{10.67\text{ V}}$.

Step 1 of 3

2.124p

Consider the circuit shown in Figure P2.117 in the text book.

The voltage across any parallel branch in the considered circuit is V_o.

Calculate the value of voltage V_x in the circuit by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = -V_x$, $R_x = 1\,\Omega$, $R_y = 2\,\Omega$, $V = V_o$ from considered figure and solve for V_x.

$$-V_x = \left(\frac{1\,\Omega}{1\,\Omega + 2\,\Omega}\right)(V_o)$$

$$V_x = \frac{-V_o}{3}$$

Step 2 of 3

Calculate the value of voltage V_y in the circuit by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = V_y$, $R_x = 2\,\Omega$, $R_y = 2\,\Omega$, $V = V_o$ from considered figure and solve for V_y.

$$V_y = \left(\frac{2\,\Omega}{2\,\Omega + 2\,\Omega}\right)(V_o)$$

$$V_y = \frac{2}{4}V_o$$

$$= \frac{V_o}{2}$$

Step 3 of 3

Apply Kirchhoff's current law at the top node in the considered figure and solve for voltage V_o.

$$2V_y + 6 = \frac{V_o}{1\,\Omega + 2\,\Omega} + \frac{V_o}{2\,\Omega + 2\,\Omega} + 4V_x$$

$$2\left(\frac{V_o}{2}\right) + 6 = \frac{V_o}{3} + \frac{V_o}{4} + 4\left(\frac{-V_o}{3}\right)$$

$$V_o - \frac{V_o}{3} - \frac{V_o}{4} + \frac{4V_o}{3} = -6$$

$$V_o\left(1 - \frac{1}{3} - \frac{1}{4} + \frac{4}{3}\right) = -6$$

Simplify the expression further.

$$V_o\left(\frac{12 - 4 - 3 + 16}{12}\right) = -6$$

$$V_o\left(\frac{21}{12}\right) = -6$$

$$V_o = (-6)\left(\frac{12}{21}\right)$$

$$= \frac{-72}{21}$$

$$= -3.43\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{-3.43\text{ V}}$.

Step 1 of 5

2.125p

Consider the circuit shown in Figure P2.118 in the text book.

Let the current flowing through $8\ \Omega$ resistor be I_4 and let the nodes in the circuit be 'A', 'B' as shown in Figure 1.

Figure 1

Step 2 of 5

The voltage across any parallel branch in Figure 1 is $24\ \text{V}$.

Calculate the current I_4 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_4$, $V = 24\ \text{V}$, $R = 8\ \Omega$ from Figure 1 and solve for I_4.

$$\begin{aligned} I_4 &= \frac{24\ \text{V}}{8\ \Omega} \\ &= 3\ \text{A} \end{aligned}$$

Step 3 of 5

Calculate the current I_1 in Figure 1 by using Ohm's law $V = IR$.

Substitute $I = I_1$, $V = 24\ \text{V}$, $R = 4\ \Omega$ from Figure 1 and solve for I_1.

$$\begin{aligned} 4I_1 &= 24\ \text{V} \\ I_1 &= \frac{24\ \text{V}}{4\ \Omega} \\ &= 6\ \text{A} \end{aligned}$$

Therefore, the value of current I_1 in the circuit is $\boxed{6\ \text{A}}$.

Step 4 of 5

Apply Kirchhoff's current law at node 'B' in Figure 1 and solve for current I_2.

$$I_1 + I_2 = 2\ \text{A}$$

$$\begin{aligned} I_2 &= 2\ \text{A} - I_1 \\ &= 2\ \text{A} - 6\ \text{A} \\ &= -4\ \text{A} \end{aligned}$$

Therefore, the value of current I_2 in the circuit is $\boxed{-4\ \text{A}}$.

Step 5 of 5

Apply Kirchhoff's current law at node 'A' in Figure 1 and solve for current I_3.

$$I_3 + I_4 = I_1$$

$$\begin{aligned} I_3 &= I_1 - I_4 \\ &= 6\ \text{A} - 3\ \text{A} \\ &= 3\ \text{A} \end{aligned}$$

Therefore, the value of current I_3 in the circuit is $\boxed{3\ \text{A}}$.

Step 1 of 2

2.126p

Refer to circuit shown in Figure P2.119 in the text book.

Let the voltage across any parallel branch in the circuit be V_y .

Calculate the voltage V_x in the considered circuit by using voltage division rule.

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V$$

Substitute $4\ \Omega$ for R_x , $8\ \Omega$ for R_y in the equation to solve for V_x .

$$\begin{aligned} V_x &= \left(\frac{4\ \Omega}{4\ \Omega + 8\ \Omega}\right)(V_y) \\ &= \left(\frac{4}{12}\right)(V_y) \\ &= \frac{V_y}{3} \end{aligned}$$

Apply Kirchhoff's voltage law to solve for voltage V_y .

$$I_o + \frac{V_y}{8+4} + 3V_x = 5\ \text{A}$$

$$\frac{V_y}{6} + \frac{V_y}{12} + 3\left(\frac{V_y}{3}\right) = 5$$

$$V_y\left(\frac{1}{6} + \frac{1}{12} + 1\right) = 5$$

$$V_y = 4\ \text{V}$$

Step 2 of 2

Calculate the current I_o by using Ohm's law.

$$I = \frac{V}{R}$$

Substitute $6\ \Omega$ for R in the equation to solve for I_o .

$$\begin{aligned} I_o &= \frac{V_y}{R} \\ &= \frac{4\ \text{V}}{6\ \Omega} \\ &= 0.67\ \text{A} \end{aligned}$$

Therefore, the value of current I_o in the network is $\boxed{0.67\ \text{A}}$.

Step 1 of 7

Figure 1

Step 2 of 7

Let the current in various branches be I_1, I_2, I_3 as shown in figure 1.
Resistors 12kΩ, 4kΩ are in parallel.
Replace with $R_{eq} = (12\text{k}\Omega) \parallel (4\text{k}\Omega)$ between nodes a and c as shown in figure 2.

$$R_{eq} = \frac{1}{\frac{1}{12\text{k}} + \frac{1}{4\text{k}}}$$

$$R_{eq} = \frac{1}{\frac{1+3}{12\text{k}}}$$

$$R_{eq} = \frac{12\text{k}}{4}$$

$$R_{eq} = 3\text{k}\Omega$$

Step 3 of 7

Figure 2

Step 4 of 7

By Voltage Division rule in figure 2,

$$V_x = V_0\left(\frac{3\text{k}}{3\text{k}+3\text{k}}\right)$$

$$V_x = \frac{V_0}{2} \qquad \text{....(1)}$$

Step 5 of 7

As shown in figure 2, By Ohm's Law,

$$V_{ab} = I_1(12\text{k})$$

$$\because V_{ab} = V_0$$

$$I_1 = \frac{V_0}{12\text{k}} \qquad \text{....(2)}$$

$$V_{ab} = I_2(3\text{k}+3\text{k})$$

$$I_2 = \frac{V_0}{6\text{k}} \qquad \text{....(3)}$$

$$V_{ab} = I_3(2\text{k})$$

$$I_3 = \frac{V_0}{2\text{k}} \qquad \text{....(4)}$$

Step 6 of 7

Applying KCL at node a,

$$5\text{m} - I_3 - \frac{V_x}{2000} - I_2 - I_1 = 0$$

$$5\text{m} - \frac{V_0}{2\text{k}} - \frac{1}{2\text{k}}\left(\frac{V_0}{2}\right) - \frac{V_0}{6\text{k}} - \frac{V_0}{12\text{k}} = 0 \quad \text{....(from (1),(2),(3) and (4))}$$

$$V_0\left(\frac{1}{2\text{k}} + \frac{1}{4\text{k}} + \frac{1}{6\text{k}} + \frac{1}{12\text{k}}\right) = 5\text{m}$$

$$V_0\left(\frac{6+3+2+1}{12\text{k}}\right) = 5\text{m}$$

$$V_0\left(\frac{12}{12\text{k}}\right) = 5\text{m}$$

$$V_0 = 5\text{ V} \qquad \text{....(5)}$$

Step 7 of 7

Therefore Power absorbed by 12kΩ the resistor is,

$$P_{abs12} = \frac{V_0^2}{12\text{k}}$$

$$P_{abs12} = \frac{(5)^2}{12\text{k}} \qquad \text{....(By(5))}$$

$$P_{abs12} = \frac{25}{12}\text{ mW}$$

Hence $\boxed{P_{abs12} = 2.083\text{ mW}}$

Step 1 of 7

Step 2 of 7

Let the current in various branches be I_0, I_1, I_2, I_3.

Resistors 6kΩ, 3kΩ are in parallel.

Replace with $R_{eq} = (6\text{k}\Omega) \parallel (3\text{k}\Omega)$ between nodes c and b.

$$R_{eq} = \frac{1}{\frac{1}{6\text{k}} + \frac{1}{3\text{k}}}$$

$$R_{eq} = \frac{6\text{k}}{1+2}$$

$$R_{eq} = 2\text{k}\Omega$$

Step 3 of 7

Step 4 of 7

By Voltage Division rule in figure 2,

$$V_{cb} = V_0\left(\frac{2\text{k}}{2\text{k}+4\text{k}}\right)$$

$$V_{cb} = \frac{1}{3}V_0 \qquad \text{....(1)}$$

By Ohm's Law in figure 1,

$$V_{cb} = I_0(3\text{k})$$

$$\frac{1}{3}V_0 = I_0(3\text{k}) \qquad \text{....(from (1))}$$

$$I_0 = V_0\left(\frac{1}{9\text{k}}\right) \qquad \text{.... (2)}$$

Step 5 of 7

As shown in figure 2, By Ohm's Law,

$$V_{ab} = I_1(12\text{k})$$

$$I_1 = \frac{V_0}{12\text{k}} \qquad \text{....(3)}$$

$$V_{ab} = I_2(4\text{k}+2\text{k})$$

$$I_2 = \frac{V_0}{6\text{k}} \qquad \text{....(4)}$$

$$V_{ab} = I_3(4\text{k})$$

$$I_3 = \frac{V_0}{4\text{k}} \qquad \text{....(5)}$$

Step 6 of 7

Applying KCL at node a,

$$6\text{m} - I_3 - 3I_0 - I_2 - I_1 = 0$$

$$6\text{m} - \frac{V_0}{4\text{k}} - 3\left(\frac{V_0}{9\text{k}}\right) - \frac{V_0}{6\text{k}} - \frac{V_0}{12\text{k}} = 0 \qquad \text{....(from (2),(3),(4) and (5))}$$

$$V_0\left(\frac{1}{4\text{k}} + \frac{1}{3\text{k}} + \frac{1}{6\text{k}} + \frac{1}{12\text{k}}\right) = 6\text{m}$$

$$V_0\left(\frac{3+4+2+1}{12\text{k}}\right) = 6\text{m}$$

$$V_0\left(\frac{10}{12\text{k}}\right) = 6\text{m}$$

$$V_0 = 7.2\text{ V} \qquad \text{....(6)}$$

Step 7 of 7

Therefore Power absorbed by 12kΩ the resistor is

$$P_{abs12} = \frac{V_0^2}{12\text{k}}$$

$$P_{abs12} = \frac{(7.2)^2}{12\text{k}} \qquad \text{....(from (6))}$$

$$P_{abs12} = 4.32\text{ mW}$$

Hence $\boxed{P_{abs12} = 4.32\text{ mW}}$

Step 1 of 5

2.129p

Refer to circuit shown in Figure P2.121 in the text book.

Calculate the equivalent resistance R of resistors $6\ \Omega$ and $3\ \Omega$ connected in parallel by using the following formula.

$$R = \frac{R_x R_y}{R_x + R_y}$$

Substitute $6\ \Omega$ for R_x, $3\ \Omega$ for R_y in the equation to solve R.

$$\begin{aligned} R &= \frac{(6\ \Omega)(3\ \Omega)}{6\ \Omega + 3\ \Omega} \\ &= \frac{(6\ \Omega)(3\ \Omega)}{9\ \Omega} \\ &= 2\ \Omega \end{aligned}$$

Step 2 of 5

The considered circuit is reduced as shown in Figure 1.

Figure 1

Step 3 of 5

Calculate the voltage V_s in Figure 1 having power of $108\ \text{W}$ supplied by $6\ \text{A}$ source by using the following formula.

$$P = VI$$

Substitute $108\ \text{W}$ for P, $6\ \text{A}$ for I in the equation to solve for V_s.

$$\begin{aligned} V_s &= \frac{P}{I} \\ &= \frac{108\ \text{W}}{6\ \text{A}} \\ &= 18\ \text{V} \end{aligned}$$

Apply Kirchhoff's current law at top node in Figure 1 and solve.

$$\frac{V_s}{6\ \Omega} + kI_o + \frac{V_s}{(4\ \Omega + 2\ \Omega)} + \frac{V_s}{12\ \Omega} = 6\ \text{A}$$

$$\frac{18}{6} + kI_o + \frac{18}{6} + \frac{18}{12} = 6$$

$$\begin{aligned} kI_o &= 6 - \left(\frac{18}{6} + \frac{18}{6} + \frac{18}{12}\right) \\ &= -1.5\ \text{A} \end{aligned}$$

Step 4 of 5

Calculate the value of current I_2.

$$I_2 = \frac{V}{R}$$

Substitute $18\ \text{V}$ for V, $(4\ \Omega + 2\ \Omega)$ for R in the equation to solve for current I_2.

$$\begin{aligned} I_2 &= \frac{18\ \text{V}}{(4\ \Omega + 2\ \Omega)} \\ &= \frac{18\ \text{V}}{6\ \Omega} \\ &= 3\ \text{A} \end{aligned}$$

Step 5 of 5

Calculate the value of current I_o in Figure P2.121 in the text book by using current division following formula.

$$I_x = \left(\frac{R_y}{R_x + R_y}\right) I$$

Substitute $6\ \Omega$ for R_y, $3\ \Omega$ for R_x in the equation to solve for I_o.

$$\begin{aligned} I_o &= \left(\frac{6\ \Omega}{3\ \Omega + 6\ \Omega}\right)(I_2) \\ &= \left(\frac{6\ \Omega}{9\ \Omega}\right)(3\ \text{A}) \\ &= 2\ \text{A} \end{aligned}$$

Calculate the value of 'k'.

$$kI_o = -1.5\ \text{A}$$

$$\begin{aligned} k &= \frac{-1.5\ \text{A}}{2\ \text{A}} \\ &= -0.75 \end{aligned}$$

Therefore, the value of 'k' in the network is $\boxed{-0.75}$.

Step 1 of 6

2.130p

Refer to circuit in Figure P2.123 in the text book.

The nodes, voltages and current flow direction for the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the current I_o having power absorbed by 10 V source is 40 W by using the following formula.

$$P = VI$$

Substitute 40 W for P, 10 V for V in the equation to solve I_o.

$$\begin{aligned} I_o &= \frac{P}{V} \\ &= \frac{40\text{ W}}{10\text{ V}} \\ &= 4\text{ A} \end{aligned}$$

Calculate the voltage V_1 in Figure 1.

$$V_1 = IR$$

Substitute 4 A for I, $5\,\Omega$ for R in the equation to solve V_1.

$$\begin{aligned} V_1 &= (5\,\Omega)(I_o) \\ &= (5\,\Omega)(4\text{ A}) \\ &= 20\text{ V} \end{aligned}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the right hand side loop in Figure 1 and solve for voltage V_x.

$$\begin{aligned} V_x &= V_1 + 10\text{ V} \\ &= 20\text{ V} + 10\text{ V} \\ &= 30\text{ V} \end{aligned}$$

Calculate the current I_x in Figure 1.

$$I_x = \frac{V}{R}$$

Substitute 30 V for V, $15\,\Omega$ for R in the equation to solve I_x.

$$\begin{aligned} I_x &= \frac{30\text{ V}}{15\,\Omega} \\ &= 2\text{ A} \end{aligned}$$

Step 4 of 6

Apply Kirchhoff's current law at node 'a' in Figure 1 and solve for current I_2.

$$\begin{aligned} I_2 &= I_x + I_o \\ &= 2\text{ A} + 4\text{ A} \\ &= 6\text{ A} \end{aligned}$$

Calculate the voltage V_2 in Figure 1.

$$V_2 = IR$$

Substitute 6 A for I, $4\,\Omega$ for R in the equation to solve V_2.

$$\begin{aligned} V_2 &= (4\,\Omega)(I) \\ &= (4\,\Omega)(6\text{ A}) \\ &= 24\text{ V} \end{aligned}$$

Step 5 of 6

Apply Kirchhoff's voltage law to the loop formed by the voltages V_s, V_2, V_x in Figure 1 and solve for voltage V_s.

$$\begin{aligned} V_s &= V_2 + V_x \\ &= 24\text{ V} + 30\text{ V} \\ &= 54\text{ V} \end{aligned}$$

Apply Kirchhoff's voltage law to the loop formed by $0.6V_x$ dependent voltage source, V_s, V_3 from Figure 1 and solve for voltage V_3.

$$\begin{aligned} -0.6V_x - V_3 + V_s &= 0 \\ V_3 &= V_s - 0.6V_x \\ &= 54\text{ V} - (0.6)(30\text{ V}) \\ &= 36\text{ V} \end{aligned}$$

Step 6 of 6

Calculate the current I_3 in Figure 1.

$$I_3 = \frac{V}{R}$$

Substitute 36 V for V, $6\,\Omega$ for R in the equation to solve I_3.

$$\begin{aligned} I_3 &= \frac{36\text{ V}}{6\,\Omega} \\ &= 6\text{ A} \end{aligned}$$

Apply Kirchhoff's current law at node 'b' in Figure 1 and solve for current I_S.

$$\begin{aligned} I_S &= I_2 + I_3 \\ &= 6\text{ A} + 6\text{ A} \\ &= 12\text{ A} \end{aligned}$$

Therefore, the value of current I_S in the circuit is $\boxed{12\text{ A}}$.

Step 1 of 7

Consider the circuit shown in Figure P2.124 in the text book.

The nodes, voltages and current flow directions for the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 7

Calculate the voltage V_2 in Figure 1 having $50\ \text{W}$ power supplied by $2\ \text{A}$ current source by using the following formula.

$$P = VI$$

Substitute $50\ \text{W}$ for P, V_2 for V, $2\ \text{A}$ for I in the equation.

$$\begin{aligned} V_2 &= \frac{P}{I} \\ &= \frac{50\ \text{W}}{2\ \text{A}} \\ &= 25\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law to the left hand side loop formed by voltages of $50\ \text{V}$, V_1, V_2 in Figure 1 and solve for voltage V_1.

$$V_1 + V_2 = 50\ \text{V}$$

$$\begin{aligned} V_1 &= 50\ \text{V} - V_2 \\ &= 50\ \text{V} - 25\ \text{V} \\ &= 25\ \text{V} \end{aligned}$$

Step 3 of 7

Calculate the current I_1 in Figure 1

$$I_1 = \frac{V}{R}$$

Substitute $25\ \text{V}$ for V, $5\ \Omega$ for R in the equation to solve I_1.

$$\begin{aligned} I_1 &= \frac{V}{R} \\ &= \frac{25\ \text{V}}{5\ \Omega} \\ &= 5\ \text{A} \end{aligned}$$

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve for current I_3.

$$\begin{aligned} I_3 &= I_1 + 2\ \text{A} \\ &= 5\ \text{A} + 2\ \text{A} \\ &= 7\ \text{A} \end{aligned}$$

Step 4 of 7

Calculate the voltage V_3 in Figure 1.

$$V_3 = IR$$

Substitute $7\ \text{A}$ for I, $2\ \Omega$ for R in the equation to solve V_3.

$$\begin{aligned} V_3 &= IR \\ &= (7\ \text{A})(2\ \Omega) \\ &= 14\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law to the loop formed by voltages V_2, V_3, V_4 in Figure 1 and solve for voltage V_4.

$$-V_2 + V_3 + V_4 = 0$$

$$\begin{aligned} V_4 &= V_2 - V_3 \\ &= 25\ \text{V} - 14\ \text{V} \\ &= 11\ \text{V} \end{aligned}$$

Step 5 of 7

Calculate the current I_4 in Figure 1.

$$I_4 = \frac{V}{R}$$

Substitute $11\ \text{V}$ for V, $5\ \Omega$ for R in the equation to solve I_4.

$$\begin{aligned} I_4 &= \frac{V}{R} \\ &= \frac{11\ \text{V}}{5\ \Omega} \\ &= 2.2\ \text{A} \end{aligned}$$

Apply Kirchhoff's current law at node '*b*' in Figure 1 and solve for current I_5.

$$I_4 + I_5 = I_3$$

$$\begin{aligned} I_5 &= I_3 - I_4 \\ &= 7\ \text{A} - 2.2\ \text{A} \\ &= 4.8\ \text{A} \end{aligned}$$

Step 6 of 7

Calculate the voltage V_5 in Figure 1.

$$V_5 = IR$$

Substitute $4.8\ \text{A}$ for I, $4\ \Omega$ for R in the equation to solve V_5.

$$\begin{aligned} V_5 &= IR \\ &= (4.8\ \text{A})(4\ \Omega) \\ &= 19.2\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law to the loop formed by voltages V_4, V_5, V_6 in Figure 1 and solve for voltage V_6.

$$-V_4 + V_5 + V_6 = 0$$

$$\begin{aligned} V_6 &= V_4 - V_5 \\ &= 11\ \text{V} - 19.2\ \text{V} \\ &= -8.2\ \text{V} \end{aligned}$$

Step 7 of 7

Calculate the current I_6 in Figure 1.

$$I_6 = \frac{V}{R}$$

Substitute $-8.2\ \text{V}$ for V, $2\ \Omega$ for R in the equation to solve I_6.

$$\begin{aligned} I_6 &= \frac{V}{R} \\ &= \frac{-8.2\ \text{V}}{2\ \Omega} \\ &= -4.1\ \text{A} \end{aligned}$$

Apply Kirchhoff's current law at node '*c*' in Figure 1 and solve for the value of 'k'.

$$I_6 + kI_1 = I_5$$

$$kI_1 = I_5 - I_6$$

$$k(5\ \text{A}) = 4.8\ \text{A} - (-4.1\ \text{A})$$

$$k = 1.78$$

Therefore, the value of '*k*' in the circuit is $\boxed{1.78}$.

Step 1 of 2

3.1e

Refer to circuit shown in Figure E3.1 in the text book.

Apply Kirchhoff's current law at node V_1 .

$$4\times10^{-3}=\frac{V_1}{6\text{ k}}+\frac{V_1-V_2}{12\text{ k}}$$

$$\frac{V_1}{6\text{ k}}+\frac{V_1}{12\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

$$\frac{2V_1+V_1}{12\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

$$\frac{V_1}{4\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

Therefore, the equation at node V_1 in the circuit is $\boxed{\frac{V_1}{4\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}}$.

Step 2 of 2

Apply Kirchhoff's current law at node V_2 .

$$\frac{V_2-V_1}{12\text{ k}}+\frac{V_2}{6\text{ k}}+2\times10^{-3}=0$$

$$\frac{V_2}{12\text{ k}}-\frac{V_1}{12\text{ k}}+\frac{V_2}{6\text{ k}}=-2\times10^{-3}$$

$$-\frac{V_1}{12\text{ k}}+\frac{V_2+2V_2}{12\text{ k}}=-2\times10^{-3}$$

$$-\frac{V_1}{12\text{ k}}+\frac{V_2}{4\text{ k}}=-2\times10^{-3}$$

Therefore, the equation at node V_2 in the circuit is $\boxed{\frac{-V_1}{12\text{ k}}+\frac{V_2}{4\text{ k}}=-2\times10^{-3}}$.

Step 1 of 2

Refer to circuit shown in Figure E3.1 in the text book.

Apply Kirchhoff's current law at node V_1 .

$$4\times10^{-3}=\frac{V_1}{6\text{ k}}+\frac{V_1-V_2}{12\text{ k}}$$

$$\frac{V_1}{6\text{ k}}+\frac{V_1}{12\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

$$\frac{2V_1+V_1}{12\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

$$\frac{V_1}{4\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}$$

Therefore, the equation at node V_1 in the circuit is $\boxed{\frac{V_1}{4\text{ k}}-\frac{V_2}{12\text{ k}}=4\times10^{-3}}$.

Step 2 of 2

Apply Kirchhoff's current law at node V_2 .

$$\frac{V_2-V_1}{12\text{ k}}+\frac{V_2}{6\text{ k}}+2\times10^{-3}=0$$

$$\frac{V_2}{12\text{ k}}-\frac{V_1}{12\text{ k}}+\frac{V_2}{6\text{ k}}=-2\times10^{-3}$$

$$-\frac{V_1}{12\text{ k}}+\frac{V_2+2V_2}{12\text{ k}}=-2\times10^{-3}$$

$$-\frac{V_1}{12\text{ k}}+\frac{V_2}{4\text{ k}}=-2\times10^{-3}$$

Therefore, the equation at node V_2 in the circuit is $\boxed{\frac{-V_1}{12\text{ k}}+\frac{V_2}{4\text{ k}}=-2\times10^{-3}}$.

Step 1 of 2

3.1p

Consider the circuit shown in Figure 3PFE-1 in the text book.

Apply Kirchhoff's current law at node V_x in the considered circuit and solve.

$$\frac{V_x-12}{2}+\frac{V_x}{1+2}+\frac{V_x-(-6)}{6}=0$$
$$\frac{V_x-12}{2}+\frac{V_x}{3}+\frac{V_x+6}{6}=0$$
$$3(V_x-12)+2V_x+V_x+6=0$$
$$3V_x-36+2V_x+V_x+6=0$$

Simplify the expression further.

$$6V_x=36-6$$

$$\begin{aligned}V_x&=\frac{30}{6}\\&=5\text{ V}\end{aligned}$$

Step 2 of 2

Calculate the value of voltage V_o in the considered circuit by using voltage division formula

$$V_1=\left(\frac{R_1}{R_1+R_2}\right)V\ .$$

Substitute $V_1=V_o$, $R_1=2\ \Omega$, $R_2=1\ \Omega$, $V=5\text{ V}$ from considered circuit and solve for V_o .

$$\begin{aligned}V_o&=\left(\frac{2\ \Omega}{2\ \Omega+1\ \Omega}\right)(5\text{ V})\\&=\left(\frac{2}{3}\right)(5\text{ V})\\&=(0.66)(5\text{ V})\\&=3.33\text{ V}\end{aligned}$$

Therefore, the value of voltage V_o in the circuit is 3.33 V and so the correct answer is option $\boxed{\text{a}}$.

Step 1 of 3

3.2e

Refer to the circuit shown in Figure E3.2 in the text book.

Apply Kirchhoff's current law at node voltage V_1 in the circuit and solve.

$$-4\text{m}+\frac{V_1-V_2}{2\text{k}}+\frac{V_1-V_3}{1\text{k}}=0$$

$$\frac{V_1}{2\text{k}}-\frac{V_2}{2\text{k}}+\frac{2V_1}{2\text{k}}-\frac{2V_3}{2\text{k}}=4\text{m}$$

$$3V_1-V_2-2V_3=8 \text{ ..... (1)}$$

Apply Kirchhoff's current law at node voltage V_2 in the circuit and solve.

$$\frac{V_2-V_1}{2\text{k}}+\frac{V_2-V_3}{4\text{k}}+\frac{V_2}{1\text{k}}=0$$

$$2(V_2-V_1)+V_2-V_3+4V_2=0$$

$$2V_2-2V_1+V_2-V_3+4V_2=0$$

$$-2V_1+7V_2-V_3=0 \text{ ..... (2)}$$

Step 2 of 3

Apply Kirchhoff's current law at node voltage V_3 in the circuit and solve.

$$\frac{V_3-V_1}{1\text{k}}+\frac{V_3-V_2}{4\text{k}}+2\text{m}=0$$

$$\frac{4(V_3-V_1)}{4\text{k}}+\frac{V_3-V_2}{4\text{k}}=-2\text{m}$$

$$4V_3-4V_1+V_3-V_2=-(2\text{m})(4\text{k})$$

$$-4V_1-V_2+5V_3=-8 \text{ ..... (3)}$$

Now write the equations of (1), (2) and (3) in the matrix notation form.

$$\begin{bmatrix}3 & -1 & -2\\ -2 & 7 & -1\\ -4 & -1 & 5\end{bmatrix}\begin{bmatrix}V_1\\ V_2\\ V_3\end{bmatrix}=\begin{bmatrix}8\\ 0\\ -8\end{bmatrix}$$

Step 3 of 3

Solve the set of three equations by using MATLAB.

```
%solving the equations by using matlab.

R=[3,-1,-2;-2,7,-1;-4,-1,5];

I=[8,0,-8]';

V=inv(R)*I

%
```

Execute the program in the command window of MATLAB.

The MATLAB output is,

```
V =

5.4286

2.0000

3.1429
```

The node voltages are,

$$V_1=5.4286 \text{ V}$$
$$V_2=2.0000 \text{ V}$$
$$V_3=3.1429 \text{ V}$$

Therefore, the values of node voltages V_1 is $\boxed{5.428 \text{ V}}$, V_2 is $\boxed{2 \text{ V}}$ and V_3 is $\boxed{3.1429 \text{ V}}$.

Step 1 of 2

3.2fe

Consider the circuit shown in Figure 3PFE-2 in the text book.

Calculate the value of current I_1 in the considered circuit by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_1$, $V = 12 - V_x$, $R = 4\ \Omega$ from the considered circuit and solve.

$$I_1 = \frac{12 - V_x}{4}$$

Apply Kirchhoff's current law at node V_x in considered circuit and solve.

$$-I_x + \frac{V_x}{6} - 2I_x + \frac{V_x}{12} = 0$$
$$-3I_x + \frac{2V_x + V_x}{12} = 0$$
$$-3\left(\frac{12 - V_x}{4}\right) + \frac{3V_x}{12} = 0$$
$$-36 + 3V_x + V_x = 0$$

Simplify the expression further.

$$4V_x = 36$$
$$V_x = 9\ \text{V}$$

Step 2 of 2

Calculate the power dissipated in the $6\ \Omega$ resistor by using the formula $P = \frac{V^2}{R}$.

Substitute $P = P_{6\Omega}$, $V = 9\ \text{V}$, $R = 6\ \Omega$ from the considered circuit and solve.

$$P_{6\Omega} = \frac{(9\ \text{V})^2}{6\ \Omega}$$
$$= \frac{81}{6}$$
$$= 13.5\ \text{W}$$

Therefore, the value of power dissipated in $6\ \Omega$ resistor is $13.5\ \text{W}$ and so the correct answer is option $\boxed{\text{d}}$.

Step 1 of 5

Figure 1

Step 2 of 5

Mark the nodes and corresponding voltage levels as shown in figure 1.

Applying KCL at node 1

$$2\text{m} - \frac{V_1 - V_2}{6\text{k}} - \frac{V_1}{3\text{k}} = 0$$
$$\frac{(-1-2)V_1}{6\text{k}} + \frac{V_2}{6\text{k}} = -2\text{m}$$
$$-3V_1 + V_2 = -12$$
$$V_2 = -12 + 3V_1 \qquad \text{....(1)}$$

Step 3 of 5

Applying KCL at node 2

$$\frac{V_1 - V_2}{6\text{k}} - \frac{V_2}{12\text{k}} - 4\text{m} = 0$$
$$\frac{2V_1 - 2V_2}{12\text{k}} - \frac{V_2}{12\text{k}} = 4\text{m}$$
$$2V_1 - 3V_2 = (4\text{m})(12\text{k})$$
$$2V_1 - 3(-12 + 3V_1) = 48 \qquad \text{....(By(1))}$$
$$-7V_1 = 48 - 36$$
$$V_1 = -\frac{12}{7}\ \text{V} \qquad \text{....(2)}$$
$$\therefore V_2 = -12 + 3\left(-\frac{12}{7}\right) \qquad \text{....(By(1) and (2))}$$
$$V_2 = -\frac{120}{7}\ \text{V} \qquad \text{....(3)}$$

Step 4 of 5

By Ohm's Law,

$$V_1 = I_O(3\text{k})$$
$$-\frac{12}{7} = I_O(3\text{k}) \qquad \text{....(By(2))}$$
$$I_O = -\frac{4}{7}\ \text{mA} \qquad \text{....(4)}$$

Hence $\boxed{I_o = -0.571\ \text{mA}}$

Step 5 of 5

Also from the figure 1,

$$V_O = V_1 - V_2$$
$$V_O = -\frac{12}{7} - \left(-\frac{120}{7}\right) \qquad \text{....(By(2) and (3))}$$
$$V_O = \frac{108}{7}\ \text{V}$$

Hence $\boxed{V_o = 15.429\ \text{V}}$

Step 1 of 5

3.3e

Refer to circuit shown in Figure E3.3 in the text book.

The nodes for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law at node V_a in the Figure 1 and solve.

$$\frac{V_a}{3\text{ k}}+\frac{V_a-V_b}{6\text{ k}}+\left(2\times10^{-3}\right)=8\times10^{-3}$$
$$\frac{V_a}{3\text{ k}}+\frac{V_a}{6\text{ k}}-\frac{V_b}{6\text{ k}}=\left(8\times10^{-3}\right)-\left(2\times10^{-3}\right)$$
$$2V_a+V_a-V_b=6\times10^{-3}$$

$V_b=3V_a-36$ ..... (1)

Step 3 of 5

Apply Kirchhoff's current law at node V_b in the Figure 1 and solve.

$$\frac{V_b-V_a}{6\text{ k}}+\frac{V_b}{6\text{ k}}+\frac{V_b-V_c}{2\text{ k}}=0$$
$$\frac{V_b}{6\text{ k}}-\frac{V_a}{6\text{ k}}+\frac{V_b}{6\text{ k}}+\frac{V_b}{2\text{ k}}-\frac{V_c}{2\text{ k}}=0$$
$$-\frac{V_a}{6\text{ k}}+\frac{V_b+V_b+3V_b}{6\text{ k}}-\frac{3V_c}{6\text{ k}}=0$$

$-V_a+5V_b-3V_c=0$ ..... (2)

Substitute the value of V_b and simplify the equation (2) further.

$$-V_a+5(3V_a-36)-3V_c=0$$
$$-V_a+15V_a-180-3V_c=0$$
$$14V_a=180+3V_c$$

$V_a=\frac{180+3V_c}{14}$ ..... (3)

Step 4 of 5

Apply Kirchhoff's current law at node V_c in the Figure 1 and solve.

$$\frac{V_c-V_b}{2\text{ k}}+\frac{V_c}{1\text{ k}}-\left(2\times10^{-3}\right)=0$$
$$\frac{V_c}{2\text{ k}}-\frac{V_b}{2\text{ k}}+\frac{2V_c}{2\text{ k}}=2\times10^{-3}$$
$$\frac{V_c+2V_c}{2\text{ k}}-\frac{V_b}{2\text{ k}}=2\times10^{-3}$$

$3V_c-V_b=4$ ..... (4)

Step 5 of 5

Substitute the values of V_a and V_b in equation (4) to calculate V_c.

$$3V_c-3V_a+36=4$$
$$3V_c-3\left(\frac{180+3V_c}{14}\right)+36=4$$
$$42V_c-540-9V_c+(36)(14)=(4)(14)$$
$$33V_c=56+540-504$$

Simplify the expression further.

$$33V_c=92$$

$$V_c=\frac{92}{33}$$
$$=2.79\text{ V}$$

In figure 1 the value of voltage at node V_c is equal to V_a.

Therefore, the value of voltage in the circuit is $\boxed{2.79\text{ V}}$.

Step 1 of 2

3.3fe

Consider the circuit shown in Figure 3PFE-3 in the text book.

The value of top node voltage in the considered circuit is V_x .

Now, apply Kirchhoff's current law to the top node V_x in the considered circuit and solve for V_x .

$$\frac{V_x - 12}{6} - 2 + \frac{V_x}{4} + \frac{V_x - 2V_x}{3} = 0$$
$$2(V_x - 12) - 2(12) + 3V_x + 4(-V_x) = 0$$
$$2V_x - 24 - 24 + 3V_x - 4V_x = 0$$
$$V_x = 48 \text{ V}$$

Step 2 of 2

Calculate the value of current I_x in the considered circuit by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = 48 \text{ V}$, $R = 4\ \Omega$ from the considered circuit and solve for I_x .

$$I_x = \frac{48 \text{ V}}{4\ \Omega}$$
$$= 12 \text{ A}$$

Therefore, the value of current I_x in the considered circuit is 12 A and so the correct answer is option $\boxed{\text{b}}$

Step 1 of 1

3.3p

Consider the circuit shown in Figure P3.2 in the text book.

Calculate the value of current I_1 in the circuit by using current division rule $I_x = \left(\frac{R_y}{R_x + R_y}\right) I$.

Substitute I_1 for I_x, $12\ \text{k}\Omega$ for R_x, $6\ \text{k}\Omega$ for R_y and $-6\ \text{mA}$ for I in the equation and solve for I_1.

$$\begin{aligned} I_1 &= \left(\frac{6\ \text{k}\Omega}{12\ \text{k}\Omega + 6\ \text{k}\Omega}\right)(-6\ \text{mA}) \\ &= \left(\frac{6\ \text{k}\Omega}{18\ \text{k}\Omega}\right)(-6\ \text{mA}) \\ &= \left(\frac{1}{3}\right)(-6\ \text{mA}) \\ &= -2\ \text{mA} \end{aligned}$$

Therefore, the value of current I_1 in the network is $\boxed{-2\ \text{mA}}$.

Step 1 of 4

3.4e

Consider the circuit shown in Figure E3.4 in the text book.

Apply Kirchhoff's current law at node V_1 in considered circuit and solve.

$$\frac{V_1}{10\text{ k}} - 4\times10^{-3} + \frac{V_1 - V_2}{10\text{ k}} = 0$$

$$\frac{V_1}{10\text{ k}} + \frac{V_1}{10\text{ k}} - \frac{V_2}{10\text{ k}} = 4\times10^{-3}$$

$$2V_1 - V_2 = \left(4\times10^{-3}\right)\left(10\times10^{-3}\right)$$

$V_2 = 2V_1 - 40$ ..... (1)

Step 2 of 4

Apply Kirchhoff's current law at node V_2 in the considered circuit and solve.

$$\frac{V_2 - V_1}{10\text{ k}} + 2I_0 + \frac{V_2}{10\text{ k}} = 0$$

$$\frac{V_2}{10\text{ k}} - \frac{V_1}{10\text{ k}} + 2\left(\frac{V_1}{10\text{ k}}\right) + \frac{V_2}{10\text{ k}} = 0$$

$$\frac{V_2 + V_2}{10\text{ k}} = \frac{-2V_1 + V_1}{10\text{ k}}$$

$2V_2 = -V_1$ ..... (2)

Step 3 of 4

Substitute $V_1 = -2V_2$ in equation (1) and solve for V_2.

$$V_2 = 2(-2V_2) - 40$$

$$V_2 = -4V_2 - 40$$

$$5V_2 = -40$$

$$V_2 = -8\text{ V}$$

Therefore, the value of voltage V_2 is $\boxed{-8\text{ V}}$.

Step 4 of 4

Substitute $V_2 = -8\text{ V}$ in equation (2) and solve for V_1.

$$\begin{aligned} V_1 &= -2V_2 \\ &= (-2)(-8\text{ V}) \\ &= 16\text{ V} \end{aligned}$$

Therefore, the value of voltage V_1 is $\boxed{16\text{ V}}$.

Step 1 of 2

3.4fe

Consider the circuit shown in Figure 3PFE-4 in the text book.

Apply Kirchhoff's current law at node V_x in the considered figure and solve.

$$\frac{V_x - 12}{4} + \frac{V_x}{2} + \frac{V_x - V_o}{4} = 0$$
$$V_x - 12 + 2V_x + V_x - V_o = 0$$
$$4V_x - V_o = 12$$

$$V_x = \frac{V_o + 12}{4} \text{ ..... (1)}$$

Step 2 of 2

Apply Kirchhoff's current law at node V_o in the considered circuit and solve.

$$\frac{V_o - V_x}{4} + 2I_x + \frac{V_o}{4} = 0$$
$$\frac{V_o - V_x}{4} + 2\left(\frac{V_x}{2}\right) + \frac{V_o}{4} = 0$$
$$V_o - V_x + 4V_x + V_o = 0$$

$$3V_x + 2V_o = 0 \text{ ..... (2)}$$

Substitute equation (1) in (2) and solve for voltage V_o .

$$3\left(\frac{V_o + 12}{4}\right) + 2V_o = 0$$
$$3V_o + 36 + 8V_o = 0$$
$$11V_o = -36$$
$$V_o = -3.28 \text{ V}$$

Therefore, the value of voltage V_o in the circuit is -3.28 V and so the correct answer is option $\boxed{\text{a}}$.

Step 1 of 4

3.4p

Consider the circuit shown in Figure P3.1 in the text book.

The nodes and current flow direction in the branches of considered circuit is shown in Figure 1.

Step 2 of 4

Figure 1

Step 3 of 4

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve for current I_2.

$$I_2 + 4\text{ mA} = 2\text{ mA}$$

$$\begin{aligned} I_2 &= 2\text{ mA} - 4\text{ mA} \\ &= -2\text{ mA} \end{aligned}$$

Step 4 of 4

Apply Kirchhoff's current law at node '*b*' in Figure 1 and solve for current I_1.

$$I_1 + I_2 = 2\text{ mA}$$

$$\begin{aligned} I_1 &= 2\text{ mA} - I_2 \\ &= 2\text{ mA} - (-2\text{ mA}) \\ &= 4\text{ mA} \end{aligned}$$

Therefore, the value of current I_1 in the circuit is $\boxed{4\text{ mA}}$.

Step 1 of 4

3.5e

Refer to circuit shown in Figure E3.5 in the text book.

Calculate the equivalent resistance R of resistors $12\ \text{k}\Omega$ and $12\ \text{k}\Omega$ connected in parallel in considered circuit by using the following formula.

$$R = \frac{R_x R_y}{R_x + R_y}$$

Substitute $12\ \text{k}\Omega$ for R_x , $12\ \text{k}\Omega$ for R_y and solve for R .

$$\begin{aligned} R &= \frac{(12\ \text{k}\Omega)(12\ \text{k}\Omega)}{12\ \text{k}\Omega + 12\ \text{k}\Omega} \\ &= \frac{(12\ \text{k}\Omega)(12\ \text{k}\Omega)}{24\ \text{k}\Omega} \\ &= 6\ \text{k}\Omega \end{aligned}$$

Step 2 of 4

The circuit is reduced as shown in Figure 1.

Figure 1

Step 3 of 4

Apply Kirchhoff's current law at node V_x in Figure 1 and solve.

$$\begin{aligned} -2\times10^{-3} + \frac{V_x}{3\text{k}} + \frac{V_x}{6000} &= 0 \\ \frac{2V_x + V_x}{6000} &= 2\times10^{-3} \\ 3V_x &= \left(2\times10^{-3}\right)\left(6\times10^{3}\right) \\ V_x &= 4\ \text{V} \end{aligned}$$

Step 4 of 4

Apply Kirchhoff's current law to node V_o in Figure 1 and solve for V_o .

$$\begin{aligned} \frac{-V_x}{6000} + \frac{V_o}{6\text{k}} &= 0 \\ \frac{V_o}{6\text{k}} &= \frac{+V_x}{6000} \\ V_o &= V_x \\ &= 4\ \text{V} \end{aligned}$$

Therefore, the voltage V_o across $12\ \text{k}\Omega$ resistor is $\boxed{4\ \text{V}}$.

Step 1 of 2

3.5fe

Consider the circuit shown in Figure 3PFE-5 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

4

The node voltages V_1 and V_2 forms a super node in Figure 1 and so the voltage V_2 is,

$$V_2 = V_1 + 10.$$

Apply Kirchhoff's current law at super node in Figure 1 and solve for V_1.

$$\frac{V_1}{3+1} + 8 - 4 + \frac{V_2 - 15}{2} = 0$$

$$\frac{V_1}{4} + \frac{V_2 - 15}{2} = -4$$

Substitute $V_1 + 10$ for V_2 in the equation.

$$\frac{V_1}{4} + \frac{(V_1 + 10) - 15}{2} = -4$$

$$\frac{V_1}{4} + \frac{(V_1 - 5)2}{4} = -4$$

$$V_1 + 2V_1 - 10 = (4)(-4)$$

Simplify the expression further.

$$3V_1 - 10 = -16$$

$$3V_1 = -6$$

$$V_1 = -2 \text{ V}$$

Therefore, the value of voltage V_1 in the circuit is -2 V and so the correct answer is option $\boxed{c}$.

Step 1 of 4

3.5p

Consider the circuit shown in Figure P3.4 in the text book.

The nodes, voltages and currents for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$\frac{V_1}{3k}+\left(6\times10^{-3}\right)+\frac{V_1-V_2}{2k}=0$$

$$\frac{2V_1}{6k}+\frac{(6k)\left(6\times10^{-3}\right)}{6k}+\frac{3(V_1-V_2)}{6k}=0$$

$$2V_1+36+3V_1-3V_2=0$$

$$5V_1-3V_2=-36 \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-V_1}{2k}+\left(4\times10^{-3}\right)+\frac{V_2}{2k}+\frac{V_2}{2k}=0$$

$$V_2-V_1+(8)+V_2+V_2=0$$

$$3V_2-V_1=-8$$

$$V_2=\frac{V_1-8}{3} \quad \text{..... (2)}$$

Step 4 of 4

Substitute equation (2) in (1) and solve for voltage V_1.

$$5V_1-3\left(\frac{V_1-8}{3}\right)=-36$$

$$5V_1-V_1+8=-36$$

$$4V_1=-36-8$$

$$V_1=-11\text{ V}$$

Therefore, the value of voltage V_1 in the circuit is $\boxed{-11\text{ V}}$.

Step 1 of 6

Consider the circuit shown in Figure P3.6 in the text book.

The nodes for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the value of current I_A from Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute I_A for I, $V_b - V_o$ for V, $2\ \text{k}\Omega$ for R from Figure 1 and solve for I_A.

$$I_A = \frac{V_b - V_o}{2\ \text{k}\Omega}$$

Apply Kirchhoff's current law at node V_a in Figure 1 and solve.

$$-2I_A + \frac{V_a}{3\ \text{k}} + \frac{V_a - V_b}{6\ \text{k}} + \left(2\times10^{-3}\right) = 0$$

$$\frac{2V_a + V_a}{6\ \text{k}} - \frac{V_b}{6\ \text{k}} = 2I_o - \left(2\times10^{-3}\right)$$

$$3V_a - V_b = (2I_a)(6\ \text{k}) - \left(2\times10^{-3}\right)\left(6\times10^{3}\right)$$

$$V_a = \frac{(12\ \text{k})I_a - 12 + V_b}{3} \quad \text{..... (1)}$$

Step 3 of 6

Apply Kirchhoff's current law at node V_b in Figure 1 and solve.

$$\frac{V_b - V_a}{6\ \text{k}} + \frac{V_b}{6\ \text{k}} + I_A = 0$$

$$\frac{2V_b}{6\ \text{k}} - \frac{V_a}{6\ \text{k}} + I_A = 0$$

Substitute the values of V_a from equation (1) and simplify further.

$$\frac{2V_b}{6\ \text{k}} - \left(\frac{12\text{k}I_A - 12 + V_b}{(3)(6\ \text{k})}\right) + I_A = 0$$

$$\frac{2V_b}{6\ \text{k}} - \frac{12\text{k}I_A}{18\ \text{k}} + \frac{12}{18\ \text{k}} - \frac{V_b}{18\ \text{k}} + I_A = 0$$

$$(2)(3)V_b - (12\ \text{k})I_A + 12 - V_b + (18\ \text{k})I_A = 0$$

$$5V_b = -6\text{k}I_A - 12 \quad \text{..... (2)}$$

Step 4 of 6

Apply Kirchhoff's current law at node V_a in Figure 1 and solve.

$$I_A + 2\times10^{-3} = \frac{V_0}{1\text{k}}$$

$$1\text{k}I_A + \left(2\times10^{-3}\right)\left(1\times10^{3}\right) = V_0$$

$$1\text{k}I_A + 2 = V_0 \quad \text{..... (3)}$$

Step 5 of 6

Substitute the value of V_b and V_o from equations (2) and (3) in (1) and solve for I_A.

$$\begin{aligned} I_A &= \frac{1}{2\ \text{k}}\left(\frac{-6\ \text{k}I_A - 12}{5} - (1\ \text{k}I_A + 2)\right) \\ &= \frac{1}{2\ \text{k}}(-1.2\ \text{k}I_A - 2.4 - 1\ \text{k}I_A - 2) \\ &= \frac{1}{2\text{k}}(-2.2\ \text{k}I_A - 4.4) \\ &= -1.1I_A - 2.2\times10^{-3} \end{aligned}$$

Simplify the expression further.

$$I_A + 1.1I_A = -2.2\times10^{-3}$$

$$2.1I_A = -2.2\times10^{-3}$$

$$I_A = -1.047\times10^{-3}$$

Step 6 of 6

Substitute the value of I_A in equation (3) and solve for V_o.

$$\begin{aligned} V_o &= (1\text{k})(-1.047\text{m}) + 2 \\ &= \left(1\times10^{3}\right)\left(-1.047\times10^{-3}\right) + 2 \\ &= -1.047 + 2 \\ &= 0.953\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{0.953\ \text{V}}$.

Step 1 of 4

3.6p

Consider the circuit shown in Figure P3.5 in the text book.

Apply Kirchhoff's current law at node V_1 in the circuit and solve.

$$-\left(4\times10^{-3}\right)+\frac{V_1}{6k}+\frac{V_1-V_2}{4k}+\left(6\times10^{-3}\right)=0$$

$$\frac{2V_1}{12k}+\frac{3V_1}{12k}-\frac{3V_2}{12k}=-2\times10^{-3}$$

$$5V_1-3V_2=-24$$

$$V_1=\frac{3V_2-24}{5} \quad \text{..... (1)}$$

Step 2 of 4

Apply Kirchhoff's current law at node V_2 in the circuit and solve.

$$\frac{V_2-V_1}{4k}+\frac{V_2}{3k}-\left(6\times10^{-3}\right)+\frac{V_2}{6k}=0$$

$$\frac{3V_2}{12k}-\frac{3V_1}{12k}+\frac{4V_2}{12k}-\frac{(12k)\left(6\times10^{-3}\right)}{12k}+\frac{2V_2}{12k}=0$$

$$9V_2-3V_1=72$$

$$3V_2-V_1=24 \quad \text{..... (2)}$$

Step 3 of 4

Substitute equation (1) in (2) and solve for voltage V_2.

$$3V_2-\left(\frac{3V_2-24}{5}\right)=24$$

$$15V_2-3V_2+24=(24)(5)$$

$$12V_2=120-24$$

$$V_2=8\text{ V}$$

Therefore, the value of voltage V_2 is in the circuit is $\boxed{8\text{ V}}$.

Step 4 of 4

Substitute $V_2=8\text{ V}$ in equation (1) and solve for voltage V_1.

$$V_1=\frac{(3)(8\text{ V})}{5}-24$$

$$=\frac{24-24}{5}$$

$$=\frac{0}{5}$$

$$=0$$

Therefore, the value of voltage V_1 in the circuit is $\boxed{0\text{ V}}$.

Step 1 of 2

3.7e

Refer to circuit shown in Figure E3.7 in the text book.

Apply Kirchhoff's current law at node V_o in the circuit and solve for V_o.

$$\frac{V_o-6}{6\text{ k}}+\frac{V_o}{3\text{ k}}+\frac{V_o-3}{6\text{ k}}=0$$
$$V_o-6+2V_o+V_o-3=0$$
$$4V_o=9$$
$$V_o=\frac{9}{4}\text{ V}$$

Step 2 of 2

Calculate the value of current I_o by using Ohm's law $I=\frac{V}{R}$.

Substitute I_o for I, $\frac{9}{4}\text{V}$ for V, $3\text{ k}\Omega$ for R from the considered circuit and solve for I_o.

$$\begin{aligned}I_o&=\frac{\frac{9}{4}\text{ V}}{3\text{ k}\Omega}\\&=\left(\frac{9\text{ V}}{4}\right)\left(\frac{1}{3\text{ k}\Omega}\right)\\&=\frac{3}{4}\text{ mA}\end{aligned}$$

Therefore, the value of current I_o in the network is $\boxed{\frac{3}{4}\text{ mA}}$.

3.7p

Step 1 of 5

Consider the circuit shown in Figure P3.6 in the text book.

Apply Kirchhoff's current law at node V_1 in the circuit and solve.

$$-\left(12\times10^{-3}\right)+\frac{V_1-V_2}{6k}+\left(2\times10^{-3}\right)+\frac{V_1}{3k}=0$$

$$\frac{V_1}{6k}-\frac{V_2}{6k}+\frac{2V_1}{6k}=10\times10^{-3}$$

$$3V_1-V_2=\left(10\times10^{-3}\right)\left(6\times10^{-3}\right)$$

$$V_2=3V_1-60 \text{ ..... (1)}$$

Step 2 of 5

Apply Kirchhoff's current law at node V_2 in the circuit and solve.

$$\frac{V_2-V_1}{6k}-\left(2\times10^{-3}\right)+\frac{V_2}{6k}+\frac{V_2-V_o}{2k}=0$$

$$\frac{V_2}{6k}-\frac{V_1}{6k}-\frac{(6k)\left(2\times10^{-3}\right)}{6k}+\frac{V_2}{6k}+\frac{3V_2}{6k}-\frac{3V_o}{6k}=0$$

$$5V_2-V_1-3V_o=12 \text{ ..... (2)}$$

Step 3 of 5

Apply Kirchhoff's current law at node V_o in the circuit and solve.

$$\frac{V_o-V_2}{2k}+\frac{V_o}{1k}=0$$

$$V_o-V_2+2V_o=0$$

$$V_2=3V_o \text{ ..... (3)}$$

Substitute equation (3) in (2) and solve.

$$(5)(3V_o)-V_1-3V_o=12$$

$$15V_o-V_1-3V_o=12$$

$$12V_o-12=V_1 \text{ ..... (4)}$$

Step 4 of 5

Substitute equation (3) and (4) in (1) and solve for V_o.

$$3V_o=(3)(12V_o-12)-60$$

$$36V_o-3V_o-36=60$$

$$33V_o=96$$

$$V_o=2.91\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{2.91\text{ V}}$.

Step 5 of 5

Substitute $V_o=2.91\text{ V}$ in equation (4) and solve.

$$\begin{aligned}V_1&=(12)(2.91\text{ V})-12\text{ V}\\&=34.92\text{ V}-12\text{ V}\\&=22.92\text{ V}\end{aligned}$$

Therefore, the value of voltage V_1 in the circuit is $\boxed{22.92\text{ V}}$.

Step 1 of 5

3.8e

Refer to circuit shown in Figure E3.8 in the text book.

The nodes and voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law at node V_a in Figure 1 and solve.

$$\left(-8\times10^{-3}\right)+\frac{V_a}{3\text{ k}}+\frac{V_a-V_b}{6\text{ k}}+\left(2\times10^{-3}\right)=0$$

$$\frac{V_a}{3\text{ k}}+\frac{V_a}{6\text{ k}}-\frac{V_b}{6\text{ k}}=6\times10^{-3}$$

$$2V_a+V_a-V_b=\left(6\times10^{-3}\right)\left(6\times10^{3}\right)$$

$$V_b=3V_a-36 \text{ ..... (1)}$$

Step 3 of 5

Apply Kirchhoff's current law at node V_b in Figure 1 and solve.

$$\frac{V_b-V_a}{6\text{ k}}+\frac{V_b-12}{6\text{ k}}+\frac{V_b-V_o}{2\text{ k}}=0$$

$$\frac{V_b}{6\text{ k}}-\frac{V_a}{6\text{ k}}+\frac{V_b}{6\text{ k}}-\frac{12}{6\text{ k}}+\frac{3V_b}{6\text{ k}}-\frac{3V_o}{6\text{ k}}=0$$

$$V_b-V_a+V_b-12+3V_b-3V_o=0$$

$$5V_b-V_a-3V_o=12 \text{ ..... (2)}$$

Substitute equation (1) in (2) and simplify the expression further.

$$5\left(3V_a-36\right)-V_a-3V_o=12$$

$$15V_a-180-V_a-3V_o=12$$

$$14V_a-3V_o=12+180$$

$$V_a=\frac{192+3V_o}{14} \text{ ..... (3)}$$

Step 4 of 5

Apply Kirchhoff's current law at node V_o in Figure 1 and solve for V_o.

$$\frac{V_o-V_b}{2\text{ k}}+\frac{V_o}{1\text{ k}}-2\times10^{-3}=0$$

$$\frac{V_o}{2\text{ k}}-\frac{V_b}{2\text{ k}}+\frac{V_o}{1\text{ k}}=2\times10^{-3}$$

$$\frac{V_o+2V_o}{2\text{ k}}-\frac{V_b}{2\text{ k}}=2\times10^{-3}$$

$$3V_o-V_b=\left(2\times10^{-3}\right)\left(2\times10^{3}\right) \text{ ..... (4)}$$

Step 5 of 5

Substitute equation (1) and (3) in (4) and simplify the expression further.

$$3V_o-3V_a+36=4$$

$$3V_o-3\left(\frac{3V_o+192}{14}\right)+36=4$$

$$3V_o-\frac{9V_o}{14}-\frac{576}{14}+36=4$$

$$3V_o-0.642V_o-41.142+36-4=0$$

Simplify the expression further.

$$2.358V_o-9.142=0$$

$$2.358V_o=9.142$$

$$V_o=\frac{9.142}{2.358}$$
$$=3.88\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{3.88\text{ V}}$.

Step 1 of 6

3.8p

The given circuit is,

Step 2 of 6

Applying KCL at node 1

$$-3\text{m} + \frac{V_1 - V_2}{1\text{k}} + \frac{V_1}{2\text{k}} = 0$$

$$\frac{V_1}{2\text{k}} + \frac{V_1 - V_2}{1\text{k}} = 3\text{m}$$

$$V_1\left(\frac{1}{2\text{k}} + \frac{1}{1\text{k}}\right) + V_2\left(\frac{-1}{1\text{k}}\right) + V_3(0) = 3\text{m} \qquad ....(1)$$

Step 3 of 6

Applying KCL at node 2

$$\frac{V_2 - V_1}{1\text{k}} - 6\text{m} + \frac{V_2 - V_3}{3\text{k}} = 0$$

$$V_1\left(\frac{-1}{1\text{k}}\right) + V_2\left(\frac{1}{1\text{k}} + \frac{1}{3\text{k}}\right) + V_3\left(\frac{-1}{3\text{k}}\right) = 6\text{m} \qquad ....(2)$$

Step 4 of 6

Applying KCL at node 3

$$\frac{V_3 - V_2}{3\text{k}} + \frac{V_3}{4\text{k}} + 3\text{m} = 0$$

$$V_1(0) + V_2\left(\frac{-1}{3\text{k}}\right) + V_3\left(\frac{1}{3\text{k}} + \frac{1}{4\text{k}}\right) = -3\text{m} \qquad ....(3)$$

Step 5 of 6

The equations (1), (2) and (3) are written in matrix form as,

$$\begin{bmatrix} \frac{1}{2\text{k}} + \frac{1}{1\text{k}} & \frac{-1}{1\text{k}} & 0 \\ \frac{-1}{1\text{k}} & \frac{1}{1\text{k}} + \frac{1}{3\text{k}} & \frac{-1}{3\text{k}} \\ 0 & \frac{-1}{3\text{k}} & \frac{1}{3\text{k}} + \frac{1}{4\text{k}} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 3\text{m} \\ 6\text{m} \\ -3\text{m} \end{bmatrix}$$

Step 6 of 6

Solution using MATLAB:
The input/output on MATLAB is shown below.
Type the following commands on the command shell in MATLAB.

```
>> G=[(1/2000+1/1000) (-1/1000)  0 ;
    (-1/1000)  (1/3000+1/1000) (-1/3000) ;
     0  (-1/3000)  (1/3000+1/4000)]

G =

   0.0015  -0.0010        0
  -0.0010   0.0013  -0.0003
        0  -0.0003   0.0006

>> I = [3/1000 ; 6/1000 ; -3/1000]

I =

   0.0030
   0.0060
  -0.0030

>> V = inv(G)*I

V =

  10.8000
  13.2000
   2.4000
```

Hence $\boxed{\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 10.8 \\ 13.2 \\ 2.4 \end{bmatrix}}$

Step 1 of 2

3.9e

Refer to circuit shown in Figure E3.9 in the text book.

The voltages V_2 and V_3 in the circuit forms a super node and so the voltage V_2 is written as $V_3 - 12$.

Apply Kirchhoff's current law at super node in the considered figure and solve for V_3 .

$$\frac{(V_3-12)(6\text{ V})}{2\text{ k}}+\frac{V_3-12}{1\text{ k}}+\frac{V_3-(-4\text{ V})}{2\text{ k}}+\frac{V_3}{2\text{ k}}=0$$

$$\frac{V_3-12-6}{2\text{ k}}+\frac{2(V_3-12)}{2\text{ k}}+\frac{V_3+4}{2\text{ k}}+\frac{V_3}{2\text{ k}}=0$$

$$V_3-18+2V_3-24+V_3+4+V_3=0$$

$$V_3=\frac{38}{5}\text{ V}$$

Step 2 of 2

Calculate the current I_o in the considered circuit by using Ohm's law $I=\frac{V}{R}$.

Substitute I_o for I , $\frac{38}{5}$ V for V , $2\text{ k}\Omega$ for R from the figure E3.9 in the text book and solve for I_o .

$$\begin{aligned} I_o &= \frac{\frac{38}{5}\text{ V}}{2\text{ k}\Omega} \\ &= \frac{38}{(5)(2\text{ k})} \\ &= \frac{7.6}{2\times10^3} \\ &= 3.8\text{ mA} \end{aligned}$$

Therefore, the value of current I_o in the network is $\boxed{3.8\text{ mA}}$.

3.9p

Figure (1)

Step 2 of 5

Mark the nodes and corresponding voltage levels as shown in figure 1.

Applying KCL at node 1

$$-2\text{m} + \frac{V_2 - V_1}{1\text{k}} - \frac{V_1}{2\text{k}} = 0$$
$$\frac{2V_2 - 2V_1}{2\text{k}} - \frac{V_1}{2\text{k}} = 2\text{m}$$
$$-3V_1 + 2V_2 = (2\text{m})(2\text{k})$$
$$2V_2 = 4 + 3V_1$$
$$V_2 = 2 + \frac{3}{2}V_1 \qquad \text{....(1)}$$

Step 3 of 5

Applying KCL at node 4

$$-\frac{V_4 - V_2}{2\text{k}} + 4\text{m} + 2\text{m} = 0$$
$$\frac{V_4 - V_2}{2\text{k}} = 6\text{m}$$
$$V_4 - \left(2 + \frac{3}{2}V_1\right) = (6\text{m})(2\text{k}) \qquad \text{....(By(1))}$$
$$V_4 = 12 + 2 + \frac{3}{2}V_1$$
$$V_4 = 14 + \frac{3}{2}V_1 \qquad \text{....(2)}$$

Step 4 of 5

Applying KCL at node 3

$$-\frac{V_3 - V_2}{1\text{k}} - \frac{V_3}{1\text{k}} - 4\text{m} = 0$$
$$V_2 - 2V_3 = (4\text{m})(1\text{k})$$
$$-2V_3 + \left(2 + \frac{3}{2}V_1\right) = 4 \qquad \text{....(By(1))}$$
$$-2V_3 = 2 - \frac{3}{2}V_1$$
$$V_3 = -1 + \frac{3}{4}V_1 \qquad \text{....(3)}$$

Step 5 of 5

Applying KCL at node 2,

$$\frac{V_3 - V_2}{1\text{k}} + \frac{V_4 - V_2}{2\text{k}} - \frac{V_2 - V_1}{1\text{k}} + 1\text{m} = 0$$
$$2(V_3 - V_2) + (V_4 - V_2) - 2(V_2 - V_1) = -(1\text{m})(2\text{k})$$
$$V_4 + 2V_3 - 5V_2 + 2V_1 = -2$$
$$(14 + \frac{3}{2}V_1) + 2(-1 + \frac{3}{4}V_1) - 5(2 + \frac{3}{2}V_1) + 2V_1 = -2 \qquad \text{....(By(1),(2)and(3))}$$
$$14 - 2 - 10 + V_1\left(\frac{3}{2} + \frac{3}{2} - \frac{15}{2} + 2\right) = -2$$
$$-\frac{5}{2}V_1 = -4$$
$$V_1 = \frac{8}{5}\text{ V} \qquad \text{....(4)}$$
$$V_O = \frac{8}{5}\text{ V} \qquad (\because V_O = V_1)$$

Hence $\boxed{V_O = 1.6\text{ V}}$

Step 1 of 3

3.10e

Consider the circuit shown in Figure E3.10 in the text book.

The nodes and voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

The voltages V_a and V_b in Figure 1 forms a super node and so the voltage V_a is written as $V_b - 12$.

Apply Kirchhoff's current law at super node in Figure 1 and solve.

$$\left(-8\times10^{-3}\right)+\frac{V_b-12}{3k}+\left(2\times10^{-3}\right)+\frac{V_b-V_o}{2k}+\frac{V_b}{6k}=0$$

$$\frac{(2)(V_b-12)}{6k}+\frac{(3)(V_b-V_o)}{6k}+\frac{V_b}{6k}=6\times10^{-3}$$

$$2V_b-24+3V_b-3V_o+V_b=\left(6\times10^{-3}\right)\left(6\times10^{3}\right)$$

$$6V_b-3V_o=36+24$$

Simplify the expression further.

$$6V_b-3V_o=60$$

$$2V_b-V_o=20$$

$$2V_b=20+V_o$$

$$V_b=\frac{20+V_o}{2} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o-V_b}{2k}+\frac{V_o}{1k}-\left(2\times10^{-3}\right)=0$$

$$V_o-V_b+2V_o-\left(2\times10^{-3}\right)(2k)=0$$

$$3V_o-V_b=\left(2\times10^{-3}\right)\left(2\times10^{3}\right)$$

$$3V_o-V_b=4 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and simplify the expression further.

$$3V_o-\left(\frac{20+V_o}{2}\right)=4$$

$$6V_o-20-V_o=(4)(2)$$

$$5V_o=8+20$$

$$V_o=5.6\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{5.6\text{ V}}$.

Step 1 of 7

3.10p

Refer to circuit shown in Figure P3.10 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Step 2 of 7

Figure 1

Step 3 of 7

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$-\left(1\times10^{-3}\right)+\frac{V_1-V_2}{2\text{ k}}+\left(2\times10^{-3}\right)+\frac{V_1}{8\text{ k}}=0$$

$$\frac{4V_1}{8\text{ k}}-\frac{4V_2}{8\text{ k}}+\frac{V_1}{8\text{ k}}=-1\times10^{-3}$$

$$5V_1-4V_2=-8$$

$$V_2=\frac{5V_1+8}{4}\text{ ..... (1)}$$

Step 4 of 7

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-V_1}{2\text{ k}}+\frac{V_2}{6\text{ k}}-\left(2\times10^{-3}\right)+\frac{V_2}{3\text{ k}}=0$$

$$\frac{3V_2}{6\text{ k}}-\frac{3V_1}{6\text{ k}}+\frac{V_2}{6\text{ k}}+\frac{2V_2}{6\text{ k}}=2\times10^{-3}$$

$$6V_2-3V_1=\left(6\times10^{3}\right)\left(2\times10^{-3}\right)$$

$$2V_2-V_1=4\text{ ..... (2)}$$

Step 5 of 7

Recall equation (2).

$$2V_2-V_1=4$$

Substitute $\frac{5V_1+8}{4}$ for V_2 in the equation and solve for V_1.

$$(2)\left(\frac{5V_1+8}{4}\right)-V_1=4$$

$$\frac{5V_1}{2}+4-V_1=4$$

$$\frac{5V_1-2V_1}{2}=0$$

$$V_1=0\text{ V}$$

Step 6 of 7

Recall equation (1).

$$V_2=\frac{5V_1+8}{4}$$

Substitute 0 for V_1 in the equation and solve for V_2.

$$V_2=\frac{5(0)+8}{4}$$

$$=\frac{8}{4}$$

$$=2\text{ V}$$

Step 7 of 7

Calculate the current I_o in Figure 1 by using Ohm's law.

$$I=\frac{V}{R}$$

Substitute I_o for I, 2 V for V, $6\text{ k}\Omega$ for R from figure 1 and solve for I_o.

$$I_o=\frac{2\text{ V}}{6\text{ k}\Omega}$$

$$=\frac{1}{3\text{ k}\Omega}$$

$$=0.333\text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{0.333\text{ mA}}$.

Step 1 of 7

3.11e

Refer to circuit shown in Figure P3.10 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Step 2 of 7

Figure 1

Step 3 of 7

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$-\left(1\times10^{-3}\right)+\frac{V_1-V_2}{2\text{ k}}+\left(2\times10^{-3}\right)+\frac{V_1}{8\text{ k}}=0$$

$$\frac{4V_1}{8\text{ k}}-\frac{4V_2}{8\text{ k}}+\frac{V_1}{8\text{ k}}=-1\times10^{-3}$$

$$5V_1-4V_2=-8$$

$$V_2=\frac{5V_1+8}{4}\text{ ..... (1)}$$

Step 4 of 7

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-V_1}{2\text{ k}}+\frac{V_2}{6\text{ k}}-\left(2\times10^{-3}\right)+\frac{V_2}{3\text{ k}}=0$$

$$\frac{3V_2}{6\text{ k}}-\frac{3V_1}{6\text{ k}}+\frac{V_2}{6\text{ k}}+\frac{2V_2}{6\text{ k}}=2\times10^{-3}$$

$$6V_2-3V_1=\left(6\times10^{3}\right)\left(2\times10^{-3}\right)$$

$$2V_2-V_1=4\text{ ..... (2)}$$

Step 5 of 7

Recall equation (2).

$$2V_2-V_1=4$$

Substitute $\frac{5V_1+8}{4}$ for V_2 in the equation and solve for V_1.

$$(2)\left(\frac{5V_1+8}{4}\right)-V_1=4$$

$$\frac{5V_1}{2}+4-V_1=4$$

$$\frac{5V_1-2V_1}{2}=0$$

$$V_1=0\text{ V}$$

Step 6 of 7

Recall equation (1).

$$V_2=\frac{5V_1+8}{4}$$

Substitute 0 for V_1 in the equation and solve for V_2.

$$V_2=\frac{5(0)+8}{4}$$

$$=\frac{8}{4}$$

$$=2\text{ V}$$

Step 7 of 7

Calculate the current I_o in Figure 1 by using Ohm's law.

$$I=\frac{V}{R}$$

Substitute I_o for I, 2 V for V, $6\text{ k}\Omega$ for R from figure 1 and solve for I_o.

$$I_o=\frac{2\text{ V}}{6\text{ k}\Omega}$$

$$=\frac{1}{3\text{ k}\Omega}$$

$$=0.333\text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{0.333\text{ mA}}$.

Step 1 of 4

3.11p

Refer to circuit shown in Figure P3.11 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node V_1 in the circuit Figure 1 and solve.

$$\frac{V_1}{2\text{ k}}+\frac{V_1-V_2}{4\text{ k}}+\left(2\times10^{-3}\right)-\left(4\times10^{-3}\right)=0$$
$$2V_1+V_1-V_2=\left(2\times10^{-3}\right)\left(4\times10^{3}\right)$$
$$3V_1-V_2=8$$
$$V_1=\frac{V_2+8}{3}\text{ ..... (1)}$$

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-V_1}{4\text{ k}}+\frac{V_2}{4\text{ k}}+\frac{V_2}{12\text{ k}}-\left(6\times10^{-3}\right)+\left(4\times10^{3}\right)=0$$
$$3V_2-3V_1+3V_2+V_2=\left(2\times10^{-3}\right)\left(12\times10^{3}\right)$$
$$-3V_1+7V_2=24\text{ ..... (2)}$$

Step 3 of 4

Recall equation (2).

$$-3V_1+7V_2=24$$

Substitute $\frac{V_2+8}{3}$ for V_1 in the equation and solve for voltage V_2.

$$-(3)\left(\frac{V_2+8}{3}\right)+7V_2=24$$
$$-V_2-8+7V_2=24$$
$$6V_2=32$$
$$V_2=5.33\text{ V}$$

Step 4 of 4

Calculate the current I_o in the Figure 1 by using Ohm's law.

$$I=\frac{V}{R}$$

Substitute I_o for I, 5.33 V for V, $12\text{ k}\Omega$ for R from figure 1 and solve for I_o.

$$I_o=\frac{5.33\text{ V}}{12\text{ k}\Omega}$$
$$=0.444\text{ mA}$$

Therefore, the value of current I_o in the network is $\boxed{0.444\text{ mA}}$.

Step 1 of 4

3.12e

Refer to circuit shown in Figure P3.11 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node V_1 in the circuit Figure 1 and solve.

$$\frac{V_1}{2\text{ k}}+\frac{V_1-V_2}{4\text{ k}}+\left(2\times10^{-3}\right)-\left(4\times10^{-3}\right)=0$$

$$2V_1+V_1-V_2=\left(2\times10^{-3}\right)\left(4\times10^{3}\right)$$

$$3V_1-V_2=8$$

$$V_1=\frac{V_2+8}{3}\text{ ..... (1)}$$

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-V_1}{4\text{ k}}+\frac{V_2}{4\text{ k}}+\frac{V_2}{12\text{ k}}-\left(6\times10^{-3}\right)+\left(4\times10^{3}\right)=0$$

$$3V_2-3V_1+3V_2+V_2=\left(2\times10^{-3}\right)\left(12\times10^{3}\right)$$

$$-3V_1+7V_2=24\text{ ..... (2)}$$

Step 3 of 4

Recall equation (2).

$$-3V_1+7V_2=24$$

Substitute $\frac{V_2+8}{3}$ for V_1 in the equation and solve for voltage V_2.

$$-(3)\left(\frac{V_2+8}{3}\right)+7V_2=24$$

$$-V_2-8+7V_2=24$$

$$6V_2=32$$

$$V_2=5.33\text{ V}$$

Step 4 of 4

Calculate the current I_o in the Figure 1 by using Ohm's law.

$$I=\frac{V}{R}$$

Substitute I_o for I, 5.33 V for V, $12\text{ k}\Omega$ for R from figure 1 and solve for I_o.

$$I_o=\frac{5.33\text{ V}}{12\text{ k}\Omega}$$
$$=0.444\text{ mA}$$

Therefore, the value of current I_o in the network is $\boxed{0.444\text{ mA}}$.

Step 1 of 4

3.12p

The given circuit is,

Step 2 of 4

Using Nodal Analysis,

Step 3 of 4

From the figure we have

$V_1 - 0 = -10$

$V_1 = -10\text{ V}$ ....(1)

$V_2 - 0 = 12$

$V_2 = 12\text{ V}$ ....(2)

Step 4 of 4

Applying KCL at node 3,

$$\frac{V_3 - V_1}{6\text{k}} + \frac{V_3 - V_2}{3\text{k}} + \frac{V_3}{4\text{k}} = 0$$

$$\frac{2(V_3 - V_1) + 4(V_3 - V_2) + 3V_3}{12\text{k}} = 0$$

$$-2V_1 - 4V_2 + (2+4+3)V_3 = 0$$

$$-2(-10) + 4(-12) + 9V_3 = 0 \qquad \text{....(By(1) and (2))}$$

$$9V_3 = -20 + 48$$

$$V_3 = \frac{28}{9}\text{V}$$

$$\therefore V_O = \frac{28}{9}\text{ V} \qquad (\because V_3 = V_O)$$

Hence $\boxed{V_o = \mathbf{3.111\text{ V}}}$

Step 1 of 4

3.13e

The given circuit is,

Step 2 of 4

Using Nodal Analysis,

Step 3 of 4

From the figure we have

$V_1 - 0 = -10$

$V_1 = -10\text{ V}$ ....(1)

$V_2 - 0 = 12$

$V_2 = 12\text{ V}$ ....(2)

Step 4 of 4

Applying KCL at node 3,

$$\frac{V_3 - V_1}{6\text{k}} + \frac{V_3 - V_2}{3\text{k}} + \frac{V_3}{4\text{k}} = 0$$

$$\frac{2(V_3 - V_1) + 4(V_3 - V_2) + 3V_3}{12\text{k}} = 0$$

$$-2V_1 - 4V_2 + (2+4+3)V_3 = 0$$

$$-2(-10) + 4(-12) + 9V_3 = 0 \qquad \text{....(By(1) and (2))}$$

$$9V_3 = -20 + 48$$

$$V_3 = \frac{28}{9}\text{V}$$

$$\therefore V_O = \frac{28}{9}\text{ V} \qquad (\because\ V_3 = V_O)$$

Hence $\boxed{V_o = \mathbf{3.111\text{ V}}}$

Step 1 of 2

3.13p

Refer to circuit shown in Figure P3.12 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve for V_1.

$$\frac{V_1-12}{6\text{ k}}+\frac{V_1}{6\text{ k}}+\frac{V_1-6}{12\text{ k}}=0$$
$$2(V_1-12)+2V_1+V_1-6=0$$
$$5V_1=24+6$$
$$V_1=6\text{ V}$$

Apply Kirchhoff's current law to the right hand side loop in Figure 1 and solve for voltage V_o.

$$V_o+6\text{ V}-V_1=0$$
$$V_o+6\text{ V}-6\text{ V}=0$$
$$V_o=0\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{0\text{ V}}$.

Step 1 of 4

3.14e

Consider the circuit shown in Figure E3.13 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$2kI_1 + 4kI_1 + 2k(I_1 - I_2) + 3 = 0$$
$$2kI_1 + 4kI_1 + 2kI_1 - 2kI_2 = -3$$
$$8kI_1 - 2kI_2 = -3$$
$$I_1 = \frac{2kI_2 - 3}{8k} \quad \text{..... (1)}$$

Step 2 of 4

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$2k(I_2 - I_1) - 6 + 6kI_2 - 3 = 0$$
$$2kI_2 - 2kI_1 + 6kI_2 = 9$$
$$-2kI_1 + 8kI_2 = 9 \quad \text{..... (2)}$$

Step 3 of 4

Substitute equation (1) in (2) and solve for I_2.

$$-2k\left(\frac{2kI_2 - 3}{8k}\right) + 8kI_2 = 9$$
$$-2kI_2 + 3 + 32kI_2 = 36$$
$$30kI_2 = 33$$
$$I_2 = \frac{33}{30k} \text{ A}$$

Step 4 of 4

Calculate the value of V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_2$, $R = 6\text{ k}\Omega$ from Figure 1 and solve for voltage V_o.

$$\begin{aligned} V_o &= I_2 R \\ &= \left(\frac{33}{30k}\right)(6\text{ k}) \\ &= \frac{33}{5} \text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{\frac{33}{5} \text{ V}}$.

Step 1 of 3

3.14p

Refer to circuit shown in Figure P3.14 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$\frac{V_1-12}{2\text{ k}}-\left(2\times10^{-3}\right)+\frac{V_1-V_o}{4\text{ k}}=0$$

$$2\left(V_1-12\right)+V_1-V_o=\left(2\times10^{-3}\right)\left(4\times10^{3}\right)$$

$$2V_1+V_1-V_o=8+24$$

$$3V_1-V_o=32 \text{ ..... (1)}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o-V_1}{4\text{ k}}+\frac{V_o}{2\text{ k}}=0$$

$$V_o-V_1+2V_o=0$$

$$3V_o=V_1 \text{ ..... (2)}$$

Recall equation (1).

$$3V_1-V_o=32$$

Substitute $3V_o$ for V_1 in the equation and solve for V_o.

$$3\left(3V_o\right)-V_o=32$$

$$9V_o-V_o=32$$

$$8V_o=32$$

$$V_o=4\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{4\text{ V}}$.

Step 1 of 3

3.15e

Consider the circuit shown in Figure E3.15 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The value of current I_1 from Figure 1 is 4 mA.

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve for current I_2.

$$4\text{k}(I_2 - I_1) + 6\text{k}I_2 + 5 = 0$$
$$4\text{k}I_2 - 4\text{k}I_1 + 6\text{k}I_2 = -5$$
$$-4\text{k}I_1 + 10\text{k}I_2 = -5$$
$$-(4\text{k})(4\text{m}) + 10\text{k}I_2 = -5$$

Simplify the expression further.

$$-16 + 10\text{k}I_2 = -5$$
$$10\text{k}I_2 = 11$$
$$I_2 = \frac{11}{10\text{k}}\text{ A}$$

Step 3 of 3

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_2$, $R = 6\text{ k}\Omega$ from Figure 1 and solve for V_o.

$$\begin{aligned} V_o &= I_2 R \\ &= \left(\frac{11}{10\text{k}}\right)(6\text{k}) \\ &= \frac{66}{10} \\ &= \frac{33}{5}\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{\frac{33}{5}\text{ V}}$.

Step 1 of 4

3.15p

Refer to circuit shown in Figure P3.15 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$\frac{V_1 - V_2}{1\text{ k}} + \frac{V_1 - (-6)}{1\text{ k}} - 4\times10^{-3} = 0$$
$$V_1 - V_2 + V_1 + 6 = 4$$
$$2V_1 - V_2 = -2$$

$$V_1 = \frac{V_2 - 2}{2} \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2 - V_1}{1\text{ k}} + \frac{V_2 - (-6)}{2\text{ k}} + 2\times10^{-3} = 0$$
$$2V_2 - 2V_1 + V_2 + 6 = -\left(2\times10^{-3}\right)(2\text{ k})$$
$$3V_2 - 2V_1 = -4 - 6$$

$$3V_2 - 2V_1 = -10 \quad \text{..... (2)}$$

Substitute $\frac{V_2 - 2}{2}$ for V_1 in the equation and solve for voltage V_2.

$$3V_2 - 2\left(\frac{V_2 - 2}{2}\right) = -10$$
$$3V_2 - V_2 + 2 = -10$$
$$2V_2 = -12$$
$$V_2 = -6\text{ V}$$

Step 4 of 4

Calculate the value of current I_o in the Figure 1 by using Ohm's law.

$$I = \frac{V}{R}$$

Substitute I_o for I, $V_2 + 6\text{ V}$ for V, $2\text{ k}\Omega$ for R from figure 1 and solve for I_o.

$$I_o = \frac{-6\text{ V} + 6\text{ V}}{2\text{ k}\Omega}$$
$$= \frac{0}{2\text{ k}\Omega}$$
$$= 0\text{ A}$$

Therefore, the value of current I_o in the network is $\boxed{0\text{ A}}$.

Step 1 of 3

3.16e

Consider the circuit shown in Figure E3.16 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The value of current I_1 from Figure 1 is 4 mA and the value of current I_2 is -2 mA.

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve for I_3.

$$1\text{k}(I_3 - I_1) + 4\text{k}I_3 - 4 = 0$$
$$1\text{k}I_3 - 1\text{k}I_1 + 4\text{k}I_3 - 4 = 0$$
$$5\text{k}I_3 - (1\text{k})(4\text{m}) = 4$$
$$5\text{k}I_3 - 4 = 4$$

Simplify the expression further.

$$5\text{k}I_3 = 8$$
$$I_3 = \frac{8}{5\text{k}}\text{ A}$$

Step 3 of 3

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_3$, $R = 4\text{ k}\Omega$ from Figure 1 and solve for V_o.

$$\begin{aligned} V_o &= I_3 R \\ &= \left(\frac{8}{5\text{k}}\right)(4\text{k}) \\ &= \frac{32}{5}\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{\frac{32}{5}\text{ V}}$.

3.16p

Figure (1)

Step 2 of 5

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = -6 \text{ V} \qquad ....(1)$$
$$V_3 = 5 \text{ V} \qquad ....(2)$$

Applying KCL at node 2

$$6\text{m} - \frac{V_2 - V_4}{12\text{k}} = 0$$
$$V_2 - V_4 = (6\text{m})(12\text{k})$$
$$V_2 = 72 + V_4 \qquad ....(3)$$

Step 3 of 5

Applying KCL at node 4

$$\frac{V_3 - V_4}{2\text{k}} + \frac{V_2 - V_4}{12\text{k}} - \frac{V_4 - V_5}{6\text{k}} = 0$$
$$\frac{6(V_3 - V_4) + (V_2 - V_4) - 2(V_4 - V_5)}{12\text{k}} = 0$$
$$6V_3 + V_2 - (6+1+2)V_4 + 2V_5 = 0 \qquad ....(\text{By}(2))$$
$$30 + (72 + V_4) - 9V_4 + 2V_5 = 0 \qquad ....(\text{By}(3))$$
$$8V_4 = 102 + 2V_5$$
$$V_4 = \frac{51}{4} + \frac{1}{4}V_5 \qquad ....(4)$$

Step 4 of 5

Applying KCL at node 5

$$-\frac{V_5 - V_1}{3\text{k}} + \frac{V_4 - V_5}{6\text{k}} = 0$$
$$\frac{-2(V_5 - V_1) + (V_4 - V_5)}{6\text{k}} = 0$$
$$2V_1 + V_4 - (2+1)V_5 = 0 \qquad ....(\text{By}(1))$$
$$-12 + \left(\frac{51}{4} + \frac{V_5}{4}\right) - 3V_5 = 0 \qquad ....(\text{By}(4))$$
$$\left(3 - \frac{1}{4}\right)V_5 = -12 + \frac{51}{4}$$
$$\frac{11}{4}V_5 = \frac{3}{4}$$
$$V_5 = \frac{3}{11} \text{ V} \qquad ....(5)$$

Step 5 of 5

$$\because V_o = V_5$$
$$V_o = \frac{3}{11} \text{ V}$$

Hence $\boxed{V_o = 272.7 \text{ mV}}$

Step 1 of 4

Figure 1

Step 2 of 4

Mark the nodes and corresponding voltage levels as shown in figure 1.

Applying KCL at node 2

$$12\text{m} - \frac{V_2 - V_1}{10\text{k}} = 0$$

$$\frac{V_2 - V_1}{10\text{k}} = 12\text{m} \qquad \text{....(1)}$$

Step 3 of 4

Applying KCL at node 3

$$\frac{V_1 - V_3}{5\text{k}} - \frac{V_3}{4\text{k}} - \frac{V_3}{4\text{k}} = 0$$

$$4(V_1 - V_3) - 5V_3 - 5V_3 = 0$$

$$4V_1 - V_3(14) = 0$$

$$V_3 = \frac{2}{7}V_1 \qquad \text{....(2)}$$

Step 4 of 4

Applying KCL at node 1

$$\frac{V_2 - V_1}{10\text{k}} - \frac{V_1 - V_3}{5\text{k}} - \frac{V_1}{5\text{k}} = 0$$

$$12\text{m} - \frac{2}{5\text{k}}V_1 + \frac{V_3}{5\text{k}} = 0 \qquad \text{....(By(1))}$$

$$12\text{m} - \frac{2V_1}{5\text{k}} + \frac{2V_1}{7(5\text{k})} = 0 \qquad \text{....(By(2))}$$

$$(12\text{m})(5\text{k}) = V_1\left(2 - \frac{2}{7}\right)$$

$$60 = V_1\left(\frac{12}{7}\right)$$

$$V_1 = 35\text{ V} \qquad \text{....(3)}$$

Hence $\boxed{V_1 = 35\text{ V}}$

Step 1 of 4

3.18e

Consider Figure E3.18 from the text book.

Identify the currents in the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the super mesh analysis in loops 1 and 2.

$$I_1(2\text{ k}+3\text{ k})+I_2(4\text{ k})+(I_2-I_3)(6\text{ k})+(I_1-I_3)(3\text{ k})-10-12+8=0$$
$$I_1(2\text{ k}+3\text{ k}+3\text{ k})+I_2(6\text{ k}+4\text{ k})+I_3(-6\text{ k}-3\text{ k})-14=0$$
$$I_1(8\text{ k})+I_2(10\text{ k})+I_3(-9\text{ k})=14$$

Substitute $I_1+2\text{ m}$ for I_2.

$$I_1(8\text{ k})+(I_1+2\text{ m})(10\text{ k})+I_3(-9\text{ k})=14$$
$$I_1(8\text{ k})+I_1(10\text{ k})+20+I_3(-9\text{ k})=14$$
$$I_1(8\text{ k}+10\text{ k})+I_3(-9\text{ k})=14-20$$
$$I_1(18\text{ k})+I_3(-9\text{ k})=-6$$
$$I_1=\frac{-6+I_3(9\text{ k})}{18\text{ k}}$$

Therefore, the expression for I_1 is $\frac{-6+I_3(9\text{ k})}{18\text{ k}}$.

Step 3 of 4

Consider the Kirchhoff's voltage law in loop-3.

$$I_3(6\text{ k})+(I_3-I_2)(6\text{ k})+(I_3-I_1)(3\text{ k})-8=0$$
$$I_3(6\text{ k}+6\text{ k}+3\text{ k})-I_2(6\text{ k})-I_1(3\text{ k})=8$$
$$I_3(15\text{ k})-I_2(6\text{ k})-I_1(3\text{ k})=8$$

Substitute $I_1+2\text{ m}$ for I_2.

$$I_3(15\text{ k})-(I_1+2\text{ m})(6\text{ k})-I_1(3\text{ k})=8$$
$$I_3(15\text{ k})-I_1(6\text{ k})-12-I_1(3\text{ k})=8$$
$$I_3(15\text{ k})-I_1(6\text{ k}+3\text{ k})=8+12$$
$$I_3(15\text{ k})-I_1(9\text{ k})=20$$

Substitute $\frac{-6+I_3(9\text{ k})}{18\text{ k}}$ for I_1.

$$I_3(15\text{ k})-\left(\frac{-6+I_3(9\text{ k})}{18\text{ k}}\right)(9\text{ k})=20$$
$$I_3(15\text{ k})-\left(\frac{-6+I_3(9\text{ k})}{2}\right)=20$$
$$I_3(15\text{ k})-(-3+I_3(4.5\text{ k}))=20$$
$$I_3(15\text{ k})+3-I_3(4.5\text{ k})=20$$
$$I_3(15\text{ k}-4.5\text{ k})=20-3$$
$$I_3(10.5\text{ k})=17$$
$$I_3=\frac{17}{10.5\text{ k}}$$
$$I_3=1.619\text{ mA}$$

Therefore, the value of the current I_3 is 1.619 mA.

Step 4 of 4

Consider the expression for output voltage V_o.

$$V_o=I_3(6\text{ k})$$

Substitute 1.619 mA for I_3.

$$V_o=(1.619\text{ m})(6\text{ k})$$
$$=9.71\text{ V}$$

Therefore, the value of the voltage V_o is $\boxed{9.71\text{ V}}$.

Step 1 of 7

3.19e

Consider the circuit shown in Figure E3.19 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 7

The value of current I_2 in Figure 1 is I_x .

Calculate the value of current I_x in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = V_o$, $R = 2\ \text{k}\Omega$ from Figure 1and solve for I_x .

$$I_x = \frac{V_o}{2\ \text{k}\Omega} \quad \text{..... (1)}$$

Step 3 of 7

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$2\text{k}I_1 + 4\text{k}(I_1 - I_2) - 2000I_x = 0$$
$$2\text{k}I_1 + 4\text{k}I_1 - 4\text{k}I_2 - 2\text{k}I_x = 0$$
$$6\text{k}I_1 - 4\text{k}I_x - 2\text{k}I_x = 0$$

$$6\text{k}I_1 - 6\text{k}I_x = 0 \quad \text{..... (2)}$$

Step 4 of 7

Substitute equation (1) in (2) and solve.

$$6\text{k}I_1 - 6\text{k}\left(\frac{V_o}{2\text{k}}\right) = 0$$
$$6\text{k}I_1 - 3V_o = 0$$

$$V_o = 2\text{k}I_1 \quad \text{..... (3)}$$

Step 5 of 7

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$4\text{k}(I_2 - I_1) - 12 + 2\text{k}I_2 = 0$$
$$4\text{k}I_2 - 4\text{k}I_1 + 2\text{k}I_2 = 12$$
$$-4\text{k}I_1 + 6\text{k}I_2 = 12$$

$$-4\text{k}I_1 + 6\text{k}I_x = 12 \quad \text{..... (4)}$$

Step 6 of 7

Substitute equations (1) and (3) in (4) and solve for V_o .

$$-4\text{k}I_1 + 6\text{k}\left(\frac{V_o}{2\text{k}}\right) = 12$$
$$-4\text{k}I_1 + 3V_o = 12$$
$$-4\text{k}I_1 + (3)(2\text{k}I_1) = 12$$
$$-4\text{k}I_1 + 6\text{k}I_1 = 12$$

Simplify the expression further.

$$2\text{k}I_1 = 12$$
$$I_1 = 6\ \text{mA}$$

Step 7 of 7

Substitute the value of $I_1 = 6\ \text{mA}$ in equation (3) and solve for voltage V_o .

$$V_o = (2\text{k})(6\text{m})$$
$$= 12\ \text{V}$$

Therefore, the value of voltage V_o is $\boxed{12\ \text{V}}$.

3.19p

Consider the circuit shown in Figure P3.18 in the text book.

Apply Kirchhoff's current law at top node V_o in the considered circuit and solve for voltage V_o .

$$\frac{V_o - 12}{1\text{k}} - \left(2\times10^{-3}\right) + \frac{V_o}{2\text{k}} = 0$$

$$2\left(V_o - 12\right) - \left(2\times10^{-3}\right)\left(2\text{k}\right) + V_o = 0$$

$$3V_o = 24 + 4$$

$$V_o = 9.33\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{9.33\ \text{V}}$.

Step 1 of 3

3.20e

Consider the circuit shown in Figure E3.10 in the text book.

The nodes and voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

The voltages V_a and V_b in Figure 1 forms a super node and so the voltage V_a is written as $V_b - 12$.

Apply Kirchhoff's current law at super node in Figure 1 and solve.

$$\left(-8\times10^{-3}\right)+\frac{V_b-12}{3\text{k}}+\left(2\times10^{-3}\right)+\frac{V_b-V_o}{2\text{k}}+\frac{V_b}{6\text{k}}=0$$

$$\frac{(2)(V_b-12)}{6\text{k}}+\frac{(3)(V_b-V_o)}{6\text{k}}+\frac{V_b}{6\text{k}}=6\times10^{-3}$$

$$2V_b-24+3V_b-3V_o+V_b=\left(6\times10^{-3}\right)\left(6\times10^{3}\right)$$

$$6V_b-3V_o=36+24$$

Simplify the expression further.

$$6V_b-3V_o=60$$

$$2V_b-V_o=20$$

$$2V_b=20+V_o$$

$$V_b=\frac{20+V_o}{2} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o-V_b}{2\text{k}}+\frac{V_o}{1\text{k}}-\left(2\times10^{-3}\right)=0$$

$$V_o-V_b+2V_o-\left(2\times10^{-3}\right)(2\text{k})=0$$

$$3V_o-V_b=\left(2\times10^{-3}\right)\left(2\times10^{3}\right)$$

$$3V_o-V_b=4 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and simplify the expression further.

$$3V_o-\left(\frac{20+V_o}{2}\right)=4$$

$$6V_o-20-V_o=(4)(2)$$

$$5V_o=8+20$$

$$V_o=5.6\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{5.6\text{ V}}$.

Step 1 of 5

3.20p

Consider the circuit shown in Figure P3.20 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Step 2 of 5

Figure 1

Step 3 of 5

The voltages V_1 and V_o in Figure 1 forms a super node. So the voltage V_1 can be written as $V_o + 12\text{ V}$.

Apply Kirchhoff's current law at super node in Figure 1 and solve.

$$-\left(4\times10^{-3}\right)+\frac{(V_o+12\text{ V})-V_2}{1\text{k}}+\frac{V_o}{2\text{k}}+\frac{V_o-V_2}{2\text{k}}=0$$

$$2(V_o+12-V_2)+V_o+V_o-V_2=\left(4\times10^{-3}\right)(2\text{k})$$

$$4V_o-3V_2=8-24$$

$$V_2=\frac{4V_o+16}{3}\text{ ..... (1)}$$

Step 4 of 5

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2-(V_o+12)}{1\text{k}}+\frac{V_2-V_o}{2\text{k}}+\frac{V_2}{1\text{k}}=0$$

$$2(V_2-V_o-12)+V_2-V_o+2V_2=0$$

$$5V_2-3V_o=24\text{ ..... (2)}$$

Step 5 of 5

Substitute equation (1) in (2) and solve for voltage V_o.

$$5\left(\frac{4V_o+16}{3}\right)-3V_o=24$$

$$20V_o+80-9V_o=(24)(3)$$

$$11V_o=72-80$$

$$V_o=-0.727\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{-0.727\text{ V}}$.

Step 1 of 3

3.21e

Consider the circuit shown in Figure E3.11 in the text book.

Apply Kirchhoff's current law to the considered circuit and solve.

$$4\text{m} = \frac{V_1}{2\text{k}} + 2\text{m} + \frac{V_2}{2\text{k}}$$
$$(4\text{m})(2\text{k}) = V_1 + 4 + V_2$$
$$8 = V_1 + V_2 + 4$$
$$8 = V_1 + 2V_1 + 4$$

Simplify the expression further.

$$3V_1 = 4$$
$$V_1 = \frac{4}{3}$$

Step 2 of 3

Calculate the voltage in between the nodes V_1 and V_2 in the considered circuit and solve.

$$V_1 - V_2 = -2\text{k}I_x$$
$$V_1 - V_2 = -2\text{k}\left(\frac{V_1}{2\text{k}}\right)$$
$$2V_1 = V_2$$
$$V_2 = \frac{8}{3}$$

Step 3 of 3

Calculate the value of current I_o in the considered figure by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_o$, $R = 2\text{k}$ from the considered figure and solve for I_o.

$$I_o = \frac{V_2}{2\text{k}}$$
$$= \frac{\frac{8}{3}}{2\text{k}}$$
$$= \frac{4}{3}\ \text{mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{\frac{4}{3}\ \text{mA}}$.

Step 1 of 2

3.21p

Consider the circuit shown in Figure P3.22 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

The voltages V_1 and V_2 in Figure 1 forms a super node. So the voltage V_o can be written as $(V_1 - 4\text{ V})$.

$$V_1 - V_o = 4\text{ V}$$
$$V_o = V_1 - 4\text{ V}$$
$$= 12\text{ V} - 4\text{ V}$$
$$= 8\text{ V}$$

Therefore, the value of voltage V_o is $\boxed{8\text{ V}}$.

Step 1 of 3

3.23e

Refer to the circuit shown in Figure E3.12 in the text book.

The nodes for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

The value of current I_x from Figure 1 is $\frac{V_o - V_2}{2\text{k}}$.

$$I_x = \frac{V_o - V_2}{2\text{k}}$$

The nodes V_1 and V_2 in Figure 1 forms a super node. The value of voltage V_1 can be written as $V_2 + 4\text{k}I_x$.

Apply Kirchhoff's current law at super node in Figure 1 and solve.

$$-8\text{m} + \frac{V_1}{3\text{k}} + 2\text{m} + \frac{V_2}{6\text{k}} + \frac{V_2 - V_o}{2\text{k}} = 0$$

$$\frac{V_1}{3\text{k}} + \frac{V_2}{6\text{k}} + \frac{V_2}{2\text{k}} - \frac{V_o}{2\text{k}} = 6\text{m}$$

$$2V_1 + V_2 + 3V_2 - 3V_o = (6\text{m})(6\text{k})$$

$$2(V_2 + 4\text{k}I_x) + 4V_2 - 3V_o = 36$$

Substitute the value of I_x and simplify the expression further.

$$2V_2 + 8\text{k}\left(\frac{V_o - V_2}{2\text{k}}\right) + 4V_2 - 3V_o = 36$$

$$2V_2 + 4(V_o - V_2) + 4V_2 - 3V_o = 36$$

$$2V_2 + 4V_o - 4V_2 + 4V_2 - 3V_o = 36$$

$$V_2 = \frac{36 - V_o}{2} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve for V_o.

$$\frac{V_o - V_2}{2\text{k}} - 2\text{m} + \frac{V_o}{1\text{k}} = 0$$

$$\frac{V_o - \left(\frac{36 - V_o}{2}\right)}{2\text{k}} - 2\text{m} + \frac{V_o}{1\text{k}} = 0$$

$$\frac{2V_o - 36 + V_o}{4\text{k}} - \frac{(2\text{m})(4\text{k})}{4\text{k}} + \frac{(4)V_o}{(4)(1\text{k})} = 0$$

$$2V_o - 36 + V_o - 8 + 4V_o = 0$$

Simplify the expression further.

$$7V_o = 44$$

$$V_o = \frac{44}{7}$$

$$= 6.29 \text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{6.29 \text{ V}}$.

Step 1 of 5

Refer to Figure P3.23 in the text book.

The value of the node voltage V_4 is,

$$V_4 = 12\text{ V}$$

Therefore, the node voltage, V_4 is $\boxed{12\text{ V}}$.

The nodes V_1 and V_3 constitutes the super node.

$$V_3 - V_1 = 24$$

$$V_1 = V_3 - 24 \text{ ..... (1)}$$

Re-draw Figure P3.23 to indicate the super node.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law at the super-node as shown in Figure 1.

$$(0.5\text{ mS})\left[(V_3 - 24) - V_2\right] + 5\text{ mA} + 3\text{ mA} + 2\text{ mS}\left[V_3 - V_2\right] + 1\text{ mS}\left[V_3 - 12\right] = 0$$

$$0.5V_3 - (0.5)(24) - 0.5V_2 + 8 + 2V_3 - 2V_2 + V_3 - 12 = 0$$

$$0.5V_3 - 12 - 0.5V_2 + 8 + 2V_3 - 2V_2 + V_3 - 12 = 0$$

$$-2.5V_2 + 3.5V_3 = 16 \text{ ..... (2)}$$

Step 3 of 5

Apply Kirchhoff's current law at the node 2 as shown in Figure 1

$$0.5\text{ mS}\left[V_2 - (V_3 - 24)\right] + 0.5\text{ mS}(V_2) + 2\text{ mS}(V_2 - V_3) = 0$$

$$0.5V_2 - 0.5V_3 + (24)(0.5) + 0.5V_2 + 2V_2 - 2V_3 = 0$$

$$3V_2 - 2.5V_3 = -12$$

$$V_2 = \frac{-12 + 2.5V_3}{3} \text{ ..... (3)}$$

Use equation (3) and substitute $\frac{-12 + 2.5V_3}{3}$ for V_2 in equation (2).

$$-2.5\left(\frac{-12 + 2.5V_3}{3}\right) + 3.5V_3 = 16$$

$$-(-30 + 6.25V_3) + (10.5V_3) = 48$$

$$4.25V_3 = 18$$

$$V_3 = 4.235\text{ V}$$

Thus, the node voltage V_3 is $\boxed{4.235\text{ V}}$.

Step 4 of 5

Substitute 4.235 V for V_3 in equation (2).

$$-2.5V_2 + 3.5(4.235) = 16$$

$$-2.5V_2 = 16 - 14.8$$

$$V_2 = -\frac{1.176}{2.5}$$

$$= -0.47\text{ V}$$

Thus, the value of the node voltage V_2 is $\boxed{-0.47\text{ V}}$.

Step 5 of 5

Substitute 4.235 V for V_3 in equation (1).

$$V_1 = V_3 - 24$$

$$= 4.235 - 24$$

$$= -19.765\text{ V}$$

Thus, the node voltage, V_1 is $\boxed{-19.765\text{ V}}$.

Step 1 of 6

3.24p

Consider the circuit shown in Figure P3.28 in the text book.

The node voltages of the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve.

$$\frac{V_2 - V_o}{1\text{k}} + \frac{V_2 - V_1}{2\text{k}} + \frac{V_2 - 12}{2\text{k}} - \left(2\times10^{-3}\right) = 0$$

$$2V_2 - 2V_o + V_2 - V_1 + V_2 - 12 = \left(2\times10^{-3}\right)(2\text{k})$$

$$4V_2 - V_1 - 2V_o = 4 + 12$$

$$V_1 = 4V_2 - 2V_o - 16 \text{ ..... (1)}$$

Step 3 of 6

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$\frac{V_1 - V_2}{2\text{k}} + \frac{V_1 - V_o}{1\text{k}} + \frac{V_1 - 12}{1\text{k}} = 0$$

$$V_1 - V_2 + 2V_1 - 2V_o + 2V_1 - 24 = 0$$

$$5V_1 - V_2 - 2V_o = 24 \text{ ..... (2)}$$

Step 4 of 6

Substitute equation (1) in (2) and solve.

$$5\left(4V_2 - 2V_o - 16\right) - V_2 - 2V_o = 24$$

$$20V_2 - 10V_o - 80 - V_2 - 2V_o = 24$$

$$19V_2 - 12V_o = 104$$

$$V_2 = \frac{12V_o + 104}{19} \text{ ..... (3)}$$

Step 5 of 6

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o - V_2}{1\text{k}} + \frac{V_o - V_1}{1\text{k}} + \frac{V_o}{1\text{k}} = 0$$

$$V_o - V_2 + V_o - V_1 + V_o = 0$$

$$3V_o - V_2 - V_1 = 0 \text{ ..... (4)}$$

Step 6 of 6

Substitute equation (1) and (3) in (4) and solve for V_0.

$$3V_0 - \left(\frac{12V_o + 104}{19}\right) - \left(4\left(\frac{12V_o + 104}{19}\right) - 2V_o - 16\right) = 0$$

$$(19)(3V_o) - 12V_o - 104 - 48V_o - 416 + (19)(2V_o) + (16)(19) = 0$$

$$57V_o - 12V_o - 104 - 48V_o - 416 + 38V_o + 304 = 0$$

$$95V_o - 60V_o = 520 - 304$$

Simplify the expression further.

$$35V_o = 216$$

$$V_o = \frac{216}{35}$$

$$= 6.17 \text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{6.17 \text{ V}}$.

Step 1 of 4

3.25p

Consider the circuit shown in Figure E3.13 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$2kI_1 + 4kI_1 + 2k(I_1 - I_2) + 3 = 0$$
$$2kI_1 + 4kI_1 + 2kI_1 - 2kI_2 = -3$$
$$8kI_1 - 2kI_2 = -3$$
$$I_1 = \frac{2kI_2 - 3}{8k} \quad \text{..... (1)}$$

Step 2 of 4

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$2k(I_2 - I_1) - 6 + 6kI_2 - 3 = 0$$
$$2kI_2 - 2kI_1 + 6kI_2 = 9$$
$$-2kI_1 + 8kI_2 = 9 \quad \text{..... (2)}$$

Step 3 of 4

Substitute equation (1) in (2) and solve for I_2.

$$-2k\left(\frac{2kI_2 - 3}{8k}\right) + 8kI_2 = 9$$
$$-2kI_2 + 3 + 32kI_2 = 36$$
$$30kI_2 = 33$$
$$I_2 = \frac{33}{30k} \text{ A}$$

Step 4 of 4

Calculate the value of V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_2$, $R = 6\text{ k}\Omega$ from Figure 1 and solve for voltage V_o.

$$V_o = I_2 R$$
$$= \left(\frac{33}{30k}\right)(6\text{ k})$$
$$= \frac{33}{5} \text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{\frac{33}{5} \text{ V}}$.

Step 1 of 5

3.26p

Figure (1)

Step 2 of 5

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 48 \text{ V} \qquad ....(1)$$

Applying KCL at node 3

$$2 + \frac{V_2 - V_3}{6} - 1 = 0$$
$$V_3 - V_2 = 6$$
$$V_3 = V_2 + 6 \qquad ....(2)$$

Step 3 of 5

Applying KCL at node 2

$$\frac{V_1 - V_2}{12} - \frac{V_2 - V_3}{6} - \frac{V_2}{4} = 0$$
$$\frac{(48 - V_2) - 2(V_2 - V_3) - 3V_2}{12} = 0 \qquad ....(By(1))$$
$$48 + (-1 - 2 - 3)V_2 + 2V_3 = 0$$
$$48 - 6V_2 + 2(V_2 + 6) = 0 \qquad ....(By(2))$$
$$48 - 4V_2 + 12 = 0$$
$$V_2 = \frac{60}{4} \text{ V}$$
$$V_2 = 15 \text{ V}$$
$$V_3 = 15 + 6 \text{ V} \qquad ....(By(1))$$
$$V_3 = 21 \text{ V}$$

Step 4 of 5

Power supplied by the 1 A source is,

$$P_{sup1} = -V_O(1)$$
$$P_{sup1} = -(21)(1) \qquad (\because V_O = V_3)$$
$$P_{sup1} = -21 \text{ W}$$

Step 5 of 5

Hence the node voltages are,

$$\boxed{V_1 = 48 \text{ V}}$$
$$\boxed{V_2 = 15 \text{ V}}$$
$$\boxed{V_3 = 21 \text{ V}}$$

The power supplied by the 1 A source is $\boxed{P_{supl} = -21 \text{ W}}$

3.27p

Figure (1)

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 6\text{ V} \qquad \text{....(1)}$$

Applying KCL at node 3

$$2\text{m} + \frac{V_1 - V_3}{1\text{k}} - \frac{V_3}{1\text{k}} = 0$$
$$V_1 - 2V_3 + (2\text{m})(1\text{k}) = 0$$
$$2V_3 = 6 + 2 \qquad \text{....(By(1))}$$
$$V_3 = \frac{8}{2}$$
$$V_3 = 4\text{ V}$$

$$\because V_o = V_3$$
$$V_o = 4\text{ V}$$

Hence $\boxed{V_o = 4\text{ V}}$

3.28p

Figure (1)

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 12 \text{ V} \qquad ....(1)$$

Applying KCL at node 2

$$2\text{m} + \frac{V_1 - V_2}{3\text{k}} - \frac{V_2}{6\text{k}} = 0$$

$$2(V_1 - V_2) - V_2 + (2\text{m})(6\text{k}) = 0$$

$$3V_2 = 2(12) + 12 \qquad ....(\text{By}(1))$$

$$V_2 = \frac{36}{3} \text{ V}$$

$$V_2 = 12 \text{ V} \qquad ....(2)$$

By Ohm's Law,

$$V_2 = I_O(6\text{k})$$

$$I_O = \frac{12}{6} \text{ mA}$$

$$I_O = 2 \text{ mA}$$

Hence $\boxed{I_O = 2 \text{ mA}}$

Step 1 of 5

3.29p

Figure (1)

Step 2 of 5

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 12 \text{ V} \qquad \text{....(1)}$$

Step 3 of 5

Applying KCL at node 2

$$2\text{m} + 4\text{m} - \frac{V_2}{2\text{k}} = 0$$
$$V_2 = (2\text{k})(6\text{m})$$
$$V_2 = 12 \text{ V} \qquad \text{....(2)}$$

Step 4 of 5

Applying KCL at node 3

$$-4\text{m} + \frac{V_1 - V_3}{2\text{k}} - \frac{V_3}{2\text{k}} = 0$$
$$(V_1 - V_3) - V_3 - (4\text{m})(2\text{k}) = 0$$
$$2V_3 = V_1 - 8$$
$$2V_3 = 12 - 8 \qquad \text{....(By(1))}$$
$$V_3 = \frac{4}{2} \text{ V}$$
$$V_3 = 2 \text{ V} \qquad \text{....(3)}$$

Step 5 of 5

Applying KCL at ground node (node 0),

$$\frac{V_2}{2\text{k}} + \frac{V_3}{2\text{k}} - I_O = 0$$
$$I_O = \frac{12+2}{2\text{k}} \qquad \text{.....(By (2) and (3))}$$
$$I_O = 7 \text{ mA}$$

Hence $\boxed{I_o = 7 \text{ mA}}$

3.30p

Figure (1)

Mark the nodes and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = -12 \text{ V} \qquad ....(1)$$
$$V_3 = 9 \text{ V} \qquad ....(2)$$

Applying KCL at node 2

$$-4\text{m} + \frac{V_1 - V_2}{6\text{k}} - \frac{V_2}{4\text{k}} = 0$$
$$-4\text{m} + \frac{2(V_1 - V_2) - 3V_2}{12\text{k}} = 0$$
$$2V_1 - 5V_2 = (4\text{m})(12\text{k})$$
$$2(-12) - 5V_2 = 48 \qquad ....(\text{By}(1))$$
$$-24 - 48 = 5V_2$$
$$V_2 = -\frac{72}{5} \text{ V} \qquad ....(3)$$

$$\because V_O = V_2$$
$$V_O = -\frac{72}{5} \text{ V}$$

Hence $\boxed{V_O = -14.4 \text{ V}}$

Step 2 of 7

Mark the nodes, branch currents and corresponding voltage levels as shown in figure 1.

From the figure we have,

$$V_2 - V_3 = 6 \text{ V}$$

$$V_2 = V_3 + 6 \qquad \text{....(1)}$$

Step 3 of 7

Applying KCL at node 1,

$$-\frac{V_1 - V_2}{6\text{k}} - \frac{V_1}{6\text{k}} = 0$$

$$-V_1 - (V_1 - V_2) = 0$$

$$2V_1 = V_2$$

$$V_1 = \frac{V_2}{2} \qquad \text{....(2)}$$

Step 4 of 7

Applying KCL at node 2,

$$I_1 + \frac{V_1 - V_2}{6\text{k}} - \frac{V_2}{12\text{k}} = 0$$

$$2V_1 - 2V_2 - V_2 + I_1(12\text{k}) = 0$$

$$2\left(\frac{V_2}{2}\right) - 3V_2 + I_1(12\text{k}) = 0 \qquad \text{....(By(2))}$$

$$-2V_2 + I_1(12\text{k}) = 0$$

$$-2(V_3 + 6) + I_1(12\text{k}) = 0 \qquad \text{....(By(1))}$$

$$I_1(12\text{k}) = 2V_3 + 12 \qquad \text{....(3)}$$

Step 5 of 7

Applying KCL at node 3,

$$-I_1 - \frac{V_3 - V_4}{6\text{k}} - \frac{V_3}{12\text{k}} = 0$$

$$-2V_3 + 2V_4 - V_3 - I_1(12\text{k}) = 0$$

$$2V_4 - 3V_3 - (2V_3 + 12) = 0 \qquad \text{....(By(3))}$$

$$2V_4 - 12 = 5V_3$$

$$V_3 = \frac{2}{5}V_4 - \frac{12}{5} \qquad \text{....(4)}$$

Step 6 of 7

Applying KCL at node 4,

$$\frac{V_3 - V_4}{6\text{k}} - \frac{V_4}{6\text{k}} = 0$$

$$V_3 - 2V_4 = 0$$

$$\frac{2}{5}V_4 - \frac{12}{5} - 2V_4 = 0 \qquad \text{....(By(4))}$$

$$\left(\frac{2-10}{5}\right)V_4 = \frac{12}{5}$$

$$-\frac{8}{5}V_4 = \frac{12}{5}$$

$$V_4 = -\frac{3}{2} \text{ V} \qquad \text{....(5)}$$

Step 7 of 7

By Ohm's Law,

$$V_4 = I_O(6\text{k})$$

$$I_O = \frac{V_4}{6\text{k}}$$

$$I_O = -\frac{3}{12} \text{ mA}$$

Hence $\boxed{I_O = -0.25 \text{ mA}}$

3.34p

Figure (1)

Mark the nodes, branch currents and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 6 \text{ V} \qquad ....(1)$$
$$V_2 - V_3 = -12 \text{ V}$$
$$V_2 = V_3 - 12 \qquad ....(2)$$

Applying KCL at node 4

$$\frac{V_3 - V_4}{4\text{k}} - \frac{V_4}{2\text{k}} = 0$$
$$V_3 - V_4 - 2V_4 = 0$$
$$V_4 = \frac{V_3}{3} \qquad ....(3)$$

Applying KCL at node 2

$$-I_1 + \frac{V_1 - V_2}{3\text{k}} - \frac{V_2}{4\text{k}} = 0$$
$$4V_1 - 4V_2 - 3V_2 - I_1(12\text{k}) = 0$$
$$4(6) - 7(V_3 - 12) - I_1(12\text{k}) = 0 \qquad ....(\text{By}(1) \text{ and } (2))$$
$$I_1(12\text{k}) = -7V_3 + 24 + 84$$
$$I_1(12\text{k}) = -7V_3 + 108 \qquad ....(4)$$

Applying KCL at node 3

$$I_1 - \frac{V_3 - V_4}{4\text{k}} - \frac{V_3}{6\text{k}} = 0$$
$$I_1 - \frac{3(V_3 - V_4) + 2V_3}{12\text{k}} = 0$$
$$-3V_3 + 3V_4 - 2V_3 + I_1(12\text{k}) = 0$$
$$3\left(\frac{V_3}{3}\right) - 5V_3 + (-7V_3 + 108) = 0 \qquad ....(\text{By}(3) \text{ and } (4))$$
$$(5 + 7 - 1)V_3 = 108$$
$$V_3 = \frac{108}{11} \text{ V} \qquad ....(5)$$

$$\because V_O = V_3$$
$$V_O = \frac{108}{11} \text{ V}$$

Hence $\boxed{V_O = 9.818 \text{ V}}$

Step 1 of 5

3.35p

Given circuit diagram:

Step 2 of 5

From the above circuit we have below equations

$V_1 = 12\text{ V}$ ..... (1)

$V_2 - V_3 = 6\text{ V}$

$V_2 = 6 + V_3$ ..... (2)

$V_3 = V_O$ ..... (3)

Step 3 of 5

Kirchhoff's current law at the node '2' is

$I = I_O + I_1$

$$\frac{V_1 - V_2}{6\text{ k}} = \frac{V_2}{3\text{ k}} + I_1$$

$$\frac{V_1 - V_2}{6\text{ k}} - \frac{V_2}{3\text{ k}} - I_1 = 0$$

$$\frac{(V_1 - V_2) - 2V_2 - I_1(6\text{ k})}{6\text{ k}} = 0$$

$$V_1 - 3V_2 - I_1(6\text{ k}) = 0$$

Using the equations (1) and (2), we get

$$(12) - 3(6 + V_3) - I_1(6\text{ k}) = 0$$

$$12 - 18 - 3V_3 - I_1(6\text{ k}) = 0$$

$$-6 - 3V_3 - I_1(6\text{ k}) = 0$$

$$I_1 = \frac{-6 - 3V_3}{(6\text{ k})}$$

$$I_1 = \frac{-2 - V_3}{2\text{ k}} \quad \text{..... (4)}$$

Step 4 of 5

Kirchhoff's current law at the node '2' is

$$I_1 + \frac{V_1 - V_3}{12\text{ k}} - \frac{V_3}{6\text{ k}} = 0$$

Using the equation (4), we get

$$\left(\frac{-2 - V_3}{2\text{ k}}\right) + \frac{V_1 - V_3}{12\text{ k}} - \frac{V_3}{6\text{ k}} = 0$$

$$\frac{6(-2 - V_3) + (V_1 - V_3) - 2V_3}{12\text{ k}} = 0$$

$$6(-2 - V_3) + (V_1 - V_3) - 2V_3 = 0$$

$$-12 - 6V_3 + V_1 - V_3 - 2V_3 = 0$$

$$-9V_3 + V_1 = 12$$

Using the equation (1), we get

$$-9V_3 + 12 = 12$$

$$V_3 = 0$$

Step 5 of 5

Finding the output voltage V_O:

From equation (3), we get

$V_O = V_3$

$\boxed{V_O = 0}$.

3.36p

Figure (1)

Step 2 of 3

Mark the nodes, branch current and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 = 6\text{ V} \qquad \text{....(1)}$$

Step 3 of 3

Also from the figure we have,

$$V_1 - V_3 = 3$$
$$V_3 = 6 - 3 \qquad \text{.....(By (1))}$$
$$V_3 = 3\text{ V}$$
$$\because V_O = V_3$$
$$V_O = 3\text{ V}$$

Hence $\boxed{V_O = 3\text{ V}}$

3.37p

Figure (1)

Mark the nodes, branch currents and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 - V_3 = 12 \text{ V}$$
$$V_1 = V_3 + 12 \qquad ....(1)$$
$$V_2 - V_3 = -6 \text{ V}$$
$$V_2 = V_3 - 6 \qquad ....(2)$$

Applying KCL at node 1

$$-I_1 - \frac{V_1 - V_2}{6\text{k}} - \frac{V_1}{4\text{k}} = 0$$
$$-3V_1 - 2(V_1 - V_2) - I_1(12\text{k}) = 0$$
$$-3(V_3 + 12) - 2(V_3 + 12 - V_3 + 6) - I_1(12\text{k}) = 0 \qquad ....(\text{By}(1) \text{ and } (2))$$
$$I_1(12\text{k}) = -3V_3 - 36 - 2(18)$$
$$I_1(12\text{k}) = -3V_3 - 72 \qquad ....(3)$$

Applying KCL at node 2

$$6\text{m} + \frac{V_1 - V_2}{6\text{k}} - I_2 = 0$$
$$(V_3 + 12 - V_3 + 6) - I_2(6\text{k}) + (6\text{m})(6\text{k}) = 0 \qquad ....(\text{By}(1) \text{ and } (2))$$
$$18 + 36 = I_2(6\text{k})$$
$$I_2 = \frac{54}{6\text{k}}$$
$$I_2 = 9 \text{ mA} \qquad ....(4)$$

Applying KCL at node 3

$$I_1 + I_2 - \frac{V_3}{6\text{k}} = 0$$
$$-V_3 + I_1(6\text{k}) + I_2(6\text{k}) = 0$$
$$-V_3 + \frac{(-3V_3 - 72)}{2} + (9\text{m})(6\text{k}) = 0 \qquad ....(\text{By}(3) \text{ and } (4))$$
$$\left(-1 - \frac{3}{2}\right)V_3 - 36 + 54 = 0$$
$$-\frac{5}{2}V_3 + 18 = 0$$
$$\frac{5}{2}V_3 = 18$$
$$V_3 = \frac{36}{5} \text{ V}$$

$$\because V_3 = V_O$$
$$V_O = \frac{36}{5} \text{ V}$$

Hence $\boxed{V_O = 7.2 \text{ V}}$

Step 1 of 2

3.38p

Refer to circuit shown in Figure P3.12 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node V_2 in Figure 1 and solve for V_1.

$$\frac{V_1-12}{6\text{ k}}+\frac{V_1}{6\text{ k}}+\frac{V_1-6}{12\text{ k}}=0$$
$$2(V_1-12)+2V_1+V_1-6=0$$
$$5V_1=24+6$$
$$V_1=6\text{ V}$$

Apply Kirchhoff's current law to the right hand side loop in Figure 1 and solve for voltage V_o.

$$V_o+6\text{ V}-V_1=0$$
$$V_o+6\text{ V}-6\text{ V}=0$$
$$V_o=0\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{0\text{ V}}$.

Step 1 of 5

3.39p

Figure (1)

Step 2 of 5

Mark the nodes, branch currents and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 - V_3 = 12 \text{ V}$$
$$V_1 = V_3 + 12 \qquad ....(1)$$
$$V_2 = -6 \text{ V} \qquad ....(2)$$

Step 3 of 5

Applying KCL at node 1

$$I_1 - \frac{V_1 - V_2}{2\text{k}} - \frac{V_1}{1\text{k}} = 0$$
$$-2V_1 - (V_1 - V_2) + I_1(2\text{k}) = 0$$
$$-2(V_3 + 12) - (V_3 + 12 - (-6)) + I_1(2\text{k}) = 0 \qquad ....(\text{By}(1) \text{ and } (2))$$
$$I_1(2\text{k}) = 3V_3 + 24 + 18$$
$$I_1(2\text{k}) = 3V_3 + 42 \qquad ....(3)$$

Step 4 of 5

Applying KCL at node 3

$$-I_1 + \frac{V_2 - V_3}{1\text{k}} - \frac{V_3}{1\text{k}} = 0$$
$$-V_3 + V_2 - V_3 - I_1(1\text{k}) = 0$$
$$-2V_3 - 6 - \frac{3V_3 + 42}{2} = 0 \qquad ....(\text{By}(2) \text{ and } (3))$$
$$\left(-2 - \frac{3}{2}\right)V_3 - 6 - 21 = 0$$
$$-\frac{7}{2}V_3 - 27 = 0$$
$$-\frac{7}{2}V_3 = 27$$
$$V_3 = -\frac{54}{7} \text{ V}$$

Step 5 of 5

$$\because V_3 = V_O$$
$$V_O = -\frac{54}{7} \text{ V}$$

Hence $\boxed{V_O = -7.714 \text{ V}}$

Step 1 of 2

3.41p

Consider the circuit shown in Figure P3.31 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 2

The nodes V_a and V_b forms super node S_1 , V_b and V_c forms super node S_2 , V_d and V_e forms super node S_3 , V_e and V_o forms super node S_4 .

Apply Kirchhoff's voltage law to the loop formed by super nodes in Figure 1 and solve.

$$V_1 - V_2 + V_3 + V_4 + V_o = 0$$
$$4\text{ V} - 6\text{ V} + 12\text{ V} + 2\text{ V} + V_o = 0$$
$$V_o = -12\text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-12\text{ V}}$.

Step 1 of 3

3.42p

Consider the circuit shown in Figure P3.32 in the text book.

Let V_o be the node voltage at top side node in the considered circuit.

Calculate the value of V_x by applying Kirchhoff's voltage law to the left hand side loop for the considered circuit.

$$-12\text{ V}+V_x+V_o=0$$
$$V_x=12-V_o$$

Step 2 of 3

Apply Kirchhoff's current law at top node V_o in circuit and solve for voltage V_o.

$$\frac{V_o-12}{1\text{k}}+\frac{V_o}{2\text{k}}+\frac{V_o-2V_x}{1\text{k}}=0$$
$$2(V_o-12)+V_o+2(V_o-2(12-V_o))=0$$
$$2V_o-24+V_o+2V_o-48+4V_o=0$$
$$9V_o=48+24$$

Simplify the expression further.

$$V_o=\frac{72}{9}$$
$$=8\text{ V}$$

Step 3 of 3

Calculate the value of current I_o by using Ohm's law $I=\frac{V}{R}$.

Substitute $I=I_o$, $V=8\text{ V}$, $R=2\text{ k}\Omega$ and solve for I_o.

$$I_o=\frac{8\text{ V}}{2\text{ k}\Omega}$$
$$=4\text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{4\text{ mA}}$.

Step 1 of 4

3.43p

The following is the circuit diagram:

Figure 1

Step 2 of 4

Use nodal analysis.
Denote the nodes V_1, V_2 and the bottom node as the reference node.
The circuit in Figure 1 is re-drawn as shown in Figure 2.

Figure 2

Step 3 of 4

Clearly in Figure 2, we have super nodes between the nodes labeled V_1 and V_2
Apply Kirchhoff's Current Law at the super node between nodes V_1 and V_2

$$\frac{V_1 - \frac{V_o}{2}}{1\,\text{k}\Omega} + \frac{V_1}{2\,\text{k}\Omega} + \frac{V_2}{1\,\text{k}\Omega} = 0$$

$$2V_1 - V_o + V_1 + 2V_2 = 0$$

Clearly from Figure 2,

$$V_o = V_2$$

Hence,

$$2V_1 - V_2 + V_1 + 2V_2 = 0$$

$$3V_1 + V_2 = 0 \qquad \text{..... (1)}$$

The constraint equation for the super node between nodes V_1 and V_2 is,

$$V_2 - V_1 = 12 \qquad \text{..... (2)}$$

Step 4 of 4

From equation (2) we have:

$$V_1 = V_2 - 12$$

Substitute $V_1 = V_2 - 12$ in equation (1)

$$3(V_1 - 12) + V_2 = 0$$

$$4V_2 = 36$$

$$V_2 = 9\text{V}$$

Since $V_o = V_2$

Hence, $V_o = 9$ V

Thus, the value of V_o is $\boxed{9\text{ V}}$.

Step 1 of 4

3.44p

Consider the circuit shown in Figure P3.33 in the text book.

Let V_1 be the node voltage at top side node in the considered circuit.

Calculate the value of current I_x in circuit by using Ohm's law $I = \frac{V}{R}$

Substitute $I = I_x$, $V = 12\text{ V} - V_1$, $R = 1\text{ k}\Omega$ from the circuit and solve for I_x .

$$I_x = \frac{V}{R}$$

$$I_x = \frac{12\text{ V} - V_1}{1\text{k}} \quad \text{..... (1)}$$

Step 2 of 4

Apply Kirchhoff's current law at node V_1 and solve for V_1 .

$$\frac{V_1 - 12}{1\text{k}} - 2\times10^{-3} + \frac{V_1 - (-4I_x)}{1\text{k}} = 0$$

$$V_1 - 12 + V_1 + 4I_x = (2\times10^{-3})(1\times10^{3})$$

$$2V_1 + 4\left(\frac{12 - V_1}{1\text{k}}\right) = 2 + 12$$

$$2V_1 + (4\times10^{-3})(12 - V_1) = 14$$

Step 3 of 4

Simplify the expression further

$$2V_1 + (48\times10^{-3}) - 0.004V_1 = 14$$

$$V_1(2 - 0.004) = 14 - 0.048$$

$$V_1 = \frac{13.952}{1.996}$$
$$= 6.99\text{ V}$$

Step 4 of 4

Apply Kirchhoff's current law at node V_1 and solve for I_o .

$$I_o = \left(\frac{12 - V_1}{1\text{k}}\right) + 2\text{ mA}$$
$$= \frac{12 - 6.99}{1\text{k}} + 2\text{ mA}$$
$$= 5.01\text{ mA} + 2\text{ mA}$$
$$= 7.01\text{ mA}$$

Therefore, the value of current I_o in the network is $\boxed{7.01\text{ mA}}$.

Step 1 of 3

3.45p

Consider the circuit shown in Figure P3.34 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law at node V_1 and solve.

$$\frac{V_1 - 2V_o}{2k} - \left(2\times10^{-3}\right) + \frac{V_1 - V_o}{2k} = 0$$

$$V_1 - 2V_o + V_1 - V_o = 4$$

$$2V_1 - 3V_o = 4 \quad \ldots\ldots (1)$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o - 2V_o}{1k} + \frac{V_o - V_1}{2k} + \frac{V_o}{1k} = 0$$

$$2V_o - 4V_o + V_o - V_1 + 2V_o = 0$$

$$V_o - V_1 = 0$$

$$V_o = V_1$$

Substitute $V_1 = V_o$ in equation (1) and solve for V_o.

$$2V_o - 3V_o = 4$$

$$-V_o = 4$$

$$V_o = -4 \text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{-4 \text{ V}}$.

Step 1 of 3

3.46p

Consider the circuit shown in Figure P3.35 in the text book.

The node voltages in the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the current I_x in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = 12 - V_1$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for I_x.

$$I_x = \frac{12 - V_1}{1\text{k}}$$

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve for V_1.

$$\frac{V_1 - 12}{1\text{k}} + \frac{V_1}{1\text{k}} + 4I_x = 0$$
$$\frac{V_1 - 12}{1\text{k}} + \frac{V_1}{1\text{k}} + 4\left(\frac{12 - V_1}{1\text{k}}\right) = 0$$
$$V_1 - 12 + V_1 + 48 - 4V_1 = 0$$
$$V_1 = 18\ \text{V}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_1 and solve for V_o.

$$\frac{V_o - 12}{1\text{k}} + \frac{V_o}{1\text{k}} = 4I_x$$
$$\frac{V_o - 12}{1\text{k}} + \frac{V_o}{1\text{k}} = 4\left(\frac{12 - V_1}{1\text{k}}\right)$$
$$V_o - 12 + V_o = 48 - 4V_1$$
$$2V_o - 12 = 48 - 4(18)$$

Simplify the expression further.

$$2V_o = 48 - 72 + 12$$
$$2V_o = -12$$

$$V_o = \frac{-12}{2}$$
$$= -6\ \text{V}$$

Therefore, the value of voltage V_o in the network is $\boxed{-6\ \text{V}}$.

Step 1 of 7

3.47p

Consider the circuit shown in Figure E3.14 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 7

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$2kI_1 + 3kI_1 + 4k(I_1 - I_2) + 3k(I_1 - I_3) + 8 - 10 = 0$$
$$2kI_1 + 3kI_1 + 4kI_1 - 4kI_2 + 3kI_1 - 3kI_3 = 2$$

$$12kI_1 - 4kI_2 - 3kI_3 = 2 \quad \text{..... (1)}$$

Step 3 of 7

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$4k(I_2 - I_1) + 4kI_2 - 12 + 6k(I_2 - I_3) = 0$$
$$4kI_2 - 4kI_1 + 4kI_2 + 6kI_2 - 6kI_3 = 12$$

$$-4kI_1 + 14kI_2 - 6kI_3 = 12 \quad \text{..... (2)}$$

Step 4 of 7

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$3k(I_3 - I_1) + 6k(I_3 - I_2) + 6kI_3 = 8$$
$$3kI_3 - 3kI_1 + 6kI_3 - 6kI_2 + 6kI_3 = 8$$
$$-3kI_1 - 6kI_2 + 15kI_3 = 8$$
$$3kI_1 = -6kI_2 + 15kI_3 - 8$$

Simplify the expression further.

$$I_1 = \frac{-6kI_2 + 15kI_3 - 8}{3k} \quad \text{..... (3)}$$

Step 5 of 7

Substitute equation (3) in (1) and solve further.

$$12k\left(\frac{-6kI_2 + 15kI_3 - 8}{3k}\right) - 4kI_2 - 3kI_3 = 2$$
$$-24kI_2 + 60kI_3 - 32 - 4kI_2 - 3kI_3 = 2$$
$$-28kI_2 + 57kI_3 = 34$$

$$I_2 = \frac{57kI_3 - 34}{28k} \quad \text{..... (4)}$$

Step 6 of 7

Substitute equation (1) and (4) in (2) and solve for I_3.

$$-4k\left(\frac{-6kI_2 + 15kI_3 - 8}{3k}\right) + 14kI_2 - 6kI_3 = 12$$
$$24kI_2 - 60kI_3 + 32 + 42kI_2 - 18kI_3 = 36$$
$$66kI_2 - 78kI_3 = 4$$
$$66k\left(\frac{57kI_3 - 34}{28k}\right) - 78kI_3 = 4$$

Simplify the expression further.

$$(66)(57kI_3) - (66)(34) - (78kI_3)(28) = (28)(4)$$
$$3762kI_3 - 2184kI_3 = 112 + 2244$$
$$1578kI_3 = 2356$$
$$I_3 = 1.493 \text{ mA}$$

Step 7 of 7

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_3$, $R = 6\text{ k}\Omega$ from Figure 1 and solve for V_o.

$$\begin{aligned} V_o &= I_3 R \\ &= (1.493\text{ mA})(6\text{ k}\Omega) \\ &= 8.96\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{8.96\text{ V}}$.

Step 1 of 9

Refer to Figure E2.17 in the textbook.

Redraw the circuit by representing currents as shown in Figure 1.

Figure 1

Step 2 of 9

Let I , I_1 and I_2 be the currents flowing in branches as shown in Figure 1. Also let resistors be $R_1 = 20\ \text{k}\Omega$, $R_2 = 20\ \text{k}\Omega$, $R_3 = 20\ \text{k}\Omega$ and $R_4 = 20\ \text{k}\Omega$.

Step 3 of 9

The resistors R_3 and R_4 are in series connection. The equivalent resistance (R_a) is,

$$\begin{aligned} R_a &= R_3 + R_4 \\ &= 40\ \text{k}\Omega + 20\ \text{k}\Omega \\ &= 60\ \text{k}\Omega \end{aligned}$$

Step 4 of 9

The resistance R_a is in parallel to R_2 . Calculate the equivalent resistance R_b as follows:

$$\begin{aligned} R_b &= \left(\frac{1}{R_a} + \frac{1}{R_2}\right)^{-1} \\ &= \frac{R_2 R_a}{R_a + R_2} \\ &= \frac{(30\ \text{k}\Omega)(60\ \text{k}\Omega)}{60\ \text{k}\Omega + 30\ \text{k}\Omega} \\ &= 20\ \text{k}\Omega \end{aligned}$$

Step 5 of 9

Now the circuit is reduced as shown in Figure 2.

Figure 2

Step 6 of 9

Calculate the value of current I from Figure 2 as follows:

$$\begin{aligned} I &= \frac{V}{R_1 + R_b} \\ &= \frac{12\ \text{V}}{20\ \text{k}\Omega + 20\ \text{k}\Omega} \\ &= 0.3\ \text{mA} \end{aligned}$$

Step 7 of 9

Calculate the value of current I_1 from Figure 1 by using current division formula as follows:

$$\begin{aligned} I_1 &= \left(\frac{R_3 + R_4}{R_3 + R_4 + R_2}\right) I \\ &= \left(\frac{40\ \text{k}\Omega + 20\ \text{k}\Omega}{40\ \text{k}\Omega + 20\ \text{k}\Omega + 30\ \text{k}\Omega}\right)(0.3\ \text{mA}) \\ &= (0.66)(0.3 \times 10^{-3}) \\ &= 0.2\ \text{mA} \end{aligned}$$

Step 8 of 9

Calculate the value of current I_2 from Figure 1 by applying Kirchhoff's current law as follows:

$$\begin{aligned} I &= I_1 + I_2 \\ I_2 &= I - I_1 \\ &= 0.3\ \text{mA} - 0.2\ \text{mA} \\ &= 0.1\ \text{mA} \end{aligned}$$

Step 9 of 9

Now, calculate the value of voltage V_o from Figure 1 as follows:

$$\begin{aligned} V_o &= I_2 R_4 \\ &= (0.1\ \text{mA})(20\ \text{k}\Omega) \\ &= (0.1 \times 10^{-3})(20 \times 10^{3}) \\ &= 2\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o is $\boxed{2\ \text{V}}$.

3.49p

Step 1 of 3

3.51p

Refer to Figure P3.39 in the text book for the circuit.

Redraw the circuit with node voltage notations as shown in Figure 1.

Figure 1

Observe from Figure 1 that the node voltages V_1 and V_o are constrained by the equation,

$$V_o - V_1 = 12$$

So,

$$V_1 = V_o - 12$$

Step 2 of 3

Redraw the circuit with the reduced node voltages.

Figure 2

Step 3 of 3

Apply Kirchhoff's current law to node 2.

$$-2\text{m} - 2I_x - I_x = 0$$
$$-2\text{m} - 3I_x = 0$$
$$-3I_x = 2\text{m}$$
$$I_x = -\frac{2}{3}\ \text{mA}$$

Apply Kirchhoff's current law to the top node.

$$\frac{V_o}{1\text{k}} + 2\text{m} + I_x + \frac{V_o - 12}{1\text{k}} = 0$$
$$\left(\frac{1}{1\text{k}} + \frac{1}{1\text{k}}\right)V_o + 2\text{m} + I_x - \frac{12}{1\text{k}} = 0$$

Substitute $-\frac{2}{3}$ mA for I_x.

$$\left(\frac{1}{1\text{k}} + \frac{1}{1\text{k}}\right)V_o + 2\text{m} - \frac{2}{3}\text{m} - \frac{12}{1\text{k}} = 0$$
$$\left(\frac{1+1}{1\text{k}}\right)V_o + \left(2 - \frac{2}{3}\right)\text{m} - \frac{12}{1\text{k}} = 0$$
$$\left(\frac{2}{1\times10^3}\right)V_o + \left(\frac{6-2}{3}\times10^{-3}\right) - \left(12\times10^{-3}\right) = 0$$
$$\left(2\times10^{-3}\right)V_o + \left(\frac{4}{3}\times10^{-3}\right) - \left(12\times10^{-3}\right) = 0$$
$$\left(2\times10^{-3}\right)V_o + \left(\frac{4}{3} - 12\right)\times10^{-3} = 0$$
$$\left(2\times10^{-3}\right)V_o + \left(\frac{4-36}{3}\right)\times10^{-3} = 0$$
$$\left(2\times10^{-3}\right)V_o = \left(\frac{32}{3}\times10^{-3}\right)$$

The output voltage is,

$$V_o = \frac{\left(\frac{32}{3}\times10^{-3}\right)}{\left(2\times10^{-3}\right)}$$
$$= \frac{32}{3\times2}$$
$$= \frac{16}{3}$$
$$= 5.33\ \text{V}$$

Thus, the output voltage is, $\boxed{V_o = 5.333\ \text{V}}$.

Step 1 of 3

3.52p

Consider the circuit shown in Figure P3.36 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of current I_o in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_o$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for I_o.

$$I_o = \frac{V_o}{1\text{k}}$$

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve.

$$\frac{V_1 - 12}{1\text{k}} + \frac{V_1 - V_o}{1\text{k}} - 2I_o = 0$$

$$V_1 - 12 + V_1 - V_o - \left(2\left(\frac{V_o}{1\text{k}}\right)\right)(1\text{k}) = 0$$

$$V_1 = \frac{3V_o + 12}{2} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's current law at node V_o in Figure 1 and solve.

$$\frac{V_o - 12}{1\text{k}} + \frac{V_o - V_1}{1\text{k}} + \frac{V_o}{1\text{k}} = 0$$

$$V_o - 12 + V_o - V_1 + V_o = 0$$

$$3V_o - V_1 = 12 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and solve for V_o.

$$3V_o - \left(\frac{3V_o + 12}{2}\right) = 12$$

$$3V_o - 1.5V_o - 6 = 12$$

$$1.5V_o = 18$$

$$V_o = 12\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{12\ \text{V}}$.

Step 1 of 4

3.55p

Refer to Figure P3.55 in the text book.

The circuit contains one super node.

Draw the equivalent circuit and indicate the supernode.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law at the supernode.

$$\frac{V_1-2V_x}{1\text{ k}\Omega}+\frac{V_1}{1\text{ k}\Omega}+\frac{V_x}{1\text{ k}\Omega}+\frac{V_x}{1\text{ k}\Omega+1\text{ k}\Omega}=4\text{ mA}$$

$$\frac{2(V_1-2V_x)+2V_1+2V_x+V_x}{2\times10^3}=4\times10^{-3}$$

$$4V_1-V_x=8 \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's voltage law in the supernode.

$$-V_1-6+V_x=0$$

$$V_1=V_x-6$$

Substitute V_x-6 in equation (1).

$$4(V_x-6)-V_x=8$$

$$4V_x-24-V_x=8$$

$$3V_x=32$$

$$V_x=\frac{32}{3}\text{ V}$$

Step 4 of 4

Use voltage division principle and write the expression of V_o in terms of V_x.

$$V_o=\left(\frac{V_x}{1\text{ k}\Omega+1\text{ k}\Omega}\right)(1\text{ k}\Omega)$$

$$=\frac{V_x}{2}$$

Substitute $\frac{32}{3}$ V for V_x.

$$V_o=\frac{32/3}{2}$$

$$=\frac{16}{3}$$

$$=5.333\text{ V}$$

Thus, the value of V_o is $\boxed{5.333\text{ V}}$.

Step 1 of 3

3.56p

Consider the circuit shown in Figure P3.40 in the text book.

Calculate the value of I_x in the circuit by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = V_o$, $R = 1\ \text{k}\Omega$ from the circuit and solve for I_x.

$$I_x = \frac{V_o}{1\ \text{k}\Omega}$$

Step 2 of 3

The node voltages V_o and V_x in the circuit forms a super node. Solve the value of V_x from super node.

$$V_x - V_o = 12\ \text{V}$$
$$V_x = V_o + 12$$

Step 3 of 3

Apply Kirchhoff's current law at super node and solve for V_o.

$$4I_x + \frac{V_x}{1\text{k}} + \frac{V_o}{1\text{k}} + \frac{V_o - 2V_x}{1\text{k}} = 2\times10^{-3}$$
$$4\left(\frac{V_o}{1\text{k}}\right) + \frac{V_o + 12}{1\text{k}} + \frac{V_o}{1\text{k}} + \frac{V_o - 2(V_o + 12)}{1\text{k}} = 2\times10^{-3}$$
$$4V_o + V_o + 12 + V_o + V_o - 2V_o - 24 = \left(2\times10^{-3}\right)\left(1\times10^{3}\right)$$
$$5V_o = 2 + 24 - 12$$

Simplify the expression further.

$$5V_o = 14$$
$$V_o = \frac{14}{5}$$
$$= 2.8\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{2.8\ \text{V}}$.

Step 1 of 6

3.59p

Given circuit is

Step 2 of 6

From the given circuit,

$$\boxed{V_3 = 20\,\text{V}}$$

$$V_4 - 20 = V_x$$

$$V_1 - V_4 = 4I_x \qquad \text{..... (1)}$$

$$I_x = \frac{20 - V_2}{10}$$

Step 3 of 6

Substitute I_x value in equation (1), we get

$$V_1 - V_4 = 4\left(\frac{20 - V_2}{10}\right)$$

$$V_1 - V_4 = 8 - 0.4V_2$$

$$V_1 = 8 - 0.4V_2 + V_4 \qquad \text{..... (2)}$$

The KCL equation at super node

$$-10 + \frac{V_1}{4} + \frac{V_1 - V_2}{8} + \frac{V_4 - 20}{5} + \frac{V_4 - V_2}{2} = 0$$

$$\frac{-400 + 10V_1 + 5V_1 - 5V_2 + 8V_4 - 160 + 20V_4 - 20V_2}{40} = 0$$

$$15V_1 - 25V_2 + 28V_4 = 560 \qquad \text{..... (3)}$$

Step 4 of 6

Substitute equation (2) in (3), we get

$$15(8 - 0.4V_2 + V_4) - 25V_2 + 28V_4 = 560$$

$$120 - 6V_2 + 15V_4 - 25V_2 + 28V_4 = 560$$

$$-31V_2 + 43V_4 = 440 \qquad \text{..... (4)}$$

The KCL equation at node V_2 as

$$\frac{V_2 - V_1}{8} + \frac{V_2 - 20}{10} + \frac{V_2 - V_4}{2} = 2V_x$$

$$\frac{5V_2 - 5V_1 + 4V_2 - 80 + 20V_2 - 20V_4}{40} = 2(V_4 - 20)$$

$$-5V_1 - 80 + 29V_2 - 100V_4 = -1600$$

$$-5V_1 + 29V_2 - 100V_4 = -1520 \qquad \text{..... (5)}$$

Step 5 of 6

Substitute equation (2) in equation (5), we get

$$-5(8 - 0.4V_2 + V_4) + 29V_2 - 100V_4 = -1520$$

$$31V_2 - 105V_4 = -1480$$

$$31V_2 = -1480 + 105V_4 \qquad \text{..... (6)}$$

Substitute equation (6) in (4), we get

$$-(-1480 + 105V_4) + 43V_4 = 440$$

$$62V_4 = 1040$$

$$V_4 = \frac{1040}{62}$$

$$\boxed{V_4 = 16.77\,\text{V}}$$

Step 6 of 6

From equation (6), we get

$$31V_2 = -1480 + 105(16.77)$$

$$V_2 = \frac{280.85}{31}$$

$$\boxed{V_2 = 9.059\,\text{V}}$$

Substitute V_2 and V_4 values in equation (2), we get

$$V_1 = 8 - 0.4(9.059) + 16.77$$

$$\boxed{V_1 = 21.146\,\text{V}}$$

Step 1 of 4

3.60p

Consider the circuit shown in Figure P3.43 in the text book.

The node voltages for the considered circuit are shown in figure 1.

Figure 1

Step 2 of 4

The node voltages V_1 and V_3 in figure 1 forms a super node S_1. So the voltage V_3 can be written as $V_1 - 2V_x$. Also the nodes V_2 and V_x in figure 1 forms a super node S_2. So the voltage V_2 can be written as $V_x - 12$.

Apply Kirchhoff's current law at super node S_1 in Figure 1 and solve.

$$\frac{V_3 - V_2}{1\text{k}} + \frac{V_1 - V_x}{1\text{k}} + \frac{V_1}{1\text{k}} + \frac{V_1}{2\text{k}} = 4\text{m}$$

$$\frac{V_1 - 2V_x - V_x + 12}{1\text{k}} + \frac{V_1 - V_x}{1\text{k}} + \frac{V_1}{1\text{k}} + \frac{V_1}{2\text{k}} = 4\text{m}$$

$$2V_1 - 6V_x + 24 + 2V_1 - 2V_x + 2V_1 + V_1 = \left(4\times10^{-3}\right)\left(2\times10^{3}\right)$$

$$7V_1 - 8V_x = -16 \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's current law at super node S_2 in Figure 1 and solve.

$$\frac{V_2 - V_3}{1\text{k}} + 2\text{m} + \frac{V_x}{1\text{k}} + \frac{V_x - V_1}{1\text{k}} = 0$$

$$\frac{(V_x - 12) - (V_1 - 2V_x)}{1\text{k}} + \frac{V_x}{1\text{k}} + \frac{V_x - V_1}{1\text{k}} = -2\text{m}$$

$$V_x - 12 - V_1 + 2V_x + 2V_x - V_1 = \left(-2\times10^{-3}\right)\left(1\times10^{3}\right)$$

$$-2V_1 + 5V_x = 10$$

Simplify the expression further.

$$V_x = \frac{10 + 2V_1}{5} \quad \text{..... (2)}$$

Step 4 of 4

Substitute equation (2) in (1) and solve for V_1.

$$7V_1 - 8\left(\frac{10 + 2V_1}{5}\right) = -16$$

$$7V_1 - (1.6)(10 + 2V_1) = -16$$

$$7V_1 - 16 - 3.2V_1 = -16$$

$$V_1 = 0$$

Therefore, the value of voltage V_1 in the circuit is 0 V and so the voltage across V_o in the Figure P3.43 is also $\boxed{0\text{ V}}$.

Step 1 of 3

3.61p

Consider the circuit shown in Figure P3.49 in the text book.

The direction of currents flowing in the branches of the considered circuit is shown in Figure 1.

Figure 1

The nodes V_1, V_2, V_3, V_4 form a super node in Figure 1. The value of voltage V_1 can be written as $V_3 + 12\ \text{V}$ from Figure 1 and the value of voltage V_4 is $2V_A$. Also, the value of voltage V_A is written as $V_3 - V_2$.

Apply Kirchhoff's current law at node voltage V_2 in Figure 1 and solve.

$$I_2 = I_5 + I_3$$
$$\frac{V_1 - V_2}{6} = \frac{V_2 - V_4}{10} + \frac{V_2 - V_3}{8}$$
$$\frac{V_1 - V_2}{3} = \frac{V_2 - V_4}{5} + \frac{V_2 - V_3}{4}$$
$$(20)(V_1 - V_2) = (V_2 - V_4)(12) + (V_2 - V_3)(15)$$

Simplify the expression further.

$$20V_1 - 20V_2 = 12V_2 - 12V_4 + 15V_2 - 15V_3$$
$$20V_1 - 47V_2 + 15V_3 + 12V_4 = 0$$
$$5V_1 - 11.75V_2 + 3.75V_3 + 3V_4 = 0 \quad \text{..... (1)}$$

Step 2 of 3

Apply Kirchhoff's current law at super node in Figure 1 and solve.

$$3 + I_1 + I_5 + I_4 = 4$$
$$\frac{V_1}{4} + \frac{V_2 - V_4}{10} + \frac{V_3}{1} = 4 - 3$$
$$5V_1 + 2V_2 - 2V_4 + 20V_3 = (20)(1)$$
$$5V_1 + 2V_2 + 20V_3 - 2V_4 = 20 \quad \text{..... (2)}$$

Calculate the voltage at node V_4 and solve the equation.

$$\begin{aligned} V_4 &= 2V_A \\ &= 2(V_3 - V_2) \\ &= 2V_3 - 2V_2 \end{aligned}$$
$$-2V_2 + 2V_3 - V_4 = 0 \quad \text{..... (3)}$$

Calculate the voltage across the voltage source.

$$V_1 - V_3 = 12 \quad \text{..... (4)}$$

Write the equations of (1), (2), (3) and (4) in matrix notation form.

$$5V_1 - 11.75V_2 + 3.75V_3 + 3V_4 = 0$$
$$5V_1 + 2V_2 + 20V_3 - 2V_4 = 20$$
$$V_1 + 0V_2 - V_3 + 0V_4 = 12$$
$$0V_1 - 2V_2 + 2V_3 - V_4 = 0$$

Step 3 of 3

Now solve the set of four matrix equations by using matlab.

```
%solving the equations by using matlab
R=[5,-11.75,3.75,3
5,2,20,-2
1,0,-1,0
0,-2,2,-1];
I=[0,20,12,0]';
V=inv(R)*I
```

V = 9.6802 1.4526 -2.3198 -7.5447

By executing this program the answer is generated in the command window of matlab.

Therefore, the values of voltages are $\boxed{V_1 = 9.68\ \text{V}}$, $\boxed{V_2 = 1.45\ \text{V}}$, $\boxed{V_1 = -2.32\ \text{V}}$, $\boxed{V_4 = -7.54\ \text{V}}$

Thus, the voltage values are calculated.

Step 1 of 3

3.65p

Consider the circuit shown in Figure P3.53 in the text book.

Let I_1 and I_o be the currents flowing in the loops of circuit as shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$6kI_1 + 6k(I_1 - I_o) + 6 = 0$$
$$6kI_1 + 6kI_1 - 6kI_o + 6 = 0$$
$$2kI_1 - 1kI_0 = -1$$

$$I_1 = \frac{-1 + 1kI_0}{2k} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$6k(I_o - I_1) + 4kI_o + 24 = 0$$
$$6kI_o - 6kI_1 + 4kI_o = -24$$

$$10kI_o - 6kI_1 = -24 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and solve for current I_o .

$$10kI_o - 6k\left(\frac{-1 + 1kI_o}{2k}\right) = -24$$
$$10kI_o - 3(-1 + 1kI_o) = -24$$
$$10kI_o + 3 - 3kI_o = -24$$
$$7kI_o = -27$$
$$I_o = -3.85 \text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{-3.85 \text{ mA}}$.

Step 1 of 4

3.66p

Consider the circuit shown in Figure P3.55 in the text book.

Let I_1 and I_2 be the currents flowing in the loops of circuit as shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$4kI_1 + 4 + 4k(I_1 - I_2) = 0$$
$$4kI_1 + 4 + 4kI_1 - 4kI_2 = 0$$
$$8kI_1 = 4kI_2 - 4$$

$$I_1 = \frac{1kI_2 - 1}{2k} \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$4k(I_2 - I_1) - 12 + 4kI_2 = 0$$
$$4kI_2 - 4kI_1 - 12 + 4kI_2 = 0$$
$$-4kI_1 + 8kI_2 = 12$$

$$-1kI_1 + 2kI_2 = 3 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and solve for I_2.

$$(-1k)\left(\frac{1kI_2 - 1}{2k}\right) + 2kI_2 = 3$$
$$-0.5kI_2 + 0.5 + 2kI_2 = 3$$
$$1.5kI_2 = 2.5$$
$$I_2 = 1.667 \text{ mA}$$

Step 4 of 4

Calculate the voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = 1.667 \text{ mA}$, $R = 4 \text{ k}\Omega$ from the Figure 1 and solve for V_o.

$$V_o = (1.667 \text{ mA})(4 \text{ k}\Omega)$$
$$= 6.668 \text{ V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{6.668 \text{ V}}$.

Figure (1)

Step 2 of 5

Let the currents in the two loops be as shown in figure 1.

From the figure we have ,

$$V_{ab} = -12 \text{ V} \qquad ....(1)$$
$$V_{bc} = 4 \text{ V} \qquad ....(2)$$

Step 3 of 5

Applying KVL in loop *abda*

$$V_{ab} + V_{bd} + V_{da} = 0$$
$$-12 + (I_1 - I_2)(2\text{k}) + I_1(2\text{k}) = 0 \qquad ....(\text{By}(1))$$
$$I_1(4\text{k}) - I_2(2\text{k}) - 12 = 0$$
$$I_1(2\text{k}) = I_2(1\text{k}) + 6 \qquad ....(3)$$
$$I_1 = \frac{1}{2} I_2 + 3 \text{ mA} \qquad ....(4)$$

Step 4 of 5

Applying KVL in loop *dbcd*

$$V_{db} + V_{bc} + V_{cd} = 0$$
$$(I_2 - I_1)(2\text{k}) + 4 + I_2(2\text{k}) = 0 \qquad ....(\text{By}(2))$$
$$I_2(4\text{k}) - I_1(2\text{k}) + 4 = 0$$
$$I_2(4\text{k}) - \left(I_2(1\text{k}) + 6\right) + 4 = 0 \qquad ....(\text{By}(3))$$
$$I_2(3\text{k}) = 2$$
$$I_2 = \frac{2}{3} \text{mA} \qquad ....(5)$$

Step 5 of 5

$$\because V_O = I_2(2\text{k})$$
$$V_O = \frac{4}{3} \text{ V}$$

Hence $\boxed{V_O = 1.333 \text{ V}}$

Step 1 of 2

3.69p

Consider the circuit shown in Figure P3.52 in the text book.

The node voltages V_1 and V_2 form a super node in the considered circuit. The value of node voltage V_x in the circuit is $-V_2$.

The value of node voltage V_3 in the circuit is $12\ \text{V}$.

$V_3 = 12\ \text{V}$ ` ..... (1)

Calculate the voltage between the nodes V_1 and V_2 .

$$V_2 - V_1 = 3I_x$$
$$V_2 - V_1 = 3\left(\frac{V_4 - V_2}{6}\right)$$
$$2V_2 - 2V_1 = V_4 - V_2$$
$$2V_1 - 3V_2 + V_4 = 0 \text{ ..... (2)}$$

Apply Kirchhoff's current law at node V_4 in the considered circuit and solve.

$$\frac{V_4 - V_3}{4} + \frac{V_4 - V_2}{6} + 4 = 0$$
$$6V_4 - 6V_3 + 4V_4 - 4V_2 + (4)(24) = 0$$
$$-4V_2 - 6V_3 + 10V_4 = -96 \text{ ..... (3)}$$

Apply Kirchhoff's current law at super node in the considered circuit and solve.

$$\frac{V_1}{5} + 2V_x - 3 + \frac{V_2}{3} + \frac{V_2 - V_3}{8} + \frac{V_2 - V_4}{6} = 0$$
$$\frac{V_1}{5} + (2)(-V_2) + \frac{V_2}{3} + \frac{V_2}{8} - \frac{V_3}{8} + \frac{V_2}{6} - \frac{V_4}{6} = 0$$
$$\frac{V_1}{5} + \left(\frac{1}{3} + \frac{1}{8} + \frac{1}{6} - 2\right)V_2 - \frac{V_3}{8} - \frac{V_4}{6} = 3$$
$$0.2V_1 - 1.375V_2 - 0.125V_3 - 0.167V_4 = 3 \text{ ..... (4)}$$

Step 2 of 2

Write the equations of (1), (2), (3) and (4) in the matrix notation form.

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 2 & -3 & 0 & 1 \\ 0 & -4 & -6 & 10 \\ 0.2 & -1.375 & -0.125 & -0.167 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} 12 \\ 0 \\ -96 \\ 3 \end{bmatrix}$$

Now, solve the set of four matrix equations by using matlab.

```
%solving the equations by using matlab

R=[0,0,1,0

2,-3,0,1

0,-4,-6,10

0.2,-1.375,-0.125,-0.167];

I=[12,0,-96,3]';

V=inv(R)*I

V =   -3.0452   -3.2655   12.0000   -3.7062
```

By executing this program the answer is generated in the command window of matlab.

Therefore, the values of voltages are $\boxed{V_1 = -3.05\ \text{V}}$, $\boxed{V_2 = -3.27\ \text{V}}$, $\boxed{V_3 = 12\ \text{V}}$, $\boxed{V_4 = -3.7\ \text{V}}$.

Thus, the values of voltages are calculated.

3.70p

Figure (1)

Let the currents in the three loops be as shown in figure 1.

From the figure we have,

$$V_{bc} = 3\text{ V} \qquad ....(1)$$
$$I_1 = 2\text{ mA} \qquad ....(2)$$

Applying KVL in loop *bdcb*

$$V_{bd} + V_{dc} + V_{cb} = 0$$
$$I_2(3\text{k}) + (I_2 - I_1)(6\text{k}) - 3 = 0$$
$$I_2(9\text{k}) - I_1(6\text{k}) - 3 = 0$$
$$I_2(9\text{k}) - (2\text{m})(6\text{k}) - 3 = 0 \qquad ....(\text{By}(2))$$
$$I_2(9\text{k}) - 12 - 3 = 0$$
$$I_2 = \frac{15}{9}\text{ mA}$$
$$I_2 = \frac{5}{3}\text{ mA}$$

$$\because I_O = I_2$$
$$I_O = \frac{5}{3}\text{mA}$$

Hence $\boxed{I_O = 1.667\text{ mA}}$

Step 1 of 4

3.73p

Consider the circuit shown in Figure P3.60 in the text book.

The currents flowing in the loops for the considered circuit is shown in Figure 1.

Step 2 of 4

Figure 1

Step 3 of 4

From Circuit the value of current I_2 is 2 mA.

Apply Kirchhoff's voltage law in the loop having current I_1 in Figure 1 and solve.

$$3kI_1 + 6k(I_1 - I_2) = 12$$
$$3kI_1 + 6kI_1 - 6kI_2 = 12$$
$$9kI_1 = 12 + 6k(2m)$$
$$I_1 = 2.667\text{ mA}$$

Step 4 of 4

Apply Kirchhoff's voltage law in loop having current I_2 in Figure 1 and solve.

$$6k(I_2 - I_1) + 2kI_2 + V_o = 0$$
$$6kI_2 - 6kI_1 + 2kI_2 + V_o = 0$$
$$8kI_2 - 6kI_1 + V_o = 0$$
$$(8k)(2m) - (6k)(2.667m) + V_o = 0$$

Simplify the expression further.

$$16 - 16.002 + V_o = 0$$
$$V_o = 2\text{ mV}$$

Therefore, the value of voltage V_o in the network is $\boxed{2\text{ mV}}$.

Step 1 of 1

3.75p

Refer to Figure P3.59 in the text book for the circuit.

Let the two loop currents be I_1 and I_2 .

Thus,

$$I_1 - I_2 = 2\,\text{mA} \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the super mesh.

$$(1\text{ k})I_1 + (2\text{k})I_1 + (2\text{ k})I_2 - 12 + (1\text{ k})I_2 = 0$$
$$(3\text{ k})I_1 + (3\text{ k})I_2 = 12$$

$$I_1 + I_2 = 4\text{ mA} \quad \text{..... (2)}$$

Solve the two equations to get current values.

$$I_1 = 3\text{ mA}$$
$$I_2 = 1\text{ mA}$$

Determine the output voltage.

$$\begin{aligned} V_0 &= (1\text{ k})(I_2) \\ &= (1\text{ k})(1\text{ mA}) \\ &= 1\text{ V} \end{aligned}$$

Thus, the output voltage is $\boxed{V_0 = 1\text{ V}}$.

Step 1 of 5

3.76p

Loading solution. Please wait ...

Step 2 of 5

Loading solution. Please wait ...

Step 3 of 5

Loading solution. Please wait ...

Step 4 of 5

Loading solution. Please wait ...

Step 2 of 5

Let the currents in the two loops be as shown in figure 1.

From the figure we have ,

$$V_{da} = 12 \text{ V} \qquad ....(1)$$
$$V_{ed} = 24 \text{ V} \qquad ....(2)$$

Step 3 of 5

Applying KVL in loop *abcda*

$$V_{ab} + V_{bc} + V_{cd} + V_{da} = 0$$
$$I_1(6\text{k}) + (I_1 - I_2)(8\text{k}) + (I_1 - I_2)(4\text{k}) + 12 = 0 \qquad ....(\text{By}(1))$$
$$I_1(18\text{k}) - I_2(12\text{k}) + 12 = 0$$
$$I_1(18\text{k}) = I_2(12\text{k}) - 12$$
$$I_1(3\text{k}) = I_2(2\text{k}) - 2 \qquad ....(3)$$
$$I_1 = \frac{2}{3} I_2 - \frac{2}{3}\text{mA} \qquad ....(4)$$

Step 4 of 5

Applying KVL in loop *dcbed*

$$V_{dc} + V_{cb} + V_{be} + V_{ed} = 0$$
$$(I_2 - I_1)(4\text{k}) + (I_2 - I_1)(8\text{k}) + I_2(4\text{k}) + 24 = 0 \qquad ....(\text{By}(2))$$
$$I_2(16\text{k}) - I_1(12\text{k}) + 24 = 0$$
$$I_2(16\text{k}) - 4(I_2(2\text{k}) - 2) + 24 = 0 \qquad ....(\text{By}(3))$$
$$I_2(8\text{k}) = -32$$
$$I_2 = -4 \text{ mA} \qquad ....(5)$$
$$I_1 = \frac{2}{3}(-4 \text{ mA}) - \frac{2}{3}\text{mA} \qquad ....(\text{By}(4))$$
$$I_1 = -\frac{10}{3} \text{ mA} \qquad ....(6)$$

Step 5 of 5

$$\because V_O = V_{cd}$$
$$V_O = (I_1 - I_2)(4\text{k})$$
$$V_O = \left(-\frac{10}{3}\text{m} - (-4\text{m})\right)(4\text{k}) \qquad ....(\text{By}(5) \text{ and } (6))$$
$$V_O = \left(\frac{2}{3}\text{m}\right)(4\text{k})$$
$$V_O = \frac{8}{3} \text{ V}$$

Hence $\boxed{V_O = 2.667 \text{ V}}$

•●

3.84p

Figure (1)

Let the currents in the four loops be as shown in figure 1.

From the figure we have,

$$V_{bc} = -12 \text{ V} \qquad ....(1)$$
$$I_4 = 12 \text{ mA} \qquad ....(2)$$
$$I_4 - I_2 = I_O$$
$$I_O = 12 \text{ mA} - I_2 \qquad ....(3)$$

Applying KVL in loop *bcb*

$$V_{bc} + V_{cb} = 0$$
$$I_1(2\text{k}) + 12 = 0 \qquad ....(\text{By}(1))$$
$$I_1 = -6 \text{ mA} \qquad ....(4)$$

Applying KVL in loop *aba*

$$V_{ab} + V_{ba} = 0$$
$$I_2(6\text{k}) + (I_3 - I_2)(3\text{k}) = 0$$
$$I_3(9\text{k}) - I_2(3\text{k}) = 0$$
$$I_3 = \frac{1}{3} I_2 \qquad ....(5)$$

Applying KVL in loop *abca*

$$V_{ab} + V_{bc} + V_{ca} = 0$$
$$(I_2 - I_3)(3\text{k}) - 12 + (I_2 - I_4)(4\text{k}) = 0$$
$$I_2(7\text{k}) - I_3(3\text{k}) - I_4(12\text{m}) = 12$$
$$I_2(7\text{k}) - I_3(3\text{k}) - (12\text{m})(4\text{k}) = 12 \qquad ....(\text{By}(2))$$
$$I_2(7\text{k}) - \left(\frac{1}{3} I_2\right)(3\text{k}) - 48 = 12 \qquad ....(\text{By}(5))$$
$$I_2(6\text{k}) = 60$$
$$I_2 = 10 \text{ mA} \qquad ....(6)$$

$$\because I_O = I_4 - I_2$$
$$I_O = 12\text{m} - 10\text{m} \qquad ....(\text{By } (6))$$
$$I_O = 2\text{m}$$

Hence ,

$$\boxed{\begin{aligned} I_O &= 2 \text{ mA} \\ I_1 &= -6 \text{ mA} \end{aligned}}$$

Step 1 of 4

3.85p

Consider the circuit shown in Figure P3.65 in the text book.

The currents flowing loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The value of current I_1 is -2 mA and I_2 is 4 mA from Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$2\text{k}(I_1+I_3)+1\text{k}I_3-4+6=0$$
$$2\text{k}I_1+2\text{k}I_3+1\text{k}I_3+2=0$$
$$2\text{k}I_1+3\text{k}I_3+2=0$$
$$2\text{k}(-2\text{m})+3\text{k}I_3+2=0$$

Simplify the expression further.

$$-4+3\text{k}I_3+2=0$$
$$3\text{k}I_3=2$$

$$\begin{aligned}I_3&=\frac{2}{3\text{k}}\\&=0.667\text{ mA}\end{aligned}$$

Step 3 of 4

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$-6+4+2\text{k}I_4+1\text{k}(I_2+I_4)=0$$
$$-2+2\text{k}I_4+1\text{k}I_2+1\text{k}I_4=0$$
$$1\text{k}I_2+3\text{k}I_4-2=0$$
$$(1\text{k})(4\text{m})+3\text{k}I_4-2=0$$

Simplify the expression further.

$$4+3\text{k}I_4-2=0$$
$$3\text{k}I_4=-2$$

$$\begin{aligned}I_4&=\frac{-2}{3\text{k}}\\&=-0.667\text{ mA}\end{aligned}$$

Step 4 of 4

Apply Kirchhoff's voltage law to the loop formed by V_o ' V_1 ' V_2 ' in Figure 1 and solve for V_o .

$$\begin{aligned}V_o&=V_1+V_2\\&=1\text{k}I_3+2\text{k}I_4\\&=(1\text{k})(0.667\text{m})+(2\text{k})(-0.667\text{m})\\&=-0.667\text{ V}\end{aligned}$$

Therefore, the value of voltage V_o in the network is $\boxed{-0.667\text{ V}}$.

Step 1 of 4

3.86p

Consider the circuit shown in Figure P3.66 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The value of current I_1 is 6 mA and I_4 is 4 mA from Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_2 and solve.

$$1\text{k}(I_2 - I_1) + 2\text{k}(I_2 - I_4) = -4$$
$$1\text{k}I_2 - 1\text{k}I_1 + 2\text{k}I_2 - 2\text{k}I_4 = -4$$
$$3\text{k}I_2 - 1\text{k}I_1 - 2\text{k}I_4 = -4$$
$$3\text{k}I_2 - (1\text{k})(6\text{m}) - (2\text{k})(4\text{ mA}) = -4$$

Simplify the expression further.

$$3\text{k}I_2 - 6 - 8 = -4$$
$$3\text{k}I_2 = -4 + 6 + 8$$

$$I_2 = \frac{10}{3\text{k}}$$
$$= 3.33\text{ mA}$$

Step 3 of 4

Apply Kirchhoff's voltage law to the loop having current I_3 and solve.

$$2\text{k}(I_3 - I_1) + 1\text{k}(I_3 - I_4) = -6$$
$$2\text{k}I_3 - 2\text{k}I_1 + 1\text{k}I_3 - 1\text{k}I_4 = -6$$
$$-2\text{k}I_1 + 3\text{k}I_3 - 1\text{k}I_4 = -6$$
$$(-2\text{k})(6\text{m}) + 3\text{k}I_3 - 1\text{k}(4\text{m}) = -6$$

Simplify the expression further.

$$-12 + 3\text{k}I_3 - 4 = -6$$
$$3\text{k}I_3 = -6 + 4 + 12$$

$$I_3 = \frac{10}{3\text{k}}$$
$$= 3.33\text{ mA}$$

Step 4 of 4

Apply Kirchhoff's voltage law to the loop formed by nodes *a b c d a* in Figure 1 and solve for V_o.

$$V_o = 4 + 2\text{k}(I_2 - I_4) + 1\text{k}(I_3 - I_4)$$
$$= 4 + (2\text{k})(3.33\text{m} - 4\text{m}) + (1\text{k})(3.33\text{m} - 4\text{m})$$
$$= 4 - 1.34 - 0.67$$
$$= 2\text{ V}$$

Therefore, the value of V_o in the circuit is $\boxed{2\text{ V}}$.

Step 1 of 3

3.87p

Consider the circuit shown in Figure P3.67 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The value of current I_3 is 6 mA from Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_1 and solve.

$$1\text{k}I_1 + 1\text{k}(I_1 + I_2) = 12$$
$$1\text{k}I_1 + 1\text{k}I_1 + 1\text{k}I_2 = 12$$
$$2\text{k}I_1 + 1\text{k}I_2 = 12$$

$$I_1 = \frac{12 - 1\text{k}I_2}{2\text{k}} \quad \text{..... (1)}$$

Step 3 of 3

Apply Kirchhoff's voltage law to the loop having current I_2 and solve.

$$1\text{k}(I_1 + I_2) + 1\text{k}I_2 + 1\text{k}(I_2 - I_3) = 0$$
$$1\text{k}I_1 + 1\text{k}I_2 + 1\text{k}I_2 + 1\text{k}I_2 - 1\text{k}I_3 = 0$$
$$1\text{k}I_1 + 3\text{k}I_2 - (1\text{k})(6\text{m}) = 0$$

$$1\text{k}I_1 + 3\text{k}I_2 = 6 \quad \text{..... (2)}$$

Substitute equation (1) in (2) and solve for I_2.

$$1\text{k}\left(\frac{12 - 1\text{k}I_2}{2\text{k}}\right) + 3\text{k}I_2 = 6$$
$$6 - 0.5\text{k}I_2 + 3\text{k}I_2 = 6$$
$$2.5\text{k}I_2 = 0$$
$$I_2 = 0$$

Therefore, the value of current I_o in the network is $\boxed{0\text{ A}}$.

Step 1 of 4

3.90p

Consider the circuit shown in Figure P3.70 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$2kI_3 + 6 + 1k(I_3 - I_4) = 0$$
$$2kI_3 + 6 + 1kI_3 - 1kI_4 = 0$$

$$3kI_3 - 1kI_4 = -6 \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1.

$$1k(I_4 - I_3) - 12 + 1kI_4 = 0$$
$$1kI_4 - 1kI_3 + 1kI_4 = 12$$
$$-1kI_3 + 2kI_4 = 12$$

$$-3kI_3 + 6kI_4 = 36 \quad \text{..... (2)}$$

Add equations (1) and (2) and solve for I_4.

$$3kI_3 - 1kI_4 - 3kI_3 + 6kI_4 = -6 + 36$$
$$5kI_4 = 30$$

$$I_4 = \frac{30}{5k}$$
$$= 6 \text{ mA}$$

Step 4 of 4

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_4$, $R = 1 \text{ k}\Omega$ from the Figure 1 and solve for V_o.

$$V_o = I_4 R$$
$$= (6 \text{ mA})(1 \text{ k}\Omega)$$
$$= 6 \text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{6 \text{ V}}$.

Step 1 of 6

3.92p

Consider the circuit shown in Figure P3.72 in the text book.

The current flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_2 from Figure 1 is 2 mA.

Apply Kirchhoff's current law at node '*e*' in Figure 1 and solve for I_o.

$$I_o + 2\text{m} = I_4 \quad \text{..... (1)}$$

Apply Kirchhoff's current law at node '*d*' in Figure 1 and solve for I_4.

$$I_4 = 4\text{m} + I_3 \quad \text{..... (2)}$$

Step 3 of 6

Apply Kirchhoff's voltage law for the loop having current I_1 in Figure 1 and solve.

$$-12 + 1\text{k}I_1 + 1\text{k}(I_1 - I_2) + 1\text{k}(I_1 - I_3) = 0$$
$$1\text{k}I_1 + 1\text{k}I_1 - 1\text{k}I_2 + 1\text{k}I_1 - 1\text{k}I_3 = 12$$
$$3\text{k}I_1 - (1\text{k})(2\text{m}) - 1\text{k}I_3 = 12$$

$$3\text{k}I_1 - 1\text{k}I_3 = 14 \quad \text{..... (3)}$$

Step 4 of 6

Apply Kirchhoff's voltage law for the loop formed by nodes *a c e f d g a* Figure 1 and solve by using equation (1) and (2).

$$1\text{k}I_3 + 1\text{k}(I_3 - I_1) + 1\text{k}I_o + 1\text{k}I_4 = 0$$
$$1\text{k}I_3 + 1\text{k}I_3 - 1\text{k}I_1 + 1\text{k}I_o + 1\text{k}I_4 = 0$$
$$-1\text{k}I_1 + 2\text{k}I_3 + 1\text{k}(I_4 - 2\text{m}) + 1\text{k}I_4 = 0$$
$$-1\text{k}I_1 + 2\text{k}I_3 + 2\text{k}I_4 = 2$$

Simplify the expression further.

$$-1\text{k}I_1 + 2\text{k}I_3 + 2\text{k}(4\text{m} + I_3) = 2$$
$$-1\text{k}I_1 + 2\text{k}I_3 + 8 + 2\text{k}I_3 = 2$$
$$-1\text{k}I_1 + 4\text{k}I_3 = -6$$

$$-3\text{k}I_1 + 12\text{k}I_3 = -18 \quad \text{..... (4)}$$

Step 5 of 6

Add equations (3) and (4) and solve for I_3.

$$3\text{k}I_1 - 1\text{k}I_3 - 3\text{k}I_1 + 12\text{k}I_3 = 14 - 18$$
$$11\text{k}I_3 = -4$$
$$I_3 = 0.364\text{ mA}$$

Step 6 of 6

Equate the equations (1) and (2) and substitute the value of I_3 to calculate I_o.

$$I_o + 2\text{m} = 4\text{m} + I_3$$

$$\begin{aligned} I_o &= 2\text{m} + I_3 \\ &= 2\text{m} + 0.364\text{ mA} \\ &= 2.364\text{ mA} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{2.364\text{ mA}}$.

Step 1 of 3

3.93p

Consider the circuit shown in Figure P3.77 in the text book.

The value of current I_1 in the considered circuit is 2 mA.

$I_1 = 2\text{ mA}$ ..... (1)

Apply Kirchhoff's voltage law to the loop having current I_2 in the considered circuit and solve.

$$1\text{k}(I_2 - I_1) + 2\text{k}I_2 + 12 + 2\text{k}(I_2 - I_4) = 0$$
$$1\text{k}I_2 - 1\text{k}I_1 + 2\text{k}I_2 + 2\text{k}I_2 - 2\text{k}I_4 = -12$$
$$-1\text{k}I_1 + 5\text{k}I_2 - 2\text{k}I_4 = -12$$

$-I_1 + 5I_2 - 2I_4 = -12\text{m}$ ..... (2)

Apply Kirchhoff's voltage law to the loop having current I_3 in the considered circuit and solve.

$$-6 + 2\text{k}(I_3 - I_1) + 1\text{k}(I_3 - I_4) = 0$$
$$2\text{k}I_3 - 2\text{k}I_1 + 1\text{k}I_3 - 1\text{k}I_4 = 6$$
$$-2\text{k}I_1 + 3\text{k}I_3 - 1\text{k}I_4 = 6$$

$-2I_1 + 3I_3 - I_4 = 6\text{m}$ ..... (3)

Step 2 of 3

Apply Kirchhoff's voltage law to the loop having current I_4 in the considered circuit and solve.

$$1\text{k}(I_4 - I_3) + 2\text{k}(I_4 - I_2) + 1\text{k}(I_4 - I_5) = 0$$
$$1\text{k}I_4 - 1\text{k}I_3 + 2\text{k}I_4 - 2\text{k}I_2 + 1\text{k}I_4 - 1\text{k}I_5 = 0$$
$$-2\text{k}I_2 - 1\text{k}I_3 + 4\text{k}I_4 - 1\text{k}I_5 = 0$$

$-2I_2 - 1I_3 + 4I_4 - I_5 = 0$ ..... (4)

Apply Kirchhoff's voltage law to the loop having current I_5 in the considered circuit and solve.

$$-12 + 1\text{k}I_5 + (I_5 - I_4)1\text{k} = 0$$
$$1\text{k}I_5 + 1\text{k}I_5 - 1\text{k}I_4 = 12$$
$$-1\text{k}I_4 + 2\text{k}I_5 = 12$$

$-I_4 + 2I_5 = 12\text{m}$ ..... (5)

Step 3 of 3

Write the equations of (1), (2), (3), (4) and (5) in the matrix notation form.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ -1 & 5 & 0 & -2 & 0 \\ -2 & 0 & 3 & -1 & 0 \\ 0 & -2 & -1 & 4 & -1 \\ 0 & 0 & 0 & -1 & 2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} 0.002 \\ -0.012 \\ 0.006 \\ 0 \\ 0.012 \end{bmatrix}$$

Now, solve the set of five matrix equations by using matlab.

```
%solving the equations by using matlab

R=[1,0,0,0,0;-1,5,0,-2,0; -2,0,3,-1,0;0,-2,-1,4,-1;0,0,0,-1,2];

V=[0.002,-0.012,0.006,0,0.012]';

I=inv(R)*V
```

MATALB output:

```
I =

0.0020

-0.0011

0.0041

0.0023

0.0071
```

Therefore, the values of currents are $\boxed{I_1 = 2\text{ mA}}$, $\boxed{I_2 = -1.1\text{ mA}}$, $\boxed{I_3 = 4.1\text{ mA}}$, $\boxed{I_4 = 2.3\text{ mA}}$ and $\boxed{I_5 = 7.1\text{ mA}}$.

3.95p

Step 2 of 4

$I_1 = 6\,\text{mA} \quad \rightarrow$ (i)

Writing KVL equation in the second loop,

$1\text{K}(I_2 - I_1) + 2\text{K}\,I_2 + 12 = 0$

$3\text{K}\,I_2 - 1\text{K}(6\text{m}) + 12 = 0$

$3\text{K}\,I_2 = -6$

$I_2 = -2\,\text{mA} \quad \rightarrow$ (ii)

Step 3 of 4

Writing KVL equation in the third loop,

$-6 + 1\text{K}(I_3 - I_1) + 1\text{K}(I_3 - I_4) = 0$

$2\text{K}\,I_3 - 1\text{K}\,I_4 - 6 - 1\text{K}(6\text{m}) = 0$

$2\text{K}\,I_3 - 1\text{K}\,I_4 - 12 = 0 \quad \rightarrow$ (iii)

Writing KVL equation in the fourth loop,

$1\text{K}(I_4 - I_3) - 12 + 2\text{K}\,I_4 = 0$

$3\text{K}\,I_4 - 1\text{K}\,I_3 - 12 = 0 \quad \rightarrow$ (iv)

Step 4 of 4

Multiplying (iv) by '2, and adding it to (iii), we get,

$5\text{K}\,I_4 - 36 = 0$

$I_4 = \dfrac{36}{5\text{K}}\,\text{A}$

Since,

$V_0 = (2\text{K})(I_4)$

$V_0 = (2\text{K})\left(\dfrac{36}{5\text{K}}\right)$

$$\boxed{V_0 = \frac{72}{5}\,\text{V}}$$

Step 1 of 3

3.97p

Step 2 of 3

$I_1 = 4\text{mA} \quad \rightarrow \text{(i)}$

$I_2 = 2\text{mA} \quad \rightarrow \text{(ii)}$

Writing KVL equation across loop '2',

$2\text{K}(I_1+I_2)+1\text{K}(I_1+I_2+I_3)-6+2\text{K}\,I_2 = 0$

$5\text{K}\,I_2+1\text{K}\,I_3+3\text{K}(4\text{m})-6 = 0$

$5\text{K}\,I_2+1\text{K}\,I_3+6 = 0 \quad \rightarrow \text{(iii)}$

Writing KVL equation across loop '3',

$1\text{K}(I_1+I_2+I_3)-6+1\text{K}(I_3+I_4)+1\text{K}(I_3-I_5) = 0$

$1\text{K}\,I_2+3\text{K}\,I_3-1\text{K}\,I_5+1\text{K}(4\text{m})+1\text{K}(2\text{m})-6 = 0$

$1\text{K}\,I_2+3\text{K}\,I_3-1\text{K}\,I_5 = 0 \quad \rightarrow \text{(iv)}$

Step 3 of 3

Writing KVL equation across loop '5',

$1\text{K}(I_5-I_3)-12+1\text{K}\,I_5 = 0$

$2\text{K}\,I_5-1\text{K}\,I_3-12 = 0 \quad \rightarrow \text{(v)}$

Multiplying equation (iv) with '5' and subtracting it from (iii),

$14\text{K}\,I_3-5\text{K}\,I_5-6 = 0 \quad \rightarrow \text{(vi)}$

Multiplying (v) with 14 and adding it to (vi),

$23\text{K}\,I_5-174 = 0$

$$I_5 = \frac{174}{23\text{K}}$$

Since,

$V_0 = 1\text{K}(I_5)$

$$\boxed{V_0 = \frac{174}{23}\text{V}}$$

Step 1 of 6

3.99p

Consider the circuit shown in Figure P3.75 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_1 is 4 mA, current I_2 is 2 mA, current I_3 is 2 mA and current I_4 is 4 mA from Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_5 in Figure 1 and solve.

$$2\text{k}(I_1+I_5)-4+1\text{k}(I_5-I_6)+1\text{k}(I_1+I_5-I_3)=0$$
$$2\text{k}I_1+2\text{k}I_5-4+1\text{k}I_5-1\text{k}I_6+1\text{k}I_1+1\text{k}I_5-1\text{k}I_3=0$$
$$3\text{k}I_1-1\text{k}I_3+4\text{k}I_5-1\text{k}I_6=4$$
$$(3\text{k})(4\text{m})-(1\text{k})(2\text{m})+(4\text{k}I_5)-1\text{k}I_6=4$$

Simplify the expression further.

$$12-2+4\text{k}I_5-1\text{k}I_6=4$$
$$4\text{k}I_5-1\text{k}I_6=4-10$$
$$4\text{k}I_5-1\text{k}I_6=-6 \quad \text{..... (1)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_6 in Figure 1 and solve.

$$1\text{k}(I_6-I_5)+1\text{k}(I_4+I_6-I_2)+2\text{k}(I_4+I_6)=6$$
$$1\text{k}I_6-1\text{k}I_5+1\text{k}I_4+1\text{k}I_6-1\text{k}I_2+2\text{k}I_4+2\text{k}I_6=6$$
$$-1\text{k}I_2+3\text{k}I_4-1\text{k}I_5+4\text{k}I_6=6$$
$$-(1\text{k})(2\text{m})+(3\text{k})(4\text{m})-1\text{k}I_5+(4\text{k}I_6)=6$$

Simplify the expression further.

$$-2+12-1\text{k}I_5+4\text{k}I_6=6$$
$$-1\text{k}I_5+4\text{k}I_6=6-10$$
$$-1\text{k}I_5+4\text{k}I_6=-4$$
$$-4\text{k}I_5+16\text{k}I_6=-16 \quad \text{..... (2)}$$

Step 4 of 6

Add equations (1) and (2) and solve for I_6.

$$4\text{k}I_5-1\text{k}I_6-4\text{k}I_5+16\text{k}I_6=-6-16$$
$$15\text{k}I_6=-22$$
$$I_6=\frac{-22}{15\text{k}}$$
$$=-1.467\text{ mA}$$

Step 5 of 6

Substitute I_6 value in equation (1) and solve for I_5.

$$4\text{k}I_5-(1\text{k})(-1.467\text{ mA})=-6$$
$$4\text{k}I_5+1.467=-6$$
$$4\text{k}I_5=-6-1.467$$
$$I_5=-1.867\text{ mA}$$

Step 6 of 6

Calculate the voltage V_o in Figure 1 by using Ohm's law $V=IR$.

Substitute $V=V_o$, $I=I_6-I_5$, $R=1\text{ k}\Omega$ from the Figure 1 and solve for V_o.

$$V_o=(I_6-I_5)R$$
$$=(-1.467\text{ mA}+1.867\text{ mA})(1\text{ k}\Omega)$$
$$=(0.4\text{ mA})(1\text{ k}\Omega)$$
$$=0.4\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{0.4\text{ V}}$.

Step 1 of 4

3.100p

Refer to circuit shown in Figure P3.80 in the text book.

The node voltages for the considered circuit are shown in Figure 1.

Step 2 of 4

Figure 1

Step 3 of 4

Calculate the value of I_x in Figure 1 by using Ohm's law.

$$I_x = \frac{V}{R}$$

Substitute V_1 for V , $10\ \text{k}\Omega$ for R from Figure 1 and solve for I_x .

$$I_x = \frac{V_1}{10\ \text{k}\Omega}$$

Apply Kirchhoff's current law at node V_1 in Figure 1 and solve for voltage V_1 .

$$(-3\ \text{m}) + \frac{V_1}{10\ \text{k}} + 2I_x = 0$$
$$-3\ \text{m} + \frac{V_1}{10\ \text{k}} + 2\left(\frac{V_1}{10\ \text{k}}\right) = 0$$
$$-(3\ \text{m})(10\ \text{k}) + V_1 + 2V_1 = 0$$
$$V_1 = 10\ \text{V}$$

Step 4 of 4

Apply Kirchhoff's current law at node V_o in Figure 1 and solve for voltage V_o .

$$-2I_x + \frac{V_o}{10\ \text{k}} = 0$$
$$-(2)\left(\frac{V_1}{10\ \text{k}}\right) + \frac{V_o}{10\ \text{k}} = 0$$
$$-2(10) + V_o = 0$$
$$V_o = 20\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{20\ \text{V}}$.

Step 1 of 4

3.101p

Consider the circuit shown in Figure P3.79 in the text book.

The nodes and current flowing direction in the branches for the considered circuit is shown in Figure **1**.

Step 2 of 4

Figure 1

Step 3 of 4

The nodes V_1 and V_2 in Figure 1 forms a super node. So the value of V_1 can be written as $V_2 + 12$. Also the value of V_o is equal to V_2 .

Apply Kirchhoff's current law for the circuit at super node in Figure 1 and solve.

$$\frac{V_1 - \frac{V_o}{2}}{1\text{k}} + \frac{V_1}{1\text{k}} + \frac{V_2}{2\text{k}} = 0$$

$$2\left(V_1 - \frac{V_2}{2}\right) + 2V_1 + V_2 = 0$$

$$2V_1 - V_2 + 2V_1 + V_2 = 0$$

$$V_1 = 0$$

Step 4 of 4

Calculate the value of V_1 from Figure 1.

$$V_1 - V_2 = 12$$

$$\begin{aligned} V_2 &= V_1 - 12 \\ &= 0 - 12 \\ &= -12 \text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-12 \text{ V}}$.

Step 1 of 5

3.102p

Consider the circuit shown in Figure P3.78 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Step 2 of 5

Figure 1

Step 3 of 5

Calculate the value of I_1 from Figure 1 by applying Kirchhoff's current law at node *a*.

$$I_1 + 2I_x = I_x$$

$$\begin{aligned} I_1 &= I_x - 2I_x \\ &= -I_x \end{aligned}$$

Step 4 of 5

The value of current I_x is equal to I_x .

Apply Kirchhoff's voltage law to the circuit in Figure 1 and solve for I_x value.

$$\begin{aligned} 2kI_1 + 4kI_2 + 2kI_2 &= 12 \\ 2k(-I_x) + 4kI_x + 2kI_x &= 12 \\ -2kI_x + 6kI_x &= 12 \\ 4kI_x &= 12 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} I_x &= \frac{12}{4k} \\ &= 3\text{ mA} \end{aligned}$$

Step 5 of 5

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_x$, $R = 2\text{ k}\Omega$ from Figure 1 and solve for V_o .

$$\begin{aligned} V_o &= I_x R \\ &= (3\text{ mA})(2\text{ k}\Omega) \\ &= 6\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the network is $\boxed{6\text{ V}}$.

Step 1 of 3

3.106p

Refer to Figure P3.106 in the text book.

The circuit contains a super node.

Draw the equivalent circuit and indicate the super node.

Figure 1

Step 2 of 3

Use Ohm's law to write the expression of the node voltage v_1 in terms of the current I_x.

$$v_1 = I_x(4\text{ k}\Omega)$$
$$= 4000I_x$$

Use Ohm's law to write the expression of the node voltage v_2 in terms of the current I_o.

$$v_2 = I_o(12\text{ k}\Omega)$$
$$= 12000I_o$$

Step 3 of 3

Apply Kirchhoff's voltage law in the super node as shown in Figure 1.

$$-v_1 + 4000I_x + v_2 = 0$$
$$v_1 - v_2 = 4000I_x$$

Substitute $12000I_o$ for v_2 and $4000I_x$ for v_1.

$$4000I_x - 12000I_o = 4000I_x$$
$$12000I_o = 4000I_x - 4000I_x$$
$$12000I_o = 0$$
$$I_o = 0\text{ A}$$

Thus, the value of the current I_o is $\boxed{0\text{ A}}$.

Step 1 of 4

3.107p

Refer Figure P3.83 from the text book.

Identify the currents in the circuit diagram.

Figure 1

Step 2 of 4

Consider the Kirchhoff's Voltage Law in loop-2 indicated by the pink line.

$$I_2(1\text{ k}+1\text{ k})-I_x(1\text{ k})=0$$
$$I_2(2\text{ k})-I_x(1\text{ k})=0$$
$$I_x=2I_2$$

Therefore, the expression for I_x is $2I_2$.

Step 3 of 4

Consider the Kirchhoff's Voltage Law in loop-1 indicated by the blue line.

$$I_3(1\text{ k})-12+I_2(1\text{ k})+I_2(1\text{ k})=0$$
$$I_3(1\text{ k})+I_2(2\text{ k})=12$$

Substitute I_1+I_x for I_3.

$$(I_1+I_x)(1\text{ k})+I_2(2\text{ k})=12$$

Substitute I_2+I_x for I_1.

$$(I_2+I_x+I_x)(1\text{ k})+I_2(2\text{ k})=12$$
$$(I_2+2I_x)(1\text{ k})+I_2(2\text{ k})=12$$
$$I_2(1\text{ k})+I_x(2\text{ k})+I_2(2\text{ k})=12$$
$$I_2(3\text{ k})+I_x(2\text{ k})=12$$

Substitute $2I_2$ for I_x.

$$I_2(3\text{ k})+2I_2(2\text{ k})=12$$
$$I_2(3\text{ k})+I_2(4\text{ k})=12$$
$$I_2(7\text{ k})=12$$
$$I_2=\frac{12}{7\text{ k}}$$
$$I_2=\frac{12}{7}\text{ mA}$$

Therefore, the expression for I_2 is $\frac{12}{7}$ mA.

Step 4 of 4

Consider the expression for the output voltage.

$$V_o=I_3(6\text{ k})$$

Substitute $\frac{12}{7}$ mA for I_3.

$$V_o=\left(\frac{12}{7}\text{ m}\right)(1\text{ k})$$
$$=\frac{12}{7}\text{ V}$$

Therefore, the value of the output voltage is V_o is $\boxed{\frac{12}{7}\text{ V}}$.

Step 1 of 6

3.108p

Refer to circuit shown in Figure P3.86 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Step 2 of 6

Figure 1

Step 3 of 6

Apply Kirchhoff's voltage law to the loop formed by super mesh in Figure 1.

$$6V_x + (12\text{ k})I_3 + (12\text{ k})I_2 = 0$$
$$6((4\text{ k})(I_2 - I_3)) + (12\text{ k})I_3 + (12\text{ k})I_2 = 0$$
$$24I_2 - 24I_3 + 12I_3 + 12I_2 = 0$$
$$36I_2 - 12I_3 = 0$$

Simplify the expression further.

$$36I_2 = 12I_3$$

$$I_2 = \frac{1}{3}I_3 \text{ ..... (1)}$$

Step 4 of 6

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$(12\text{ k})I_2 + (8\text{ k})(I_2 - I_1) + (4\text{ k})(I_2 - I_3) = 0$$
$$12I_2 + 8I_2 - 8I_1 + 4I_2 - 4I_3 = 0$$
$$-8I_1 + 24I_2 - 4I_3 = 0$$
$$-8I_1 + (24)\left(\frac{1}{3}I_3\right) - 4I_3 = 0$$

Simplify the expression further.

$$-8I_1 + 8I_3 - 4I_3 = 0$$
$$-8I_1 + 4I_3 = 0$$
$$-2I_1 + I_3 = 0$$

$$I_1 = \frac{I_3}{2} \text{ ..... (2)}$$

Step 5 of 6

Calculate the value of current I_3 in Figure 1 by applying Kirchhoff's current law at node 'a'.

$$I_1 + 6\text{ mA} = I_3$$
$$\frac{I_3}{2} + 6\text{ mA} = I_3$$
$$I_3 - \frac{I_3}{2} = 6\text{ mA}$$
$$I_3\left(1 - \frac{1}{2}\right) = 6\text{ mA}$$

Simplify further.

$$I_3\left(\frac{1}{2}\right) = 6\text{ mA}$$
$$I_3 = 12\text{ mA}$$

Step 6 of 6

Calculate the voltage V_o in Figure 1 by using Ohm's law.

$$V_o = IR$$

Substitute 12 mA for I , $12\text{ k}\Omega$ for R from the Figure 1 and solve for V_o .

$$V_o = (12\text{ mA})(12\text{ k}\Omega)$$
$$= 144\text{ V}$$

Therefore, the value of voltage V_o in the network is $\boxed{144\text{ V}}$.

Step 1 of 4

Refer to circuit shown in Figure P3.87 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The value of current I_2 is 6 mA from Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$(2\text{ k})(I_3 - I_1) + (4\text{ k})I_3 + (4\text{ k})(I_3 - I_2) = 0$$
$$2I_3 - 2I_1 + 4I_3 + 4I_3 - 4I_2 = 0$$
$$-2I_1 - 4I_2 + 10I_3 = 0$$
$$-2I_1 - (4)(6\text{ mA}) + 10I_3 = 0$$

Simplify the expression further.

$$-2I_1 + 10I_3 = (4)(6\text{ mA})$$
$$-2I_1 + 10I_3 = 24\text{ mA}$$

$-1I_1 + 5I_3 = 12\text{ mA}$ ..... (1)

Step 3 of 4

Calculate the value of I_1 from Figure 1.

$$\begin{aligned} I_1 &= \frac{V_x}{4000} \\ &= \frac{(4\text{ k})(I_2 - I_3)}{4000} \\ &= I_2 - I_3 \end{aligned}$$

$I_1 = 6\text{ mA} - I_3$ ..... (2)

Recall equation (1).

$$-1I_1 + 5I_3 = 12\text{ mA}$$

Substitute $6\text{ mA} - I_3$ for I_1 in the equation and solve for I_3.

$$-(1\text{ k})(6\text{ m} - I_3) + (5\text{ k})I_3 = 12$$
$$-6 + (1\text{ k})I_3 + (5\text{ k})I_3 = 12$$
$$(6\text{ k})I_3 = 18$$
$$I_3 = 3\text{ mA}$$

Step 4 of 4

Calculate the voltage V_o by using Ohm's law in Figure 1.

$$V_o = IR$$

Substitute 3 mA for I, $4\text{ k}\Omega$ for R from the Figure 1 and solve for V_o.

$$\begin{aligned} V_o &= I_3 R \\ &= (3\text{ mA})(4\text{ k}\Omega) \\ &= 12\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{12\text{ V}}$.

Step 1 of 3

3.110p

Refer to Figure P3.110 in the textbook for the circuit.

Redraw the circuit by representing nodes in the circuit as shown in Figure 1.

Figure 1

Step 2 of 3

Apply Nodal analysis at node V_A .

$$\frac{V_A-12}{1\times10^3}+\frac{V_A}{1\times10^3}+\frac{V_o-12}{1\times10^3}+\frac{V_o}{1\times10^3}=0$$

$$\frac{V_A-12+V_A+V_o-12+V_o}{1\times10^3}=0$$

$$2V_A+2V_o=24$$

$$V_A+V_o=12$$

$$V_A=12-V_o$$

At super node, the voltage equation is,

$V_o-V_A=2\times10^3 I_x$ ..... (1)

From Figure 1, the current I_x is,

$$I_x=\frac{V_A}{1\times10^3}$$

Step 3 of 3

Substitute $\frac{V_A}{1\times10^3}$ for I_x in equation (1).

$$V_o-V_A=2\times10^3\left(\frac{V_A}{1\times10^3}\right)$$

$$V_o-V_A=2V_A$$

$$V_o=3V_A$$

Substitute $12-V_o$ for V_A in the equation.

$$V_o=3(12-V_o)$$

$$V_o=36-3V_o$$

$$4V_o=36$$

$$V_o=9\text{ V}$$

Therefore, the voltage V_o is $\boxed{9\text{ V}}$.

Step 2 of 4

Mark the nodes, branch currents and corresponding voltage levels as shown in figure 1.

From the figure we have ,

$$V_1 - V_2 = V_x$$
$$V_1 = V_2 + V_x \qquad ....(1)$$
$$V_3 = 2V_x \qquad ....(2)$$

Step 3 of 4

Applying KCL at node 1

$$\frac{V_3 - V_1}{2k} - \frac{V_1 - V_2}{4k} - \frac{V_1}{6k} = 0$$
$$6(V_3 - V_1) - 3(V_1 - V_2) - 2V_1 = 0$$
$$6V_3 + 3V_2 - 11V_1 = 0$$
$$6(2V_x) + 3V_2 - 11(V_2 + V_x) = 0$$
$$V_x - 8V_2 = 0 \qquad ....(\text{By}(1) \text{ and } (2))$$
$$V_2 = \frac{1}{8}V_x \qquad ....(3)$$

Step 4 of 4

Applying KCL at node 2

$$\frac{V_3 - V_2}{2k} + \frac{V_1 - V_2}{4k} - \frac{V_2}{4k} = 0$$
$$2(V_3 - V_2) + (V_1 - V_2) - V_2 = 0$$
$$2V_3 - 4V_2 + V_1 = 0$$
$$4V_x - 4V_2 + (V_2 + V_x) = 0 \qquad ....(\text{By}(1), (2))$$
$$5V_x - 3V_2 = 0$$
$$5V_x - 3\left(\frac{1}{8}V_x\right) = 0 \qquad ....(\text{By}(3))$$
$$\frac{37}{8}V_x = 0$$
$$V_x = 0\text{V}$$

Hence $\boxed{V_x = \mathbf{0\ V}}$

Step 1 of 7

The following is the given circuit diagram:

Figure 1

Step 2 of 7

The following is the circuit diagram designating with loop currents I_1, I_2, and I_3:

Figure 2

Step 3 of 7

Observing we have supermesh between meshes labeled I_1 and I_2.

Apply Kirchhoff's voltage law in the super mesh.

$$(5\text{k})I_1 - 12 + (6\text{k})I_2 + 5 + (8\text{k})(I_1 - I_3) = 0$$

$$(13\text{k})I_1 + (6\text{k})I_2 - (8\text{k})I_3 = 7 \qquad \text{..... (1)}$$

The constraint equation for the supermesh between meshes I_1 and I_2 is,

$$I_1 - I_2 = 20I_x$$

Where, $I_x = I_3 - I_2$

$$I_1 - I_2 = 20(I_3 - I_2)$$

$$I_1 + 19I_2 - 20I_3 = 0 \qquad \text{..... (2)}$$

Step 4 of 7

Apply Kirchhoff's voltage law in the loop 3.

$$(8\text{k})(I_3 - I_1) - 5 + (4\text{k})I_3 = 0$$

$$-(8\text{k})I_1 + (12\text{k})I_3 = 5 \qquad \text{..... (3)}$$

Step 5 of 7

Solution using MATLAB:

The equations (1),(2) and (3) can be together written in matrix form as follows.

$$\begin{bmatrix} 13\text{k} & 6\text{k} & -8\text{k} \\ 1\text{k} & 19\text{k} & -20\text{k} \\ -8\text{k} & 0 & 12\text{k} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 7 \\ 0 \\ 5 \end{bmatrix}$$

The following are the input / output of the solution on the MATLAB command shell.

```
>> R=[13000 6000 -8000;1000 19000 -20000; -8000 0
12000]
R =
        13000         6000        -8000
         1000        19000       -20000
        -8000            0        12000

>> V=[7;0;5]
V =
     7
     0
     5

>> I=inv(R)*V
I =
  1.0e-003 *
    0.6662
    0.8710
    0.8608
```

Step 6 of 7

From the MATLAB results, the current in mesh 3 is,

$$I_3 = 0.8608 \text{ mA}$$

Step 7 of 7

From Figure 3, the current I_o is given by,

$$I_o = I_3$$

$$= 0.8608 \text{ mA}$$

Therefore, the current I_o is $\boxed{0.861 \text{ mA}}$.

Step 1 of 3

Step 2 of 3

By observation,

$$\boxed{I_3 = 2\text{A}} \quad \rightarrow \text{(i)}$$

For the dependent current source, super mesh,

$$I_2 - I_1 = 0.5V_x$$

Where, $V_x = 5(I_3 - I_2)$

$$I_2 - I_1 = 2.5(I_3 - I_2)$$

$$2I_2 - 2I_1 = 5I_3 - 5I_2$$

$$-2I_1 + 7I_2 - 5I_3 = 0$$

$$\boxed{-2I_1 + 7I_2 - 10 = 0} \quad \rightarrow \text{(ii)}$$

Step 3 of 3

At the super mesh, applying KVL,

$$-12 + 4(I_1 - I_3) + 5(I_2 - I_3) + 2(I_2 - I_4) = 0$$

$$4I_1 + 7I_2 - 2I_4 - 9I_3 - 12 = 0$$

$$\boxed{4I_1 + 7I_2 - 2I_4 - 30 = 0} \quad \rightarrow \text{(iii)}$$

For the mesh '4',

$$2(I_4 - I_2) + I_4(4) + 20 = 0$$

$$\boxed{-2I_2 + 6I_4 + 20 = 0} \quad \rightarrow \text{(iv)}$$

Step 1 of 5

Consider the circuit shown in Figure P3.95 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The value of current I_1 is 2 mA and current I_2 is I_x in Figure 1.

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve for current I_x .

$$I_x + I_1 = I_3$$
$$I_x = I_3 - I_1$$

$$I_x = I_3 - 2\text{ mA} \quad \ldots\ldots (1)$$

Step 3 of 5

Calculate the value of V_x in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_x$, $I = (I_2 - I_1)$, $R = 2\text{ k}\Omega$ from the Figure 1 and solve.

$$\begin{aligned} V_x &= 2\text{k}(I_2 - I_1) \\ &= 2\text{k}I_2 - 2\text{k}I_1 \end{aligned}$$

Step 4 of 5

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$1\text{k}(I_3 - I_2) + 1\text{k}(I_3 - I_1) = -V_x$$
$$1\text{k}I_3 - 1\text{k}I_2 + 1\text{k}I_3 - 1\text{k}I_1 = -2\text{k}I_2 + 2\text{k}I_1$$
$$-3\text{k}I_1 + 1\text{k}I_2 + 2\text{k}I_3 = 0$$
$$-3\text{k}I_1 + 1\text{k}(I_3 - I_1) + 2\text{k}I_3 = 0$$

Simplify the expression further.

$$-3\text{k}I_1 + 1\text{k}I_3 - 1\text{k}I_1 + 2\text{k}I_3 = 0$$
$$-4\text{k}I_1 + 3\text{k}I_3 = 0$$
$$3\text{k}I_3 = (4\text{k})(2\text{m})$$
$$I_3 = \frac{8}{3}\text{ mA}$$

Step 5 of 5

Calculate the value of I_x from equation (1).

$$\begin{aligned} I_x &= \frac{8\text{ mA}}{3} - 2\text{ mA} \\ &= 2.667\text{ mA} - 2\text{ mA} \\ &= 0.667\text{ mA} \end{aligned}$$

Therefore, the value of current I_x in the circuit is $\boxed{0.667\text{ mA}}$.

Step 1 of 6

3.115p

Consider the circuit shown in Figure P3.98 in the text book.

The value of current I_4 is 2 A from the considered circuit.

Calculate the currents flowing in the dependent current source and solve.

$$3I_A = I_1 - I_2$$
$$3(I_3 - I_4) = I_1 - I_2$$
$$-I_1 + I_2 + 3I_3 - 3I_4 = 0$$

$$-I_1 + I_2 + 3I_3 - 6 = 0 \text{ ..... (1)}$$

Step 2 of 6

Apply Kirchhoff's voltage law to the loop having current I_3 in considered circuit and solve.

$$2I_3 + 1I_3 + 8(I_3 - I_1) = 2V_A$$
$$2I_3 + 1I_3 + 8I_3 - 8I_1 = 2(8(I_1 - I_3))$$
$$2I_3 + 1I_3 + 8I_3 - 8I_1 - 16I_1 + 16I_3 = 0$$
$$-24I_1 + 27I_3 = 0$$

Simplify the expression further.

$$27I_3 = 24I_1$$
$$I_3 = \frac{24I_1}{27}$$

$$= 0.89I_1 \text{ ..... (2)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having currents I_1, I_2 in considered circuit and solve.

$$5(I_2 - I_4) + 8(I_1 - I_3) + 9 + 2I_2 = 0$$
$$5I_2 - 5I_4 + 8I_1 - 8I_3 + 2I_2 = -9$$

$$8I_1 + 7I_2 - 8I_3 - 5I_4 = -9 \text{ ..... (3)}$$

Substitute equation (2) in (3) and solve.

$$8I_1 + 7I_2 - (8)(0.89I_1) - (5)(2) = -9$$
$$8I_1 + 7I_2 - 7.12I_1 = 1$$
$$0.88I_1 = 1 - 7I_2$$

$$I_1 = \frac{1 - 7I_2}{0.88} \text{ ..... (4)}$$

Step 4 of 6

Substitute equation (2) and (3) in (1) and solve for I_2.

$$-\left(\frac{1-7I_2}{0.88}\right) + I_2 + 3(0.88)\left(\frac{1-7I_2}{0.88}\right) = 6$$
$$\left(\frac{1-7I_2}{0.88}\right)(-1 + (3)(0.88)) + I_2 = 6$$
$$\left(\frac{1.64}{0.88}\right)(1 - 7I_2) + I_2 = 6$$
$$1.86 - 13.02I_2 + I_2 = 6$$

Simplify the expression further.

$$-12.02I_2 = 4.14$$

$$I_2 = \frac{4.14}{-12.02}$$
$$= -0.34\text{ A}$$

Therefore, the value of current I_2 is $\boxed{-0.34\text{ A}}$.

Step 5 of 6

Substitute I_2 value in equation (4) and solve for I_1.

$$I_1 = \frac{1 - (7)(-0.34\text{ A})}{0.88}$$
$$= \frac{1 + 2.38\text{ A}}{0.88}$$
$$= 3.84\text{ A}$$

Therefore, the value of current I_1 is $\boxed{3.84\text{ A}}$.

Step 6 of 6

Substitute I_1 value in equation (2) and solve for I_3.

$$I_3 = (0.89)(3.84\text{ A})$$
$$= 3.41\text{ A}$$

Therefore, the value of current I_3 is $\boxed{3.41\text{ A}}$.

Figure (1)

Step 2 of 7

Let the currents in the four loops be as shown in figure 1.
From the figure we have,

$$V_{ad} = 40 \text{ V} \qquad ....(1)$$
$$V_{fg} = 25 \text{ V} \qquad ....(2)$$
$$V_{ed} = 2I_A \qquad ....(3)$$
$$I_A = I_1 - I_2 \qquad ....(4)$$
$$I_3 - I_2 = 4\text{A}$$
$$I_3 = I_2 + 4 \qquad ....(5)$$

Step 3 of 7

Applying KVL in loop *abda*

$$V_{ab} + V_{bd} + V_{da} = 0$$
$$I_1(8) + (I_1 - I_2)(4) - 40 = 0 \qquad ....(\text{By}(1))$$
$$I_1(12) - I_2(4) - 40 = 0$$
$$I_1 = \frac{1}{3}I_2 + \frac{10}{3} \qquad ....(6)$$

Step 4 of 7

Applying KVL in loop *dbced*

$$V_{db} + V_{bc} + V_{ce} + V_{ed} = 0$$
$$(I_2 - I_1)(4) + I_2(6) + I_3(5) + 2I_A = 0$$
$$I_2(10) - I_1(4) + (4 + I_2)(5) + 2(I_1 - I_2) = 0 \qquad ....(\text{By (5)and (4)})$$
$$I_2(13) - I_1(2) + 20 = 0$$
$$I_2(13) - 2\left(\frac{1}{3}I_2 + \frac{10}{3}\right) + 20 = 0 \qquad ....(\text{By}(6))$$
$$I_2\left(13 - \frac{2}{3}\right) = \frac{20}{3} - 20$$
$$I_2\left(\frac{37}{3}\right) = -\frac{40}{3}$$
$$I_2 = -\frac{40}{37} \text{ A} \qquad ....(7)$$
$$I_2 = -1.081 \text{ A}$$

Step 5 of 7

$$\therefore I_1 = \frac{1}{3}\left(-\frac{40}{37}\right) + \frac{10}{3} \text{ A} \qquad ....(\text{By } (6))$$
$$I_1 = \frac{110}{37} \text{ A} \qquad ....(8)$$
$$I_1 = 2.973 \text{ A}$$
$$\therefore I_3 = -\frac{40}{37} + 4 \qquad ....(\text{By}(5))$$
$$I_3 = \frac{108}{37} \text{ A} \qquad ....(9)$$
$$I_3 = 2.919 \text{ A}$$

Step 6 of 7

Applying KVL in loop *efde*

$$V_{ef} + V_{fd} + V_{de} = 0$$
$$I_4(4) + 25 - 2I_A = 0 \qquad ....(\text{By}(2) \text{ and } (3))$$
$$I_4(4) + 25 - 2(I_1 - I_2) = 0 \qquad ....(\text{By } (4))$$
$$I_4(4) + 25 - 2\left(\frac{110}{37}\right) + 2\left(-\frac{40}{37}\right) = 0 \qquad ....(\text{By } (8) \text{ and } (7))$$
$$I_4(4) + \left(\frac{625}{37}\right) = 0$$
$$I_4 = -\frac{625}{148} \text{ A} \qquad ....(10)$$
$$I_4 = -4.223 \text{ A}$$

Step 7 of 7

Hence ,

$$\boxed{\begin{aligned} I_1 &= 2.973 \text{ A} \\ I_2 &= -1.081 \text{ A} \\ I_3 &= 2.919 \text{ A} \\ I_4 &= -4.223 \text{ A} \end{aligned}}$$

Step 1 of 5

Step 2 of 5

Let the currents in the four loops be as shown in figure 1.

From the figure we have,

$$V_{dc} = 18\text{ V} \qquad ....(1)$$
$$I_2 = -2\text{ A} \qquad ....(2)$$
$$I_3 = I_A \qquad ....(3)$$
$$I_4 - I_3 = 5\text{A}$$
$$I_4 = I_A + 5\text{ A} \qquad ....(4)$$
$$V_{ae} = 5I_A \qquad ....(5)$$

Step 3 of 5

Applying KVL in loop *abdea*

$$V_{ab} + V_{bd} + V_{de} + V_{ea} = 0$$
$$I_1(3) + (I_1 - I_2)(12) + (I_1 - I_4)(8) - 5I_A = 0 \qquad ....(\text{By}(5))$$
$$I_1(23) - I_2(12) - I_4(8) - 5I_A = 0$$
$$I_1(23) - (-2)(12) - (I_A + 5)(8) - 5I_A = 0 \qquad ....(\text{By}(2)\text{ and }(4))$$
$$I_1(23) = 40 + 13I_A - 24$$
$$I_1 = \frac{13}{23}I_A + \frac{16}{23} \qquad ....(6)$$

Step 4 of 5

Applying KVL in loop *fedcf*

$$V_{fe} + V_{ed} + V_{dc} + V_{cf} = 0$$
$$I_4(4) + (I_4 - I_1)(8) + 18 + I_3(5) = 0 \qquad ....(\text{By}(1))$$
$$I_4(12) - I_1(8) + 18 + I_3(5) = 0$$
$$(I_A + 5)(12) - \left(\frac{13}{23}I_A + \frac{16}{23}\right)(8) + 18 + I_A(5) = 0 \qquad ....(\text{By }(3),(4)\text{and }(6))$$
$$I_A\left(12 - \frac{104}{23} + 5\right) + 60 - \frac{128}{23} + 18 = 0$$
$$I_A\left(\frac{287}{23}\right) = -\frac{1666}{23}$$
$$I_A = -\frac{238}{41}\text{ A} \qquad ....(7)$$

Step 5 of 5

Hence Power supplied by the dependent source is

$$P_{sup.Dep} = (5I_A)I_A$$
$$P_{sup.Dep} = 5\left(-\frac{238}{41}\right)^2 \qquad ....(\text{By }(7))$$
$$P_{sup.Dep} = 168.483\text{ W}$$
$$\boxed{P_{sup.Dep} = 168.483\text{ W}}$$

Step 1 of 5

3.118p

Refer to circuit shown in Figure P3.88 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The value of current I_4 in Figure 1 is **4 mA** .

Calculate the value of V_x from Figure 1 by using Ohm's law.

$$V = IR$$

Substitute $-V_x$ for V , I_2 for I , $1\ \text{k}\Omega$ for R from Figure 1 and solve for V_x .

$$-V_x = I_2(1\ \text{k}\Omega)$$
$$V_x = -(1\ \text{k})I_2$$

Calculate the value of current I_3 from Figure 1.

$$I_3 = \frac{V_x}{1000}$$
$$= \frac{-(1\ \text{k})I_2}{1000}$$
$$= -I_2$$

Step 3 of 5

Apply Kirchhoff's voltage law to the super mesh in Figure 1 and solve.

$$(1\ \text{k})I_1 + (1\ \text{k})I_2 + (1\ \text{k})I_2 + (1\ \text{k})(I_2 - I_4) + (1\ \text{k})(I_1 - I_3) = 0$$
$$I_1 + I_2 + I_2 + I_2 - I_4 + I_1 - I_3 = 0$$
$$2I_1 + 3I_2 - I_3 - I_4 = 0$$

Simplify expression further.

$$2I_1 + 3I_2 - (-I_2) - 4\ \text{m} = 0$$
$$2I_1 + 4I_2 = 4\ \text{m}$$

$$I_1 + 2I_2 = 2\ \text{mA} \quad \text{..... (1)}$$

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve.

$$I_1 = I_2 + 12\ \text{mA} \quad \text{..... (2)}$$

Step 4 of 5

Recall equation (1).

$$I_1 + 2I_2 = 2\ \text{mA}$$

Substitute $I_2 + 12\ \text{mA}$ for I_1 in the equation and solve for I_2 .

$$(I_2 + 12\ \text{mA}) + 2I_2 = 2\ \text{mA}$$
$$3I_2 = -10\ \text{mA}$$
$$I_2 = -3.33\ \text{mA}$$

Step 5 of 5

Calculate the value of voltage V_o in Figure 1 by using Ohm's law.

$$V_o = IR$$

Substitute $-3.33\ \text{mA}$ for I , $1\ \text{k}\Omega$ for R from the Figure 1 and solve for V_o .

$$V_o = (-3.33\ \text{mA})(1\ \text{k}\Omega)$$
$$= -3.33\ \text{V}$$

Therefore, the value of voltage V_o in the network is $\boxed{-3.33\ \text{V}}$.

Step 1 of 4

3.119p

Refer to Figure P3.89 in the text book.

Draw the circuit with current notations.

Figure 1

Step 2 of 4

From the current source in Figure 1,

$$I_3 - I_4 = 2\times10^{-3}$$
$$I_4 = I_3 - 0.002$$

Calculate the expression for the voltage, V_x.

$$V_x = 1000I_4$$

Substitute $I_3 - 0.002$ for I_4.

$$V_x = 1000(I_3 - 0.002)$$
$$= 1000I_3 - 2$$

Step 3 of 4

Apply Kirchhoff's voltage law to loop1.

$$2000I_1 + 1000(I_1 - I_4) + 2000(I_1 - I_2) = 0$$
$$5000I_1 - 2000I_2 - 1000I_4 = 0$$

Substitute $I_3 - 0.002$ for I_4.

$$5000I_1 - 2000I_2 - 1000(I_3 - 0.002) = 0$$

$$5000I_1 - 2000I_2 - 1000I_3 = -2 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law to loop2.

$$2000(I_2 - I_1) - 2V_x - 12 = 0$$

Substitute $1000I_3 - 2$ for V_x.

$$2000I_2 - 2000I_1 - 2(1000I_3 - 2) - 12 = 0$$

$$-2000I_1 + 2000I_2 - 2000I_3 = 8 \text{ ..... (2)}$$

Step 4 of 4

Apply Kirchhoff's voltage law to loop3 and loop4 combined.

$$V_x + 1000I_3 + 2V_x + 1000(I_4 - I_1) = 0$$
$$1000I_3 + 3V_x + 1000I_4 - 1000I_1 = 0$$

Substitute $1000I_3 - 2$ for V_x and $I_3 - 0.002$ for I_4.

$$1000I_3 + 3(1000I_3 - 2) + 1000(I_3 - 0.002) - 1000I_1 = 0$$

$$-1000I_1 + 5000I_3 = 8 \text{ ..... (3)}$$

Solve equation (1), (2) and (3).

$$I_1 = 4.5 \text{ mA}$$
$$I_2 = 11 \text{ mA}$$
$$I_3 = 2.5 \text{ mA}$$

Apply Ohm's law to calculate the output voltage.

$$V_o = I_3(1 \text{ k}\Omega)$$

Substitute 2.5 mA for I_3.

$$V_o = (2.5 \text{ mA})(1 \text{ k}\Omega)$$
$$= 2.5 \text{ V}$$

Thus, the value of the output voltage, V_o is $\boxed{2.5 \text{ V}}$.

Step 1 of 3

3.120p

Refer to circuit shown in Figure P3.90 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The value of current I_2 in Figure 1 is $\mathbf{2\ mA}$.

Calculate the value of current I_1 from Figure 1.

$$\begin{aligned} I_1 &= -2I_x \\ &= -2(I_4 - I_2) \\ &= -2I_4 + 2I_2 \end{aligned}$$

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1.

$$12 + (1\text{ k})(I_4 - I_2) + (1\text{ k})I_4 = 0$$
$$12 + (1\text{ k})I_4 - (1\text{ k})I_2 + (1\text{ k})I_4 = 0$$
$$-(1\text{ k})I_2 + (2\text{ k})I_4 = -12$$
$$-(1\text{ k})(2\text{m}) + (2\text{ k})I_4 = -12$$

Simplify the expression further.

$$(2\text{ k})I_4 = -12 + 2$$

$$\begin{aligned} I_4 &= \frac{-10}{2\text{ k}} \\ &= -5\text{ mA} \end{aligned}$$

Step 3 of 3

Calculate the value of voltage V_o in Figure 1 by using Ohm's law.

$$V_o = IR$$

Substitute -5 mA for I , $1\text{ k}\Omega$ for R from the Figure 1 and solve for V_o .

$$\begin{aligned} V_o &= (-5\text{ mA})(1\text{ k}\Omega) \\ &= -5\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-5\text{ V}}$.

Step 1 of 6

3.121p

Consider the circuit shown in Figure P3.91 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law to the loop having current I_3 .

$$1\text{k}(I_3 - I_1) + 1\text{k}(I_3 - I_4) = 2V_o$$
$$1\text{k}I_3 - 1\text{k}I_1 + 1\text{k}I_3 - 1\text{k}I_4 = 2(2\text{k}I_4)$$

$$-1\text{k}I_1 + 2\text{k}I_3 - 5\text{k}I_4 = 0 \text{ ..... (1)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the outer loop of Figure 1 and solve.

$$2V_o = 1\text{k}I_1 + 1\text{k}I_2 + 2\text{k}I_4$$
$$2(2\text{k}I_4) = 1\text{k}I_1 + 1\text{k}I_2 + 2\text{k}I_4$$

$$1\text{k}I_1 + 1\text{k}I_2 - 2\text{k}I_4 = 0 \text{ ..... (2)}$$

Apply Kirchhoff's current law at node 'a' in Figure 1 and solve.

$$I_2 = I_1 + 4\text{ mA} \text{ ..... (3)}$$

Step 4 of 6

Substitute equation (3) in (2) and solve for I_1 .

$$1\text{k}I_1 + 1\text{k}(I_1 + 4\text{m}) - 2\text{k}I_4 = 0$$
$$1\text{k}I_1 + 1\text{k}I_1 + 4 - 2\text{k}I_4 = 0$$
$$2\text{k}I_1 - 2\text{k}I_4 = -4$$

$$I_1 = \frac{-4 + 2\text{k}I_4}{2\text{k}} \text{ ..... (4)}$$

Step 5 of 6

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1 and solve.

$$2\text{k}I_4 + 1\text{k}(I_4 - I_2) = 12$$
$$2\text{k}I_4 + 1\text{k}I_4 - 1\text{k}I_3 = 12$$
$$3\text{k}I_4 - 1\text{k}I_3 = 12$$

$$I_3 = \frac{3\text{k}I_4 - 12}{1\text{k}} \text{ ..... (5)}$$

Step 6 of 6

Substitute equations (4) and (5) in (1) and solve for I_4 .

$$-1\text{k}\left(\frac{-4 + 2\text{k}I_4}{2\text{k}}\right) + 2\text{k}\left(\frac{3\text{k}I_4 - 12}{1\text{k}}\right) - 5\text{k}I_4 = 0$$
$$-(0.5)(-4 + 2\text{k}I_4) + (2)(3\text{k}I_4 - 12) - 5\text{k}I_4 = 0$$
$$2 - 1\text{k}I_4 + 6\text{k}I_4 - 24 - 5\text{k}I_4 = 0$$

Therefore, the value of I_4 cannot be determined because the current equations are contradictory. So voltage V_o cannot be defined as it is an open circuit.

Step 1 of 6

3.123p

Consider the circuit shown in Figure P3.93 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_4 in Figure 1 is -2 mA .

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$2V_x + 1\text{k}I_3 + 1\text{k}(I_3 - I_6) = 0$$
$$2(1\text{k}I_6) + 1\text{k}I_3 + 1\text{k}I_3 - 1\text{k}I_6 = 0$$
$$2\text{k}I_3 + 1\text{k}I_6 = 0$$

$$I_3 = \frac{-1\text{k}I_6}{2\text{k}} \quad \text{..... (1)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_6 in Figure 1 and solve.

$$1\text{k}(I_6 - I_3) + 1\text{k}I_6 = 12$$
$$1\text{k}I_6 - 1\text{k}I_3 + 1\text{k}I_6 = 12$$

$$-1\text{k}I_3 + 2\text{k}I_6 = 12 \quad \text{..... (2)}$$

Step 4 of 6

Substitute equation (1) in (2) and solve for I_6 .

$$-1\text{k}\left(\frac{-1\text{k}I_6}{2\text{k}}\right) + 2\text{k}I_6 = 12$$
$$0.5I_6 + 2I_6 = 12\text{m}$$
$$2.5I_6 = 12\text{m}$$
$$I_6 = 4.8\text{ mA}$$

Step 5 of 6

Substitute the value of I_6 in equation (1) and solve for I_3 .

$$I_3 = \frac{-1\text{k}(4.8\text{ mA})}{2\text{k}}$$
$$= -2.4\text{ mA}$$

Step 6 of 6

Apply Kirchhoff's current law at node '*a*' in Figure **1** and solve for current I_o .

$$I_o + I_3 = I_6$$

$$I_o = I_6 - I_3$$
$$= 4.8\text{ mA} - (-2.4\text{ mA})$$
$$= 7.2\text{ mA}$$

Therefore, the value of current I_o in the network is $\boxed{7.2\text{ mA}}$.

Step 1 of 6

3.124p

Consider the circuit shown in Figure P3.94 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$1\text{k}(I_2 - I_1) + 1\text{k}(I_2 - I_3) = 6$$
$$1\text{k}I_2 - 1\text{k}I_1 + 1\text{k}I_2 - 1\text{k}I_3 = 6$$

$$-1\text{k}I_1 + 2\text{k}I_2 - 1\text{k}I_3 = 6 \text{ ..... (1)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$1\text{k}(I_3 - I_2) + 1\text{k}(I_3 - I_1) + 2V_x = 0$$
$$1\text{k}I_3 - 1\text{k}I_2 + 1\text{k}I_3 - 1\text{k}I_1 + 2((I_2 - I_1)(1\text{k})) = 0$$
$$2\text{k}I_3 - 1\text{k}I_2 - 1\text{k}I_1 + 2\text{k}I_2 - 2\text{k}I_1 = 0$$

$$-3\text{k}I_1 + 1\text{k}I_2 + 2\text{k}I_3 = 0 \text{ ..... (2)}$$

Step 4 of 6

Add equations (1) and (2) and solve.

$$-1\text{k}I_1 + 2\text{k}I_2 - 1\text{k}I_3 + 1\text{k}I_1 - 3\text{k}I_2 + 2\text{k}I_3 = 6 + 0$$
$$-1\text{k}I_2 + 1\text{k}I_3 = 6$$
$$1\text{k}I_3 = 6 + 1\text{k}I_2$$

$$I_3 = \frac{6 + 1\text{k}I_2}{1\text{k}} \text{ ..... (3)}$$

Step 5 of 6

Calculate the value of I_1 from Figure 1.

$$I_1 = 2I_x$$
$$= 2(I_2 - I_3)$$

$$I_1 = 2I_2 - 2I_3 \text{ ..... (4)}$$

Substitute equations (3) and (4) in (1) and solve for I_2.

$$-1\text{k}(2I_2 - 2I_3) + 2\text{k}I_2 - 1\text{k}I_3 = 6$$
$$-2\text{k}I_2 + 2\text{k}I_3 + 2\text{k}I_2 - 1\text{k}I_3 = 6$$
$$1\text{k}I_3 = 6$$
$$I_3 = 6 \text{ mA}$$

Step 6 of 6

Simplify the equation (2) further and solve for I_2.

$$-3\text{k}(2I_2 - 2I_3) + 1\text{k}I_2 + 2\text{k}I_3 = 0$$
$$-6\text{k}I_2 + 6\text{k}I_3 + 1\text{k}I_2 + 2\text{k}I_3 = 0$$
$$-5\text{k}I_2 + 8\text{k}I_3 = 0$$
$$-5\text{k}I_2 + 8\text{k}(6 \text{ mA}) = 0$$

Simplify the expression further.

$$5\text{k}I_2 = 48$$

$$I_2 = \frac{48}{5\text{k}}$$
$$= 9.6 \text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{9.6 \text{ mA}}$.

Step 1 of 6

3.125p

Consider the circuit shown in Figure P3.97 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_3 is -2 mA and I_5 is 4 mA from Figure 1. The value of I_x at node by using Kirchhoff's current law is $I_4 - I_5$.

Calculate the value of current I_1 in Figure 1.

$$\begin{aligned} I_1 &= 2I_x \\ &= 2(I_4 - I_5) \\ &= 2I_4 - 2(4\text{m}) \end{aligned}$$

$I_1 = 2I_4 - 8\text{m}$ ..... (1)

Step 3 of 6

Calculate the voltage V_x in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_x$, $I = I_5 - I_3$, $R = 1\text{ k}\Omega$ from the Figure 1 and solve for V_x.

$$\begin{aligned} V_x &= (I_5 - I_3)R \\ &= (4\text{ mA} + 2\text{ mA})(1\text{ k}\Omega) \\ &= (6\text{ mA})(1\text{ k}\Omega) \\ &= 6\text{ V} \end{aligned}$$

Step 4 of 6

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1 and solve.

$$\begin{aligned} &1\text{k}(I_4 - I_1) + 2V_x + 2\text{k}(I_4 - I_5) = 0 \\ &1\text{k}I_4 - 1\text{k}I_1 + 2\text{k}I_4 - 2\text{k}I_5 = -2V_x \\ &-1\text{k}I_1 + 3\text{k}I_4 - 2\text{k}I_5 = -(2)(6) \\ &-(1\text{k})(2I_4 - 8\text{m}) + 3\text{k}I_4 - (2\text{k})(4\text{m}) = -12 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} &-2\text{k}I_4 + 8 + 3\text{k}I_4 - 8 = -12 \\ &1\text{k}I_4 = -12 \\ &I_4 = -12\text{ mA} \end{aligned}$$

Step 5 of 6

Substitute the value of I_4 in equation (1) and solve.

$$\begin{aligned} I_1 &= 2I_4 - 8\text{m} \\ &= (2)(-12\text{m}) - 8\text{m} \\ &= -24\text{m} - 8\text{m} \\ &= -32\text{m} \end{aligned}$$

Step 6 of 6

Calculate the value of voltage V_o in Figure 1 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_1 - I_4$, $R = 1\text{ k}\Omega$ from Figure 1 and solve for V_o.

$$\begin{aligned} V_o &= (I_1 - I_4)R \\ &= (-32\text{ mA} + 12\text{ mA})(1\text{ k}\Omega) \\ &= -20\text{ V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-20\text{ V}}$.

Step 1 of 6

3.126p

Consider the circuit shown in Figure P3.101 in the text book.

The nodes and currents flowing in the loops of the considered circuit are shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_x at node '*b*' in Figure 1 is $I_4 - I_5$ and the value of current I_3 is -6 mA. The value of voltage V_x in Figure 1 is $1\text{k}I_6$.

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$1\text{k}I_1 + 12 + 1\text{k}(I_1 - I_4) = 0$$

$$2\text{k}I_1 - 1\text{k}I_4 = -12 \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve.

$$-12 + 1\text{k}(I_2 - I_3) + 1\text{k}(I_2 - I_5) = 0$$
$$1\text{k}I_2 - 1\text{k}I_3 + 1\text{k}I_2 - 1\text{k}I_5 = 12$$
$$2\text{k}I_2 - 1\text{k}(-6\text{m}) - 1\text{k}I_5 = 12$$

$$2\text{k}I_2 - 1\text{k}I_5 = 6 \quad \text{..... (2)}$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1 and solve.

$$2V_x + 1\text{k}(I_4 - I_1) + 1\text{k}(I_4 - I_5) = 0$$
$$2(1\text{k}I_6) + 1\text{k}I_4 - 1\text{k}I_1 + 1\text{k}I_4 - 1\text{k}I_5 = 0$$

$$-1\text{k}I_1 + 2\text{k}I_4 - 1\text{k}I_5 + 2\text{k}I_6 = 0 \quad \text{..... (3)}$$

Apply Kirchhoff's current law at node '*a*' in Figure 1 and solve.

$$I_6 = 2I_x + I_5$$
$$I_6 = 2(I_4 - I_5) + I_5$$
$$2I_4 - 2I_5 + I_5 - I_6 = 0$$

$$2I_4 - I_5 - I_6 = 0 \quad \text{..... (4)}$$

Apply Kirchhoff's voltage law to the loop formed by nodes *e f c g h a b d e* in Figure 1 and solve.

$$2V_x + 1\text{k}(I''') + 1\text{k}I_o + 1\text{k}I'' + 1\text{k}I_6 = 0$$
$$2(1\text{k}I_6) + (1\text{k})(I_4 - I_1) + (1\text{k})(I_5 - I_2) + (1\text{k})(I_6 - I_3) + 1\text{k}I_6 = 0$$
$$2\text{k}I_6 + 1\text{k}I_4 - 1\text{k}I_1 + 1\text{k}I_5 - 1\text{k}I_2 + 1\text{k}I_6 - (1\text{k})(-6\text{m}) + 1\text{k}I_6 = 0$$

$$-1\text{k}I_1 - 1\text{k}I_2 + 1\text{k}I_4 + 1\text{k}I_5 + 4\text{k}I_6 = -6 \quad \text{..... (5)}$$

Step 4 of 6

Now, write the equations of (1), (2), (3), (4) and (5) in the matrix notation form.

$$\begin{bmatrix} 2 & 0 & -1 & 0 & 0 \\ 0 & 2 & 0 & -1 & 0 \\ -1 & 0 & 2 & -1 & 2 \\ 0 & 0 & 2 & -1 & -1 \\ -1 & -1 & 1 & 1 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_4 \\ I_5 \\ I_6 \end{bmatrix} = \begin{bmatrix} -0.012 \\ 0.006 \\ 0 \\ 0 \\ -0.006 \end{bmatrix}$$

Now, solve the set of matrix by using matlab.

```
%solving the equations by using matlab.
R=[2,0,-1,0,0;0,2,0,-1,0;-1,0,2,-1,2;0,0,2,-1,-1; -1,-1,1,1,4];
V=[-0.012,0.006,0,0,-0.006]';
I=inv(R)*V
```

MATLAB output:

```
I =
-0.0065
0.0031
-0.0010
0.0002
-0.0022
```

Therefore, the values of currents are $I_1 = -6.5\text{ mA}$, $I_2 = 3.1\text{ mA}$, $I_4 = -1.0\text{ mA}$, $I_5 = 0.2\text{ mA}$, $I_6 = -2.2\text{ mA}$.

Step 5 of 6

Now, calculate the value of current I_o by apply Kirchhoff's current law at node '*c*' in Figure 1.

$$I_o + I + 2I_x = I''$$
$$I_o + (I_2 - I_3) + 2(I_4 - I_5) = I_6 - I_3$$
$$I_o = -I_2 + I_3 - 2I_4 + 2I_5 + I_6 - I_3$$
$$I_o = -I_2 - 2I_4 + 2I_5 + I_6$$

Step 6 of 6

Simplify the expression further.

$$\begin{aligned} I_o &= -3.1\text{ mA} - 2(-1\text{ mA}) + 2(0.2\text{ mA}) - 2.2\text{ mA} \\ &= -3.1\text{ mA} + 2\text{ mA} + 0.4\text{ mA} - 2.2\text{ mA} \\ &= -2.9\text{ mA} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{-2.9\text{ mA}}$.

Step 1 of 6

3.127p

Consider the circuit shown in Figure P3.102 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_2 is 40 mA in Figure 1.

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$200I_1 + 100I_1 + 6V_x = 0$$
$$300I_1 + 6(600I_4) = 0$$
$$300I_1 + 3600I_4 = 0$$

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_3 in Figure 1 and solve.

$$100I_3 + 3 = 0$$
$$100I_3 = -3$$

$$I_3 = \frac{-3}{100}$$
$$= -30\text{ mA}$$

Step 4 of 6

Apply Kirchhoff's voltage law to the loop having current I_4 in Figure 1 and solve.

$$300(I_4 - I_2) + 600I_4 - 3 = 0$$
$$300I_4 - 300I_2 + 600I_4 = 3$$
$$900I_4 = (300)(40\text{m}) + 3$$
$$I_4 = 16.67\text{ mA}$$

Step 5 of 6

Calculate the value of current I flowing through 3 V source by applying Kirchhoff's current law at node 'a'.

$$I + I_4 = I_3$$

$$I = I_3 - I_4$$
$$= -30\text{ mA} - 16.67\text{ mA}$$
$$= -46.67\text{ mA}$$

Step 6 of 6

Calculate the power (*P*) delivered by the 3 V source by using the formula $P = VI$.

Substitute $P = P_{3\text{V}}$, $V = 3\text{ V}$, $I = -46.67\text{ mA}$ from the Figure 1 and solve for $P_{3\text{V}}$.

$$P_{3\text{V}} = VI$$
$$= (3\text{ V})(-46.67\text{ mA})$$
$$= -140\text{ mW}$$

Therefore, the power delivered by the 3 V independent source in the network is $\boxed{140\text{ mW}}$.

Step 1 of 6

3.129p

Given circuit is

Step 2 of 6

Writing nodal equations

We have two super nodes

$V_4 - V_3 = 12\text{V}$ ..... (1)

$V_3 - V_2 = 2V_x$

Where $V_x = V_4$

Hence,

$V_3 - V_2 = 2\text{V}_4$ ..... (2)

The KCL equation at node V_1, we get

$$\frac{V_1 - V_2}{1\text{k}} + \frac{V_1 - V_3}{1\text{k}} + \frac{V_1 - V_4}{1\text{k}} + \frac{V_1 - V_0}{1\text{k}} = 0$$

$$4V_1 - V_2 - V_3 - V_4 - V_0 = 0 \quad \text{..... (3)}$$

Step 3 of 6

The KCL equation at reference node, we get

$$\frac{0 - V_3}{2\text{k}} + \frac{0 - V_4}{2\text{k}} + \frac{0 - V_0}{1\text{k}} + \frac{4}{1\text{k}} = 0$$

$$\frac{V_3}{2\text{k}} + \frac{V_4}{2\text{k}} + \frac{V_0}{1\text{k}} = \frac{4}{1\text{k}}$$

$$V_3 + V_4 + 2V_0 = 8 \quad \text{..... (4)}$$

The KCL equation at node V_0 is

$$\frac{V_0}{1\text{k}} + \frac{V_0 - V_1}{1\text{k}} + \frac{V_0 - V_4}{2\text{k}} = 0$$

$$2V_0 + 2V_0 - 2V_1 + V_0 - V_4 = 0$$

$$-2V_1 - V_4 + 5V_0 = 0 \quad \text{..... (5)}$$

Step 4 of 6

From equation (1), we get

$V_3 = V_4 - 12$

From equation (2), we get

$V_2 = V_3 - 2V_4$

$V_2 = V_4 - 12 - 2V_4$

$V_2 = -V_4 - 12$

From equation (5), we get

$2V_1 = 5V_0 - V_4$

Step 5 of 6

Substituting these in equation (3), we get

$$2(5V_0 - V_4) - (-V_4 - 12) - (V_4 - 12) - V_4 - V_0 = 0$$

$$10V_0 - 2V_4 + V_4 + 12 - V_4 + 12 - V_4 - V_0 = 0$$

$$9V_0 - 3V_4 + 24 = 0$$

$$3V_4 = 9V_0 + 24$$

$$V_4 = 3V_0 + 8 \quad \text{..... (6)}$$

Step 6 of 6

Substituting these in (4), we get

$V_4 - 12 + V_4 + 2V_0 = 8$

$2V_0 + 2V_4 = 20$ ..... (7)

Substituting equation (6) in (7)

$$2V_0 + 2(3V_0 + 8) = 20$$

$$2V_0 + 6V_0 + 16 = 20$$

$$8V_0 = 4$$

$$\boxed{V_0 = 0.5\text{V}}$$

Step 1 of 6

Consider the circuit shown in Figure P3.103 in the text book.

The currents flowing in the loops of the considered circuit is shown in Figure 1.

Figure 1

Step 2 of 6

The value of current I_x in Figure 1 is $-I_4$ and I_2 is $I_1 - 3\text{ A}$.

Calculate the value of current I_3 in Figure 1.

$$\begin{aligned} I_3 &= \frac{V_x}{8} \\ &= \frac{6I_1}{8} \\ &= \frac{3I_1}{4} \end{aligned}$$

$I_3 = 0.75I_1$ ..... (1)

Step 3 of 6

Apply Kirchhoff's voltage law to the loop having current I_4 and solve.

$$\begin{aligned} &32(I_4 - I_3) - 15I_x + I_4 = 0 \\ &32I_4 - 32I_3 - 15(-I_4) + I_4 = 0 \\ &48I_4 = 32I_3 \end{aligned}$$

$I_4 = 0.667I_3$ ..... (2)

Step 4 of 6

Apply Kirchhoff's voltage law to super mesh in Figure 1 and solve.

$$\begin{aligned} &6I_1 + 6I_2 + 15I_x = 0 \\ &6I_1 + 6I_2 + 15(-I_4) = 0 \\ &6I_1 + 6I_2 - 15(0.667I_3) = 0 \\ &6I_1 + 6I_2 - 10I_3 = 0 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} &6I_1 + 6I_2 - (10)(0.75I_1) = 0 \\ &-1.5I_1 + 6(I_1 - 3) = 0 \\ &4.5I_1 = 18 \\ &I_1 = 4\text{ A} \end{aligned}$$

Step 5 of 6

Substitute I_1 value in equation (1) and solve for I_3.

$$\begin{aligned} I_3 &= (0.75)(4\text{ A}) \\ &= 3\text{ A} \end{aligned}$$

Substitute I_3 value in equation (2) and solve for I_4.

$$\begin{aligned} I_4 &= (0.667)(3\text{ A}) \\ &= 2\text{ A} \end{aligned}$$

Step 6 of 6

Calculate the power delivered by $15I_x$ current control voltage source in Figure 1 by using the formula $P = VI$.

Substitute $P = P_{\text{CCVS}}$, $V = 15I_x$, $I = I_4 - I_2$ from the Figure 1 and solve for P_{CCVS}.

$$\begin{aligned} P_{\text{CCVS}} &= (15I_x)(I_4 - I_2) \\ &= 15(-I_4)(I_4 - I_1 + 3\text{ A}) \\ &= 15(-2\text{ A})(2\text{ A} - 4\text{ A} + 3\text{ A}) \\ &= -30\text{ W} \end{aligned}$$

Therefore, the power delivered by the $15I_x$ source in the network is $\boxed{30\text{ W}}$.

Step 1 of 3

Refer to waveform shown in Figure P4.1 in the textbook.

The value of gain (A_o) is 15.

It is known that, for an amplifier the output voltage is,

$$v_o = A_o v_{in}$$

Calculate the output voltage at $t = 0$.

$$\begin{aligned} v_o &= 15(0\text{ mV}) \\ &= 0\text{ V} \end{aligned}$$

Calculate the output voltage at $t = 0.5^+$.

$$\begin{aligned} v_o &= 15(50\text{ mV}) \\ &= 750\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 0.5^-$.

$$\begin{aligned} v_o &= 15(-100\text{ mV}) \\ &= -1500\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1^+$.

$$\begin{aligned} v_o &= 15(0) \\ &= 0\text{ V} \end{aligned}$$

Step 2 of 3

Calculate the output voltage at $t = 1^-$.

$$\begin{aligned} v_o &= 15(-150\text{ mV}) \\ &= -2250\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1.5^+$.

$$\begin{aligned} v_o &= 15(50\text{ mV}) \\ &= 750\text{ mV} \end{aligned}$$

Calculate the output voltage at $t = 1.5^-$.

$$\begin{aligned} v_o &= 15(0\text{ mV}) \\ &= 0\text{ V} \end{aligned}$$

Calculate the output voltage at $t = 2$.

$$\begin{aligned} v_o &= 15(0) \\ &= 0\text{ V} \end{aligned}$$

Step 3 of 3

The output waveform is shown in Figure 1.

Figure 1

Therefore, the output waveform for the amplifier is shown in Figure 1.

Step 1 of 2

4.2E

Refer to circuit diagram in Figure E4.2 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Substitute the values V_S for v_- in the expression.

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

$$\frac{V_S}{R_1} = \frac{V_o - V_S}{R_2}$$

$$\frac{V_o}{R_2} = V_S\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

Therefore, the gain of the op-amp is $\boxed{1 + \frac{R_2}{R_1}}$.

Step 1 of 3

Refer to Figure 4PFE-2 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the first op-amp.

$$I_1 + I_2 = I_3$$

$$\frac{2-v_-}{6} + \frac{-1-v_-}{12} = \frac{v_- - v_x}{18}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute the values $v_- = 0$ in the expression.

$$\frac{2-v_-}{6} + \frac{-1-v_-}{12} = \frac{v_- - v_x}{18}$$

$$\frac{2-0}{6} + \frac{-1-0}{12} = \frac{0-v_x}{18}$$

$$\frac{v_x}{18} = \frac{1}{12} - \frac{2}{6}$$

$$v_x = -4.5\,\text{V}$$

Step 3 of 3

Write the node equation at the inverting terminal of the second op-amp.

$$I_4 + I_5 = I_6$$

$$\frac{v_x - v_-}{6} + \frac{3-v_-}{12} = \frac{v_- - V_o}{36}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute the values $v_- = 0$ and $v_x = -4.5\,\text{V}$ in the expression.

$$\frac{v_x - v_-}{6} + \frac{3-v_-}{12} = \frac{v_- - V_o}{36}$$

$$\frac{-4.5-0}{6} + \frac{3-0}{12} = \frac{0-V_o}{36}$$

$$\frac{V_o}{36} = \frac{4.5}{6} - \frac{3}{12}$$

$$V_o = 18\,\text{V}$$

Hence, the output voltage V_o is $18\,\text{V}$.

Therefore, the correct option is $\boxed{b}$.

Step 1 of 2

4.2P

Consider the waveform shown in textbook Figure P4.2. The waveform is the output of an amplifier with gain -5. We know that $v_{in} = \frac{v_o}{A_o}$

Where $A_0 = -5$

The output voltage values from the waveform with respect to time instants are

$v_0 = 0, 4, 12, 12, 12, 8, 0$ at $t = 0$ to 6 respectively

$v_0 = -8$ at $t = 6^-$

And

$v_0 = -12, -6, 0$ at $t = 7$ to 9 respectively

From the output voltage values, we can find the voltage values from the above equation.

Therefore at

$t = 0$

$v_{in} = \frac{0}{-5}$

$= 0$ V

$t = 1$

$v_{in} = \frac{4}{-5}$

$= -0.8$ V

$t = 2$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 3$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 4$

$v_{in} = \frac{12}{-5}$

$= -2.4$ V

$t = 5$

$v_{in} = \frac{8}{5}$

$= 1.6$ V

$t = 6^+$

$v_{in} = 0$ V

$t = 6^-$

$v_{in} = \frac{-8}{-5}$

$= 1.6$ V

$t = 7$

$v_{in} = \frac{-12}{-5}$

$= 2.4$ V

$t = 8$

$v_{in} = \frac{-6}{-5}$

$= 1.2$ V

$t = 9$

$v_{in} = 0$ V

Step 2 of 2

From the above voltage values, the input waveform is

Figure 1

Therefore the input waveform for the given amplifier is as shown in Figure 1.

Step 1 of 4

4.3E

Refer to circuit diagram in Figure E4.3 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 4

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_- - 0}{1} = \frac{V_o - v_-}{100}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Substitute 1 mV for v_- in the expression.

$$\frac{v_- - 0}{1} = \frac{V_o - v_-}{100}$$

$$\frac{V_S}{R_1} = \frac{V_o - V_S}{R_2}$$

$$\frac{V_o}{R_2} = V_S\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

Step 3 of 4

Calculate the gain of the op-amp circuit by substitute $1\text{ k}\Omega$ for R_1 and $100\text{ k}\Omega$ for R_2 in the equation.

$$\begin{aligned}\frac{V_o}{V_S} &= 1 + \frac{R_2}{R_1}\\ &= 1 + \frac{100\text{ k}\Omega}{1\text{ k}\Omega}\\ &= 1 + 100\\ &= 101\end{aligned}$$

Therefore, the gain of the op-amp is $\boxed{101}$.

Step 4 of 4

Write the expression for the gain of the op-amp circuit.

$$\frac{V_o}{V_S} = 101$$

Calculate the output voltage of the op-amp by substitute 1 mV for V_S in the equation.

$$\begin{aligned}\frac{V_o}{V_S} &= 101\\ V_o &= (101)V_S\\ &= (101)(1\text{ mV})\\ &= 0.101\text{ V}\end{aligned}$$

Therefore, the output voltage of the op-amp is $\boxed{0.101\text{ V}}$.

Refer to Figure 4PFE-3 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$I_1 + I_2 = I_3$$

$$\frac{6 - v_-}{3} + \frac{2 - v_-}{4} = \frac{v_- - V_o}{2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

Since non-inverting terminal is grounded, by using the fact that $v_- = 0$.

Substitute the values $v_- = 0$ in the expression.

$$\frac{6 - v_-}{3} + \frac{2 - v_-}{4} = \frac{v_- - V_o}{2}$$

$$\frac{6 - 0}{3} + \frac{2 - 0}{4} = \frac{0 - V_o}{2}$$

$$-\frac{V_o}{2} = \frac{6}{3} + \frac{2}{4}$$

$$V_o = -5\,\text{V}$$

Hence, the output voltage V_o is $-5\,\text{V}$.

Therefore, the correct option is $\boxed{\text{a}}$.

Step 1 of 6

(a)

Refer to waveform shown in Figure P4.3 in the textbook.

The value of gain (A_o) is 20 and the supply voltages are $\pm 5\ \text{V}$.

It is known that, for an amplifier the output voltage is,

$$v_o = A_0 v_{in}$$
$$v_{in} = \frac{v_o}{A_0}$$

Calculate the output voltage at $t = 0$.

$$v_o = 0\ \text{V}$$
$$v_{in} = \frac{0\ \text{V}}{20}$$
$$= 0\ \text{V}$$

Calculate the output voltage at $t = 25\ \text{ms}$.

$$v_o = 3\ \text{V}$$
$$v_{in} = \frac{3\ \text{V}}{20}$$
$$= 0.15\ \text{V}$$

Step 2 of 6

Calculate the output voltage at $t = 50\ \text{ms}$.

$$v_o = 2\ \text{V}$$
$$v_{in} = \frac{2\ \text{V}}{20}$$
$$= 0.1\ \text{V}$$

Calculate the output voltage at at $t = 75\ \text{ms}$.

$$v_o = 0\ \text{V}$$
$$v_{in} = \frac{0\ \text{V}}{20}$$
$$= 0\ \text{V}$$

Calculate the output voltage at $t = 100\ \text{ms}$.

$$v_o = -3\ \text{V}$$
$$v_{in} = \frac{-3\ \text{V}}{20}$$
$$= -0.15\ \text{V}$$

Calculate the output voltage at $t = 125\ \text{ms}$.

$$v_o = 0\ \text{V}$$
$$v_{in} = \frac{0\ \text{V}}{20}$$
$$= 0\ \text{V}$$

Step 3 of 6

The output waveform is shown in Figure 1.

Figure 1

Therefore, the output waveform for the amplifier is shown in Figure 1.

Step 4 of 6

(b)

Now the amplitude of the amplifier is doubled.

Calculate the output voltage at $t = 0$.

$$v_o = 0\ \text{V}$$
$$v_{in} = 2\left(\frac{0\ \text{V}}{20}\right)$$
$$= 0\ \text{V}$$

Calculate the output voltage at $t = 25\ \text{ms}$.

$$v_o = 3\ \text{V}$$
$$v_{in} = 2\left(\frac{3\ \text{V}}{20}\right)$$
$$= 0.3\ \text{V}$$

Step 5 of 6

Calculate the output voltage at $t = 50\ \text{ms}$.

$$v_o = 2\ \text{V}$$
$$v_{in} = 2\left(\frac{2\ \text{V}}{20}\right)$$
$$= 0.2\ \text{V}$$

Calculate the output voltage at at $t = 75\ \text{ms}$.

$$v_o = 0\ \text{V}$$
$$v_{in} = 2\left(\frac{0\ \text{V}}{20}\right)$$
$$= 0\ \text{V}$$

Calculate the output voltage at $t = 100\ \text{ms}$.

$$v_o = -3\ \text{V}$$
$$v_{in} = 2\left(\frac{-3\ \text{V}}{20}\right)$$
$$= -0.3\ \text{V}$$

Calculate the output voltage at $t = 125\ \text{ms}$.

$$v_o = 0\ \text{V}$$
$$v_{in} = 2\left(\frac{0\ \text{V}}{20}\right)$$
$$= 0\ \text{V}$$

Step 6 of 6

The output waveform is shown in Figure 2.

Figure 2

Therefore, the output waveform for the amplifier is shown in Figure 2.

4.4E

Refer to circuit diagram in Figure E4.4 in the text book.

Convert current source in parallel with resistor to Thevenin equivalent, the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 6

For an ideal op-amp, the current entering in to the input terminals of the op-amp is zero.

Hence, $I_1 = 0$.

Therefore, the current I_1 is $\boxed{0}$.

Step 3 of 6

Write the node equation at the inverting terminal.

$$I_5 = -I_3$$

$$\frac{v_-}{10\text{ k}} = -\frac{v_- - V_o}{5\text{ k}}$$

Apply ideal op-amp conditions.

$$v_- = v_+$$

And,

$$i_- = i_+$$

Since no current flows through the input terminals of the op-amp, the voltage $v_- = 5\text{ V}$ and $i_- = 0$.

Substitute the values 5 V for v_- and 0 for i_- in the expression.

$$\frac{v_-}{10\text{ k}} = \frac{V_o - v_-}{5\text{ k}}$$

$$\frac{5}{10} = \frac{V_o - 5}{5}$$

$$V_o - 5 = 2.5$$

$$V_o = 7.5\text{ V}$$

Step 4 of 6

Write the expression for the current I_3.

$$I_3 = \frac{v_- - V_o}{5}$$

Substitute 5 V for v_- and 7.5 V for V_o in the equation.

$$\begin{aligned} I_3 &= \frac{v_- - V_o}{5\text{ k}} \\ &= \frac{5 - 7.5}{5\text{ k}} \\ &= -0.5\text{ mA} \end{aligned}$$

Therefore, the current I_3 is $\boxed{-0.5\text{ mA}}$.

Step 5 of 6

Write the expression for the current I_4.

$$I_4 = \frac{V_o}{10\text{k}}$$

Substitute 7.5 V for V_o in the equation.

$$\begin{aligned} I_4 &= \frac{V_o}{10\text{ k}} \\ &= \frac{7.5}{10\text{ k}} \\ &= 0.75\text{ mA} \end{aligned}$$

Therefore, the current I_4 is $\boxed{0.75\text{ mA}}$.

Step 6 of 6

Write the expression for the current I_2.

$$I_2 = I_4 - I_3$$

Substitute 0.75 mA for I_4 and -0.5 mA for I_3 in the equation.

$$\begin{aligned} I_2 &= I_4 - I_3 \\ &= 0.75\text{ mA} - (-0.5\text{ mA}) \\ &= 0.75\text{ mA} + 0.5\text{ mA} \\ &= 1.25\text{ mA} \end{aligned}$$

Therefore, the current I_2 is $\boxed{1.25\text{ mA}}$.

Step 1 of 4

Refer to Figure 4PFE-4 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 4

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_f}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = V_{in}$.

Substitute the values $v_- = V_{in}$ in the expression.

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_f}$$

$$\frac{V_{in}}{R_1} = \frac{V_o - V_{in}}{R_f}$$

$$\frac{V_o}{R_f} = V_{in}\left(\frac{1}{R_1} + \frac{1}{R_f}\right)$$

$$\frac{V_o}{V_{in}} = 1 + \frac{R_f}{R_1}$$

Step 3 of 4

Since voltage gain is 50, substitute the value $50 \text{ for } \frac{V_o}{V_{in}}$ in the expression.

$$\frac{V_o}{V_{in}} = 1 + \frac{R_f}{R_1}$$

$$= 50$$

$$\frac{R_f}{R_1} = 49$$

$$R_f = 49R_1$$

Step 4 of 4

Calculate the resistance R_1 by substituting $5\,\text{k}\Omega \text{ for } R_1$

$$R_f = 49R_1$$

$$= 49(5\,\text{k}\Omega)$$

$$= 245\,\text{k}\Omega$$

Hence, the value of resistance R_f is $245\,\text{k}\Omega$.

Therefore, the correct option is $\boxed{\text{d}}$.

Step 1 of 3

4.4P

(a)

The gain and input resistance for the amplifier are infinite. Therefore almost any signal source can drive the amplifier. Therefore, an input voltage of zero produces a finite output voltage.

Hence, the input voltage is, $\boxed{v_{in} = 0\ \text{V}}$.

Step 2 of 3

(b)

The input resistance is infinite. Therefore, no input current flows.

Hence, the input current is, $\boxed{i_{in} = 0\ \text{A}}$.

Step 3 of 3

(c)

Since output resistance is zero, output current is limited by external circuitry. Draw the required circuit.

Figure 1

Hence, the output current is, $\boxed{i_o = \dfrac{v_o}{R_{EQ}}\ \text{A}}$.

Step 1 of 3

4.5E

Refer to Figure E4.5 in the textbook for the circuit.

Calculate the voltage at non inverting terminal of op-amp.

$$v_+ = V_2\left(\frac{7\times10^3}{4\times10^3+7\times10^3}\right)$$
$$= \frac{7}{11}V_2$$

It is known that, in an ideal op-amp the inverting terminal voltage is same as the non-inverting terminal voltage.

$$v_- = v_+$$
$$= \frac{7}{11}V_2$$

Apply nodal analysis at inverting terminal of op-amp.

$$\frac{v_- - V_1}{5\times10^3} + \frac{v_-}{4\times10^3} + \frac{v_- - V_O}{10\times10^3} = 0$$
$$\frac{4v_- - 4V_1 + 5v_- + 2v_- - 2V_O}{20\times10^3} = 0$$
$$11v_- - 4V_1 - 2V_O = 0$$

Substitute $\frac{7}{11}V_2$ for v_- in the equation.

$$11\left(\frac{7}{11}V_2\right) - 4V_1 - 2V_O = 0$$
$$7V_2 - 4V_1 = 2V_O$$
$$V_O = -2V_1 + 3.5V_2$$

Therefore, the voltage V_O in terms of V_1 and V_2 is,

$$\boxed{V_O = -2V_1 + 3.5V_2}$$

Step 2 of 3

Consider the voltage V_O in terms of V_1 and V_2.

$$V_O = -2V_1 + 3.5V_2$$

Substitute 4 V for V_1 and 4 V for V_2 in the equation.

$$V_O = -2(4) + 3.5(4)$$
$$= -8 + 14$$
$$= 6\text{ V}$$

Thus, the value of V_O is $\boxed{6\text{ V}}$.

Step 3 of 3

If the op-amp power supplies are $\pm15\text{ V}$, then the maximum output voltage is $V_{O(\max)} = +15\text{ V}$ and the minimum output voltage is $V_{O(\min)} = -15\text{ V}$.

Calculate the maximum value of V_1.

$$V_{O(\min)} = -2V_{1(\max)} + 3.5V_2$$

Substitute -15 V for $V_{O(\min)}$ and 2 V for V_2 in the equation.

$$-15 = -2V_{1(\max)} + 3.5(2)$$
$$-15 = -2V_{1(\max)} + 7$$
$$2V_{1(\max)} = 22$$
$$V_{1(\max)} = 11\text{ V}$$

Calculate the minimum value of V_1.

$$V_{O(\max)} = -2V_{1(\min)} + 3.5V_2$$

Substitute 15 V for $V_{O(\max)}$ and 2 V for V_2 in the equation.

$$15 = -2V_{1(\min)} + 3.5(2)$$
$$15 = -2V_{1(\min)} + 7$$
$$2V_{1(\min)} = -8$$
$$V_{1(\min)} = -4\text{ V}$$

The allowable range of V_1 is,

$$V_{1(\min)} \le V_1 \le V_{1(\max)}$$
$$-4\text{ V} \le V_1 \le 11\text{ V}$$

Therefore, the allowable range of V_1 is $\boxed{-4\text{ V} \le V_1 \le 11\text{ V}}$.

Step 1 of 3

4.5FE

Refer to Figure 4PFE-5 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_1 = I_2$$

$$\frac{v_-}{2} = \frac{v_x - v_-}{8}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 5\,\text{V}$ and $i_- = 0$.

Substitute $5\,\text{V}$ for v_- and 0 for i_- in the expression.

$$\frac{v_-}{2} = \frac{v_x - v_-}{8}$$

$$\frac{5}{2} = \frac{v_x - 5}{8}$$

$$v_x - 5 = 20$$

$$v_x = 25\,\text{V}$$

Hence, the voltage $v_x = 25\,\text{V}$ ..... (1)

Step 3 of 3

Write the current equation at the output terminal

$$I = I_3 + I_4$$

$$\frac{v_- - V_o}{6\text{k}} = \frac{V_o - v_x}{2\text{k}} + \frac{V_o}{1\text{k}}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 5\,\text{V}$ and $v_x = 25\,\text{V}$.

Substitute $5\,\text{V}$ for v_- and $25\,\text{V}$ for v_x in the expression.

$$\frac{v_- - V_o}{6\text{k}} = \frac{V_o - v_x}{2\text{k}} + \frac{V_o}{1\text{k}}$$

$$\frac{5 - V_o}{6\text{k}} = \frac{V_o - 25}{2\text{k}} + \frac{V_o}{1\text{k}}$$

$$V_o\left(\frac{6+3+1}{6}\right) = \frac{5+75}{6}$$

$$V_o = 8\,\text{V}$$

Hence, the voltage V_o is $\boxed{8\,\text{V}}$.

Therefore, the correct option is $\boxed{\text{c}}$.

Step 1 of 4

4.5P

(a)

The gain of the given amplifier is not equal to infinity. Therefore, $v_{in} \neq 0$.

Since input resistance is infinity there will be no input current.

Since output resistance is zero, output current is limited by external circuit. Draw the required circuit.

Figure 1

Step 2 of 4

From Figure 1, output current is $i_o = \frac{v_o}{R_{EQ}}$, where $R_{EQ} = R_L + R_{out}$. Here R_{out} is the output resistance.

Since, output resistance is zero, the output current is,

$$i_o = \frac{v_o}{R_L}$$

Hence, $\boxed{v_{in} \neq 0}$.

Step 3 of 4

(b)

For an op-amp it is given that, $R_{in} = \infty; R_{out} > 0; A_o = \infty$.

Since input resistance is infinity there will be no input current.

Since gain of the amplifier is ∞ , the input voltage is zero.

The output resistance is greater than zero. Therefore the output current is limited by both R_o and R_L .

Hence, $\boxed{i_{in} = 0}$.

Step 4 of 4

(c)

For an op-amp it is given that, $R_{in} \neq \infty; R_{out} = 0; A_o = \infty$.

Since gain of the amplifier is ∞ , the input voltage is zero.

Since $R_{in} \neq \infty$, the input current is given by $i_{in} = \frac{v_{in}}{R_{in}}$. As $v_{in} = 0$, the input current is zero.

Since output resistance is zero, output current is limited by external circuitry.

Hence, the result is, $\boxed{i_o = \frac{v_o}{R_L}}$.

4.7E

Consider the network in textbook Figure E 4.7. Redraw the diagram with modifications as shown below

Figure 1

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = V_1$ and $i_1 = i_2 = 0\ \text{A}$.

Now apply Kirchhoff's current law equation at node V_1 .

$$\frac{V_1 - V}{R_2} + \frac{V_1}{R_1} = 0$$

$$\frac{V}{R_2} = V_1\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$V = V_1\left(1 + \frac{R_2}{R_1}\right)$$

Now apply Kirchhoff's current law at node V .

$$\frac{V - V_1}{R_2} + \frac{V - V_o}{R_3} + \frac{V}{R_4} = 0$$

$$V\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) - \frac{V_1}{R_2} = \frac{V_o}{R_3}$$

Now substitute $V = V_1\left(1 + \frac{R_2}{R_1}\right)$ in the above equation. Therefore

$$\frac{V_o}{R_3} = V_1\left(\left(1 + \frac{R_2}{R_1}\right)\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) - \frac{1}{R_2}\right)$$

$$V_o = V_1\left(\left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_3}{R_2} + 1 + \frac{R_3}{R_4}\right) - \frac{R_3}{R_2}\right)$$

Therefore the output voltage is $\boxed{V_o = V_1\left(\left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_3}{R_2} + 1 + \frac{R_3}{R_4}\right) - \frac{R_3}{R_2}\right)}$.

Step 1 of 1

4.8P

Consider for an op-amp based amplifier, the supply voltages are $\pm 18\ \text{V}$ and gain is -80.

Consider the following expression for the gain of a linear operation of an amplifier:

$$\frac{v_o}{v_{in}} = -80$$

Simplify the expression for the input voltage.

$$v_{in} = -\frac{v_o}{80}$$

The output voltage due to output limits is $|v_o| \le 18\ \text{V}$.

Substitute 18 V for v_o to find the range of input voltage.

$$\begin{aligned} v_{in} &= -\frac{18}{80} \\ &= 0.225\ \text{V} \end{aligned}$$

Thus, the range of input over which the amplifier is linear is $\boxed{|v_{in}| \le 0.225\ \text{V}}$.

Step 1 of 2

4.9P

Refer to Figure P4.9 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 - i_2 = i_-$$

$$\frac{0 - v_-}{1\text{k}} + \frac{v_o - v_-}{20\text{k}} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+ \text{ and } i_- = i_+$.

By using the fact that $v_- = v_1 \text{ and } i_- = 0$.

Substitute the values $v_- = v_1 \text{ and } i_- = 0$ in the expression.

$$\frac{0 - v_-}{1\text{k}} + \frac{v_o - v_-}{20\text{k}} = i_-$$

$$\frac{-v_1}{1\text{k}} + \frac{v_o - v_1}{20\text{k}} = 0$$

$$\frac{v_o}{20} = v_1\left(1 + \frac{1}{20}\right)$$

$$\frac{v_o}{v_1} = 21$$

Therefore, the voltage gain of the circuit is $\boxed{21}$.

Step 1 of 2

4.10P

Refer to Figure P4.10 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 = i_2$$

$$\frac{v_-}{200} = \frac{v_o - v_-}{4+2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = v_1$ and $i_- = 0$.

Substitute the values $v_- = v_1$ and $i_- = 0$ in the expression.

$$\frac{v_-}{200} = \frac{v_o - v_-}{4+2}$$

$$\frac{v_1}{200} = \frac{v_o - v_1}{6}$$

$$\frac{v_o}{6} = v_1\left(\frac{1}{6} + \frac{1}{200}\right)$$

$$\frac{v_o}{v_1} = 1.03$$

Therefore, the voltage gain of the circuit is $\boxed{1.03}$.

4.12P

Refer to Figure P4.12 in the text book.

The resistors 100Ω and 150Ω are connected in series, the series equivalent resistance is as follows:

$$\begin{aligned} R_S &= 100\Omega + 150\Omega \\ &= 250\Omega \end{aligned}$$

The resistors $18\,\text{k}\Omega$ and $9\,\text{k}\Omega$ are connected in parallel, the parallel equivalent resistance is as follows:

$$\begin{aligned} R_P &= \frac{(18)(9)}{18+9} \\ &= 6\,\text{k}\Omega \end{aligned}$$

The circuit is redrawn as shown in Figure 1.

Figure 1

Write the node equation at the inverting terminal.

$$i_1 - i_2 = i_-$$

$$\frac{v_1 - v_-}{250\Omega} + \frac{v_o - v_-}{6\,\text{k}\Omega} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute the values $v_- = 0$ and $i_- = 0$ in the expression.

$$\frac{v_1 - v_-}{250\Omega} + \frac{v_o - v_-}{6\,\text{k}\Omega} = i_-$$

$$\frac{v_1 - 0}{250\Omega} + \frac{v_o - 0}{6\,\text{k}\Omega} = 0$$

$$\frac{v_o}{6\,\text{k}\Omega} = \frac{-v_1}{250\Omega}$$

$$\frac{v_o}{v_1} = -24$$

Therefore, the gain of the network is $\boxed{-24}$.

Step 1 of 2

4.13P

Refer to Figure P4.13 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 - i_2 = i_-$$

$$\frac{v_1 - v_-}{1} + \frac{v_o - v_-}{4} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+ \text{ and } i_- = i_+$.

By using the fact that $v_- = 2\,\text{V} \text{ and } i_- = 0$.

Substitute the values $v_- = 2\,\text{V}, v_1 = 6\,\text{V} \text{ and } i_- = 0$ in the expression.

$$\frac{v_1 - v_-}{1} + \frac{v_o - v_-}{4} = i_-$$

$$\frac{6-2}{1} + \frac{v_o - 2}{4} = 0$$

$$v_o - 2 = -4(4)$$

$$v_o = -14\,\text{V}$$

Therefore, the output voltage is $\boxed{-14\,\text{V}}$.

Step 1 of 3

Refer to Figure P4.14 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_1 = I_o$$

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = V_{in}$ and $i_- = 0$.

Substitute the values $3.3\,\text{k}\Omega$ for R_1 and $20\,\text{k}\Omega$ for R_2 in the expression.

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

$$\frac{V_{in}}{3.3} = \frac{V_o - V_{in}}{20}$$

$$\frac{V_o}{20} = V_{in}\left(\frac{1}{3.3} + \frac{1}{20}\right)$$

$$\frac{V_o}{V_{in}} = 7$$

Therefore, the gain of the amplifier is $\boxed{7}$.

Step 3 of 3

Write the expression for the current I_o.

$$I_o = \frac{V_o - V_{in}}{R_2}$$

Calculate the current I_o by substituting $7V_{in}$ for V_o, $2\,\text{V}$ for V_{in} and $20\,\text{k}\Omega$ for R_2.

$$\begin{aligned} I_o &= \frac{V_o - V_{in}}{R_2} \\ &= \frac{7V_{in} - V_{in}}{R_2} \\ &= \frac{6(2)}{20\times10^3} \\ &= 0.6\,\text{mA} \end{aligned}$$

Therefore, the value of current I_o is $\boxed{0.6\,\text{mA}}$.

Step 1 of 3

Refer to Figure P4.15 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_1 = I_O$$

$$\frac{v_- - V_S}{R_1} = \frac{V_o - v_-}{R_2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute the values $3.3\,\text{k}\Omega$ for R_1 and $20\,\text{k}\Omega$ for R_2 in the expression.

$$\frac{v_- - V_S}{R_1} = \frac{V_o - v_-}{R_2}$$

$$\frac{0 - V_S}{3.3} = \frac{V_o - 0}{20}$$

$$\frac{V_o}{20} = \frac{-V_S}{3.3}$$

$$\frac{V_o}{V_S} = -6$$

Therefore, the gain of the amplifier is $\boxed{-6}$.

Step 3 of 3

Write the expression for the current I_o.

$$I_o = \frac{V_o - v_-}{R_2}$$

Calculate the current I_o by substituting $-6V_S$ for V_o, $2\,\text{V}$ for V_S and $20\,\text{k}\Omega$ for R_2.

$$\begin{aligned} I_o &= \frac{V_o - v_-}{R_2} \\ &= \frac{-6V_S - 0}{R_2} \\ &= \frac{-6(2)}{20\times10^3} \\ &= -0.6\,\text{mA} \end{aligned}$$

Therefore, the value of current I_o is $\boxed{-0.6\,\text{mA}}$.

Step 1 of 3

4.16P

Refer to Figure P4.16 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_2 = I_o$$

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 11\text{ V}$ and $i_- = 0$.

Substitute 11 V for v_-, $1\text{ k}\Omega$ for R_1 and $10\text{ k}\Omega$ for R_2 in the equation.

$$\frac{v_- - 0}{R_1} = \frac{V_o - v_-}{R_2}$$

$$\frac{11}{1} = \frac{V_o - 11}{10}$$

$$V_o - 11 = 110$$

$$V_o = 121\text{V}$$

Therefore, the output voltage is $\boxed{121\text{V}}$.

Step 3 of 3

For an ideal op-amp, the current entering in to the input terminal of the op-amp is zero.

$$I_1 = i_+$$
$$= 0\text{ A}$$

Therefore, the current I_1 is $\boxed{0\text{ A}}$.

Step 1 of 3

4.17P

Refer to Figure P4.17 in the text book.

From the Figure P4.17, the current I_1 flow through the resistor R_1 is equal to the source current.

$$I_1 = 1\,\text{mA}$$

Therefore, the current I_1 is $\boxed{1\,\text{mA}}$.

Step 2 of 3

For an ideal op-amp, the current entering in to the input terminal of the op-amp is zero.

$$\begin{aligned} I_2 &= i_- \\ &= 0 \end{aligned}$$

Therefore, the current I_2 is $\boxed{0}$.

Step 3 of 3

Since for an ideal op-amp, the current entering in to the input terminal of the op-amp is zero, the same current flow through the resistor R_1 flows through the resistor R_2.

$$\begin{aligned} I_3 &= I_1 \\ &= 1\,\text{mA} \end{aligned}$$

Therefore, the current I_3 is $\boxed{1\,\text{mA}}$.

Step 1 of 2

Refer to Figure P4.11 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 = i_2$$

$$\frac{v_-}{R_X} = \frac{v_o - v_-}{4}$$

Apply ideal op-amp conditions, $v_- = v_+ \text{ and } i_- = i_+$.

By using the fact that $v_- = v_1 \text{ and } i_- = 0$.

Substitute the values $v_- = v_1 \text{ and } i_- = 0$ in the expression.

$$\frac{v_-}{R_X} = \frac{v_o - v_-}{4\text{k}}$$

$$\frac{v_1}{R_X} = \frac{v_o - v_1}{4\text{k}}$$

$$\frac{v_o}{4\text{k}} = v_1\left(\frac{1}{4\text{k}} + \frac{1}{R_X}\right)$$

$$\frac{v_o}{v_1} = 1 + \frac{4\text{k}}{R_X}$$

Calculate the resistance by substituting 26 for voltage gain.

$$\frac{v_o}{v_1} = 1 + \frac{4\text{k}}{R_X}$$

$$26 = 1 + \frac{4\text{k}}{R_X}$$

$$\frac{4\text{k}}{R_X} = 25$$

$$R_X = 160\Omega$$

Therefore, the value of the resistance R_X is $\boxed{160\Omega}$.

Step 1 of 4

4.19P

Consider the network in textbook Figure P 4.19. Redraw the diagram with modifications as shown below

Figure 1

Step 2 of 4

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = V_S$ and $i_1 = i_2 = 0\ \text{A}$.

Now apply Kirchhoff's current law equation at node V_- .

$$\frac{V_-}{R_1} + \frac{V_- - V_o}{R_2} = 0$$

$$\frac{V_S}{R_1} + \frac{V_S}{R_2} = \frac{V_o}{R_2}$$

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

$$\frac{V_o}{V_S} = \frac{R_1 + R_2}{R_1}$$

It is given that $R_1 + R_2 = 10\ \text{k}\Omega$. Therefore

$$\frac{V_o}{V_S} = \frac{10^4}{R_1}$$

Step 3 of 4

It is given that, the maximum value of V_S is $1\ \text{V}$, $I_o \le 200\ \text{mA}$ and the op-amp operates with $\pm 15\ \text{V}$ supplies. Therefore we have $|V_o| = \frac{10^4}{R_1}$. Now calculate the output current from Figure 1.

$$\begin{aligned} I_o &= \frac{V_o}{R_1 + R_2} + \frac{V_o}{R_L} \\ &= \frac{\frac{10^4}{R_1}}{10^4} + \frac{\frac{10^4}{R_1}}{50} \\ &= \frac{1}{R_1}\left[1 + \frac{10^4}{50}\right] \\ &= \frac{1}{R_1}(201) \end{aligned}$$

Step 4 of 4

The output current is less than or equal to $200\ \text{mA}$. Therefore

$$\frac{1}{R_1}(201) \le 200\ \text{mA}$$

$$R_1 \ge \frac{201}{0.2}$$

$$R_1 \ge 1005$$

Since $R_1 + R_2 = 10^4\ \Omega$,

$$\begin{aligned} R_2 &= 10^4 - 1005 \\ &= 8995\ \Omega \end{aligned}$$

Calculate the gain of the amplifier.

$$\begin{aligned} \text{gain} &= 1 + \frac{R_2}{R_1} \\ &= 9.95 \end{aligned}$$

Therefore, the maximum gain that is allowable for the amplifier is $\boxed{A_0 = 9.95\ \text{V}}$.

Step 1 of 6

4.20P

Refer to Figure P4.20 in the textbook for the circuit.

The circuit is a basic non-inverting op-amp amplifier.

$$\frac{V_o}{V_S} = 1 + \frac{R_2}{R_1}$$

$$V_o = V_S\left(1 + \frac{R_2}{R_1}\right)$$

$$V_o = 2\left(1 + \frac{R_2}{R_1}\right)$$

From the circuit, the output current delivered by the op-amp is,

$$I_o = \frac{V_o}{R_L \| (R_1 + R_2)}$$

(a)

Since the supply voltages are $\pm 10\ \text{V}$, the output voltage is,

$$|V_0| \le 10\ \text{V}$$

$$2\left(1 + \frac{R_2}{R_1}\right) \le 10$$

$$1 + \frac{R_2}{R_1} \le 5$$

$$\frac{R_2}{R_1} \le 4$$

$$R_2 \le 4R_1$$

Substitute $100\ \text{k}\Omega$ for R_1 in the equation.

$$R_2 \le 4(100 \times 10^3)$$

$$R_2 \le 400\ \text{k}\Omega$$

Thus, the allowable value of R_2 is $\boxed{400\,\text{k}\Omega}$

Step 2 of 6

The output current delivered by the op-amp is,

$$I_o = \frac{V_o}{R_L \| (R_1 + R_2)}$$

Substitute $10\ \text{V}$ for V_o , $10\ \text{k}\Omega$ for R_L , $100\ \text{k}\Omega$ for R_1 , and $400\ \text{k}\Omega$ for R_2 in the equation.

$$\begin{aligned} I_o &= \frac{10}{R_L \| (R_1 + R_2)} \\ &= \frac{10}{10\times10^3 \| (100\times10^3 + 400\times10^3)} \\ &= \frac{10}{10\times10^3 \| (500\times10^3)} \\ &= \frac{10}{9.804\times10^3} \\ &= 1.02\ \text{mA} \end{aligned}$$

Thus, the current delivered by the op-amp is $1.02\,\text{mA}$, which is less than rated value of $100\,\text{mA}$.

Step 3 of 6

(b)

Since the supply voltages are $\pm 3\ \text{V}$, the output voltage is,

$$|V_0| \le 10\ \text{V}$$

$$2\left(1 + \frac{R_2}{R_1}\right) \le 3$$

$$1 + \frac{R_2}{R_1} \le 1.5$$

$$\frac{R_2}{R_1} \le 0.5$$

$$R_2 \le 0.5R_1$$

Substitute $100\ \text{k}\Omega$ for R_1 in the equation.

$$R_2 \le 0.5(100\times10^3)$$

$$R_2 \le 50\ \text{k}\Omega$$

Thus, the allowable value of R_2 is $\boxed{50\,\text{k}\Omega}$.

Step 4 of 6

The output current delivered by the op-amp is,

$$I_o = \frac{V_o}{R_L \| (R_1 + R_2)}$$

Step 5 of 6

Substitute $3\ \text{V}$ for V_o , $10\ \text{k}\Omega$ for R_L , $100\ \text{k}\Omega$ for R_1 , and $400\ \text{k}\Omega$ for R_2 in the equation.

$$\begin{aligned} I_o &= \frac{3}{R_L \| (R_1 + R_2)} \\ &= \frac{3}{10\times10^3 \| (100\times10^3 + 50\times10^3)} \\ &= \frac{3}{10\times10^3 \| (150\times10^3)} \\ &= \frac{3}{9.375\times10^3} \\ &= 0.32\ \text{mA} \end{aligned}$$

Thus, the current delivered by the op-amp is $0.32\,\text{mA}$, which is less than rated value of $100\,\text{mA}$.

Step 6 of 6

(c)

The maximum allowable gain, $A_{v\max}$ is linearly related to the supply voltage, for a given V_S value, until I_o is not limited.

Step 1 of 5

(a)

Refer to Figure P4.21 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 5

Write the node equation at the inverting terminal.

$$I_2 = I_3 + I_4$$
$$\frac{V_2 - v_-}{2} = \frac{v_-}{1} + \frac{v_- - V_o}{2}$$

Apply ideal op-amp conditions, $v_- = v_+ \text{ and } i_- = i_+$.

By using the fact that $v_- = V_1 \text{ and } i_- = 0$.

Substitute the values $v_- = V_1 \text{ and } i_- = 0$ in the expression.

$$\frac{V_2 - v_-}{2} = \frac{v_-}{1} + \frac{v_- - V_o}{2}$$
$$\frac{V_o}{2} = \frac{v_-}{1} + \frac{v_-}{2} - \frac{V_2}{2} + \frac{v_-}{2}$$
$$V_o = 2V_1 + V_1 - V_2 + V_1$$
$$= 4V_1 - V_2$$

Therefore, the output voltage is $\boxed{4V_1 - V_2}$.

Step 3 of 5

(b)

Write the expression for the output voltage.

$$V_o = 4V_1 - V_2$$

Calculate the output voltage.

Substitute $2\text{ V for } V_1$ and $6\text{ V for } V_2$ in the equation.

$$V_o = 4V_1 - V_2$$
$$= 4(2) - 6$$
$$= 8 - 6$$
$$= 2\text{V}$$

Therefore, the output voltage is $\boxed{2\text{V}}$.

Step 4 of 5

(c)

Consider the value of output voltage is, $V_0 = \pm 12\text{ V}$

Write the expression for the output voltage.

$$V_o = 4V_1 - V_2$$

Calculate the voltage V_2 .

Substituting $12\text{ V for } V_o$ and $4\text{ V for } V_1$.

$$V_o = 4V_1 - V_2$$
$$12 = 4(4) - V_2$$

$$V_2 = 16 - 12$$
$$= 4\text{V}$$

Step 5 of 5

Calculate the voltage V_2 .

Substituting $-12\text{ V for } V_o$ and $4\text{ V for } V_1$.

$$V_o = 4V_1 - V_2$$
$$-12 = 4(4) - V_2$$

$$V_2 = 16 + 12$$
$$= 28\text{V}$$

Therefore, the range of voltage V_2 is $\boxed{4\text{V} \le V_2 \le 28\text{ V}}$.

Step 1 of 2

4.22P

Refer to Figure P4.22 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 - i_2 = i_-$$

$$\frac{v_1 - v_-}{R_1} + \frac{V_o - v_-}{R_2} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute $1\ \text{V}$ for v_1 , $1\ \text{k}\Omega$ for R_1 and $5\ \text{k}\Omega$ for R_2 in the equation.

$$\frac{v_1 - v_-}{R_1} + \frac{V_o - v_-}{R_2} = i_-$$

$$\frac{1-0}{1} + \frac{V_o - 0}{5} = 0$$

$$\frac{V_o}{5} = -1$$

$$V_o = -5\,\text{V}$$

Therefore, the output voltage is $\boxed{-5\,\text{V}}$.

Step 1 of 2

4.23P

Refer to Figure P4.23 in the text book.

Since for an ideal op-amp, the current entering in to the input terminal of the op-amp is zero, the entire source current flows through the resistor R_2.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write Kirchhoff's current law (KCL) at the inverting terminal.

$$i_2 = i_S$$

$$\frac{v_o - v_-}{R_2} = i_S$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute the values 0 for v_- and 1Ω for R_2 in the expression.

$$\frac{v_o - v_-}{R_2} = i_S$$

$$\frac{v_o - 0}{1} = i_S$$

$$\frac{v_o}{i_S} = 1$$

Therefore, the gain of the trans-conductance amplifier is $\boxed{1}$.

Step 1 of 2

Refer to Figure P4.24 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 = i_o$$

$$\frac{v_- - 0}{R_I} = i_o$$

Apply ideal op-amp conditions, $v_- = v_+ \text{ and } i_- = i_+$.

By using the fact that $v_- = v_1 \text{ and } i_- = 0$.

Substitute the values $v_- = v_1 \text{ and } i_- = 0$ in the expression.

$$\frac{v_- - 0}{R_I} = i_o$$

$$\frac{v_1}{R_I} = i_o$$

$$\frac{i_o}{v_1} = \frac{1}{R_I}$$

Therefore, the transfer function for the network is $\boxed{\frac{1}{R_I}}$.

Step 1 of 2

4.25P

Refer to Figure P4.25 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 + i_o = i_-$$

$$\frac{v_1 - v_-}{R_I} + i_o = i_-$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute the values $v_- = 0$ and $i_- = 0$ in the expression.

$$\frac{v_1 - v_-}{R_I} + i_o = i_-$$

$$\frac{v_1 - 0}{R_I} + i_o = 0$$

$$\frac{v_1}{R_I} = -i_o$$

$$\frac{v_1}{i_o} = -R_I$$

Therefore, the ration of v_1 and i_o is $\boxed{-R_I}$.

Step 1 of 2

4.26P

Refer to Figure P4.26 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$i_1 - i_2 = i_-$$

$$\frac{v_1 - v_-}{2} + \frac{V_o - v_-}{10} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = 0$ and $i_- = 0$.

Substitute the values $2\text{ V for } v_1$ in the expression.

$$\frac{v_1 - v_-}{2} + \frac{V_o - v_-}{10} = i_-$$

$$\frac{2-0}{2} + \frac{V_o - 0}{10} = 0$$

$$\frac{V_o}{10} = 1$$

$$V_o = 10\text{ V}$$

Therefore, the output voltage is $\boxed{10\text{ V}}$.

Since the resistor is grounded, it won't effect the output of the network.

Step 1 of 2

4.27P

Consider the network in textbook Figure P 4.27. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

Assume that the op-amp in Figure 1 is ideal. Therefore we have $V^+ = V^- = V$ and hence $V = v_B$. The currents are $i_1 = i_2 = 0$.

Now write Kirchhoff's current law at node V .

$$\frac{V - v_o}{R_2} + \frac{V - v_A}{R_1} + i_1 = 0$$

$$\frac{v_B - v_o}{R_2} + \frac{v_B - v_A}{R_1} = 0$$

$$v_B\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{v_A}{R_1} = \frac{v_o}{R_2}$$

$$v_B\left(\frac{R_1 + R_2}{R_1 R_2}\right) - \frac{v_A}{R_1} = \frac{v_o}{R_2}$$

$$v_o = v_B\left(\frac{R_1 + R_2}{R_1}\right) - \frac{R_2 v_A}{R_1}$$

Therefore the expression for v_o for the given network is $\boxed{v_B\left(1 + \frac{R_2}{R_1}\right) - \frac{R_2}{R_1} v_A}$.

Step 1 of 2

4.28P

Consider the network in textbook Figure P 4.28. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

Assume that the op-amp in Figure 1 is ideal. Therefore we have $V_+ = V_-$ and $i_1 = i_2 = 0\ \mathrm{A}$. As $i_1 = 0\ \mathrm{A}$, we have $V_+ = V_1$ and therefore $V_- = V_1$.

Now write Kirchhoff's current law at node V_-.

$$\frac{V_- - V_2}{R_1} + \frac{V_- - V_o}{R_2} + i_2 = 0$$

$$\frac{V_1 - V_2}{R_1} + \frac{V_1 - V_o}{R_2} = 0$$

$$V_1\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{V_2}{R_1} = \frac{V_o}{R_2}$$

$$V_1\left(\frac{R_1 + R_2}{R_1 R_2}\right) - \frac{V_2}{R_1} = \frac{V_o}{R_2}$$

$$V_o = V_1\left(\frac{R_1 + R_2}{R_1}\right) - \frac{R_2 V_2}{R_1}$$

Therefore, the output voltage for the network is $\boxed{V_o = V_1\left(1 + \frac{R_2}{R_1}\right) - \frac{R_2}{R_1}V_2}$.

Step 1 of 2

4.30P

Consider the network in textbook Figure P 4.30. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

The voltage at node V_+ is,

$$V_+ = (V_1)\left(\frac{80\text{ k}}{80\text{ k}+20\text{ k}}\right)$$
$$= \frac{4}{5}V_1$$

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = \frac{4}{5}V_1$ and $i_1 = i_2 = 0\text{ A}$.

Now write Kirchhoff's current law equation at node V_-.

$$\frac{V_- - V_o}{24} + \frac{V_-}{1} + i_2 = 0$$
$$\frac{\frac{4}{5}V_1 - V_o}{24} + \frac{\frac{4}{5}V_1}{1} = 0$$
$$\frac{4V_1 - 5V_o}{120} + \frac{4V_1}{5} = 0$$
$$V_1\left(\frac{4}{120} + \frac{4}{5}\right) = \frac{5}{120}V_o$$
$$V_1(100) = 5V_o$$
$$\frac{V_o}{V_1} = 20$$

Therefore, the voltage gain of the op-amp circuit is $\boxed{\frac{V_o}{V_1} = 20}$.

Step 1 of 2

4.31P

Consider the network in textbook Figure P 4.31. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

The voltage at node V_+ is,

$$V_+ = (v_{in})\left(\frac{R_2}{R_2 + R_1}\right)$$

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = (v_{in})\left(\frac{R_2}{R_2 + R_1}\right)$ and $i_1 = i_2 = 0\ \text{A}$.

Now write Kirchhoff's current law equation at node V_-.

$$\frac{V_-}{R_I} + \frac{V_- - v_o}{R_F} + i_2 = 0$$

$$\frac{v_{in}}{R_I}\left(\frac{R_2}{R_2 + R_1}\right) + \frac{v_{in}\left(\frac{R_2}{R_2 + R_1}\right)}{R_F} = 0$$

$$\frac{v_{in}}{R_I}\left(\frac{R_2}{R_2 + R_1}\right) + \frac{v_{in}}{R_F}\left(\frac{R_2}{R_2 + R_1}\right) - \frac{v_o}{R_F} = 0$$

$$v_{in}\left[\frac{R_2}{R_I(R_2 + R_1)} + \frac{R_2}{R_F(R_2 + R_1)}\right] = \frac{v_o}{R_F}$$

$$\frac{v_o}{v_{io}} = R_F\left[\frac{R_2}{R_I(R_2 + R_1)} + \frac{R_2}{R_F(R_2 + R_1)}\right]$$

$$= \frac{R_F}{R_I}\left(\frac{R_2}{R_2 + R_1}\right) + \left(\frac{R_2}{R_2 + R_1}\right)$$

$$= \left(\frac{R_2}{R_2 + R_1}\right)\left(1 + \frac{R_F}{R_I}\right)$$

Therefore, the relationship between v_o and v_{in} is $\boxed{\frac{v_o}{v_{in}} = \left(\frac{R_2}{R_2 + R_1}\right)\left(1 + \frac{R_F}{R_I}\right)}$.

Step 1 of 3

4.32P

Refer to Figure P4.32 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the non-inverting terminal.

$$I_2 = I_l$$

$$\frac{v_2 - v_+}{R_2} = \frac{v_+ - 0}{R_l}$$

$$v_+\left(\frac{1}{R_l} + \frac{1}{R_2}\right) = \frac{v_2}{R_2}$$

$$v_+ = \frac{v_2}{\left(1 + \frac{R_2}{R_l}\right)}$$

Write the node equation at the inverting terminal.

$$I_1 = I_F$$

$$\frac{v_1 - v_-}{R_1} = \frac{v_- - v_o}{R_F}$$

$$\frac{v_o}{R_F} = v_-\left(\frac{1}{R_1} + \frac{1}{R_F}\right) - \frac{v_1}{R_1}$$

$$v_o = v_-\left(1 + \frac{R_F}{R_1}\right) - \frac{R_F}{R_1}v_1$$

Step 3 of 3

Apply ideal op-amp condition, $v_- = v_+$.

Substitute the expression for v_+ in the expression of v_o.

$$\begin{aligned} v_o &= v_-\left(1 + \frac{R_F}{R_1}\right) - \frac{R_F}{R_1}v_1 \\ &= \frac{v_2}{\left(1 + \frac{R_2}{R_l}\right)}\left(1 + \frac{R_F}{R_1}\right) - \frac{R_F}{R_1}v_1 \\ &= \frac{\left(1 + \frac{R_F}{R_1}\right)}{\left(1 + \frac{R_2}{R_l}\right)}v_2 - \frac{R_F}{R_1}v_1 \end{aligned}$$

Therefore, the expression for the output voltage is $\boxed{\frac{\left(1 + \frac{R_F}{R_1}\right)}{\left(1 + \frac{R_2}{R_l}\right)}v_2 - \frac{R_F}{R_1}v_1}$.

Step 1 of 2

4.33P

Consider the network in textbook Figure P 4.33. The given voltage gain is 10. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = V_1$ and $i_1 = i_2 = 0\ \text{A}$.

Now write Kirchhoff's current law equation at node V_- .

$$\frac{V_- - V_o}{18\ \text{k}} + \frac{V_-}{R_1} + i_2 = 0$$

$$\frac{V_1 - V_o}{18\ \text{k}} + \frac{V_1}{R_1} = 0$$

$$V_1\left(\frac{1}{18\ \text{k}} + \frac{1}{R_1}\right) = \frac{V_o}{18\ \text{k}}$$

$$\frac{V_o}{V_1} = \left(\frac{R_1 + 18\ \text{k}}{R_1}\right)$$

$$10R_1 = R_1 + 18\ \text{k}$$

$$9R_1 = 18\ \text{k}$$

$$R_1 = 2\ \text{k}\Omega$$

Therefore, the required resistance is $\boxed{R_1 = 2\ \text{k}\Omega}$.

Step 1 of 2

4.34P

Consider the network in textbook Figure P 4.34. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

Assume that the op-amp is ideal. Therefore we have $V_+ = V_-$ and $i_1 = i_2 = 0\ \text{A}$.

The voltage at node V_+ is,

$$V_+ = (4)\frac{20\ \text{k}}{25\ \text{k}}$$
$$= \frac{16}{5}\ \text{V}$$

As $V_+ = V_-$, we have $V_- = \frac{16}{5}\ \text{V}$

Now apply Kirchhoff's current law equation at node V_- .

$$\frac{V_- - 5}{5} + \frac{V_- - V_o}{40} + i_1 = 0$$
$$\frac{\frac{16}{5} - 5}{5} + \frac{\frac{16}{5} - V_o}{40} = 0$$
$$\frac{16 - 25}{25} + \frac{16 - 5V_o}{200} = 0$$
$$16 - 72 - 5V_o = 0$$

$$5V_o = -56$$

$$V_o = \frac{-56}{5}$$
$$= -11.2\ \text{V}$$

Therefore the output voltage is $\boxed{V_0 = -11.2\ \text{V}}$.

Step 1 of 2

Refer to Figure P 4.35 in the textbook.

Redraw the diagram with modifications.

Figure 1

Step 2 of 2

Assume that the op-amp is ideal. Therefore we have $V_+ = V_- = 6\text{ V}$ and $i_1 = i_2 = 0\text{ A}$.

Apply Kirchhoff's current law equation at node V_- .

$$\frac{V_- - 9}{10} + \frac{V_- - 10}{20} + \frac{V_- + 12}{30} + \frac{V_-}{40} + \frac{V_- - V_o}{100} + i_1 = 0$$

$$\frac{6-9}{10} + \frac{6-10}{20} + \frac{6+12}{30} + \frac{6}{40} + \frac{6-V_o}{100} = 0$$

$$\frac{-3}{10} + \frac{-4}{20} + \frac{18}{30} + \frac{6}{40} + \frac{6}{100} = \frac{V_o}{100}$$

$$\frac{V_o}{100} = \frac{-180-120+360+90+36}{600}$$

$$V_o = \frac{186}{6}$$
$$= 31$$

Therefore, the output voltage is $\boxed{V_o = 31\text{ V}}$.

Step 1 of 2

4.36P

Refer to Figure P4.36 in the textbook.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 2

Write the node equation at the inverting terminal.

$$I = I_1 + I_2 + I_3$$

$$\frac{v_- - v_o}{R_F} = \frac{v_1 - v_-}{R_1} + \frac{v_2 - v_-}{R_2} + \frac{v_3 - v_-}{R_3}$$

Apply ideal op-amp condition, $v_- = v_+$.

Since non-inverting terminal is grounded, use the fact that $v_- = 0$.

Substitute 0 for v_- in the expression.

$$\frac{0 - v_o}{R_F} = \frac{v_1 - 0}{R_1} + \frac{v_2 - 0}{R_2} + \frac{v_3 - 0}{R_3}$$

$$v_o = -R_F\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3}\right)$$

Therefore, the expression for the output voltage of the op-amp is $\boxed{v_o = -R_F\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3}\right)}$.

Step 1 of 2

4.37P

Consider the network in textbook Figure P 4.29. Redraw the diagram with modifications as shown in Figure 1.

Figure 1

Step 2 of 2

Assume that the op-amp in Figure 1 is ideal. Therefore we have $V_+ = V_-$ and $V_+ = V_- = 4\text{ V}$.

Now write Kirchhoff's current law at node V_-.

$$\frac{V_- - V_o}{4} + \frac{V_- - 5}{1} + i_1 = 0$$

$$\frac{4 - V_o}{4} + \frac{4-5}{1} = 0$$

$$1 - \frac{V_o}{4} - 1 = 0$$

$$V_o = 0\text{ V}$$

Therefore, the output voltage is $\boxed{V_o = 0\text{ V}}$.

Step 1 of 3

4.38P

Refer to Figure P4.38 in the textbook.

Redraw the circuit with node voltages and currents represented on the circuit.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the first op-amp (O_1).

$$i_{in} = \frac{v1_ - v_x}{R_F}$$

Apply ideal op-amp conditions, $v_ = v_+$ **and** $i_ = i_+$.

Consider the following since the non-inverting terminal is grounded:

$$\begin{aligned} v1_ &= v1_+ \\ &= 0 \end{aligned}$$

Substitute 0 for $v1_$ in the expression of i_{in}.

$$\begin{aligned} i_{in} &= \frac{v1_ - v_x}{R_F} \\ &= \frac{0 - v_x}{R_F} \end{aligned}$$

Simplify the expression.

$$v_x = -i_{in} R_F$$

Hence, the expression for node voltage v_x is $v_x = -i_{in} R_F$.

Step 3 of 3

Write the expression for the current i_o for the second op-amp (O_2).

$$i_o = \frac{v2_}{R_I}$$

Simplify the equation.

$$v2_ = i_o R_I$$

Apply ideal op-amp conditions, $v_ = v_+$ **and** $i_ = i_+$. Therefore,

$$v_x = v2_$$

Substitute the expression for the voltages, v_x and $v2_$.

$$\begin{aligned} v_x &= v2_ \\ -i_{in} R_F &= i_o R_I \\ \frac{i_o}{i_{in}} &= -\frac{R_F}{R_I} \end{aligned}$$

Hence, the current gain of the amplifier is $\frac{i_o}{i_{in}} = -\frac{R_F}{R_I}$.

Therefore, the input/output relationship for the current amplifier is $\boxed{\frac{i_o}{i_{in}} = -\frac{R_F}{R_I}}$.

Step 1 of 3

4.39P

Refer to circuit diagram in Figure P4.39 in the text book.

The circuit with current notations is shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal.

$$I_1 = I_2 + I_3$$

$$\frac{5 - v_-}{10\ \text{k}\Omega} = \frac{v_- - v_x}{40\ \text{k}\Omega} + \frac{v_- - v_y}{80\ \text{k}\Omega}$$

Apply ideal op-amp conditions,

$$v_- = v_+$$

And,

$$i_- = i_+$$

Since non-inverting terminal is grounded, by using the fact that $v_- = 0 \text{ and } i_- = 0$.

Substitute the values 0 for v_- and 0 for i_- in the expression.

$$\frac{5 - v_-}{10} = \frac{v_- - v_x}{40} + \frac{v_- - v_y}{80}$$

$$\frac{5 - 0}{10} = \frac{0 - v_x}{40} + \frac{0 - v_y}{80}$$

$$5 = -\frac{v_x}{4} - \frac{v_y}{8} \quad \text{..... (1)}$$

Step 3 of 3

Write the expression for the current I_3 .

$$I_3 = \frac{v_y - V_o}{20\ \text{k}\Omega}$$

$$\frac{0 - v_y}{80\ \text{k}\Omega} = \frac{v_y - V_o}{20\ \text{k}\Omega}$$

$$v_y\left(\frac{1}{80} + \frac{1}{20}\right) = \frac{V_o}{20}$$

$$v_y = 0.8V_o$$

Recall equation (1).

$$5 = -\frac{v_x}{4} - \frac{v_y}{8}$$

Since V_o for v_x , and $0.8V_o$ for v_y in the equation.

$$5 = -\frac{V_o}{4} - \frac{0.8V_o}{8}$$

$$V_o\left(\frac{1}{4} + \frac{1}{10}\right) = -5$$

$$V_o = -14.3\ \text{V}$$

Therefore, the voltage V_o is $\boxed{-14.3\ \text{V}}$.

Step 1 of 3

4.40P

Refer to Figure P4.40 in the text book.

The circuit is redrawn as shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the first op-amp.

$$i_2 = i_1$$

$$\frac{v_- - 0}{R_2} = \frac{v_3 - v_-}{R_1}$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = v_1$ and $i_- = 0$.

Substitute v_1 for v_- in the expression.

$$\frac{v_- - 0}{R_2} = \frac{v_3 - v_-}{R_1}$$

$$\frac{v_1}{R_2} = \frac{v_3 - v_1}{R_1}$$

$$\frac{v_3}{R_1} = \left(\frac{1}{R_2} + \frac{1}{R_1}\right)v_1$$

$$v_3 = \left(1 + \frac{R_1}{R_2}\right)v_1$$

Step 3 of 3

Write the node equation at the inverting terminal of the second op-amp.

$$i_3 - i_4 = i_-$$

$$\frac{v_3 - v_-}{R_1} + \frac{v_o - v_-}{R_2} = i_-$$

Apply ideal op-amp conditions, $v_- = v_+$ and $i_- = i_+$.

By using the fact that $v_- = v_2$ and $i_- = 0$.

Substitute v_2 for v_- in the expression.

$$\frac{v_3 - v_-}{R_1} + \frac{v_o - v_-}{R_2} = i_-$$

$$\frac{v_3 - v_2}{R_1} + \frac{v_o - v_2}{R_2} = 0$$

$$\frac{v_o}{R_2} = \frac{v_2}{R_1} + \frac{v_2}{R_2} - \frac{v_3}{R_1}$$

$$v_o = \left(\frac{R_2}{R_1}v_2 + v_2 - \frac{R_2}{R_1}v_3\right)$$

Substitute $\left(1 + \frac{R_1}{R_2}\right)v_1$ for v_3 in the expression.

$$\begin{aligned} v_o &= \left(\frac{R_2}{R_1}v_2 + v_2 - \frac{R_2}{R_1}v_3\right) \\ &= \left(\frac{R_2}{R_1}v_2 + v_2 - \frac{R_2}{R_1}\left(1 + \frac{R_1}{R_2}\right)v_1\right) \\ &= \left(1 + \frac{R_2}{R_1}\right)v_2 - \left(1 + \frac{R_2}{R_1}\right)v_1 \\ &= \left(1 + \frac{R_2}{R_1}\right)(v_2 - v_1) \end{aligned}$$

Therefore, the output voltage is $\boxed{\left(1 + \frac{R_2}{R_1}\right)(v_2 - v_1)}$.

Step 1 of 3

4.41P

Refer to circuit diagram in Figure P4.41 in the text book.

The circuit with current notation is shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the down op-amp.

$$I_1 = I_2$$

$$\frac{v_2 - v_-}{R_1} = \frac{v_- - v_x}{R_1}$$

$$v_2 - v_- = v_- - v_x$$

Apply ideal op-amp conditions,

$$v_- = v_+$$

And,

$$i_- = i_+$$

Since non-inverting terminal is grounded, $v_- = 0$.

Substitute the values 0 for v_- in the expression.

$$v_2 - v_- = v_- - v_x$$

$$v_2 - 0 = 0 - v_x$$

$$v_x = -v_2 \text{ ..... (1)}$$

Step 3 of 3

Write the node equation at the inverting terminal of the top op-amp.

$$I_3 = I_4 + I_5$$

$$\frac{v_1 - v_-}{R_1} = \frac{v_- - v_o}{R_F} + \frac{v_- - v_x}{R_1}$$

Substitute the values 0 for v_- in the expression.

$$\frac{v_1 - v_-}{R_1} = \frac{v_- - v_o}{R_F} + \frac{v_- - v_x}{R_1}$$

$$\frac{v_1 - 0}{R_1} = \frac{0 - v_o}{R_F} + \frac{0 - v_x}{R_1}$$

$$\frac{v_1}{R_1} = \frac{-v_o}{R_F} + \frac{-v_x}{R_1}$$

Substitute the values $-v_2$ for v_x in the expression.

$$\frac{v_1}{R_1} = \frac{-v_o}{R_F} + \frac{-v_x}{R_1}$$

$$\frac{v_1}{R_1} = \frac{-v_o}{R_F} + \frac{v_2}{R_1}$$

$$\frac{v_o}{R_F} = \frac{v_2}{R_1} - \frac{v_1}{R_1}$$

$$v_o = \frac{R_F}{R_1}(v_2 - v_1)$$

Therefore, the expression for the output voltage is $\boxed{\frac{R_F}{R_1}(v_2 - v_1)}$.

Step 1 of 3

Refer to circuit diagram in Figure P4.42 in the text book.

The circuit with current notations is shown in Figure 1.

Figure 1

Step 2 of 3

Write the node equation at the inverting terminal of the op-amp.

$$I_1 = I_2$$

$$\frac{v_1 - v_-}{R_1} = \frac{v_- - v_x}{R_2}$$

Apply ideal op-amp conditions,

$$v_- = v_+$$

And,

$$i_- = i_+$$

Since non-inverting terminal is grounded, $v_- = 0$.

Substitute the value 0 for v_- in the expression.

$$\frac{v_1 - v_-}{R_1} = \frac{v_- - v_x}{R_2}$$

$$\frac{v_1 - 0}{R_1} = \frac{0 - v_x}{R_2}$$

$$v_x = \frac{-R_2}{R_1} v_1$$

Step 3 of 3

Write the node equation at the node V_x .

$$I_2 = I_3 + I_4$$

$$\frac{v_- - v_x}{R_2} = \frac{v_x}{R_4} + \frac{v_x - v_o}{R_3}$$

Substitute the values 0 for v_- and $\frac{-R_2}{R_1} v_1$ for v_x in the expression.

$$\frac{v_- - v_x}{R_2} = \frac{v_x}{R_4} + \frac{v_x - v_o}{R_3}$$

$$\frac{0 - \left(-\frac{R_2}{R_1}\right) v_1}{R_2} = \frac{\left(-\frac{R_2}{R_1}\right) v_1}{R_4} + \frac{\left(-\frac{R_2}{R_1}\right) v_1 - v_o}{R_3}$$

$$\frac{v_o}{R_3} = -v_1 \left(\frac{1}{R_1} + \frac{R_2}{R_1} \frac{1}{R_4} + \frac{R_2}{R_1} \frac{1}{R_3} \right)$$

$$v_o = -v_1 \left(\frac{R_3}{R_1} + \frac{R_2}{R_1} \frac{R_3}{R_4} + \frac{R_2}{R_1} \right)$$

Therefore, the expression for the output voltage is $\boxed{-v_1 \left(\frac{R_3}{R_1} + \frac{R_2}{R_1} \frac{R_3}{R_4} + \frac{R_2}{R_1} \right)}$.

Step 1 of 4

4.43P

Refer to Figure P4.43 in the text book.

The circuit is labeled as shown in Figure 1.

Figure 1

Step 2 of 4

The op-amp on the right side of the circuit is connected in the differential amplifier configuration. Write the expression for the voltage gain for this portion of the network.

$$v_o = (v_y - v_x)\left(\frac{R_4}{R_3}\right) \quad \text{..... (1)}$$

Apply Kirchhoff current law (KCL) at node A.

$$\frac{v_1 - v_2}{R_1} = \frac{v_x - v_1}{R_2}$$

$$\frac{v_x}{R_2} = \frac{v_1}{R_1} - \frac{v_2}{R_1} + \frac{v_1}{R_2}$$

$$v_x = \frac{R_2}{R_1}(v_1 - v_2) + v_1$$

$$= v_1\left(1 + \frac{R_2}{R_1}\right) - v_2\frac{R_2}{R_1}$$

Hence, the voltage v_x is $v_x = v_1\left(1 + \frac{R_2}{R_1}\right) - v_2\frac{R_2}{R_1}$ ..... (2)

Step 3 of 4

Apply Kirchhoff current law (KCL) at node B.

$$\frac{v_1 - v_2}{R_1} = \frac{v_2 - v_y}{R_2}$$

$$\frac{v_y}{R_2} = -\frac{v_1}{R_1} + \frac{v_2}{R_1} + \frac{v_2}{R_2}$$

$$v_y = -\frac{R_2}{R_1}(v_1 - v_2) + v_2$$

$$= v_1\left(-\frac{R_2}{R_1}\right) + v_2\left(1 + \frac{R_2}{R_1}\right)$$

Hence, the voltage v_x is $v_y = v_1\left(-\frac{R_2}{R_1}\right) + v_2\left(1 + \frac{R_2}{R_1}\right)$ ..... (3)

Step 4 of 4

Substitute equation (2) and equation (3) in equation (1).

$$v_o = (v_y - v_x)\frac{R_4}{R_3}$$

$$= \left(-v_1\frac{R_2}{R_1} + v_2 + v_2\frac{R_2}{R_1} - v_1 - v_1\frac{R_2}{R_1} + v_2\frac{R_2}{R_1}\right)\frac{R_4}{R_3}$$

$$= (v_2 - v_1)\frac{R_4}{R_3} + (-v_1 + v_2)\frac{2R_2}{R_1}\frac{R_4}{R_3}$$

$$= (v_2 - v_1)\left(\frac{R_4}{R_3}\right)\left(1 + \frac{2R_2}{R_1}\right)$$

Therefore, the output voltage is $\boxed{(v_2 - v_1)\left(\frac{R_4}{R_3}\right)\left(1 + \frac{2R_2}{R_1}\right)}$.

Step 1 of 5

5.2P

The following is the given circuit diagram:

Figure 1

Step 2 of 5

Assume, $I_o = 1\text{ mA}$

The voltage across $4\text{k}\Omega$ is,

$$V_2 = (4\text{k})(1\text{m})$$
$$= 4\text{ V}$$

The current I_3 is given by,

$$I_3 = \frac{V_2}{(4\text{k}+8\text{k})}$$
$$= \frac{4}{12\text{k}}$$
$$= \frac{1}{3}\text{ mA}$$

Step 3 of 5

Apply Kirchhoff's current law node V_2.

$$I_2 = I_0 + I_3$$
$$= 1\text{m} + \frac{1}{3}\text{m}$$
$$= \frac{4}{3}\text{ mA}$$

The voltage across $3\text{k}\Omega$ resistor is,

$$V_{3\text{k}\Omega} = \left(\frac{4}{3}\text{m}\right)(3\text{k}) + V_2$$
$$= 4 + 4$$
$$= 8\text{ V}$$

Step 4 of 5

The current I_1 is given by,

$$I_1 = \frac{8}{3\text{k}}$$
$$= \frac{8}{3}\text{ mA}$$

Apply Kirchhoff's current law at left top node.

$$I = I_1 + I_2$$
$$= \frac{4}{3} + \frac{8}{3}$$
$$= 4\text{ mA}$$

Step 5 of 5

Therefore, the assumption that $I_o = 1\text{ mA}$ produced a current source of 4 mA. However, since the actual source current is 2 mA.

The actual output current is,

$$I_o = 1\text{mA}\left(\frac{2\text{mA}}{4\text{mA}}\right)$$
$$= \frac{1}{2}\text{ mA}$$
$$= 0.5\text{ mA}$$

Therefore, the output current, I_o is $\boxed{0.5\text{ mA}}$.

Step 1 of 4

5.3E

Refer to Figure E5.3 in the text book.

Contribution of the 2 mA current source to the output voltage is calculated by using Figure 1.

Figure 1

Step 2 of 4

Calculate the value of I_1.

$$\begin{aligned} I_1 &= 2\left(10^{-3}\right)\left(\frac{3000}{3000+2000+4000}\right) \\ &= 2\left(10^{-3}\right)\left(\frac{3}{9}\right) \\ &= \left(\frac{2}{3}\right)\text{ mA} \end{aligned}$$

Calculate the value of V_{01}.

$$\begin{aligned} V_{01} &= 2000\left(-I_1\right) \\ &= 2000\left(-\frac{2}{3}\left(10^{-3}\right)\right) \\ &= -\frac{4}{3}\text{ V} \end{aligned}$$

Step 3 of 4

Contribution of the 12 V voltage source to the output voltage is calculated by using Figure 2.

Figure 2

Calculate the value of I_2.

$$\begin{aligned} I_2 &= \frac{12}{3000+4000+2000} \\ &= \frac{12}{9000} \\ &= \frac{4}{3}\text{ mA} \end{aligned}$$

Calculate the value of V_{02}.

$$\begin{aligned} V_{02} &= 2000\left(I_2\right) \\ &= 2000\left(\frac{4}{3}\left(10^{-3}\right)\right) \\ &= \frac{8}{3}\text{ V} \end{aligned}$$

Step 4 of 4

Calculate the total output voltage from V_{01} and V_{02}.

$$\begin{aligned} V_0 &= V_{01} + V_{02} \\ &= -\frac{4}{3} + \frac{8}{3} \\ &= \frac{4}{3}\text{ V} \end{aligned}$$

Therefore, the total output voltage V_0 is $\boxed{\frac{4}{3}\text{ V}}$.

Step 1 of 8

Refer to Figure PFE-3 in the text book.

The Thevenin voltage can be calculated by break the left to 12Ω resistor from the circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff current law (KCL) at the top node.

$$I = I_x + 2I_x$$
$$= 3I_x$$

Apply Kirchhoff voltage law (KVL) around the first loop.

$$-12 + 3I_x + 12I = 0$$
$$3I_x + 12I = 12$$

Substitute $3I_x$ for I in the expression.

$$3I_x + 12I = 12$$
$$3I_x + 12(3I_x) = 12$$
$$I_x = \frac{12}{39}$$
$$= 0.307\text{ A}$$

Step 3 of 8

Write the expression for the Thevenin voltage V_{oc}.

$$V_{oc} = 12I$$
$$= 12(3I_x)$$
$$= 36I_x$$

Substitute 0.307 A for I_x in the expression.

$$V_{oc} = 36I_x$$
$$= 36(0.307\text{ A})$$
$$= 11.08\text{ V}$$

Step 4 of 8

The circuit for calculating shorted-circuit current is shown in Figure 2.

Figure 2

Step 5 of 8

Apply Kirchhoff current law (KCL) at the top node.

$$I_{sh} = I_x + I_1 + 2I_x$$
$$= 3I_x + I_1$$

Since 12Ω parallel resistor is shorted, $I_1 = 0$.

$$I_{sh} = 3I_x + I_1$$
$$= 3I_x$$

Calculate the current I_x.

$$I_x = \frac{12\text{ V}}{3\Omega}$$
$$= 4\text{ A}$$

Calculate the current I_{sh}.

$$I_{sh} = 3I_x$$
$$= 3(4\text{ A})$$
$$= 12\text{ A}$$

Step 6 of 8

Write the expression for the Thevenin resistance.

$$R_{Th} = \frac{V_{oc}}{I_{sh}}$$

Calculate the Thevenin resistance by substituting 11.08 V for V_{oc} and 12 mA for I_{sh}.

$$R_{Th} = \frac{V_{oc}}{I_{sh}}$$
$$= \frac{11.08\text{ V}}{12\text{ mA}}$$
$$= 0.92\,\Omega$$

Step 7 of 8

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 8 of 8

For a maximum power transfer to the load, the load resistance is as follows:

$$R_L = R_{Th} + 12\Omega$$

Calculate the load resistance by substituting $0.92\,\Omega$ for R_{Th}.

$$R_L = R_{Th} + 12\Omega$$
$$= 0.92 + 12$$
$$= 12.92\,\Omega$$

Therefore, the for maximum power transferred to the load resistance is $12.92\,\Omega$.

Therefore, the correct option is $\boxed{a}$.

Step 1 of 5

5.3P

Refer to Figure P5.3 in the text book.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Let assume that $I_0 = 1\text{ mA}$.

Calculate the voltage across the resistor $4\text{ k}\Omega$.

$$\begin{aligned} V_3 &= 4(10^3)I_0 \\ &= 4(10^3)1(10^{-3}) \\ &= 4\text{ V} \end{aligned}$$

Apply Kirchhoff's voltage law at loop 4.

$$(2+2)(10^3)I_4 = 4$$

$$\begin{aligned} I_4 &= \frac{4}{4000} \\ &= 1\text{ mA} \end{aligned}$$

Step 3 of 5

Apply Kirchhoff's voltage law at loop 3.

$$2(10^3)I_3 = 4(10^3)I_0$$

$$\begin{aligned} I_3 &= \frac{4}{2}1(10^{-3}) \\ &= 2\text{ mA} \end{aligned}$$

Apply Kirchhoff's current law at node 2.

$$\begin{aligned} I_1 &= I_3 + I_0 + I_4 \\ &= (2+1+1)(10^{-3}) \\ &= 4\text{ mA} \end{aligned}$$

Step 4 of 5

Apply Kirchhoff's voltage law to loop 2.

$$2(10^3)I_2 = 2(10^3)I_1 + 2(10^3)I_3$$

$$\begin{aligned} I_2 &= \frac{2(10^3)(2+4)(10^{-3})}{2000} \\ &= 6\text{ mA} \end{aligned}$$

Apply Kirchhoff's current law at node 1.

$$\begin{aligned} I_S &= I_1 + I_2 \\ &= 4+6 \\ &= 10\text{ mA} \end{aligned}$$

Step 5 of 5

But the actual value of I_S is 12 mA.

Apply linearity between I_S and I_0 to find actual value of current I_0.

$$\frac{10}{1} = \frac{12}{x}$$

$$\begin{aligned} x &= \frac{12}{10} \\ &= 1.2\text{ mA} \end{aligned}$$

Therefore, the actual value of I_0 is $\boxed{1.2\text{ mA}}$.

Step 1 of 3

5.4FE

Refer to Figure 5PFE-4 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 3

Since the resistors 4Ω and 2Ω are shorted, apply current division rule and calculate the current through the 3Ω resistor I'.

$$I' = \frac{2}{2+3}(-10\text{A})$$
$$= -4\text{A}$$

Acting only voltage source, the current source is open-circuit as shown in Figure 2.

Figure 2

Step 3 of 3

Since the parallel branch voltage is 20 V, calculate the current through the series 3Ω and 2Ω resistors.

$$I'' = \frac{20\text{ V}}{3+2}$$
$$= 4\text{A}$$

Write the expression for the current I through the 3Ω resistor.

$$I = I' + I''$$

Calculate the current I through the 3Ω resistor by substituting -4 A for I' and 4 A for I''.

$$I = I' + I''$$
$$= -4 + 4$$
$$= 0$$

Therefore, the current I through the 3Ω resistor is 0.

Therefore, the correct option is $\boxed{c}$.

Step 1 of 4

5.4P

Refer to Figure P5.5 in the text book.

The circuit is labeled as shown in Figure 1.

Figure 1

Step 2 of 4

Since the voltage V_o is $1\,\text{V}$ and the same current I_3 flows through the another $3\,\text{k}\Omega$ resistor in series, the voltage across the both resistors is $2\,\text{V}(1\,\text{V}+1\,\text{V})$.

Since the resistors $3\,\text{k}\Omega, 6\,\text{k}\Omega$ and $(3\,\text{k}\Omega+3\,\text{k}\Omega)$ are in parallel, the voltage across the resistors is same and equal to $2\,\text{V}$.

Hence, the voltage V_4 is $2\,\text{V}$.

Write the expression for the current I_2.

$$\begin{aligned} I_2 &= I_3 + I_4 + I_5 \\ &= \frac{2\,\text{V}}{3\,\text{k}\Omega+3\,\text{k}\Omega} + \frac{2\,\text{V}}{6\,\text{k}\Omega} + \frac{2\,\text{V}}{3\,\text{k}\Omega} \\ &= 0.333\,\text{mA} + 0.333\,\text{mA} + 0.666\,\text{mA} \\ &= 1.33\,\text{mA} \end{aligned}$$

Step 3 of 4

Write the expression for the voltage V_2.

$$\begin{aligned} V_2 &= I_2(3\,\text{k}\Omega) + V_4 \\ &= (1.33\,\text{mA})(3\,\text{k}\Omega) + 2\,\text{V} \\ &= 6\,\text{V} \end{aligned}$$

Write the expression for the current I_1.

$$\begin{aligned} I_1 &= I_2 + \frac{V_2}{3} \\ &= 1.33\,\text{mA} + \frac{6\,\text{V}}{3\,\text{k}\Omega} \\ &= 1.33\,\text{mA} + 2\,\text{mA} \\ &= 3.33\,\text{mA} \end{aligned}$$

Step 4 of 4

Write the expression for the source voltage V_S.

$$\begin{aligned} V_S &= I_1(3\,\text{k}\Omega) + V_2 \\ &= (3.33\,\text{mA})(3\,\text{k}\Omega) + 6\,\text{V} \\ &= 16\,\text{V} \end{aligned}$$

For a voltage V_o of $1\,\text{V}$, the source voltage should be $16\,\text{V}$. Calculate the voltage V_o, if the source voltage is $8\,\text{V}$.

$$\begin{aligned} V_o &= \frac{8\,\text{V}}{16\,\text{V}}(1\,\text{V}) \\ &= 0.5\,\text{V} \end{aligned}$$

Therefore, the voltage V_o is $\boxed{0.5\,\text{V}}$.

Step 1 of 8

Refer to Figure E5.5 in the text book.

Let 2 mA current source be active and deactivate 6 mA current source and 12 V voltage source.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 8

Calculate the equivalent impedance Z_1 of the parallel branches.

$$\begin{aligned} Z_1 &= \frac{(4\text{ k})(2\text{ k})}{4\text{ k}+2\text{ k}} \\ &= \frac{(4\text{ k})(2\text{ k})}{6\text{ k}} \\ &= \frac{4}{3}\text{ k}\Omega \end{aligned}$$

Therefore, the value of the impedance Z_1 is $\frac{4}{3}\text{ k}\Omega$.

Step 3 of 8

The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 8

Calculate the value of the current I_o'.

$$\begin{aligned} I_o' &= (2\text{ m})\left(\frac{4\text{ k}}{4\text{ k}+2\text{ k}}\right) \\ &= (2\text{ m})\left(\frac{4\text{ k}}{6\text{ k}}\right) \\ &= (2\text{ m})\left(\frac{2}{3}\right) \\ &= \frac{4}{3}\text{ mA} \end{aligned}$$

Therefore, the value of the current I_o' is $\frac{4}{3}\text{ mA}$.

Step 5 of 8

Let 6 mA current source be active and deactivate 2 mA current source and 12 V voltage source.

The modified circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 8

In Figure 3, no current flows through $2\text{ k}\Omega$ resistor since the series connection of $2\text{ k}\Omega$ and $4\text{ k}\Omega$ resistors are shorted.

Hence, the value of the current I_o'' is 0 A.

Let 12 V voltage source be active and deactivate 2 mA current source and 6 mA current source.

The modified circuit diagram is shown in Figure 4.

Figure 4

Step 7 of 8

Calculate the value of the current I_o'''.

$$\begin{aligned} I_o''' &= \frac{-12}{2\text{ k}+4\text{ k}} \\ &= \frac{-12}{6\text{ k}} \\ &= -2\text{ mA} \end{aligned}$$

Therefore, the value of the current I_o''' is -2 mA.

Step 8 of 8

Consider the expression for the current I_o.

$$I_o = I_o' + I_o'' + I_o'''$$

Substitute -2 mA for I_o''', 0 A for I_o'' and $\frac{4}{3}\text{ mA}$ for I_o'.

$$\begin{aligned} I_o &= \frac{4}{3}\text{ mA} + 0\text{ mA} - 2\text{ mA} \\ &= \frac{4-6}{3}\text{ m} \\ &= \frac{-2}{3}\text{ mA} \end{aligned}$$

Therefore, the value of the current, I_o is $\boxed{\frac{-2}{3}\text{ mA}}$.

Step 1 of 2

Consider Figure 5PFE-5 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 2

Apply nodal analysis at node-1.

$$\frac{V_1}{2}+\frac{V_1+12}{4}-12=0$$

$$\frac{2V_1}{4}+\frac{V_1+12}{4}-\frac{48}{4}=0$$

$$2V_1+V_1+12-48=0$$

$$3V_1-36=0$$

$$3V_1=36$$

$$V_1=\frac{36}{3}$$

$$V_1=12\text{ V}$$

Therefore, the value of the voltage V_1 is 12 V .

The value of the open circuit voltage is equal to the voltage V_1 . Therefore, the value of the open circuit voltage is $\boxed{12\text{ V}}$.

Hence, the correct option is $\boxed{\textbf{(b)}}$.

Step 1 of 3

5.5P

Refer to Figure P5.4 in the text book.

The circuit is labeled as shown in Figure 1.

Figure 1

Step 2 of 3

Since the $4\,\text{k}\Omega$ and $2\,\text{k}\Omega$ resistors are in series, the same current I_o $(1\,\text{mA})$ flows through the both resistors. Hence the voltage V_2 across the parallel $4\,\text{k}\Omega$ resistor is $6\,\text{V}$.

Calculate the current I_2 through the $4\,\text{k}\Omega$ parallel resistor.

$$\begin{aligned} I_2 &= \frac{6\,\text{V}}{4\,\text{k}\Omega} \\ &= 1.5\,\text{mA} \end{aligned}$$

Write the expression for the current I_1 .

$$\begin{aligned} I_1 &= I_2 + I_o \\ &= 1.5\,\text{mA} + 1\,\text{mA} \\ &= 2.5\,\text{mA} \end{aligned}$$

Calculate the equivalent resistance to the right side of the current source.

$$\begin{aligned} R &= 4\,\text{k}\Omega + (4\,\text{k}\Omega) \| (4\,\text{k}\Omega + 2\,\text{k}\Omega) \\ &= 4\,\text{k}\Omega + \frac{(4\,\text{k}\Omega)(6\,\text{k}\Omega)}{4\,\text{k}\Omega + 6\,\text{k}\Omega} \\ &= 4\,\text{k}\Omega + 2.4\,\text{k}\Omega \\ &= 6.4\,\text{k}\Omega \end{aligned}$$

The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

Since the current flow through the $6.4\,\text{k}\Omega$ resistor is $2.5\,\text{mA}$, calculate the current flow through the parallel $16\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_3 &= \frac{6.4\,\text{k}\Omega}{16\,\text{k}\Omega}(2.5\,\text{mA}) \\ &= 1\,\text{mA} \end{aligned}$$

Write the expression for the source current.

$$\begin{aligned} I_S &= I_3 + I_1 \\ &= 1\,\text{mA} + 2.5\,\text{mA} \\ &= 3.5\,\text{mA} \end{aligned}$$

For a current I_o of $1\,\text{mA}$, the source current should be $3.5\,\text{mA}$. Calculate the current I_o , if the source current is $4\,\text{mA}$.

$$\begin{aligned} I_o &= \frac{4\,\text{mA}}{3.5\,\text{mA}}(1\,\text{mA}) \\ &= 1.14\,\text{mA} \end{aligned}$$

Therefore, the current I_o is $\boxed{1.14\,\text{mA}}$.

Step 1 of 6

5.6E

Refer to Figure E5.6 in the text book.

Disconnect the $4\ \text{k}\Omega$ resistor from the circuit. Identify voltages in the circuit

Figure 1

Step 2 of 6

In Figure 1, observe that no current flows through the $2\ \text{k}\Omega$ resistor.

Apply Kirchhoff's current at node *V*.

$$\frac{V-6}{6\ \text{k}}+\frac{V+12}{3\ \text{k}}=0$$

$$V\left(\frac{1}{6\ \text{k}}+\frac{1}{3\ \text{k}}\right)=\frac{6}{6\ \text{k}}-\frac{12}{3\ \text{k}}$$

$$V\left(\frac{3}{6\ \text{k}}\right)=\frac{6-24}{6\ \text{k}}$$

$$V(3)=-18$$

$$V=\frac{-18}{3}$$

$$V=-6\ \text{V}$$

Therefore, the value of the voltage V is $-6\ \text{V}$.

The value of the open circuit voltage V_{oc} is equal to the value of the voltage V . Therefore, the value of the voltage V_{oc} is $-6\ \text{V}$.

Step 3 of 6

Disconnect the sources from the circuit diagram.

Figure 2

Step 4 of 6

Calculate the value of the Thevenin's resistance.

$$\begin{aligned}R_{\text{Th}}&=2\ \text{k}+(3\ \text{k}\|6\ \text{k})\\&=2\ \text{k}+\frac{(3\ \text{k})(6\ \text{k})}{3\ \text{k}+6\ \text{k}}\\&=2\ \text{k}+2\ \text{k}\\&=4\ \text{k}\Omega\end{aligned}$$

Therefore, the value of the Thevenin's resistance R_{Th} is $4\ \text{k}\Omega$.

Step 5 of 6

Draw the Thevenin's equivalent circuit diagram with a load resistor $4\ \text{k}\Omega$.

Figure 3

Step 6 of 6

Apply voltage division rule to calculate the value of the output voltage V_o .

$$\begin{aligned}V_o&=(-6)\left(\frac{4\ \text{k}}{4\ \text{k}+4\ \text{k}}\right)\\&=(-6)\left(\frac{4\ \text{k}}{2(4\ \text{k})}\right)\\&=(-6)\left(\frac{1}{2}\right)\\&=-3\ \text{V}\end{aligned}$$

Therefore, the value of the output voltage V_o is $\boxed{-3\ \text{V}}$.

Step 1 of 6

5.6P

Refer to Figure P5.6 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $2\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$R_1 = \frac{(6\,\text{k}\Omega)(2\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(2\,\text{k}\Omega)}$$
$$= 1.5\,\text{k}\Omega$$

This $1.5\,\text{k}\Omega$ and $3\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$R_2 = R_1 + 3\,\text{k}\Omega$$
$$= 1.5\,\text{k}\Omega + 3\,\text{k}\Omega$$
$$= 4.5\,\text{k}\Omega$$

Apply current division rule and calculate the current I_1 through the $3\,\text{k}\Omega$ resistor.

$$I_1 = \frac{3\,\text{k}\Omega}{4.5\,\text{k}\Omega + 3\,\text{k}\Omega}(2\,\text{mA})$$
$$= 0.8\,\text{mA}$$

Step 3 of 6

Apply current division rule and calculate the current I'_o through the $2\,\text{k}\Omega$ resistor.

$$I'_o = \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 2\,\text{k}\Omega}(0.8\,\text{mA})$$
$$= 0.6\,\text{mA}$$

Hence, the current I'_o through the $2\,\text{k}\Omega$ resistor is $0.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $3\,\text{k}\Omega$ resistor and $3\,\text{k}\Omega$ resistor are in series. The equivalent resistance is $6\,\text{k}\Omega$.

$$R_1 = 3\,\text{k}\Omega + 3\,\text{k}\Omega$$
$$= 6\,\text{k}\Omega$$

This $6\,\text{k}\Omega$ resistor is in parallel with $2\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$R_2 = \frac{(6\,\text{k}\Omega)(2\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(2\,\text{k}\Omega)}$$
$$= 1.5\,\text{k}\Omega$$

This $1.5\,\text{k}\Omega$ and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$R_3 = R_2 + 6\,\text{k}\Omega$$
$$= 1.5\,\text{k}\Omega + 6\,\text{k}\Omega$$
$$= 7.5\,\text{k}\Omega$$

Apply ohms law and calculate the total current I by substituting $6\,\text{V}$ for V and $7.5\,\text{k}\Omega$ for R_3.

$$I = \frac{V}{R_3}$$
$$= \frac{6\,\text{V}}{7.5\,\text{k}\Omega}$$
$$= 0.8\,\text{mA}$$

Apply current division rule and calculate the current I''_o through the $2\,\text{k}\Omega$ resistor.

$$I''_o = \frac{3\,\text{k}\Omega + 3\,\text{k}\Omega}{2\,\text{k}\Omega + 3\,\text{k}\Omega + 3\,\text{k}\Omega}(0.8\,\text{mA})$$
$$= 0.6\,\text{mA}$$

Hence, the current I''_o through the $2\,\text{k}\Omega$ resistor is $0.6\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $2\,\text{k}\Omega$ resistor.

$$I_o = I'_o + I''_o$$

Calculate the current I_o through the $2\,\text{k}\Omega$ resistor by substituting $0.6\,\text{mA}$ for I'_o and $0.6\,\text{mA}$ for I''_o.

$$I_o = I'_o + I''_o$$
$$= 0.6\,\text{mA} + 0.6\,\text{mA}$$
$$= 1.2\,\text{mA}$$

Therefore, the current I_o through the $2\,\text{k}\Omega$ resistor is $\boxed{1.2\,\text{mA}}$.

Step 1 of 5

5.7P

Refer to Figure P5.7 in the textbook for the circuit.

The contribution of the 30V voltage source to the output current is found from the network shown in Figure 1.

Figure 1

Step 2 of 5

The current *I* in the circuit is,

$$\begin{aligned} I &= \frac{30}{6\text{k}+\left[12\text{k}\,\|\,(2\text{k}+2\text{k}+2\text{k})\right]} \\ &= \frac{30}{6\text{k}+\left[12\text{k}\,\|\,6\text{k}\right]} \\ &= \frac{30}{6\text{k}+\left[\frac{(12\text{k})(6\text{k})}{12\text{k}+6\text{k}}\right]} \\ &= \frac{30}{6\text{k}+4\text{k}} \\ &= \frac{30}{10\text{k}} \\ &= 3\text{ mA} \end{aligned}$$

Apply current division to find the current I_0' .

$$\begin{aligned} I_0' &= I\left(\frac{2\text{k}+2\text{k}+2\text{k}}{12\text{k}+2\text{k}+2\text{k}+2\text{k}}\right) \\ &= (3\text{m})\left(\frac{6\text{k}}{18\text{k}}\right) \\ &= 1\text{ mA} \end{aligned}$$

Step 3 of 5

The contribution of the 30mA current source to the output current is found from the network shown in Figure 2.

Figure 2

Step 4 of 5

The current *I* in the circuit is,

$$\begin{aligned} I &= -(30\text{m})\left[\frac{2\text{k}+2\text{k}}{\left[(6\text{k}\,\|\,12\text{k})+2\text{k}\right]+2\text{k}+2\text{k}}\right] \\ &= -(30\text{m})\left[\frac{4\text{k}}{\left[4\text{k}+2\text{k}\right]+4\text{k}}\right] \\ &= -12\text{ mA} \end{aligned}$$

Apply current division to find the current I_0' .

$$\begin{aligned} I_0'' &= I\left(\frac{6\text{k}}{6\text{k}+12\text{k}}\right) \\ &= (-12\text{m})\left(\frac{6\text{k}}{6\text{k}+12\text{k}}\right) \\ &= -4\text{ mA} \end{aligned}$$

Step 5 of 5

The total current flow due to two sources is,

$$\begin{aligned} I_0 &= I_0' + I_0'' \\ &= 1\text{m}+(-4\text{m}) \\ &= -3\text{ mA} \end{aligned}$$

Therefore, the current, I_0 is $\boxed{-3\text{ mA}}$.

Step 1 of 6

5.8P

Refer to Figure P5.7 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 3\,\text{k}\Omega \end{aligned}$$

This $3\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= R_1 + 6\,\text{k}\Omega \\ &= 3\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 9\,\text{k}\Omega \end{aligned}$$

Step 3 of 6

Apply current division rule and calculate the current I_o' through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o' &= \frac{9\,\text{k}\Omega}{9\,\text{k}\Omega + 6\,\text{k}\Omega}(-6\,\text{mA}) \\ &= -3.6\,\text{mA} \end{aligned}$$

Hence, the current I_o' through the $6\,\text{k}\Omega$ resistor is $-3.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $6\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistor are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= 6\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 12\,\text{k}\Omega \end{aligned}$$

This $12\,\text{k}\Omega$ resistor is in parallel with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= \frac{(12\,\text{k}\Omega)(6\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 4\,\text{k}\Omega \end{aligned}$$

This $4\,\text{k}\Omega$ resistor is in series with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_3 &= R_2 + 6\,\text{k}\Omega \\ &= 4\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 10\,\text{k}\Omega \end{aligned}$$

Apply ohms law and calculate the total current I by substituting $12\,\text{V}$ for V and $10\,\text{k}\Omega$ for R_3.

$$\begin{aligned} I &= \frac{V}{R_3} \\ &= \frac{12\,\text{V}}{10\,\text{k}\Omega} \\ &= 1.2\,\text{mA} \end{aligned}$$

Apply current division rule and calculate the current I_o'' through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o'' &= \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 12\,\text{k}\Omega}(1.2\,\text{mA}) \\ &= 0.4\,\text{mA} \end{aligned}$$

Hence, the current I_o'' through the $6\,\text{k}\Omega$ resistor is $0.4\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $6\,\text{k}\Omega$ resistor.

$$I_o = I_o' + I_o''$$

Calculate the current I_o through the $6\,\text{k}\Omega$ resistor by substituting $-3.6\,\text{mA}$ for I_o' and $0.4\,\text{mA}$ for I_o''.

$$\begin{aligned} I_o &= I_o' + I_o'' \\ &= -3.6\,\text{mA} + 0.4\,\text{mA} \\ &= -3.2\,\text{mA} \end{aligned}$$

Therefore, the current I_o through the $6\,\text{k}\Omega$ resistor is $\boxed{-3.2\,\text{mA}}$.

Step 1 of 10

5.9P

Refer to Figure E5.9 from the text book.

Disconnect the $6\ \text{k}\Omega$ load resistor and short the terminals.

Figure 1

Step 2 of 10

Consider the relation between the currents I_1 and I_2.

$$I_2 - I_1 = 2\ \text{mA}$$
$$I_1 = I_2 - 2\ \text{mA}$$

Step 3 of 10

Apply Super mesh analysis in Loops 1 and Loop 2.

$$I_1(2\ \text{k}+3\ \text{k}) + I_2(4\ \text{k}) + (I_1 - I_3)(3\ \text{k}) - 10 - 12 + 8 = 0$$
$$I_1(2\ \text{k}+3\ \text{k}+3\ \text{k}) + I_2(4\ \text{k}) - I_3(3\ \text{k}) - 14 = 0$$
$$I_1(8\ \text{k}) + I_2(4\ \text{k}) - I_3(3\ \text{k}) - 14 = 0$$

Substitute $I_2 - 2\ \text{mA}$ for I_1.

$$(I_2 - 2\ \text{m})(8\ \text{k}) + I_2(4\ \text{k}) - I_3(3\ \text{k}) - 14 = 0$$
$$I_2(8\ \text{k}) - (2\ \text{m})(8\ \text{k}) + I_2(4\ \text{k}) - I_3(3\ \text{k}) - 14 = 0$$
$$I_2(8\ \text{k}+4\ \text{k}) - 16 - I_3(3\ \text{k}) - 14 = 0$$
$$I_2(12\ \text{k}) - I_3(3\ \text{k}) - 30 = 0$$

$$I_2(12\ \text{k}) = 30 + I_3(3\ \text{k})$$

$$I_2 = \frac{30 + I_3(3\ \text{k})}{12\ \text{k}} \quad \text{..... (1)}$$

Step 4 of 10

Apply Kirchhoff's current law in loop-3.

$$I_3(6\ \text{k}) + (I_3 - I_1)(3\ \text{k}) - 8 = 0$$
$$I_3(9\ \text{k}) - I_1(3\ \text{k}) - 8 = 0$$

Substitute $I_2 - 2\ \text{mA}$ for I_1.

$$I_3(9\ \text{k}) - (I_2 - 2\ \text{m})(3\ \text{k}) - 8 = 0$$
$$I_3(9\ \text{k}) - I_2(3\ \text{k}) + (2\ \text{m})(3\ \text{k}) - 8 = 0$$
$$I_3(9\ \text{k}) - I_2(3\ \text{k}) + 6 - 8 = 0$$
$$I_3(9\ \text{k}) - I_2(3\ \text{k}) - 2 = 0$$

Substitute $\frac{30 + I_3(3\ \text{k})}{12\ \text{k}}$ for I_2.

$$I_3(9\ \text{k}) - \left(\frac{30 + I_3(3\ \text{k})}{12\ \text{k}}\right)(3\ \text{k}) - 2 = 0$$
$$I_3(9\ \text{k}) - \left(\frac{30 + I_3(3\ \text{k})}{4}\right) - 2 = 0$$
$$I_3(36\ \text{k}) - 30 - I_3(3\ \text{k}) - 8 = 0$$
$$I_3(36\ \text{k} - 3\ \text{k}) - 38 = 0$$

$$I_3(33\ \text{k}) = 38$$
$$I_3 = \frac{38}{33\ \text{k}}$$
$$I_3 = 1.1515\ \text{mA}$$

Step 5 of 10

Consider equation (1).

$$I_2 = \frac{30 + I_3(3\ \text{k})}{12\ \text{k}}$$

Substitute $1.1515\ \text{mA}$ for I_3.

$$I_2 = \frac{30 + (1.1515\ \text{m})(3\ \text{k})}{12\ \text{k}}$$
$$= \frac{30 + 3.4545}{12\ \text{k}}$$
$$= \frac{33.4545}{12\ \text{k}}$$
$$= 2.7879\ \text{mA}$$

Step 6 of 10

Consider the expression for the short circuit current.

$$I_{SC} = I_3 - I_2$$

Substitute $2.7879\ \text{mA}$ for I_2 and $1.1515\ \text{mA}$ for I_3.

$$I_{SC} = 1.1515\ \text{m} - 2.7879\ \text{m}$$
$$= -1.6364\ \text{mA}$$

Therefore, the value of the short circuit current is $-1.6364\ \text{mA}$.

Step 7 of 10

Deactivate the sources in the circuit.

Figure 2

Step 8 of 10

Consider the expression for the Norton's equivalent resistance.

$$R_N = 3\text{k} + \left[6\ \text{k} \| (3\ \text{k} + 4\ \text{k} + 2\ \text{k})\right]$$
$$= 3\text{k} + \left[6\ \text{k} \| 9\ \text{k}\right]$$
$$= 3\text{k} + \left[\frac{(6\ \text{k})(9\ \text{k})}{6\ \text{k} + 9\ \text{k}}\right]$$
$$= 3\text{k} + \left[\frac{(6\ \text{k})(9\ \text{k})}{15\ \text{k}}\right]$$

$$= 3\text{k} + 3.6\ \text{k}$$
$$= 6.6\ \text{k}\Omega$$

Therefore, the expression for the Norton's resistance R_N is $6.6\ \text{k}\Omega$.

Step 9 of 10

Draw the Norton's equivalent circuit diagram with a load resistor $6\ \text{k}\Omega$.

Figure 3

Step 10 of 10

Apply current division rule to calculate the value of the output current I_O.

$$I_O = (-1.6364\ \text{m})\left(\frac{6.6\ \text{k}}{6.6\ \text{k} + 6\ \text{k}}\right)$$
$$= (-1.6364\ \text{m})\left(\frac{6.6\ \text{k}}{12.6\ \text{k}}\right)$$
$$= (-1.6364\ \text{m})\left(\frac{6.6}{12.6}\right)$$
$$= -0.857\ \text{mA}$$

Therefore, the value of the output current I_O is $\boxed{-0.857\ \text{mA}}$.

Step 1 of 6

5.10P

Refer to Figure P5.7 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 3\,\text{k}\Omega \end{aligned}$$

This $3\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= R_1 + 6\,\text{k}\Omega \\ &= 3\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 9\,\text{k}\Omega \end{aligned}$$

Step 3 of 6

Apply current division rule and calculate the current I_o' through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o' &= \frac{9\,\text{k}\Omega}{9\,\text{k}\Omega + 6\,\text{k}\Omega}(-6\,\text{mA}) \\ &= -3.6\,\text{mA} \end{aligned}$$

Hence, the current I_o' through the $6\,\text{k}\Omega$ resistor is $-3.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $6\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistor are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= 6\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 12\,\text{k}\Omega \end{aligned}$$

This $12\,\text{k}\Omega$ resistor is in parallel with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= \frac{(12\,\text{k}\Omega)(6\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 4\,\text{k}\Omega \end{aligned}$$

This $4\,\text{k}\Omega$ resistor is in series with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_3 &= R_2 + 6\,\text{k}\Omega \\ &= 4\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 10\,\text{k}\Omega \end{aligned}$$

Apply ohms law and calculate the total current I by substituting $12\,\text{V}$ for V and $10\,\text{k}\Omega$ for R_3 .

$$\begin{aligned} I &= \frac{V}{R_3} \\ &= \frac{12\,\text{V}}{10\,\text{k}\Omega} \\ &= 1.2\,\text{mA} \end{aligned}$$

Apply current division rule and calculate the current I_o'' through the $6\,\text{k}\Omega$ resistor .

$$\begin{aligned} I_o'' &= \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 12\,\text{k}\Omega}(1.2\,\text{mA}) \\ &= 0.4\,\text{mA} \end{aligned}$$

Hence, the current I_o'' through the $6\,\text{k}\Omega$ resistor is $0.4\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $6\,\text{k}\Omega$ resistor.

$$I_o = I_o' + I_o''$$

Calculate the current I_o through the $6\,\text{k}\Omega$ resistor by substituting $-3.6\,\text{mA}$ for I_o' and $0.4\,\text{mA}$ for I_o'' .

$$\begin{aligned} I_o &= I_o' + I_o'' \\ &= -3.6\,\text{mA} + 0.4\,\text{mA} \\ &= -3.2\,\text{mA} \end{aligned}$$

Therefore, the current I_o through the $6\,\text{k}\Omega$ resistor is $\boxed{-3.2\,\text{mA}}$.

5.11P

Step 1 of 11

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Step 2 of 11

Loading solution. Please wait ...

Step 3 of 11

Loading solution. Please wait ...

Step 4 of 11

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Step 5 of 11

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Step 6 of 11

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Step 7 of 11

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Step 8 of 11

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Step 9 of 11

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Step 10 of 11

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Step 11 of 11

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Step 1 of 6

5.12P

Refer to Figure P5.7 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 3\,\text{k}\Omega \end{aligned}$$

This $3\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= R_1 + 6\,\text{k}\Omega \\ &= 3\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 9\,\text{k}\Omega \end{aligned}$$

Step 3 of 6

Apply current division rule and calculate the current I_o' through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o' &= \frac{9\,\text{k}\Omega}{9\,\text{k}\Omega + 6\,\text{k}\Omega}(-6\,\text{mA}) \\ &= -3.6\,\text{mA} \end{aligned}$$

Hence, the current I_o' through the $6\,\text{k}\Omega$ resistor is $-3.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $6\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistor are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= 6\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 12\,\text{k}\Omega \end{aligned}$$

This $12\,\text{k}\Omega$ resistor is in parallel with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= \frac{(12\,\text{k}\Omega)(6\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 4\,\text{k}\Omega \end{aligned}$$

This $4\,\text{k}\Omega$ resistor is in series with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_3 &= R_2 + 6\,\text{k}\Omega \\ &= 4\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 10\,\text{k}\Omega \end{aligned}$$

Apply ohms law and calculate the total current I by substituting $12\,\text{V}$ for V and $10\,\text{k}\Omega$ for R_3.

$$\begin{aligned} I &= \frac{V}{R_3} \\ &= \frac{12\,\text{V}}{10\,\text{k}\Omega} \\ &= 1.2\,\text{mA} \end{aligned}$$

Apply current division rule and calculate the current I_o'' through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o'' &= \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 12\,\text{k}\Omega}(1.2\,\text{mA}) \\ &= 0.4\,\text{mA} \end{aligned}$$

Hence, the current I_o'' through the $6\,\text{k}\Omega$ resistor is $0.4\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $6\,\text{k}\Omega$ resistor.

$$I_o = I_o' + I_o''$$

Calculate the current I_o through the $6\,\text{k}\Omega$ resistor by substituting $-3.6\,\text{mA}$ for I_o' and $0.4\,\text{mA}$ for I_o''.

$$\begin{aligned} I_o &= I_o' + I_o'' \\ &= -3.6\,\text{mA} + 0.4\,\text{mA} \\ &= -3.2\,\text{mA} \end{aligned}$$

Therefore, the current I_o through the $6\,\text{k}\Omega$ resistor is $\boxed{-3.2\,\text{mA}}$.

Step 1 of 5

5.13E

Refer to Figure E5.13 in the text book.

Apply the source voltage of $1\ \mathrm{V}$ at the open terminals.

Figure 1

Step 2 of 5

Consider the relation between the currents I_1 and I_2.

$$I_1 + I_2 = \frac{V_x}{2000}$$

Substitute $-I_2(1\ \mathrm{k})$ for V_x.

$$I_1 + I_2 = -\frac{I_2(1\ \mathrm{k})}{2000}$$

$$I_1 + I_2 = -\frac{I_2}{2}$$

$$I_1 = -\frac{I_2}{2} - I_2$$

$$I_1 = -\frac{I_2 + 2I_2}{2}$$

$$I_1 = -\frac{3I_2}{2}$$

Step 3 of 5

Apply super mesh analysis in loop 1 and loop 2.

$$-I_1(5\ \mathrm{k}) + I_2(1\ \mathrm{k}) + (I_2 + I_3)(2\ \mathrm{k}) = 0$$

$$-I_1(5\ \mathrm{k}) + I_2(1\ \mathrm{k}) + I_2(2\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$-I_1(5\ \mathrm{k}) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

Substitute $-\frac{3I_2}{2}$ for I_1.

$$-\left(-\frac{3I_2}{2}\right)(5\ \mathrm{k}) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k}}{2}\right) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k}}{2} + 3\ \mathrm{k}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k} + 6\ \mathrm{k}}{2}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{21\ \mathrm{k}}{2}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2(21) + I_3(4) = 0$$

$$I_2(21) = -I_3(4)$$

$$I_2 = -I_3\left(\frac{4}{21}\right)$$

Step 4 of 5

Apply Kirchhoff's Voltage Law in loop-3.

$$-1 + (I_2 + I_3)(2\ \mathrm{k}) = 0$$

$$(I_2 + I_3)(2\ \mathrm{k}) = 1$$

Substitute $-I_3\left(\frac{4}{21}\right)$ for I_2.

$$\left(-I_3\left(\frac{4}{21}\right) + I_3\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{21-4}{21}\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{17}{21}\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{34\ \mathrm{k}}{21}\right) = 1$$

$$I_3 = \frac{21}{34}\ \mathrm{mA}$$

The value of the short circuit current is equal to the value of current I_3.

Therefore, the value of the short circuit current is $\frac{21}{34}\ \mathrm{mA}$.

Step 5 of 5

Calculate the value of the Thevenin's resistance.

$$R_{\mathrm{Th}} = \frac{1}{I_{\mathrm{SC}}}$$

Substitute $\frac{21}{34}\ \mathrm{mA}$ for I_{SC}.

$$\begin{aligned} R_{\mathrm{Th}} &= \frac{1}{\frac{21}{34}\ \mathrm{m}} \\ &= \frac{34}{21}\ \mathrm{k} \\ &\approx 1619\ \Omega \end{aligned}$$

Therefore, the value of the Thevenin's resistance R_{Th} is $\boxed{1619\ \Omega}$.

5.13P

Figure (1)

Step 2 of 11

The contribution of 40-V source to I_A is found from the network in Fig. 2 by replacing current sources with an open circuit.

Figure (2)

Step 3 of 11

The three resistors are in series and their combination is a $20+5+10=35\Omega$ resistor as shown in Fig.3.

Figure (3)

Step 4 of 11

Applying KVL,

$$I_A' = \frac{40}{35}$$

Step 5 of 11

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Step 6 of 11

The 20Ω and 5Ω resistors are in series and their combination is a $20+5=25\Omega$ resistor as shown in Fig. 5.

Figure (5)

Step 7 of 11

Applying current division in Fig. 5,

$$I_A'' = -\frac{(25)(2)}{25+10}$$
$$I_A'' = -\frac{50}{35}\text{A}$$

Step 8 of 11

Next, the contribution of 4A source to I_A is found from the network in Fig. 6 by replacing voltage source with short circuit and current source with an open circuit.

Figure (6)

Step 9 of 11

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Step 10 of 11

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Step 11 of 11

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 5

5.14E

Refer to Figure E5.3 in the textbook for the circuit.

Convert voltage source into current source.

Redraw the circuit by converting the series combination of the and resistor into current source in parallel with resistor.

Figure 1

Step 2 of 5

The equivalent combination of the two current sources is,

The equivalent circuit is shown in Figure 2.

Figure 2

Step 3 of 5

Convert the $2\ \text{mA}$ current source to voltage source.

$$\begin{aligned} V &= IR \\ &= \left(2\times10^{-3}\right)\left(3\times10^{3}\right) \\ &= 6\ \text{V} \end{aligned}$$

Redraw the circuit in Figure 2, by converting the $2\ \text{mA}$ current source in parallel with $3\ \text{k}\Omega$ resistor into series combination of the voltage source and $3\ \text{k}\Omega$ resistor.

Figure 3

Step 3 of 5

Convert the $2\ \text{mA}$ current source to voltage source.

$$\begin{aligned} V &= IR \\ &= \left(2\times10^{-3}\right)\left(3\times10^{3}\right) \\ &= 6\ \text{V} \end{aligned}$$

Redraw the circuit in Figure 2, by converting the $2\ \text{mA}$ current source in parallel with $3\ \text{k}\Omega$ resistor into series combination of the voltage source and $3\ \text{k}\Omega$ resistor.

Step 1 of 8

5.14P

The following is the given circuit diagram:

Figure 1

Step 2 of 8

Loading solution. Please wait ...

Step 3 of 8

Loading solution. Please wait ...

Step 4 of 8

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Step 5 of 8

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Step 6 of 8

Loading solution. Please wait ...

Step 7 of 8

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Step 8 of 8

Loading solution. Please wait ...

Step 1 of 11

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Step 2 of 11

The contribution of 6-V source to I_o is found from the network in Fig. 2 by replacing current source with an open circuit.

Figure (2)

Step 3 of 11

The two 12k resistors are in series and their combination is a $12k+12k=24k\Omega$ resistor as shown in Fig.3.

Figure (3)

Step 4 of 11

Loading solution. Please wait ...

Step 5 of 11

By Ohm's Law,

$$I_o' = -\frac{6}{8k+12k}$$
$$I_o' = -0.3mA$$

Step 6 of 11

Next, the contribution of 4mA source to I_o is found from the network in Fig. 6 by replacing voltage source with short circuit.

Step 7 of 11

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Step 8 of 11

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Step 9 of 11

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 10 of 11

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 11 of 11

There was a problem loading this step. We have been notified and we will fix it shortly.

5.15P

Figure (1)

Step 2 of 10

The contribution of 6-V source to I_A is found from the network in Fig. 2 by replacing current source with an open circuit.

Figure (2)

Step 3 of 10

The 12k and 6k resistors are getting shorted, thus can be safely removed from the network as shown in Fig.3.

Figure (3)

Step 4 of 10

The 6k and 3k resistors are in parallel and their combination is a $\frac{(6k)(3k)}{6k+3k} = 2k\Omega$ resistor as shown in Fig. 4.

Figure (4)

Step 5 of 10

Applying KVL,

$$I_o = \frac{6}{2k+2k}$$
$$I_o = \frac{3}{2}\text{mA}$$

Step 6 of 10

By using current division in Fig. 3,

$$I_A' = -\left(\frac{6k}{6k+3k}\right)(I_o)$$
$$I_A' = -\left(\frac{6k}{6k+3k}\right)\left(\frac{3}{2}\text{m}\right)$$
$$I_A' = -1\text{mA}$$

Step 7 of 10

Next, the contribution of 2mA source to I_A is found from the network in Fig. 5 by replacing voltage source with short circuit.

Figure (5)

Step 8 of 10

The 6k and 2k resistors are in parallel and their combination is a $\frac{(6k)(2k)}{6k+2k} = \frac{3}{2}k\Omega$ resistor as shown in Fig. 6.

Figure (6)

Step 9 of 10

Applying current division in Fig. 6

$$I_A'' = -\frac{(6k)(2m)}{12k+6k}$$
$$I_A'' = -\frac{(6k)(2m)}{18k}$$
$$I_A'' = -0.667\text{mA}$$

Step 10 of 10

Then,

$$I_A = I_A' + I_A''$$
$$I_o = -1\text{m} - 0.667\text{m}$$
$$\boxed{I_o = -1.667\text{mA}}$$

Step 1 of 9

5.16P

Refer to Figure P5.20 in the text book.

Contribution of the current source to the output voltage is calculated by using Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's voltage law at loop 2.

Apply Kirchhoff's voltage law at loop 3.

Apply Kirchhoff's current law at node 1.

Step 1 of 9

Refer to Figure P5.20 in the text book.

Contribution of the current source to the output voltage is calculated by using Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's voltage law at loop 2.

Apply Kirchhoff's voltage law at loop 3.

Apply Kirchhoff's current law at node 1.

Step 1 of 8

5.17E

Refer to Figure E5.17 from the text book.

Disconnect the load resistor and open the terminals.

Step 2 of 8

Apply nodal analysis at node-1.

$$\frac{V-12}{3\text{ k}}+\frac{V}{6\text{ k}}+2\text{ m}=o$$

$$V\left(\frac{1}{3\text{ k}}+\frac{1}{6\text{ k}}\right)-\frac{12}{3\text{ k}}+2\text{ m}=0$$

$$V\left(\frac{3}{6\text{ k}}\right)-4\text{ m}+2\text{ m}=0$$

$$V\left(\frac{3}{6\text{ k}}\right)=2\text{ m}$$

Step 2 of 8

Apply nodal analysis at node-1.

$$\frac{V-12}{3\text{ k}}+\frac{V}{6\text{ k}}+2\text{ m}=o$$

$$V\left(\frac{1}{3\text{ k}}+\frac{1}{6\text{ k}}\right)-\frac{12}{3\text{ k}}+2\text{ m}=0$$

$$V\left(\frac{3}{6\text{ k}}\right)-4\text{ m}+2\text{ m}=0$$

$$V\left(\frac{3}{6\text{ k}}\right)=2\text{ m}$$

$$V=\frac{(2\text{ m})(6\text{ m})}{3}$$

$$V=4\text{ V}$$

Step 3 of 8

Apply voltage division rule to calculate the value of the open circuit voltage.

$$\begin{aligned}V_{oc}&=(4)\left(\frac{2\text{ k}}{2\text{ k}+4\text{ k}}\right)\\&=(4)\left(\frac{2\text{ k}}{6\text{ k}}\right)\\&=(4)\left(\frac{1}{3}\right)\\&=\frac{4}{3}\text{ V}\end{aligned}$$

Therefore, the value of the open circuit voltage is .

Step 4 of 8

Deactivate the sources (replace voltage source by short circuit and current source by open circuit) in Figure E5.17, to calculate the Thevenin's equivalent resistance

Step 5 of 8

Calculate the value of then Thevenin's resistance.

Therefore, the value of the Thevenin's resistance is .

For a maximum value of the power to be delivered to the load, the value of the load resistance should be equal to the Thevenin's resistance.

Hence, the value of the load resistance is .

Step 6 of 8

Draw the Thevenin's equivalent circuit diagram.

Step 1 of 7

Refer to Figure P5.21 in the text book.

Contribution of the 6 mA current source to the output current is calculated by using Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 1.

Apply Kirchhoff's voltage law at loop 1.

$$I_{01}(6000+6000)=0$$
$$I_{01}=0\text{ mA}$$

Step 3 of 7

Contribution of the 4 mA current source to the output current is calculated by using Figure 2.

Figure 2.

Step 4 of 7

Refer to Figure 2.

Apply Kirchhoff's voltage law at loop 3.

$$I_1(6000+6000)=0$$
$$I_1=0\text{ mA}$$

Calculate the value of I_{02}.

$$\begin{aligned} I_{02} &= -4(10^{-3})\left(\frac{6000}{6000+6000}\right) \\ &= -4(10^{-3})\left(\frac{1}{2}\right) \\ &= -2\text{ mA} \end{aligned}$$

Step 5 of 7

Contribution of the 12 V voltage source to the output current is calculated by using Figure 3.

Figure 3.

Step 6 of 7

Refer to Figure 3.

Apply Kirchhoff's voltage law at loop 1.

$$12+I_{03}(6000+6000)=0$$
$$I_{03}(12000)=-12$$
$$\begin{aligned} I_{03} &= \frac{-12}{12000} \\ &= -1\text{ mA} \end{aligned}$$

Step 7 of 7

Calculate the total output current from I_{01}, I_{02} and I_{03}.

$$\begin{aligned} I_0 &= I_{01}+I_{02}+I_{03} \\ &= 0-2-1 \\ &= -3\text{ mA} \end{aligned}$$

Therefore, the total output current is $\boxed{-3\text{ mA}}$.

Step 1 of 9

Refer to Figure E5.18 in the text book.

Disconnect the load resistor and calculate the value of the Thevenin's resistance as seen from the terminals.

Figure 1

Step 2 of 9

Consider the expression for the voltage V_x.

$$V_x = 12 - V_{oc}$$

Apply nodal analysis at node-1.

$$\frac{V_{oc}-12}{4\text{ k}} + \frac{V_{oc}+\frac{V_x}{2}}{4\text{ k}} + \frac{V_{oc}}{6\text{ k}} = 0$$

$$\frac{V_{oc}-12}{4\text{ k}} + \frac{2V_{oc}+V_x}{8\text{ k}} + \frac{V_{oc}}{6\text{ k}} = 0$$

Substitute $12 - V_{oc}$ for V_x.

$$\frac{V_{oc}-12}{4\text{ k}} + \frac{2V_{oc}+12-V_{oc}}{8\text{ k}} + \frac{V_{oc}}{6\text{ k}} = 0$$

$$\frac{V_{oc}-12}{4\text{ k}} + \frac{V_{oc}+12}{8\text{ k}} + \frac{V_{oc}}{6\text{ k}} = 0$$

$$V_{oc}\left(\frac{1}{4\text{ k}} + \frac{1}{8\text{ k}} + \frac{1}{6\text{ k}}\right) - \frac{12}{4\text{ k}} + \frac{12}{8\text{ k}} = 0$$

$$V_{oc}\left(\frac{6+3+4}{24\text{ k}}\right) = \frac{24-12}{8\text{ k}}$$

$$V_{oc}\left(\frac{13}{3}\right) = 12$$

$$V_{oc} = \frac{(12)(3)}{13}$$

$$V_{oc} = \frac{36}{13}\text{ V}$$

Hence, the value of the open circuit voltage is $\frac{36}{13}$ V.

Step 3 of 9

Short the output terminals. Identify the currents in the circuit diagram.

Figure 2

Step 4 of 9

Consider the Kirchhoff's voltage law in loop-2.

$$(I_2 - I_1)(4\text{ k}) + \frac{V_x}{2} = 0$$

Substitute $I_1(4\text{ k})$ for V_x.

$$(I_2 - I_1)(4\text{ k}) + \frac{I_1(4\text{ k})}{2} = 0$$

$$(I_2 - I_1)(4\text{ k}) + I_1(2\text{ k}) = 0$$

$$I_2(4\text{ k}) - I_1(4\text{ k}) + I_1(2\text{ k}) = 0$$

$$I_2(4\text{ k}) - I_1(4\text{ k} - 2\text{ k}) = 0$$

$$I_2(4\text{ k}) - I_1(2\text{ k}) = 0$$

$$I_1 = I_2(2)$$

Step 5 of 9

Apply Kirchhoff's voltage law in loop-1.

$$I_1(4\text{ k}) + (I_1 - I_2)(4\text{ k}) - 12 - \frac{V_x}{2} = 0$$

Substitute $I_1(4\text{ k})$ for V_x.

$$I_1(4\text{ k}) + (I_1 - I_2)(4\text{ k}) - 12 - \frac{I_1(4\text{ k})}{2} = 0$$

$$I_1(4\text{ k}) + (I_1 - I_2)(4\text{ k}) - 12 - I_1(2\text{ k}) = 0$$

$$I_1(4\text{ k} + 4\text{ k} - 2\text{ k}) - I_2(4\text{ k}) = 12$$

$$I_1(6\text{ k}) - I_2(4\text{ k}) = 12$$

Substitute $I_2(2)$ for I_1.

$$I_2(2)(6\text{ k}) - I_2(4\text{ k}) = 12$$

$$I_2(12\text{ k} - 4\text{ k}) = 12$$

$$I_2(8\text{ k}) = 12$$

$$I_2 = \frac{12}{8\text{ k}}$$

$$I_2 = \frac{3}{2}\text{ mA}$$

The value of the short circuit current is equal to the value of current I_2.

Therefore, the value of the short circuit current is $\frac{3}{2}$ mA.

Step 6 of 9

Calculate the value of the Thevenin's resistance.

$$R_{Th} = \frac{V_{oc}}{I_{sc}}$$

Substitute $\frac{3}{2}$ mA for I_{sc} and $\frac{36}{13}$ V for V_{oc}.

$$R_{Th} = \frac{\frac{36}{13}}{\frac{3}{2}\text{ m}}$$

$$= \frac{24}{13}\text{ k}\Omega$$

Therefore, the value of the Thevenin's resistance R_{Th} is $\frac{24}{13}$ kΩ.

For a maximum value of the power to be delivered to the load, the value of the load resistance sho equal to the Thevenin's resistance.

Hence, the value of the load resistance is $\frac{24}{13}$ kΩ.

Step 7 of 9

Draw the Thevenin's equivalent circuit diagram with a load resistor $\frac{24}{13}$ kΩ.

Figure 3

Step 8 of 9

Apply voltage division rule to calculate the value of the load voltage V_o.

$$V_o = \left(\frac{36}{13}\right)\left(\frac{\frac{24}{13}\text{ k}}{\frac{24}{13}\text{ k} + \frac{24}{13}\text{ k}}\right)$$

$$= \left(\frac{36}{13}\right)\left(\frac{\frac{24}{13}\text{ k}}{2\left(\frac{24}{13}\text{ k}\right)}\right)$$

$$= \left(\frac{36}{13}\right)\left(\frac{1}{2}\right)$$

$$= \frac{18}{13}\text{ V}$$

Therefore, the value of the load voltage is $\frac{18}{13}$ V.

Step 9 of 9

Calculate the value of the maximum power transferred to the load.

$$P = \frac{V_o^2}{R_L}$$

Substitute $\frac{24}{13}$ kΩ for R_L and $\frac{18}{13}$ V for V_{oc}.

$$P = \frac{\left(\frac{18}{13}\right)^2}{\frac{24}{13}\text{ k}}$$

$$= \frac{\frac{324}{169}}{\frac{24}{13}\text{ k}}$$

$$= \frac{27}{26}\text{ mW}$$

Therefore, the value of the maximum power transferred to the load is $\boxed{\frac{27}{26}\text{ mW}}$.

Step 1 of 7

Refer to Figure P5.21 in the text book.

Contribution of the 6 mA current source to the output current is calculated by using Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 1.

Apply Kirchhoff's voltage law at loop 1.

$$I_{01}(6000+6000)=0$$
$$I_{01}=0\text{ mA}$$

Step 3 of 7

Contribution of the 4 mA current source to the output current is calculated by using Figure 2.

Figure 2.

Step 4 of 7

Refer to Figure 2.

Apply Kirchhoff's voltage law at loop 3.

$$I_1(6000+6000)=0$$
$$I_1=0\text{ mA}$$

Calculate the value of I_{02} .

$$\begin{aligned} I_{02} &= -4\left(10^{-3}\right)\left(\frac{6000}{6000+6000}\right) \\ &= -4\left(10^{-3}\right)\left(\frac{1}{2}\right) \\ &= -2\text{ mA} \end{aligned}$$

Step 5 of 7

Contribution of the 12 V voltage source to the output current is calculated by using Figure 3.

Figure 3.

Step 6 of 7

Refer to Figure 3.

Apply Kirchhoff's voltage law at loop 1.

$$12+I_{03}(6000+6000)=0$$
$$I_{03}(12000)=-12$$
$$\begin{aligned} I_{03} &= \frac{-12}{12000} \\ &= -1\text{ mA} \end{aligned}$$

Step 7 of 7

Calculate the total output current from I_{01}, I_{02} and I_{03}.

$$\begin{aligned} I_0 &= I_{01}+I_{02}+I_{03} \\ &= 0-2-1 \\ &= -3\text{ mA} \end{aligned}$$

Therefore, the total output current is $\boxed{-3\text{ mA}}$.

Step 1 of 6

Refer to Figure P5.7 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 3\,\text{k}\Omega \end{aligned}$$

This $3\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= R_1 + 6\,\text{k}\Omega \\ &= 3\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 9\,\text{k}\Omega \end{aligned}$$

Step 3 of 6

Apply current division rule and calculate the current $I_o^{'}$ through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o^{'} &= \frac{9\,\text{k}\Omega}{9\,\text{k}\Omega + 6\,\text{k}\Omega}(-6\,\text{mA}) \\ &= -3.6\,\text{mA} \end{aligned}$$

Hence, the current $I_o^{'}$ through the $6\,\text{k}\Omega$ resistor is $-3.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $6\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistor are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= 6\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 12\,\text{k}\Omega \end{aligned}$$

This $12\,\text{k}\Omega$ resistor is in parallel with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= \frac{(12\,\text{k}\Omega)(6\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 4\,\text{k}\Omega \end{aligned}$$

This $4\,\text{k}\Omega$ resistor is in series with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_3 &= R_2 + 6\,\text{k}\Omega \\ &= 4\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 10\,\text{k}\Omega \end{aligned}$$

Apply ohms law and calculate the total current I by substituting $12\,\text{V}$ for V and $10\,\text{k}\Omega$ for R_3 .

$$\begin{aligned} I &= \frac{V}{R_3} \\ &= \frac{12\,\text{V}}{10\,\text{k}\Omega} \\ &= 1.2\,\text{mA} \end{aligned}$$

Apply current division rule and calculate the current $I_o^{''}$ through the $6\,\text{k}\Omega$ resistor .

$$\begin{aligned} I_o^{''} &= \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 12\,\text{k}\Omega}(1.2\,\text{mA}) \\ &= 0.4\,\text{mA} \end{aligned}$$

Hence, the current $I_o^{''}$ through the $6\,\text{k}\Omega$ resistor is $0.4\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $6\,\text{k}\Omega$ resistor.

$$I_o = I_o^{'} + I_o^{''}$$

Calculate the current I_o through the $6\,\text{k}\Omega$ resistor by substituting $-3.6\,\text{mA}$ for $I_o^{'}$ and $0.4\,\text{mA}$ for $I_o^{''}$.

$$\begin{aligned} I_o &= I_o^{'} + I_o^{''} \\ &= -3.6\,\text{mA} + 0.4\,\text{mA} \\ &= -3.2\,\text{mA} \end{aligned}$$

Therefore, the current I_o through the $6\,\text{k}\Omega$ resistor is $\boxed{-3.2\,\text{mA}}$.

Step 1 of 6

Refer to Figure P5.7 in the text book.

Apply superposition principle to the circuit. Acting only current source, the voltage source is short-circuited as shown in Figure 1.

Figure 1

Step 2 of 6

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 3\,\text{k}\Omega \end{aligned}$$

This $3\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistors are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= R_1 + 6\,\text{k}\Omega \\ &= 3\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 9\,\text{k}\Omega \end{aligned}$$

Step 3 of 6

Apply current division rule and calculate the current $I_o^{'}$ through the $6\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_o^{'} &= \frac{9\,\text{k}\Omega}{9\,\text{k}\Omega + 6\,\text{k}\Omega}(-6\,\text{mA}) \\ &= -3.6\,\text{mA} \end{aligned}$$

Hence, the current $I_o^{'}$ through the $6\,\text{k}\Omega$ resistor is $-3.6\,\text{mA}$.

Step 4 of 6

Apply superposition principle to the circuit. Acting only voltage source, the current source is open-circuited as shown in Figure 2.

Figure 2

Step 5 of 6

The $6\,\text{k}\Omega$ resistor and $6\,\text{k}\Omega$ resistor are in series. Calculate the equivalent resistance.

$$\begin{aligned} R_1 &= 6\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 12\,\text{k}\Omega \end{aligned}$$

This $12\,\text{k}\Omega$ resistor is in parallel with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_2 &= \frac{(12\,\text{k}\Omega)(6\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(6\,\text{k}\Omega)} \\ &= 4\,\text{k}\Omega \end{aligned}$$

This $4\,\text{k}\Omega$ resistor is in series with $6\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_3 &= R_2 + 6\,\text{k}\Omega \\ &= 4\,\text{k}\Omega + 6\,\text{k}\Omega \\ &= 10\,\text{k}\Omega \end{aligned}$$

Apply ohms law and calculate the total current I by substituting $12\,\text{V}$ for V and $10\,\text{k}\Omega$ for R_3 .

$$\begin{aligned} I &= \frac{V}{R_3} \\ &= \frac{12\,\text{V}}{10\,\text{k}\Omega} \\ &= 1.2\,\text{mA} \end{aligned}$$

Apply current division rule and calculate the current $I_o^{''}$ through the $6\,\text{k}\Omega$ resistor .

$$\begin{aligned} I_o^{''} &= \frac{6\,\text{k}\Omega}{6\,\text{k}\Omega + 12\,\text{k}\Omega}(1.2\,\text{mA}) \\ &= 0.4\,\text{mA} \end{aligned}$$

Hence, the current $I_o^{''}$ through the $6\,\text{k}\Omega$ resistor is $0.4\,\text{mA}$.

Step 6 of 6

Write the expression for the current I_o through the $6\,\text{k}\Omega$ resistor.

$$I_o = I_o^{'} + I_o^{''}$$

Calculate the current I_o through the $6\,\text{k}\Omega$ resistor by substituting $-3.6\,\text{mA}$ for $I_o^{'}$ and $0.4\,\text{mA}$ for $I_o^{''}$.

$$\begin{aligned} I_o &= I_o^{'} + I_o^{''} \\ &= -3.6\,\text{mA} + 0.4\,\text{mA} \\ &= -3.2\,\text{mA} \end{aligned}$$

Therefore, the current I_o through the $6\,\text{k}\Omega$ resistor is $\boxed{-3.2\,\text{mA}}$.

Refer to Figure E5.8 in the text book.

Disconnect the $1\ \text{k}\Omega$ resistor from the circuit diagram. Identify the currents and voltages in the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff's Current Law at node V_1.

$$\frac{V_1 - V_2}{6\ \text{k}} + \frac{V_1}{3\ \text{k}} - 8\ \text{m} + 2\ \text{m} = 0$$

$$V_1\left(\frac{1}{6\ \text{k}} + \frac{1}{3\ \text{k}}\right) - \frac{V_2}{6\ \text{k}} = 6\ \text{m}$$

$$V_1\left(\frac{3}{6\ \text{k}}\right) - \frac{V_2}{6\ \text{k}} = 6\ \text{m}$$

$$V_1(3) - V_2 = (6\ \text{m})(6\ \text{k})$$

$$V_1(3) - V_2 = 36$$

$$V_1(3) = 36 + V_2$$

$$V_1 = \frac{36 + V_2}{3}$$

Step 3 of 8

Apply Kirchhoff's Current Law at node V_2.

$$\frac{V_2 - V_1}{6\ \text{k}} + \frac{V_2 - 12}{6\ \text{k}} - 2\ \text{m} = 0$$

$$V_2\left(\frac{1}{6\ \text{k}} + \frac{1}{6\ \text{k}}\right) - \frac{V_1}{6\ \text{k}} - \frac{12}{6\ \text{k}} - 2\ \text{m} = 0$$

$$V_2\left(\frac{2}{6\ \text{k}}\right) - \frac{V_1}{6\ \text{k}} - 2\ \text{m} - 2\ \text{m} = 0$$

$$V_2\left(\frac{2}{6\ \text{k}}\right) - \frac{V_1}{6\ \text{k}} = 4\ \text{m}$$

$$V_2(2) - V_1 = (4\ \text{m})(6\ \text{k})$$

$$V_2(2) - V_1 = 24$$

Substitute $\frac{36 + V_2}{3}$ for V_1.

$$V_2(2) - \left(\frac{36 + V_2}{3}\right) = 24$$

$$V_2(2) - \frac{36}{3} - \frac{V_2}{3} = 24$$

$$V_2\left(2 - \frac{1}{3}\right) - 12 = 24$$

$$V_2\left(\frac{5}{3}\right) = 24 + 12$$

$$V_2\left(\frac{5}{3}\right) = 36$$

$$V_2 = 36\left(\frac{3}{5}\right)$$

$$V_2 = \frac{108}{5}$$

$$V_2 = 21.6\ \text{V}$$

Step 4 of 8

Calculate the value of the open circuit voltage V_{oc}.

$$V_{oc} = V_2 + (2\ \text{m})(2\ \text{k})$$

Substitute $21.6\ \text{V}$ for V_2.

$$V_{oc} = 21.6 + 4$$
$$= 25.6\ \text{V}$$

Therefore, the value of the open circuit voltage V_{oc} is $25.6\ \text{V}$.

Step 5 of 8

Disconnect the sources from the circuit diagram.

Figure 2

Step 6 of 8

Calculate the value of the Thevenin's resistance.

$$R_{\text{Th}} = 2\ \text{k} + \left((6\ \text{k} + 3\ \text{k}) \| 6\ \text{k}\right)$$
$$= 2\ \text{k} + (9\ \text{k} \| 6\ \text{k})$$
$$= 2\ \text{k} + \frac{(9\ \text{k})(6\ \text{k})}{9\ \text{k} + 6\ \text{k}}$$
$$= 2\ \text{k} + \frac{(9\ \text{k})(6\ \text{k})}{15\ \text{k}}$$

$$= 2\ \text{k} + 3.6\ \text{k}$$
$$= 5.6\ \text{k}\Omega$$

Therefore, the value of the Thevenin's resistance R_{Th} is $5.6\ \text{k}\Omega$.

Step 7 of 8

Draw the Thevenin's equivalent circuit diagram with a load resistor $1\ \text{k}\Omega$.

Figure 3

Step 8 of 8

Apply voltage division rule, to calculate the value of the output voltage V_o.

$$V_o = (25.6)\left(\frac{1\ \text{k}}{1\ \text{k} + 5.6\ \text{k}}\right)$$
$$= (25.6)\left(\frac{1\ \text{k}}{6.6\ \text{k}}\right)$$
$$= 3.88\ \text{V}$$

Therefore, the value of the output voltage V_o is $\boxed{3.88\ \text{V}}$.

Step 1 of 14

Refer to circuit diagram in Figure P5.23 in the text book.

Contribution of the 6 mA current source to the output voltage is calculated by using Figure 1.

Figure 1

Step 2 of 14

Apply Kirchhoff's voltage law at loop 1.

$$V = 3000I_2$$

Apply Kirchhoff's voltage law at loop 2.

$$3000I_2 = 3000I_3 + 3000I_4$$
$$I_2 = I_3 + I_4$$

Step 3 of 14

Apply Kirchhoff's voltage law at loop 3.

$$V = 3000I_4 + 3000I_1$$

Substitute $V = 3000I_2$

$$3000I_2 = 3000I_4 + 3000I_1$$
$$I_2 = I_4 + I_1$$

Substitute $I_2 = I_3 + I_4$

$$I_4 + I_1 = I_3 + I_4$$
$$I_1 = I_3$$

Step 4 of 14

Apply Kirchhoff's current law at node 4.

$$I_4 = I_3 + I_1$$

Substitute $I_3 = I_1$

$$I_4 = I_1 + I_1$$
$$= 2I_1$$

Step 5 of 14

Recall the equation $I_2 = I_3 + I_4$.

Substitute $I_3 = I_1$ and $I_4 = 2I_1$

$$I_2 = I_1 + 2I_1$$
$$= 3I_1$$

Step 6 of 14

Apply Kirchhoff's current law at node 6.

$$I = I_3 + I_2$$

Substitute $I_3 = I_1$ and $I_2 = 3I_1$

$$I = I_1 + 3I_1$$
$$= 4I_1$$

Step 7 of 14

Apply Kirchhoff's current law at node 7.

$$6\left(10^{-3}\right) = I + I_1$$

Substitute $I = 4I_1$

$$6\left(10^{-3}\right) = 4I_1 + I_1$$
$$I_1 = \frac{6\left(10^{-3}\right)}{5}$$

Step 8 of 14

Calculate the value of V_{01}.

$$V_{01} = 3000I_1$$
$$= 3000\left(\frac{6\left(10^{-3}\right)}{5}\right)$$
$$= 3.6\text{ V}$$

Step 9 of 14

Contribution of the 12 V voltage source to the output voltage is calculated by using Figure 1.

Figure 2

Step 10 of 14

Apply Kirchhoff's voltage law at loop 1.

$$3000I_3 = (3000 + 3000)I_2$$
$$I_3 = 2I_2$$

Step 11 of 14

Apply Kirchhoff's current law at node 2.

$$I_1 = I_2 + I_3$$

Substitute $I_3 = 2I_2$

$$I_1 = I_2 + 2I_2$$
$$I_1 = 3I_2$$
$$I_2 = \left(\frac{I_1}{3}\right)$$

Step 12 of 14

Apply Kirchhoff's voltage law at loop 3.

$$-12 = 3000I_1 + (3000 + 3000)I_2$$
$$= 3000I_1 + 6000I_2$$

Substitute $I_2 = \frac{I_1}{3}$

$$-12 = 3000I_1 + 6000\left(\frac{I_1}{3}\right)$$

$$-12 = 3000I_1 + 2000I_1$$
$$I_1 = -\frac{12}{5000}$$

Step 13 of 14

Calculate the value of V_{02}.

$$V_{02} = 3000I_1$$
$$= 3000\left(-\frac{12}{5000}\right)$$
$$= -7.2$$

Step 14 of 14

Calculate the total output voltage from V_{01} and V_{02}.

$$V_0 = V_{01} + V_{02}$$
$$= 3.6 - 7.2$$
$$= -3.6\text{ V}$$

Therefore, the total output voltage is $\boxed{-3.6\text{ V}}$.

Step 1 of 7

5.023P

Fist, let us find the response using only the current source, and hence short circuiting the voltage sources.

Step 2 of 7

Hence

$$I_0' = 2\text{m}\left(\frac{1\text{k}}{\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}} + 1\text{k} + 4\text{k}}\right)$$

$$= 2\text{m}\left(\frac{1}{\frac{1}{2}+1+4}\right)$$

$$I_0' = \frac{4}{11}\text{mA}$$

Step 3 of 7

Now let us open the current source and short circuit the 4V source and find the response using only 2V source.

Step 4 of 7

Redrawing the circuit.

Step 5 of 7

Since it is a parallel circuit, KCL at top node,

$$\frac{V-2}{1\text{k}} + \frac{V}{1\text{k}} + \frac{V}{5\text{k}} = 0$$

$$11V = 10$$

$$V = \frac{10}{11}\text{V}$$

Hence $I_0'' = \dfrac{\frac{-10}{11}}{5\text{k}}$

$$I_0'' = \frac{-2}{11}\text{mA}$$

Step 6 of 7

Now let us find the response using only 4V source,

Step 7 of 7

Now KVL across the loop gives I_0'''

$$I_0''' = \frac{4}{\left(1\text{k}+4\text{k}+\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}}\right)}$$

$$I_0''' = \frac{8}{11}\text{mA}$$

Hence total response $I_0 = I_0' + I_0'' + I_0'''$

$$= \frac{4}{11} - \frac{2}{11} + \frac{8}{11}$$

$$\boxed{I_0 = \frac{10}{11}\text{mA}}$$

Step 1 of 5

Refer to Figure E5.13 in the text book.

Apply the source voltage of $1\ \mathrm{V}$ at the open terminals.

Figure 1

Step 2 of 5

Consider the relation between the currents I_1 and I_2.

$$I_1 + I_2 = \frac{V_x}{2000}$$

Substitute $-I_2(1\ \mathrm{k})$ for V_x.

$$I_1 + I_2 = -\frac{I_2(1\ \mathrm{k})}{2000}$$

$$I_1 + I_2 = -\frac{I_2}{2}$$

$$I_1 = -\frac{I_2}{2} - I_2$$

$$I_1 = -\frac{I_2 + 2I_2}{2}$$

$$I_1 = -\frac{3I_2}{2}$$

Step 3 of 5

Apply super mesh analysis in loop 1 and loop 2.

$$-I_1(5\ \mathrm{k}) + I_2(1\ \mathrm{k}) + (I_2 + I_3)(2\ \mathrm{k}) = 0$$

$$-I_1(5\ \mathrm{k}) + I_2(1\ \mathrm{k}) + I_2(2\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$-I_1(5\ \mathrm{k}) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

Substitute $-\frac{3I_2}{2}$ for I_1.

$$-\left(-\frac{3I_2}{2}\right)(5\ \mathrm{k}) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k}}{2}\right) + I_2(3\ \mathrm{k}) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k}}{2} + 3\ \mathrm{k}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{15\ \mathrm{k} + 6\ \mathrm{k}}{2}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2\left(\frac{21\ \mathrm{k}}{2}\right) + I_3(2\ \mathrm{k}) = 0$$

$$I_2(21) + I_3(4) = 0$$

$$I_2(21) = -I_3(4)$$

$$I_2 = -I_3\left(\frac{4}{21}\right)$$

Step 4 of 5

Apply Kirchhoff's Voltage Law in loop-3.

$$-1 + (I_2 + I_3)(2\ \mathrm{k}) = 0$$

$$(I_2 + I_3)(2\ \mathrm{k}) = 1$$

Substitute $-I_3\left(\frac{4}{21}\right)$ for I_2.

$$\left(-I_3\left(\frac{4}{21}\right) + I_3\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{21-4}{21}\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{17}{21}\right)(2\ \mathrm{k}) = 1$$

$$I_3\left(\frac{34\ \mathrm{k}}{21}\right) = 1$$

$$I_3 = \frac{21}{34}\ \mathrm{mA}$$

The value of the short circuit current is equal to the value of current I_3.

Therefore, the value of the short circuit current is $\frac{21}{34}\ \mathrm{mA}$.

Step 5 of 5

Calculate the value of the Thevenin's resistance.

$$R_{\mathrm{Th}} = \frac{1}{I_{\mathrm{SC}}}$$

Substitute $\frac{21}{34}\ \mathrm{mA}$ for I_{SC}.

$$\begin{aligned} R_{\mathrm{Th}} &= \frac{1}{\frac{21}{34}\ \mathrm{m}} \\ &= \frac{34}{21}\ \mathrm{k} \\ &\approx 1619\ \Omega \end{aligned}$$

Therefore, the value of the Thevenin's resistance R_{Th} is $\boxed{1619\ \Omega}$.

Step 1 of 7

Refer to Figure P5.32 in the text book.

Calculate thevenin's resistance by using circuit shown in Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 1.

Calculate the value of R_{th} .

$$R_{th} = \frac{2000(4000)}{2000+4000}$$
$$= \frac{8000000}{6000}$$
$$= \frac{4}{3}\ \text{k}\Omega$$

Step 3 of 7

Calculate the open Circuit voltage by using circuit shown in Figure 2.

Figure 2

Step 4 of 7

Refer to Figure 2.

Calculate the value of voltage V_x .

$$V_x = (-6)\frac{4000}{4000+2000}$$
$$= (-6)\frac{4000}{6000}$$
$$= -4\ \text{V}$$

Step 5 of 7

Calculate the value of voltage V_{oc} .

$$V_{oc} = 12 + V_x$$
$$= 12 - 4$$
$$= 8\ \text{V}$$

Step 6 of 7

Calculate the value of output voltage by using Thevenin's equivalent circuit shown in Figure 3.

Figure 2

Step 7 of 7

Refer to Figure 3.

Calculate the value of voltage V_0 .

$$V_0 = V_{oc}\left(\frac{2000}{2000+R_{th}}\right)$$
$$= 8\left(\frac{2000}{2000+\frac{4000}{3}}\right)$$
$$= 8\left(\frac{2000(3)}{6000+4000}\right)$$
$$= 4.8\ \text{V}$$

Therefore, the output voltage is $\boxed{4.8\ \text{V}}$.

Step 1 of 6

Consider Figure P5.36 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 6

Calculate the value of the open circuit voltage.

$$V_{OC} = (i_2 + i_3)(2\text{ k}) + (i_2 + i_1)(1\text{ k})$$

Substitute 6 mA for i_2, 4 mA for i_3 and 2 mA for i_1.

$$\begin{aligned} V_{OC} &= (6\text{ m} + 4\text{ m})(2\text{ k}) + (6\text{ m} + 2\text{ m})(1\text{ k}) \\ &= (10\text{ m})(2\text{ k}) + (8\text{ m})(1\text{ k}) \\ &= 20 + 8 \\ &= 28\text{ V} \end{aligned}$$

Therefore, the value of the open circuit voltage V_{OC} is 28 V.

Step 3 of 6

Disconnect the sources from the circuit diagram.

Figure 2

Step 4 of 6

Calculate the value of the Thevenin's resistance.

$$\begin{aligned} R_{Th} &= 2\text{ k} + 1\text{ k} \\ &= 3\text{ k}\Omega \end{aligned}$$

$$R_{Th} = 4.5\text{ k}\Omega$$

Therefore, the value of the Thevenin's resistance is $3\text{ k}\Omega$.

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the value of the output current.

$$\begin{aligned} I_o &= \frac{28}{3\text{ k} + 1\text{ k}} \\ &= \frac{28}{4\text{ k}} \\ &= 7\text{ mA} \end{aligned}$$

Therefore, the value of the output current I_o is $\boxed{7\text{ mA}}$.

Step 1 of 9

The given circuit is,

Figure (1)

Step 2 of 9

To determine the Thevenin equivalent, break the network at the 4kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

By using voltage division in Fig. 2,

$$V_1 = \frac{(6k)(12)}{3k+6k}$$
$$V_1 = 8V$$

Step 4 of 9

By using Ohm's Law in Fig. 2,

$$V_2 = -(2k)(2m)$$
$$V_2 = -4V$$

Step 5 of 9

Hence,

$$V_{oc} = V_1 - V_2$$
$$V_{oc} = 8+4$$
$$V_{oc} = 12V$$

Step 6 of 9

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 7 of 9

The 6k and 3k resistors are in parallel and their combination is,

$\frac{(6k)(3k)}{6k+3k} = 2k\Omega$ resistor as shown in Fig. 4,

Figure (4)

Step 8 of 9

Hence,

$$R_{th} = 2k + 2k$$
$$R_{th} = 4k\Omega$$

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 4k load as shown in Fig. 5.

Figure (5)

Step 9 of 9

Applying voltage division in Fig. 5,

$$V_o = \left(\frac{4k}{4k+4k}\right)V_{oc}$$
$$V_o = \left(\frac{4k}{8k}\right)(12)$$
$$\boxed{V_o = 6V}$$

Step 1 of 7

The given circuit is,

Figure (1)

Step 2 of 7

To determine the Thevenin voltage equivalent, break the network at the 6kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 7

Applying KVL to the circuit in Fig. 2,

$V_{oc} = 12-(-3k)(2m)$

$V_{oc} = 18V$

Step 4 of 7

Thevenin resistance:

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 5 of 7

The series combination of 4k and 2k resistors are getting shorted thus can be safely removed from the network in Fig. 3 as shown in Fig. 4

Figure (4)

Hence,

$$R_{th} = 3k\Omega$$

Step 6 of 7

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 6k load as shown in Fig. 5.

Figure (5)

Step 7 of 7

Applying KVL,

$$I_o = \frac{V_{oc}}{3k+6k}$$

$$I_o = \frac{18}{9k}$$

$$\boxed{I_o = 2mA}$$

Step 1 of 7

Figure (1)

Step 2 of 7

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the 2kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 7

Applying KVL in Fig. 2,

$$V_{oc} = 12 - (-2k)(2m)$$
$$V_{oc} = 16V$$

Step 4 of 7

Thevenin resistance:

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 5 of 7

The two 1k resistors are getting shorted thus can be safely removed from the network in Fig. 3 as shown in Fig. 4

Figure (4)

Hence,

$$R_{th} = 2k\Omega$$

Step 6 of 7

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 2k load as shown in Fig. 5.

Step 7 of 7

Figure (5)

Using Voltage division in Fig. 5

$$V_o = \left(\frac{V_{oc}}{2k + 2k}\right)(2k)$$
$$V_o = \left(\frac{16}{4k}\right)(2k)$$
$$\boxed{V_o = 8V}$$

5.030P

Figure (1)

Step 2 of 9

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the $2k\Omega$ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

Applying KVL in Fig. 2,

$$12 = (6k)(I_1) + (2k)(I_1) + (1k)(I_1 + 2m)$$
$$I_1 = \frac{10}{9k}$$
$$I_1 = \frac{10}{9}\text{mA}$$

Step 4 of 9

Using Ohm's Law,

$$V_{oc} = 12 - (6k)(I_1)$$
$$V_{oc} = 12 - (6k)\left(\frac{10}{9}\text{m}\right)$$
$$V_{oc} = \frac{16}{3}\text{V}$$

Step 5 of 9

Thevenin resistance:

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 9

The 2k and 1k resistors are in series and their combination is a $2k + 1k = 3k$ as shown in Fig. 4

Figure (4)

Step 7 of 9

The 3k resistor is further in parallel with 6k resistor thus equivalent resistance has value $\frac{(6k)(3k)}{6k+3k} = 2k$

Hence,

$$R_{th} = 2k\Omega$$

Step 8 of 9

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 2k load as shown in Fig. 5.

Figure (5)

Step 9 of 9

Applying KVL,

$$I_o = \frac{V_{oc}}{2k + 2k}$$
$$I_o = \frac{\frac{16}{3}}{4k}$$
$$\boxed{I_o = 1.33\text{mA}}$$

Step 6 of 6

Calculate the value of the output current.

$$I_o = \frac{28}{3\text{ k} + 1\text{ k}}$$
$$= \frac{28}{4\text{ k}}$$
$$= 7\text{ mA}$$

Therefore, the value of the output current I_o is $\boxed{7\text{ mA}}$.

$= 7\text{ mA}$

Therefore, the value of the output current I_o is $\boxed{7\text{ mA}}$.

Figure 1

mA for i_1.

)

Step 1 of 9

Figure (1)

Step 2 of 9

Thevenin voltage:

Step 1 of 9

Figure (1)

Step 2 of 9

Thevenin voltage:

Figure (3)

Step 6 of 9

The 2k and 1k resistors are in series and their combination is a $2k+1k=3k$ as shown in Fig. 4

Figure (4)

Step 7 of 9

The 3k resistor is further in parallel with 6k resistor thus equivalent resistance has value

$$\frac{(6k)(3k)}{6k+3k}=2k$$

Figure (3)

Step 6 of 9

The 2k and 1k resistors are in series and their combination is a $2k+1k=3k$ as shown in Fig. 4

Step 1 of 5

Step 2 of 5

First calculate Rth by removing 6k resistance
Rth = 6k

Step 3 of 5

Now calculate VoC between terminal A&B

Step 4 of 5

Apply loop eq.
12-4i-4(i-6)=0
12-4i-4i+24=0
26=8i
$i=\frac{36}{8}=4.5mAmp$
Now VoC-12+6×6=0
VoC=-24volt

Step 5 of 5

Now the thevenin's equivalent ckt are shown in fig

$I_0=\frac{-24}{6+6}=\frac{-24}{12}$
$I_o=-2mAmp$

Step 1 of 7

Figure (1)

Step 2 of 7

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the 1kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 7

By using Ohm's Law in Fig. 2,

$$6 = V_{oc} + (1\text{k})(1\text{m})$$
$$V_{oc} = 5\text{V}$$

Step 4 of 7

Thevenin resistance:

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,
s

Figure (3)

Step 5 of 7

From Fig. 3,

$$R_{th} = 1\text{k}\Omega$$

Step 6 of 7

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 1k load as shown in Fig. 5.

Figure (4)

Step 7 of 7

Using Ohm's Law,

$$I_o = \frac{V_{oc}}{1\text{k}+1\text{k}}$$
$$I_o = \frac{5}{2\text{k}}$$
$$I_o = \boxed{2.5\text{mA}}$$

Step 1 of 9

Figure (1)

Step 2 of 9

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the 2kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

By analyzing current sources in Fig. 2 we get,

$$I_1 = 6\text{mA}$$

Step 4 of 9

By using KVL in loop *abcd* in Fig. 2,

$$0 = -V_1 + (1\text{k})(2\text{m}) + (2\text{k})(I_1)$$
$$V_1 = (1\text{k})(2\text{m}) + (2\text{k})(6\text{m})$$
$$V_1 = 14\text{V}$$

Step 5 of 9

Thus,

$$V_{oc} = V_1 + 12$$
$$V_{oc} = 14 + 12$$
$$V_{oc} = 26\text{V}$$

Step 6 of 9

Thevenin resistance:

By replacing current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 7 of 9

All resistors are in series and their combination is a $2\text{k} + 1\text{k} = 3\text{k}\Omega$ resistor thus

$$R_{th} = 3\text{k}\Omega$$

Step 8 of 9

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 2k load as shown in Fig. 4.

Figure (4)

Step 9 of 9

Using KVL in Fig. 4,

$$I_o = \frac{V_{oc}}{3\text{k} + 2\text{k}}$$
$$I_o = \frac{26}{5\text{k}}$$
$$\boxed{I_o = 5.2\text{mA}}$$

Step 1 of 7

Refer to Figure P5.32 in the text book.

Calculate thevenin's resistance by using circuit shown in Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 1.

Calculate the value of R_{th} .

$$R_{th} = \frac{2000(4000)}{2000+4000}$$
$$= \frac{8000000}{6000}$$
$$= \frac{4}{3}\ \text{k}\Omega$$

Step 3 of 7

Calculate the open Circuit voltage by using circuit shown in Figure 2.

Figure 2

Step 4 of 7

Refer to Figure 2.

Calculate the value of voltage V_x .

$$V_x = (-6)\frac{4000}{4000+2000}$$
$$= (-6)\frac{4000}{6000}$$
$$= -4\ \text{V}$$

Step 5 of 7

Calculate the value of voltage V_{oc} .

$$V_{oc} = 12 + V_x$$
$$= 12 - 4$$
$$= 8\ \text{V}$$

Step 6 of 7

Calculate the value of output voltage by using Thevenin's equivalent circuit shown in Figure 3.

Figure 2

Step 7 of 7

Refer to Figure 3.

Calculate the value of voltage V_0 .

$$V_0 = V_{oc}\left(\frac{2000}{2000+R_{th}}\right)$$
$$= 8\left(\frac{2000}{2000+\frac{4000}{3}}\right)$$
$$= 8\left(\frac{2000(3)}{6000+4000}\right)$$
$$= 4.8\ \text{V}$$

Therefore, the output voltage is $\boxed{4.8\ \text{V}}$.

Step 1 of 8

Figure (1)

Step 2 of 8

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the 40V voltage source as shown in Fig. 2.

Figure (2)

Step 3 of 8

By analyzing current sources in Fig. 2 we get,

$$I_1 = 6\text{mA}$$

Step 4 of 8

By using KVL,

$$V_{oc} = (10)(4) + (5)(I_1) + (20)(2)$$
$$V_{oc} = 80 + (5)(6)$$
$$V_{oc} = 110\text{V}$$

Step 5 of 8

Thevenin resistance:

By replacing current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 8

All resistors are in series and their combination is a $20+5+10=35\Omega$ resistor (Ignore 5Ω resistor since it is not connected), thus

$$R_{th} = 35\Omega$$

Step 7 of 8

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 40-V source as shown in Fig. 4.

Step 8 of 8

Figure (4)

Using KVL in Fig. 4,

$$I_A = \frac{40 - V_{oc}}{35}$$
$$I_A = \frac{40 - 110}{35}$$
$$\boxed{I_A = -2\text{A}}$$

Figure (1)

Step 2 of 9

To determine the Thevenin equivalent, break the network at the $5\text{k}\Omega$ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

By using KVL in Fig. 2,

$$40 = (6\text{k}+4\text{k})(I_1)+(8\text{k})(I_1+2\text{m})$$
$$I_1 = \frac{24}{18\text{k}}$$
$$I_1 = \frac{4}{3}\text{mA}$$

Step 4 of 9

Thus,

$$V_{oc} = -(6\text{k})(I_1)+(2\text{k})(2\text{m})-20$$
$$V_{oc} = -(6\text{k})\left(\frac{4}{3}\text{m}\right)+4-20$$
$$V_{oc} = -24\text{V}$$

Step 5 of 9

By replacing current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 9

The 8k and 4k resistors are in series and their combination is a $8\text{k}+4\text{k} = 12\text{k}\Omega$ resistor which is further in parallel with 6k resistor thus equivalent resistor has a value of $\frac{(12\text{k})(6\text{k})}{12\text{k}+6\text{k}} = 4\text{k}\Omega$ as shown in Fig. 4

Figure (4)

Step 7 of 9

All the resistors are in series and their combination is a resistor of value $4\text{k}+4\text{k}+2\text{k} = 10\text{k}\Omega$, hence

$$R_{th} = 10\text{k}\Omega$$

Step 8 of 9

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 5k load as shown in Fig. 4.

Figure (5)

Step 9 of 9

Applying voltage division in Fig. 5,

$$V_o = \left(\frac{V_{oc}}{10\text{k}+5\text{k}}\right)(5\text{k})$$
$$V_o = \left(\frac{-24}{15\text{k}}\right)(5\text{k})$$
$$\boxed{V_o = -8\text{V}}$$

Step 1 of 5

Refer to Figure E5.3 in the textbook for the circuit.

Convert 12-V voltage source into current source.

$$\begin{aligned} I &= \frac{V}{R} \\ &= \frac{12}{3\times10^3} \\ &= 4\text{ mA} \end{aligned}$$

Redraw the circuit by converting the series combination of the 12-V and $3\text{ k}\Omega$ resistor into current source in parallel with $3\text{ k}\Omega$ resistor.

Figure 1

Step 2 of 5

The equivalent combination of the two current sources is,

$$\begin{aligned} I_{eq} &= 4\times10^{-3} - 2\times10^{-3} \\ &= 2\text{ mA} \end{aligned}$$

The equivalent circuit is shown in Figure 2.

Figure 2

Step 3 of 5

Convert the 2 mA current source to voltage source.

$$\begin{aligned} V &= IR \\ &= \left(2\times10^{-3}\right)\left(3\times10^3\right) \\ &= 6\text{ V} \end{aligned}$$

Redraw the circuit in Figure 2, by converting the 2 mA current source in parallel with $3\text{ k}\Omega$ resistor into series combination of the voltage source and $3\text{ k}\Omega$ resistor.

Figure 3

Step 4 of 5

In Figure 3, the $3\text{ k}\Omega$ resistor and $4\text{ k}\Omega$ resistor are in series. The equivalent resistance of the series combination is,

$$\begin{aligned} R_{eq} &= 3\times10^3 + 4\times10^3 \\ &= 7\text{ k}\Omega \end{aligned}$$

The equivalent circuit is shown in Figure 4.

Figure 4

Step 5 of 5

From Figure 4, the output voltage is,

$$\begin{aligned} V_o &= 6\left(\frac{2\times10^3}{7\times10^3 + 2\times10^3}\right) \\ &= \frac{12}{9} \\ &= \frac{4}{3}\text{ V} \end{aligned}$$

Therefore, the output voltage, V_o is $\boxed{\frac{4}{3}\text{ V}}$.

Step 1 of 8

The following is the given circuit diagram:

Figure 1

Step 2 of 8

The contribution of 6-V source to I_A is found from the network in Figure 2, by replacing 12-V voltage source with short circuit.

Figure 2

Step 3 of 8

The 4 kΩ and 2kΩ resistors are getting shorted thus can be removed safely from network as shown in Figure 3.

Figure 3

Step 4 of 8

Now, Apply Ohm's law to calculate the current I_A'

$$I_A' = \frac{6}{8\,\text{k}}$$
$$= 0.75\ \text{mA}$$

Step 5 of 8

Next, the contribution of 12-V source to I_A is found from the network in Fig. 4 by replacing 6-V voltage source with short circuit.

Figure 4

Step 6 of 8

The 4k, 8k and 2k resistors are in parallel and their combination is a $\frac{1}{\frac{1}{2\text{k}}+\frac{1}{4\text{k}}+\frac{1}{8\text{k}}} = \frac{8}{7}\text{k}$ resistor as shown in Figure 5.

Figure 5

Step 7 of 8

Apply Kirchhoff's voltage law to calculate the current I_A''.

$$I_A'' = -\frac{12}{\left(\frac{8}{7}\text{k}\right)}$$
$$= -10.5\ \text{mA}$$

Step 8 of 8

Now, apply the principle of super position to calculate the current the unknown current I_A.

$$I_A = I_A' + I_A''$$
$$= 0.75\ \text{m} - 10.5\ \text{m}$$

Thus, the current I_A of the circuit is, $\boxed{-9.75\ \text{mA}}$.

Step 1 of 7

Refer to Figure P5.21 in the text book.

Contribution of the 6 mA current source to the output current is calculated by using Figure 1.

Figure 1

Step 2 of 7

Refer to Figure 1.

Apply Kirchhoff's voltage law at loop 1.

$$I_{01}(6000+6000)=0$$
$$I_{01}=0\text{ mA}$$

Step 3 of 7

Contribution of the 4 mA current source to the output current is calculated by using Figure 2.

Figure 2.

Step 4 of 7

Refer to Figure 2.

Apply Kirchhoff's voltage law at loop 3.

$$I_1(6000+6000)=0$$
$$I_1=0\text{ mA}$$

Calculate the value of I_{02}.

$$\begin{aligned} I_{02} &= -4(10^{-3})\left(\frac{6000}{6000+6000}\right) \\ &= -4(10^{-3})\left(\frac{1}{2}\right) \\ &= -2\text{ mA} \end{aligned}$$

Step 5 of 7

Contribution of the 12 V voltage source to the output current is calculated by using Figure 3.

Figure 3.

Step 6 of 7

Refer to Figure 3.

Apply Kirchhoff's voltage law at loop 1.

$$12+I_{03}(6000+6000)=0$$
$$I_{03}(12000)=-12$$
$$\begin{aligned} I_{03} &= \frac{-12}{12000} \\ &= -1\text{ mA} \end{aligned}$$

Step 7 of 7

Calculate the total output current from I_{01}, I_{02} and I_{03}.

$$\begin{aligned} I_0 &= I_{01}+I_{02}+I_{03} \\ &= 0-2-1 \\ &= -3\text{ mA} \end{aligned}$$

Therefore, the total output current is $\boxed{-3\text{ mA}}$.

Step 1 of 10

Refer to Figure P5.22 in the text book.

Contribution of the 6 mA current source to the output current is calculated by using Figure 1.

Figure 1

Step 2 of 10

Refer to Figure 1.

Apply Kirchhoff's current law at node 1.

$$I + I_2 = 6\left(10^{-3}\right)$$
$$I_2 = 6\left(10^{-3}\right) - I$$

Apply Kirchhoff's current law at node 2.

$$I = I_2 + I_{01}$$

Apply Kirchhoff's voltage law at loop 4.

$$3000I_{01} = 6000I_3$$
$$I_3 = \frac{1}{2}I_{01}$$

Apply Kirchhoff's current law at loop 3.

$$I_1 + I_2 = I_3$$

Step 3 of 10

Substitute $I_2 = 6\left(10^{-3}\right) - I$

$$6\left(10^{-3}\right) - I + I_2 = I_3$$

Step 4 of 10

Substitute $I = I_2 + I_{01}$

$$6\left(10^{-3}\right) - I_2 - I_{01} + I_2 = I_3$$
$$6\left(10^{-3}\right) = I_{01} + I_3$$

Step 5 of 10

Substitute, $I_3 = \frac{1}{2}I_{01}$.

$$I_{01} + \frac{1}{2}I_{01} = 6\left(10^{-3}\right)$$
$$\frac{3}{2}I_{01} = 6\left(10^{-3}\right)$$
$$I_{01} = 6\left(10^{-3}\right)\left(\frac{2}{3}\right)$$
$$= 4\text{ mA}$$

Step 6 of 10

Contribution of the 12 V voltage source to the output current is calculated by using Figure 2.

Figure 2

Step 7 of 10

Refer to Figure 2.

Apply Kirchhoff's voltage law at loop 1.

$$I_{02}(3000 + 6000) = 0$$
$$I_{02} = 0\text{ A}$$

Step 8 of 10

Contribution of the 6 V voltage source to the output current is calculated by using Figure 3.

Figure 3

Step 9 of 10

Refer to Figure 3.

Apply Kirchhoff's voltage law at loop 1.

$$6 + I_{03}(6000 + 3000) = 0$$
$$I_{03}(9000) = -6$$
$$I_{03} = \frac{-6}{9000}$$
$$= -0.67\text{ mA}$$

Step 10 of 10

Calculate the total output current from I_{01}, I_{02} and I_{03}.

$$I_o = I_{01} + I_{02} + I_{03}$$
$$= 4\text{ mA} + 0 - 0.67\text{ mA}$$
$$= 3.33\text{ mA}$$

Therefore, the total output current is $\boxed{3.33\text{ mA}}$.

Step 1 of 9

Figure (1)

Step 2 of 9

Thevenin voltage:

To determine the Thevenin equivalent, break the network at the 4kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

By using Ohm's Law in Fig. 2,

$$6 = (4k)(I_1 - 3m) + (12k+2k)(I_1 + 1m)$$
$$I_1 = \frac{4}{18k}$$
$$I_1 = \frac{2}{9}\text{mA}$$

Step 4 of 9

Thus,

$$V_{oc} = (2k)(3m) + (12k)(I_1 + 1m)$$
$$V_{oc} = 6 + (12k)\left(\frac{2}{9}m + 1m\right)$$
$$V_{oc} = \frac{62}{3}\text{V}$$

Step 5 of 9

Thevenin resistance:

By replacing voltage source with short circuit and current source with open circuit, find the Thevenin equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 9

The 2k and 4k resistors are in series and their combination is a $2k + 4k = 6k\Omega$ resistor which is further in parallel with 12k resistor thus equivalent resistance has value $\frac{(6k)(12k)}{6k+12k} = 4k\Omega$ as shown in Fig. 4

Figure (4)

Step 7 of 9

The 4k resistor is in series with 2k resistor in Fig. 4, thus

$$R_{th} = 6k\Omega$$

Step 8 of 9

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 4k load as shown in Fig. 5.

Figure (5)

Step 9 of 9

Using voltage division,

$$V_o = \left(\frac{V_{oc}}{4k + 6k}\right)(4k)$$
$$V_o = \left(\frac{\frac{62}{3}}{10k}\right)(4k)$$
$$\boxed{V_o = 8.27\text{V}}$$

Step 1 of 7

Fist, let us find the response using only the current source, and hence short circuiting the voltage sources.

Step 2 of 7

Hence

$$I_0' = 2\text{m}\left(\frac{1\text{k}}{\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}} + 1\text{k} + 4\text{k}}\right)$$

$$= 2\text{m}\left(\frac{1}{\frac{1}{2}+1+4}\right)$$

$$I_0' = \frac{4}{11}\text{mA}$$

Step 3 of 7

Now let us open the current source and short circuit the 4V source and find the response using only 2V source.

Step 4 of 7

Redrawing the circuit.

Step 5 of 7

Since it is a parallel circuit, KCL at top node,

$$\frac{V-2}{1\text{k}} + \frac{V}{1\text{k}} + \frac{V}{5\text{k}} = 0$$

$$11V = 10$$

$$V = \frac{10}{11}\text{V}$$

Hence $I_0'' = \dfrac{\frac{-10}{11}}{5\text{k}}$

$$I_0'' = \frac{-2}{11}\text{mA}$$

Step 6 of 7

Now let us find the response using only 4V source,

Step 7 of 7

Now KVL across the loop gives I_0'''

$$I_0''' = \frac{4}{\left(1\text{k}+4\text{k}+\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}}\right)}$$

$$I_0''' = \frac{8}{11}\text{mA}$$

Hence total response $I_0 = I_0' + I_0'' + I_0'''$

$$= \frac{4}{11} - \frac{2}{11} + \frac{8}{11}$$

$$\boxed{I_0 = \frac{10}{11}\text{mA}}$$

Step 1 of 5

Consider Figure P5.43 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 5

Calculate the value of the open circuit voltage from loop-1.

$$V_{oc} = (2\text{ m})(4\text{ k}) + 16 - 8$$
$$V_{oc} = 8 + 8$$
$$V_{oc} = 16\text{ V}$$

Therefore, the value of the open circuit voltage V_{oc} is 16 V .

Step 3 of 5

Disconnect the sources from the circuit diagram.

Figure 2

The resistors indicated in dotted lines are shorted. Hence, the value of the Thevenin's resistance is $4\text{ k}\Omega$.

Step 4 of 5

Draw the Thevenin's equivalent circuit.

Figure 3

Step 5 of 5

Calculate the value of the output current.

$$I_o = \frac{16}{4\text{ k} + 2\text{ k}}$$
$$= \frac{16}{6\text{ k}}$$
$$= \frac{8}{3}\text{ mA}$$

Therefore, the value of the output current I_o is $\boxed{\frac{8}{3}\text{ mA}}$.

Step 1 of 7

Fist, let us find the response using only the current source, and hence short circuiting th voltage sources.

Step 2 of 7

Hence

$$I_0' = 2\text{m}\left(\frac{1\text{k}}{\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}} + 1\text{k} + 4\text{k}}\right)$$

$$= 2\text{m}\left(\frac{1}{\frac{1}{2}+1+4}\right)$$

$$I_0' = \frac{4}{11}\text{mA}$$

Step 3 of 7

Now let us open the current source and short circuit the 4V source and find the respons using only 2V source.

Step 4 of 7

Redrawing the circuit.

Step 5 of 7

Since it is a parallel circuit, KCL at top node,

$$\frac{V-2}{1\text{k}} + \frac{V}{1\text{k}} + \frac{V}{5\text{k}} = 0$$

$$11V = 10$$

$$V = \frac{10}{11}\text{V}$$

Hence $I_0'' = \dfrac{\frac{-10}{11}}{5\text{k}}$

$$I_0'' = \frac{-2}{11}\text{mA}$$

Step 6 of 7

Now let us find the response using only 4V source,

Step 7 of 7

Now KVL across the loop gives I_0'''

$$I_0''' = \frac{4}{\left(1\text{k}+4\text{k}+\frac{1\text{k}\times 1\text{k}}{1\text{k}+1\text{k}}\right)}$$

$$I_0''' = \frac{8}{11}\text{mA}$$

Hence total response $I_0 = I_0' + I_0'' + I_0'''$

$$= \frac{4}{11} - \frac{2}{11} + \frac{8}{11}$$

$$\boxed{I_0 = \frac{10}{11}\text{mA}}$$

Step 1 of 4

5.048P

The load R_L is connected to the terminals A-B of the linear having voltage V_{AB} for the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The voltage V_{AB} across R_L in Figure 1 can be calculated by using the voltage division rule of

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V .$$

Substitute $V_x = V_{AB}$, $R_x = R_L$, $R_y = R_{TH}$, $V = V_{oc}$ from Figure 1 and solve.

$$V_{AB} = \left(\frac{R_L}{R_L + R_{TH}}\right)V_{oc}$$

$$V_{oc} = \left(\frac{R_L + R_{TH}}{R_L}\right)V_{AB} \text{ ..... (1)}$$

Initially, $8\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $16\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) \text{ ..... (2)}$$

Secondly, $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $8\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V}) \text{ ..... (3)}$$

Step 3 of 4

Now equate the equations (2) and (3) and solve for R_{TH} .

$$\left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V})$$

$$\frac{8\ \text{k}\Omega + R_{TH}}{2} = 2\ \text{k}\Omega + R_{TH}$$

$$8\ \text{k}\Omega + R_{TH} = 4\ \text{k}\Omega + 2R_{TH}$$

$$R_{TH} = 4\ \text{k}\Omega$$

Substitute $R_{TH} = 4\ \text{k}\Omega$ in equation (2) and solve for V_{oc} .

$$\begin{aligned} V_{oc} &= \left(\frac{8\ \text{k}\Omega + 4\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= \left(\frac{12\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= (1.5)(16\ \text{V}) \\ &= 24\ \text{V} \end{aligned}$$

Step 4 of 4

Now calculate the voltage V_{AB} in Figure 1 if the $20\ \text{k}\Omega$ load is connected to the terminals A-B from equation (1).

$$\begin{aligned} V_{AB} &= \left(\frac{20\ \text{k}\Omega}{20\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= \left(\frac{20\ \text{k}\Omega}{24\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= 20\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_{AB} if load of $20\ \text{k}\Omega$ is connected to terminals A-B in the circuit is $\boxed{20\ \text{V}}$

Step 1 of 4

5.049P

The load R_L having current I_o is connected to the terminals A-B of the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The current I_o is flowing in the circuit of Figure 1 and solve for V_{oc}.

$$I_o = \frac{V_{oc}}{R_{TH} + R_L}$$

$V_{oc} = I_o\left(R_{TH} + R_L\right)$ ..... (1)

Initially $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $10\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right)$ ..... (2)

Secondly $10\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $6\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)$ ..... (3)

Step 3 of 4

Now equate equations (2) and (3) and solve for R_{TH}.

$$\begin{aligned}(10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right) &= (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)\\ 10R_{TH} + 20\ \text{k}\Omega &= 6R_{TH} + 60\ \text{k}\Omega\\ 4R_{TH} &= 40\ \text{k}\Omega\\ R_{TH} &= 10\ \text{k}\Omega\end{aligned}$$

Substitute $R_{TH} = 10\ \text{k}\Omega$ in equation (2) and solve for V_{oc}.

$$\begin{aligned}V_{oc} &= (10\ \text{mA})(10\ \text{k}\Omega + 2\ \text{k}\Omega)\\ &= (10\ \text{mA})(12\ \text{k}\Omega)\\ &= 120\ \text{V}\end{aligned}$$

Step 4 of 4

Now calculate the current I_o in Figure 1 if the load resistance R_L value is $20\ \text{k}\Omega$ from equation (1).

$$\begin{aligned}I_o &= \frac{V_{oc}}{R_{TH} + R_L}\\ &= \frac{120\ \text{V}}{10\ \text{k}\Omega + 20\ \text{k}\Omega}\\ &= \frac{120\ \text{V}}{30\ \text{k}\Omega}\\ &= 4\ \text{mA}\end{aligned}$$

Therefore, the value of current I_o in a $20\ \text{k}\Omega$ load in the circuit is $\boxed{4\ \text{mA}}$.

Step 1 of 4

5.050P

The load R_L is connected to the terminals A-B of the linear having voltage V_{AB} for the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The voltage V_{AB} across R_L in Figure 1 can be calculated by using the voltage division rule of

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V .$$

Substitute $V_x = V_{AB}$, $R_x = R_L$, $R_y = R_{TH}$, $V = V_{oc}$ from Figure 1 and solve.

$$V_{AB} = \left(\frac{R_L}{R_L + R_{TH}}\right)V_{oc}$$

$$V_{oc} = \left(\frac{R_L + R_{TH}}{R_L}\right)V_{AB} \text{ ..... (1)}$$

Initially, $8\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $16\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) \text{ ..... (2)}$$

Secondly, $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $8\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V}) \text{ ..... (3)}$$

Step 3 of 4

Now equate the equations (2) and (3) and solve for R_{TH} .

$$\left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V})$$

$$\frac{8\ \text{k}\Omega + R_{TH}}{2} = 2\ \text{k}\Omega + R_{TH}$$

$$8\ \text{k}\Omega + R_{TH} = 4\ \text{k}\Omega + 2R_{TH}$$

$$R_{TH} = 4\ \text{k}\Omega$$

Substitute $R_{TH} = 4\ \text{k}\Omega$ in equation (2) and solve for V_{oc} .

$$\begin{aligned} V_{oc} &= \left(\frac{8\ \text{k}\Omega + 4\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= \left(\frac{12\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= (1.5)(16\ \text{V}) \\ &= 24\ \text{V} \end{aligned}$$

Step 4 of 4

Now calculate the voltage V_{AB} in Figure 1 if the $20\ \text{k}\Omega$ load is connected to the terminals A-B from equation (1).

$$\begin{aligned} V_{AB} &= \left(\frac{20\ \text{k}\Omega}{20\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= \left(\frac{20\ \text{k}\Omega}{24\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= 20\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_{AB} if load of $20\ \text{k}\Omega$ is connected to terminals A-B in the circuit is $\boxed{20\ \text{V}}$

Step 1 of 9

The given circuit is,

Figure (1)

Step 2 of 9

To determine the Norton equivalent, short circuit the network at the $2\text{k}\Omega$ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

Applying KVL to the loop 'acdba'

$$0 = (I_1)(3\text{k}) + (I_1 - 4\text{m})(2\text{k} + 1\text{k})$$
$$I_1 = 2\text{mA}$$

Step 4 of 9

Also, again using KVL to the loop 'abfea'

$$12 = (I_1 + I_{sc})(3\text{k})$$
$$12 = (2\text{m} + I_{sc})(3\text{k})$$
$$I_{sc} = 2\text{mA}$$

Step 5 of 9

By replacing current source with open circuit and voltage sources with short circuit, find the Norton equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 9

The 3k, 2k and 1k resistors are in series and their combination is a $3\text{k} + 2\text{k} + 1\text{k} = 6\text{k}\Omega$ resistor as shown in Fig. 4

Figure (4)

Step 7 of 9

The 6k resistor is in parallel with 3k resistor and their equivalent is a $\frac{(6\text{k})(3\text{k})}{6\text{k} + 3\text{k}} = 2\text{k}\Omega$ resistor, thus

$$R_{th} = 2\text{k}\Omega$$

Now Norton equivalent circuit consisting of R_{th} and I_{sc} is connected to the 2k load as shown in Fig. 5.

Step 8 of 9

Figure (5)

Step 9 of 9

Using current division in Fig. 5,

$$I_o = \left(\frac{I_{sc}}{2\text{k} + 2\text{k}}\right)(2\text{k})$$
$$I_o = \left(\frac{2\text{m}}{4\text{k}}\right)(2\text{k})$$
$$\boxed{I_o = 1\text{mA}}$$

Step 1 of 8

5.052P

Consider the circuit shown in Figure P5.51 in the text book.

To apply Norton's theorem first short circuit the branch having current I_o in the considered circuit as shown in Figure 1. Also the currents flowing in the loops of the circuit are shown in Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$6kI_1 = 12$$
$$I_1 = \frac{12}{6k}$$
$$= 2\text{ mA}$$

Apply Kirchhoff's current law at node 'b' in figure 1 and solve for current I_3.

$$I_3 + 1\text{ mA} = I_2$$
$$I_3 = I_2 - 1\text{ mA}$$

Step 3 of 8

Apply Kirchhoff's voltage law to the loop formed by nodes 'fedcba' in Figure 1 and solve for current I_2.

$$3kI_2 + 3kI_3 = 0$$
$$3kI_2 + (3k)(I_2 - 1\text{ mA}) = 0$$
$$3kI_2 + 3kI_2 = (3k)(1\text{ mA})$$
$$6kI_2 = 3$$

Simplify the expression further.

$$I_2 = \frac{3}{6k}$$
$$= 0.5\text{ mA}$$

Step 4 of 8

Apply Kirchhoff's current law at node 'a' in Figure 1 and calculate the value of current I_{sc}.

$$I_{sc} + I_2 = I_1$$
$$I_{sc} + 0.5\text{ mA} = 2\text{ mA}$$
$$I_{sc} = 2\text{ mA} - 0.5\text{ mA}$$
$$= 1.5\text{ mA}$$

Step 5 of 8

Let the Thevenin's resistance be R_{TH} and now the voltage sources be short circuited and current sources be open circuited for the considered circuit of Figure P5.51 in the text book as shown in Figure 2.

Figure 2

Step 6 of 8

Calculate the value of R_{TH} from Figure 2 having resistors connected in parallel by using the formula $R = \frac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_{TH}$, $R_x = 6\text{ k}\Omega$, $R_y = 3\text{ k}\Omega + 3\text{ k}\Omega$ from Figure 4 and solve for R_{TH}.

$$R_{TH} = \frac{(6\text{ k}\Omega)(3\text{ k}\Omega + 3\text{ k}\Omega)}{6\text{ k}\Omega + 3\text{ k}\Omega + 3\text{ k}\Omega}$$
$$= \frac{(6\text{ k}\Omega)(6\text{ k}\Omega)}{12\text{ k}\Omega}$$
$$= \frac{6\text{ k}\Omega}{2}$$
$$= 3\text{ k}\Omega$$

Step 7 of 8

Now draw the Norton's equivalent circuit as shown in Figure 3.

Figure 3

Step 8 of 8

Calculate the value of current I_o in Figure 3 by using current division formula $I_x = \left(\frac{R_y}{R_x + R_y}\right) I$.

Substitute $I_x = I_o$, $R_x = 3\text{ k}\Omega$, $R_y = 3\text{ k}\Omega$, $I = I_{sc}$ from Figure 5 and solve for I_o.

$$I_o = \left(\frac{3\text{ k}\Omega}{3\text{ k}\Omega + 3\text{ k}\Omega}\right)(1.5\text{ mA})$$
$$= \left(\frac{3\text{ k}\Omega}{6\text{ k}\Omega}\right)(1.5\text{ mA})$$
$$= \left(\frac{1}{2}\right)(1.5\text{ mA})$$
$$= 0.75\text{ mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{0.75\text{ mA}}$.

Step 1 of 4

The load R_L is connected to the terminals A-B of the linear having voltage V_{AB} for the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The voltage V_{AB} across R_L in Figure 1 can be calculated by using the voltage division rule of

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V .$$

Substitute $V_x = V_{AB}$, $R_x = R_L$, $R_y = R_{TH}$, $V = V_{oc}$ from Figure 1 and solve.

$$V_{AB} = \left(\frac{R_L}{R_L + R_{TH}}\right)V_{oc}$$

$$V_{oc} = \left(\frac{R_L + R_{TH}}{R_L}\right)V_{AB} \text{ ..... (1)}$$

Initially, $8\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $16\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) \text{ ..... (2)}$$

Secondly, $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $8\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V}) \text{ ..... (3)}$$

Step 3 of 4

Now equate the equations (2) and (3) and solve for R_{TH} .

$$\left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V})$$

$$\frac{8\ \text{k}\Omega + R_{TH}}{2} = 2\ \text{k}\Omega + R_{TH}$$

$$8\ \text{k}\Omega + R_{TH} = 4\ \text{k}\Omega + 2R_{TH}$$

$$R_{TH} = 4\ \text{k}\Omega$$

Substitute $R_{TH} = 4\ \text{k}\Omega$ in equation (2) and solve for V_{oc} .

$$\begin{aligned} V_{oc} &= \left(\frac{8\ \text{k}\Omega + 4\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= \left(\frac{12\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= (1.5)(16\ \text{V}) \\ &= 24\ \text{V} \end{aligned}$$

Step 4 of 4

Now calculate the voltage V_{AB} in Figure 1 if the $20\ \text{k}\Omega$ load is connected to the terminals A-B from equation (1).

$$\begin{aligned} V_{AB} &= \left(\frac{20\ \text{k}\Omega}{20\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= \left(\frac{20\ \text{k}\Omega}{24\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= 20\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_{AB} if load of $20\ \text{k}\Omega$ is connected to terminals A-B in the circuit is $\boxed{20\ \text{V}}$

Step 1 of 4

The load R_L having current I_o is connected to the terminals A-B of the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The current I_o is flowing in the circuit of Figure 1 and solve for V_{oc}.

$$I_o = \frac{V_{oc}}{R_{TH} + R_L}$$

$V_{oc} = I_o\left(R_{TH} + R_L\right)$ ..... (1)

Initially $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $10\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right)$ ..... (2)

Secondly $10\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $6\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)$ ..... (3)

Step 3 of 4

Now equate equations (2) and (3) and solve for R_{TH}.

$$\begin{aligned}(10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right) &= (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)\\ 10R_{TH} + 20\ \text{k}\Omega &= 6R_{TH} + 60\ \text{k}\Omega\\ 4R_{TH} &= 40\ \text{k}\Omega\\ R_{TH} &= 10\ \text{k}\Omega\end{aligned}$$

Substitute $R_{TH} = 10\ \text{k}\Omega$ in equation (2) and solve for V_{oc}.

$$\begin{aligned}V_{oc} &= (10\ \text{mA})(10\ \text{k}\Omega + 2\ \text{k}\Omega)\\ &= (10\ \text{mA})(12\ \text{k}\Omega)\\ &= 120\ \text{V}\end{aligned}$$

Step 4 of 4

Now calculate the current I_o in Figure 1 if the load resistance R_L value is $20\ \text{k}\Omega$ from equation (1).

$$\begin{aligned}I_o &= \frac{V_{oc}}{R_{TH} + R_L}\\ &= \frac{120\ \text{V}}{10\ \text{k}\Omega + 20\ \text{k}\Omega}\\ &= \frac{120\ \text{V}}{30\ \text{k}\Omega}\\ &= 4\ \text{mA}\end{aligned}$$

Therefore, the value of current I_o in a $20\ \text{k}\Omega$ load in the circuit is $\boxed{4\ \text{mA}}$.

Step 1 of 4

The load R_L is connected to the terminals A-B of the linear having voltage V_{AB} for the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The voltage V_{AB} across R_L in Figure 1 can be calculated by using the voltage division rule of

$$V_x = \left(\frac{R_x}{R_x + R_y}\right)V .$$

Substitute $V_x = V_{AB}$, $R_x = R_L$, $R_y = R_{TH}$, $V = V_{oc}$ from Figure 1 and solve.

$$V_{AB} = \left(\frac{R_L}{R_L + R_{TH}}\right)V_{oc}$$

$$V_{oc} = \left(\frac{R_L + R_{TH}}{R_L}\right)V_{AB} \text{ ..... (1)}$$

Initially, $8\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $16\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) \text{ ..... (2)}$$

Secondly, $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in voltage V_{AB} of $8\ \text{V}$.

Calculate the value of V_{oc} from equation (1).

$$V_{oc} = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V}) \text{ ..... (3)}$$

Step 3 of 4

Now equate the equations (2) and (3) and solve for R_{TH} .

$$\left(\frac{8\ \text{k}\Omega + R_{TH}}{8\ \text{k}\Omega}\right)(16\ \text{V}) = \left(\frac{2\ \text{k}\Omega + R_{TH}}{2\ \text{k}\Omega}\right)(8\ \text{V})$$

$$\frac{8\ \text{k}\Omega + R_{TH}}{2} = 2\ \text{k}\Omega + R_{TH}$$

$$8\ \text{k}\Omega + R_{TH} = 4\ \text{k}\Omega + 2R_{TH}$$

$$R_{TH} = 4\ \text{k}\Omega$$

Substitute $R_{TH} = 4\ \text{k}\Omega$ in equation (2) and solve for V_{oc} .

$$\begin{aligned} V_{oc} &= \left(\frac{8\ \text{k}\Omega + 4\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= \left(\frac{12\ \text{k}\Omega}{8\ \text{k}\Omega}\right)(16\ \text{V}) \\ &= (1.5)(16\ \text{V}) \\ &= 24\ \text{V} \end{aligned}$$

Step 4 of 4

Now calculate the voltage V_{AB} in Figure 1 if the $20\ \text{k}\Omega$ load is connected to the terminals A-B from equation (1).

$$\begin{aligned} V_{AB} &= \left(\frac{20\ \text{k}\Omega}{20\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= \left(\frac{20\ \text{k}\Omega}{24\ \text{k}\Omega}\right)(24\ \text{V}) \\ &= 20\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_{AB} if load of $20\ \text{k}\Omega$ is connected to terminals A-B in the circuit is $\boxed{20\ \text{V}}$

Step 1 of 9

The given circuit is,

Figure (1)

Step 2 of 9

To determine the Norton equivalent, short circuit the network at the $2\text{k}\Omega$ load as shown in Fig. 2.

Figure (2)

Step 3 of 9

Applying KVL to the loop 'acdba'

$$0 = (I_1)(3\text{k}) + (I_1 - 4\text{m})(2\text{k} + 1\text{k})$$
$$I_1 = 2\text{mA}$$

Step 4 of 9

Also, again using KVL to the loop 'abfea'

$$12 = (I_1 + I_{sc})(3\text{k})$$
$$12 = (2\text{m} + I_{sc})(3\text{k})$$
$$I_{sc} = 2\text{mA}$$

Step 5 of 9

By replacing current source with open circuit and voltage sources with short circuit, find the Norton equivalent resistance as shown in Fig. 3,

Figure (3)

Step 6 of 9

The 3k, 2k and 1k resistors are in series and their combination is a $3\text{k} + 2\text{k} + 1\text{k} = 6\text{k}\Omega$ resistor as shown in Fig. 4

Figure (4)

Step 7 of 9

The 6k resistor is in parallel with 3k resistor and their equivalent is a $\frac{(6\text{k})(3\text{k})}{6\text{k} + 3\text{k}} = 2\text{k}\Omega$ resistor, thus

$$R_{th} = 2\text{k}\Omega$$

Now Norton equivalent circuit consisting of R_{th} and I_{sc} is connected to the 2k load as shown in Fig. 5.

Step 8 of 9

Figure (5)

Step 9 of 9

Using current division in Fig. 5,

$$I_o = \left(\frac{I_{sc}}{2\text{k} + 2\text{k}}\right)(2\text{k})$$
$$I_o = \left(\frac{2\text{m}}{4\text{k}}\right)(2\text{k})$$
$$\boxed{I_o = 1\text{mA}}$$

Step 1 of 7

Consider the circuit shown in Figure P5.52 in the text book.

To apply Norton's theorem first short circuit the branch having current I_o in the considered circuit as shown in Figure 1.

Also the currents flowing in the loops of the circuit are shown in Figure 1.

Figure 1

Step 2 of 7

Calculate the value of current I_1 in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_1$, $V = -12\text{ V}$, $R = 2\text{ k}\Omega$ from Figure 1 and solve for I_1.

$$\begin{aligned} I_1 &= \frac{-12\text{ V}}{2\text{ k}\Omega} \\ &= -6\text{ mA} \end{aligned}$$

Calculate the value of current I_2 from Figure 1.

$$I_3 - I_2 = 4\text{ mA}$$

$$I_2 = I_3 - 4\text{ mA} \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the outer loop of circuit in Figure 1 and solve for current I_3 by using equation (1).

$$\begin{aligned} &2\text{k}I_1 + 12 + 4\text{k}I_2 + 2\text{k}I_3 + 4\text{k}I_3 = 0 \\ &(2\text{k})(-6\text{m}) + 12 + (4\text{k})(I_3 - 4\text{m}) + 8\text{k}I_3 = 0 \\ &-12 + 12 + 4\text{k}I_3 - 16 + 8\text{k}I_3 = 0 \\ &12\text{k}I_3 = 16 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} I_3 &= \frac{16}{12\text{k}} \\ &= \frac{4}{3}\text{ mA} \end{aligned}$$

Step 3 of 7

Calculate the value of current I_2 from equation (1).

$$\begin{aligned} I_2 &= I_3 - 4\text{ mA} \\ &= \frac{4}{3}\text{ mA} - 4\text{ mA} \\ &= -\frac{8}{3}\text{ mA} \end{aligned}$$

Calculate the value of current I_{sc} in Figure 1 by applying Kirchhoff's current law at node 'a'.

$$I_{sc} + I_2 = I_1$$

$$\begin{aligned} I_{sc} &= I_1 - I_2 \\ &= -6\text{ mA} + \frac{8}{3}\text{ mA} \\ &= -\frac{10}{3}\text{ mA} \\ &= -3.33\text{ mA} \end{aligned}$$

Step 4 of 7

Now short circuit the voltage sources and open circuit the current sources in Figure 1 to calculate the value of R_{TH} as shown in Figure 2.

Figure 2

Step 5 of 7

Calculate the value of R_{TH} in Figure 2 for resistors connected in parallel by using the formula $R = \frac{R_x R_y}{R_x + R_y}$.

Substitute $R = R_{TH}$, $R_x = 2\text{ k}\Omega$, $R_y = (4\text{ k}\Omega + 2\text{ k}\Omega + 4\text{ k}\Omega)$ from Figure 2 and solve for R_{TH}.

$$\begin{aligned} R_{TH} &= \frac{(2\text{ k}\Omega)(2\text{ k}\Omega + 4\text{ k}\Omega + 4\text{ k}\Omega)}{2\text{ k}\Omega + 2\text{ k}\Omega + 4\text{ k}\Omega + 4\text{ k}\Omega} \\ &= \frac{(2\text{ k}\Omega)(10\text{ k}\Omega)}{12\text{ k}\Omega} \\ &= \frac{10\text{ k}\Omega}{6} \\ &= 1.667\text{ k}\Omega \end{aligned}$$

Step 6 of 7

Now draw the Norton's equivalent circuit as shown in Figure 3.

Figure 3

Step 7 of 7

Calculate the value of current I_o in Figure 3 by using current division formula $I_x = \left(\frac{R_y}{R_x + R_y}\right) I$.

Substitute $I_x = I_o$, $R_x = 2\text{ k}\Omega$, $R_y = R_{TH}$, $I = I_{sc}$ from Figure 3 and solve for I_o.

$$\begin{aligned} I_o &= \left(\frac{1.667\text{ k}\Omega}{2\text{ k}\Omega + 1.667\text{ k}\Omega}\right)\left(-\frac{10}{3}\text{ mA}\right) \\ &= \left(\frac{1.667\text{ k}\Omega}{3.667\text{ k}\Omega}\right)\left(-\frac{10}{3}\text{ mA}\right) \\ &= (0.454)\left(-\frac{10}{3}\text{ mA}\right) \\ &= -1.51\text{ mA} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{-1.51\text{ mA}}$.

Step 1 of 4

5.058P

The load R_L having current I_o is connected to the terminals A-B of the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 4

The current I_o is flowing in the circuit of Figure 1 and solve for V_{oc}.

$$I_o = \frac{V_{oc}}{R_{TH} + R_L}$$

$V_{oc} = I_o\left(R_{TH} + R_L\right)$ ..... (1)

Initially $2\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $10\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right)$ ..... (2)

Secondly $10\ \text{k}\Omega$ load is connected to the terminals A-B in Figure 1 and resulted in load current of $6\ \text{mA}$.

Calculate the value of V_{oc} from equation (1).

$V_{oc} = (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)$ ..... (3)

Step 3 of 4

Now equate equations (2) and (3) and solve for R_{TH}.

$$\begin{aligned}(10\ \text{mA})\left(R_{TH} + 2\ \text{k}\Omega\right) &= (6\ \text{mA})\left(R_{TH} + 10\ \text{k}\Omega\right)\\ 10R_{TH} + 20\ \text{k}\Omega &= 6R_{TH} + 60\ \text{k}\Omega\\ 4R_{TH} &= 40\ \text{k}\Omega\\ R_{TH} &= 10\ \text{k}\Omega\end{aligned}$$

Substitute $R_{TH} = 10\ \text{k}\Omega$ in equation (2) and solve for V_{oc}.

$$\begin{aligned}V_{oc} &= (10\ \text{mA})(10\ \text{k}\Omega + 2\ \text{k}\Omega)\\ &= (10\ \text{mA})(12\ \text{k}\Omega)\\ &= 120\ \text{V}\end{aligned}$$

Step 4 of 4

Now calculate the current I_o in Figure 1 if the load resistance R_L value is $20\ \text{k}\Omega$ from equation (1).

$$\begin{aligned}I_o &= \frac{V_{oc}}{R_{TH} + R_L}\\ &= \frac{120\ \text{V}}{10\ \text{k}\Omega + 20\ \text{k}\Omega}\\ &= \frac{120\ \text{V}}{30\ \text{k}\Omega}\\ &= 4\ \text{mA}\end{aligned}$$

Therefore, the value of current I_o in a $20\ \text{k}\Omega$ load in the circuit is $\boxed{4\ \text{mA}}$.

Step 1 of 8

Refer to Figure P5.57 in the textbook.

Disconnect the load resistor and short the terminals to calculate the short circuit current.

Figure 1

Step 2 of 8

Apply Kirchhoff's voltage law to loop-3.

$$(I_3 - I_1)(6\ \text{k}\Omega) = 0$$
$$I_3 - I_1 = 0$$
$$I_3 = I_1$$

Therefore, the expression for the current I_3 is I_1.

Consider the relation between the currents I_1 and I_2.

$$I_2 - I_1 = 2\ \text{mA}$$
$$I_2 = I_1 + 2\ \text{mA}$$

Substitute I_3 for I_1.

$$I_2 = I_3 + 2\ \text{mA}$$

Therefore, the expression for the current I_2 is $I_3 + 2\ \text{mA}$.

Step 3 of 8

Apply super mesh analysis for the loops 1 and 2.

$$-24 + (I_1 - I_3)(6\ \text{k}\Omega) + I_2(3\ \text{k}\Omega) = 0$$

Substitute I_3 for I_1 and $I_3 + 2\ \text{mA}$ for I_2.

$$-24 + (I_3 - I_3)(6\ \text{k}\Omega) + (I_3 + 2\ \text{mA})(3\ \text{k}\Omega) = 0$$
$$-24 + I_3(3\ \text{k}\Omega) + 6 = 0$$
$$I_3(3\ \text{k}\Omega) = 24 - 6$$
$$I_3(3\ \text{k}\Omega) = 18$$

$$I_3 = \frac{18}{3\ \text{k}\Omega}$$
$$I_3 = 6\ \text{mA}$$

Therefore, the value of the current I_3 is $6\ \text{mA}$.

Step 4 of 8

Apply super mesh analysis in Loops 4 and 5.

$$(I_4)(2\ \text{k}\Omega) = 0$$
$$I_4 = 0$$

Therefore, the value of the current I_4 is $0\ \text{A}$.

Consider the relation between the currents I_4 and I_5.

$$I_4 + I_5 = 2\ \text{mA}$$

Substitute $0\ \text{A}$ for I_4.

$$I_5 = 2\ \text{mA}$$

Therefore, the value of the current I_5 is $2\ \text{mA}$.

Calculate the value of the short circuit current I_{SC}.

$$I_{SC} = I_3 + I_5$$

Substitute $2\ \text{mA}$ for I_5 and $6\ \text{mA}$ for I_3.

$$I_{SC} = 2\ \text{mA} + 6\ \text{mA}$$
$$= 8\ \text{mA}$$

Therefore, the value of the short circuit current I_{SC} is $8\ \text{mA}$.

Step 5 of 8

Deactivate the sources from the circuit.

Figure 2

Step 6 of 8

Calculate the value of the Norton's resistance.

$$R_N = 6\ \text{k}\Omega \| 3\ \text{k}\Omega \| 2\ \text{k}\Omega$$
$$= \frac{(6\ \text{k}\Omega)(3\ \text{k}\Omega)(2\ \text{k}\Omega)}{(6\ \text{k}\Omega)(3\ \text{k}\Omega) + (3\ \text{k}\Omega)(2\ \text{k}\Omega) + (6\ \text{k}\Omega)(2\ \text{k}\Omega)}$$
$$= \frac{36}{18 + 6 + 12}$$
$$= 1\ \text{k}\Omega$$

Therefore, the value of the Norton's resistance is $1\ \text{k}\Omega$.

Step 7 of 8

Draw the Norton's equivalent circuit.

Figure 3

Step 8 of 8

Calculate the value of the output current using current division rule.

$$I_o = (8\ \text{mA})\left(\frac{1\ \text{k}\Omega}{1\ \text{k}\Omega + 4\ \text{k}\Omega}\right)$$
$$= (8\ \text{mA})\left(\frac{1\ \text{k}\Omega}{5\ \text{k}\Omega}\right)$$
$$= (8\ \text{mA})\left(\frac{1}{5}\right)$$
$$= 1.6\ \text{mA}$$

Therefore, the value of the output current I_o is $\boxed{1.6\ \text{mA}}$.

Step 1 of 11

Figure (1)

Step 2 of 11

To find open circuit voltage, break the network at the 2kΩ load as shown in Fig. 2.

Figure (2)

Step 3 of 11

Using Ohm's Law,

$$V_x' = (I_1)(2k) \qquad ...(1)$$

Applying KVL,

$$20 = (I_1)(2k+4k)+2V_x' \qquad ...(2)$$
$$20 = I_1(6k)+4kI_1$$
$$20 = 10kI_1$$
$$I_1 = 2mA$$
$$V_x' = (2m)(2k)$$
$$V_x' = 4V$$

Step 4 of 11

Hence ,

$$V_{oc} = 20 - V_x'$$
$$V_{oc} = 20 - 4$$
$$V_{oc} = 16V$$

Step 5 of 11

To find short circuit current, short circuit the network at 2kΩ load as shown in Fig. 3

Figure (3)

Step 6 of 11

Applying KVL,

$$20 = (2k)(I_2)$$
$$I_2 = 10mA$$

Using Ohm's Law,

$$V_x'' = (2k)(I_2)$$
$$V_x'' = (2k)(10m)$$
$$V_x'' = 20V$$

Step 7 of 11

Again applying KVL,

$$2V_x'' = (4k)(I_3)$$
$$I_3 = \frac{40}{4k}$$
$$I_3 = 10mA$$

Step 8 of 11

Hence,

$$I_{sc} = I_2 + I_3$$
$$I_{sc} = 10m + 10m$$
$$I_{sc} = 20mA$$

Step 9 of 11

Now,

$$R_{th} = \frac{V_{oc}}{I_{sc}}$$
$$R_{th} = \frac{16}{20m}$$
$$R_{th} = 0.8k\Omega$$

Step 10 of 11

Now Thevenin equivalent circuit consisting of R_{th} and V_{oc} is connected to the 2kΩ load as shown in Fig. 4.

Figure (4)

Step 11 of 11

Using KVL in Fig. 4,

$$I_o = \frac{V_{oc}}{0.8k + 2k}$$
$$I_o = \frac{16}{2.8k}$$
$$\boxed{I_o = 5.71mA}$$

Step 1 of 5

Refer to Figure P5.59 in the textbook.

Open circuit the network at $4\ \text{k}\Omega$ load to find open circuit voltage.

Figure 1

Step 2 of 5

Apply Kirchhoff's voltage law to the circuit in Figure 1.

$$-12+(4\ \text{k}\Omega)I_1+(2\ \text{k}\Omega)I_1=0$$
$$I_1(4\ \text{k}\Omega+2\ \text{k}\Omega)=12$$

$$I_1=\frac{12\ \text{V}}{6\ \text{k}\Omega}$$
$$=2\ \text{mA}$$

Use Ohm's law to find the voltage V_A' in the circuit.

$$V_A'=I_1(4\ \text{k}\Omega)$$
$$=(2\ \text{mA})(4\ \text{k}\Omega)$$
$$=8\ \text{V}$$

Find the open circuit voltage, V_{oc} .

$$V_{oc}=(2\ \text{k}\Omega)I_1-2V_A'$$
$$=(2\ \text{k}\Omega)(2\ \text{mA})-2(8\ \text{V})$$
$$=4\ \text{V}-16\ \text{V}$$
$$=-12\ \text{V}$$

Step 3 of 5

Short the network at $4\ \text{k}\Omega$ load to find short circuit current.

Figure 2

Step 4 of 5

Use Ohm's law to find the voltage V_A'' in the circuit.

$$V_A''=(I_2+I_{sc})(4\ \text{k}\Omega)$$

Apply Kirchhoff's voltage law to the right loop of the circuit in Figure 2.

$$(2\ \text{k}\Omega)I_2=2V_A''$$

Substitute the expression for V_A'' .

$$(2\ \text{k}\Omega)I_2=2(4\ \text{k}\Omega)(I_2+I_{sc})$$
$$(2\ \text{k}\Omega)I_2-(8\ \text{k}\Omega)I_2=(8\ \text{k}\Omega)(I_{sc})$$
$$-(6\ \text{k}\Omega)I_2=(8\ \text{k}\Omega)I_{sc}$$
$$I_2=-1.34I_{sc}$$

Apply Kirchhoff's voltage law to the left loop of the circuit in Figure 2.

$$12=(4\ \text{k}\Omega)(I_{sc}+I_2)+(2\ \text{k}\Omega)I_2$$

Substitute the expression for I_2 .

$$12=(4\ \text{k}\Omega)(I_{sc}-1.34I_{sc})+(2\ \text{k}\Omega)(-1.34)I_{sc}$$
$$12=(4\ \text{k}\Omega)I_{sc}-(5.34\ \text{k}\Omega)I_{sc}-(2.67\ \text{k}\Omega)I_{sc}$$
$$-(4\ \text{k}\Omega)I_{sc}=12$$
$$I_{sc}=-3\ \text{mA}$$

Find the Thevenin's equivalent resistance.

$$R_{th}=\frac{V_{oc}}{I_{sc}}$$
$$=\frac{-12\ \text{V}}{-3\ \text{mA}}$$
$$=4\ \text{k}\Omega$$

Step 5 of 5

Draw the Thevenin equivalent circuit consisting of R_{th} and V_{oc} connected to the $4\ \text{k}\Omega$ load resistance.

Figure 3

Use voltage division method to find the output voltage.

$$V_o=V_{oc}\left(\frac{4\ \text{k}\Omega}{4\ \text{k}\Omega+4\ \text{k}\Omega}\right)$$
$$=(-12\ \text{V})\left(\frac{4\ \text{k}\Omega}{8\ \text{k}\Omega}\right)$$
$$=-6\ \text{V}$$

Thus, the output voltage, V_o is, $\boxed{-6\ \text{V}}$.

Step 1 of 4

Consider the circuit shown in Figure P5.60 in the text book.

Let the open circuit voltage V_{oc} present across the $1\ \text{k}\Omega$ resistor having voltage V_o in the considered circuit as shown in Figure 1.

Figure 1

The value of open circuit voltage from Figure 1 is $6\ \text{V}$.

$V_{oc} = 6\ \text{V}$

Step 2 of 4

In the circuit of Figure P5.60 in the text book, short circuit the branch having resistance of $1\ \text{k}\Omega$ with voltage V_o as shown in Figure 2.

Figure 2

The value of current I_x is equal to I_{sc} .

Apply Kirchhoff's current law at node 'a' in Figure 2 and solve.

$$I + 2I_x = I_x$$
$$I = I_x - 2I_x$$
$$I = -I_x$$

Apply Kirchhoff's voltage law to the outer loop of the circuit in Figure 2 and solve for current I_x .

$$1\text{k}I + 2\text{k}I_x - 6 = 0$$
$$1\text{k}(-I_x) + 2\text{k}I_x - 6$$
$$1\text{k}I_x = 6$$
$$I_x = 6\ \text{mA}$$

Therefore, the value of current I_{sc} is also $6\ \text{mA}$.

Step 3 of 4

Now, calculate the value of Thevenin's resistance R_{TH} by using the formula $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH} .

$$\begin{aligned} R_{TH} &= \frac{V_{oc}}{I_{sc}} \\ &= \frac{6\ \text{V}}{6\ \text{mA}} \\ &= 1\ \text{k}\Omega \end{aligned}$$

Step 4 of 4

The Thevenin's circuit is drawn as shown in Figure 3.

Figure 3

Calculate the value of voltage V_o in Figure 3 by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = V_o$, $R_x = 1\ \text{k}\Omega$, $R_y = R_{TH}$, $V = 6\ \text{V}$ from Figure 3 and solve for V_o .

$$\begin{aligned} V_o &= \left(\frac{1\ \text{k}\Omega}{1\ \text{k}\Omega + 1\ \text{k}\Omega}\right)(6\ \text{V}) \\ &= \left(\frac{1\ \text{k}\Omega}{2\ \text{k}\Omega}\right)(6\ \text{V}) \\ &= \left(\frac{1}{2}\right)(6\ \text{V}) \\ &= 3\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{3\ \text{V}}$.

Step 1 of 7

5.067P

Consider the circuit shown in Figure P5.61 in the text book.

Let the open circuit voltage V_{oc} present across the $2\ \text{k}\Omega$ resistance having current I_o in the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 7

Calculate the value of voltage V_x in Figure 1 by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $R_x = 4\ \text{k}\Omega$, $R_y = 8\ \text{k}\Omega$, $V = 12\ \text{V}$ from Figure 1 and solve for voltage V_x.

$$\begin{aligned} V_x &= \left(\frac{4\ \text{k}\Omega}{4\ \text{k}\Omega + 8\ \text{k}\Omega}\right)(12\ \text{V}) \\ &= \left(\frac{4\ \text{k}\Omega}{12\ \text{k}\Omega}\right)(12\ \text{V}) \\ &= \left(\frac{1}{3}\right)(12\ \text{V}) \\ &= 4\ \text{V} \end{aligned}$$

Step 3 of 7

Calculate the value of voltage V_y in Figure 1 by using voltage division rule $V_y = \left(\frac{R_y}{R_x + R_y}\right)V$.

Substitute $R_y = 4\ \text{k}\Omega$, $R_x = 12\ \text{k}\Omega$, $V = 2V_x$ from Figure 1 and solve for voltage V_y.

$$\begin{aligned} V_y &= \left(\frac{4\ \text{k}\Omega}{12\ \text{k}\Omega + 8\ \text{k}\Omega}\right)(2V_x) \\ &= \left(\frac{4\ \text{k}\Omega}{16\ \text{k}\Omega}\right)(2)(4\ \text{V}) \\ &= \left(\frac{1}{4}\right)(2)(4\ \text{V}) \\ &= 2\ \text{V} \end{aligned}$$

Now calculate the value of open circuit voltage V_{oc} in Figure 1.

$$\begin{aligned} V_{oc} &= V_x - V_y \\ &= 4\ \text{V} - 2\ \text{V} \\ &= 2\ \text{V} \end{aligned}$$

Step 4 of 7

Now, short circuit the $2\ \text{k}\Omega$ resistance branch having current I_o in Figure P5.61 in the text book is shown in Figure 2.

Figure 2

Apply Kirchhoff's current law at node 'a' in Figure 2 and solve for voltage V_x.

$$\frac{V_x - 12}{8\text{k}} + \frac{V_x}{4\text{k}} + \frac{V_x}{4\text{k}} + \frac{V_x - 2V_x}{12\text{k}} = 0$$

$$\frac{3(V_x - 12)}{24} + \frac{6V_x}{24} + \frac{6V_x}{24} + \frac{2(-V_x)}{24} = 0$$

$$3V_x - 36 + 6V_x + 6V_x - 2V_x = 0$$

$$13V_x = 36$$

Simplify the expression further.

$$V_x = \frac{36}{13}$$

$$V_x = 2.77\ \text{V}$$

Step 5 of 7

Now apply Kirchhoff's current law at node 'a' and solve for current I_{sc} in Figure 2.

$$\begin{aligned} I_{sc} &= I - I_1 \\ &= \frac{12 - V_x}{8\text{k}} - \frac{V_x}{4\text{k}} \\ &= \frac{12 - 2.77}{8\text{k}} - \frac{2.77}{4\text{k}} \\ &= \frac{9.23}{8\text{k}} - \frac{2.77}{4\text{k}} \end{aligned}$$

Step 6 of 7

Simplify the expression further.

$$\begin{aligned} I_{sc} &= 1.153\text{m} - 0.7\text{m} \\ &= 0.453\ \text{mA} \end{aligned}$$

Now calculate the value of Thevenin's resistance R_{TH} by using Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$\begin{aligned} R_{TH} &= \frac{V_{oc}}{I_{sc}} \\ &= \frac{2\ \text{V}}{0.453\ \text{mA}} \\ &= 4.4\ \text{k}\Omega \end{aligned}$$

Step 7 of 7

Now draw the Thevenin's equivalent circuit as shown in Figure 3.

Figure 3

Calculate the value of current I_o in Figure 3 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_{oc}$, $R = R_{TH} + 2\ \text{k}\Omega$ and solve for I_o.

$$\begin{aligned} I_o &= \frac{V_{oc}}{R_{TH} + 2\ \text{k}\Omega} \\ &= \frac{2\ \text{V}}{4.4\ \text{k}\Omega + 2\ \text{k}\Omega} \\ &= \frac{2\ \text{V}}{6.4\ \text{k}\Omega} \\ &= 0.3125\ \text{mA} \end{aligned}$$

Therefore, the value of current I_o in the circuit is $\boxed{0.3125\ \text{mA}}$.

Step 1 of 9

Consider the circuit shown in Figure P5.62 in the text book.

Let the open circuit voltage V_{oc} present across $1\ \text{k}\Omega$ resistor having voltage V_o in the considered circuit as shown in Figure 1.

Figure 1

The nodes V_1 and V_2 in Figure 1 forms a super node.

$V_1 = V_2 - 12$ ..... (1)

Calculate the value of current I_x in Figure 1 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = V_2$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for I_x.

$$I_x = \frac{V_2}{1\ \text{k}\Omega}$$

Step 2 of 9

Now apply Kirchhoff's current law at super node in Figure 1 and solve by using equation (1).

$$2I_x + \frac{V_1}{1\text{k}} + \frac{V_2}{1\text{k}} + \frac{V_2 - V_{oc}}{1\text{k}} = 0$$
$$2\left(\frac{V_2}{1\text{k}}\right) + \frac{V_2 - 12}{1\text{k}} + \frac{V_2}{1\text{k}} + \frac{V_2 - V_{oc}}{1\text{k}} = 0$$
$$5V_2 - V_{oc} = 12$$
$$V_2 = \frac{V_{oc} + 12}{5} \text{ ..... (2)}$$

Step 3 of 9

Apply Kirchhoff's current law at node V_{oc} in Figure 1 and solve by using equation (2).

$$\frac{V_{oc} - V_2}{1\text{k}} = 0$$
$$V_{oc} - \frac{V_{oc} + 12}{5} = 0$$
$$5V_{oc} - V_{oc} = 12$$
$$V_{oc} = 3\ \text{V}$$

Step 4 of 9

Now short circuit the $1\ \text{k}\Omega$ resistance having voltage V_o in Figure P5.62 in the text book as shown in Figure 2. Also the currents flowing in the loops of the circuit is shown in Figure 2.

Figure 2

Step 5 of 9

The value of current I_x in Figure 2 is $I_2 - I_3$.

Calculate the value of current I_1 in figure 2.

$$\begin{aligned} I_1 &= -2I_x \\ &= -2(I_2 - I_3) \\ &= -2I_2 + 2I_3 \end{aligned}$$

Now apply Kirchhoff's voltage law to the loop having current I_2 in Figure 2 and solve.

$$1\text{k}(I_2 - I_1) - 12 + 1\text{k}(I_2 - I_3) = 0$$
$$2kI_2 - 1kI_1 - 1kI_3 = 12$$
$$2kI_2 - (1\text{k})(-2I_2 + 2I_3) - 1kI_3 = 12$$
$$2kI_2 + 2kI_2 - 2kI_3 - 1kI_3 = 12$$

Simplify the expression further.

$$4kI_2 = 12 + 3kI_3$$
$$I_2 = \frac{3kI_3 + 12}{4\text{k}}$$

Step 6 of 9

Now apply Kirchhoff's voltage law to the loop having current I_3 in Figure 2 and solve.

$$1\text{k}(I_3 - I_2) + 1kI_3 = 0$$
$$2kI_3 - 1kI_2 = 0$$
$$2kI_3 - 1\text{k}\left(\frac{3kI_3 + 12}{4\text{k}}\right) = 0$$
$$8kI_3 - 3kI_3 - 12 = 0$$

Step 7 of 9

Simplify the expression further.

$$5kI_3 = 12$$
$$\begin{aligned} I_3 &= \frac{12}{5\text{k}} \\ &= 2.4\ \text{mA} \end{aligned}$$

The value of current I_{sc} from Figure 2 is equal to $2.4\ \text{mA}$.

Step 8 of 9

Calculate the value of Thevenin's resistance R_{TH}.

$$\begin{aligned} R_{TH} &= \frac{V_{oc}}{I_{sc}} \\ &= \frac{3\ \text{V}}{2.4\ \text{mA}} \\ &= 1250\ \Omega \end{aligned}$$

Step 9 of 9

The Thevenin's equivalent circuit for the considered circuit is shown in Figure 3.

Figure 3

Calculate the value of voltage V_o in Figure 3 by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = V_o$, $R_x = 1\ \text{k}\Omega$, $R_y = R_{TH}$, $V = 3\ \text{V}$ from Figure 3 and solve for V_o.

$$\begin{aligned} V_o &= \left(\frac{1\ \text{k}\Omega}{1\ \text{k}\Omega + 1250\ \Omega}\right)(3\ \text{V}) \\ &= \left(\frac{1\ \text{k}\Omega}{2.25\ \text{k}\Omega}\right)(3\ \text{V}) \\ &= \left(\frac{1}{2.25}\right)(3\ \text{V}) \\ &= 1.34\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{1.34\ \text{V}}$.

Step 1 of 10

Consider Figure P5.64 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 10

Apply super node analysisatnodes-1 and 2.

$$\frac{V_1}{2\text{ k}}+\frac{V_1+3}{6\text{ k}}-1\text{m}=0$$

$$V_1\left(\frac{1}{2\text{ k}}+\frac{1}{6\text{ k}}\right)+\frac{3}{6\text{ k}}-1\text{m}=0$$

$$V_1\left(\frac{4}{6\text{ k}}\right)-0.5\text{ m}=0$$

$$V_1(4)-3=0$$

$$V_1=\frac{3}{4}\text{ V}$$

Therefore, the value of the voltage V_1 is $\frac{3}{4}$ V .

Step 3 of 10

Calculate the value of the open circuit voltage V_{oc} .

$$V_{oc}=1000I_x+V_1$$

Substitute $\frac{V_1}{2\text{ k}}$ for I_x .

$$V_{oc}=1000\left(\frac{V_1}{2\text{ k}}\right)+V_1$$

$$=\frac{V_1}{2}+V_1$$

$$=\frac{3V_1}{2}$$

Substitute $\frac{3}{4}$ V for V_1 .

$$V_{oc}=\frac{3\left(\frac{3}{4}\right)}{2}$$

$$=\frac{9}{8}\text{ V}$$

Therefore, the value of the open circuit voltage is $\frac{9}{8}$ V .

Step 4 of 10

Disconnect the load resistor and short the terminals to calculate the short circuit current.

Figure 2

Step 5 of 10

Consider the relation between the voltages V_1 and V_2 .

$$V_2-V_1=1000I_x$$

Substitute $\frac{V_1}{2\text{ k}}$ for I_x .

$$V_2-V_1=1000\left(\frac{V_1}{2\text{ k}}\right)$$

$$V_2-V_1=\frac{V_1}{2}$$

$$\frac{3V_1}{2}=V_2$$

$$V_1=\frac{2}{3}V_2$$

Therefore, the expression for the voltage V_1 is $\frac{2}{3}V_2$.

Step 6 of 10

Apply super node analysis at nodes-1 and 2.

$$\frac{V_1}{2\text{ k}}+\frac{V_1+3}{6\text{ k}}+\frac{V_2}{1\text{ k}}-1\text{m}=0$$

$$V_1\left(\frac{1}{2\text{ k}}+\frac{1}{6\text{ k}}\right)+\frac{V_2}{1\text{ k}}+\frac{3}{6\text{ k}}-1\text{m}=0$$

$$V_1\left(\frac{4}{6\text{ k}}\right)+\frac{V_2}{1\text{ k}}-0.5\text{ m}=0$$

$$V_1(4)+V_2(6)-3=0$$

Substitute $\frac{2}{3}V_2$ for V_1

$$\left(\frac{2}{3}V_2\right)(4)+V_2(6)-3=0$$

$$\frac{8}{3}V_2+V_2(6)=3$$

$$V_2\left(\frac{26}{3}\right)=3$$

$$V_2=\frac{9}{26}\text{ V}$$

Therefore, the value of the voltage V_2 is $\frac{9}{26}$ V .

Step 7 of 10

Calculate the value of the short circuit current.

$$I_{sc}=\frac{V_2}{1\text{ k}}$$

Substitute $\frac{9}{26}$ V for V_2 .

$$I_{sc}=\frac{\frac{9}{26}}{1\text{ k}}$$

$$=\frac{9}{26}\text{ mA}$$

Therefore, the value of the short circuit current is $\frac{9}{26}$ mA .

Step 8 of 10

Calculate the value of the Thevenin's resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sc}}$$

Substitute $\frac{9}{26}$ mA for I_{sc} and $\frac{9}{8}$ V for V_{oc} .

$$R_{Th}=\frac{\frac{9}{8}}{\frac{9}{26}\text{ m}}$$

$$=\frac{26}{8}$$

$$=\frac{13}{4}\text{ k}\Omega$$

Therefore, the value of the Thevenin's resistance is $\frac{13}{4}$ kΩ .

Step 9 of 10

Draw the Thevenin's equivalent circuit diagram.

Figure 3

Step 10 of 10

Calculate the value of the output voltage.

$$V_o=\left(\frac{9}{8}\right)\left(\frac{2\text{ k}}{2\text{ k}+\frac{13}{4}\text{ k}}\right)$$

$$=\left(\frac{9}{8}\right)\left(\frac{8\text{ k}}{8\text{ k}+13\text{ k}}\right)$$

$$=\left(\frac{9}{8}\right)\left(\frac{8}{21}\right)$$

$$=\frac{3}{7}\text{ V}$$

Therefore, the value of the output voltage V_o is $\boxed{\frac{3}{7}\text{ V}}$.

Step 1 of 9

Consider the circuit shown in Figure P5.65 in the text book.

Let the open circuit voltage V_{oc} present across the $4\ \text{k}\Omega$ resistor of circuit in the considered circuit as shown in Figure 1.

Figure 1

Step 2 of 9

The value of current I_x in Figure 1 is $\frac{V_1}{2\text{k}}$. The nodes V_1 and V_2 forms a super node in Figure 1.

Calculate the value of voltage V_1.

$$V_2 - V_1 = 2000I_x$$
$$V_2 - V_1 = 2\text{k}\left(\frac{V_1}{2\text{k}}\right)$$
$$2V_1 = V_2$$
$$V_1 = \frac{V_2}{2}$$

Apply Kirchhoff's current law at super node in Figure 1 and solve for voltage V_2.

$$\frac{V_1-(-6)}{6\text{k}} + \frac{V_1}{2\text{k}} - 3\text{m} + \frac{V_2 - V_{oc}}{4\text{k}} = 0$$
$$\frac{(2)(V_1+6)}{12\text{k}} + \frac{6V_1}{12\text{k}} - \frac{(3\text{m})(12\text{k})}{12\text{k}} + \frac{(3)(V_2-V_{oc})}{12\text{k}} = 0$$
$$2V_1 + 12 + 6V_1 - 36 + 3V_2 - 3V_{oc} = 0$$
$$8V_1 + 3V_2 - 3V_{oc} = 24$$

Simplify the expression further.

$$(8)\left(\frac{V_2}{2}\right) + 3V_2 - 3V_{oc} = 24$$
$$7V_2 = 3V_{oc} + 24$$
$$V_2 = \frac{3V_{oc}+24}{7}$$

Step 3 of 9

Apply Kirchhoff's current law at node V_{oc} in Figure 1 and solve.

$$\frac{V_{oc}-V_2}{4\text{k}} = 0$$
$$V_{oc} - \frac{3V_{oc}+24}{7} = 0$$
$$7V_{oc} - 3V_{oc} = 24$$
$$V_{oc} = 6\ \text{V}$$

Step 4 of 9

Now short circuit the branch having V_{oc} in Figure 1 as shown in Figure 2. Also the currents flowing in the loops of the circuit is shown in Figure 2.

Figure 2

Step 5 of 9

The value of current I_2 in Figure 2 is $-3\ \text{mA}$.

Apply Kirchhoff's current law at node 'a' and calculate the value of current I_x in figure 2.

$$I_1 = I_x + I_2 + I_3$$
$$I_x = I_1 - I_2 - I_3$$
$$= I_1 + 3\text{m} - I_3$$

Now apply Kirchhoff's voltage law to the loop having current I_1 in Figure 2 and solve.

$$6\text{k}I_1 + 2\text{k}I_x + 6 = 0$$
$$6\text{k}I_1 + (2\text{k})(I_1 + 3\text{m} - I_3) + 6 = 0$$
$$6\text{k}I_1 + 2\text{k}I_1 + (2\text{k})(3\text{m}) - 2\text{k}I_3 + 6 = 0$$
$$8\text{k}I_1 - 2\text{k}I_3 = -6 - 6$$

Simplify the expression further.

$$8\text{k}I_1 = -12 + 2\text{k}I_3$$
$$I_1 = \frac{2\text{k}I_3 - 12}{8\text{k}}$$

Step 6 of 9

Now apply Kirchhoff's voltage law to the loop having current I_3 in Figure 2 and solve.

$$-2\text{k}I_x + 4\text{k}I_3 - 2\text{k}I_x = 0$$
$$-(4\text{k})(I_1 + 3\text{m} - I_3) + 4\text{k}I_3 = 0$$
$$-4\text{k}I_1 - 12 + 4\text{k}I_3 + 4\text{k}I_3 = 0$$
$$-4\text{k}I_1 + 8\text{k}I_3 = 12$$

Simplify the expression further.

$$-(4\text{k})\left(\frac{2\text{k}I_3 - 12}{8\text{k}}\right) + 8\text{k}I_3 = 12$$
$$-(0.5)(2\text{k}I_3) + (0.5)(12) + 8\text{k}I_3 = 12$$
$$7\text{k}I_3 = 12 - 6$$
$$I_3 = 0.857\ \text{mA}$$

The value of current I_{sc} from Figure 2 is equal to $0.857\ \text{mA}$.

Step 7 of 9

Calculate the value of Thevenin's resistance R_{TH} by using the Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$R_{TH} = \frac{V_{oc}}{I_{sc}}$$
$$= \frac{6\ \text{V}}{0.857\ \text{mA}}$$
$$= 7\ \text{k}\Omega$$

Step 8 of 9

Now the Norton's equivalent circuit is drawn as shown in Figure 3.

Figure 3

Step 9 of 9

Calculate the value of current I_o in Figure 3 by using current division formula $I_x = \left(\frac{R_y}{R_x + R_y}\right)I$.

Substitute $I_x = I_o$, $R_y = 7\ \text{k}\Omega$, $R_x = 4\ \text{k}\Omega$, $I = 0.857\ \text{mA}$ from Figure 3 and solve for I_o.

$$I_o = \left(\frac{7\ \text{k}\Omega}{4\ \text{k}\Omega + 7\ \text{k}\Omega}\right)(0.857\ \text{mA})$$
$$= \left(\frac{7\ \text{k}\Omega}{11\ \text{k}\Omega}\right)(0.857\ \text{mA})$$
$$= (0.636)(0.857\ \text{mA})$$
$$= 0.545\ \text{mA}$$

Calculate the value of voltage V_o in Figure 3 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = 0.545\ \text{mA}$, $R = 4\ \text{k}\Omega$ from Figure 5 and solve for V_o.

$$V_o = (0.545\ \text{mA})(4\ \text{k}\Omega)$$
$$= 2.18\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{2.18\ \text{V}}$.

Step 1 of 10

Consider Figure P5.66 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 10

Calculate the value of the voltage, V_x.

$$V_x = (6)\left(\frac{2\text{ k}}{2\text{ k}+4\text{ k}}\right)$$
$$= (6)\left(\frac{2\text{ k}}{6\text{ k}}\right)$$
$$= 2\text{ V}$$

Therefore, the value of the voltage V_x is 2 V.

Step 3 of 10

Calculate the value of the voltage V_1.

$$V_1 = 12 - \left(\frac{V_x}{1000}\right)(4\text{ k})$$
$$= 12 - 4V_x$$

Substitute 2 V for V_x.

$$V_1 = 12 - 4(2)$$
$$= 12 - 8$$
$$= 4\text{ V}$$

Therefore, the value of the voltage V_1 is 4 V.

Step 4 of 10

Calculate the value of the open circuit voltage.

$$V_{OC} = V_x - V_1$$

Substitute 4 V for V_1 and 2 V for V_x.

$$V_{OC} = 2 - 4$$
$$= -2\text{ V}$$

Therefore, the value of the open circuit voltage is -2 V.

Step 5 of 10

Disconnect the load resistorand short the terminals to calculate the short circuit current.

Figure 2

Step 6 of 10

Apply Kirchhoff's Current Law at node 1.

$$\frac{V_x - 6}{4\text{ k}} + \frac{V_x}{2\text{ k}} + \frac{V_x - 12}{4\text{ k}} + \frac{V_x}{1000} = 0$$
$$V_x\left(\frac{1}{4\text{ k}} + \frac{1}{2\text{ k}} + \frac{1}{4\text{ k}} + \frac{1}{1\text{k}}\right) - \frac{6}{4\text{ k}} - \frac{12}{4\text{ k}} = 0$$
$$V_x\left(\frac{1}{4\text{ k}} + \frac{2}{4\text{ k}} + \frac{1}{4\text{ k}} + \frac{4}{4\text{k}}\right) - \frac{6}{4\text{ k}} - \frac{12}{4\text{ k}} = 0$$
$$V_x\left(\frac{8}{4\text{ k}}\right) - \frac{18}{4\text{ k}} = 0$$
$$V_x(8) = 18$$
$$V_x = \frac{18}{8}$$
$$V_x = \frac{9}{4}\text{ V}$$

Therefore, the value of the voltage V_x is $\frac{9}{4}\text{ V}$.

Step 7 of 10

Calculate the value of the short circuit current.

$$I_{SC} = \frac{V_x - 12}{4\text{ k}} + \frac{V_x}{1000}$$
$$= V_x\left(\frac{1}{4\text{ k}} + \frac{1}{1\text{ k}}\right) - \frac{12}{4\text{ k}}$$
$$= V_x\left(\frac{1}{4\text{ k}} + \frac{4}{4\text{ k}}\right) - \frac{12}{4\text{ k}}$$
$$= V_x\left(\frac{5}{4\text{ k}}\right) - \frac{12}{4\text{ k}}$$

Substitute $\frac{9}{4}\text{ V}$ for V_x.

$$I_{SC} = \left(\frac{9}{4}\right)\left(\frac{5}{4\text{ k}}\right) - \frac{12}{4\text{ k}}$$
$$= \frac{45}{16\text{ k}} - \frac{12}{4\text{ k}}$$
$$= \frac{45 - 12(4)}{16\text{ k}}$$
$$= \frac{45 - 48}{16\text{ k}}$$
$$I_{SC} = -\frac{3}{16}\text{ mA}$$

Therefore, the value of the short circuit current is $-\frac{3}{16}\text{ mA}$.

Step 8 of 10

Calculate the value of the Thevenin's resistance.

$$R_{Th} = \frac{V_{OC}}{I_{SC}}$$

Substitute $-\frac{3}{16}\text{ mA}$ for I_{SC} and -2 V for V_{OC}.

$$R_{Th} = \frac{-2}{-\frac{3}{16}\text{ m}}$$
$$= \frac{32}{3}\text{ k}\Omega$$

Therefore, the value of the Thevenin's resistance is $\frac{32}{3}\text{ k}\Omega$.

Step 9 of 10

Draw the Thevenin's equivalent circuit diagram.

Figure 3

Step 10 of 10

Calculate the value of the output voltage.

$$V_O = (-2)\left(\frac{2\text{ k}}{2\text{ k} + \frac{32}{3}\text{ k}}\right)$$
$$= (-2)\left(\frac{6\text{ k}}{6\text{ k} + 32\text{ k}}\right)$$
$$= (-2)\left(\frac{6\text{ k}}{38\text{ k}}\right)$$
$$= -\frac{12}{38}$$
$$V_O = -\frac{6}{19}\text{ V}$$

Therefore, the value of the output voltage V_O is $\boxed{-\frac{6}{19}\text{ V}}$.

Step 1 of 9

Consider Figure P5.67 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 9

Apply Kirchhoff's Current Law at node 1.

$$I_x + 2I_x = -2 \text{ m}$$
$$3I_x = -2 \text{ m}$$
$$I_x = -\frac{2}{3} \text{ mA}$$

Therefore, the value of the current I_x is $-\frac{2}{3}$ mA .

Step 3 of 9

Consider the expression for the open circuit voltage.

$$V_{OC} = 12 + 2I_x(1 \text{ k})$$

Substitute $-\frac{2}{3}$ mA for I_x .

$$V_{OC} = 12 + 2\left(-\frac{2}{3} \text{ m}\right)(1 \text{ k})$$
$$= 12 - \frac{4}{3}$$
$$= \frac{36-4}{3}$$
$$= \frac{32}{3} \text{ V}$$

Therefore, the value of the open circuit voltage is $\frac{32}{3}$ V .

Step 4 of 9

Disconnect the load resistor and short the terminals to calculate the short circuit current.

Figure 2

Step 5 of 9

Apply Kirchhoff's Current Law at node 1.

$$I_x + 2I_x = -2 \text{ m}$$
$$3I_x = -2 \text{ m}$$
$$I_x = -\frac{2}{3} \text{ mA}$$

Therefore, the value of the current I_x is $-\frac{2}{3}$ mA .

Step 6 of 9

Apply Kirchhoff's Current Law at node 2.

$$I_{SC} = 2I_x - \frac{V}{1 \text{ k}}$$

Substitute $-\frac{2}{3}$ mA for I_x and -12 V for V .

$$I_{SC} = 2\left(-\frac{2}{3} \text{ m}\right) - \frac{(-12)}{1 \text{ k}}$$
$$= -\frac{4}{3} \text{ m} + 12 \text{ m}$$
$$= \frac{-4+36}{3} \text{ m}$$
$$= \frac{32}{3} \text{ mA}$$

Therefore, the value of the short circuit current is $\frac{32}{3}$ mA .

Step 7 of 9

Calculate the value of the Thevenin's resistance.

$$R_{Th} = \frac{V_{OC}}{I_{SC}}$$

Substitute $\frac{32}{3}$ mA for I_{SC} and $\frac{32}{3}$ V for V_{OC} .

$$R_{Th} = \frac{\frac{32}{3}}{\frac{32}{3} \text{ m}}$$
$$= 1 \text{ k}\Omega$$

Therefore, the value of the Thevenin's resistance is $1 \text{ k}\Omega$.

Step 8 of 9

Draw the Thevenin's equivalent circuit diagram.

Figure 3

Step 9 of 9

Calculate the value of the output voltage.

$$V_O = \left(\frac{32}{3}\right)\left(\frac{1 \text{ k}}{1 \text{ k} + 1 \text{ k}}\right)$$
$$= \left(\frac{32}{3}\right)\left(\frac{1 \text{ k}}{2 \text{ k}}\right)$$
$$= \frac{16}{3}$$
$$= 5.33 \text{ V}$$

Therefore, the value of the output voltage V_O is $\boxed{5.33 \text{ V}}$.

Step 1 of 7

5.073P

Consider the circuit shown in Figure P5.71 in the text book.

Let the open circuit voltage V_{oc} be present across the $3\ \text{k}\Omega$ resistor having voltage V_o in the considered circuit as shown in Figure 1. Also the currents flowing in the loops of circuit are shown in Figure 1.

Figure 1

Step 2 of 7

The value of current I_2 in Figure 1 is $1\ \text{mA}$.

Calculate the value of voltage V_x by using Ohm's law $V = IR$.

Substitute $V = V_x$, $I = 1\ \text{mA}$, $R = 3\ \text{k}\Omega$ from Figure 1 and solve for V_x.

$$\begin{aligned} V_x &= (1\ \text{mA})(3\ \text{k}\Omega) \\ &= 3\ \text{V} \end{aligned}$$

Calculate the value of voltage V_1 by using Ohm's law $V = IR$.

Substitute $V = V_1$, $I = \frac{V_x}{4000}$, $R = 1\ \text{k}\Omega$ from Figure 1 and solve for V_1.

$$\begin{aligned} V_1 &= \left(\frac{V_x}{4000}\right)(1\ \text{k}\Omega) \\ &= \left(\frac{3\ \text{V}}{4000}\right)(1\ \text{k}\Omega) \\ &= \frac{3}{4} \\ &= 0.75\ \text{V} \end{aligned}$$

Apply Kirchhoff's voltage law to the right side loop in Figure 1 and solve for V_{oc}.

$$\begin{aligned} V_{oc} &= V_1 + V_x \\ &= 0.75\ \text{V} + 3\ \text{V} \\ &= 3.75\ \text{V} \end{aligned}$$

Step 3 of 7

Now, short circuit the voltage V_{oc} in Figure 1 is shown in Figure 2.

Figure 2

The value of I_1 is $\frac{V_x}{4000}$ and I_2 is $1\ \text{mA}$.

Calculate the value of voltage V_x by using Ohm's law $V = IR$.

Substitute $V = V_x$, $I = I_2 - I_{sc}$, $R = 3\ \text{k}\Omega$ from Figure 2 and solve by using $I_2 = 1\ \text{mA}$.

$$\begin{aligned} V_x &= (3\text{k})(I_2 - I_{sc}) \\ 4000 I_1 &= (3\text{k})(1\text{m} - I_{sc}) \\ 4\text{k} I_1 &= 3 - 3\text{k} I_{sc} \\ I_1 &= \frac{3 - 3\text{k} I_{sc}}{4} \quad \text{..... (1)} \end{aligned}$$

Step 4 of 7

Apply Kirchhoff's voltage law to the loop having current I_{sc} in Figure 2 and solve for I_{sc}.

$$\begin{aligned} &1\text{k}(I_{sc} - I_1) + 3\text{k}(I_{sc} - I_2) = 0 \\ &1\text{k} I_{sc} - 1\text{k} I_1 + 3\text{k} I_{sc} - 3\text{k} I_2 = 0 \\ &4\text{k} I_{sc} - (1\text{k})\left(\frac{3 - 3\text{k} I_{sc}}{4\text{k}}\right) - (3\text{k})(1\text{m}) = 0 \\ &(4)(4\text{k} I_{sc}) - 3 + 3\text{k} I_{sc} - (3)(4) = 0 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} 16\text{k} I_{sc} + 3\text{k} I_{sc} &= 3 + 12 \\ 19\text{k} I_{sc} &= 15 \\ I_{sc} &= \frac{15}{19\text{k}} \\ I_{sc} &= 0.79\ \text{mA} \end{aligned}$$

Step 5 of 7

Calculate the value of Thevenin's resistance R_{TH} by using Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$\begin{aligned} R_{TH} &= \frac{3.75\ \text{V}}{0.79\ \text{mA}} \\ &= 4.75\ \text{k}\Omega \end{aligned}$$

Step 6 of 7

Now the Thevenin's equivalent circuit is drawn as shown in Figure 3.

Figure 3

Step 7 of 7

Calculate the value of current I_o in Figure 3 by using current division rule $I_x = \left(\frac{R_y}{R_x + R_y}\right) I$.

Substitute $I_x = I_o$, $R_y = 4.75\ \text{k}\Omega$, $R_x = 3\ \text{k}\Omega$, $I = 0.79\ \text{mA}$ from Figure 3 and solve for I_o.

$$\begin{aligned} I_o &= \left(\frac{4.75\text{k}}{4.75\text{k} + 3\text{k}}\right)(0.79\ \text{mA}) \\ &= \left(\frac{4.75\text{k}}{7.75\text{k}}\right)(0.79\ \text{mA}) \\ &= (0.613)(0.79\ \text{mA}) \\ &= 0.484\ \text{mA} \end{aligned}$$

Calculate the value of voltage V_o in Figure 3 by using Ohm's law $V = IR$.

Substitute $V = V_o$, $I = I_o$, $R = 3\ \text{k}\Omega$ from Figure 3 and solve for V_o.

$$\begin{aligned} V_o &= I_o R \\ &= (0.484\ \text{mA})(3\ \text{k}\Omega) \\ &= 1.452\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{1.452\ \text{V}}$.

Step 1 of 8

5.074P

Consider the circuit shown in Figure P5.72 in the text book.

Let the open circuit voltage V_{oc} present across $2\ \text{k}\Omega$ resistor having current I_o in the considered circuit as shown in Figure 1. Also the currents flowing in the loops of the circuit are shown in Figure 1.

Figure 1

Step 2 of 8

The value of voltage V_x in Figure 1 is $1\text{k}(I_1 - I_2)$.

Apply Kirchhoff's voltage law to the loop having current I_1 in Figure 1 and solve.

$$1\text{k}I_1 + 2V_x + V_x = 4$$
$$1\text{k}I_1 + 3V_x = 4$$
$$1\text{k}I_1 + (3)(1\text{k})(I_1 - I_2) = 4$$
$$1\text{k}I_1 + 3\text{k}I_1 - 3\text{k}I_2 = 4$$

Simplify the expression further.

$$4\text{k}I_1 - 3\text{k}I_2 = 4$$
$$4\text{k}I_1 = 4 + 3\text{k}I_2$$
$$I_1 = \frac{4 + 3\text{k}I_2}{4\text{k}} \quad \text{..... (1)}$$

Step 3 of 8

Apply Kirchhoff's voltage law to the loop having current I_2 in Figure 1 and solve by using equation (1).

$$1\text{k}(I_2 - I_1) + 1\text{k}I_2 + 1\text{k}I_2 = -2$$
$$1\text{k}I_2 - 1\text{k}I_1 + 1\text{k}I_2 + 1\text{k}I_2 = -2$$
$$-1\text{k}I_1 + 3\text{k}I_2 = -2$$
$$-(1\text{k})\left(\frac{4 + 3\text{k}I_2}{4\text{k}}\right) + 3\text{k}I_2 = -2$$

Simplify the expression further.

$$-(1)(4 + 3\text{k}I_2) + (4)(3\text{k}I_2) = -(2)(4)$$
$$-4 - 3\text{k}I_2 + 12\text{k}I_2 = -8$$
$$9\text{k}I_2 = -8 + 4$$
$$I_2 = -0.45\ \text{mA}$$

Step 4 of 8

Calculate the value of current I_1 from equation (1).

$$I_1 = \frac{4 + (3\text{k})(-0.45\ \text{mA})}{4\text{k}}$$
$$= \frac{4 - 1.35}{4\text{k}}$$
$$= \frac{2.65}{4\text{k}}$$
$$= 0.66\ \text{mA}$$

Calculate the value of voltage V_x from Figure 1.

$$V_x = (I_1 - I_2)1\text{k}$$
$$= (1\text{k})(0.66\ \text{mA} + 0.45\ \text{mA})$$
$$= (1\text{k})(1.11\ \text{mA})$$
$$= 1.11\ \text{V}$$

Now calculate the value of V_{oc} by using Kirchhoff's voltage law.

$$V_{oc} = 2V_x + 1\text{k}I_2$$
$$= (2)(1.11) + (1\text{k})(-0.45\text{m})$$
$$= 2.22 - 0.45$$
$$= 1.77\ \text{V}$$

Step 5 of 8

Now, short circuit the V_{oc} in Figure 1 and calculate the value of I_{sc} as shown in Figure 2.

Figure 2

Step 6 of 8

Calculate the value of current I_{sc} in Figure 2 by using Kirchhoff's voltage law in loop having current I_{sc}.

$$2V_x = (I_{sc} - I_2)1\text{k}$$
$$2(1.11) = 1\text{k}I_{sc} - (1\text{k})(-0.45\text{m})$$
$$2.22 = 1\text{k}I_{sc} + 0.45$$
$$1\text{k}I_{sc} = 2.22 - 0.45$$

Simplify the expression further.

$$1\text{k}I_{sc} = 1.77$$
$$I_{sc} = \frac{1.77}{1\text{k}}$$
$$= 1.77\ \text{mA}$$

Step 7 of 8

Now draw the Thevenin's equivalent circuit as shown in Figure 3.

Figure 3

Step 8 of 8

Calculate the value of R_{TH} in Figure 3 by using Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$R_{TH} = \frac{V_{oc}}{I_{sc}}$$
$$= \frac{1.77\ \text{V}}{1.77\ \text{mA}}$$
$$= 1\ \text{k}\Omega$$

Now, calculate the value of I_o in Figure 3 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_o$, $V = V_{oc}$, $R = R_{TH} + 2\ \text{k}\Omega$ from Figure 3 and solve for I_o.

$$I_o = \frac{V_{oc}}{R_{TH} + 2\ \text{k}\Omega}$$
$$= \frac{1.77\ \text{V}}{1\ \text{k}\Omega + 2\ \text{k}\Omega}$$
$$= \frac{1.77\ \text{V}}{3\ \text{k}\Omega}$$
$$= 0.6\ \text{mA}$$

Therefore, the value of current I_o in the circuit is $\boxed{0.6\ \text{mA}}$.

Step 1 of 4

Consider the circuit shown in Figure P5.73 in the text book.

Let the open circuit voltage V_{oc} be present across the $1\ \text{k}\Omega$ resistor having voltage V_o in the considered circuit is shown in Figure 1.

Figure 1

Calculate the value of voltage V_{oc} in Figure 1 by using Kirchhoff's voltage law.

$$V_{oc} + 12 - (2\text{m})(1\text{k}) = 0$$
$$V_{oc} = -12 + 2$$
$$V_{oc} = -10\ \text{V}$$

Step 2 of 4

Now short circuit the open circuit voltage V_{oc} in Figure 1 to calculate the value of I_{sc} and is shown in Figure 2.

Figure 2

Step 3 of 4

Calculate the value of current I_x in Figure 2 by using Ohm's law $I = \frac{V}{R}$.

Substitute $I = I_x$, $V = -12\ \text{V}$, $R = 1\ \text{k}\Omega$ from Figure 2 and solve for current I_x.

$$I_x = \frac{-12\ \text{V}}{1\ \text{k}\Omega}$$
$$= -12\ \text{mA}$$

Apply Kirchhoff's current law at node 'a' in Figure 2 and solve for current I_{sc}.

$$I_{sc} = I_x + 2\ \text{mA}$$
$$= -12\ \text{mA} + 2\ \text{mA}$$
$$= -10\ \text{mA}$$

Calculate the value of Thevenin's resistance R_{TH} by using Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$R_{TH} = \frac{V_{oc}}{I_{sc}}$$
$$= \frac{-10\ \text{V}}{-10\ \text{mA}}$$
$$= 1\ \text{k}\Omega$$

Step 4 of 4

The Thevenin's circuit is drawn as shown in Figure 3.

Figure 3

Calculate the value of voltage V_o in Figure 3 by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = V_o$, $R_x = 1\ \text{k}\Omega$, $R_y = R_{TH}$, $V = V_{oc}$ from Figure 3 and solve for V_o.

$$V_o = (-10\ \text{V})\left(\frac{1\ \text{k}\Omega}{1\ \text{k}\Omega + 1\ \text{k}\Omega}\right)$$
$$= (-10\ \text{V})\left(\frac{1\ \text{k}\Omega}{2\ \text{k}\Omega}\right)$$
$$= (-10\ \text{V})\left(\frac{1}{2}\right)$$
$$= -5\ \text{V}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-5\ \text{V}}$.

Step 1 of 5

5.077P

Consider the circuit shown in Figure P5.75 in the text book.

Let the open circuit voltage V_{oc} be present across $1\ \text{k}\Omega$ resistor having voltage V_o in the considered circuit is shown in Figure 1. Also the node voltages and currents flowing in the branches are shown in Figure 1.

Figure 1

The value of current I_1 is $1\ \text{mA}$ and current I_3 is $-4\ \text{mA}$ from figure 1. The value of voltage V_x across $1\ \text{k}\Omega$ resistor in figure 1 is $0\ \text{V}$.

Calculate the value of current I_2 in Figure 1.

$$\begin{aligned} I_2 &= \frac{2V_x}{1000} \\ &= \left(\frac{2}{1000}\right)(0\ \text{V}) \\ &= 0\ \text{A} \end{aligned}$$

Step 2 of 5

Apply Kirchhoff's current law at node 'a' in figure 1 and solve for current I.

$$\begin{aligned} I + I_1 &= I_2 \\ I + 1\ \text{mA} &= 0\ \text{mA} \\ I &= -1\ \text{mA} \end{aligned}$$

Apply Kirchhoff's voltage law to the top loop in figure 1 and solve for voltage V_{oc}.

$$\begin{aligned} &2\text{k}I_1 + 1\text{k}I_1 - V_x + V_{oc} - 1\text{k}I_3 - 1\text{k}I = 0 \\ &-V_x + V_{oc} = 1\text{k}I_3 + 1\text{k}I - 3\text{k}I_1 \\ &V_{oc} = (1\text{k})(-4\text{m}) + (1\text{k})(-1\text{m}) - (3\text{k})(1\text{m}) \\ &= -8\ \text{V} \end{aligned}$$

Step 3 of 5

Now short circuit the V_{oc} in Figure 1 and solve for current I_{sc} as shown in Figure 2.

Figure 2

The value of voltage V_x is $-1\text{k}I_4$ and current I_3 is $-4\ \text{mA}$. Also the value of current I_4 is equal to I_{sc}.

$$\begin{aligned} I_2 &= \frac{2V_x}{1000} \\ &= \left(\frac{2}{1000}\right)(-1\text{k}I_4) \\ &= \left(\frac{2}{1\text{k}}\right)(-1\text{k}I_{sc}) \\ &= -2I_{sc} \end{aligned}$$

Step 4 of 5

The value of current I_1 by using Kirchhoff's current law at node 'a' in figure 2 is $1\ \text{mA} + I_{sc}$.

Apply Kirchhoff's voltage law to the top loop in figure 2 and solve for current I_{sc}.

$$\begin{aligned} &3\text{k}I_1 + 1\text{k}I_{sc} + 1\text{k}(I_{sc} - I_3) + 1\text{k}(I_1 - I_2) = 0 \\ &3\text{k}(1\ \text{mA} + I_{sc}) + 1\text{k}I_{sc} + 1\text{k}I_{sc} \\ &-1\text{k}(-4\ \text{mA}) + 1\text{k}(1\ \text{mA} + I_{sc}) - 1\text{k}(-2I_{sc}) = 0 \\ &3 + 3\text{k}I_{sc} + 1\text{k}I_{sc} + 1\text{k}I_{sc} + 4 + 1 + +1\text{k}I_{sc} + 2\text{k}I_{sc} = 0 \\ &8\text{k}I_{sc} + 8 = 0 \end{aligned}$$

Simplify the expression further.

$$\begin{aligned} 8\text{k}I_{sc} &= -8 \\ I_{sc} &= \frac{-8}{8\text{k}} \\ &= -1\ \text{mA} \end{aligned}$$

Step 5 of 5

Calculate the value of Thevenin's resistance R_{TH} by using Ohm's law $R = \frac{V}{I}$.

Substitute $R = R_{TH}$, $V = V_{oc}$, $I = I_{sc}$ and solve for R_{TH}.

$$\begin{aligned} R_{TH} &= \frac{V_{oc}}{I_{sc}} \\ &= \frac{-8\ \text{V}}{-1\ \text{mA}} \\ &= 8\ \text{k}\Omega \end{aligned}$$

Now draw the Thevenin's equivalent circuit as shown in Figure 3.

Figure 3

Calculate the value of voltage V_o in Figure 3 by using voltage division rule $V_x = \left(\frac{R_x}{R_x + R_y}\right)V$.

Substitute $V_x = V_o$, $R_x = 1\ \text{k}\Omega$, $R_y = 8\ \text{k}\Omega$, $V = -8\ \text{V}$ from Figure 3 and solve for V_o.

$$\begin{aligned} V_o &= \left(\frac{1\ \text{k}\Omega}{8\ \text{k}\Omega + 1\ \text{k}\Omega}\right)(-8\ \text{V}) \\ &= \left(\frac{1\ \text{k}\Omega}{9\ \text{k}\Omega}\right)(-8\ \text{V}) \\ &= (0.11)(-8\ \text{V}) \\ &= -0.88\ \text{V} \end{aligned}$$

Therefore, the value of voltage V_o in the circuit is $\boxed{-0.88\ \text{V}}$.

Step 1 of 12

Consider Figure P5.76 from the text book.

Disconnect the load resistor and open the terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 12

Calculate the value of the current I_1.

$$I_1 = 4I_A - I_A$$
$$= 3I_A$$

Therefore, the expression for the current I_1 is $3I_A$.

Step 3 of 12

Consider the expression for the voltage V_A.

$$V_A = I_A(12)$$

Therefore, the expression for the voltage V_A is $I_A(12)$.

Step 4 of 12

Apply Kirchhoff's Voltage Law in Loop-1.

$$I_A(12+3) + 2V_A - I_1(6) = 0$$

Substitute $I_A(12)$ for V_A and $3I_A$ for I_1.

$$I_A(12+3) + 2I_A(12) - 3I_A(6) = 0$$
$$I_A(12+3+24-18) = 0$$
$$I_A = 0 \text{ A}$$

Therefore, the value of the current I_A is 0 A.

Step 5 of 12

Calculate the value of the open circuit voltage V_{OC}.

$$V_{OC} = 12 + I_A(6)$$

Substitute 0 A for I_A.

$$V_{OC} = 12 + (0)(6)$$
$$= 12 \text{ V}$$

Therefore, the value of the open circuit voltage V_{OC} is 12 V.

Step 6 of 12

Disconnect the load resistor and short the terminals to calculate the short circuit current.

Figure 2

Step 7 of 12

Apply Kirchhoff's Voltage Law in Loop-1.

$$I_1(12+3) + 2V_A + (I_1 - I_2)(6) = 0$$
$$I_1(12+3) + 2V_A + (I_1 - I_2)(6) = 0$$
$$I_1(15+6) - I_2(6) + 2V_A = 0$$
$$I_1(21) - I_2(6) + 2V_A = 0$$

Substitute $I_1(12)$ for V_A.

$$I_1(21) - I_2(6) + 2I_1(12) = 0$$
$$I_1(21) - I_2(6) + I_1(24) = 0$$
$$I_1(21+24) - I_2(6) = 0$$
$$I_1(45) - I_2(6) = 0$$
$$I_1(45) = I_2(6)$$
$$I_1 = I_2\left(\frac{6}{45}\right)$$
$$I_1 = I_2\left(\frac{2}{15}\right) \quad \text{..... (1)}$$

Here, I_1 is I_A.

$$I_A = I_2\left(\frac{2}{15}\right)$$

Therefore, the expression for the current I_A is $I_2\left(\frac{2}{15}\right)$.

Step 8 of 12

Apply Kirchhoff's Voltage Law in Loop-3.

$$(I_2 - I_1)(6) - 12 = 0$$
$$(I_2 - I_1)(6) = 12$$
$$I_2 - I_1 = \frac{12}{6}$$
$$I_2 - I_1 = 2$$

Substitute $I_2\left(\frac{2}{15}\right)$ for I_1.

$$I_2 - I_2\left(\frac{2}{15}\right) = 2$$
$$I_2\left(1 - \frac{2}{15}\right) = 2$$
$$I_2\left(\frac{15-2}{15}\right) = 2$$
$$I_2\left(\frac{13}{15}\right) = 2$$
$$I_2 = 2\left(\frac{15}{13}\right)$$
$$I_2 = \frac{30}{13} \text{ A}$$

Therefore, the value of the current I_2 is $\frac{30}{13}$ A.

Step 9 of 12

Calculate the value of the short circuit current.

$$I_{SC} = I_2 - 4I_A$$

Substitute I_1 for I_A.

$$I_{SC} = I_2 - 4I_1$$

Substitute $I_2\left(\frac{2}{15}\right)$ for I_1.

$$I_{SC} = I_2 - 4\left(I_2\left(\frac{2}{15}\right)\right)$$
$$= I_2 - I_2\left(\frac{8}{15}\right)$$
$$= I_2\left(\frac{7}{15}\right)$$

Substitute $\frac{30}{13}$ A for I_2.

$$I_{SC} = \left(\frac{30}{13}\right)\left(\frac{7}{15}\right)$$
$$= \frac{14}{13} \text{ A}$$

Therefore, the value of the short circuit current is $\frac{14}{13}$ A.

Step 10 of 12

Calculate the value of the Thevenin's resistance.

$$R_{Th} = \frac{V_{OC}}{I_{SC}}$$

Substitute $\frac{14}{13}$ A for I_{SC} and 12 V for V_{OC}.

$$R_{Th} = \frac{12}{\left(\frac{14}{13}\right)}$$
$$= (12)\left(\frac{13}{14}\right)$$
$$= \frac{156}{14}$$
$$= \frac{78}{7} \ \Omega$$

Therefore, the value of the Thevenin's resistance is $\frac{78}{7}$ Ω.

Step 11 of 12

Draw the Thevenin's equivalent circuit diagram.

Figure 3

Step 12 of 12

Calculate the value of the current I_O.

$$I_O = \frac{12}{\frac{78}{7} + 7}$$
$$= \frac{12(7)}{78+49}$$
$$= \frac{84}{127}$$
$$= 0.6614 \text{ A}$$

Therefore, the value of the current I_O is $\boxed{0.6614 \text{ A}}$.

Step 1 of 8

5.079P

Refer to Figure P5.77 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Write the mesh equation for the loop 2.

$$-2V_A + I_2(2+1) - V_A = 0$$
$$3V_A = 3I_2$$
$$V_A = I_2$$

Hence, the expression loop 2 is $V_A = I_2$ ..... (1)

From the Figure 1, write the expressions for V_A, I_1 and I_2.

$V_A = 8I_1$ and $I_2 = I_A - 2\text{A}$ ..... (2)

Write the current equation at the center node.

$$3I_A + 2 = I_1 + I_A$$
$$I_1 = 2I_A + 2$$

Hence, the current expression at center node is $I_1 = 2I_A + 2$ ..... (3)

Substitute equation (2) in equation (1).

$$V_A = I_2$$
$$8I_1 = I_A - 2$$

Substitute equation (3) for I_1.

$$8I_1 = I_A - 2$$
$$8(2I_A + 2) = I_A - 2$$
$$16I_A - I_A = -2 - 16$$
$$I_A = -1.2\text{A}$$

Step 3 of 8

Write the mesh equation for the bottom half part.

$$-V_{oc} + (5)(2) + V_A + 9 = 0$$

$$\begin{aligned} V_{oc} &= V_A + 9 + 10 \\ &= 8(I_1) + 19 \\ &= 8(2I_A + 2) + 19 \end{aligned}$$

Substitute -1.2A for I_A.

$$\begin{aligned} V_{oc} &= 8(2I_A + 2) + 19 \\ &= 8(2(-1.2) + 2) + 19 \\ &= 15.8\text{V} \end{aligned}$$

Step 4 of 8

The circuit for calculating short-circuited current is shown in Figure 2.

Figure 2

Step 5 of 8

Write the mesh equation for the loop 1.

$$1I_1 + 2I_1 + 2V_A + 8(I_1 - I_3) = 0$$
$$11I_1 - 8I_3 + 2V_A = 0$$

But the expression for the voltage $V_A = 8(I_1 - I_3)$

$$11I_1 - 8I_3 + 2V_A = 0$$
$$11I_1 - 8I_3 + 16(I_1 - I_3) = 0$$
$$27I_1 - 24I_3 = 0$$

Step 6 of 8

But the currents are as follows:

$$I_A = I_2 - I_1$$
$$I_1 = I_2 - I_A$$

and

$$\begin{aligned} I_4 - I_3 &= 3I_A \\ I_3 &= I_4 - 3I_A \end{aligned} \quad \text{..... (4)}$$

$$27I_1 - 24I_3 = 0$$
$$27(I_2 - I_A) - 24(I_4 - 3I_A) = 0$$
$$27I_2 - 27I_A - 24I_4 + 72I_A = 0$$
$$45I_A = -27I_2 + 24I_4$$

But the value of current $I_2 = 2\text{A}$

$$\begin{aligned} 45I_A &= -27I_2 + 24I_4 \\ &= -27(2\text{A}) + 24I_4 \end{aligned}$$

$$\begin{aligned} I_A &= \frac{-54 + 24I_4}{45} \\ &= -1.2 + 0.533I_4 \end{aligned}$$

Step 7 of 8

Apply Kirchhoff voltage law (KVL) around the bottom loop.

$$-9 - V_A + (5\Omega)(I_4 - I_2) = 0$$
$$-9 - (8\Omega)(I_1 - I_3) + (5\Omega)(I_4 - I_2) = 0$$
$$-9 - (8\Omega)(I_2 - I_A - I_4 + 3I_A) + (5\Omega)(I_4 - 2) = 0$$
$$-9 - (8\Omega)(2 + 2I_A - I_4) + (5\Omega)(I_4 - 2) = 0$$

Further simplification

$$-9 - (8\Omega)(2 + 2I_A - I_4) + (5\Omega)(I_4 - 2) = 0$$
$$-9 - (8\Omega)(2 + 2(-1.2 + 0.533I_4) - I_4) + (5\Omega)(I_4 - 2) = 0$$
$$-9 - (8\Omega)(-0.4 + 0.066I_4) + (5\Omega)(I_4 - 2) = 0$$
$$4.472I_4 = 9 - 3.2 + 10$$

$$I_4 = 3.533\text{A}$$

Write the expression for the short-circuited current.

$$\begin{aligned} I_{sh} &= I_4 \\ &= 3.533\text{A} \end{aligned}$$

Write the expression for the Thevenin resistance.

$$\begin{aligned} R_{Th} &= \frac{V_{oc}}{I_{sh}} \\ &= \frac{15.8\text{V}}{3.533\text{A}} \\ &= 4.472\Omega \end{aligned}$$

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 8 of 8

Apply voltage division rule, calculate the voltage V_o.

$$V_o = \left(\frac{2\Omega}{R_{Th} + 2\Omega}\right)(V_{oc})$$

Calculate the voltage V_o by substituting 15.8V for V_{oc} and 3.3Ω for R_{Th}.

$$\begin{aligned} V_o &= \left(\frac{2\Omega}{R_{Th} + 2\Omega}\right)(V_{oc}) \\ &= \left(\frac{2\Omega}{4.472\Omega + 2\Omega}\right)(15.8\text{V}) \\ &= 4.883\text{V} \end{aligned}$$

Therefore, the voltage V_o is $\boxed{4.883\text{V}}$.

Step 1 of 9

Refer to Figure P5.69 in the textbook.

Open circuit the right side unknown value resistor and calculate the open circuit voltage across the open terminals.

Draw the modified circuit.

Figure 1

Step 2 of 9

There is a voltage source between nodes V_1 and V_2. Write the voltage expression.

$$V_2 - V_1 = 12$$

$$V_2 = V_1 + 12 \text{ ..... (1)}$$

Apply Kirchhoff's current law at super node.

$$\frac{V_1 - 2V_x}{1\text{ k}} + \frac{V_1}{1\text{ k}} + \frac{V_2 - V_x}{1\text{ k}} = 2\text{ m}$$

$$\frac{2V_1}{1\text{ k}} + \frac{V_2}{1\text{ k}} - \frac{3V_x}{1\text{ k}} = 2\text{ m}$$

$$2V_1 + V_2 - 3V_x = 2 \text{ ..... (2)}$$

Apply Kirchhoff's current law at node V_x.

$$\frac{V_x - V_2}{1\text{ k}} + \frac{V_x}{1\text{ k}} = 4\text{ m}$$

$$\frac{2V_x}{1\text{ k}} - \frac{V_2}{1\text{ k}} = 4\text{ m}$$

$$V_2 = 2V_x - 4 \text{ ..... (3)}$$

Step 3 of 9

Substitute $2V_x - 4$ for V_2 in $V_2 = V_1 + 12$ equation (3).

$$2V_x - 4 = V_1 + 12$$

$$V_1 = 2V_x - 16 \text{ ..... (4)}$$

Substitute $2V_x - 16$ for V_1 and $2V_x - 4$ for V_2 in $2V_1 + V_2 - 3V_x = 2$ equation (4).

$$2(2V_x - 16) + 2V_x - 4 - 3V_x = 2$$

$$(4 + 2 - 3)V_x = 2 + 4 + 32$$

$$3V_x = 38$$

$$V_x = 12.67\text{ V}$$

The voltage, V_x is nothing but the open circuit voltage.

Therefore, the open circuit voltage, V_{oc} is $\boxed{12.67\text{ V}}$.

Step 4 of 9

Short circuit the resistor right side unknown value resistor and calculate the short circuit current through shorted path.

Draw the modified circuit.

Figure 2

Step 5 of 9

There is a voltage source between nodes V_1 and V_2. Write the voltage expression.

$$V_2 - V_1 = 12$$

$$V_2 = V_1 + 12 \text{ ..... (5)}$$

Apply Kirchhoff's current law at super node.

$$\frac{V_1 - 2V_x}{1\text{ k}} + \frac{V_1}{1\text{ k}} + \frac{V_2 - V_x}{1\text{ k}} = 2\text{ m}$$

$$\frac{2V_1}{1\text{ k}} + \frac{V_2}{1\text{ k}} - \frac{3V_x}{1\text{ k}} = 2\text{ m}$$

$$2V_1 + V_2 - 3V_x = 2 \text{ ..... (6)}$$

Step 6 of 9

Apply Kirchhoff's current law at node V_x.

$$\frac{V_x - V_2}{1\text{ k}} + \frac{V_x}{1\text{ k}} + \frac{V_x}{1\text{ k}} = 4\text{ m}$$

$$\frac{3V_x}{1\text{ k}} - \frac{V_2}{1\text{ k}} = 4\text{ m}$$

$$V_2 = 3V_x - 4 \text{ ..... (7)}$$

Substitute $3V_x - 4$ for V_2 in $V_2 = V_1 + 12$ equation (7).

$$3V_x - 4 = V_1 + 12$$

$$V_1 = 3V_x - 16 \text{ ..... (8)}$$

Substitute $3V_x - 16$ for V_1 and $3V_x - 4$ for V_2 in $2V_1 + V_2 - 3V_x = 2$ equation (8).

$$2(3V_x - 16) + 3V_x - 4 - 3V_x = 2$$

$$(6 + 3 - 3)V_x = 2 + 4 + 32$$

$$6V_x = 38$$

$$V_x = 6.33\text{ V}$$

Step 7 of 9

Calculate the short circuit current.

$$\begin{aligned} I_{sc} &= \frac{V_x}{1\text{ k}} \\ &= \frac{6.33}{1\text{ k}} \\ &= 6.33\text{ mA} \end{aligned}$$

Calculate the Thevenin's equivalent resistance.

$$\begin{aligned} R_{Th} &= \frac{V_{oc}}{I_{sc}} \\ &= \frac{12.67}{6.33\text{ m}} \\ &= 2\text{ k}\Omega \end{aligned}$$

Therefore, the value of the Thevenin's equivalent resistance, R_{Th} is $\boxed{1\text{ k}\Omega}$.

Step 8 of 9

The value of the resistor is not given and all the values of remaining resistors are $1\text{ k}\Omega$. So, consider the value of the resistor as $1\text{ k}\Omega$.

Draw the Thevenin's equivalent circuit along with the load.

Figure 3

Step 9 of 9

Apply voltage division rule to calculate the output voltage.

$$\begin{aligned} V_o &= \left(\frac{1\text{ k}}{3\text{ k} + 1\text{ k}}\right)(12.67) \\ &= \left(\frac{1\text{ k}}{3\text{ k}}\right)(12.67) \\ &= (0.33)(12.67) \\ &= 4.22\text{ V} \end{aligned}$$

Therefore, the value of the output voltage, V_o is $\boxed{4.22\text{ V}}$.

Step 1 of 7

Refer to Figure P5.78 in the text book.

The Thevenin voltage can be calculated with the circuit shown in Figure 1.

Figure 1

Step 2 of 7

Apply Kirchhoff current law at the node 2.

$$\frac{V_{oc}-V_1}{1\text{k}}+\frac{V_{oc}-V_3}{1\text{k}}=0$$

$$2V_{oc}=V_1+V_3$$

Hence, the expression at the node 2 is $2V_{oc}=V_1+V_3$ ..... (1)

The voltages $V_1=6\text{ V}$ and $V_3=2\text{ V}$ ..... (2)

Substitute equation (2) in equation (1).

$$\begin{aligned}2V_{oc}&=V_1+V_3\\&=6+2\\V_{oc}&=4\text{ V}\end{aligned}$$

Step 3 of 7

The short-circuited current can be calculated with the circuit shown in Figure 2.

Figure 2

Step 4 of 7

Write the expression for the current I_{sh}.

$$I_{sh}=\frac{V_1}{1\text{k}}+\frac{V_3}{1\text{k}}$$

Calculate the current I_{sh} by substituting 6 V for V_1 and 2 V for V_3.

$$\begin{aligned}I_{sh}&=\frac{V_1}{1\text{k}}+\frac{V_3}{1\text{k}}\\&=\frac{6\text{ V}}{1\text{k}}+\frac{2\text{ V}}{1\text{k}}\\&=6\Omega+2\Omega\\&=8\Omega\end{aligned}$$

Write the expression for the current I_{sh}.

$$I_{sh}=\frac{V_o}{3\text{k}}$$

Calculate the current I_{sh} by substituting 1.167 V for V_o.

$$\begin{aligned}I_{sh}&=\frac{V_o}{3\text{k}}\\&=\frac{-1.167\text{ V}}{3\text{k}}\\&=-0.389\text{ mA}\end{aligned}$$

Step 5 of 7

Write the expression for the Thevenin resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sh}}$$

Calculate the Thevenin resistance by substituting 4 V for V_{oc} and 8 mA for I_{sh}.

$$\begin{aligned}R_{Th}&=\frac{V_{oc}}{I_{sh}}\\&=\frac{4\text{ V}}{8\text{ mA}}\\&=0.5\text{ k}\Omega\end{aligned}$$

Step 6 of 7

The Thevenin equivalent circuit is shown in Figure 3.

Figure 3

Step 7 of 7

Apply Ohm's law and calculate the current I_o.

$$\begin{aligned}I_o&=\frac{4\text{ V}}{0.5\text{k}+2\text{k}}\\&=1.6\text{ mA}\end{aligned}$$

Therefore, the current I_o is $\boxed{1.6\text{ mA}}$.

Step 1 of 10

Refer to Figure P5.79 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 10

Write the expression for the current I_1.

$$I_1 = -2I_x$$

But,

$$I_x = I_2 - I_3$$

Then write the expression for the current I_1.

$$\begin{aligned} I_1 &= -2I_x \\ &= -2(I_2 - I_3) \end{aligned}$$

$= -2I_2 + 2I_3$ ..... (1)

Write the mesh equation for the loop 2.

$$-4 + 1(I_2 - I_1) + 1(I_2 - I_3) = 0$$

$-I_1 + 2I_2 - I_3 = 4$ ..... (2)

Write the expression for the current I_4.

$$I_4 = -2\text{mA}$$

Write the mesh equation for the loop 3.

$$\begin{aligned} &1(I_3 - I_2) + 1(I_3 - I_1) + 1(I_3 - I_4) + 6 = 0 \\ &-I_1 - I_2 + 3I_3 - I_4 = -6 \end{aligned}$$

Substitute -2mA for I_4 in the equation.

$$\begin{aligned} &-I_1 - I_2 + 3I_3 - I_4 = -6 \\ &-I_1 - I_2 + 3I_3 - (-2) = -6 \end{aligned}$$

$-I_1 - I_2 + 3I_3 = -8$ ..... (3)

Step 3 of 10

Substitute equation (1) in equation (2).

$$\begin{aligned} &-I_1 + 2I_2 - I_3 = 4 \\ &-(-2I_2 + 2I_3) + 2I_2 - I_3 = 4 \end{aligned}$$

$4I_2 - 3I_3 = 4$ ..... (4)

Substitute equation (1) in equation (3).

$$-(-2I_2 + 2I_3) - I_2 + 3I_3 = -8$$

$I_2 + I_3 = -8$ ..... (5)

Multiply equation (5) with 4 and subtract from equation (4).

$$\begin{aligned} 4I_2 - 3I_3 &= 4 \\ 4I_2 + 4I_3 &= -32 \\ \hline -7I_3 &= 36 \end{aligned}$$

$$I_3 = -5.14\text{mA}$$

Step 4 of 10

Calculate the expression for the current I.

$$\begin{aligned} I &= I_3 - I_4 \\ &= -5.14 - (-2) \\ &= -3.14\text{mA} \end{aligned}$$

Write the equation for the Thevenin voltage.

$$-6 - 1\text{k}(I) + I_4 + V_{oc} = 0$$

Substitute -3.14 mA for I and -2 mA for I_4 in the equation.

$$\begin{aligned} &-6 - 1\text{k}(I) + 1\text{k}(I_4) + V_{oc} = 0 \\ &-6 - 1\text{k}(-3.14\text{mA}) + 1\text{k}(-2\text{mA}) + V_{oc} = 0 \end{aligned}$$

$$\begin{aligned} V_{oc} &= 6 + 1\text{k}(-3.14\text{mA}) - 1\text{k}(-2\text{mA}) \\ &= 4.86\text{ V} \end{aligned}$$

Step 5 of 10

The circuit for calculating short-circuited current is shown in Figure 2

Figure 2

Step 6 of 10

Write the expression for the current I_1.

$$I_1 = -2I_x$$

But,

$$I_x = I_2 - I_3$$

Then write the expression for the current I_1.

$$\begin{aligned} I_1 &= -2I_x \\ &= -2(I_2 - I_3) \\ &= -2I_2 + 2I_3 \end{aligned}$$

$I_1 + 2I_2 - 2I_3 = 0$ ..... (6)

Write the mesh equation for the loop 2.

$$-4 + 1(I_2 - I_1) + 1(I_2 - I_3) = 0$$

$-I_1 + 2I_2 - I_3 = 4$ ..... (7)

Write the expression for the current I_4.

$I_5 - I_4 = 2\text{mA}$ ..... (8)

Write the mesh equation for the loop 3.

$$1(I_3 - I_2) + 1(I_3 - I_1) + 1(I_3 - I_4) + 6 = 0$$

$-I_1 - I_2 + 3I_3 - I_4 = -6$ ..... (9)

Write the expression for super mesh.

$$\begin{aligned} &-6 + 1(I_4 - I_3) + 1I_4 = 0 \\ &-I_3 + 2I_4 = 6 \end{aligned}$$

$I_3 = 2I_4 - 6$ ..... (5)

Step 7 of 10

Add equation (6) to equation (9).

$$\begin{aligned} -I_1 - I_2 + 3I_3 - I_4 &= -6 \\ I_1 + 2I_2 - 2I_3 &= 0 \\ \hline I_2 + I_3 - I_4 &= -6 \end{aligned}$$

$I_2 + I_3 - I_4 = -6$ ..... (11)

Add equation (6) to equation (7).

$$\begin{aligned} I_1 + 2I_2 - 2I_3 &= 0 \\ -I_1 + 2I_2 - I_3 &= 4 \\ \hline 4I_2 - 3I_3 &= 4 \end{aligned}$$

$$I_2 = \frac{4 + 3I_3}{4}$$

$I_2 = \dfrac{4 + 3I_3}{4}$ ..... (12)

Substitute equation (12) in equation (11).

$$I_2 + I_3 - I_4 = -6$$

$$\frac{4 + 3I_3}{4} + I_3 - I_4 = -6$$

$$4 + 3I_3 + 4I_3 - 4I_4 = -24$$

$7I_3 - 4I_4 = -28$ ..... (13)

Step 8 of 10

Substitute equation (10) in equation (13).

$$\begin{aligned} &7I_3 - 4I_4 = -28 \\ &7(2I_4 - 6) - 4I_4 = -28 \\ &14I_4 - 42 - 4I_4 = -28 \\ &I_4 = 1.4\text{mA} \end{aligned}$$

Substitute 1.4mA for I_4 in equation (8).

$$\begin{aligned} &I_5 - I_4 = 2\text{mA} \\ &I_5 - 1.4\text{mA} = 2\text{mA} \\ &I_5 = 3.4\text{mA} \end{aligned}$$

Write the expression for short-circuited current.

$$\begin{aligned} I_{sh} &= I_5 \\ &= 3.4\text{mA} \end{aligned}$$

Write the expression for the Thevenin resistance.

$$\begin{aligned} R_{Th} &= \frac{V_{oc}}{I_{sh}} \\ &= \frac{4.86\text{ V}}{3.4\text{mA}} \\ &= 1.43\text{k}\Omega \end{aligned}$$

Step 9 of 10

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 10 of 10

Apply voltage division rule, calculate the voltage V_o.

$$V_o = \left(\frac{1\text{k}\Omega}{R_{Th} + 1\text{k}\Omega}\right)(V_{oc})$$

Calculate the voltage V_o by substituting 4.86 V for V_{oc} and $1.43\text{k}\Omega$ for R_{Th}.

$$\begin{aligned} V_o &= \left(\frac{1\text{k}\Omega}{R_{Th} + 1\text{k}\Omega}\right)(V_{oc}) \\ &= \left(\frac{1\text{k}\Omega}{1.43\text{k}\Omega + 1\text{k}\Omega}\right)(4.86\text{ V}) \\ &= 2\text{ V} \end{aligned}$$

Therefore, the voltage V_o is $\boxed{2\text{ V}}$.

Step 1 of 4

5.083P

Refer to Figure P5.80 in the text book.

Since the circuit having dependable source, break the circuit left of the $2\,\mathrm{k\Omega}$ resistor and apply current source at the terminals and compute the terminal voltage V_2 as shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff current law (KCL) at top node.

$$\frac{V_x}{1000} + I = \frac{V_x}{1\mathrm{k}}$$

$$I = \frac{V_x}{1000} - \frac{V_x}{1\mathrm{k}}$$

$$= 0$$

Write the expression for the resistance.

$$R = \frac{V_2}{I}$$

Since the current I is 0, the resistance is ∞ .

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 3 of 4

Write the expression for the Thevenin resistance.

$$R_{\mathrm{Th}} = (R + 2\mathrm{k}) \| 1\mathrm{k}$$

Since the resistance R is ∞ , the parallel combination with the $1\mathrm{k}$ resistor is almost equal to the lower resistance among them.

$$R_{\mathrm{Th}} \simeq 1\mathrm{k\Omega}$$

Therefore, the Thevenin resistance is $\boxed{1\mathrm{k\Omega}}$.

Step 4 of 4

Since the circuit contains only dependent source, the Thevenin or Norton equivalent is only the Thevenin resistance as shown in Figure 4.

Figure 4

Therefore, the Thevenin's equivalent of the network is shown in Figure 4.

Step 1 of 4

Refer to Figure P5.81 in the text book.

Since the circuit having dependable source, apply current source at the terminals A-B and compute the terminal voltage V_2 as shown in Figure 1.

Figure 1

Step 2 of 4

The dependable source forms a super node.

Write the expression at super node.

$$V_1 - V_2 = 1000 I_x$$

Hence, the expression at super node is $V_1 - V_2 = 1000 I_x$ ..... (1)

and $I_x = \frac{V_1}{2\text{k}}$ ..... (2)

Substitute equation (2) in equation (1).

$$V_1 - V_2 = 1000 I_x$$
$$V_1 - V_2 = 1000\left(\frac{V_1}{2\text{k}}\right)$$
$$0.5V_1 = V_2$$
$$V_1 = 2V_2$$

Hence, the expression at node 2 is $V_1 = 2V_2$ ..... (3)

Step 3 of 4

Apply Kirchhoff current law at the super node.

$$\frac{V_1}{1\text{k}+1\text{k}} + \frac{V_1}{2\text{k}} + \frac{V_2}{2\text{k}} - I = 0$$
$$V_1 + V_1 + V_2 = I(2\text{k})$$
$$2V_1 + V_2 = I(2\text{k})$$

Substitute equation (3) in the expression.

$$2V_1 + V_2 = I(2\text{k})$$
$$2(2V_2) + V_2 = I(2\text{k})$$
$$\frac{V_2}{I} = \frac{2k}{5}$$
$$= 400\Omega$$

Write the expression for the Thevenin resistance.

$$R_{\text{Th}} = \frac{V_2}{I}$$
$$= 400\Omega$$

Therefore, the Thevenin resistance is $\boxed{400\Omega}$.

Step 4 of 4

Since the circuit contains only dependent source, the Thevenin or Norton equivalent is only the Thevenin resistance as shown in Figure 2.

Figure 2

Step 1 of 8

Figure (1)

Step 2 of 8

For circuit containing only dependent sources, so for the above circuit only Thevenin resistance is there thevenin voltage will be zero

To find R_{TH}, use a 1 V source as shown in Fig. 2 . Let the currents be as shown in Fig. 2.

Step 3 of 8

Figure (2)

Step 4 of 8

By analyzing Fig. 2 we get,

$$V_A = 1\,\text{V} \qquad ....(1)$$
$$V_x = V_1 \qquad ....(2)$$
$$I_O = \frac{1-V_2}{3\text{k}} \qquad ....(3)$$

Step 5 of 8

By using KCL at node 1 in Fig. 2,

$$\frac{V_2 - V_1}{2\text{k}} - \frac{V_1}{1\text{k}} = 0$$
$$V_2 - 3V_x = 0 \qquad ....(\text{By}(2))$$
$$V_2 = 3V_x \qquad ....(4)$$

Step 6 of 8

By using KCL at node 2 in Fig. 2,

$$-\frac{V_2 - V_1}{2\text{k}} + \frac{1-V_2}{3\text{k}} - \frac{4V_x}{1000} = 0$$
$$-3(V_2 - V_1) + 2(1 - V_2) - 6(4V_x) = 0$$
$$-3(3V_x - V_x) + 2(1 - 3V_x) - 24V_x = 0$$
$$-6V_x + 2 - 6V_x - 24V_x = 0$$
$$36V_x = 2$$
$$V_x = \frac{1}{18}\text{V} \qquad ....(5)$$

Step 7 of 8

$$\therefore V_2 = 3\left(\frac{1}{18}\right)\text{V} \qquad ....(\text{By }(5))$$
$$V_2 = \frac{1}{6}\text{V}$$
$$I_o = \frac{1 - \frac{1}{6}}{3\text{k}} \qquad ....(\text{By}(3))$$
$$I_o = \frac{5}{18\text{k}}$$
$$I_o = 0.2778\,\text{mA}$$

Step 8 of 8

Therefore,

$$R_{TH} = \frac{1}{I_o}$$
$$R_{TH} = \frac{18}{5}\text{k}$$
$$\boxed{R_{TH} = 3.6\,\text{k}\Omega}$$

Step 1 of 8

Figure (1)

Step 2 of 8

For circuit containing only dependent sources the Thevenin equivalent is only R_{TH}, and thevenin voltage is zero. To find R_{TH},use a 1 mA source as shown in Fig. 2.Let the currents be as shown in Fig. 2.

Figure (2)

Step 3 of 8

By analyzing Fig. 2 we get,

$$V_x = V_B \qquad ....(1)$$

Step 4 of 8

By KCL at node B in Fig. 2,

$$1\text{m} + \frac{V_1 - V_B}{2\text{k}} - \frac{V_B}{1\text{k}} = 0$$
$$2 + V_1 - V_B - 2V_B = 0$$
$$V_1 - 3V_x + 2 = 0 \qquad ....(\text{By}(1))$$
$$V_1 = 3V_x - 2 \qquad ....(2)$$

Step 5 of 8

By KCL at node A in Fig. 2,

$$\frac{V_1 - V_A}{4\text{k}} - 1\text{m} - \frac{V_A}{2\text{k}} = 0$$
$$V_1 - V_A - 4 - 2V_A = 0$$
$$3V_A = V_1 - 4$$
$$3V_A = 3V_x - 2 - 4 \qquad ....(\text{By } (2))$$
$$V_A = V_x - 2 \qquad ....(3)$$

Step 6 of 8

By KCL at node 1 in Fig. 2,

$$\frac{V_x}{2000} - \frac{V_1 - V_B}{2\text{k}} - \frac{V_1 - V_A}{4\text{k}} = 0$$
$$2V_x - 2(V_1 - V_B) - (V_1 - V_A) = 0$$
$$2V_x - 3V_1 + 2V_B + V_A = 0$$
$$2V_x - 3(3V_x - 2) + 2V_x + V_x - 2 = 0 \qquad ....(\text{By } (1),(2) \text{ and } (3))$$
$$-4V_x + 6 - 2 = 0$$
$$V_x = 1\text{ V} \qquad ....(4)$$

Step 7 of 8

$$\therefore V_B = 1\text{ V} \qquad ....(\text{By } (1))$$
$$V_A = 1 - 2\text{ V} \qquad ....(\text{By } (3))$$
$$V_A = -1\text{ V}$$

Step 8 of 8

Therefore,

$$R_{TH} = \frac{V_B - V_A}{1\text{m}}$$
$$R_{TH} = \frac{1-(-1)}{1}\text{k}$$
$$\boxed{R_{TH} = 2\text{ k}\Omega}$$

Step 1 of 5

Given circuit diagram:

Figure (1)

Step 2 of 5

For circuit containing only dependent sources, the Thevenin equivalent is only R_{Th} and Thevenin voltage is zero.

To find R_{Th}, use a 1 V test source as shown in Fig. 2. Let the mesh currents be as shown in Fig. 2.

Figure (2)

Step 3 of 5

By analyzing Fig. 2 we get

$V_{AB} = 1\text{ V}$ ..... (1)

$I_o = -I_3$ ..... (2)

$I_x = I_1 - I_2$ ..... (3)

$V_{cd} = 2000 I_x$ ..... (4)

By Ohm's Law in Fig. 2:

$V_{AB} = (I_2 - I_3)(4\text{k})$

$\Rightarrow I_2 = I_3 + \frac{1}{4}\text{m}$ ..... (5)

Step 4 of 5

Apply Kirchhoff's voltage law in the loop dBd in Fig. 2:

$(I_1 - I_2)(2\text{k}) + I_1(6\text{k}) = 0$

$\Rightarrow 8I_1 - 2I_2 = 0$

$\Rightarrow I_1 = \frac{1}{4} I_2$

$\Rightarrow I_1 = \frac{1}{4}\left(I_3 + \frac{1}{4}\text{m}\right)$ [From Equation (5)]

$\Rightarrow I_1 = \frac{1}{4} I_3 + \frac{1}{16}\text{ m}$ ..... (6)

Step 5 of 5

Apply Kirchhoff's voltage law in the loop $dcABd$ in Fig. 2:

$-I_x(2000) + I_2(4\text{k}) + (I_2 - I_3)(4\text{k}) + (I_2 - I_1)(2\text{k}) = 0$ ..... (7)

$-2(I_1 - I_2) + 4I_2 + 4(I_2 - I_3) + 2(I_2 - I_1) = 0$ (As $I_x = I_1 - I_2$)

$-(I_1 - I_2) + 2I_2 + 2(I_2 - I_3) + I_2 - I_1 = 0$

$-2I_1 + 6I_2 - 2I_3 = 0$

$-\left(\frac{1}{4} I_3 + \frac{1}{16}\text{ m}\right) + 3\left(I_3 + \frac{1}{4}\text{m}\right) - I_3 = 0$ [By equations (5) and (6)]

$I_3\left(\frac{7}{4}\right) + \frac{11}{16}\text{ m} = 0$

$I_3 = -\frac{11}{28}\text{ mA}$

So

$I_0 = -I_3$ [By equations (2) and (7)]

$= -\left(-\frac{11}{28}\text{ mA}\right)$

$= \frac{11}{28}\text{ mA}$

Therefore,

$R_{Th} = \frac{1}{I_0}$

$= \frac{28}{11}\text{k}$

$\boxed{R_{Th} = 2.545\text{ k}\Omega}$

Step 1 of 9

Figure (1)

Step 2 of 9

The 12V source and 4kΩ in Fig. 1 is transformed to $\frac{12\text{V}}{4\text{k}}$=3mA and 4kΩ as in Fig. 2.

Replace the parallel resistances (4k + 2k) and 12k in Fig. 1 between node a and c as shown in Fig 2,

$$R_{eq} = \frac{(4\text{k}+2\text{k})(12\text{k})}{(4\text{k}+2\text{k}+12\text{k})}$$
$$R_{eq} = 4\text{k}\Omega$$

Step 3 of 9

Figure (2)

Step 4 of 9

Replace the parallel resistances 4k and 12k in Fig. 2 between node b and c as shown in Fig 3,

$$R_{eq} = \frac{(12\text{k})(4\text{k})}{(12\text{k}+4\text{k})}$$
$$\Rightarrow R_{eq} = 3\text{k}\Omega$$

Step 5 of 9

Figure (3)

Step 6 of 9

The 3mA source and 3kΩ in Fig.3 is transformed to $(3\text{m})(3\text{k}) = 9\text{V}$ and 3kΩ as in Fig. 4.
The 2mA source and 4kΩ in Fig.3 is transformed to $(2\text{m})(4\text{k}) = 8\text{V}$ and 4kΩ as in Fig. 4.

Step 7 of 9

Figure (4)

Step 8 of 9

Applying KVL in the loop in Fig. 4

$$I_0(4\text{k}) + I_0(3\text{k}) + I_0(3\text{k}) + 9 - 8 = 0$$
$$I_0(10\text{k}) = -1$$
$$I_0 = -0.1\text{ mA}$$

Step 9 of 9

By Ohm's Law,

$$V_0 = I_0(3\text{k})$$
$$V_0 = (-0.1\text{mA})(3\text{k})$$
$$\boxed{V_0 = -0.3\text{ V}}$$

Step 1 of 6

Figure (1)

Step 2 of 6

The 6V source and 6kΩ in Fig.1 is transformed to $\frac{6V}{6k} = 1mA$ and 6kΩ as in Fig. 2.

Figure (2)

Step 3 of 6

Replace the parallel resistances in Fig. 2 between node a and d as shown in Fig 3,

$$R_{eq} = \frac{(6k \times 6k)}{(6k + 6k)}$$

$$R_{eq} = 3k\Omega$$

Figure (3)

Step 4 of 6

The 1mA source and 3kΩ in Fig.3 is transformed to $(1m)(3k) = 3V$ and 3kΩ as in Fig. 4.

Figure (4)

Step 5 of 6

Replace the series resistances in Fig. 4 as shown in Fig 5,

$$R_{eq} = (3k) + (6k)$$

$$\Rightarrow R_{eq} = 9k\Omega$$

Figure (5)

Step 6 of 6

The 3V source and 9kΩ in Fig.5 is transformed to $\frac{3V}{9k} = \frac{1}{3}mA$ and 9kΩ as in Fig. 6.

Figure (6)

By Current Division Rule ,

$$I_O = \left(\frac{1}{3}m - 1m\right)\left(\frac{9k}{9k + 6k}\right)$$

$$I_O = -\frac{2}{3}\left(\frac{9}{15}\right)mA$$

$$I_O = -\frac{2}{5}mA$$

$$\boxed{I_O = -0.4\ mA}$$

Step 1 of 4

5.090P

Refer to Figure P5.85 in the text book.

Since the 2 mA current source is in parallel with $6\,\text{k}\Omega$ resistor, the source transformation is equal to 12 V voltage source in series with $6\,\text{k}\Omega$ resistor. The 24 V voltage source is in series with $12\,\text{k}\Omega$ resistor, the source transformation is equal to 2 mA current source in parallel with $12\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Since the two 12 V and 6 V voltage sources are in series, the resultant voltage is 18 V and $6\,\text{k}\Omega$ resistor is in series with it, the source transformation is equal to 3 mA current source in parallel with $6\,\text{k}\Omega$ resistor. Then the equivalent circuit is shown in Figure 2.

Figure 2

Step 3 of 4

The resultant current source is 1 mA upward. The resistors $6\,\text{k}$ and $12\,\text{k}$ are in parallel. Calculate the equivalent resistance.

$$R = \frac{(6\,\text{k})(12\,\text{k})}{6\,\text{k} + 12\,\text{k}}$$
$$= 4\,\text{k}\Omega$$

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 4

Apply current division rule, write the expression for the current I_o.

$$I_o = \frac{4}{4+4}(1\,\text{mA})$$
$$= 0.5\,\text{mA}$$

Write the expression for the voltage V_o.

$$V_o = I_o(4\,\text{k}\Omega)$$

Calculate the voltage V_o by substituting $0.5\,\text{mA}$ for I_o.

$$V_o = I_o(4\,\text{k}\Omega)$$
$$= (0.5\,\text{mA})(4\,\text{k}\Omega)$$
$$= 2\,\text{V}$$

Therefore, the voltage V_o is $\boxed{2\,\text{V}}$.

Step 1 of 4

5.091P

Refer to Figure P5.88 in the text book.

The resistors $2\,\text{k}\Omega$ and $4\,\text{k}\Omega$ are in series. Their equivalent resistance is $6\,\text{k}\Omega$. Since the $2\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ resistor, the source transformation is equal to $12\,\text{V}$ voltage source in series with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Since the two $12\,\text{V}$ and $6\,\text{V}$ voltage sources are in series, the resultant voltage is $6\,\text{V}$. Then the equivalent circuit is shown in Figure 2.

Figure 2

Step 3 of 4

Apply Kirchhoff current law (KCL) at the node 1.

$$\frac{V_1+6}{6}+\frac{V_1}{2}+\frac{V_1-3}{6}=0$$

$$\frac{V_1+6+3V_1+V_1-3}{6}=0$$

$$5V_1=-3$$

$$V_1=-\frac{3}{5}\text{V}$$

Step 4 of 4

Write the expression for the current I_o.

$$I_o=\frac{V_1}{2\,\text{k}\Omega}$$

Calculate the current I_o by substituting $-\frac{3}{5}\text{V}$ for V_1.

$$I_o=\frac{V_1}{2\,\text{k}\Omega}$$

$$=\frac{-\frac{3}{5}}{2\,\text{k}\Omega}$$

$$=-0.3\,\text{mA}$$

Therefore, the current I_o is $\boxed{-0.3\,\text{mA}}$.

Step 1 of 4

5.092P

Refer to Figure P5.86 in the text book.

The $9\,\text{k}$ and $3\,\text{k}$ resistors are in series and resultant is in parallel with $4\,\text{k}$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R &= 4 \parallel (9+3) \\ &= 4 \parallel 12 \\ &= \frac{(4)(12)}{4+12} \\ &= 3\,\text{k}\Omega \end{aligned}$$

Since the 4 mA current source is in parallel with $3\,\text{k}\Omega$ resistor, the source transformation is equal to 12 V voltage source in series with $3\,\text{k}\Omega$ resistor.

is a Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The $3\,\text{k}$ and $3\,\text{k}$ resistors are in series, the resultant is $6\,\text{k}$ resistor that is in series with 12 V voltage source. The source transformation is equal to 2 mA current source in parallel with $6\,\text{k}$ resistor. The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 4

The $12\,\text{k}$ and $6\,\text{k}$ resistors are in parallel, the resultant is $4\,\text{k}$ resistor that is in parallel with 2 mA current source. The source transformation is equal to 8 V voltage source in series with $4\,\text{k}$ resistor. The simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 4

Apply Kirchhoff voltage law (KVL) around the loop.

$$-6 + 6\,\text{k}(I_o) + 4\,\text{k}(I_o) + 8 = 0$$

$$10\,\text{k}\,I_o = -2$$

$$I_o = \frac{-2}{10\,\text{k}}$$

$$= -0.2\,\text{mA}$$

Therefore, the current I_o is $\boxed{-0.2\,\text{mA}}$.

Step 1 of 3

5.093P

Refer to Figure P5.87 in the text book.

Since the $6\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to $1\,\text{A}$ current source in parallel with $6\,\text{k}\Omega$ resistor. The $12\,\text{V}$ voltage source is in series with $3\,\text{k}\Omega$ resistor, convert into source transformation, $4\,\text{A}$ current source is in parallel with $3\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The $6\,\text{k}\Omega$ and $3\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$R = \frac{(6)(3)}{6+3}$$
$$= 2\,\text{k}\Omega$$

The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

The $3\,\text{A}$ current source in parallel with $2\,\text{k}\Omega$ resistor, convert into source transformation, $6\,\text{V}$ voltage source in series with $2\,\text{k}\Omega$ resistor.

The simplified circuit is shown in Figure 3.

Figure 3

Apply voltage division rule, write the expression for the voltage V_o .

$$V_o = \frac{4}{2+2+4}(-6\,\text{V})$$
$$= -3\,\text{V}$$

Therefore, the voltage V_o is $\boxed{-3\,\text{V}}$.

Step 1 of 8

Refer to Figure P5.82 in the text book.

The circuit has no independent sources and it has only dependent sources only. Therefore, there is no Thevenin voltage in the circuit and there is only Thevenin resistance R_{Th}.

Step 2 of 8

To determine Thevenin resistance R_{Th}, consider a test voltage source of $1\ \text{V}$ across terminals A and B.

Draw the modified circuit diagram.

Figure 1.

Step 3 of 8

Apply Kirchhoff's Voltage Law for loop 1.

$$6(I - I_A) + 7(I - 4I_A) - 1 = 0$$
$$6I - 6I_A + 7I - 28I_A - 1 = 0$$

$$13I - 34I_A = 1 \text{ ..... (1)}$$

Apply Kirchhoff's Voltage Law for loop 2.

$$12I_A + 3I_A + 2V_A - 6(I - I_A) = 0$$

$$21I_A + 2V_A - 6I = 0 \text{ ..... (2)}$$

Step 4 of 8

Apply Kirchhoff's Voltage Law for loop 3.

$$5I_1 + 9(I_1 - 4I_A) - 2V_A = 0$$
$$5I_1 + 9I_1 - 36I_A - 2V_A = 0$$

$$14I_1 - 36I_A - 2V_A = 0 \text{ ..... (3)}$$

Apply Kirchhoff's Voltage Law for loop 4.

$$-9(I_1 - 4I_A) - 7(I - 4I_A) = 0$$
$$-9I_1 + 36I_A - 7I + 28I_A = 0$$

$$-9I_1 + 64I_A - 7I = 0 \text{ ..... (4)}$$

Step 5 of 8

From equation (2),

$$2V_A = 6I - 21I_A$$

Substitute $6I - 21I_A$ for $2V_A$ in equation (3).

$$14I_1 - 36I_A - (6I - 21I_A) = 0$$
$$8I_1 - 15I_A = 0$$
$$I_1 = \frac{15}{8} I_A$$

Step 6 of 8

Substitute $\frac{15}{8} I_A$ for I_1 in equation (4).

$$-9I_1 + 64I_A - 7I = 0$$
$$-9\left(\frac{15}{8}\right) I_A + 64I_A - 7I = 0$$

$$47.125I_A - 7I = 0 \text{ ..... (5)}$$

Step 7 of 8

From equation (5),

$$47.125I_A = 7I$$
$$I_A = \frac{7I}{47.125}$$

Substitute $\frac{7I}{47.125}$ for I_A in equation (1).

$$13I - 34\left(\frac{7I}{47.125}\right) = 1$$
$$7.95I = 1$$
$$I = 0.126\ \text{A}$$

Step 8 of 8

Determine the Thevenin resistance.

$$R_{Th} = \frac{V_{AB}}{I}$$

Substitute $1\ \text{V}$ for V_{AB} and $0.126\ \text{A}$ for I in the equation.

$$R_{Th} = \frac{1}{0.126}$$
$$= 7.94\ \Omega$$

Thus, the value of Thevenin resistance, R_{Th} is $\boxed{7.94\ \Omega}$.

Step 1 of 13

The following is the circuit diagram:

Figure 1

Step 2 of 13

Replace the series resistances $(4\ \text{k}\Omega+8\ \text{k}\Omega)$ and $(3\ \text{k}\Omega+3\ \text{k}\Omega)$ in Figure 1 and the 12 V source and 4 kΩ resistance in Figure 1 is transformed to 3 mA and 4 kΩ as shown in Figure 2.

Figure 2

Step 3 of 13

Replace the parallel resistances 4 kΩ and 12 kΩ in Figure 2 between node a and d as shown in Figure 3.

$$R_{eq}=\frac{(12\ \text{k}\Omega)(4\ \text{k}\Omega)}{(12\ \text{k}\Omega+4\ \text{k}\Omega)}$$
$$=3\text{k}\Omega$$

Figure 3

Step 4 of 13

The 3 mA source and 3 kΩ resistance in Figure 3 is transformed to 9 V and 3 kΩ as shown in Figure 4.

Figure 4

Step 5 of 13

The 9 V source and $3\ \text{k}\Omega+3\ \text{k}\Omega=6\ \text{k}\Omega$ in Figure 4 is transformed to 1.5 mA and 6 kΩ as shown in Figure 5.

Step 6 of 13

Figure 5

Step 7 of 13

Clearly in Figure 5, the two parallel current sources 1.5 mA and −2 mA are linearly combined as shown in Figure 6.

Figure 6

Step 8 of 13

The −0.5 mA source and 6 kΩ resistance in Figure 6 is transformed to −3 V source and 6 kΩ resistance as shown in Figure 7.

Figure 7

Step 9 of 13

Clearly, in Figure 7, the two series voltage sources −3 V and 9 V are linearly combined $(-3\text{V}-9\text{V}=-12\text{V})$ as shown in Figure 8.

Figure 8

Step 10 of 13

The −12 V source and 6 kΩ resistance in Figure 8 is transformed to −2 mA source and 6 kΩ resistance as shown in Figure 9.

Figure 9

Step 11 of 13

Replace the parallel resistances 6 kΩ and 6 kΩ in Figure 9 between node b and d as shown in Figure 10.

$$R_{eq}=\frac{(6\ \text{k}\Omega)(6\ \text{k}\Omega)}{(6\ \text{k}\Omega+6\ \text{k}\Omega)}=3\ \text{k}\Omega$$

Step 12 of 13

Figure 10

Step 13 of 13

Use Current Division Rule in Figure 10.

$$I_o=(-2\ \text{mA})\left(\frac{3\ \text{k}\Omega}{3\ \text{k}\Omega+3\ \text{k}\Omega}\right)$$
$$=-1\ \text{mA}$$

Thus the value of current I_o is $\boxed{-1\ \text{mA}}$.

Step 1 of 12

Figure (1)

Step 2 of 12

The 2mA source and 3kΩ in Fig.1 is transformed to $(2m)(3k) = 6V$ and 3kΩ as in Fig. 2.

Figure (2)

Step 3 of 12

The two series voltage sources 6V and $-6V$ in Fig. 2 are linearly combined as $6V-(-6V)=12V$ as shown in Fig.3

Figure (3)

Step 4 of 12

The 12V source and 3kΩ in Fig.3 is transformed to $\frac{12V}{3k}$=4mA and 3kΩ as in Fig. 4.

Figure (4)

Step 5 of 12

Replace the parallel resistances 3k and 6k in Fig 4 between node b and e as shown in Fig 5,

$$R_{eq} = \frac{(3k)(6k)}{(3k+6k)}$$
$$\Rightarrow R_{eq} = 2k\Omega$$

Figure (5)

Step 6 of 12

The 4mA source and 2kΩ in Fig.5 is transformed to $(4m)(2k) = 8V$ and 2kΩ as in Fig. 6.

Figure (6)

Step 7 of 12

The 8V source and $2k\Omega+2k\Omega=4k\Omega$ in Fig.6 is transformed to $\frac{8V}{4k}$=2mA and 6kΩ as in Fig. 7.

Figure (7)

Step 8 of 12

The two parallel current sources 2mA and $-1mA$ in Fig. 7 are linearly combined as shown in Fig. 8.

Figure (8)

Step 9 of 12

The 1mA source and 4kΩ in Fig.8 is transformed to $(1m)(4k) = 4V$ and 4kΩ as in Fig. 9.

Figure (9)

Step 10 of 12

The 4V source and $4k\Omega+4k\Omega=8k\Omega$ in Fig.9 is transformed to $\frac{4V}{8k}$=0.5mA and 8kΩ as in Fig. 10.

Figure (10)

Step 11 of 12

The two parallel current sources 0.5mA and $-2mA$ in Fig. 10 are linearly combined as shown in Fig. 11.

Figure (11)

Step 12 of 12

By Current Division Rule in Fig. 10 ,

$$I_O = (-1.5mA)\left(\frac{8k}{8k+4k}\right)$$
$$\Rightarrow I_O = -1\text{ mA}$$

Hence ,

$$\boxed{I_O = -1\text{ mA}}$$

Step 1 of 9

Figure (1)

Step 2 of 9

The 2mA source and 6kΩ in Fig.1 is transformed to (2m)(6k) = 12V and 6kΩ as in Fig. 2.
The 1mA source and 18kΩ in Fig.1 is transformed to (1m)(18k) = 18V and 18kΩ as in Fig. 2.

Figure (2)

Step 3 of 9

The 6mA source and 3kΩ in Fig.2 is transformed to (6m)(3k) = 18V and 3kΩ as in Fig. 3.

Figure (3)

Step 4 of 9

The two series voltage sources −12V and 18V in Fig. 3 are linearly combined as 18V + (−12V) = 6V as shown in Fig.4
Also the series resistances 6kΩ+3kΩ = 9kΩ are added as in Fig. 4

Figure (4)

Step 5 of 9

The 6V source and 9kΩ in Fig.4 is transformed to $\frac{6V}{9k} = \frac{2}{3}$mA and 9kΩ as in Fig. 5.
The 18V source and 18kΩ in Fig.4 is transformed to $\frac{18V}{18k}$=1mA and 18kΩ as in Fig. 5.

Step 6 of 9

Figure (5)

Step 7 of 9

Add the parallel current sources in Fig 5 as shown in Fig 6.
Replace the parallel resistances 9k and 18k in Fig. 4 between node b and c as shown in Fig 6,

$$R_{eq} = \frac{(9k \times 18k)}{(9k+18k)}$$
$$R_{eq} = 6k\Omega$$

Figure (6)

Step 8 of 9

The $\frac{1}{3}$mA source and 6kΩ in Fig.6 is transformed to $\left(\frac{1}{3}m\right)(6k) = 2V$ and 6kΩ as in Fig. 7.

Figure (7)

Step 9 of 9

By KVL around the loop in Fig. 7,

$$I_0(4k) + 12 + I_0(6k) + 2 = 0$$
$$I_0(10k) = -14$$
$$I_0 = -1.4 \text{ mA}$$

Hence ,

$$\boxed{I_0 = -1.4 \text{ mA}}$$

Step 1 of 4

5.098P

Refer to Figure P5.89 in the text book.

Since the $2\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ $(3\,\text{k}\Omega + 3\,\text{k}\Omega)$ resistor, the source transformation is equal to $12\,\text{V}$ voltage source in series with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff current law (KCL) at the node 1.

$$\frac{V_1+12}{6}+\frac{V_1}{12}+\frac{V_1-V_2}{3}=0$$

$$\frac{2V_1+24+V_1+4V_1-4V_2}{12}=0$$

$$7V_1-4V_2=-24$$

Hence, the expression at node 1 is $7V_1-4V_2=-24$ ..... (1)

Apply Kirchhoff current law (KCL) at the node 2.

$$\frac{V_2+6}{4}+\frac{V_2}{12}+\frac{V_2-V_1}{3}=0$$

$$\frac{3V_2+18+V_2+4V_2-4V_1}{12}=0$$

$$-4V_1+8V_2=-18$$

$$-2V_1+4V_2=-9$$

Hence, the expression at node 1 is $-2V_1+4V_2=-9$ ..... (2)

Step 3 of 4

Add equation (1) to equation (2).

$$\begin{aligned} 7V_1-4V_2&=-24\\ -2V_1+4V_2&=-9\\ \hline 5V_1&=-33\\ V_1&=-6.6\,\text{V}\end{aligned}$$

Substitute the value $-6.6\,\text{V}$ for V_1 in equation (2).

$$-2V_1+4V_2=-9$$

$$-2(-6.6)+4V_2=-9$$

$$4V_2=-22.2$$

$$V_2=-5.55\,\text{V}$$

Step 4 of 4

Write the expression for the voltage, V_o.

$$V_o=V_1-V_2$$

Calculate the voltage V_o by substituting $-6.6\,\text{V}$ for V_1 and $-5.55\,\text{V}$ for V_2.

$$\begin{aligned} V_o&=V_1-V_2\\ &=-6.6-(-5.55)\\ &=-1.05\,\text{V}\end{aligned}$$

Therefore, the voltage V_o is $\boxed{-1.05\,\text{V}}$.

Step 1 of 5

5.099P

Refer to Figure P5.90 in the text book.

Since the $2\,\text{mA}$ current source is in parallel with $12\,\text{k}\Omega$ resistor, the source transformation is equal to $24\,\text{V}$ voltage source in series with $12\,\text{k}\Omega$ resistor. The $4\,\text{mA}$ current source is in parallel with $3\,\text{k}\Omega$ resistor, the source transformation is equal to $12\,\text{V}$ voltage source in series with $3\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The $4\,\text{mA}$ current source is in parallel with $3\,\text{k}\Omega$ resistor, the source transformation is equal to $12\,\text{V}$ voltage source in series with $3\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 2.

Figure 2

Step 3 of 5

This $12\,\text{V}$ and $12\,\text{V}$ voltage sources are in series, the equivalent voltage is $24\,\text{V}$ and $3\,\text{k}\Omega$ and $3\,\text{k}\Omega$ resistors are in series, the equivalent resistance is $6\,\text{k}\Omega$. The source transformation of this is equal to $4\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ resistor. The $24\,\text{V}$ voltage source is in series with $12\,\text{k}\Omega$ resistor. The source transformation is equal to $2\,\text{mA}$ current source is in parallel with $12\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 3.

Figure 3

Step 4 of 5

Since the $4\,\text{mA}$ and $2\,\text{mA}$ current sources are in upwards, the equivalent current is $6\,\text{mA}$ upwards. The $6\,\text{k}\Omega$ and $12\,\text{k}\Omega$ resistors are in parallel, the equivalent resistance is $4\,\text{k}\Omega$. The source transformation of this is equal to $24\,\text{V}$ voltage source is in series with $4\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 4.

Figure 4

Step 5 of 5

Apply Kirchhoff voltage law (KVL) around the loop.

$$-24+4\text{k}(I_o)+4\text{k}(I_o)+12=0$$

$$8\text{k}I_o=12$$

$$I_o=\frac{12}{8\text{k}}$$

$$=1.5\,\text{mA}$$

Therefore, the current I_o is $\boxed{1.5\,\text{mA}}$.

Step 1 of 5

Refer to Figure P5.91 in the text book.

The resistors $6\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are in series. Their equivalent resistance is $12\,\text{k}\Omega$. Since the $6\,\text{V}$ voltage source is in series with $4\,\text{k}\Omega$ resistor, the source transformation is equal to $1.5\,\text{mA}$ current source in parallel with $4\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

The $12\,\text{k}\Omega$ and $4\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$R = \frac{(12)(4)}{12+4}$$
$$= 3\,\text{k}\Omega$$

The $1.5\,\text{mA}$ current source is in parallel with $3\,\text{k}\Omega$ resistor. The source transformation is equal to the $4.5\,\text{V}$ voltage source is in series with $3\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 2.

Figure 2

Step 2 of 5

The $4.5\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor convert in to source transformation, $0.75\,\text{mA}$ current source in parallel with $6\,\text{k}\Omega$ resistor. Adding this $0.75\,\text{mA}$ source to $2\,\text{mA}$ current source, the simplified circuit is shown in Figure 3.

Figure 3

Step 3 of 5

The $2.75\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ resistor. The source transformation is equal to the $16.5\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor. By adding the adjacent $12\,\text{V}$ voltage source, the simplified circuit is shown in Figure 4.

Figure 4

Step 4 of 5

The $4.5\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor, convert it in to source transformation, $0.75\,\text{mA}$ current source in parallel with $6\,\text{k}\Omega$ resistor. This $6\,\text{k}\Omega$ and $6\,\text{k}\Omega(3\,\text{k}\Omega + 3\,\text{k}\Omega)$ resistors are in parallel. Their equivalent resistance is half of the one of the resistor. That is equal to $3\,\text{k}\Omega$. The simplified circuit is shown in Figure 5.

Figure 5

Step 5 of 5

Apply current division rule, write the expression for the current I_o.

$$I_o = \frac{3}{3+3}(-0.75\,\text{mA})$$
$$= -0.375\,\text{mA}$$

Therefore, the current I_o is $\boxed{-0.375\,\text{mA}}$.

Step 1 of 6

Refer to Figure P5.98 in the text book.

Convert the 12 V voltage source into an equivalent current source.

$$I = \frac{12}{6k}$$
$$= 3\text{ mA}$$

Convert the 2 mA current source into an equivalent voltage source.

$$V = (2\text{ m})(3k)$$
$$= 6\text{ V}$$

Draw the modified circuit.

Figure 1

Step 2 of 6

In Figure 1, the resistors $6\text{ k}\Omega$ and $12\text{ k}\Omega$ are connected in parallel. Calculate their equivalent resistance.

$$R_{eq1} = (6k)\|(12k)$$
$$= \frac{(6k)(12k)}{6k+12k}$$
$$= 4\text{ k}\Omega$$

In Figure 1, the resistors $3\text{ k}\Omega$, $6\text{ k}\Omega$ and $3\text{ k}\Omega$ are connected in series. Calculate their equivalent resistance.

$$R_{eq2} = 3k + 6k + 3k$$
$$= 12\text{ k}\Omega$$

Draw the reduced circuit of Figure 1.

Figure 2

Step 3 of 6

Convert the 6 V voltage source into an equivalent current source.

$$I = \frac{6}{12k}$$
$$= 0.5\text{ mA}$$

Draw the reduced circuit of Figure 2.

Figure 3

Step 4 of 6

In Figure 3, the two current sources are connected in parallel. Calculate the equivalent current source value.

$$I = 2\text{m} - 0.5\text{m}$$
$$= 1.5\text{ mA}$$

In Figure 3, the resistors $4\text{ k}\Omega$ and $12\text{ k}\Omega$ are connected in parallel. Calculate their equivalent resistance.

$$R_{eq3} = (4k)\|(12k)$$
$$= \frac{(4k)(12k)}{4k+12k}$$
$$= 3\text{ k}\Omega$$

Step 5 of 6

Draw the reduced circuit of Figure 3.

Figure 4

Step 6 of 6

Calculate the current flows through $6\text{ k}\Omega$ resistor.

$$I_o = (-1.5\text{m})\left(\frac{3k}{3k+6k}\right)$$
$$= (-1.5\text{m})\left(\frac{1}{3}\right)$$
$$= -0.5\text{ mA}$$

Therefore, the current flowing through $6\text{ k}\Omega$ resistor, I_o is $\boxed{-0.5\text{ mA}}$.

Step 1 of 3

5.102P

Refer to Figure P5.99 in the text book.

In Figure 1, the $12\ \mathrm{V}$ voltage source is in series with $6\,\mathrm{k\Omega}$ resistor, the source transformation is equal to $2\ \mathrm{mA}$ current source in parallel with $6\,\mathrm{k\Omega}$ resistor.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 3

In Figure 1, the $6\,\mathrm{k\Omega}$ and $3\,\mathrm{k\Omega}$ resistors are in parallel. Calculate their equivalent resistance.

$$R = \frac{(6\,\mathrm{k\Omega})(3\,\mathrm{k\Omega})}{6\,\mathrm{k\Omega}+3\,\mathrm{k\Omega}}$$
$$= 2\,\mathrm{k\Omega}$$

The $2\ \mathrm{mA}$ current source is in parallel with $2\,\mathrm{k\Omega}$ resistor. The source transformation is equal to the $4\ \mathrm{V}$ voltage source is in series with $2\,\mathrm{k\Omega}$ resistor.

The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

Apply Kirchhoff voltage law (KVL) around the loop.

$$-4+(2\times10^3)I+(8\times10^3)I+(4\times10^3)I-4+(2\times10^3)I=0$$
$$(16\times10^3)\,I=8$$
$$I=\frac{8}{16\times10^3}$$
$$I=0.5\,\mathrm{mA}$$

Write the expression for the voltage across the $4\,\mathrm{k\Omega}$ resistor.

$$V_o=(I)(4\,\mathrm{k\Omega})$$

Substitute $0.5\,\mathrm{mA}$ for I in the equation.

$$V_o=(0.5\,\mathrm{mA})(4\,\mathrm{k\Omega})$$
$$=2\,\mathrm{V}$$

Thus, the value of voltage, V_o is $\boxed{2\,\mathrm{V}}$.

Step 1 of 5

Refer to Figure P5.101 in the text book.

The circuit is re-arranged as shown in Figure 1.

Figure 1

Step 2 of 5

Since the 4 mA current source is in parallel with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 24 V voltage source is in series with $6\,\text{k}\Omega$ resistor. The 2 mA current source is in parallel with the $4\,\text{k}\Omega$ resistor, the source transformation is equal to the 8 V voltage source is in series with $4\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 2.

Figure 2

Step 3 of 5

The 24 V and 12 V voltage sources are in series, the resultant voltage is 12 V is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 2 mA current source is in parallel with $6\,\text{k}\Omega$ resistor. The 8 V voltage source is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 1.33 mA current source is in parallel with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 2.

Figure 3

Step 4 of 5

Since the current sources 2 mA and 1.33 mA are in parallel, the resultant current is 0.67 mA upwards.

The resistors $6\text{k}, 6\text{k and } 6\text{k}$ are in parallel. Calculate their equivalent resistance.

$$\begin{aligned}\frac{1}{R} &= \frac{1}{6\text{k}}+\frac{1}{6\text{k}}+\frac{1}{6\text{k}}\\ &= \frac{1+1+1}{6\text{k}}\\ &= \frac{1}{2\text{k}}\\ R &= 2\,\text{k}\Omega\end{aligned}$$

Then the simplified circuit is shown in Figure 4.

Figure 4

Step 5 of 5

Apply current division rule. Calculate the current I_o.

$$\begin{aligned}I_o &= \frac{2\text{k}}{2\text{k}+3\text{k}}(0.67\,\text{mA})\\ &= 0.268\,\text{mA}\end{aligned}$$

Therefore, the current I_o is $\boxed{0.268\,\text{mA}}$.

Step 1 of 3

5.104P

Refer to Figure P5.103 in the text book.

In Figure P5.103, the $6\ \mathrm{V}$ voltage source is in series with $3\,\mathrm{k\Omega}$ resistor, the source transformation is equal to the 2 mA current source is in parallel with $3\,\mathrm{k\Omega}$ resistor.

The $12\ \mathrm{V}$ voltage source is in series with $6\,\mathrm{k\Omega}$ resistor, the source transformation is equal to the 2 mA current source is in parallel with $6\,\mathrm{k\Omega}$ resistor.

The $12\ \mathrm{V}$ voltage source is in series with $2\,\mathrm{k\Omega}$ resistor, the source transformation is equal to the $6\ \mathrm{mA}$ current source is in parallel with $2\,\mathrm{k\Omega}$.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The $3\,\mathrm{k\Omega}$ and $6\,\mathrm{k\Omega}$ resistors are in parallel. Calculate their equivalent resistance.

$$R = \frac{(3\,\mathrm{k\Omega})(6\,\mathrm{k\Omega})}{3\,\mathrm{k\Omega}+6\,\mathrm{k\Omega}}$$
$$= 2\,\mathrm{k\Omega}$$

In Figure 1, the 2 mA current sources are cancelled and the resultant current is $6\ \mathrm{mA} - 2\ \mathrm{mA} = 4\ \mathrm{mA}$ upwards.

The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

Apply current division rule to calculate the current I_o.

$$I_o = \left(\frac{2\ \mathrm{k\Omega}}{2\ \mathrm{k\Omega}+2\ \mathrm{k\Omega}+4\ \mathrm{k\Omega}}\right)(4\,\mathrm{mA})$$
$$= 1\,\mathrm{mA}$$

Thus, the value of current I_o is $\boxed{1\,\mathrm{mA}}$.

Step 1 of 5

Refer to Figure P5.104 in the text book.

The $4\,\text{k and } 4\,\text{k}$ resistors are in parallel. Calculate the resultant resistance.

$$R = \frac{(4\text{k})(4\text{k})}{4\text{k}+4\text{k}}$$
$$= 2\,\text{k}\Omega$$

Since the 2 mA current source is in parallel with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 12 V voltage source is in series with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The 18 V voltage source is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 3 mA current source is in parallel with $6\,\text{k}\Omega$ resistor. The 12 V voltage source is in series with $12\,\text{k}\Omega$ $(6\text{k}+6\text{k})$ resistor, the source transformation is equal to the 1 mA current source is in parallel with $12\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 2.

Figure 2

Step 3 of 5

Since the current sources 3 mA and 1 mA are in parallel, the resultant current is 2 mA upwards.

The resistors $6\,\text{k and } 12\,\text{k}$ are in parallel. Calculate their equivalent resistance.

$$R = \frac{(6\text{k})(12\text{k})}{6\text{k}+12\text{k}}$$
$$= 4\,\text{k}\Omega$$

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 5

The 2 mA current source is in parallel with $4\,\text{k}\Omega$ resistor, the source transformation is equal to the 8 V voltage source is in series with $4\,\text{k}\Omega$ resistor. This $4\,\text{k}\Omega$ resistor is in series with $2\,\text{k}\Omega$ resistor. The resultant resistance is $6\,\text{k}\Omega$. Then the modified circuit is shown in Figure 4.

Figure 4

Step 5 of 5

The 8 V voltage source is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to the 1.33 mA current source is in parallel with $6\,\text{k}\Omega$ resistor. Since the current sources 1.33 mA and 1 mA are in parallel, the resultant current is 2.33 mA upwards.

Apply current division rule. Calculate the current I_o .

$$I_o = \frac{6\text{k}}{6\text{k}+3\text{k}}(2.33\,\text{mA})$$
$$= 1.55\,\text{mA}$$

Therefore, the current I_o is $\boxed{1.55\,\text{mA}}$.

Step 1 of 3

Refer to Figure P5.92 in the text book.

The $20\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ resistor. The source transformation is equal to the $120\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor. The two $120\,\text{V}$ and $6\,\text{V}$ voltage sources are in series. The equivalent voltage is $126\,\text{V}$. This $126\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor, the source transformation is equal to $21\,\text{mA}$ current source in parallel with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

The $6\,\text{k}\Omega$ and $3\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$R_1 = \frac{(6\,\text{k}\Omega)(3\,\text{k}\Omega)}{6\,\text{k}\Omega + 3\,\text{k}\Omega}$$
$$= 2\,\text{k}\Omega$$

The $21\,\text{mA}$ current source is in parallel with $2\,\text{k}\Omega$ resistor. The source transformation is equal to the $42\,\text{V}$ voltage source is in series with $2\,\text{k}\Omega$ resistor. This $2\,\text{k}\Omega$ is in series with $4\,\text{k}\Omega$ resistor. The equivalent resistance is $6\,\text{k}\Omega$. The $42\,\text{V}$ voltage source is in series with $6\,\text{k}\Omega$ resistor convert in to source transformation, $7\,\text{mA}$ current source in parallel with $6\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 2.

Figure 2

Step 2 of 3

The $6\,\text{k}\Omega$ and $12\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$R_2 = \frac{(6\,\text{k}\Omega)(12\,\text{k}\Omega)}{6\,\text{k}\Omega + 12\,\text{k}\Omega}$$
$$= 4\,\text{k}\Omega$$

This $4\,\text{k}\Omega$ resistor is in parallel with $7\,\text{mA}$ current source. The source transformation is equal to the $28\,\text{V}$ voltage source is in series with $4\,\text{k}\Omega$ resistor. The two $28\,\text{V}$ and $8\,\text{V}$ voltage sources are in series. The equivalent voltage is $36\,\text{V}$. This $36\,\text{V}$ voltage source is in series with $4\,\text{k}\Omega$ resistor, the source transformation is equal to $9\,\text{mA}$ current source in parallel with $4\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 3.

Figure 3

Step 3 of 3

The $4\,\text{k}\Omega$ and $3\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$R_3 = \frac{(4\,\text{k}\Omega)(3\,\text{k}\Omega)}{4\,\text{k}\Omega + 3\,\text{k}\Omega}$$
$$= 1.714\,\text{k}\Omega$$

Apply current division rule, write the expression for the current I_o.

$$I_o = \frac{1.714\,\text{k}\Omega}{1.714\,\text{k}\Omega + 6\,\text{k}\Omega}(9\,\text{mA})$$
$$= 2\,\text{mA}$$

Therefore, the current I_o is $\boxed{2\,\text{mA}}$.

Step 1 of 5

Refer to Figure P5.93 in the text book.

The top left two $6\,\text{k}\Omega$ resistors are in series. The equivalent resistance is $12\,\text{k}\Omega$. The bottom left two $6\,\text{k}\Omega$ resistor are in series. The equivalent resistance is $12\,\text{k}\Omega$. Convert the three $4\,\text{k}\Omega$ resistors star connection in to delta connection.

$$R_1 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B}$$

$$R_2 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}$$

$$R_3 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A}$$

Here the resistors values are as follows:

$$R_A = 4\,\text{k}\Omega$$
$$R_B = 4\,\text{k}\Omega$$
$$R_C = 4\,\text{k}\Omega$$

Then

$$R_1 = \frac{(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)}{(4\,\text{k}\Omega)}$$
$$= 12\,\text{k}\Omega$$

$$R_2 = \frac{(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)}{(4\,\text{k}\Omega)}$$
$$= 12\,\text{k}\Omega$$

$$R_3 = \frac{(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)+(4\,\text{k}\Omega)(4\,\text{k}\Omega)}{(4\,\text{k}\Omega)}$$
$$= 12\,\text{k}\Omega$$

Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The resistors $12\,\text{k}\Omega \text{ and } 12\,\text{k}\Omega$ are in parallel. Calculate the equivalent resistance.

$$R_4 = \frac{(12\,\text{k}\Omega)(12\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(12\,\text{k}\Omega)}$$
$$= 6\,\text{k}\Omega$$

The resistors $12\,\text{k}\Omega \text{ and } 12\,\text{k}\Omega$ are in parallel. Calculate the equivalent resistance.

$$R_5 = \frac{(12\,\text{k}\Omega)(12\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(12\,\text{k}\Omega)}$$
$$= 6\,\text{k}\Omega$$

The resistors $R_4 \text{ and } R_5$ are in series, their equivalent resistance is $12\,\text{k}\Omega$.

The resistors $12\,\text{k}\Omega \text{ and } 12\,\text{k}\Omega$ are in parallel. Calculate the equivalent resistance.

$$R_5 = \frac{(12\,\text{k}\Omega)(12\,\text{k}\Omega)}{(12\,\text{k}\Omega)+(12\,\text{k}\Omega)}$$
$$= 6\,\text{k}\Omega$$

Then the simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 5

The two $6\,\text{V}$ voltage sources are in series. Their equivalent voltage is $12\,\text{V}$. This is in series with $6\,\text{k}\Omega$ resistor. Convert it in to source transformation, it is equal to $2\,\text{mA}$ current source is in parallel with $6\,\text{k}\Omega$ resistor.
The $2\,\text{mA}$ current source is in parallel with $4\,\text{k}\Omega$ resistor. Convert it in to source transformation, it is equal to $8\,\text{V}$ voltage source in series with $4\,\text{k}\Omega$. Then the simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 5

The resistors $6\,\text{k}\Omega \text{ and } 6\,\text{k}\Omega$ are in parallel. Calculate the equivalent resistance.

$$R_6 = \frac{(6\,\text{k}\Omega)(6\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(6\,\text{k}\Omega)}$$
$$= 3\,\text{k}\Omega$$

The $2\,\text{mA}$ current source is in parallel with $3\,\text{k}\Omega$ resistor. Convert it in to source transformation, it is equal to $6\,\text{V}$ voltage source in series with $3\,\text{k}\Omega$. Then the simplified circuit is shown in Figure 4.

Figure 4

Step 5 of 5

Apply Kirchhoff voltage law (KVL) around the loop.

$$-6 + 3i_o + 3i_o + 4i_o + 8 = 0$$
$$10i_o = -2$$
$$i_o = -0.2\,\text{mA}$$

Therefore, the current i_o is $\boxed{-0.2\,\text{mA}}$.

Step 1 of 7

5.109P

Refer to Figure P5.95 in the text book.

The $2\,\text{k}\Omega$ and $1\,\text{k}\Omega$ resistors are in series. The equivalent resistance is $3\,\text{k}\Omega$. This $3\,\text{k}\Omega$ resistor is in parallel with $2\,\text{mA}$ current source. Convert in to source transformation. It is equal to $6\,\text{V}$ voltage source in series with $3\,\text{k}\Omega$ resistor. The two $12\,\text{k}\Omega$ and $12\,\text{k}\Omega$ resistors are in parallel. Calculate the equivalent resistance.

$$R_1 = \frac{(12\,\text{k}\Omega)(12\,\text{k}\Omega)}{12\,\text{k}\Omega + 12\,\text{k}\Omega}$$
$$= 6\,\text{k}\Omega$$

This $6\,\text{k}\Omega$ resistor is in series with $24\,\text{V}$ voltage source. Convert it in to source transformation. It is equal to $4\,\text{mA}$ current source in parallel with $6\,\text{k}\Omega$ resistor. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 7

The bottom $6\,\text{V}$ voltage source in series with $6\,\text{k}\Omega$ resistor is no effect since it is shunted.

The $6\,\text{V}$ voltage source is in series with $3\,\text{k}\Omega$ resistor. Convert it in to source transformation. It is equal to $2\,\text{mA}$ current source in parallel with $3\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 7

The resultant current is $2\,\text{mA}$ current source upwards. The two $3\,\text{k}\Omega$ and $6\,\text{k}\Omega$ resistors are in parallel. Calculate the equivalent resistance.

$$R_2 = \frac{(3\,\text{k}\Omega)(6\,\text{k}\Omega)}{3\,\text{k}\Omega + 6\,\text{k}\Omega}$$
$$= 2\,\text{k}\Omega$$

This $2\,\text{k}\Omega$ resistor is in parallel with $2\,\text{mA}$ current source. Convert it in to source transformation. It is equal to $4\,\text{V}$ voltage source in series with $2\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 7

Write the expression for the loop 1.

$$-4 + 2I_1 + 1(I_1 - I_2) + 2(I_1 - I_3) = 0$$
$$5I_1 - I_2 - 2I_3 = 4$$

Hence, the expression for super mesh is $5I_1 - I_2 - 2I_3 = 4$ ..... (1)

Write the expression for the loop 2.

$$8 + 2I_2 + 2(I_2 - I_3) + 1(I_2 - I_1) = 0$$
$$-I_1 + 5I_2 - 2I_3 = -8$$

Hence, the expression for super mesh is $-I_1 + 5I_2 - 2I_3 = -8$ ..... (2)

Write the expression for the loop 3.

$$2(I_3 - I_1) + 2(I_3 - I_2) = 0$$
$$-2I_1 - 2I_2 + 4I_3 = 0$$
$$-I_1 - I_2 + 2I_3 = 0$$

Step 5 of 7

Hence, the expression for super mesh is $-I_1 - I_2 + 2I_3 = 0$ ..... (3)
Subtract equation (3) from equation (1).

$$\begin{array}{r} 5I_1 - I_2 - 2I_3 = 4 \\ -I_1 - I_2 + 2I_3 = 0 \\ \hline 6I_1 - 4I_3 = 4 \\ 3I_1 - 2I_3 = 2 \end{array}$$

Hence, the expression for super mesh is $3I_1 - 2I_3 = 2$ ..... (4)

Multiply equation (1) with 5 and add to equation (2).

$$\begin{array}{r} 25I_1 - 5I_2 - 10I_3 = 20 \\ -I_1 + 5I_2 - 2I_3 = -8 \\ \hline 24I_1 - 12I_3 = 12 \\ 2I_1 - I_3 = 1 \end{array}$$

Hence, the expression for super mesh is $2I_1 - I_3 = 1$ ..... (5)

Step 6 of 7

Multiply equation (5) with 2 and subtract equation (4).

$$\begin{array}{r} 4I_1 - 2I_3 = 2 \\ 3I_1 - 2I_3 = 2 \\ \hline I_1 = 0 \end{array}$$

Substitute $0\,\text{mA}$ for I_1 in equation (5).

$$2I_1 - I_3 = 1$$
$$I_3 = 2I_1 - 1$$
$$= 2(0) - 1$$
$$= -1\,\text{mA}$$

Step 7 of 7

Substitute $0\,\text{mA}$ for I_1 and $-1\,\text{mA}$ for I_3 in equation (3)

$$-I_1 - I_2 + 2I_3 = 0$$
$$-0 - I_2 + 2(-1) = 0$$
$$I_2 = -2\,\text{mA}$$

Write the expression for the current I_o .

$$I_o = I_3 - I_2$$
$$= -1\,\text{mA} - (-2\,\text{mA})$$
$$= 1\,\text{mA}$$

Therefore, the current I_o is $\boxed{1\,\text{mA}}$.

Step 1 of 3

Refer to Figure P5.96 in the text book.

The three $12\,\text{k}\Omega, 6\,\text{k}\Omega$ and $12\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$\begin{aligned}\frac{1}{R_1} &= \frac{1}{12\,\text{k}\Omega} + \frac{1}{6\,\text{k}\Omega} + \frac{1}{12\,\text{k}\Omega}\\ &= \frac{1+2+1}{12\,\text{k}\Omega}\\ &= \frac{4}{12\,\text{k}\Omega}\\ R_1 &= 3\,\text{k}\Omega\end{aligned}$$

The $8\,\text{k}\Omega$ resistor is shunted. Hence, it is nullified. The two $4\,\text{k}\Omega$ and $4\,\text{k}\Omega$ resistors are in series. Their equivalent resistance is $8\,\text{k}\Omega$. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 3

The $8\,\text{k}\Omega$ and $8\,\text{k}\Omega$ resistors are in parallel. Calculate their equivalent resistance.

$$\begin{aligned}R_2 &= \frac{(8\,\text{k}\Omega)(8\,\text{k}\Omega)}{8\,\text{k}\Omega + 8\,\text{k}\Omega}\\ &= 4\,\text{k}\Omega\end{aligned}$$

This $4\,\text{k}\Omega$ is in series with $8\,\text{k}\Omega$ resistor. The equivalent resistance is $12\,\text{k}\Omega$. This $12\,\text{k}\Omega$ is in series with $2\,\text{k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned}R_3 &= \frac{(12\,\text{k}\Omega)(2\,\text{k}\Omega)}{12\,\text{k}\Omega + 2\,\text{k}\Omega}\\ &= \frac{12}{7}\,\text{k}\Omega\\ &= 1.714\,\text{k}\Omega\end{aligned}$$

The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

Write the expression for the super mesh.

$$\begin{aligned}3I_2 + 2I_3 - 12 + 3I_2 &= 0\\ 6I_2 + 2I_3 &= 12\\ 3I_2 + I_3 &= 6\end{aligned}$$

Hence, the expression for super mesh is $3I_2 + I_3 = 6$ ..... (1)

Write the expression for currents.

$$\begin{aligned}I_3 - I_2 &= 2\\ -I_2 + I_3 &= 2\end{aligned}$$

Hence, the expression for super mesh is $-I_2 + I_3 = 2$ ..... (2)

Subtract equation 92) from equation (1).

$$\begin{aligned}3I_2 + I_3 &= 6\\ -I_2 + I_3 &= 2\\ \hline 4I_2 &= 4\\ I_2 &= 1\,\text{mA}\end{aligned}$$

Calculate the current I_o .

$$\begin{aligned}I_o &= I_2\\ &= 1\,\text{mA}\end{aligned}$$

Therefore, the current I_o is $\boxed{1\,\text{mA}}$.

Step 1 of 10

Refer to Figure P5.97 in the text book.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 10

In Figure 1, there is a short circuit between the nodes (A) and (B). The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 3 of 10

In Figure 2, the resistors $3\,k\Omega$ and $6\,k\Omega$ are in parallel.

$$R_{eq} = (3\,k\Omega) \| (6\,k\Omega)$$
$$= \frac{(3\,k\Omega)\times(6\,k\Omega)}{(3\,k\Omega)+(6\,k\Omega)}$$
$$= 2\,k\Omega$$

Step 4 of 10

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 5 of 10

In Figure 3, the resistors $4\,k\Omega$ and $2\,k\Omega$ are in series. The series combination is replaced by single $6\,k\Omega$ and parallel combination $2\,mA$ current source and $3\,k\Omega$ resistor is replaced by 6 V voltage source and in series with $3\,k\Omega$ resistor.

The simplified circuit diagram is shown in Figure 4.

Figure 4

Apply source transformation to 4 mA current source and $3\,k\Omega$ resistor and replaced by $12\,V$ voltage source in series with $3\,k\Omega$ resistor. The series combination of $+12\,V$ and $-6\,V$ can be replaced by a single + 6 V voltage source.

The simplified circuit diagram is shown in Figure 5.

Figure 5

Step 6 of 10

The series combination of $3\,k\Omega$ and $6\,k\Omega$ resistors is replaced by single $9\,k\Omega$ resistor is shown in Figure 6.

Figure 6

Step 7 of 10

The network shown in Figure 6 can be redrawn as follows:

Figure 7

Step 8 of 10

Apply source transformation to series combination of 12 V with $9\,k\Omega$ and 6 V with $3\,k\Omega$ voltage source shown in Figure 7 can be replaced by parallel combination of $\frac{4}{3}\,mA$ with $9\,k\Omega$ and 2 mA with $3\,k\Omega$.

The modified circuit diagram is shown Figure 8.

Figure 8

Step 9 of 10

The parallel combination $-\frac{4}{3}\,mA$ and 2 mA can be replaced by single $\frac{2}{3}\,mA$ current source. In Figure 8, the resistors $9\,k\Omega, 3\,k\Omega$ and $2\,k\Omega$ are in parallel.

$$R_{eq} = \frac{1}{\frac{1}{9k\Omega}+\frac{1}{3k\Omega}+\frac{1}{2k\Omega}}$$
$$= \left(\frac{18}{17}\right)k\Omega$$

The modified circuit diagram is shown Figure 9.

Figure 9

Step 10 of 10

Apply current division rule to determine the value of current, I_o.

$$I_o = \left(\frac{2}{3}\,mA\right)\left(\frac{\frac{18}{17}\,k\Omega}{\frac{18}{17}\,k\Omega + 2\,k\Omega}\right)$$
$$= \left(\frac{2}{3}\,mA\right)\left(\frac{9}{26}\right)$$
$$= 230.77\,\mu A$$

Thus, the value of current, I_o is $\boxed{230.77\,\mu A}$.

Step 1 of 7

5.112P

Refer to Figure P5.106 in the text book.

First calculate the Thevenin equivalent circuit for the network exclusive of the load. The Thevenin voltage V_{oc} can be calculated from the circuit shown in Figure 1.

Figure 1

Step 2 of 7

Write the mesh equation for the first loop.

$$-12+(2\times10^3)I_1+(2\times10^3)(I_1-I_2)=0$$
$$(4\times10^3)I_1-(2\times10^3)I_2=12$$
$$(2\times10^3)I_1-(1\times10^3)I_2=6 \text{ ..... (1)}$$

Step 3 of 7

Write the mesh equation for the second loop.

$$(2\times10^3)I_2+(2\times10^3)I_2+(2\times10^3)(I_2-I_1)=0$$
$$-(2\times10^3)I_1+(6\times10^3)I_2=0 \text{ ..... (2)}$$

Step 4 of 7

Add equation (1) and equation (2).

$$\begin{aligned}-(2\times10^3)I_1+(6\times10^3)I_2&=0\\(2\times10^3)I_1-(1\times10^3)I_2&=6\\\hline(5\times10^3)I_2&=6\\I_2&=1.2\,\text{mA}\end{aligned}$$

Write the expression for the Thevenin voltage V_{oc}.

$$V_{oc}=I_2(2\,\text{k}\Omega)$$

Substitute $1.2\,\text{mA}$ for I_2.

$$\begin{aligned}V_{oc}&=(1.2\,\text{mA})(2\,\text{k}\Omega)\\&=2.4\,\text{V}\end{aligned}$$

Step 5 of 7

The circuit for calculating the Thevenin resistance is shown in Figure 2.

Figure 2

Step 6 of 7

Calculate their equivalent resistance.

$$\begin{aligned}R_{Th}&=((2\,\text{k}\Omega\,\|\,2\,\text{k}\Omega)+2\,\text{k}\Omega)\,\|\,2\,\text{k}\Omega\\&=(1\,\text{k}\Omega+2\,\text{k}\Omega)\,\|\,2\,\text{k}\Omega\\&=\frac{(3\,\text{k}\Omega)(2\,\text{k}\Omega)}{3\,\text{k}\Omega+2\,\text{k}\Omega}\\&=1.2\,\text{k}\Omega\end{aligned}$$

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{1.2\,\text{k}\Omega}$.

Step 7 of 7

Write the expression for the maximum power transferred to the load.

$$P_L=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)$$

Substitute $2.4\,\text{V}$ for V_{oc}, $1.2\,\text{k}\Omega$ for R_{Th} and $1.2\,\text{k}\Omega$ for R_L in the equation.

$$\begin{aligned}P_L&=\left(\frac{2.4}{1.2\text{k}+1.2\text{k}}\right)^2(1.2\text{k})\\&=1.2\,\text{mW}\end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{1.2\,\text{mW}}$.

Step 1 of 5

5.113P

Refer to Figure P5.107 in the text book.

First calculate the Thevenin equivalent circuit for the network exclusive of the load. The Thevenin voltage V_{oc} can be calculated from the circuit shown in Figure 1.

Figure 1

Step 2 of 5

Apply current division rule, calculate the current through the $4\,\text{k}\Omega$ resistor.

$$\begin{aligned} I_2 &= \frac{[1\,\text{k}\Omega + 2\,\text{k}\Omega]}{[1\,\text{k}\Omega + 2\,\text{k}\Omega] + [2\,\text{k}\Omega + 4\,\text{k}\Omega]}(4\,\text{mA}) \\ &= \frac{3}{9}(4\,\text{mA}) \\ &= 1.33\,\text{mA} \end{aligned}$$

Write the expression for the Thevenin voltage V_{oc}.

$$V_{oc} = I_2(4\,\text{k}\Omega)$$

Substitute $1.33\,\text{mA}$ for I_2 in the equation.

$$\begin{aligned} V_{oc} &= I_2(4\,\text{k}\Omega) \\ &= (1.33\,\text{mA})(4\,\text{k}\Omega) \\ &= 5.32\,\text{V} \end{aligned}$$

Step 3 of 5

The circuit for calculating the Thevenin resistance is shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the Thevenin resistance.

$$\begin{aligned} R_{Th} &= (2\,\text{k}\Omega + 1\,\text{k}\Omega + 2\,\text{k}\Omega) \| 4\,\text{k}\Omega \\ &= 5\,\text{k}\Omega \| 2\,\text{k}\Omega \\ &= \frac{(5\,\text{k}\Omega)(4\,\text{k}\Omega)}{5\,\text{k}\Omega + 4\,\text{k}\Omega} \\ &= 2.22\,\text{k}\Omega \end{aligned}$$

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{2.22\,\text{k}\Omega}$.

Step 5 of 5

Write the expression for the maximum power transferred to the load.

$$P_L = \left(\frac{V_{oc}}{R_{Th} + R_L}\right)^2 (R_L)$$

Substitute $5.32\,\text{V}$ for V_{oc}, $2.22\,\text{k}\Omega$ for R_{Th} and $2.22\,\text{k}\Omega$ for R_L in the equation..

$$\begin{aligned} P_L &= \left(\frac{5.32}{2.22\,\text{k} + 2.22\,\text{k}}\right)^2 (2.22\,\text{k}) \\ &\approx 3.2\,\text{mW} \end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{3.2\,\text{mW}}$.

Step 1 of 8

Refer to Figure P5.108 in the text book.

Calculate the Thevenin equivalent circuit for the network exclusive of the load. The Thevenin voltage V_{oc} can be calculated from the circuit shown in Figure 1.

Figure 1

Step 2 of 8

Since the $6\,\text{V}$ voltage source is in series with $3\,\text{k}\Omega$ resistor, the source transformation is equal to $2\,\text{mA}$ current source in parallel with $3\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 8

The resistors $3\,\text{k}\Omega$ and $6\,\text{k}\Omega$ are in parallel, calculate their equivalent resistance.

$$R = \frac{(3\,\text{k}\Omega)(6\,\text{k}\Omega)}{3\,\text{k}\Omega + 6\,\text{k}\Omega}$$
$$= 2\,\text{k}\Omega$$

Since the $2\,\text{mA}$ current source is in parallel with $2\,\text{k}\Omega$ resistor, the source transformation is equal to $4\,\text{V}$ voltage source in series with $2\,\text{k}\Omega$ resistor and also the other $2\,\text{mA}$ current source is in parallel with $2\,\text{k}\Omega$ resistor, the source transformation is equal to $4\,\text{V}$ voltage source in series with $2\,\text{k}\Omega$ resistor. The simplified circuit is shown in Figure 3.

Figure 3

Step 4 of 8

Calculate the Thevenin voltage V_{oc}.

$$V_{oc} = 4\,\text{V} + 4\,\text{V}$$
$$= 8\,\text{V}$$

The circuit for calculating the Thevenin resistance is shown in Figure 4.

Figure 4

Step 5 of 8

Calculate the Thevenin resistance.

$$R_{Th} = 2\,\text{k}\Omega + (3\,\text{k}\Omega \parallel 6\,\text{k}\Omega)$$
$$= 2\,\text{k}\Omega + \frac{(3\,\text{k}\Omega)(6\,\text{k}\Omega)}{3\,\text{k}\Omega + 6\,\text{k}\Omega}$$
$$= 4\,\text{k}\Omega$$

Step 6 of 8

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.
Therefore, the load resistance R_L is $\boxed{4\,\text{k}\Omega}$.

Step 7 of 8

The Thevenin equivalent circuit is shown in Figure 5.

Figure 5

Step 8 of 8

Write the expression for the maximum power transferred to the load.

$$P_L = \left(\frac{V_{oc}}{R_{Th} + R_L}\right)^2 (R_L)$$

Calculate the maximum power transferred to the load by substituting $8\,\text{V}$ for V_{oc}, $4\,\text{k}\Omega$ for R_{Th} and $4\,\text{k}\Omega$ for R_L.

$$P_L = \left(\frac{V_{oc}}{R_{Th} + R_L}\right)^2 (R_L)$$
$$= \left(\frac{8\,\text{V}}{4\,\text{k}\Omega + 4\,\text{k}\Omega}\right)^2 (4\,\text{k}\Omega)$$
$$= 4\,\text{mW}$$

Therefore, the maximum power transferred to the load is $\boxed{4\,\text{mW}}$.

5.115P

Figure (1)

Step 2 of 14

Remove the R_L and Thevenin equivalent between node a and b is found as shown in Fig. 2.

Calculation of V_{TH}:

Figure (2)

Step 3 of 14

By analyzing Fig. 2 we get,

$V_c = -6\text{ V}$ ....(1)

$I_3 = 1\text{mA}$ ....(2)

Step 4 of 14

By using KCL at node e in Fig. 2,

$2\text{m} - I_1 - 1\text{m} = 0$

$\Rightarrow I_1 = 1\text{mA}$ ....(3)

Step 5 of 14

By using KCL at node b in Fig. 2,

$2\text{m} + I_1 - I_2 = 0$

$I_2 = 2\text{m} + 1\text{m}$ ....(By(3))

$I_2 = 3\text{mA}$ ....(4)

Step 6 of 14

We have in Fig. 2,

$V_{bc} = V_b - V_c$

$I_2(0.5\text{k}) = V_b - (-6)$ ....(By (1))

$V_b = (3\text{m})(0.5\text{k}) - 6\text{ V}$ ....(By (4))

$V_b = -4.5\text{ V}$ ....(5)

Step 7 of 14

By Ohm's Law in Fig. 2,

$V_a = I_3(1\text{k})$

$V_a = (1\text{m})(1\text{k})$ ....(By (2))

$V_a = 1\text{ V}$ ....(6)

Step 8 of 14

Therefore,

$V_{TH} = V_a - V_b$

$V_{TH} = 1 - (-4.5)$ .... (By (5) and (6))

$V_{TH} = 5.5\text{ V}$ .... (7)

Step 9 of 14

For Calculation of R_{TH} open circuit the current sources and short circuit the voltage sources as shown in Fig. 3

Step 10 of 14

Figure (3)

Step 11 of 14

From Fig 3,

$R_{TH} = 1\text{k} + 0.5\text{k}$

$R_{TH} = 1.5\text{k}\Omega$ .... (8)

Step 12 of 14

The Thevenin equivalent is drawn and R_L connected as shown in Fig. 4

Figure (4)

Step 13 of 14

Therefore for Maximum Power Transfer to R_L ,

$R_L = R_{TH}$

$\boxed{R_L = 1.5\text{k}\Omega}$

Step 14 of 14

Maximum Power Transferred to R_L is

$$P_{\max R_L} = \frac{V_{TH}^2}{4R_L}$$

$$P_{\max R_L} = \frac{5.5^2}{4(1.5\text{k})}$$

$$P_{\max R_L} = \frac{121}{24}\text{m}$$

$$\boxed{P_{\max R_L} = 5.0417\text{ mW}}$$

5.116P

Figure (1)

Step 2 of 12

Remove the R_L and Thevenin equivalent between node b and d is found as shown in Fig. 2.

Calculation of V_{TH}:

Figure (2)

Step 3 of 12

By KCL at node b Fig. 2,

$$\frac{V_a - V_b}{4k} - 2m - 4m = 0$$
$$V_a - V_b = (6m)(4k)$$
$$V_a = V_b + 24 \qquad ....(1)$$

Step 4 of 12

By using KCL at node a in Fig. 2,

$$-\frac{V_a - V_e}{2k} - \frac{V_a - V_b}{4k} + 8m = 0$$
$$2(V_a - V_e) + V_a - V_b = (8m)(4k)$$
$$3V_a - 2V_e - V_b = 32$$
$$3(V_b + 24) - 2V_e - V_b = 32 \qquad ....(By\ (1))$$
$$2V_b + 72 - 32 = 2V_e$$
$$V_e = V_b + 20 \qquad ....(2)$$

Step 5 of 12

By using KCL at node e in Fig. 2,

$$\frac{V_a - V_e}{2k} - \frac{V_e - V_c}{4k} + 4m = 0$$
$$-2(V_a - V_e) + V_e - V_c = (4m)(4k)$$
$$-2(V_b + 24) + 3(V_b + 20) - V_c = 16 \qquad ....(By\ (1)\ and\ (2))$$
$$V_b - 48 + 60 - 16 = V_c$$
$$V_c = V_b - 4 \qquad ....(3)$$

Step 6 of 12

By using KCL at node c in Fig. 2,

$$-\frac{V_c}{2k} + \frac{V_e - V_c}{4k} + 2m = 0$$
$$2V_c - (V_e - V_c) = (2m)(4k)$$
$$3(V_b - 4) - (V_b + 20) = 8 \qquad ....(By\ (2)\ and\ (3))$$
$$2V_b = 12 + 20 + 8$$
$$V_b = 20\ V \qquad ....(4)$$

Step 7 of 12

Therefore,

$$V_{TH} = V_b - V_d$$
$$V_{TH} = 20 - 0 \qquad ....\ (By\ (4))$$
$$V_{TH} = 20\ V \qquad ....\ (5)$$

Step 8 of 12

For Calculation of R_{TH} open circuit the current sources as shown in Fig. 3

Figure (3)

Step 9 of 12

From Fig 3,

$$R_{TH} = 4k + 2k + 4k + 2k$$
$$R_{TH} = 12k\Omega \qquad ....\ (6)$$

Step 10 of 12

The Thevenin equivalent is drawn and R_L connected as shown in Fig. 4

Figure (4)

Step 11 of 12

Therefore for Maximum Power Transfer to R_L ,

$$R_L = R_{TH}$$
$$\boxed{R_L = 12k\Omega}$$

Step 12 of 12

Maximum Power Transferred to R_L is

$$P_{max\,R_L} = \frac{V_{TH}^2}{4R_L}$$
$$P_{max\,R_L} = \frac{20^2}{4(12k)}$$
$$P_{max\,R_L} = \frac{25}{3}m$$
$$\boxed{P_{max\,R_L} = 8.333\ mW}$$

5.117P

Figure (1)

Remove the R_L and Thevenin equivalent between node b and e is found as shown in Fig.2.

Calculation of V_{TH}:

Figure (2)

From the Fig. 2,

$$I_3 - I_1 = 1\text{m}$$
$$\Rightarrow I_1 = I_3 - 1\text{m} \qquad ....(1)$$
$$I_2 - I_3 = 0.5\text{m}$$
$$\Rightarrow I_2 = I_3 + 0.5\text{m} \qquad ....(2)$$

By using KVL around loop *aecda* in Fig. 2,

$$V_{ae} + V_{ec} + V_{cd} + V_{da} = 0$$
$$-3 + I_1(2\text{k}) + I_2(1\text{k}) + I_3(3\text{k}) = 0$$
$$(I_3 - 1\text{m})(2\text{k}) + (I_3 + 0.5\text{m})(1\text{k}) + I_3(3\text{k}) = 3 \quad ....(\text{By (1) and (2)})$$
$$I_3(2\text{k} + 1\text{k} + 3\text{k}) - 2 + 0.5 = 3$$
$$I_3 = \frac{4.5}{6\text{k}}$$
$$I_3 = 0.75\text{ mA} \qquad ....(3)$$

$$\therefore I_1 = 0.75\text{m} - 1\text{m}$$
$$\Rightarrow I_1 = -0.25\text{m} \qquad ....(4)$$
$$\therefore I_2 = 0.75\text{m} + 0.5\text{m}$$
$$\Rightarrow I_2 = 1.25\text{m} \qquad ....(5)$$

By using KVL around loop *ecbe* in Fig. 2,

$$V_{ec} + V_{cb} + V_{be} = 0$$
$$I_1(2\text{k}) + (I_1 - I_2)(1\text{k}) + V_{TH} = 0$$
$$(-0.25\text{m})(2\text{k}) + (-0.25\text{m} - 1.25\text{m})(1\text{k}) + V_{TH} = 0 \quad ....(\text{By (4) and (5)})$$
$$V_{TH} = 0.5 + 1.5$$
$$V_{TH} = 2\text{ V} \qquad ....(6)$$

For Calculation of R_{TH} open circuit the current sources as shown in Fig. 3

Figure (3)

Replace series resistances 3k+1k=4k in Fig 3 as shown in Fig. 4

Figure (4)

Replace parallel resistances $4\text{k}||2\text{k} = \frac{(4\text{k})(2\text{k})}{(4\text{k}+2\text{k})} = \frac{4}{3}\text{k}\Omega$ in Fig 4 as shown in Fig. 5

Figure (5)

From Fig 5

$$R_{TH} = 1\text{k} + \frac{4}{3}\text{k}$$
$$R_{TH} = \frac{7}{3}\text{k}\Omega$$

Therefore for Maximum Power Transfer to R_L ,

$$R_L = R_{TH}$$
$$\boxed{R_L = \frac{7}{3}\text{k}\Omega}$$

Maximum Power Transferred to R_L is

$$P_{\max R_L} = \frac{V_{TH}^2}{4R_L}$$
$$P_{\max R_L} = \frac{2^2}{4(\frac{7}{3}\text{k})}$$
$$P_{\max R_L} = \frac{3}{7}\text{m}$$
$$\boxed{P_{\max R_L} = 0.429\text{ mW}}$$

Step 1 of 5

5.118P

Refer to Figure P5.112 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff current law (KCL) at the top node.

$$\frac{V_{oc}-12}{5k+5k}-100I=0$$
$$-I-100I=0$$
$$-101I=0$$
$$I=0$$

But the expression for current I is $I=\frac{12-V_{oc}}{5k+5k}$ ..... (1)

Step 3 of 5

Substitute 0 for I in equation (1).

$$I=\frac{12-V_{oc}}{5k+5k}$$
$$0=\frac{12-V_{oc}}{10k}$$
$$V_{oc}=12\,V$$

The circuit for calculating shorted-circuit current is shown in Figure 2.

Figure 2

Step 4 of 5

Apply Kirchhoff current law (KCL) at the top node.

$$I_{sh}=I+100I$$
$$=101I$$

Hence, the expression for current I_{sh} is $I_{sh}=101I$ ..... (2)

Calculate the current, I.

$$I=\frac{12}{5k+5k}$$
$$=1.2\,mA$$

Substitute $1.2\,mA$ for I in equation (2).

$$I_{sh}=101I$$
$$=101(1.2\,mA)$$
$$=121.2\,mA$$

Step 5 of 5

Write the expression for the Thevenin resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sh}}$$

Calculate the Thevenin resistance by substituting $12\,V$ for V_{oc} and $121.2\,mA$ for I_{sh}.

$$R_{Th}=\frac{V_{oc}}{I_{sh}}$$
$$=\frac{12\,V}{121.2\,mA}$$
$$=99\,\Omega$$

For a maximum power transfer the load resistance is equal to the Thevenin resistance.

Therefore, the value of load resistance for maximum power transfer is $\boxed{99\,\Omega}$.

Step 1 of 7

Refer to Figure P5.113 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 7

Apply Kirchhoff current law (KCL) at the node 1.

$$-1\,\text{mA}+\frac{V_x}{1\text{k}}+\frac{V_x-V_{oc}}{2\text{k}}=0$$
$$3V_x-V_{oc}=2$$

Hence, the expression at node 1 is $3V_x-V_{oc}=2$ ..... (1)

Apply Kirchhoff current law (KCL) at the node 2.

$$\frac{4V_x}{1000}+\frac{V_{oc}-V_x}{2\text{k}}=0$$
$$7V_x+V_{oc}=0$$

Hence, the expression at node 2 is $7V_x+V_{oc}=0$ ..... (2)

Add equation (2) to equation (1).

$$\begin{aligned}3V_x-V_{oc}&=2\\7V_x+V_{oc}&=0\\\hline 10V_x&=2\\V_x&=0.2\,\text{V}\end{aligned}$$

Substitute $0.2\,\text{V}$ for V_x in equation (2).

$$7V_x+V_{oc}=0$$
$$7(0.2)+V_{oc}=0$$
$$V_{oc}=-1.4\,\text{V}$$

Step 3 of 7

The circuit for calculating short-circuited current is shown in Figure 2.

Figure 2

Step 4 of 7

Apply Kirchhoff current law (KCL) at the node V_x.

$$-1\,\text{mA}+\frac{V_x}{1\text{k}}+\frac{V_x-V_O}{2\text{k}}=0$$
$$3V_x-V_O=2$$

Hence, the expression at node 1 is $3V_x-V_O=2$ ..... (3)

Apply Kirchhoff current law (KCL) at the node V_O.

$$\frac{4V_x}{1000}+\frac{V_O-V_x}{2\text{k}}+\frac{V_O}{3\text{k}}=0$$
$$\frac{24V_x+3V_O-3V_x+2V_O}{6\text{k}}=0$$
$$21V_x+5V_O=0$$

Hence, the expression at node 2 is $21V_x+5V_O=0$ ..... (4)

Multiply equation (3) with 3 and add it to equation (4).

$$\begin{aligned}15V_x-5V_O&=10\\21V_x+5V_O&=0\\\hline 36V_x&=10\\V_x&=0.278\,\text{V}\end{aligned}$$

Substitute $0.278\,\text{V}$ for V_x in equation (4).

$$21V_x+5V_O=0$$
$$21(0.278)+5V_O=0$$
$$5V_O=-5.83$$
$$V_O=-1.167\,\text{V}$$

Step 5 of 7

Write the expression for the current I_{sc}.

$$I_{sc}=\frac{V_O}{3\text{k}}$$

Calculate the current I_{sc} by substituting $1.167\,\text{V}$ for V_O.

$$\begin{aligned}I_{sc}&=\frac{V_O}{3\text{k}}\\&=\frac{-1.167\,\text{V}}{3\text{k}}\\&=-0.389\,\text{mA}\end{aligned}$$

Step 6 of 7

Write the expression for the Thevenin resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sc}}$$

Calculate the Thevenin resistance by substituting $-1.4\,\text{V}$ for V_{oc} and $0.389\,\text{mA}$ for I_{sh}.

$$\begin{aligned}R_{Th}&=\frac{V_{oc}}{I_{sc}}\\&=\frac{-1.4\,\text{V}}{-0.389\,\text{mA}}\\&=3.6\,\text{k}\Omega\end{aligned}$$

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{3.6\,\text{k}\Omega}$.

The simplified circuit is shown in Figure 3.

Figure 3

Step 7 of 7

Write the expression for the maximum power transferred to the load.

$$P_L=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)$$

Calculate the maximum power transferred to the load by substituting $-1.4\,\text{V}$ for V_{oc}, $3.6\,\text{k}\Omega$ for R_{Th} and $3.6\,\text{k}\Omega$ for R_L.

$$\begin{aligned}P_L&=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)\\&=\left(\frac{-1.4}{3.6\text{k}+3.6\text{k}}\right)^2(3.6\text{k})\\&=0.136\,\text{mW}\end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{0.136\,\text{mW}}$.

Step 1 of 5

Refer to Figure P5.114 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff voltage law (KVL) around the outer loop.

$$-4V_x + 2I + V_{oc} + 4I = 0$$
$$-4V_x + 6I + V_{oc} = 0$$

Hence, the expression at node 1 is $-4V_x + 6I + V_{oc} = 0$ ..... (1)

But $V_x = 2I$ and $I = -2\text{ A}$ ..... (2)

Substitute equation (2) in equation (1).

$$-4V_x + 6I + V_{oc} = 0$$
$$-4(2I) + 6I + V_{oc} = 0$$
$$V_{oc} = 2(-2)$$
$$= -4\text{ V}$$

Step 3 of 5

The circuit for calculating short-circuited current is shown in Figure 2.

Figure 2

Step 4 of 5

Apply Kirchhoff voltage law (KVL) around the outer loop.

$$-4V_x + V_x + 4I_2 + 4I_1 = 0$$
$$-4(2I_1) + 2I_1 + 4I_2 + 4I_1 = 0$$
$$-2I_1 + 4I_2 = 0$$
$$-I_1 + 2I_2 = 0$$

Hence, the expression at node 1 is $-I_1 + 2I_2 = 0$ ..... (3)

Apply Kirchhoff current law (KCL) at the top node.

$$I_1 + 2 = I_2$$
$$I_1 - I_2 = -2$$

Hence, the expression at node 1 is $I_1 - I_2 = -2$ ..... (4)

Add equation (3) and equation (4).

$$-I_1 + 2I_2 = 0$$
$$\underline{I_1 - I_2 = -2}$$
$$I_2 = -2\text{ A}$$

Step 5 of 5

Write the expression for the current I_{sc}.

$$I_{sc} = I_2$$
$$= -2\text{ A}$$

Write the expression for the Thevenin resistance.

$$R_{Th} = \frac{V_{oc}}{I_{sc}}$$

Calculate the Thevenin resistance by substituting -4 V for V_{oc} and -2 A for I_{sc}.

$$R_{Th} = \frac{V_{oc}}{I_{sc}}$$
$$= \frac{-4\text{ V}}{-2\text{ A}}$$
$$= 2\Omega$$

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{2\Omega}$.

Figure (1)

Step 2 of 12

Remove the R_L and Thevenin equivalent between node d and c is found by calculation open circuit voltage and short circuit current between node as shown in Fig. 2. and Fig. 3

Calculation of V_{TH}:

Figure (2)

Step 3 of 12

By KVL around loop *edabe* in Fig. 2,

$$V_{ed}+V_{da}+V_{ab}+V_{be}=0$$
$$I_0(12)+I_0(4)+I_0(4)-30=0$$
$$I_0(20)=30$$
$$I_0=1.5\text{ A} \qquad ....(1)$$

Also ,

$$V_x=I_0(4) \qquad ....(2)$$

Step 4 of 12

By KVL around loop *dabcd* in Fig. 2,

$$V_{da}+V_{ab}+V_{bc}+V_{cd}=0$$
$$I_O(4)+I_O(4)+4V_x-V_{oc}=0$$
$$I_O(8)+4(I_O(4))-V_{oc}=0 \qquad ....(\text{By }(2))$$
$$(1.5)(24)=V_{oc} \qquad ....(\text{By }(1))$$
$$V_{oc}=36\text{ V} \qquad ....(3)$$
$$V_{TH}=36\text{ V}$$

Step 5 of 12

Figure (3)

Step 6 of 12

Let the loop currents be as in Fig. 3 ,

We have from Fig. 3

$$V_x=I_2(4) \qquad ....(4)$$
$$I_{sc}=I_1-I_2 \qquad ....(5)$$

By KVL around loop *dabcd* in Fig. 3,

$$V_{da}+V_{ab}+V_{bc}+V_{cd}=0$$
$$I_2(4)+I_2(4)+4V_x=0$$
$$I_2(8)+4(I_2(4))=0 \qquad ....(\text{By }(4))$$
$$I_2=0\text{ A} \qquad ....(6)$$
$$V_x=0\text{ V} \qquad ....(7)$$

Step 7 of 12

By KVL around loop *edcbe* in Fig. 3,

$$V_{ed}+V_{dc}+V_{cb}+V_{be}=0$$
$$I_1(12)+4V_x-30=0$$
$$I_1=\frac{30}{12} \qquad ....(\text{By }(7))$$
$$I_1=2.5\text{ A} \qquad ....(8)$$

Step 8 of 12

$$\therefore I_{sc}=2.5-0 \qquad ....(\text{By }(5),(6)\text{ and }(8))$$
$$I_{sc}=2.5\text{ A} \qquad ....(9)$$

Step 9 of 12

Calculation of R_{TH}:

$$R_{TH}=\frac{V_{oc}}{I_{sc}}$$
$$R_{TH}=\frac{36}{2.5} \qquad ....(\text{By }(3)\text{ and }(9))$$
$$R_{TH}=\frac{72}{5}$$
$$R_{TH}=14.4\,\Omega \qquad ....(10)$$

Step 10 of 12

The Thevenin equivalent is drawn and R_L connected as shown in Fig. 4

Figure (4)

Step 11 of 12

Therefore for Maximum Power Transfer to R_L ,

$$R_L=R_{TH}$$
$$\boxed{R_L=14.4\,\Omega}$$

Step 12 of 12

Maximum Power Transferred to R_L is

$$P_{\max R_L}=\frac{V_{TH}^2}{4R_L}$$
$$P_{\max R_L}=\frac{(36)^2}{4(14.4)}$$
$$P_{\max R_L}=\frac{45}{2}$$
$$\boxed{P_{\max R_L}=22.5\text{ W}}$$

5.122P

Figure (1)

Step 2 of 11

Remove the R_L and Thevenin equivalent between node b and d is found by calculation open circuit voltage and short circuit current between node as shown in Fig. 2. and Fig. 3

Calculation of V_{TH}:

Figure (2)

Step 3 of 11

From Fig. 2 ,

$$V_0 = I_0(1000) \qquad ....(1)$$

By KVL around loop $abcdea$ in Fig. 2,

$$V_{ab} + V_{bc} + V_{cd} + V_{de} + V_{ea} = 0 \qquad ....(2)$$
$$I_0(500) + I_0(1000) - 12 + I_0(500) - 0.5V_0 = 0$$
$$I_0(2000) - 0.5I_0(1000) = 12 \qquad ....(By(1))$$
$$I_0(1500) = 12 \text{ A}$$
$$I_0 = 8 \text{ mA}$$

Step 4 of 11

By KVL around loop $bcdb$ in Fig. 2,

$$V_{bc} + V_{cd} + V_{db} = 0$$
$$I_0(1000) - 12 - V_{oc} = 0$$
$$(8\text{m})(1000) - 12 = V_{oc} \qquad ....(By\ (2))$$
$$V_{oc} = 8 - 12$$
$$V_{oc} = -4 \text{ V} \qquad ....(3)$$
$$V_{TH} = -4 \text{ V}$$

Step 5 of 11

Figure (3)

Let the loop currents be as in Fig. 3 ,

We have from Fig. 3

$$V_0 = I_2(1000) \qquad ....(4)$$
$$I_{sc} = I_1 - I_2 \qquad ....(5)$$

Step 6 of 11

By KVL around loop $bcdb$ in Fig. 3,

$$V_{bc} + V_{cd} + V_{db} = 0$$
$$I_2(1000) - 12 = 0$$
$$I_2 = 12 \text{ mA} \qquad ....(6)$$
$$V_0 = 12 \text{ V} \qquad ....(7)$$

Step 7 of 11

By KVL around loop $abdea$ in Fig. 3,

$$V_{ab} + V_{bd} + V_{de} + V_{ea} = 0$$
$$I_1(500) + 0 + I_1(500) - 0.5V_0 = 0$$
$$I_1(1000) = 0.5(12) \qquad ....(By\ (7))$$
$$I_1 = 6 \text{ mA} \qquad ....(8)$$
$$\therefore I_{sc} = 6\text{m} - 12\text{m} \qquad ....(By\ (5),(6)\ and\ (8))$$
$$I_{sc} = -6 \text{ mA} \qquad ....(9)$$

Step 8 of 11

Calculation of R_{TH}:

$$R_{TH} = \frac{V_{oc}}{I_{sc}}$$
$$R_{TH} = \frac{-4}{-6\text{m}} \qquad ....(By\ (3)\ and\ (9))$$
$$R_{TH} = \frac{2}{3}\text{k}$$
$$R_{TH} = 666.67\ \Omega \qquad ....(10)$$

Step 9 of 11

The Thevenin equivalent is drawn and R_L connected as shown in Fig. 4

Figure (4)

Step 10 of 11

Therefore for Maximum Power Transfer to R_L ,

$$R_L = R_{TH}$$
$$R_L = 666.67\ \Omega$$

Step 11 of 11

Maximum Power Transferred to R_L is

$$P_{max\,R_L} = \frac{V_{TH}^2}{4R_L}$$
$$P_{max\,R_L} = \frac{(-4)^2}{4\left(\frac{2}{3}\text{k}\right)}$$
$$P_{max\,R_L} = \frac{3}{500}$$
$$\boxed{P_{max\,R_L} = 6 \text{ mW}}$$

Step 1 of 8

5.123P

Refer to Figure E5.3 in the textbook for the circuit.

By Thevenin's theorem, open circuit the $1k\Omega$ and find the open circuit voltage across it.

Figure 1

Step 2 of 8

From Figure1, write the following relations:

$$V_1 = -12V$$

$$V_2 = 2V_x$$

$$V_3 = V_x + V_{oc} \text{ ..... (1)}$$

Apply nodal analysis at node V_3 .

$$\frac{V_3 - V_1}{2k} + \frac{V_3 - V_2}{1k} + \frac{V_3 - V_{oc}}{1k} = 0$$

$$V_3 - V_1 + 2V_3 - 2V_2 + 2V_3 - 2V_{oc} = 0$$

$$-V_1 - 2V_2 + 5V_3 - 2V_{oc} = 0 \text{ ..... (2)}$$

Apply nodal analysis at node V_{oc} .

$$\frac{V_{oc} - V_3}{1k} - 2m = 0$$

$$V_{oc} - V_3 = 2$$

$$V_3 = V_{oc} - 2$$

Substitute $V_{oc} - 2$ for V_3 in equation (1).

$$V_{oc} - 2 = V_x + V_{oc}$$

$$V_x = -2$$

Substitute -12 V for V_1 , $2V_x$ for V_2 , $V_{oc} - 2$ for V_3 in equation (2).

$$-(-12) - 2(2V_x) + 5(V_{oc} - 2) - 2V_{oc} = 0$$

$$12 - 4V_x + 5V_{oc} - 10 - 2V_{oc} = 0$$

$$12 - 4V_x + 3V_{oc} - 10 = 0$$

Substitute -2 for V_x in the equation.

$$12 - 4(-2) + 3V_{oc} - 10 = 0$$

$$12 + 8 + 3V_{oc} - 10 = 0$$

$$3V_{oc} = -10$$

$$V_{oc} = -\frac{10}{3} \text{ V}$$

Step 3 of 8

Find the short circuit current through from the equivalent circuit shown in Figure 2.

Step 4 of 8

Figure 2

Step 5 of 8

From Figure1, write the following relations:

$$V_1 = -12V$$

$$V_2 = 2V_x \text{ ..... (3)}$$

$$V_3 = V_x$$

Apply nodal analysis at node V_3 .

$$\frac{V_3 - V_1}{2k} + \frac{V_3 - V_2}{1k} + \frac{V_3}{1k} = 0$$

$$V_3 - V_1 + 2V_3 - 2V_2 + 2V_3 = 0$$

$$-V_1 - 2V_2 + 5V_3 = 0 \text{ ..... (4)}$$

Apply Kirchhoff's Current Law at node *V*.

$$I_{SC} = \frac{2}{1k} + \frac{V_3}{1k} \text{ ..... (5)}$$

Substitute V_3 for V_x in equation (3).

$$V_2 = 2V_3$$

Substitute -12 V for V_1 and $2V_3$ for V_2 in equation (2).

$$-(-12) - 2(2V_3) + 5V_3 = 0$$

$$12 - 4V_3 + 5V_3 = 0$$

$$12 + V_3 = 0$$

$$V_3 = -12$$

Substitute -12 V for V_3 in equation (5).

$$I_{SC} = \frac{2}{1k} + \frac{(-12)}{1k}$$

$$= -10 \text{ mA}$$

Step 6 of 8

The Thevenin's resistance is,

$$R_{th} = \frac{V_{oc}}{I_{sc}}$$

$$= \frac{\left(-\frac{10}{3}\right)}{(-10m)}$$

$$= \frac{1}{3} \text{ k}\Omega$$

Step 7 of 8

The Thevenin's equivalent circuit is shown in Figure 3.

Step 8 of 8

The value of R_L for maximum power transfer is,

$$R_L = R_{th}$$

$$= \frac{1}{3} \text{ k}\Omega$$

Thus, the value of R_L for maximum power transfer is $\boxed{\frac{1}{3} \text{ k}\Omega}$.

The maximum power dissipated in R_L is,

$$P_{R_L} = \left(\frac{-\frac{10}{3}}{\frac{1}{3} + \frac{1}{3}}\right)^2 \left(\frac{1}{3}\right)$$

$$= \left(\frac{10}{2}\right)^2 \left(\frac{1}{3}\right)$$

$$= \frac{25}{3} \text{ W}$$

Thus, the maximum power dissipated in R_L is $\boxed{\frac{25}{3} \text{ W}}$.

Step 1 of 14

The given circuit is,

Figure (1)

Step 2 of 14

Remove the R_L and Thevenin equivalent between node a and b is found by calculation open circuit voltage and short circuit current between node as shown in Fig. 2. and Fig. 3

Calculation of V_{TH}:

Figure (2)

Step 3 of 14

From Fig. 2,

$I_3 = 10$ mA ....(1)

$I_1 = I_3 - I_2$ ....(2)

Step 4 of 14

By KVL around loop $adbca$ in Fig. 2,

$V_{ad} + V_{db} + V_{bc} + V_{ca} = 0$ ....(3)

$-1000I_1 + I_2(10\text{k}) + I_2(10\text{k}) + (I_2 - I_3)(5\text{k}) = 0$

$-1000(I_3 - I_2) + I_2(25\text{k}) - I_3(5\text{k}) = 0$ ....(By(2))

$I_2(26\text{k}) - (10\text{m})(6\text{k}) = 0$ ....(By(1))

$I_2 = \frac{60}{26}$ mA

$I_2 = \frac{30}{13}$ mA

Step 5 of 14

By KVL around loop $abca$ in Fig. 2,

$V_{ab} + V_{bc} + V_{ca} = 0$

$V_{oc} + I_2(10\text{k}) + (I_2 - I_3)(5\text{k}) = 0$

$V_{oc} + \left(\frac{30}{13}\text{m}\right)(15\text{k}) - (10\text{m})(5\text{k}) = 0$ ....(By (1) and (3))

$V_{oc} = 50 - \frac{450}{13}$

$V_{oc} = \frac{200}{13}$ V ....(4)

$V_{TH} = 15.385$ V

Step 6 of 14

Figure (3)

Step 7 of 14

Let the loop currents be as in Fig. 3,

We have from Fig. 3

$I_3 = 10$ mA ....(5)

$I_1 = I_3 - I_2$ ....(6)

$I_{sc} = I_2 - I_4$ ....(7)

Step 8 of 14

By KVL around loop $abca$ in Fig. 3,

$V_{ab} + V_{bc} + V_{ca} = 0$

$0 + I_2(10\text{k}) + (I_2 - I_3)(5\text{k}) = 0$

$I_2(15\text{k}) - (10\text{m})(5\text{k}) = 0$ ....(By (5))

$I_2 = \frac{50}{15}$ mA

$I_2 = \frac{10}{3}$ mA ....(8)

Step 9 of 14

By KVL around loop $adba$ in Fig. 3,

$V_{ad} + V_{db} + V_{ba} = 0$

$-1000I_1 + I_4(10\text{k}) + 0 = 0$

$-1000(I_3 - I_2) + I_4(10\text{k}) = 0$

$I_4(10\text{k}) - \left(10\text{m} - \frac{10}{3}\text{m}\right)(1000) = 0$ ....(By (5) and (8))

$I_4(10\text{k}) = \frac{20}{3}$

$I_4 = \frac{2}{3}$ mA ....(9)

Step 10 of 14

$\therefore I_{sc} = \frac{10}{3}\text{m} - \frac{2}{3}\text{m}$ ....(By (7),(8) and (9))

$I_{sc} = \frac{8}{3}$ mA ....(10)

Step 11 of 14

Calculation of R_{TH}:

$R_{TH} = \frac{V_{oc}}{I_{sc}}$

$R_{TH} = \frac{\frac{200}{13}}{\frac{8}{3}\text{m}}$ ....(By (4) and (10))

$R_{TH} = \frac{75}{13}\text{k}$

$R_{TH} = 5.769$ kΩ .... (11)

Step 12 of 14

The Thevenin equivalent is drawn and R_L connected as shown in Fig. 4

Figure (4)

Step 13 of 14

Therefore for Maximum Power Transfer to R_L,

$R_L = R_{TH}$

$\boxed{R_L = 5.769 \text{ k}\Omega}$

Step 14 of 14

Maximum Power Transferred to R_L is

$P_{\max R_L} = \frac{V_{TH}^2}{4R_L}$

$P_{\max R_L} = \frac{\left(\frac{200}{13}\right)^2}{4\left(\frac{75}{13}\times 10^3\right)}$

$P_{\max R_L} = \frac{400}{39}$ m

$\boxed{P_{\max R_L} = 10.256 \text{ mW}}$

Step 1 of 9

Refer to Figure P5.118 in the text book.

Calculate the Thevenin equivalent circuit for the network exclusive of the load. Calculate the Thevenin equivalent voltage, V_{oc} .

Figure 1

Step 2 of 9

Apply Kirchhoff voltage law (KVL) at node 1.

$$\frac{V_1-12}{6\,\text{k}\Omega}+\frac{V_1-V_x}{3\,\text{k}\Omega}=0$$
$$\frac{V_1-12+2V_1-2V_x}{6\,\text{k}\Omega}=0$$
$$3V_1-2V_x=12$$

Hence, the voltage at node 1 is,

$3V_1-2V_x=12$ ..... (1)

Apply Kirchhoff voltage law (KVL) at node 2.

$$\frac{V_x}{2\,\text{k}\Omega}+\frac{V_x-V_1}{3\,\text{k}\Omega}-3\,\text{mA}=0$$
$$\frac{3V_x+2V_x-2V_1-18}{6\,\text{k}\Omega}=0$$
$$-2V_1+5V_x=18$$

Hence, the voltage at node 2 is,

$-2V_1+5V_x=18$ ..... (2)

Step 3 of 9

Multiply equation (1) with 2 and equation (2) with 3 and add both equations.

$$\begin{aligned}6V_1-4V_x&=24\\-6V_1+15V_x&=54\\\hline 11V_x&=78\\V_x&=7.09\,\text{V}\end{aligned}$$

Substitute 7.09 V for V_x in equation (1).

$$3V_1-2V_x=12$$
$$3V_1=12+2(7.09\text{ V})$$
$$3V_1=26.18$$
$$V_1=8.72\text{ V}$$

Find the current through $6\text{ k}\Omega$ resistor.

$$I=\frac{12\text{ V}-V_1}{6\text{ k}\Omega}$$
$$=\frac{12\text{ V}-8.72\text{ V}}{6\text{ k}\Omega}$$
$$=0.546\text{ mA}$$

Apply Kirchhoff current law (KVL) around the first loop.

$$-12+6\text{k}I+V_{oc}+0.5V_x=0$$
$$V_{oc}=12-6\text{k}I-0.5V_x$$

Substitute 7.09 V for V_x and 0.546 mA for I to calculate the Thevenin voltage.

$$\begin{aligned}V_{oc}&=12-(6\text{ k}\Omega)I-0.5V_x\\&=12-(6\text{ k}\Omega)(0.546\text{ mA})-(0.5)(7.09\text{ V})\\&=12-3.276-3.545\\&=5.18\text{ V}\end{aligned}$$

Step 4 of 9

Calculate the short-circuited current in the circuit.

Figure 2

Step 5 of 9

Apply Kirchhoff current law (KCL) around the loop 1.

$$-12+6I_1+0.5V_x=0$$
$$6I_1+0.5V_x=12$$

Hence, the expression for loop 1 is,

$6I_1+0.5V_x=12$ ..... (3)

Write the expression for current.

$$I_3-I_2=3\text{mA}$$
$$\frac{V_x}{2\text{k}\Omega}-I_2=3\text{mA}$$
$$V_x-(2\text{ k}\Omega)I_2=6$$
$$V_x=6+(2\text{ k}\Omega)I_2$$

Hence, the expression for loop 2 is,

$V_x=6+2\text{k}I_2$ ..... (4)

Substitute equation (4) in equation (3).

$$6I_1+0.5V_x=12$$
$$6I_1+0.5(6+2I_2)=12$$
$$6I_1+I_2=9$$

Hence, the expression is,

$6I_1+I_2=9$ ..... (5)

Step 6 of 9

Apply Kirchhoff current law (KCL) around the super loop.

$$0.5V_x+3I_2+V_x=0$$
$$0.5V_x+3I_2=0$$
$$V_x+6I_2=0$$

Further simplification

$$V_x=-6\text{k}I_2$$
$$6+2\text{k}I_2=-6\text{k}I_2$$
$$I_2=-0.75\text{ mA}$$

Substitute $-0.75\text{ mA for }I_2$ in equation (5).

$$6I_1+I_2=9$$
$$6I_1-0.75=9$$
$$6I_1=9.75$$
$$I_1=1.625\text{mA}$$

Step 7 of 9

Write the expression for the short-circuited current.

$$I_{sh}=I_1-I_2$$

Substitute -0.75 mA for I_2 and 1.625 mA for I_1 to calculate the short-circuited current.

$$\begin{aligned}I_{sh}&=I_1-I_2\\&=1.625\text{ mA}-(-0.75\text{ mA})\\&=2.375\text{ mA}\end{aligned}$$

Write the expression for the Thevenin resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sh}}$$

Calculate the Thevenin resistance by substituting $5.18\text{ V for }V_{oc}$ and $2.375\text{ mA for }I_{sh}$.

$$\begin{aligned}R_{Th}&=\frac{V_{oc}}{I_{sh}}\\&=\frac{5.18\text{ V}}{2.375\text{ mA}}\\&=2.18\text{ k}\Omega\end{aligned}$$

Step 8 of 9

Draw the simplified Thevenin's equivalent circuit.

Figure 3

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{2.18\text{ k}\Omega}$.

Step 9 of 9

Write the expression for the maximum power transferred to the load.

$$P_L=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)$$

Substitute 5.18 V for V_{oc} , $2.18\text{ k}\Omega$ for R_{Th} and R_L to calculate the maximum power transferred to the load.

$$\begin{aligned}P_L&=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)\\&=\left(\frac{5.18\text{ V}}{2.18\text{k}\Omega+2.18\text{k}\Omega}\right)^2(2.18\text{k}\Omega)\\&=3.07\text{ mW}\end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{3.07\text{ mW}}$.

Step 1 of 11

Refer to Figure P5.119 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 11

Apply Kirchhoff voltage law (KVL) around the loop 1.

$$-100+4(I_1-I_2)+4I_1+20=0$$
$$8I_1-4I_2=80$$
$$2I_1-I_2=20$$

Hence, the expression for the first loop is $2I_1-I_2=20$ ..... (1)

Apply Kirchhoff voltage law (KVL) around the loop 2.

$$-4V_x+4I_2+4I_2+4(I_2-I_1)=0$$

But $V_x=4I_1$, then the expression becomes

$$-4V_x+4I_2+4I_2+4(I_2-I_1)=0$$
$$-4(4I_1)+4I_2+4I_2+4I_2-4I_1=0$$
$$-20I_1+12I_2=0$$
$$-5I_1+3I_2=0$$

Hence, the expression for the second loop is $-5I_1+3I_3=0$ ..... (2)

Step 3 of 11

Multiply equation (1) with 3 and add it to equation (2).

$$\begin{array}{r} 6I_1-3I_2=60 \\ -5I_1+3I_2=0 \\ \hline I_1=60\text{ A} \end{array}$$

Substitute 60 A for I_1 in equation (1).

$$2I_1-I_2=20$$
$$2(60)-I_2=20$$
$$I_2=120-20$$
$$=100\text{ A}$$

Step 4 of 11

Calculate the Thevenin voltage.

$$-20-4I_1-4I_2+V_{oc}=0$$

$$\begin{aligned} V_{oc}&=20+4I_1+4I_2 \\ &=20+4(60)+4(100) \\ &=660\text{ V} \end{aligned}$$

Step 5 of 11

The circuit for calculating short-circuited current is shown in Figure 2.

Figure 2

Step 6 of 11

Apply Kirchhoff voltage law (KVL) around the loop 1.

$$-100+4(I_1-I_2)+4(I_1-I_3)+20=0$$
$$8I_1-4I_2-4I_3=80$$
$$2I_1-I_2-I_3=20$$

Hence, the expression for the second loop is $2I_1-I_2-I_3=20$ ..... (3)

Apply Kirchhoff voltage law (KVL) around the loop2.

$$-4V_x+4I_2+4(I_2-I_3)+4(I_2-I_1)=0$$
$$-4(4)(I_1-I_3)+4I_2+4I_2-4I_3+4I_2-4I_1=0$$
$$-20I_1+12I_2+12I_3=0$$
$$-5I_1+3I_2+3I_3=0$$

Hence, the expression for the second loop is $-5I_1+3I_3+3I_3=0$ ..... (4)

Step 7 of 11

Apply Kirchhoff voltage law (KVL) around the loop 3.

$$4(I_3-I_3)-20+4(I_3-I_1)=0$$
$$-4I_1-4I_2+8I_3=20$$
$$-I_1-I_2+2I_3=5$$

Hence, the expression for the second loop is $-I_1-I_2+2I_3=5$ ..... (5)

Step 8 of 11

Multiply equation (3) with 3 and add it to equation (4).

$$\begin{array}{r} 6I_1-3I_2-3I_3=60 \\ -5I_1+3I_2+3I_3=0 \\ \hline I_1=60\text{ A} \end{array}$$

Multiply equation (3) with 2 and add it to equation (5).

$$\begin{array}{r} 4I_1-2I_2-2I_3=40 \\ -I_1-I_2+2I_3=5 \\ \hline 3I_1-3I_2=45 \end{array}$$

Hence, the expression for the second loop is $3I_1-3I_2=45$ ..... (6)

Substitute 60 A for I_1 in equation (6).

$$3I_1-3I_2=45$$
$$3(60)-3I_2=45$$
$$3I_2=180-45$$
$$I_2=45\text{ A}$$

Substitute 60 A for I_1 and 45 A for I_2 in equation (5).

$$-I_1-I_2+2I_3=5$$
$$-60-45+2I_3=5$$
$$2I_3=5+60+45$$
$$I_3=55\text{ A}$$

Step 9 of 11

Write the expression for the current I_{sh}.

$$\begin{aligned} I_{sh}&=I_3 \\ &=55\text{ A} \end{aligned}$$

Write the expression for the Thevenin resistance.

$$R_{Th}=\frac{V_{oc}}{I_{sh}}$$

Calculate the Thevenin resistance by substituting 660 V for V_{oc} and 55 A for I_{sh}.

$$\begin{aligned} R_{Th}&=\frac{V_{oc}}{I_{sh}} \\ &=\frac{660\text{ V}}{55\text{ A}} \\ &=12\ \Omega \end{aligned}$$

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 10 of 11

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

Therefore, the load resistance R_L is $\boxed{12\Omega}$.

Step 11 of 11

Write the expression for the maximum power transferred to the load.

$$P_L=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L)$$

Calculate the maximum power transferred to the load by substituting 660 V for V_{oc}, 12Ω for R_{Th} and 12Ω for R_L.

$$\begin{aligned} P_L&=\left(\frac{V_{oc}}{R_{Th}+R_L}\right)^2(R_L) \\ &=\left(\frac{660}{12+12}\right)^2(12) \\ &=9075\text{ W} \end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{9075\text{ W}}$.

Step 1 of 9

Refer to Figure P5.121 in the text book.

The Thevenin voltage can be calculated from the circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Write the mesh equation for the loop 1.

$$-2V_A + I_2(2+1) - V_A = 0$$
$$3V_A = 3I_2$$
$$V_A = I_2$$

Hence, the expression loop 1 is,

$V_A = I_2$ ..... (1)

From the Figure 1, the expressions are,

$$V_A = 8I_1$$

$$I_2 = I_A + 2$$

$I_1 = 2I_A$ ..... (2)

Substitute equation (2) in equation (1).

$$V_A = I_2$$
$$8I_1 = I_A + 2$$
$$8(2I_A) = I_A + 2$$
$$I_A = 0.133\text{ A}$$

Step 3 of 9

Write the mesh equation for the loop 2.

$$-V_{oc} + V_A + 9 + 2(2) = 0$$

$$\begin{aligned} V_{oc} &= V_A + 13 \\ &= 8(2I_A) + 13 \\ &= 16(0.133) + 13 \\ &= 15.13\text{ V} \end{aligned}$$

Step 4 of 9

The circuit for calculating short-circuited current is shown in Figure 2.

Figure 2

Step 5 of 9

Write the mesh equation for the loop 1.

$$11I_1 + 2I_1 + 2V_A + 8(I_1 - I_3) = 0$$
$$11I_1 - 8I_3 + 2V_A = 0$$

But, the expression for the voltage is,

$$V_A = 8(I_1 - I_3)$$

Therefore,

$$11I_1 - 8I_3 + 2V_A = 0$$
$$11I_1 - 8I_3 + 16(I_1 - I_3) = 0$$

$$27I_1 - 24I_3 = 0$$

Step 6 of 9

From the circuit shown in Figure 2, the currents are,

$$I_1 = I_2 - I_A$$
$$I_3 = -3I_A$$

Substitute $I_2 - I_A$ for I_1 and $-3I_A$ for I_3 in $27I_1 - 24I_3 = 0$ equation.

$$27I_1 - 24I_3 = 0$$
$$-27(I_2 - I_A) - 24(-3I_A) = 0$$
$$-27I_2 + 27I_A + 72I_A = 0$$
$$99I_A = 27I_2$$

Substitute -2 A for I_2 in $99I_A = 27I_2$ equation.

$$\begin{aligned} 99I_A &= 27I_2 \\ &= 27(-2\text{ A}) \end{aligned}$$

$$\begin{aligned} I_A &= \frac{27(-2\text{ A})}{99} \\ &= -0.545\text{ A} \end{aligned}$$

Write the expression for the short-circuited current.

$$I_{sh} = 3I_A - I_2$$

Calculate the short-circuited current by substituting -0.545 A for I_A and -2 A for I_2.

$$\begin{aligned} I_{sh} &= I_A - I_2 \\ &= 3I_A - I_2 \\ &= 3(-0.545\text{ A}) - (-2\text{ A}) \\ &= 0.365\text{ A} \end{aligned}$$

Write the expression for the Thevenin resistance.

$$\begin{aligned} R_{Th} &= \frac{V_{oc}}{I_{sh}} \\ &= \frac{15.13\text{ V}}{0.365\text{ A}} \\ &= 41.45\,\Omega \end{aligned}$$

Step 7 of 9

Then the simplified circuit is shown in Figure 3.

Figure 3

Step 8 of 9

For a maximum power transfer, the Thevenin resistance is equal to the load resistance.

$$\begin{aligned} R_L &= R_{Th} \\ &= 41.45\,\Omega \end{aligned}$$

Therefore, the load resistance R_L is $\boxed{41.45\,\Omega}$.

Step 9 of 9

Write the expression for the maximum power transferred to the load.

$$P_L = \left(\frac{V_{oc}}{R_{Th} + R_L}\right)^2 (R_L)$$

Calculate the maximum power transferred to the load by substituting 15.13 V for V_{oc}, $41.45\,\Omega$ for R_{Th} and $41.45\,\Omega$ for R_L in the equation.

$$\begin{aligned} P_L &= \left(\frac{V_{oc}}{R_{Th} + R_L}\right)^2 (R_L) \\ &= \left(\frac{15.13\text{ V}}{41.45\,\Omega + 41.45\,\Omega}\right)^2 (41.45\,\Omega) \\ &= 1.38\text{ W} \end{aligned}$$

Therefore, the maximum power transferred to the load is $\boxed{1.38\text{ W}}$.

Step 1 of 12

Step 2 of 12

a) For maximum output power,

$R_{cell} = R_{ant}$

$\therefore \boxed{R_{cell} = 50\Omega}$

Step 3 of 12

b) $P_{out} = \dfrac{V_0^2}{R_{cell}}$

$V_0 = 0.1\left[\dfrac{50}{50+50}\right]$

$V_0 = 0.05\text{V}$

$P_{out} = \dfrac{(0.05)^2}{50}$

$\boxed{P_{out} = 50\mu\text{W}}$

Step 4 of 12

c) $P_{ant} = \dfrac{(V_{ant} - V_0)^2}{R_{ant}} + \dfrac{(V_0)^2}{R_{cell}}$

Since,

$V_{ant} - V_0 = V_0$

$R_{ant} = \dfrac{2(V_0)^2}{R_{cell}}$

Therefore at maximum power transfer

$P_{ant} = 2P_{out}$

$\boxed{P_{ant} = 100\mu\text{W}}$

Step 5 of 12

d) $\dfrac{V_0}{V_{ant}} = \dfrac{R_{cell}}{R_{cell} + R_{ant}}$

$\boxed{\dfrac{V_0}{V_{ant}} = 0.5}$

Step 6 of 12

e) The amount of power lost is same as P_{out},

$P_{R_{ant}} = P_{out}$

$\boxed{P_{R_{ant}} = 50\mu\text{W}}$

Step 7 of 12

f) $\eta = \dfrac{P_{out}}{P_{ant}} \times 100$

$= \dfrac{P_{out}}{2P_{out}} \times 100$

$= \dfrac{1}{2} \times 100$

$\boxed{\eta = 50\ \%}$

Step 8 of 12

g) $\eta = 90\%$

$0.9 = \dfrac{P_{out}}{P_{ant}}$

$0.9 = \dfrac{\left(\dfrac{V_0^2}{R_{cell}}\right)}{\dfrac{(V_{ant})^2}{(R_{cell} + R_{ant})}}$

$0.9 = \dfrac{\left[\dfrac{(V_{ant})^2\left[\dfrac{R_{cell}}{R_{cell} + R_{ant}}\right]^2}{R_{cell}}\right]}{\left[\dfrac{(V_{ant})^2}{R_{cell} + R_{ant}}\right]}$

$0.9 = \dfrac{R_{cell}}{R_{cell} + R_{ant}}$

Step 9 of 12

$\dfrac{R_{cell} + R_{ant}}{R_{cell}} = \dfrac{1}{0.9}$

$1 + \dfrac{R_{ant}}{R_{cell}} = \dfrac{10}{9}$

$\dfrac{R_{ant}}{R_{cell}} = \dfrac{10}{9} - 1$

$R_{cell} = 9\ R_{ant}$

$\boxed{R_{cell} = 450\,\Omega}$

Step 10 of 12

h) $P_{ant} = \dfrac{(V_{ant})^2}{R_{ant} + R_{cell}}$

$= \dfrac{(0.1)^2}{50 + 450}$

$\boxed{P_{ant} = 20\ \mu\text{W}}$

Step 11 of 12

i) $P_{out} = \dfrac{(V_0)^2}{R_{cell}}$

$V_0 = V_{ant}\left[\dfrac{R_{cell}}{R_{cell} + R_{ant}}\right]$

$= 0.1\left[\dfrac{450}{500}\right]$

$= 0.09\,\text{V}$

$P_{out} = \dfrac{(0.09)^2}{450}$

$\boxed{P_{out} = 18\mu\text{W}}$

Step 12 of 12

j) As efficiency increases, the P_{ant} drops faster as efficiency rises. The P_{ant} decreases as efficiency increases.

Step 1 of 3

Step 2 of 3

Given that both the generated voltage and the customer load are constant.

i.e. V_{gen} is fixed and I also is fixed

Now $P_{LOAD} = V_L I$

Here $V_L = V_{gen} - I R_{del}$

$\therefore \; P_{LOAD} = \left(V_{gen} - I \; R_{del}\right) I$

And $\qquad P_{GEN} = V_{gen} I$

Step 3 of 3

$$\therefore \text{ efficiency is } \eta = \frac{P_{LOAD}}{P_{GEN}}$$

$$= \frac{\left(V_{gen} - I \; R_{del}\right) I}{V_{gen} I}$$

$$\eta = \frac{V_{gen} - I R_{del}}{V_{gen}}$$

$$\eta = 1 - \frac{I}{V_{gen}} R_{del}$$

As R_{del} tends to zero then efficiency tends to 100%.

Therefore no power is lost in the system and all the generated power is sold out to the customer at lower operating cost.

6.001E

The charge, Q in a capacitor is proportional to the voltage, V across the capacitor. Write the expression for the charge of on the capacitor.

$$Q = CV$$

Substitute $10\ \mu\text{F}$ for C , and 500 nC for Q to calculate the voltage across the capacitor.

$$500\ \text{nC} = (500\ \mu\text{F})V$$

$$\begin{aligned} V &= \frac{500\ \text{nC}}{10\ \mu\text{F}} \\ &= \frac{500\times10^{-9}\ \text{C}}{500\times10^{-6}\ \text{F}} \\ &= 0.05\ \text{V} \end{aligned}$$

Therefore, the voltage across the capacitor, V is, $\boxed{0.05\ \text{V}}$.

The charge, Q in a capacitor is proportional to the voltage, V across the capacitor. Write the expression for the charge of on the capacitor.

$$Q = CV$$

Substitute $10\ \mu\text{F}$ for C , and 500 nC for Q to calculate the voltage across the capacitor.

$$500\ \text{nC} = (500\ \mu\text{F})V$$

$$\begin{aligned} V &= \frac{500\ \text{nC}}{10\ \mu\text{F}} \\ &= \frac{500\times10^{-9}\ \text{C}}{500\times10^{-6}\ \text{F}} \\ &= 0.05\ \text{V} \end{aligned}$$

Therefore, the voltage across the capacitor, V is, $\boxed{0.05\ \text{V}}$.

Step 1 of 2

The equivalent capacitance of $3\,\mu\mathrm{F}$ can be achieved by connecting the capacitors, $2\,\mu\mathrm{F}$ and $4\,\mu\mathrm{F}$ in parallel and then by connecting the parallel combination in series with $6\,\mu\mathrm{F}$ as shown in Figure 1.

Figure 1

Step 2 of 2

Verify the circuit by finding the equivalent capacitance.

Determine the equivalent capacitance of the parallel combination.

$$\begin{aligned} C_P &= 2+4 \\ &= 6\ \mu\mathrm{F} \end{aligned}$$

Determine the equivalent capacitance of the network.

$$\begin{aligned} C_{eq} &= \frac{(6)(6)}{6+6} \\ &= 3\ \mu\mathrm{F} \end{aligned}$$

Thus, the parallel combination of $2\,\mu\mathrm{F}$ and $4\,\mu\mathrm{F}$ capacitors in series with $6\,\mu\mathrm{F}$ capacitor gives the required equivalent capacitance.

Step 1 of 3

Refer to Figure E6.2 in the textbook for voltage across a capacitor.

The equation for a straight line between the points, (x_1, y_1) **and** (x_2, y_2) in the XY plane is,

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(0,0)$ **and** $(2,12)$.

$$\frac{y-0}{12-0}=\frac{x-0}{2-0}$$
$$2y=12x$$
$$y=6x$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(2,12)$ **and** $(6,0)$.

$$\frac{y-12}{0-12}=\frac{x-2}{6-2}$$
$$4(y-12)=-12(x-2)$$
$$y-12=-3x+6$$
$$y=-3x+18$$

Here, the planes, $y=v$ **and** $x=t$ and since the time is in milliseconds, the equations for the waveform in the specific time intervals are,

$$v(t)=\begin{cases}\dfrac{6t}{10^{-3}}, & 0\le t\le 2\,\text{ms},\\[2ex] \dfrac{-3t}{10^{-3}}+18 & 2\,\text{ms}\le t\le 6\,\text{ms}.\end{cases}$$

Step 2 of 3

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Substitute $2\ \mu\text{F}$ for C to calculate the capacitor current in the interval, $0\le t\le 2\ \text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(2\times10^{-6}\right)\frac{d}{dt}\left(\frac{6t}{10^{-3}}\right)\\&=\left(2\times10^{-6}\right)\left(6\times10^{3}\right)\\&=12\ \text{mA}\end{aligned}$$

Substitute $2\ \mu\text{F}$ for C to calculate the capacitor current in the interval, $2\ \text{ms}\le t\le 6\ \text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(2\times10^{-6}\right)\frac{d}{dt}\left(\frac{-3t}{10^{-3}}+18\right)\\&=\left(2\times10^{-6}\right)\left(-3\times10^{3}\right)\\&=-6\ \text{mA}\end{aligned}$$

Step 3 of 3

Draw the waveform for the capacitor current.

Figure 1

The charge Q of the capacitor is proportional to the voltage V across the capacitor. Write the expression for the charge.

$$Q = CV$$

Here, C is the capacitance.

Calculate the capacitance.

Substitute $5\ \mathrm{V}$ for V and $600\ \mu\mathrm{C}$ for Q in the equation.

$$Q = CV$$

$$\begin{aligned} C &= \frac{Q}{V} \\ &= \frac{600\times10^{-6}\ \mathrm{C}}{5\ \mathrm{V}} \\ &= 120\ \mu\mathrm{F} \end{aligned}$$

Therefore, the capacitance is $\boxed{120\ \mu\mathrm{F}}$.

Step 1 of 4

Refer to Figure 6PFE-2 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,6)$ and $(1,6)$ is as follows.

$$\frac{y-6}{6-6}=\frac{x-0}{1-0}$$
$$y=6$$

Here, the planes $y=i$ and $x=t$ and since the time is in microseconds, the equations for the waveforms in the specific time intervals are as follows.

$$i(t)=6 \qquad 0\le t\le 1\,\mu s$$

Step 2 of 4

Write the expression for the voltage across the capacitor.

$$v(t)=\frac{1}{C}\int_{t_0}^{t} i(t)\,dt$$

Calculate the voltage across the capacitor for the interval $0\le t\le 1\,\mu s$ by substituting $1\,\mu F$ for *C*.

$$\begin{aligned} v(t)&=\frac{1}{C}\int_0^{1\mu s} i(t)\,dt \\ &=\frac{1}{1\times 10^{-6}}\int_0^{1\mu s} 6\,dt \\ &=\frac{6t}{1\times 10^{-6}} \\ &=6\times 10^{6}\,t\ \text{V} \end{aligned}$$

Step 3 of 4

Write the expression for the energy stored in the electric field of the capacitor.

$$w(t)=\frac{1}{2}Cv^2(t)$$

Calculate the energy stored in the capacitor for the interval $0\le t\le 1\,\mu s$ by substituting $1\,\mu F$ for *C* and $6\times 10^{6}\,t\,\text{V}$ for $v(t)$.

$$\begin{aligned} w(t)&=\frac{1}{2}Cv^2(t) \\ &=\frac{1}{2}\left(1\times 10^{-6}\right)\left(6\times 10^{6}\,t\right)^2 \\ &=\frac{1}{2}\left(1\times 10^{-6}\right)\left(36\times 10^{12}\,t^2\right) \\ &=18\times 10^{6}\,t^2\ \text{J} \end{aligned}$$

Therefore, the energy stored in the capacitor for the interval $0\le t\le 1\,\mu s$ is $18\times 10^{6}\,t^2\ \text{J}$.

Step 4 of 4

Since the current is zero for $t\le 0$, the voltage is zero. There by the energy stored in the capacitor for $t\le 0$ is 0.

Therefore, the energy stored in the capacitor is 0.

Write the voltage across the capacitor for the interval, $0\le t\le 1\,\mu s$.

$$v(t)=6\times 10^{6}\,t\ \text{V}$$

For $t>1\,\mu s$, calculate the voltage across the capacitor by substituting $1\,\mu s$ for *t*.

$$\begin{aligned} v(t)&=6\times 10^{6}\,t\ \text{V} \\ &=6\times 10^{6}\left(1\times 10^{-6}\right)\text{V} \\ &=6\,\text{V} \end{aligned}$$

Write the expression for the energy stored in the electric field of the capacitor.

$$w(t)=\frac{1}{2}Cv^2(t)$$

Calculate the energy stored in the capacitor for $t>1\,\mu s$ by substituting $1\,\mu F$ for *C* and 6 V for v.

$$\begin{aligned} w(t)&=\frac{1}{2}Cv^2(t) \\ &=\frac{1}{2}\left(1\times 10^{-6}\right)(6)^2 \\ &=\frac{1}{2}\left(1\times 10^{-6}\right)(36) \\ &=18\,\mu J \end{aligned}$$

Therefore, the energy stored in the capacitor for $t>1\,\mu s$ is $18\,\mu J$.

Therefore, the correct option is $\boxed{c}$.

The charge Q of the capacitor is proportional to the voltage V across the capacitor. Write the expression for the charge.

$$Q = CV$$

Here, C is the capacitance.

Calculate the capacitance.

Substitute $5\ \mathrm{V}$ for V and $600\ \mu\mathrm{C}$ for Q in the equation.

$$Q = CV$$

$$\begin{aligned} C &= \frac{Q}{V} \\ &= \frac{600\times10^{-6}\ \mathrm{C}}{5\ \mathrm{V}} \\ &= 120\ \mu\mathrm{F} \end{aligned}$$

Therefore, the capacitance is $\boxed{120\ \mu\mathrm{F}}$.

Step 1 of 2

Refer to Figure 6PFE-3 in the text book.

Let the voltage across the capacitor C_x is V_x .

Apply Kirchhoff's voltage law (KVL) around the loop.

$$-24+8+V_x=0$$
$$V_x=16\,\text{V}$$

Write the expression for the charge through the capacitor.

$$Q=CV$$

Calculate the charge through the $60\,\mu\text{F}$ capacitor by substituting 8 V for *V* and $60\,\mu\text{F}$ for *C*.

$$\begin{aligned}Q&=CV\\&=\left(60\times10^{-6}\right)(8)\\&=480\,\mu\text{C}\end{aligned}$$

Since the capacitors are connected in series, same charge flow through both the capacitors. Hence, the charge through the series capacitors is $480\,\mu\text{C}$.

Step 2 of 2

Calculate the capacitance C_x by substituting 16 V for V_x and $480\,\mu\text{C}$ for Q.

$$Q=C_xV_x$$
$$C_x=\frac{Q}{V_x}$$
$$=\frac{480\times10^{-6}}{16}$$
$$=30\,\mu\text{F}$$

Hence, the required capacitance is $30\,\mu\text{F}$.

Therefore, the correct option is $\boxed{\text{b}}$.

Step 1 of 7

Refer to Figure E6.4 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is,

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(0,0)$ and $(1,5)$.

$$\frac{y-0}{5-0}=\frac{x-0}{1-0}$$
$$y=5x$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(1,5)$ and $(3,5)$.

$$\frac{y-5}{5-5}=\frac{x-1}{3-1}$$
$$y=5$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(3,5)$ and $(4,10)$.

$$\frac{y-5}{10-5}=\frac{x-3}{4-3}$$
$$y=5x-10$$

Step 2 of 7

Use the equation for straight line to find the equation for the voltage waveform between the points, $(4,10)$ and $(7,-5)$.

$$\frac{y-10}{-5-10}=\frac{x-4}{7-4}$$
$$y-10=\frac{-15(x-4)}{3}$$
$$y=-5x+30$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(7,-5)$ and $(9,-5)$.

$$\frac{y-(-5)}{-5-(-5)}=\frac{x-7}{9-7}$$
$$y+5=0$$
$$y=-5$$

Use the equation for straight line to find the equation for the voltage waveform between the points, $(9,-5)$ and $(10,0)$.

$$\frac{y-(-5)}{0-(-5)}=\frac{x-9}{10-9}$$
$$y+5=5x-45$$
$$y=5x-50$$

Here, the planes, $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveforms in the specific time intervals are,

$$v(t)=\begin{cases}\frac{5t}{10^{-3}}, & 0\le t\le 1\,\text{ms},\\ 5, & 1\,\text{ms}\le t\le 3\,\text{ms},\\ \frac{5t}{10^{-3}}-10, & 3\,\text{ms}\le t\le 4\,\text{ms},\\ \frac{-5t}{10^{-3}}+30, & 4\,\text{ms}\le t\le 7\,\text{ms},\\ -5, & 7\,\text{ms}\le t\le 9\,\text{ms},\\ \frac{5t}{10^{-3}}-50, & 9\,\text{ms}\le t\le 10\,\text{ms}.\end{cases}$$

Step 3 of 7

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $0\le t\le 1\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}\left(\frac{5t}{10^{-3}}\right)\\&=\left(5\times10^{-6}\right)\left(5\times10^{3}\right)\\&=25\,\text{mA}\end{aligned}$$

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $1\,\text{ms}\le t\le 3\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}(5)\\&=\left(5\times10^{-6}\right)(0)\\&=0\end{aligned}$$

Step 4 of 7

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $3\le t\le 4\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}\left(\frac{5t}{10^{-3}}-10\right)\\&=\left(5\times10^{-6}\right)\left(5\times10^{3}\right)\\&=25\,\text{mA}\end{aligned}$$

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $4\le t\le 7\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}\left(\frac{-5t}{10^{-3}}+30\right)\\&=\left(5\times10^{-6}\right)\left(-5\times10^{3}\right)\\&=-25\,\text{mA}\end{aligned}$$

Step 5 of 7

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $7\le t\le 9\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}(-5)\\&=\left(5\times10^{-6}\right)(0)\\&=0\end{aligned}$$

Substitute $5\,\mu\text{F}$ for C to calculate the capacitor current in the interval, $9\le t\le 10\,\text{ms}$.

$$\begin{aligned}i(t)&=C\frac{dv(t)}{dt}\\&=\left(5\times10^{-6}\right)\frac{d}{dt}\left(\frac{5t}{10^{-3}}-50\right)\\&=\left(5\times10^{-6}\right)\left(5\times10^{3}\right)\\&=25\,\text{mA}\end{aligned}$$

Step 6 of 7

Draw the waveform for the capacitor current.

Figure 1

Step 7 of 7

Write the expression for the energy stored in the electric field of the capacitor.

$$w(t)=\frac{1}{2}Cv^2(t)$$

From the Figure E6.4, at $t=4\,\text{ms}$, the voltage across the capacitor is 10 V.

Substitute $5\,\mu\text{F}$ for C and 10 V for v to calculate the energy stored in the electric field of the capacitor.

$$\begin{aligned}w(t)&=\frac{1}{2}Cv^2(t)\\&=\frac{1}{2}\left(5\times10^{-6}\right)(10)^2\\&=250\,\mu\text{J}\end{aligned}$$

Therefore, the energy stored in the capacitor at $t=4\,\text{ms}$ is, $\boxed{250\,\mu\text{J}}$.

Step 1 of 4

Refer to Figure PFE-4 in the text book.

When N numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When N numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors $3\,\text{mH and } 9\,\text{mH}$ are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{3,9} &= L_3 + L_9 \\ &= 3 + 9 \\ &= 12\,\text{mH} \end{aligned}$$

Step 2 of 4

This $12\,\text{mH}$ is in parallel with the $12\,\text{mH}$ inductor. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{12,12}} &= \frac{1}{L_{12}} + \frac{1}{L_{12}} \\ &= \frac{1}{12} + \frac{1}{12} \\ &= \frac{1+1}{12} \\ L_{12,12} &= 6\,\text{mH} \end{aligned}$$

The inductors $3\,\text{mH and } 6\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{3,6}} &= \frac{1}{L_3} + \frac{1}{L_6} \\ &= \frac{1}{3} + \frac{1}{6} \\ &= \frac{2+1}{6} \\ L_{3,6} &= 2\,\text{mH} \end{aligned}$$

Step 3 of 4

Then the modified circuit is shown in Figure 1.

Figure 1

Step 4 of 4

The inductors $3\,\text{mH and } 6\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{2,6}} &= \frac{1}{L_2} + \frac{1}{L_6} \\ &= \frac{1}{2} + \frac{1}{6} \\ &= \frac{3+1}{6} \\ L_{2,6} &= 1.5\,\text{mH} \end{aligned}$$

This $1.5\,\text{mH}$ inductor is in series with the $2\,\text{mH}$ inductor. Calculate their equivalent inductance.

$$\begin{aligned} L_{eq} &= L_2 + L_{1.5} \\ &= 2 + 1.5 \\ &= 3.5\,\text{mH} \end{aligned}$$

Hence, the equivalent inductance is $3.5\,\text{mH}$

Therefore, the correct option is $\boxed{\text{d}}$.

Step 1 of 4

Refer to Figure PFE-4 in the text book.

When *N* numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors $3\,\text{mH and } 9\,\text{mH}$ are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{3,9} &= L_3 + L_9 \\ &= 3 + 9 \\ &= 12\,\text{mH} \end{aligned}$$

Step 2 of 4

This $12\,\text{mH}$ is in parallel with the $12\,\text{mH}$ inductor. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{12,12}} &= \frac{1}{L_{12}} + \frac{1}{L_{12}} \\ &= \frac{1}{12} + \frac{1}{12} \\ &= \frac{1+1}{12} \\ L_{12,12} &= 6\,\text{mH} \end{aligned}$$

The inductors $3\,\text{mH and } 6\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{3,6}} &= \frac{1}{L_3} + \frac{1}{L_6} \\ &= \frac{1}{3} + \frac{1}{6} \\ &= \frac{2+1}{6} \\ L_{3,6} &= 2\,\text{mH} \end{aligned}$$

Step 3 of 4

Then the modified circuit is shown in Figure 1.

Figure 1

Step 4 of 4

The inductors $3\,\text{mH and } 6\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{2,6}} &= \frac{1}{L_2} + \frac{1}{L_6} \\ &= \frac{1}{2} + \frac{1}{6} \\ &= \frac{3+1}{6} \\ L_{2,6} &= 1.5\,\text{mH} \end{aligned}$$

This $1.5\,\text{mH}$ inductor is in series with the $2\,\text{mH}$ inductor. Calculate their equivalent inductance.

$$\begin{aligned} L_{eq} &= L_2 + L_{1.5} \\ &= 2 + 1.5 \\ &= 3.5\,\text{mH} \end{aligned}$$

Hence, the equivalent inductance is $3.5\,\text{mH}$

Therefore, the correct option is $\boxed{\text{d}}$.

Step 1 of 5

Refer to Figure E6.5 in the text book.

The capacitance is, $C = 1\times10^{-9}\ \text{F}$.

The equation for the current waveform in the specific time intervals is,

$$i(t) = \begin{cases} -\dfrac{5t}{10^{-3}}\ \mu\text{A} & 0 \le t \le 2\text{ms} \\ -10\ \mu\text{A} & 2 \le t \le 4\text{ms} \\ 0\ \mu\text{A} & 4 \le t \le 5\text{ms} \\ 10\ \mu\text{A} & 5 \le t \le 10\text{ms} \end{cases}$$

Calculate the voltage expression for the interval, $0 \le t \le 2\text{ms}$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i_C(t)\,dt + v_C(0) \\ &= \frac{1}{1\times10^{-9}}\int_0^t \frac{-5\mu}{10^{-3}}t\,dt - 5 \\ &= \frac{-5\times10^{-6}}{1\times10^{-12}}\left[\frac{t^2}{2}\right]_0^t - 5 \\ &= \frac{-5\times10^{-6}}{2\times10^{-12}}t^2 - 5 \end{aligned}$$

$$v(t) = -2.5\times10^6 t^2 - 5 \qquad \text{for } 0 \le t \le 2\text{ms}$$

Substitute 2ms for t .

$$\begin{aligned} v(2\text{ms}) &= -2.5\times10^6\left(2\times10^{-3}\right)^2 - 5 \\ &= -10 - 5 \\ &= -15\ \text{V} \end{aligned}$$

Step 2 of 5

Calculate the voltage expression for the interval, $2 \le t \le 4\text{ ms}$.

$$\begin{aligned} v(t) &= \frac{10^{-6}}{1\times10^{-9}}\int_{2\text{ms}}^t -10\,dt + v(2\text{ms}) \\ &= \frac{-10\times10^{-6}}{1\times10^{-9}}\left(t - 2\times10^{-3}\right) - 15 \end{aligned}$$

$$v(t) = -10000\left(t - 2\times10^{-3}\right) - 15 \qquad \text{for } 2 \le t \le 4\text{ms}$$

Substitute 4 ms for t .

$$\begin{aligned} v(4\text{ms}) &= -10000\left(4\times10^{-3} - 2\times10^{-3}\right) - 15 \\ &= -20 - 15 \\ &= -35\ \text{V} \end{aligned}$$

Calculate the voltage expression for the interval, $4 \le t \le 5\text{ms}$.

$$\begin{aligned} v(t) &= \frac{10^{-6}}{1\times10^{-9}}\int_{4\text{ms}}^t -0\,dt + v(4\text{ms}) \\ &= \frac{-10\times10^{-6}}{1\times10^{-9}}(0) - 35 \end{aligned}$$

$$v(t) = -35\ \text{V} \qquad \text{for } 4\text{ms} \le t \le 5\text{ms}$$

From the expression,

$$v(5\text{ms}) = -35\ \text{V}$$

Step 3 of 5

Calculate the voltage expression for the interval, $5 \le t \le 10\text{ms}$.

$$\begin{aligned} v(t) &= \frac{1}{1\times10^{-4}}\int_{5\text{ms}}^t 10\,dt + v(5\text{ms}) \\ &= \frac{10\times10^{-6}}{1\times10^{-9}}\left(t - 5\times10^{-3}\right) - 35 \end{aligned}$$

$$v(t) = 10000\left(t - 5\times10^{-3}\right) - 35 \qquad \text{for } 5 \le t \le 10\text{ms}$$

Substitute 10 ms for t .

$$\begin{aligned} v(10\text{ms}) &= 10000\left(10\times10^{-3} - 5\times10^{-3}\right) - 35 \\ &= 50 - 35 \\ &= 15\ \text{V} \end{aligned}$$

Step 4 of 5

Draw the waveform for capacitor voltage.

Step 5 of 5

Write the formula for energy stored in the capacitor.

$$w(t) = \frac{1}{2}Cv^2(t)$$

Calculate the energy stored in the capacitor at $t = 6\text{ms}$.

$$w(6\text{ms}) = \frac{1}{2}C\left(v(6\text{ms})\right)^2 \quad \text{..... (1)}$$

Calculate the voltage across the capacitor at $t = 6\text{ ms}$.

$$\begin{aligned} v(6\text{ms}) &= 10000\left(6\times10^{-3} - 5\times10^{-3}\right) - 35 \\ &= 10 - 35 \\ &= -25\ \text{V} \end{aligned}$$

Substitute $-25\ \text{V}$ for $v(6\text{ms})$ and 1×10^{-9} for C in equation (1).

$$\begin{aligned} w(6\text{ ms}) &= \frac{1}{2}\left(1\times10^{-9}\right)(-25)^2 \\ &= \frac{625\times10^{-9}}{2} \\ &= 312.5\times10^{-9} \\ &= 312.5\ \text{nJ} \end{aligned}$$

Therefore, the energy stored in the capacitor at 6 ms , $w(6\text{ ms})$ is $\boxed{312.5\ \text{nJ}}$.

Step 1 of 7

The given voltage waveform across a capacitor is,

Step 2 of 7

Given $C = 50\mu F$

$$C = 50\times10^{-6}F$$

The current through a capacitor is given by,

$$i = C\frac{dv}{dt}$$

Where, C is the Capacitance.

$\frac{dv}{dt}$ is the change in voltage per unit change in time.

Step 3 of 7

From the given voltage waveform,

$$v(t) = \begin{cases} 5000t & \text{for } 0 \le t \le 2\text{ms} \\ 10 & \text{for } 2\text{ms} \le t \le 4\text{ms} \\ 30-5000t & \text{for } 4\text{ms} \le t \le 8\text{ms} \\ -10 & \text{for } 8\text{ms} \le t \le 10\text{ms} \\ 5000t-60 & \text{for } 10\text{ms} \le t \le 12\text{ms} \end{cases}$$

Therefore,

for $0 \le t \le 2\text{ms}$

$$i = \left(50\times10^{-6}\right)\frac{d}{dt}(5000t)$$

$$i = \left(50\times10^{-6}\right)(5000)$$

$$i = 0.25\text{A}$$

Step 4 of 7

for $2\text{ms} \le t \le 4\text{ms}$

$$i = \left(50\times10^{-6}\right)\frac{d}{dt}(10)$$

$$i = \left(50\times10^{-6}\right)(0)$$

$$i = 0\text{A}$$

for $4\text{ms} \le t \le 8\text{ms}$

$$i = \left(50\times10^{-6}\right)\frac{d}{dt}(30-5000t)$$

$$i = \left(50\times10^{-6}\right)(0-5000)$$

$$i = -0.25\text{A}$$

Step 5 of 7

for $8\text{ms} \le t \le 10\text{ms}$

$$i = \left(50\times10^{-6}\right)\frac{d}{dt}(-10)$$

$$i = \left(50\times10^{-6}\right)(0)$$

$$i = 0\text{A}$$

for $10\text{ms} \le t \le 12\text{ms}$

$$i = \left(50\times10^{-6}\right)\frac{d}{dt}(5000t-60)$$

$$i = \left(50\times10^{-6}\right)(5000)$$

$$i = 0.25\text{A}$$

Step 6 of 7

The summary is,

$$i(t) = \begin{cases} 0.25 & \text{for } 0 \le t \le 2\text{ms} \\ 0 & \text{for } 2\text{ms} \le t \le 4\text{ms} \\ -0.25 & \text{for } 4\text{ms} \le t \le 8\text{ms} \\ 0 & \text{for } 8\text{ms} \le t \le 10\text{ms} \\ 0.25 & \text{for } 10\text{ms} \le t \le 12\text{ms} \end{cases}$$

Step 7 of 7

The required current waveform is shown below:

Step 1 of 2

Refer to Figure 6PFE-5 in the text book.

The operating characteristics of a current source are as follows.

$$i(t)=\begin{cases}0\text{ A} & t<0\\ 20te^{-2t}\text{ A} & t>0\end{cases}$$

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the voltage across the inductor for $t<0$ by substituting $10\,\text{mH}$ for L .

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=\left(10\times10^{-3}\right)\frac{d}{dt}(0) && t<0\\&=\left(10\times10^{-3}\right)(0) && t<0\\&=0\,\text{V}\end{aligned}$$

Step 2 of 2

Calculate the voltage across the inductor for $t>0$ by substituting $10\,\text{mH}$ for L .

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=\left(10\times10^{-3}\right)\frac{d}{dt}\left(20te^{-2t}\right) && t>0\\&=\left(10\times10^{-3}\right)(20)\left[t\frac{d}{dt}e^{-2t}+e^{-2t}\frac{d}{dt}t\right] && t>0\\&=(0.2)\left[-2te^{-2t}+e^{-2t}\right]\end{aligned}$$

$$=0.2e^{-2t}-0.4te^{-2t}$$

Therefore, the voltage across the inductor as a function of time can be expressed as follows:

$$\boxed{v(t)=\begin{cases}0\text{ V} & t<0\\ 0.2e^{-2t}-0.4te^{-2t} & t>0\end{cases}}.$$

The correct answer is not given in the options. If could consider typo error in option (a), that is, 4 instead of 0.4. Then the correct option is $\boxed{\text{a}}$.

Step 1 of 3

Refer to Figure E6.6 in the textbook for the current in an inductor.

The equation of a straight line between the points, (x_1, y_1) and (x_2, y_2) in the XY plane is,

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

Use the equation of a straight line to find the equation for the current waveform between the points, $(0,0)$ and $(1,20)$.

$$\frac{y-0}{20-0}=\frac{x-0}{1-0}$$
$$y=20x$$

Use the equation of a straight line to find the equation for the current waveform between the points, $(1,20)$ and $(2,10)$.

$$\frac{y-20}{10-20}=\frac{x-1}{2-1}$$
$$y-20=-10(x-1)$$
$$y=-10x+30$$

Use the equation of a straight line to find the equation for the current waveform between the points, $(2,10)$ and $(3,10)$.

$$\frac{y-10}{10-10}=\frac{x-2}{3-2}$$
$$y=10$$

Use the equation of a straight line to find the equation for the current waveform between the points, $(3,10)$ and $(4,0)$.

$$\frac{y-10}{0-10}=\frac{x-3}{4-3}$$
$$y-10=-10(x-3)$$
$$y=-10x+40$$

Here, the planes, $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are,

$$i(t)=\begin{cases}\dfrac{20\times10^{-3}t}{10^{-3}}, & 0\le t\le 1\text{ ms},\\[2mm] \dfrac{-10\times10^{-3}t}{10^{-3}}+30\times10^{-3}, & 1\text{ ms}\le t\le 2\text{ ms},\\[2mm] 10\times10^{-3}, & 2\text{ ms}\le t\le 3\text{ ms},\\[2mm] \dfrac{-10\times10^{-3}t}{10^{-3}}+40\times10^{-3}, & 3\text{ ms}\le t\le 4\text{ ms}.\end{cases}$$

Step 2 of 3

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Substitute 5 mH for L to calculate the inductor voltage in the interval, $0\le t\le 1\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(5\times10^{-3})\frac{d}{dt}\left(\frac{20\times10^{-3}t}{10^{-3}}\right)\\&=(5\times10^{-3})(20)\\&=100\text{ mV}\end{aligned}$$

Substitute 5 mH for L to calculate the inductor voltage in the interval, $1\text{ ms}\le t\le 2\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(5\times10^{-3})\frac{d}{dt}\left(\frac{-10\times10^{-3}t}{10^{-3}}+30\times10^{-3}\right)\\&=(5\times10^{-3})(-10)\\&=-50\text{ mV}\end{aligned}$$

Substitute 5 mH for L to calculate the inductor voltage in the interval, $2\text{ ms}\le t\le 3\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(5\times10^{-3})\frac{d}{dt}(10\times10^{-3})\\&=(5\times10^{-3})(0)\\&=0\end{aligned}$$

Substitute 5 mH for L to calculate the inductor voltage in the interval, $3\text{ ms}\le t\le 4\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(5\times10^{-3})\frac{d}{dt}\left(\frac{-10\times10^{-3}t}{10^{-3}}+40\times10^{-3}\right)\\&=(5\times10^{-3})(-10)\\&=-50\text{ mV}\end{aligned}$$

Step 3 of 3

Draw the waveform for the inductor voltage.

Figure 1

Step 1 of 6

Step 2 of 6

Given $C = 12\mu\text{F}$

$C = 12\times10^{-6}\text{F}$

The current through a capacitor is given by,

$$i = C\frac{dv}{dt}$$

Where, C is the Capacitance.

$\frac{dv}{dt}$ is the change in voltage per unit change in time.

Step 3 of 6

From the given voltage waveform,

$$v(t) = \begin{cases} 2\times10^6 t & \text{for } 0 \le t \le 6\mu\text{s} \\ 42 - 5\times10^6 t & \text{for } 6\mu\text{s} \le t \le 10\mu\text{s} \\ \frac{-64}{3} + \frac{4}{3}\times10^6 t & \text{for } 10\mu\text{s} \le t \le 16\mu\text{s} \\ 0 & \text{for } t > 16\mu\text{s} \end{cases}$$

Therefore,

for $0 \le t \le 6\mu\text{s}$

$$i = \left(12\times10^{-6}\right)\frac{d}{dt}\left(2\times10^6 t\right)$$

$$i = \left(12\times10^{-6}\right)\left(2\times10^6\right)$$

$$i = 24\text{A}$$

Step 4 of 6

for $6\mu\text{s} \le t \le 10\mu\text{s}$

$$i = \left(12\times10^{-6}\right)\frac{d}{dt}\left(42 - 5\times10^6 t\right)$$

$$i = \left(12\times10^{-6}\right)\left(-5\times10^6\right)$$

$$i = -60\text{A}$$

for $10\mu\text{s} \le t \le 16\mu\text{s}$

$$i = \left(12\times10^{-6}\right)\frac{d}{dt}\left(\frac{-64}{3} + \frac{4\times10^6}{3}t\right)$$

$$i = \left(12\times10^{-6}\right)\left(\frac{4\times10^6}{3}\right)$$

$$i = 16\text{A}$$

Step 5 of 6

for $t > 16\mu\text{s}$

$$i = \left(12\times10^{-6}\right)\frac{d}{dt}(0)$$

$$i = \left(12\times10^{-6}\right)(0)$$

$$i = 0\text{A}$$

The summary is,

$$i(t) = \begin{cases} 24\text{A} & \text{for } 0 \le t \le 6\mu\text{s} \\ -60\text{A} & \text{for } 6\mu\text{s} \le t \le 10\mu\text{s} \\ 16\text{A} & \text{for } 10\mu\text{s} \le t \le 16\mu\text{s} \\ 0 & \text{for } t > 16\mu\text{s} \end{cases}$$

Step 6 of 6

The required current waveform is shown below:

6.007E

Refer to Figure E6.6 in the textbook.

Write the expression for the energy stored in the magnetic field of the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

From the Figure E6.6, at $t = 1.5\,\text{ms}$, the current through the inductor is 15 mA.

Substitute 5 mH for L and 15 mA for i to calculate the energy stored in the magnetic field of the inductor.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(5\times10^{-3}\right)\left(15\times10^{-3}\right)^2 \\ &= 562.5\,\text{nJ} \end{aligned}$$

Therefore, the energy stored in the magnetic field of the inductor is $\boxed{562.5\,\text{nJ}}$.

Step 1 of 2

6.007P

Refer to Figure P6.8 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows:

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(4,2)$ is as follows:

$$\frac{y-0}{2-0}=\frac{x-0}{4-0}$$
$$y=0.5x$$

The equation for the voltage waveform between the points $(4,2)$ and $(8,2)$ is as follows:

$$\frac{y-2}{2-2}=\frac{x-4}{8-4}$$
$$y=2$$

The equation for the voltage waveform between the points $(8,2)$ and $(12,6)$ is as follows:

$$\frac{y-2}{6-2}=\frac{x-8}{12-8}$$
$$y-2=x-8$$
$$y=x-6$$

The equation for the voltage waveform between the points $(12,6)$ and $(16,0)$ is as follows:

$$\frac{y-6}{0-6}=\frac{x-12}{16-12}$$
$$y-6=\frac{-6(x-12)}{4}$$
$$y=\frac{-6x+72}{4}+6$$
$$=-1.5x+24$$

Here, the planes $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveforms in the specific time intervals are as follows:

$$\begin{aligned} v(t) &= \frac{0.5t}{10^{-3}} && 0\le t\le 4\,\text{ms} \\ &= 2 && 4\,\text{ms}\le t\le 8\,\text{ms} \\ &= \frac{t}{10^{-3}}-6 && 8\,\text{ms}\le t\le 12\,\text{ms} \\ &= -1.5x+24 && 12\,\text{ms}\le t\le 16\,\text{ms} \end{aligned}$$

Step 2 of 2

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 4\,\text{ms}$ by substituting $10\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(10\times10^{-6}\right)\frac{d}{dt}\left(\frac{0.5t}{10^{-3}}\right) && 0\le t\le 4\,\text{ms} \\ &= \left(10\times10^{-6}\right)\left(0.5\times10^{3}\right) && 0\le t\le 4\,\text{ms} \\ &= 5\,\text{mA} \end{aligned}$$

Calculate the capacitor current for the interval $4\,\text{ms}\le t\le 8\,\text{ms}$ by substituting $10\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(10\times10^{-6}\right)\frac{d}{dt}(2) && 4\,\text{ms}\le t\le 8\,\text{ms} \\ &= \left(10\times10^{-6}\right)(0) && 4\,\text{ms}\le t\le 8\,\text{ms} \\ &= 0 \end{aligned}$$

Calculate capacitor current for the interval $8\,\text{ms}\le t\le 12\,\text{ms}$ by substituting $10\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(10\times10^{-6}\right)\frac{d}{dt}\left(\frac{t}{10^{-3}}-6\right) && 8\,\text{ms}\le t\le 12\,\text{ms} \\ &= \left(10\times10^{-6}\right)\left(1\times10^{3}\right) && 8\,\text{ms}\le t\le 12\,\text{ms} \\ &= 10\,\text{mA} \end{aligned}$$

Calculate the capacitor current for the interval $12\,\text{ms}\le t\le 16\,\text{ms}$ by substituting $10\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(10\times10^{-6}\right)\frac{d}{dt}\left(\frac{-1.5t}{10^{-3}}+24\right) && 12\,\text{ms}\le t\le 16\,\text{ms} \\ &= \left(10\times10^{-6}\right)\left(-1.5\times10^{3}\right) && 12\,\text{ms}\le t\le 16\,\text{ms} \\ &= -15\,\text{mA} \end{aligned}$$

The required waveform for the capacitor current is shown in Figure 1.

Figure 1

Step 1 of 4

Refer to Figure E6.8 in the textbook for the current in an inductor.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is,

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(2,-5)$ is,

$$\frac{y-0}{-5-0}=\frac{x-0}{2-0}$$
$$y=-2.5x$$

The equation for the current waveform between the points $(2,-5)$ and $(6,-10)$ is,

$$\frac{y-(-5)}{-10-(-5)}=\frac{x-2}{6-2}$$
$$y+5=\frac{-5(x-2)}{4}$$
$$y=\frac{-5x}{4}-\frac{10}{4}$$

The equation for the current waveform between the points $(6,-10)$ and $(9,5)$ is,

$$\frac{y-(-10)}{5-(-10)}=\frac{x-6}{9-6}$$
$$y+10=\frac{15(x-6)}{3}$$
$$y=5x-40$$

The equation for the current waveform between the points $(9,5)$ and $(12,0)$ is,

$$\frac{y-5}{0-5}=\frac{x-9}{12-9}$$
$$y-5=\frac{-5(x-9)}{3}$$
$$y=\frac{-5x}{3}+20$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are,

$$i(t)=\begin{cases}\dfrac{-2.5\times10^{-3}t}{10^{-3}}, & 0\le t\le 2\text{ ms},\\[2mm] \dfrac{-5\times10^{-3}t}{4\times10^{-3}}-\dfrac{10}{4}\times10^{-3}, & 2\text{ ms}\le t\le 6\text{ ms},\\[2mm] \dfrac{5\times10^{-3}t}{10^{-3}}-40\times10^{-3}, & 6\text{ ms}\le t\le 9\text{ ms},\\[2mm] \dfrac{-5\times10^{-3}t}{3\times10^{-3}}+20\times10^{-3}, & 9\text{ ms}\le t\le 12\text{ ms}.\end{cases}$$

Step 2 of 4

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Substitute 2 H for L to calculate the inductor voltage in the interval $0\le t\le 2\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(2)\frac{d}{dt}\left(\frac{-2.5\times10^{-3}t}{10^{-3}}\right)\\&=(2)(-2.5)\\&=-5\text{ V}\end{aligned}$$

Substitute 2 H for L to calculate the inductor voltage in the interval $2\text{ ms}\le t\le 6\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(2)\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{4\times10^{-3}}-\frac{10}{4}\times10^{-3}\right)\\&=(2)\left(\frac{-5}{4}\right)\\&=-2.5\text{ V}\end{aligned}$$

Substitute 2 H for L to calculate the inductor voltage in the interval, $-2.5\text{ V}\le t\le 9\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(2)\frac{d}{dt}\left(\frac{5\times10^{-3}t}{10^{-3}}-40\times10^{-3}\right)\\&=(2)(5)\\&=10\text{ V}\end{aligned}$$

Substitute 2 H for L to calculate the inductor voltage in the interval $9\text{ ms}\le t\le 12\text{ ms}$.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\&=(2)\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{3\times10^{-3}}+20\times10^{-3}\right)\\&=(2)\left(\frac{-5}{3}\right)\\&=-3.33\text{ V}\end{aligned}$$

Step 3 of 4

Between the interval, $2\text{ ms}\le t\le 6\text{ ms}$, average voltage is -2.5 V, which can be write as a full cycle, the waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 4 of 4

Write the expression for the energy stored in the magnetic field of the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

From the Figure E6.8, at $t=3\text{ ms}$, the current through the inductor is -6.25 mA.

Substitute 2 H for L and -6.25 mA for i to calculate the energy stored in the inductor.

$$\begin{aligned}w_L(t)&=\frac{1}{2}Li^2(t)\\&=\frac{1}{2}(2)\left(-6.25\times10^{-3}\right)^2\\&=39\,\mu\text{J}\end{aligned}$$

Therefore, the energy stored in the inductor at $t=3\text{ ms}$ is, $\boxed{39\,\mu\text{J}}$.

From the Figure E6.8, at $t=2\text{ ms}$, the current through the inductor is -5 mA.

Substitute 2 H for L and -5 mA for i to calculate the energy stored in the inductor.

$$\begin{aligned}w_L(t)&=\frac{1}{2}Li^2(t)\\&=\frac{1}{2}(2)\left(-5\times10^{-3}\right)^2\\&=25\,\mu\text{J}\end{aligned}$$

Therefore, the energy stored in the inductor at $t=2\text{ ms}$ is, $\boxed{25\,\mu\text{J}}$.

Step 1 of 4

6.008P

Refer to Figure P6.11 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(5,10)$ is as follows.

$$\frac{y-0}{10-0}=\frac{x-0}{5-0}$$
$$y=2x$$

The equation for the voltage waveform between the points $(5,10)$ and $(10,5)$ is as follows.

$$\frac{y-10}{5-10}=\frac{x-5}{10-5}$$
$$y-10=\frac{-5(x-5)}{5}$$
$$y=-x+15$$

The equation for the voltage waveform between the points $(10,5)$ and $(15,5)$ is as follows.

$$\frac{y-5}{5-5}=\frac{x-10}{15-10}$$
$$y=5$$

The equation for the voltage waveform between the points $(15,5)$ and $(20,0)$ is as follows.

$$\frac{y-5}{0-5}=\frac{x-15}{20-15}$$
$$y-5=\frac{-5(x-15)}{5}$$
$$=-x+15$$
$$y=-x+20$$

Here, the planes $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveforms in the specific time intervals are as follows.

$$\begin{aligned} v(t) &= \frac{2t}{10^{-3}} && 0\le t\le 5\,\text{ms} \\ &= \frac{-t}{10^{-3}}+15 && 5\,\text{ms}\le t\le 10\,\text{ms} \\ &= 5 && 10\,\text{ms}\le t\le 15\,\text{ms} \\ &= \frac{-x}{10^{-3}}+20 && 15\,\text{ms}\le t\le 20\,\text{ms} \end{aligned}$$

Step 2 of 4

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 5\,\text{ms}$ by substituting $100\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(100\times10^{-6}\right)\frac{d}{dt}\left(\frac{2t}{10^{-3}}\right) && 0\le t\le 5\,\text{ms} \\ &= \left(100\times10^{-6}\right)\left(2\times10^{3}\right) && 0\le t\le 5\,\text{ms} \\ &= 200\,\text{mA} \end{aligned}$$

Calculate the capacitor current for interval $5\,\text{ms}\le t\le 10\,\text{ms}$ by substituting $100\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(100\times10^{-6}\right)\frac{d}{dt}\left(\frac{-t}{10^{-3}}+15\right) && 5\,\text{ms}\le t\le 10\,\text{ms} \\ &= \left(100\times10^{-6}\right)\left(-1\times10^{3}\right) && 5\,\text{ms}\le t\le 10\,\text{ms} \\ &= -100\,\text{mA} \end{aligned}$$

Calculate capacitor current for the interval $10\,\text{ms}\le t\le 15\,\text{ms}$ by substituting $100\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(100\times10^{-6}\right)\frac{d}{dt}(5) && 10\,\text{ms}\le t\le 15\,\text{ms} \\ &= \left(100\times10^{-6}\right)(0) && 10\,\text{ms}\le t\le 15\,\text{ms} \\ &= 0\,\text{mA} \end{aligned}$$

Step 3 of 4

Calculate the capacitor current for the interval $15\,\text{ms}\le t\le 20\,\text{ms}$ by substituting $100\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(100\times10^{-6}\right)\frac{d}{dt}\left(\frac{-t}{10^{-3}}+20\right) && 15\,\text{ms}\le t\le 20\,\text{ms} \\ &= \left(100\times10^{-6}\right)\left(-1\times10^{3}\right) && 15\,\text{ms}\le t\le 20\,\text{ms} \\ &= -100\,\text{mA} \end{aligned}$$

Step 4 of 4

The required waveform for the capacitor current is shown in Figure 1.

Figure 1

Step 1 of 5

6.009E

Refer to Figure E6.9 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows:

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(2,10)$ is as follows:

$$\frac{y-0}{10-0}=\frac{x-0}{2-0}$$
$$y=5x$$

The equation for the current waveform between the points $(2,-5)$ and $(4,-5)$ is as follows:

$$\frac{y-(-5)}{-5-(-5)}=\frac{x-2}{4-2}$$
$$y=-5$$

The equation for the current waveform between the points $(4,-10)$ and $(6,-10)$ is as follows:

$$\frac{y-(-10)}{-10-(-10)}=\frac{x-4}{6-4}$$
$$y=-10$$

The equation for the current waveform between the points $(6,-5)$ and $(9,-5)$ is as follows:

$$\frac{y-(-5)}{-5-(-5)}=\frac{x-6}{9-6}$$
$$y=-5$$

Here, the planes $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveform in the specific time intervals are as follows:

$$v(t)=\begin{cases}\dfrac{5t}{10^{-3}} & 0\le t\le 2\,\text{ms}\\ -5 & 2\le t\le 4\,\text{ms}\\ -10 & 4\le t\le 6\,\text{ms}\\ -5 & 6\le t\le 9\,\text{ms}\end{cases}$$

Step 2 of 5

Write the expression for the current through the inductor.

$$i(t)=i(0)+\frac{1}{L}\int_{t_0}^{t}v(t)\,dt$$

Calculate the current in the inductor for the interval $0\le t\le 2\,\text{ms}$ by substituting $0.1\,\text{A}$ for $i(0)$ and $0.1\,\text{H}$ for L.

$$\begin{aligned}i(t)&=i(0)+\frac{1}{L}\int_{t_0}^{t}v(t)\,dt\\&=0.1+\frac{1}{0.1}\int_0^{2\,\text{ms}}\frac{5t}{10^{-3}}\,dt\\&=0.1+\left(\frac{5\times10^3}{0.1}\right)\frac{t^2}{2}\Bigg|_0^{2\,\text{ms}}\\&=0.1+\frac{5\times10^3}{2\times0.1}\left(4\times10^{-6}\right)\\&=0.2\,\text{A}\end{aligned}$$

Calculate the inductor voltage for the interval $2\,\text{ms}\le t\le 4\,\text{ms}$ by substituting $0.2\,\text{A}$ for $i(0)$ and $0.1\,\text{H}$ for L.

$$\begin{aligned}i(t)&=i(0)+\frac{1}{L}\int_{t_0}^{t}v(t)\,dt\\&=0.2+\frac{1}{0.1}\int_{2\,\text{ms}}^{4\,\text{ms}}(-5)\,dt\\&=0.2+\left(\frac{-5}{0.1}\right)t\Big|_{2\,\text{ms}}^{4\,\text{ms}}\\&=0.2+\frac{-5}{0.1}\left(4\times10^{-3}-2\times10^{-3}\right)\\&=0.1\,\text{A}\end{aligned}$$

Calculate the inductor voltage for the interval $4\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $0.1\,\text{A}$ for $i(0)$ and $0.1\,\text{H}$ for L.

$$\begin{aligned}i(t)&=i(0)+\frac{1}{L}\int_{t_0}^{t}v(t)\,dt\\&=0.1+\frac{1}{0.1}\int_{4\,\text{ms}}^{6\,\text{ms}}(-10)\,dt\\&=0.1+\left(\frac{-10}{0.1}\right)t\Big|_{4\,\text{ms}}^{6\,\text{ms}}\\&=0.1+\frac{-10}{0.1}\left(6\times10^{-3}-4\times10^{-3}\right)\\&=-0.1\,\text{A}\end{aligned}$$

Step 3 of 5

Calculate the inductor voltage for the interval $6\,\text{ms}\le t\le 9\,\text{ms}$ by substituting $-0.1\,\text{A}$ for $i(0)$ and $0.1\,\text{H}$ for L.

$$\begin{aligned}i(t)&=i(0)+\frac{1}{L}\int_{t_0}^{t}v(t)\,dt\\&=-0.1+\frac{1}{0.1}\int_{6\,\text{ms}}^{9\,\text{ms}}(-5)\,dt\\&=-0.1+\left(\frac{-5}{0.1}\right)t\Big|_{6\,\text{ms}}^{49\,\text{ms}}\\&=-0.1+\frac{-5}{0.1}\left(9\times10^{-3}-6\times10^{-3}\right)\\&=-0.25\,\text{A}\end{aligned}$$

Step 4 of 5

The waveform for the inductor current is shown in Figure 1.

Figure 1

Step 5 of 5

Write the expression for the energy stored in the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

From the Figure 1, at $t=7\,\text{ms}$, the current through the inductor is $-0.15\,\text{A}$.

Calculate the energy stored in the inductor by substituting $0.1\,\text{H}$ for L and $-0.75\,\text{mA}$ for i.

$$\begin{aligned}w_L(t)&=\frac{1}{2}Li^2(t)\\&=\frac{1}{2}(0.1)(-0.15)^2\\&=1.125\,\text{mJ}\end{aligned}$$

Therefore, the energy stored in the inductor at $t=7\,\text{ms}$ is $\boxed{1.125\ \text{mJ}}$.

Step 1 of 4

6.009P

Refer to Figure P6.14 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(0.2,20)$ is as follows.

$$\frac{y-0}{20-0}=\frac{x-0}{0.2-0}$$
$$y=100x$$

The equation for the voltage waveform between the points $(0.2,20)$ and $(0.4,20)$ is as follows.

$$\frac{y-20}{20-20}=\frac{x-0.2}{0.4-0.2}$$
$$y=20$$

The equation for the voltage waveform between the points $(0.4,20)$ and $(0.8,-20)$ is as follows.

$$\frac{y-20}{-20-20}=\frac{x-0.4}{0.8-0.4}$$
$$y-20=\frac{-40(x-0.2)}{0.4}$$
$$=-100x+20$$
$$y=-100x+40$$

The equation for the voltage waveform between the points $(0.8,-20)$ and $(1.0,-20)$ is as follows.

$$\frac{y-(-20)}{-20-(-20)}=\frac{x-0.8}{1.0-0.8}$$
$$y=-20$$

The equation for the voltage waveform between the points $(1,-20)$ and $(1.2,0)$ is as follows.

$$\frac{y-(-20)}{0-(-20)}=\frac{x-1.0}{1.2-1.0}$$
$$y+20=\frac{20(x-1.0)}{0.2}$$
$$=100x-100$$
$$y=100x-120$$

Here, the planes $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveforms in the specific time intervals are as follows.

$$\begin{aligned}
v(t)&=\frac{100t}{10^{-3}} && 0\le t\le 0.2\,\text{ms}\\
&=20 && 0.2\,\text{ms}\le t\le 0.4\,\text{ms}\\
&=\frac{-100t}{10^{-3}}+40 && 0.4\,\text{ms}\le t\le 0.8\,\text{ms}\\
&=-20 && 0.8\,\text{ms}\le t\le 1.0\,\text{ms}\\
&=\frac{100t}{10^{-3}}-120 && 1.0\,\text{ms}\le t\le 1.2\,\text{ms}
\end{aligned}$$

Step 2 of 4

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 0.2\,\text{ms}$ by substituting $25\,\mu\text{F}$ for C.

$$\begin{aligned}
i(t)&=C\frac{dv(t)}{dt}\\
&=\left(25\times10^{-6}\right)\frac{d}{dt}\left(\frac{100t}{10^{-3}}\right) && 0\le t\le 0.2\,\text{ms}\\
&=\left(25\times10^{-6}\right)\left(100\times10^{3}\right) && 0\le t\le 0.2\,\text{ms}\\
&=2.5\,\text{A}
\end{aligned}$$

Calculate the capacitor current for interval $0.2\,\text{ms}\le t\le 0.4\,\text{ms}$ by substituting $25\,\mu\text{F}$ for C.

$$\begin{aligned}
i(t)&=C\frac{dv(t)}{dt}\\
&=\left(25\times10^{-6}\right)\frac{d}{dt}(20) && 0.2\,\text{ms}\le t\le 0.4\,\text{ms}\\
&=\left(25\times10^{-6}\right)(0) && 0.2\,\text{ms}\le t\le 0.4\,\text{ms}\\
&=0
\end{aligned}$$

Step 3 of 4

Calculate capacitor current for the interval $0.4\,\text{ms}\le t\le 0.8\,\text{ms}$ by substituting $25\,\mu\text{F}$ for C.

$$\begin{aligned}
i(t)&=C\frac{dv(t)}{dt}\\
&=\left(25\times10^{-6}\right)\frac{d}{dt}\left(\frac{-100t}{10^{-3}}+40\right) && 0.4\,\text{ms}\le t\le 0.8\,\text{ms}\\
&=\left(25\times10^{-6}\right)\left(-100\times10^{3}\right) && 0.4\,\text{ms}\le t\le 0.8\,\text{ms}\\
&=-2.5\,\text{A}
\end{aligned}$$

Calculate the capacitor current for the interval $0.8\,\text{ms}\le t\le 1.0\,\text{ms}$ by substituting $25\,\mu\text{F}$ for C.

$$\begin{aligned}
i(t)&=C\frac{dv(t)}{dt}\\
&=\left(25\times10^{-6}\right)\frac{d}{dt}(-20) && 0.8\,\text{ms}\le t\le 1.0\,\text{ms}\\
&=\left(25\times10^{-6}\right)(0) && 0.8\,\text{ms}\le t\le 1.0\,\text{ms}\\
&=0
\end{aligned}$$

Calculate the capacitor current for the interval $1.0\,\text{ms}\le t\le 1.2\,\text{ms}$ by substituting $25\,\mu\text{F}$ for C.

$$\begin{aligned}
i(t)&=C\frac{dv(t)}{dt}\\
&=\left(25\times10^{-6}\right)\frac{d}{dt}\left(\frac{100t}{10^{-3}}-120\right) && 1.0\,\text{ms}\le t\le 1.2\,\text{ms}\\
&=\left(25\times10^{-6}\right)\left(100\times10^{3}\right) && 1.0\,\text{ms}\le t\le 1.2\,\text{ms}\\
&=2.5\,\text{A}
\end{aligned}$$

Step 4 of 4

The required waveform for the capacitor current is shown in Figure 1.

Figure 1

Step 1 of 5

Refer to Figure E6.10 in the textbook.

The circuit has only dc sources, replace the capacitor with open circuits and the inductors with short circuits.

Figure 1

Step 2 of 5

Use source transformation and redraw the circuit.

Figure 2

Step 3 of 5

The resistors $6\,\text{k}\Omega$ and $2\,\text{k}\Omega$ are in parallel. The equivalent resistance is,

$$\frac{(6\,\text{k}\Omega)(2\,\text{k}\Omega)}{6\,\text{k}\Omega+2\,\text{k}\Omega}=1.5\,\text{k}\Omega$$

Use the source transformation again and redraw the circuit.

Figure 3

Step 4 of 5

The node voltage, V_1 in the circuit of Figure 3 is,

$$-24+(3)(2)+V_1=0$$
$$V_1=18\,\text{V}$$

The node voltage, V_2 in the circuit of Figure 3 is,

$$-3-(1.5)(2)+V_2=0$$
$$V_2=6\,\text{V}$$

The voltage across the capacitor is,

$$V_C=V_1-V_2$$

Substitute 18 V for V_1 and 6 V for V_2 to calculate the capacitor voltage.

$$\begin{aligned}V_C&=V_1-V_2\\&=18-6\\&=12\text{ V}\end{aligned}$$

Write the expression for the energy stored in the capacitor.

$$w_C(t)=\frac{1}{2}Cv^2(t)$$

Substitute 10 nF for C and 12 V for v to calculate the energy stored in the capacitor.

$$\begin{aligned}w_C(t)&=\frac{1}{2}Cv^2(t)\\&=\frac{1}{2}(10\times10^{-9})(12)^2\\&=0.72\,\mu\text{J}\end{aligned}$$

Therefore, the energy stored in the capacitor is $\boxed{0.72\ \mu\text{J}}$.

Step 5 of 5

Use current division in the circuit of Figure 2 to find the current flow through the inductor.

$$I_L=\frac{R_2}{R_1+R_2}(I)$$

Here,

$$\begin{aligned}I&=2\text{ mA}+2\text{ mA}\\&=4\text{ mA}\end{aligned}$$

Substitute 4 mA for I, $6\,\text{k}\Omega$ for R_1, and $2\,\text{k}\Omega$ for R_2 to calculate the inductor current.

$$\begin{aligned}I_L&=\frac{R_2}{R_1+R_2}(I)\\&=\frac{2}{6+2}(4)\\&=1\text{ mA}\end{aligned}$$

Write the expression for the energy stored in the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

Substitute 1H for L and 1 mA for i to calculate the energy stored in the inductor.

$$\begin{aligned}w_L(t)&=\frac{1}{2}Li^2(t)\\&=\frac{1}{2}(1)(1\times10^{-3})^2\\&=0.5\ \mu\text{J}\end{aligned}$$

Therefore, the energy stored in the inductor is, $\boxed{0.5\ \mu\text{J}}$.

Step 1 of 4

Refer to Figure P6.15 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(20,12)$ is as follows.

$$\frac{y-0}{12-0}=\frac{x-0}{20-0}$$
$$y=0.6x$$

Step 2 of 4

The equation for the voltage waveform between the points $(20,12)$ and $(30,-12)$ is as follows.

$$\frac{y-12}{-12-12}=\frac{x-20}{30-20}$$
$$y-12=\frac{-24(x-20)}{10}$$
$$=-2.4x+48$$
$$y=-2.4x+60$$

The equation for the voltage waveform between the points $(30,-12)$ and $(50,0)$ is as follows.

$$\frac{y-(-12)}{0-(-12)}=\frac{x-30}{50-30}$$
$$y+12=\frac{12(x-30)}{20}$$
$$=0.6x-18$$
$$y=0.6x-30$$

Here, the planes $y=v$ and $x=t$, the equations for the waveforms in the specific time intervals are as follows.

$$v(t)=0.6t \qquad 0\le t\le 20\text{s}$$
$$=-2.4t+60 \qquad 20\text{s}\le t\le 30\text{s}$$
$$=0.6t-30 \qquad 30\text{s}\le t\le 50\text{s}$$

Step 3 of 4

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 20\text{s}$ by substituting 2F for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(0.6t) \quad 0\le t\le 20\text{s}$$
$$=(2)(0.6) \qquad 0\le t\le 20\text{s}$$
$$=1.2\text{A}$$

Calculate the capacitor current for interval $20\text{s}\le t\le 30\text{s}$ by substituting 2F for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(-2.4t+60) \quad 20\text{s}\le t\le 30\text{s}$$
$$=(2)(-2.4) \qquad 20\text{s}\le t\le 30\text{s}$$
$$=-4.8\text{A}$$

Calculate capacitor current for the interval $30\text{s}\le t\le 50\text{s}$ by substituting 2F for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(0.6t-30) \quad 30\text{s}\le t\le 50\text{s}$$
$$=(2)(0.6) \qquad 30\text{s}\le t\le 50\text{s}$$
$$=1.2\text{A}$$

Step 4 of 4

The required waveform for the capacitor current is shown in Figure 1.

Figure 1

Step 1 of 4

Refer to Figure P6.15 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(20,12)$ is as follows.

$$\frac{y-0}{12-0}=\frac{x-0}{20-0}$$
$$y=0.6x$$

Step 2 of 4

The equation for the voltage waveform between the points $(20,12)$ and $(30,-12)$ is as follows.

$$\frac{y-12}{-12-12}=\frac{x-20}{30-20}$$
$$y-12=\frac{-24(x-20)}{10}$$
$$=-2.4x+48$$
$$y=-2.4x+60$$

The equation for the voltage waveform between the points $(30,-12)$ and $(50,0)$ is as follows.

$$\frac{y-(-12)}{0-(-12)}=\frac{x-30}{50-30}$$
$$y+12=\frac{12(x-30)}{20}$$
$$=0.6x-18$$
$$y=0.6x-30$$

Here, the planes $y=v$ and $x=t$, the equations for the waveforms in the specific time intervals are as follows.

$$v(t)=0.6t \qquad 0\le t\le 20\text{s}$$
$$=-2.4t+60 \qquad 20\text{s}\le t\le 30\text{s}$$
$$=0.6t-30 \qquad 30\text{s}\le t\le 50\text{s}$$

Step 3 of 4

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 20\text{s}$ by substituting $2\,\text{F}$ for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(0.6t) \quad 0\le t\le 20\text{s}$$
$$=(2)(0.6) \qquad 0\le t\le 20\text{s}$$
$$=1.2\,\text{A}$$

Calculate the capacitor current for interval $20\text{s}\le t\le 30\text{s}$ by substituting $2\,\text{F}$ for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(-2.4t+60) \quad 20\text{s}\le t\le 30\text{s}$$
$$=(2)(-2.4) \qquad 20\text{s}\le t\le 30\text{s}$$
$$=-4.8\,\text{A}$$

Calculate capacitor current for the interval $30\text{s}\le t\le 50\text{s}$ by substituting $2\,\text{F}$ for C.

$$i(t)=C\frac{dv(t)}{dt}$$
$$=(2)\frac{d}{dt}(0.6t-30) \quad 30\text{s}\le t\le 50\text{s}$$
$$=(2)(0.6) \qquad 30\text{s}\le t\le 50\text{s}$$
$$=1.2\,\text{A}$$

Step 4 of 4

The required waveform for the capacitor current is shown in Figure 1.

Figure 1

Step 1 of 3

Refer to Figure P6.16 in the text book for the waveform of the voltage across a capacitor.

The equation of the straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is,

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the voltage waveform between the points $(0,0)$ and $(2,-12)$ is as follows:

$$\frac{y-0}{-12-0}=\frac{x-0}{2-0}$$
$$y=-6x$$

The equation for the voltage waveform between the points $(2,-12)$ and $(3,-12)$ is as follows.

$$\frac{y-(-12)}{-12-(-12)}=\frac{x-2}{3-2}$$
$$y=-12$$

The equation for the voltage waveform between the points $(3,-12)$ and $(6,0)$ is as follows.

$$\frac{y-(-12)}{0-(-12)}=\frac{x-3}{6-3}$$
$$y+12=\frac{12(x-3)}{3}$$
$$=4x-12$$
$$y=4x-24$$

Here, the planes $y=v$ and $x=t$ and since the time is in milliseconds, the equations for the waveforms in the specific time intervals are as follows.

$$\begin{aligned} v(t) &= \frac{-6t}{10^{-3}} && 0\le t\le 2\,\text{ms} \\ &= -12 && 2\,\text{ms}\le t\le 3\,\text{ms} \\ &= \frac{4t}{10^{-3}}-24 && 3\,\text{ms}\le t\le 6\,\text{ms} \end{aligned}$$

Step 2 of 3

Write the expression for the current through the capacitor.

$$i(t)=C\frac{dv(t)}{dt}$$

Calculate the capacitor current for the interval $0\le t\le 2\,\text{ms}$ by substituting $2\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(2\times10^{-6}\right)\frac{d}{dt}\left(\frac{-6t}{10^{-3}}\right) && 0\le t\le 2\,\text{ms} \\ &= \left(2\times10^{-6}\right)\left(-6\times10^{3}\right) && 0\le t\le 2\,\text{ms} \\ &= -12\,\text{mA} \end{aligned}$$

Calculate the capacitor current for interval $2\,\text{ms}\le t\le 3\,\text{ms}$ by substituting $2\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(2\times10^{-6}\right)\frac{d}{dt}(-12) && 2\,\text{ms}\le t\le 3\,\text{ms} \\ &= \left(2\times10^{-6}\right)(0) && 2\,\text{ms}\le t\le 3\,\text{ms} \\ &= 0 \end{aligned}$$

Calculate capacitor current for the interval $3\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $2\,\mu\text{F}$ for C.

$$\begin{aligned} i(t) &= C\frac{dv(t)}{dt} \\ &= \left(2\times10^{-6}\right)\frac{d}{dt}\left(\frac{-4t}{10^{-3}}-24\right) && 3\,\text{ms}\le t\le 6\,\text{ms} \\ &= \left(2\times10^{-6}\right)\left(-4\times10^{3}\right) && 3\,\text{ms}\le t\le 6\,\text{ms} \\ &= -8\,\text{mA} \end{aligned}$$

Step 3 of 3

Draw the waveform of the capacitor current.

Thus, the current waveform of the capacitor is drawn.

Step 1 of 3

Refer to Figure E6.12 in the text book.

When *N* numbers of capacitors are connected in parallel, the equivalent capacitance can be writing as follows.

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, the equivalent capacitance can be writing as follows.

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $2\mu F$ and $4\mu F$ are in parallel, their equivalent capacitance is as follows.

$$\begin{aligned} C_{2,4} &= C_2 + C_4 \\ &= 2 + 4 \\ &= 6\mu F \end{aligned}$$

This $6\mu F$ and $3\mu F$ are in series, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{6,3}} &= \frac{1}{6} + \frac{1}{3} \\ &= \frac{1}{2} \\ C_{6,3} &= 2\mu F \end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The capacitors $2\mu F$ and $2\mu F$ are in parallel, their equivalent capacitance is as follows.

$$\begin{aligned} C_{2,2} &= C_2 + C_2 \\ &= 2 + 2 \\ &= 4\mu F \end{aligned}$$

This $4\mu F$ and $3\mu F$ and $12\mu F$ are in series, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{eq}} &= \frac{1}{3} + \frac{1}{4} + \frac{1}{12} \\ &= \frac{4+3+1}{12} \\ C_{eq} &= \frac{12}{8} \\ &= 1.5\mu F \end{aligned}$$

Therefore, the equivalent capacitance C_{eq} is $\boxed{1.5\mu F}$.

Step 1 of 7

Refer to Figure E6.13 in the text book.

When N numbers of capacitors are connected in parallel, the equivalent capacitance can be writing as follows:

$$C_p = C_1 + C_2 + ... + C_N$$

When N numbers of capacitors are connected in series, the equivalent capacitance can be writing as follows:

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $6\mu F, 6\mu F \text{ and } 6\mu F$ are in parallel, their equivalent capacitance is as follows:

$$\begin{aligned} C_{6,6,6} &= C_6 + C_6 + C_6 \\ &= 6 + 6 + 6 \\ &= 18\mu F \end{aligned}$$

This $18\mu F$ and $2\mu F$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned} \frac{1}{C_{18,2}} &= \frac{1}{18} + \frac{1}{2} \\ &= \frac{1+9}{18} \\ C_{18,2} &= \frac{18}{10} \\ &= 1.8\mu F \end{aligned}$$

Step 2 of 7

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 7

The capacitors $4\mu F \text{ and } 1.8\mu F$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned} \frac{1}{C_{4,1.8}} &= \frac{1}{4} + \frac{1}{1.8} \\ &= \frac{1.8+4}{7.2} \\ C_{4,1.8} &= \frac{7.2}{5.8} \\ &= 1.241\mu F \end{aligned}$$

This $1.24\mu F$ is in parallel with $8\mu F$ capacitor, their equivalent capacitance is as follows:

$$\begin{aligned} C_{1.24,8} &= C_{1.24} + C_8 \\ &= 1.24 + 8 \\ &= 9.24\mu F \end{aligned}$$

Step 4 of 7

The modified circuit is shown in Figure 2.

Figure 2

Step 5 of 7

The capacitors $9.24\mu F \text{ and } 10\mu F$ are in series, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{9.24,10}} &= \frac{1}{9.24} + \frac{1}{10} \\ &= \frac{10+9.24}{92.4} \\ C_{9.24,10} &= \frac{92.4}{19.24} \\ &= 4.8\mu F \end{aligned}$$

Step 6 of 7

This $4.8\mu F$ is in parallel with $5\mu F$ capacitor, their equivalent capacitance is as follows.

$$\begin{aligned} C_{4.8,5} &= C_{4.8} + C_5 \\ &= 4.8 + 5 \\ &= 9.8\mu F \end{aligned}$$

Then the modified circuit is shown in Figure 3.

Figure 3

Step 7 of 7

The capacitors $6\mu F, 9.8\mu F \text{ and } 3\mu F$ are in series, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_T} &= \frac{1}{9.8} + \frac{1}{6} + \frac{1}{3} \\ &= \frac{18+29.4+58.8}{(9.8)(6)(3)} \\ C_T &= \frac{176.4}{106.2} \\ &= 1.667\mu F \end{aligned}$$

Therefore, the equivalent capacitance C_T is $\boxed{1.667\mu F}$.

Step 1 of 3

Refer to Figure P6.19 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(40,10)$ is as follows.

$$\frac{y-0}{10-0}=\frac{x-0}{40-0}$$
$$y=0.25x$$

Here, the planes $y=i$ and $x=t$ and since the time and current are in milliseconds, the equations for the waveforms in the specific time intervals are as follows.

$$i(t)=0.25t \qquad 0\le t\le 40\,\text{ms}$$

Step 2 of 3

Write the expression for the voltage across the capacitor.

$$v(t)=\frac{1}{C}\int_0^t i(t)\,dt$$

Calculate the voltage across the capacitor by substituting $50\,\mu\text{F}$ for C.

$$\begin{aligned}v(t)&=\frac{1}{C}\int_0^t i(t)\,dt\\&=\frac{1}{50\times10^{-6}}\int_0^{40\text{ms}}(0.25)t\,dt\\&=\frac{0.25}{50\times10^{-6}}\left(\frac{t^2}{2}\right)_0^{40\text{ms}}\\&=\frac{0.25}{2\times50\times10^{-6}}\left(40\times10^{-3}-0\right)^2\\&=4\,\text{V}\end{aligned}$$

Step 3 of 3

The required waveform for the voltage across the capacitor is shown in Figure 1.

Figure 1

Step 1 of 5

Refer to Figure E6.14 in the text book.

Draw the circuit with the inductor numbers.

Figure 1

Step 2 of 5

Write the expression for the equivalent inductance of N number of inductors that are connected in series.

$$L_S = L_1 + L_2 + \cdots + L_N$$

Write the expression for the equivalent inductance of N number of inductors that are connected in parallel.

$$\frac{1}{L_P} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}$$

Consider that all the inductors values in the circuit are 6 mH.

The inductors 1 and 2 are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{12}} &= \frac{1}{L_1} + \frac{1}{L_2} \\ &= \frac{1}{6\text{ mH}} + \frac{1}{6\text{ mH}} \\ &= \frac{2}{6\text{ mH}}\end{aligned}$$

Therefore,

$$\begin{aligned}L_{12} &= \frac{6\text{ mH}}{2} \\ &= 3\text{ mH}\end{aligned}$$

The resultant 3 mH and inductor 3 are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{123}} &= \frac{1}{L_{12}} + \frac{1}{L_3} \\ &= \frac{1}{3\text{ mH}} + \frac{1}{6\text{ mH}} \\ &= \frac{2+1}{6\text{ mH}}\end{aligned}$$

Therefore,

$$\begin{aligned}L_{123} &= \frac{6\text{ mH}}{3} \\ &= 2\text{ mH}\end{aligned}$$

Step 3 of 5

Draw the modified circuit.

Figure 2

Step 4 of 5

The resultant 2 mH and inductor 5 are in series. Calculate their equivalent inductance.

$$\begin{aligned}L_{1235} &= L_{123} + L_5 \\ &= 2\text{ mH} + 6\text{ mH} \\ &= 8\text{ mH}\end{aligned}$$

The resultant 8 mH and inductor 6 are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{12356}} &= \frac{1}{L_{1235}} + \frac{1}{L_6} \\ &= \frac{1}{8\text{ mH}} + \frac{1}{6\text{ mH}} \\ &= \frac{3+4}{24\text{ mH}}\end{aligned}$$

Therefore,

$$\begin{aligned}L_{12356} &= \frac{24\text{ mH}}{7} \\ &= 3.4285\text{ mH}\end{aligned}$$

Step 5 of 5

Draw the modified circuit.

Figure 3

The resultant 3.4285 mH and inductor 4 are in series. Calculate their equivalent inductance.

$$\begin{aligned}L_{eq} &= L_{12356} + L_4 \\ &= 3.4285\text{ mH} + 6\text{ mH} \\ &= 9.4285\text{ mH}\end{aligned}$$

Therefore, the equivalent inductance, L_{eq} is $\boxed{9.4285\text{ mH}}$.

Step 1 of 6

The given circuit is,

Step 2 of 6

The current flowing through the capacitor is,

Step 3 of 6

It is given that,
Capacitance, $C = 10\mu F$
Voltage, $v_c(0) = 1V$

The voltage across a capacitor is given by,

$$v_c(t) = \frac{1}{C}\int_0^t i(x)dx + v_c(0)$$

Now at t = 1ms,

$$v_c(t) = \frac{1}{10\times10^{-6}}\int_0^t 15\times10^{-3}dx + v_c(0)$$

$$v_c(t) = \frac{15\times10^{-3}}{10\times10^{-6}}(t-0)+1$$

$$v_c(t) = 1500t+1$$

The voltage, $v_c(t)$ at $t = 1ms$ is,

$$v_c(1ms) = 1500(1\times10^{-3})+1$$

$$v_c(1ms) = 1.5+1$$

$$v_c(1ms) = 2.5V$$

Thus the voltage, $v_c(t)$ at $t = 1ms$ is $\boxed{2.5V}$

Step 4 of 6

Now at $t = 3ms$,

$$v_c(t) = \frac{1}{10\times10^{-6}}\int_{1m}^t 15\times10^{-3}dx + v_c(1ms)$$

$$v_c(t) = \frac{15\times10^{-3}}{10\times10^{-6}}(t-1\times10^{-3})+2.5$$

$$v_c(t) = 1500t-1.5+2.5$$

$$v_c(t) = 1500t+1$$

The voltage, $v_c(t)$ at $t = 3ms$ is,

$$v_c(3ms) = 1500(3\times10^{-3})+1$$

$$v_c(3ms) = 4.5+1$$

$$v_c(3ms) = 5.5V$$

Thus the voltage, $v_c(t)$ at $t = 3ms$ is $\boxed{5.5V}$

Step 5 of 6

Now at $t = 4ms$,

$$v_c(t) = \frac{1}{10\times10^{-6}}\int_{3m}^t (-10\times10^{-3})dx + v_c(3ms)$$

$$v_c(t) = \frac{-10\times10^{-3}}{10\times10^{-6}}(t-3\times10^{-3})+5.5$$

$$v_c(t) = -1000t+8.5$$

The voltage, $v_c(t)$ at $t = 4ms$ is,

$$v_c(4ms) = -1000(4\times10^{-3})+8.5$$

$$v_c(4ms) = -4+8.5$$

$$v_c(4ms) = 4.5V$$

Thus the voltage, $v_c(t)$ at $t = 4ms$ is $\boxed{4.5V}$

Step 6 of 6

Now at $t = 5ms$,

$$v_c(t) = \frac{1}{10\times10^{-6}}\int_{4m}^t (-10\times10^{-3})dx + v_c(4ms)$$

$$v_c(t) = \frac{-10\times10^{-3}}{10\times10^{-6}}(t-4\times10^{-3})+4.5$$

$$v_c(t) = -1000t+8.5$$

The voltage, $v_c(t)$ at $t = 5ms$ is,

$$v_c(5ms) = -1000(5\times10^{-3})+8.5$$

$$v_c(5ms) = -5+8.5$$

$$v_c(5ms) = 3.5V$$

Thus the voltage, $v_c(t)$ at $t = 1ms$ is $\boxed{3.5V}$

Step 1 of 6

Refer to Figure E6.15 in the text book.

When *N* numbers of inductors are connected in parallel, the equivalent inductance can be writing as follows:

$$\frac{1}{L_P}=\frac{1}{L_1}+\frac{1}{L_2}+....+\frac{1}{L_N}$$

When *N* numbers of inductor are connected in series, the equivalent inductors can be writing as follows:

$$L_S=L_1+L_2+....+L_N$$

The left side three $2\,\text{mH}$ inductors are in series, their equivalent inductance is as follows:

$$\begin{aligned}L_{2,2,2}&=L_2+L_2+L_2\\&=2+2+2\\&=6\,\text{mH}\end{aligned}$$

Step 2 of 6

This $6\,\text{mH}$ is in parallel with $6\,\text{mH}$ inductor, their equivalent inductance is as follows:

$$\begin{aligned}\frac{1}{L_{6,6}}&=\frac{1}{6}+\frac{1}{6}\\&=\frac{1+1}{6}\\L_{6,6}&=\frac{6}{2}\\&=3\,\text{mH}\end{aligned}$$

In the right side, $12\,\text{mH and }4\,\text{mH}$ inductors are in parallel, their equivalent inductance is as follows:

$$\begin{aligned}\frac{1}{L_{12,4}}&=\frac{1}{12}+\frac{1}{4}\\&=\frac{1+3}{12}\\L_{12,4}&=\frac{12}{4}\\&=3\,\text{mH}\end{aligned}$$

Step 3 of 6

Then the modified circuit is shown in Figure 1.

Figure 1

Step 4 of 6

The inductors $4\,\text{mH},3\,\text{mH and }3\,\text{mH}$ are in series, their equivalent inductance is as follows:

$$\begin{aligned}L_{4,3,3}&=L_4+L_3+L_3\\&=4+3+3\\&=10\,\text{mH}\end{aligned}$$

The inductors $5\,\text{mH},3\,\text{mH and }2\,\text{mH}$ are in series, their equivalent inductance is as follows:

$$\begin{aligned}L_{5,3,2}&=L_5+L_3+L_2\\&=5+3+2\\&=10\,\text{mH}\end{aligned}$$

Step 5 of 6

The modified circuit is shown in Figure 2.

Figure 2

Step 6 of 6

The inductors $10\,\text{mH and }10\,\text{mH}$ are in parallel, their equivalent inductance is as follows:

$$\begin{aligned}\frac{1}{L_T}&=\frac{1}{10}+\frac{1}{10}\\L_T&=\frac{10}{2}\\&=5\,\text{mH}\end{aligned}$$

Therefore, the equivalent inductance L_T is $\boxed{5\,\text{mH}}$.

Step 1 of 4

Refer to Figure P6.20 in the text book.

The equations for the waveforms in the specific time intervals are as follows.

$$\begin{aligned} i(t) &= 10\times10^{-3} && 0 \le t \le 10\,\text{ms} \\ &= -10\times10^{-3} && 10\,\text{ms} \le t \le 20\,\text{ms} \\ &= 10\times10^{-3} && 20\,\text{ms} \le t \le 30\,\text{ms} \\ &= -10\times10^{-3} && 30\,\text{ms} \le t \le 40\,\text{ms} \\ &= 10\times10^{-3} && 40\,\text{ms} \le t \le 50\,\text{ms} \end{aligned}$$

Step 2 of 4

Write the expression for the voltage across the capacitor.

$$v(t) = \frac{1}{C}\int_0^t i(t)\,dt$$

Calculate the voltage across the capacitor for the interval $0 \le t \le 10\,\text{ms}$ by substituting $50\,\mu\text{F}$ for C and $10\,\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i(t)\,dt \\ &= \frac{1}{50\times10^{-6}}\int_0^{10\text{ms}} \left(10\times10^{-3}\right)dt \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}(t)_0^{10\text{ms}} \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}\left(10\times10^{-3}-0\right) \\ &= 2\,\text{V} \end{aligned}$$

Calculate the voltage across the capacitor for the interval $10\,\text{ms} \le t \le 20\,\text{ms}$ by substituting $50\,\mu\text{F}$ for C and $-10\,\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i(t)\,dt \\ &= \frac{1}{50\times10^{-6}}\int_{10\text{ms}}^{20\text{ms}} \left(-10\times10^{-3}\right)dt \\ &= \frac{-10\times10^{-3}}{50\times10^{-6}}(t)_{10\text{ms}}^{20\text{ms}} \\ &= \frac{-10\times10^{-3}}{50\times10^{-6}}\left(20\times10^{-3}-10\times10^{-3}\right) \\ &= -2\,\text{V} \end{aligned}$$

Step 3 of 4

Calculate the voltage across the capacitor for the interval $20\,\text{ms} \le t \le 30\,\text{ms}$ by substituting $50\,\mu\text{F}$ for C and $10\,\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i(t)\,dt \\ &= \frac{1}{50\times10^{-6}}\int_{20\text{ms}}^{30\text{ms}} \left(10\times10^{-3}\right)dt \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}(t)_{20\text{ms}}^{30\text{ms}} \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}\left(30\times10^{-3}-20\times10^{-3}\right) \\ &= 2\,\text{V} \end{aligned}$$

Calculate the voltage across the capacitor for the interval $30\,\text{ms} \le t \le 40\,\text{ms}$ by substituting $50\,\mu\text{F}$ for C and $-10\,\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i(t)\,dt \\ &= \frac{1}{50\times10^{-6}}\int_{30\text{ms}}^{40\text{ms}} \left(-10\times10^{-3}\right)dt \\ &= \frac{-10\times10^{-3}}{50\times10^{-6}}(t)_{30\text{ms}}^{40\text{ms}} \\ &= \frac{-10\times10^{-3}}{50\times10^{-6}}\left(40\times10^{-3}-30\times10^{-3}\right) \\ &= -2\,\text{V} \end{aligned}$$

Calculate the voltage across the capacitor for the interval $40\,\text{ms} \le t \le 50\,\text{ms}$ by substituting $50\,\mu\text{F}$ for C and $10\,\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= \frac{1}{C}\int_0^t i(t)\,dt \\ &= \frac{1}{50\times10^{-6}}\int_{40\text{ms}}^{50\text{ms}} \left(10\times10^{-3}\right)dt \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}(t)_{40\text{ms}}^{50\text{ms}} \\ &= \frac{10\times10^{-3}}{50\times10^{-6}}\left(50\times10^{-3}-40\times10^{-3}\right) \\ &= 2\,\text{V} \end{aligned}$$

Step 4 of 4

The required waveform for the voltage across the capacitor is shown in Figure 1.

Figure 1

Step 1 of 3

Consider Figure P6.18 from the text book.

Consider the expression for the voltage waveform.

$$\begin{aligned} v(t) &= 12\sin\frac{2\pi}{10\text{ m}}t \\ &= 12\sin 628.32t \end{aligned}$$

Therefore, the expression for the voltage is $12\sin 628.32t$.

Step 2 of 3

Consider the expression for the current through the capacitor.

$$i(t) = C\frac{dv(t)}{dt}$$

Substitute $12\sin 628.32t$ for $v(t)$ and $10\ \mu\text{F}$ for C .

$$\begin{aligned} i(t) &= (10\ \mu)\frac{d}{dt}(12\sin 628.32t) \\ &= (120\ \mu)\frac{d}{dt}(\sin 628.32t) \\ &= (120\ \mu)(628.32)\cdot\cos 628.32t \end{aligned}$$

$$i(t) = 75.4\cos 628.32t\ \text{mA} \quad \text{..... (1)}$$

Therefore, the expression for the current through the capacitor is $75.4\cos 628.32t\ \text{mA}$.

Step 3 of 3

Draw the current waveform using the expression (1).

Figure 1

Therefore, the required voltage waveform is shown in Figure 1.

Step 1 of 6

Step 2 of 6

First we find the voltage across the capacitor $V_C(t)$ at $t = 6S$

$$V_C = \frac{1}{C}\int i\,dt$$
$$= \frac{1}{C}\int_2^6 i\,dt + V(2s)$$
$$= \frac{1}{0.5}\int_2^6 2\,dt + 10$$
$$= 2\left[2t\right]_2^6 + 10$$
$$= 2\left[2t\right]_2^6 + 10$$
$$= 16 + 10$$
$$V_C(t) = 26\text{V}$$

Step 3 of 6

Therefore at 6s, $V_C(t) = 26\text{V}$

Hence, energy stored in the capacitor is

$$E = \frac{1}{2}CV_C^2$$
$$= \frac{1}{2}(0.5)(26)^2$$
$$\boxed{E = 169\text{J}}$$

Step 4 of 6

At $t = 6s$

Step 5 of 6

$$R_{eq} = \frac{3\times 6}{3+6}$$
$$= 2\Omega$$

Voltage across 2Ω, $V_{2\Omega} = 2\times 2$
$= 4\text{V}$

Step 6 of 6

Therefore voltage across the 2A source is

$$V_{2A} = 26 + 4$$
$$= 30\text{ V}$$

Hence power supplied is

$$P = V\,I$$
$$= (30)(2)$$
$$\boxed{P_{2A} = 60\text{ W}}$$

Step 1 of 2

(a)

Write the expression for the voltage across the inductor.

$$v(t) = L\frac{di(t)}{dt}$$

Calculate the voltage across the inductor by substituting $100\times10^{-3}\ \text{H}$ for L and $2\sin 377t$ for $i(t)$.

$$\begin{aligned} v(t) &= L\frac{di(t)}{dt} \\ &= \left(100\times10^{-3}\right)\frac{d}{dt}(2\sin 377t) \\ &= \left(100\times10^{-3}\right)(2)(377)(\cos 377t) \\ &= 75.4\cos 377t\ \text{V} \end{aligned}$$

Therefore, the voltage across the inductor is $\boxed{75.4\cos 377t\ \text{V}}$.

Step 2 of 2

(b)

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $100\times10^{-3}\ \text{H}$ for L and $2\sin 377t$ for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(100\times10^{-3}\right)(2\sin 377t)^2 \\ &= \frac{1}{2}\left(100\times10^{-3}\right)\left(4\sin^2 377t\right) \\ &= 200\sin^2 377t\ \text{mJ} \end{aligned}$$

Therefore, the energy stored in the inductor is $\boxed{200\sin^2 377t\ \text{mJ}}$.

Step 1 of 2

(a)

Write the expression for the voltage across the inductor.

$$v(t) = L\frac{di(t)}{dt}$$

Calculate the voltage across the inductor for $t < 0$ by substituting $25\times10^{-3}\ \text{H}$ for *L* and 0 for $i(t)$.

$$\begin{aligned} v(t) &= L\frac{di(t)}{dt} \\ &= \left(25\times10^{-3}\right)\frac{d}{dt}(0) \\ &= \left(25\times10^{-3}\right)(0) \\ &= 0 \end{aligned}$$

Calculate the voltage across the inductor for $t > 0$ by substituting $25\times10^{-3}\ \text{H}$ for *L* and $10\left(1-e^{-t}\right)\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= L\frac{di(t)}{dt} \\ &= \left(25\times10^{-3}\right)\frac{d}{dt}\left[10\left(1-e^{-t}\right)\text{mA}\right] \\ &= \left(25\times10^{-3}\right)(10)(-1)(-1)\left(e^{-t}\right) \\ &= 250e^{-t}\ \text{mV} \end{aligned}$$

Therefore, the voltage across the inductor is $\boxed{250e^{-t}\ \text{mV}}$.

Step 2 of 2

(b)

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor for $t < 0$ by substituting $25\times10^{-3}\ \text{H}$ for *L* and 0 for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(25\times10^{-3}\right)(0)^2 \\ &= 0 \end{aligned}$$

Calculate the energy stored in the inductor for $t > 0$ by substituting $25\times10^{-3}\ \text{H}$ for *L* and $10\left(1-e^{-t}\right)\text{mA}$ for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(25\times10^{-3}\right)\left(10\left(1-e^{-t}\right)\text{mA}\right)^2 \\ &= \frac{1}{2}\left(25\times10^{-3}\right)(100)\left(1-e^{-t}\right)^2 \\ &= 1.25\left(1-e^{-t}\right)^2\ \text{J} \end{aligned}$$

Therefore, the energy stored in the inductor is $\boxed{1.25\left(1-e^{-t}\right)^2\ \text{J}}$.

Step 1 of 2

Write the expression for the voltage across the inductor.

$$v(t) = L\frac{di(t)}{dt}$$

Calculate the voltage across the inductor for $t < 0$ by substituting $25\,\text{mH}$ for L and 0 for $i(t)$.

$$\begin{aligned} v(t) &= L\frac{di(t)}{dt} \\ &= \left(25\times10^{-3}\right)\frac{d}{dt}(0) \\ &= \left(25\times10^{-3}\right)(0) \\ &= 0 \end{aligned}$$

Calculate the voltage across the inductor for $t > 0$ by substituting $25\,\text{mH}$ for L and $10\left(1-e^{-t}\right)\text{mA}$ for $i(t)$.

$$\begin{aligned} v(t) &= L\frac{di(t)}{dt} \\ &= \left(25\times10^{-3}\right)\frac{d}{dt}\left(10\left(1-e^{-t}\right)\text{mA}\right) \\ &= \left(25\times10^{-3}\right)(10)(-1)(-1)\left(e^{-t}\right) \\ &= 250e^{-t}\,\text{mV} \end{aligned}$$

The voltage across the inductor after 1 s is,

$$\begin{aligned} v(t) &= 250e^{-t}\,\text{mV} \\ &= 250e^{-1} \\ &= (250)(0.3678) \\ &= 91.97\,\text{mV} \end{aligned}$$

Therefore, the voltage across the inductor after 1 s is $\boxed{91.97\,\text{mV}}$.

Step 2 of 2

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor for $t < 0$ by substituting $25\,\text{mH}$ for L and 0 for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(25\times10^{-3}\right)(0)^2 \\ &= 0 \end{aligned}$$

Determine the energy stored in the inductor for $t > 0$ by substituting $25\,\text{mH}$ for L and $10\left(1-e^{-t}\right)\text{mA}$ for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}\left(25\times10^{-3}\right)\left(10\left(1-e^{-t}\right)\text{mA}\right)^2 \\ &= \frac{1}{2}\left(25\times10^{-3}\right)(100)\left(1-e^{-t}\right)^2 \\ &= 1.25\left(1-e^{-t}\right)^2\,\text{J} \end{aligned}$$

The voltage across the inductor after 1 s is ,

$$\begin{aligned} w_L(t) &= 1.25\left(1-e^{-t}\right)^2\,\text{J} \\ &= 1.25\left(1-e^{-1}\right)^2 \\ &= 1.25(1-0.3678)^2 \\ &= 0.5\,\text{J} \end{aligned}$$

Therefore, the energy stored in the inductor after 1 s is $\boxed{0.5\,\text{J}}$.

Step 1 of 4

Refer to the waveform in Figure P6.27 in the text book.

The equations for the waveforms in the specific time intervals are as follows:

$$v(t)=\begin{cases} 5 & 0\le t\le 2\text{s} \\ 0 & 2\text{s}\le t\le 4\text{s} \\ -5 & 4\text{s}\le t\le 6\text{s} \end{cases}$$

Step 2 of 4

Write the expression for the current in the inductor.

$$i(t)=i(t_o)+\frac{1}{L}\int_0^t v(t)dt$$

Since the current through the inductor at $t<0$ is 0, calculate the current in the inductor for the interval $0\le t\le 2\text{s}$ by substituting 2 for L, 0 for $i(t_0)$ and 5 for $v(t)$.

$$\begin{aligned} i(t)&=i(t_0)+\frac{1}{L}\int_0^t v(t)dt \\ &=0+\frac{1}{2}\int_0^2(5)dt \\ &=\frac{5}{2}(t)_0^2 \\ &=\frac{5}{2}(2-0) \\ &=5\text{A} \end{aligned}$$

Step 3 of 4

Calculate the current in the inductor for the interval $2\text{s}\le t\le 4\text{s}$ by substituting

2 for L, 5 for $i(t)$ and 0 for $v(t)$.

$$\begin{aligned} i(t)&=i(t)+\frac{1}{L}\int_2^4 v(t)dt \\ &=5\text{A}+\frac{1}{2}\int_2^4(0)dt \\ &=5\text{A} \end{aligned}$$

Calculate the current in the inductor for the interval $4\text{s}\le t\le 6\text{s}$ by substituting 2 for L, 5 for $i(t)$ and -5 for $v(t)$.

$$\begin{aligned} i(t)&=i(t)+\frac{1}{L}\int_4^6 v(t)dt \\ &=5+\frac{1}{2}\int_4^6(-5)dt \\ &=5+\frac{-5}{2}t\Big|_4^6 \\ &=5+\frac{-5}{2}(6-4) \\ &=0 \end{aligned}$$

Step 4 of 4

Thus, the required waveform for the voltage across the capacitor is shown in Figure 1.

Figure 1

Step 1 of 6

Refer to the waveform in Figure P6.28 in the text book.

The equations for the waveforms in the specific time intervals are as follows:

$$v(t)=\begin{cases}2.4\times10^{-3} & 0\le t\le 10\,\text{ms}\\ 0 & 10\,\text{ms}\le t\le 20\,\text{ms}\\ 2.4\times10^{-3} & 20\,\text{ms}\le t\le 30\,\text{ms}\\ 0 & 30\,\text{ms}\le t\le 40\,\text{ms}\\ 2.4\times10^{-3} & 40\,\text{ms}\le t\le 50\,\text{ms}\end{cases}$$

Step 2 of 6

Write the expression for the current in the inductor.

$$i(t)=i(t_0)+\frac{1}{L}\int_0^t v(t)\,dt$$

Calculate the current in the inductor for the interval $0\le t\le 10\,\text{ms}$ by substituting 4 for L, 0 for $i(t_0)$ and 2.4 mV for $v(t)$.

$$\begin{aligned}i(t)&=i(t_0)+\frac{1}{L}\int_0^{10\,\text{ms}} v(t)\,dt\\&=0+\frac{1}{4}\int_0^{10\,\text{ms}}\left(2.4\times10^{-3}\right)dt\\&=\frac{2.4\times10^{-3}}{4}(t)_0^{10\,\text{ms}}\\&=\frac{2.4\times10^{-3}}{4}\left(10\times10^{-3}-0\right)\\&=6\,\mu\text{A}\end{aligned}$$

Step 3 of 6

Calculate the current in the inductor for the interval $10\,\text{ms}\le t\le 20\,\text{ms}$ by substituting 4 for L, $6\,\mu\text{A}$ for $i(t)$ and 0 for $v(t)$.

$$\begin{aligned}i(t)&=i(t)+\frac{1}{L}\int_{10\,\text{ms}}^{20\,\text{ms}} v(t)\,dt\\&=6\times10^{-6}+\frac{1}{4}\int_{10\,\text{ms}}^{20\,\text{ms}}\left(0\times10^{-3}\right)dt\\&=6\,\mu\text{A}\end{aligned}$$

Calculate the current in the inductor for the interval $20\,\text{ms}\le t\le 30\,\text{ms}$ by substituting 4 for L, $6\,\mu\text{A}$ for $i(t)$ and 2.4×10^{-3} for $v(t)$.

$$\begin{aligned}i(t)&=i(t_0)+\frac{1}{L}\int_{20\,\text{ms}}^{30\,\text{ms}} v(t)\,dt\\&=6\,\mu\text{A}+\frac{1}{4}\int_{10\,\text{ms}}^{30\,\text{ms}}\left(2.4\times10^{-3}\right)dt\\&=6\,\mu\text{A}+\frac{2.4\times10^{-3}}{4}(t)_{20\,\text{ms}}^{30\,\text{ms}}\\&=6\,\mu\text{A}+\frac{2.4\times10^{-3}}{4}\left(30\times10^{-3}-20\times10^{-3}\right)\\&=12\,\mu\text{A}\end{aligned}$$

Step 4 of 6

Calculate the current in the inductor for the interval $30\,\text{ms}\le t\le 40\,\text{ms}$ by substituting 4 for L, 12×10^{-6} for $i(t)$ and 0 for $v(t)$.

$$\begin{aligned}i(t)&=i(t)+\frac{1}{L}\int_{30\,\text{ms}}^{40\,\text{ms}} v(t)\,dt\\&=12\times10^{-6}+\frac{1}{4}\int_{30\,\text{ms}}^{40\,\text{ms}}\left(0\times10^{-3}\right)dt\\&=12\,\mu\text{A}\end{aligned}$$

Step 5 of 6

Calculate the current in the inductor for the interval $40\,\text{ms}\le t\le 50\,\text{ms}$ by substituting4 for L, 12×10^{-6} for $i(t)$ and 2.4×10^{-3} for $v(t)$.

$$\begin{aligned}i(t)&=i(t)+\frac{1}{L}\int_{40\,\text{ms}}^{50\,\text{ms}} v(t)\,dt\\&=12\times10^{-6}+\frac{1}{4}\int_{40\,\text{ms}}^{50\,\text{ms}}\left(2.4\times10^{-3}\right)dt\\&=12\times10^{-6}+\frac{2.4\times10^{-3}}{4}(t)_{40\,\text{ms}}^{50\,\text{ms}}\\&=12\times10^{-6}+\frac{2.4\times10^{-3}}{4}\left(50\times10^{-3}-40\times10^{-3}\right)\\&=18\,\mu\text{A}\end{aligned}$$

Step 6 of 6

The required waveform for the voltage across the capacitor is shown in Figure 1.

Figure 1

Step 1 of 7

The voltage across an inductor is,

Step 2 of 7

The current through the inductor is,

$$i = \frac{1}{L}\int_{-\infty}^{t} v(x)dx$$

Where, L is the inductance.

$$L = 10\text{mH}$$

From the given voltage waveform,

$$v(t) = \begin{cases} 10t, & 0 \le t \le 1\text{ms} \\ 0.02 - 10t, & 1\text{ms} \le t \le 2\text{ms} \\ 0, & t \ge 2\text{ms} \end{cases}$$

Step 3 of 7

For $0 \le t \le 1\text{ms}$,

$$i(t) = \frac{1}{10\times10^{-3}}\int_{0}^{t} 10x\ dx$$

$$i(t) = 1000\left[\frac{x^2}{2}\right]_0^t$$

$$i(t) = 1000\left[\frac{(t)^2 - 0}{2}\right]$$

$$i(t) = 500t^2$$

$$i(1\text{ms}) = 500\left(1\times10^{-3}\right)^2$$

$$i(1\text{ms}) = 500\times10^{-6}$$

$$i(1\text{ms}) = 500\mu\text{A}$$

Step 4 of 7

For $1\text{ms} \le t \le 2\text{ms}$,

$$i(t) = \frac{1}{10\times10^{-3}}\int_{1\text{m}}^{t} (0.02 - 10x)\ dx + i(1\text{m})$$

$$i(t) = 100\left[0.02x - 10\frac{x^2}{2}\right]_{1\text{m}}^{t} + 500\times10^{-6}$$

$$i(t) = 100\left[0.02t - 5t^2 - 0.02\left(1\times10^{-3}\right) + 5\left(1\times10^{-3}\right)^2\right] + 500\times10^{-6}$$

$$i(t) = 100\left[0.02t - 5t^2 - 20\times10^{-6} + 5\times10^{-6}\right] + 500\times10^{-6}$$

$$i(t) = 2t - 500t^2 - 2000\times10^{-6} + 500\times10^{-6} + 500\times10^{-6}$$

$$i(t) = 2t - 500t^2 - 1\times10^{-3}$$

$$i(t) = 2t - 500t^2 - 1\times10^{-3}$$

$$i(2\text{ms}) = 2\left(2\times10^{-3}\right) - 500\left(2\times10^{-3}\right)^2 - 1\times10^{-3}$$

$$i(2\text{ms}) = 1\text{mA}$$

Step 5 of 7

For $t > 2\text{ms}$,

$$i(t) = \frac{1}{10\times10^{-3}}\int_{2\text{m}}^{t} (0)\ dx + i(2\text{m})$$

$$i(t) = 1\text{mA}$$

Step 6 of 7

The summary of the current waveform is,

$$i(t) = \begin{cases} 500t^2, & 0 \le t \le 1\text{ms} \\ 2t - 500t^2 - 0.001, & 1\text{ms} \le t \le 2\text{ms} \\ 0.001, & t \ge 2\text{ms} \end{cases}$$

The plot of the current waveform is done using MATLAB,

The MATLAB code is,

```
>> t1=0:(1*10^-5):(1*10^-3);
>> f1=(500*t1.^2);
>> t2=(1*10^-3):(1*10^-5):(2*10^-3);
>> f2=((2*t2)-(500*t2.^2)-(1*10^-3));
>> t3=(2*10^-3):(1*10^-5):(4*10^-3);
>> f3=(10^-3)*(ones(1,201));
>> t=[t1 t2 t3];
>> f=[f1 f2 f3];
>> figure
>> plot(t,f)
>> xlabel('t[sec]')
>> ylabel('i(t)[A]')
```

Step 7 of 7

The required inductor current waveform is shown below:

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $2\,\mathrm{H}$ for L and $1.5t$ for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}(2)(1.5t)^2 \\ &= \frac{1}{2}(2)(2.25t^2) \\ &= 2.25t^2 \end{aligned}$$

Determine the energy stored in the inductor by substituting $2\ \mathrm{s}$ for t.

$$\begin{aligned} w_L(t) &= 2.25t^2 \\ &= (2.25)(2)^2 \\ &= 10\,\mathrm{J} \end{aligned}$$

Therefore, the energy stored in the inductor is $\boxed{10\,\mathrm{J}}$.

Step 1 of 4

Refer to Figure P6.29 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(10,120)$ is as follows.

$$\frac{y-0}{120-0}=\frac{x-0}{10-0}$$
$$y=12x$$

The equation for the current waveform between the points $(10,120)$ and $(20,120)$ is as follows.

$$y=120$$

The equation for the current waveform between the points $(20,120)$ and $(30,60)$ is as follows.

$$\frac{y-120}{60-120}=\frac{x-20}{30-20}$$
$$y-120=\frac{-60(x-20)}{10}$$
$$=-6x+120$$
$$y=-6x+240$$

The equation for the current waveform between the points $(30,60)$ and $(40,60)$ is as follows.

$$y=60$$

The equation for the current waveform between the points $(40,60)$ and $(50,120)$ is as follows.

$$\frac{y-60}{120-60}=\frac{x-40}{50-40}$$
$$y-60=\frac{60(x-40)}{10}$$
$$=6x-240$$
$$y=6x-180$$

The equation for the current waveform between the points $(50,120)$ and $(60,120)$ is as follows.

$$y=120$$

The equation for the current waveform between the points $(60,120)$ and $(70,0)$ is as follows.

$$\frac{y-120}{0-120}=\frac{x-60}{70-60}$$
$$y-120=\frac{-120(x-60)}{10}$$
$$=-12x+720$$
$$y=-12x+840$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows.

$$\begin{aligned}
i(t)&=\frac{12\times10^{-3}t}{10^{-3}} && 0\le t\le 10\,\text{ms}\\
&=120\times10^{-3} && 10\,\text{ms}\le t\le 20\,\text{ms}\\
&=\frac{-6\times10^{-3}t}{10^{-3}}+240\times10^{-3} && 20\,\text{ms}\le t\le 30\,\text{ms}\\
&=60\times10^{-3} && 30\,\text{ms}\le t\le 40\,\text{ms}\\
&=\frac{6\times10^{-3}t}{10^{-3}}-180\times10^{-3} && 40\,\text{ms}\le t\le 50\,\text{ms}\\
&=120\times10^{-3} && 50\,\text{ms}\le t\le 60\,\text{ms}\\
&=\frac{-12\times10^{-3}t}{10^{-3}}+840\times10^{-3} && 60\,\text{ms}\le t\le 70\,\text{ms}
\end{aligned}$$

Step 2 of 4

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 10\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}\left(\frac{12\times10^{-3}t}{10^{-3}}\right) && 0\le t\le 10\,\text{ms}\\
&=(30\times10^{-3})(12) && 0\le t\le 10\,\text{ms}\\
&=360\,\text{mV}
\end{aligned}$$

Step 3 of 4

Calculate the inductor voltage for the interval $10\,\text{ms}\le t\le 20\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}(120\times10^{-3}) && 10\,\text{ms}\le t\le 20\,\text{ms}\\
&=(30\times10^{-3})(0) && 10\,\text{ms}\le t\le 20\,\text{ms}\\
&=0
\end{aligned}$$

Calculate the inductor voltage for the interval $20\,\text{ms}\le t\le 30\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}\left(\frac{-6\times10^{-3}t}{10^{-3}}+240\times10^{-3}\right) && 20\,\text{ms}\le t\le 30\,\text{ms}\\
&=(30\times10^{-3})(-6) && 20\,\text{ms}\le t\le 30\,\text{ms}\\
&=-180\,\text{mV}
\end{aligned}$$

Calculate the inductor voltage for the interval $30\,\text{ms}\le t\le 40\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}(60\times10^{-3}) && 30\,\text{ms}\le t\le 40\,\text{ms}\\
&=(30\times10^{-3})(0) && 30\,\text{ms}\le t\le 40\,\text{ms}\\
&=0
\end{aligned}$$

Calculate the inductor voltage for the interval $40\,\text{ms}\le t\le 50\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}\left(\frac{6\times10^{-3}t}{10^{-3}}-180\times10^{-3}\right) && 40\,\text{ms}\le t\le 50\,\text{ms}\\
&=(30\times10^{-3})(6) && 40\,\text{ms}\le t\le 50\,\text{ms}\\
&=180\,\text{mV}
\end{aligned}$$

Calculate the inductor voltage for the interval $50\,\text{ms}\le t\le 60\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}(120\times10^{-3}) && 50\,\text{ms}\le t\le 60\,\text{ms}\\
&=(30\times10^{-3})(0) && 50\,\text{ms}\le t\le 60\,\text{ms}\\
&=0
\end{aligned}$$

Calculate the inductor voltage for the interval $60\,\text{ms}\le t\le 70\,\text{ms}$ by substituting $30\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(30\times10^{-3})\frac{d}{dt}\left(\frac{-12\times10^{-3}t}{10^{-3}}+840\times10^{-3}\right) && 60\,\text{ms}\le t\le 70\,\text{ms}\\
&=(30\times10^{-3})(-12) && 60\,\text{ms}\le t\le 70\,\text{ms}\\
&=-360\,\text{mV}
\end{aligned}$$

Step 4 of 4

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 1 of 4

Refer to Figure P6.30 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(2,5)$ is as follows.

$$\frac{y-0}{5-0}=\frac{x-0}{2-0}$$
$$y=2.5x$$

The equation for the current waveform between the points $(2,5)$ and $(4,5)$ is as follows.

$$y=5$$

The equation for the current waveform between the points $(4,5)$ and $(6,20)$ is as follows.

$$\frac{y-5}{20-5}=\frac{x-4}{6-4}$$
$$y-5=\frac{15(x-4)}{2}$$
$$=7.5x-30$$
$$y=7.5x-25$$

The equation for the current waveform between the points $(6,20)$ and $(8,5)$ is as follows.

$$\frac{y-20}{5-20}=\frac{x-6}{8-6}$$
$$y-20=\frac{-15(x-6)}{2}$$
$$=-7.5x+45$$
$$y=-7.5x+65$$

The equation for the current waveform between the points $(8,5)$ and $(10,5)$ is as follows.

$$y=5$$

The equation for the current waveform between the points $(10,5)$ and $(12,0)$ is as follows.

$$\frac{y-5}{0-5}=\frac{x-10}{12-10}$$
$$y-5=\frac{-5(x-10)}{2}$$
$$=-2.5x+25$$
$$y=-2.5x+30$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows.

$$\begin{aligned}
i(t)&=\frac{2.5\times10^{-3}t}{10^{-3}} && 0\le t\le 2\,\text{ms}\\
&=5\times10^{-3} && 2\,\text{ms}\le t\le 4\,\text{ms}\\
&=\frac{7.5\times10^{-3}t}{10^{-3}}-25\times10^{-3} && 4\,\text{ms}\le t\le 6\,\text{ms}\\
&=\frac{-7.5\times10^{-3}t}{10^{-3}}+65\times10^{-3} && 6\,\text{ms}\le t\le 8\,\text{ms}\\
&=5\times10^{-3} && 8\,\text{ms}\le t\le 10\,\text{ms}\\
&=\frac{-2.5\times10^{-3}t}{10^{-3}}+30\times10^{-3} && 10\,\text{ms}\le t\le 12\,\text{ms}
\end{aligned}$$

Step 2 of 4

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 2\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}\left(\frac{2.5\times10^{-3}t}{10^{-3}}\right) && 0\le t\le 2\,\text{ms}\\
&=(40\times10^{-3})(2.5) && 0\le t\le 2\,\text{ms}\\
&=100\,\text{mV}
\end{aligned}$$

Calculate the inductor voltage for interval $2\,\text{ms}\le t\le 4\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}(5\times10^{-3}) && 2\,\text{ms}\le t\le 4\,\text{ms}\\
&=(40\times10^{-3})(0) && 2\,\text{ms}\le t\le 4\,\text{ms}\\
&=0
\end{aligned}$$

Step 3 of 4

Calculate the inductor voltage for interval $4\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}\left(\frac{7.5\times10^{-3}t}{10^{-3}}-25\times10^{-3}\right) && 4\,\text{ms}\le t\le 6\,\text{ms}\\
&=(40\times10^{-3})(7.5) && 4\,\text{ms}\le t\le 6\,\text{ms}\\
&=300\,\text{mV}
\end{aligned}$$

Calculate the inductor voltage for the interval $6\,\text{ms}\le t\le 8\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}\left(\frac{-7.5\times10^{-3}t}{10^{-3}}+65\times10^{-3}\right) && 6\,\text{ms}\le t\le 8\,\text{ms}\\
&=(40\times10^{-3})(-7.5) && 6\,\text{ms}\le t\le 8\,\text{ms}\\
&=-300\,\text{mV}
\end{aligned}$$

Calculate the inductor voltage for interval $8\,\text{ms}\le t\le 10\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}(5\times10^{-3}) && 8\,\text{ms}\le t\le 10\,\text{ms}\\
&=(40\times10^{-3})(0) && 8\,\text{ms}\le t\le 10\,\text{ms}\\
&=0
\end{aligned}$$

Calculate the inductor voltage for the interval $10\,\text{ms}\le t\le 12\,\text{ms}$ by substituting $40\,\text{mH}$ for L.

$$\begin{aligned}
v(t)&=L\frac{di(t)}{dt}\\
&=(40\times10^{-3})\frac{d}{dt}\left(\frac{-2.5\times10^{-3}t}{10^{-3}}+30\times10^{-3}\right) && 10\,\text{ms}\le t\le 12\,\text{ms}\\
&=(40\times10^{-3})(-2.5) && 10\,\text{ms}\le t\le 12\,\text{ms}\\
&=-100\,\text{mV}
\end{aligned}$$

Step 4 of 4

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 1 of 10

Refer to the waveform in Figure P6.33 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(1,10)$ is as follows:

$$\frac{y-0}{10-0}=\frac{x-0}{1-0}$$
$$y=10x$$

The equation for the current waveform between the points $(1,10)$ and $(2,5)$ is as follows:

$$\frac{y-10}{5-10}=\frac{x-1}{2-1}$$
$$y-10=\frac{-5(x-1)}{1}$$
$$=-5x+5$$
$$y=-5x+15$$

The equation for the current waveform between the points $(2,5)$ and $(3,5)$ is as follows:

$$y=5$$

Step 2 of 10

The equation for the current waveform between the points $(3,5)$ and $(4,-10)$ is as follows:

$$\frac{y-5}{-10-5}=\frac{x-3}{4-3}$$
$$y-5=\frac{-15(x-3)}{1}$$
$$=-15x+45$$
$$y=-15x+50$$

The equation for the current waveform between the points $(4,-10)$ and $(6,0)$ is as follows:

$$\frac{y-(-10)}{0-(-10)}=\frac{x-4}{6-4}$$
$$y+10=\frac{10(x-4)}{2}$$
$$=5x-20$$
$$y=5x-30$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows:

$$i(t)=\begin{cases}\dfrac{10\times10^{-3}t}{10^{-3}} & 0\le t\le 1\,\text{ms}\\[2mm] \dfrac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3} & 1\,\text{ms}\le t\le 2\,\text{ms}\\[2mm] 5\times10^{-3} & 2\,\text{ms}\le t\le 3\,\text{ms}\\[2mm] \dfrac{-15\times10^{-3}t}{10^{-3}}+50\times10^{-3} & 3\,\text{ms}\le t\le 4\,\text{ms}\\[2mm] \dfrac{5\times10^{-3}t}{10^{-3}}-30\times10^{-3} & 4\,\text{ms}\le t\le 6\,\text{ms}\end{cases}$$

Step 3 of 10

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 1\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{10\times10^{-3}t}{10^{-3}}\right)\quad 0\le t\le 1\,\text{ms}$$
$$=(0.5)(10)\quad 0\le t\le 1\,\text{ms}$$
$$=5\,\text{V}$$

Calculate the inductor voltage for interval $1\,\text{ms}\le t\le 2\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3}\right)\quad 1\,\text{ms}\le t\le 2\,\text{ms}$$
$$=(0.5)(-5)\quad 1\,\text{ms}\le t\le 2\,\text{ms}$$
$$=-2.5\,\text{V}$$

Step 4 of 10

Calculate the inductor voltage for the interval $2\,\text{ms}\le t\le 3\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(5\times10^{-3}\right)\quad 2\,\text{ms}\le t\le 3\,\text{ms}$$
$$=(0.5)(0)\quad 2\,\text{ms}\le t\le 3\,\text{ms}$$
$$=0$$

Calculate the inductor voltage for the interval $3\,\text{ms}\le t\le 4\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{-15\times10^{-3}t}{10^{-3}}+50\times10^{-3}\right)\quad 3\,\text{ms}\le t\le 4\,\text{ms}$$
$$=(0.5)(-15)\quad 3\,\text{ms}\le t\le 4\,\text{ms}$$
$$=-7.5\,\text{V}$$

Calculate the inductor voltage for the interval $4\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{5\times10^{-3}t}{10^{-3}}-30\times10^{-3}\right)\quad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=(0.5)(5)\quad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=2.5\,\text{V}$$

Step 5 of 10

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 6 of 10

(a)

From the Figure P6.33, at $t=1.7\,\text{ms}$, the current through the inductor is 7 mA.

Write the expression for the voltage across the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $0.5\,\text{H}$ for L and $7\,\text{mA}$ for $i(t)$.

$$w_L(t)=\frac{1}{2}Li^2(t)$$
$$=\frac{1}{2}(0.5)\left(7\times10^{-3}\right)\left(7\times10^{-3}\right)$$
$$=12.25\,\mu\text{J}$$

Therefore, the energy stored in the inductor is $\boxed{12.25\,\mu\text{J}}$.

Step 7 of 10

(b)

From the Figure P6.33, at $t=4.2\,\text{ms}$, the current through the inductor is $-8.5\,\text{mA}$.

Write the expression for the voltage across the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $0.5\,\text{H}$ for L and $-8.5\,\text{mA}$ for $i(t)$.

$$w_L(t)=\frac{1}{2}Li^2(t)$$
$$=\frac{1}{2}(0.5)\left(-8.5\times10^{-3}\right)\left(-8.5\times10^{-3}\right)$$
$$=18.06\,\mu\text{J}$$

Therefore, the energy stored in the inductor is $\boxed{18.06\,\mu\text{J}}$.

Step 8 of 10

(c)

From the Figure P6.33, at $t=1.2\,\text{ms}$, the current through the inductor is $9\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $-8.5\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)\left(9\times10^{-3}\right)\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3}\right)$$
$$=(0.5)\left(9\times10^{-3}\right)(-5)$$
$$=-22.5\,\text{mW}$$

Therefore, the power absorbed by the inductor is $\boxed{-22.5\,\text{mW}}$.

Step 9 of 10

From the Figure P6.33, at $t=2.8\,\text{ms}$, the current through the inductor is $5\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $5\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)\left(9\times10^{-3}\right)\frac{d}{dt}\left(5\times10^{-3}\right)$$
$$=(0.5)\left(9\times10^{-3}\right)(0)$$
$$=0$$

Therefore, the power absorbed by the inductor is $\boxed{0}$.

Step 10 of 10

From the Figure P6.33, at $t=5.3\,\text{ms}$, the current through the inductor is $-3\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $-3\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)\left(-3\times10^{-3}\right)\frac{d}{dt}\left(\frac{5\times10^{-3}t}{10^{-3}}-30\times10^{-3}\right)$$
$$=(0.5)\left(-3\times10^{-3}\right)(5)$$
$$=-7.5\,\text{mW}$$

Therefore, the power absorbed by the inductor is $\boxed{-7.5\,\text{mW}}$.

Step 1 of 10

Refer to the waveform in Figure P6.33 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows:

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(1,10)$ is as follows:

$$\frac{y-0}{10-0}=\frac{x-0}{1-0}$$
$$y=10x$$

The equation for the current waveform between the points $(1,10)$ and $(2,5)$ is as follows:

$$\frac{y-10}{5-10}=\frac{x-1}{2-1}$$
$$y-10=\frac{-5(x-1)}{1}$$
$$=-5x+5$$
$$y=-5x+15$$

The equation for the current waveform between the points $(2,5)$ and $(3,5)$ is as follows:

$$y=5$$

Step 2 of 10

The equation for the current waveform between the points $(3,5)$ and $(4,-10)$ is as follows:

$$\frac{y-5}{-10-5}=\frac{x-3}{4-3}$$
$$y-5=\frac{-15(x-3)}{1}$$
$$=-15x+45$$
$$y=-15x+50$$

The equation for the current waveform between the points $(4,-10)$ and $(6,0)$ is as follows:

$$\frac{y-(-10)}{0-(-10)}=\frac{x-4}{6-4}$$
$$y+10=\frac{10(x-4)}{2}$$
$$=5x-20$$
$$y=5x-30$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows:

$$i(t)=\begin{cases}\frac{10\times10^{-3}t}{10^{-3}} & 0\le t\le 1\,\text{ms}\\ \frac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3} & 1\,\text{ms}\le t\le 2\,\text{ms}\\ 5\times10^{-3} & 2\,\text{ms}\le t\le 3\,\text{ms}\\ \frac{-15\times10^{-3}t}{10^{-3}}+50\times10^{-3} & 3\,\text{ms}\le t\le 4\,\text{ms}\\ \frac{5\times10^{-3}t}{10^{-3}}-30\times10^{-3} & 4\,\text{ms}\le t\le 6\,\text{ms}\end{cases}$$

Step 3 of 10

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 1\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{10\times10^{-3}t}{10^{-3}}\right)\quad 0\le t\le 1\,\text{ms}$$
$$=(0.5)(10)\quad 0\le t\le 1\,\text{ms}$$
$$=5\,\text{V}$$

Calculate the inductor voltage for the interval $1\,\text{ms}\le t\le 2\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3}\right)\quad 1\,\text{ms}\le t\le 2\,\text{ms}$$
$$=(0.5)(-5)\quad 1\,\text{ms}\le t\le 2\,\text{ms}$$
$$=-2.5\,\text{V}$$

Step 4 of 10

Calculate the inductor voltage for the interval $2\,\text{ms}\le t\le 3\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}(5\times10^{-3})\quad 2\,\text{ms}\le t\le 3\,\text{ms}$$
$$=(0.5)(0)\quad 2\,\text{ms}\le t\le 3\,\text{ms}$$
$$=0$$

Calculate the inductor voltage for the interval $3\,\text{ms}\le t\le 4\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{-15\times10^{-3}t}{10^{-3}}+50\times10^{-3}\right)\quad 3\,\text{ms}\le t\le 4\,\text{ms}$$
$$=(0.5)(-15)\quad 3\,\text{ms}\le t\le 4\,\text{ms}$$
$$=-7.5\,\text{V}$$

Calculate the inductor voltage for the interval $4\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $0.5\,\text{H}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(0.5)\frac{d}{dt}\left(\frac{5\times10^{-3}t}{10^{-3}}-30\times10^{-3}\right)\quad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=(0.5)(5)\quad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=2.5\,\text{V}$$

Step 5 of 10

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 6 of 10

(a)

From the Figure P6.33, at $t=1.7\,\text{ms}$, the current through the inductor is 7 mA.

Write the expression for the voltage across the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $0.5\,\text{H}$ for L and $7\,\text{mA}$ for $i(t)$.

$$w_L(t)=\frac{1}{2}Li^2(t)$$
$$=\frac{1}{2}(0.5)(7\times10^{-3})(7\times10^{-3})$$
$$=12.25\,\mu\text{J}$$

Therefore, the energy stored in the inductor is $\boxed{12.25\,\mu\text{J}}$.

Step 7 of 10

(b)

From the Figure P6.33, at $t=4.2\,\text{ms}$, the current through the inductor is $-8.5\,\text{mA}$.

Write the expression for the voltage across the inductor.

$$w_L(t)=\frac{1}{2}Li^2(t)$$

Calculate the energy stored in the inductor by substituting $0.5\,\text{H}$ for L and $-8.5\,\text{mA}$ for $i(t)$.

$$w_L(t)=\frac{1}{2}Li^2(t)$$
$$=\frac{1}{2}(0.5)(-8.5\times10^{-3})(-8.5\times10^{-3})$$
$$=18.06\,\mu\text{J}$$

Therefore, the energy stored in the inductor is $\boxed{18.06\,\mu\text{J}}$.

Step 8 of 10

(c)

From the Figure P6.33, at $t=1.2\,\text{ms}$, the current through the inductor is $9\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $-8.5\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)(9\times10^{-3})\frac{d}{dt}\left(\frac{-5\times10^{-3}t}{10^{-3}}+15\times10^{-3}\right)$$
$$=(0.5)(9\times10^{-3})(-5)$$
$$=-22.5\,\text{mW}$$

Therefore, the power absorbed by the inductor is $\boxed{-22.5\,\text{mW}}$.

Step 9 of 10

From the Figure P6.33, at $t=2.8\,\text{ms}$, the current through the inductor is $5\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $5\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)(9\times10^{-3})\frac{d}{dt}(5\times10^{-3})$$
$$=(0.5)(9\times10^{-3})(0)$$
$$=0$$

Therefore, the power absorbed by the inductor is $\boxed{0}$.

Step 10 of 10

From the Figure P6.33, at $t=5.3\,\text{ms}$, the current through the inductor is $-3\,\text{mA}$.

Write the expression for the power absorbed by the inductor.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$

Calculate the power absorbed by the inductor by substituting $0.5\,\text{H}$ for L and $-3\,\text{mA}$ for $i(t)$.

$$P_L(t)=Li(t)\frac{di(t)}{dt}$$
$$=(0.5)(-3\times10^{-3})\frac{d}{dt}\left(\frac{5\times10^{3}t}{10^{-3}}-30\times10^{-3}\right)$$
$$=(0.5)(-3\times10^{-3})(5)$$
$$=-7.5\,\text{mW}$$

Therefore, the power absorbed by the inductor is $\boxed{-7.5\,\text{mW}}$.

Step 1 of 4

Refer to Figure P6.35 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(2,0)$ is as follows.

$$y=0$$

The equation for the current waveform between the points $(2,0)$ and $(4,-100)$ is as follows.

$$\begin{aligned}\frac{y-0}{-100-0}&=\frac{x-2}{4-2}\\ y&=\frac{-100(x-2)}{2}\\ &=-50x+100\end{aligned}$$

The equation for the current waveform between the points $(4,-100)$ and $(8,100)$ is as follows.

$$\begin{aligned}\frac{y-(-100)}{100-(-100)}&=\frac{x-4}{8-4}\\ y+100&=\frac{200(x-4)}{4}\\ &=50x-200\\ y&=50x-300\end{aligned}$$

The equation for the current waveform between the points $(8,100)$ and $(10,0)$ is as follows.

$$\begin{aligned}\frac{y-100}{0-100}&=\frac{x-8}{10-8}\\ y-100&=\frac{-100(x-8)}{2}\\ &=-50x+400\\ y&=-50x+500\end{aligned}$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows.

$$\begin{aligned}i(t)&=0 && 0\le t\le 2\,\text{ms}\\ &=\frac{-50\times10^{-3}t}{10^{-3}}+100\times10^{-3} && 2\le t\le 4\,\text{ms}\\ &=\frac{50\times10^{-3}t}{10^{-3}}-300\times10^{-3} && 4\,\text{ms}\le t\le 8\,\text{ms}\\ &=\frac{-50\times10^{-3}t}{10^{-3}}+500\times10^{-3} && 8\,\text{ms}\le t\le 10\,\text{ms}\end{aligned}$$

Step 2 of 4

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 2\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\ &=\left(10\times10^{-3}\right)\frac{d}{dt}(0) && 0\le t\le 2\,\text{ms}\\ &=\left(10\times10^{-3}\right)(0) && 0\le t\le 2\,\text{ms}\\ &=0\end{aligned}$$

Calculate the inductor voltage for interval $2\,\text{ms}\le t\le 4\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\ &=\left(50\times10^{-3}\right)\frac{d}{dt}\left(\frac{-50\times10^{-3}t}{10^{-3}}+100\times10^{-3}\right) && 2\,\text{ms}\le t\le 4\,\text{ms}\\ &=\left(50\times10^{-3}\right)(-50) && 2\,\text{ms}\le t\le 4\,\text{ms}\\ &=-2.5\,\text{V}\end{aligned}$$

Calculate the inductor voltage for the interval $4\,\text{ms}\le t\le 8\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\ &=\left(50\times10^{-3}\right)\frac{d}{dt}\left(\frac{50\times10^{-3}t}{10^{-3}}-300\times10^{-3}\right) && 4\,\text{ms}\le t\le 8\,\text{ms}\\ &=\left(50\times10^{-3}\right)(50) && 4\,\text{ms}\le t\le 8\,\text{ms}\\ &=2.5\,\text{V}\end{aligned}$$

Step 3 of 4

Calculate the inductor voltage for the interval $8\,\text{ms}\le t\le 10\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$\begin{aligned}v(t)&=L\frac{di(t)}{dt}\\ &=\left(50\times10^{-3}\right)\frac{d}{dt}\left(\frac{-50\times10^{-3}t}{10^{-3}}+500\times10^{-3}\right) && 8\,\text{ms}\le t\le 10\,\text{ms}\\ &=\left(50\times10^{-3}\right)(-50) && 8\,\text{ms}\le t\le 10\,\text{ms}\\ &=-2.5\,\text{V}\end{aligned}$$

Step 4 of 4

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 1 of 3

6.032P

Refer to Figure P6.34 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(4,-12)$ is as follows.

$$\frac{y-0}{-12-0}=\frac{x-0}{4-0}$$
$$y=-3x$$

The equation for the current waveform between the points $(4,-12)$ and $(6,0)$ is as follows.

$$\frac{y-(-12)}{0-(-12)}=\frac{x-4}{6-4}$$
$$y+12=\frac{12(x-4)}{2}$$
$$=6x-24$$
$$y=6x-36$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows.

$$i(t)=\frac{-3\times10^{-3}t}{10^{-3}} \qquad 0\le t\le 4\,\text{ms}$$
$$=\frac{6\times10^{-3}t}{10^{-3}}-36\times10^{-3} \qquad 4\,\text{ms}\le t\le 6\,\text{ms}$$

Step 2 of 3

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 4\,\text{ms}$ by substituting $10\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(10\times10^{-3})\frac{d}{dt}\left(\frac{-3\times10^{-3}t}{10^{-3}}\right) \qquad 0\le t\le 4\,\text{ms}$$
$$=(10\times10^{-3})(-3) \qquad 0\le t\le 4\,\text{ms}$$
$$=-30\,\text{mV}$$

Calculate the inductor voltage for the interval $4\,\text{ms}\le t\le 6\,\text{ms}$ by substituting $10\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(10\times10^{-3})\frac{d}{dt}\left(\frac{6\times10^{-3}t}{10^{-3}}-36\times10^{-3}\right) \qquad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=(10\times10^{-3})(6) \qquad 4\,\text{ms}\le t\le 6\,\text{ms}$$
$$=60\,\text{mV}$$

Step 3 of 3

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Step 1 of 4

Refer to Figure P6.36 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(20,-20)$ is as follows.

$$\frac{y-0}{-20-0}=\frac{x-0}{20-0}$$
$$y=-x$$

The equation for the current waveform between the points $(20,-20)$ and $(40,10)$ is as follows.

$$\frac{y-(-20)}{10-(-20)}=\frac{x-20}{40-20}$$
$$y+20=\frac{30(x-20)}{20}$$
$$=1.5x-30$$
$$y=1.5x-50$$

Step 2 of 4

The equation for the current waveform between the points $(40,10)$ and $(60,10)$ is as follows.

$$y=10$$

The equation for the current waveform between the points $(60,10)$ and $(70,0)$ is as follows.

$$\frac{y-10}{0-10}=\frac{x-60}{70-60}$$
$$y-10=\frac{-10(x-60)}{10}$$
$$=-x+60$$
$$y=-x+70$$

Here, the planes $y=i$ and $x=t$ and since the time and currents are in milliseconds, the equations for the waveform in the specific time intervals are as follows.

$$i(t)=\begin{cases}\dfrac{-10^{-3}t}{10^{-3}} & 0\le t\le 20\,\text{ms}\\ \dfrac{1.5\times10^{-3}t}{10^{-3}}-50\times10^{-3} & 20\,\text{ms}\le t\le 40\,\text{ms}\\ 10\times10^{-3} & 40\,\text{ms}\le t\le 60\,\text{ms}\\ \dfrac{-1\times10^{-3}t}{10^{-3}}+70\times10^{-3} & 60\,\text{ms}\le t\le 70\,\text{ms}\end{cases}$$

Step 3 of 4

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0\le t\le 20\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(50\times10^{-3})\frac{d}{dt}\left(\frac{-10^{-3}t}{10^{-3}}\right) \qquad 0\le t\le 20\,\text{ms}$$
$$=(50\times10^{-3})(-1) \qquad 0\le t\le 20\,\text{ms}$$
$$=-50\,\text{mV}$$

Calculate the inductor voltage for interval $20\,\text{ms}\le t\le 40\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(50\times10^{-3})\frac{d}{dt}\left(\frac{1.5\times10^{-3}t}{10^{-3}}-50\times10^{-3}\right) \qquad 20\,\text{ms}\le t\le 40\,\text{ms}$$
$$=(50\times10^{-3})(1.5) \qquad 20\,\text{ms}\le t\le 40\,\text{ms}$$
$$=75\,\text{mV}$$

Calculate the inductor voltage for the interval $40\,\text{ms}\le t\le 60\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(50\times10^{-3})\frac{d}{dt}(10\times10^{-3}) \qquad 40\,\text{ms}\le t\le 60\,\text{ms}$$
$$=(50\times10^{-3})(0) \qquad 40\,\text{ms}\le t\le 60\,\text{ms}$$
$$=0$$

Calculate the inductor voltage for the interval $60\,\text{ms}\le t\le 70\,\text{ms}$ by substituting $50\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(50\times10^{-3})\frac{d}{dt}\left(\frac{-1\times10^{-3}t}{10^{-3}}+70\times10^{-3}\right) \qquad 60\,\text{ms}\le t\le 70\,\text{ms}$$
$$=(50\times10^{-3})(-1) \qquad 60\,\text{ms}\le t\le 70\,\text{ms}$$
$$=-50\,\text{mV}$$

Step 4 of 4

The waveform for the inductor voltage is shown in Figure 1.

Figure 1

Thus, the voltage across the inductor is determined.

Step 1 of 3

6.034P

Refer to Figure P6.37 in the text book.

The equation of a straight line between the points (x_1, y_1) and (x_2, y_2) in the XY plane is as follows.

$$\frac{y-y_1}{y_2-y_1}=\frac{x-x_1}{x_2-x_1}$$

The equation for the current waveform between the points $(0,0)$ and $(0.3,4)$ is as follows.

$$\frac{y-0}{4-0}=\frac{x-0}{0.3-0}$$
$$y=\frac{4x}{0.3}$$

The equation for the current waveform between the points $(0.3,4)$ and $(0.6,-2)$ is as follows.

$$\frac{y-4}{-2-4}=\frac{x-0.3}{0.6-0.3}$$
$$y-4=\frac{-6(x-0.3)}{0.3}$$
$$=-20x+6$$
$$y=-20x+10$$

The equation for the current waveform between the points $(0.6,-2)$ and $(0.9,-2)$ is as follows.

$$y=-2$$

The equation for the current waveform between the points $(0.9,-2)$ and $(1.1,8)$ is as follows.

$$\frac{y-(-2)}{8-(-2)}=\frac{x-0.9}{1.1-0.9}$$
$$y+2=\frac{10(x-0.9)}{0.2}$$
$$=50x-45$$
$$y=50x-47$$

The equation for the current waveform for $t \geq 1.1$ is as follows.

$$y=8$$

Here, the planes $y=i$ and $x=t$, the equations for the waveform in the specific time intervals are as follows.

$$i(t)=\begin{cases}\frac{4t}{0.3} & 0 \leq t \leq 0.3\text{s}\\ -20t+10 & 0.3\text{s} \leq t \leq 0.6\text{s}\\ -2 & 0.6\text{s} \leq t \leq 0.9\text{s}\\ 50t-47 & 0.9\text{s} \leq t \leq 1.1\text{s}\\ 8 & t \geq 1.1\text{s}\end{cases}$$

Step 2 of 3

Write the expression for the voltage across the inductor.

$$v(t)=L\frac{di(t)}{dt}$$

Calculate the inductor voltage for the interval $0 \leq t \leq 0.3\text{s}$ by substituting $24\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(24\times10^{-3})\frac{d}{dt}\left(\frac{4t}{0.3}\right) \quad 0 \leq t \leq 0.3\text{s}$$
$$=(24\times10^{-3})\left(\frac{4}{0.3}\right) \quad 0 \leq t \leq 0.3\text{s}$$
$$=320\,\text{mV}$$

Calculate the inductor voltage for interval $0.3\text{s} \leq t \leq 0.6\text{s}$ by substituting $24\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(24\times10^{-3})\frac{d}{dt}(-20t+10) \quad 0.3\text{s} \leq t \leq 0.6\text{s}$$
$$=(24\times10^{-3})(-20) \quad 0.3\text{s} \leq t \leq 0.6\text{s}$$
$$=-480\,\text{mV}$$

Calculate the inductor voltage for the interval $0.6\text{s} \leq t \leq 0.9\text{s}$ by substituting $24\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(24\times10^{-3})\frac{d}{dt}(-2) \quad 0.6\text{s} \leq t \leq 0.9\text{s}$$
$$=(24\times10^{-3})(0) \quad 0.6\text{s} \leq t \leq 0.9\text{s}$$
$$=0$$

Calculate the inductor voltage for the interval $0.9\text{s} \leq t \leq 1.1\text{s}$ by substituting $24\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(24\times10^{-3})\frac{d}{dt}(50t-47) \quad 0.9\text{s} \leq t \leq 1.1\text{s}$$
$$=(24\times10^{-3})(50) \quad 0.9\text{s} \leq t \leq 1.1\text{s}$$
$$=1200\,\text{mV}$$

Calculate the inductor voltage for $t \geq 1.1\text{s}$ by substituting $24\,\text{mH}$ for L.

$$v(t)=L\frac{di(t)}{dt}$$
$$=(24\times10^{-3})\frac{d}{dt}(8) \quad t \geq 1.1\text{s}$$
$$=(24\times10^{-3})(0) \quad t \geq 1.1\text{s}$$
$$=0$$

Step 3 of 3

Draw the waveform for the inductor voltage.

Thus, the voltage waveform is drawn.

Step 1 of 3

Refer to Figure P6.38 in the text book.

Form Figure P6.38, the expression for the current is,

$$\begin{aligned} i(t) &= -0.12\sin\left(\frac{2\pi}{1\times10^{-3}}\right)t \text{ mA} \\ &= -0.12\sin 2000\pi t \text{ mA} \end{aligned}$$

Thus, the expression for the current is $-0.12\sin 2000\pi t \text{ mA}$.

Step 2 of 3

Determine the expression for the voltage across the inductor.

$$v(t) = L\frac{di(t)}{dt}$$

Substitute $-0.12\sin 2000\pi t \text{ mA}$ for $i(t)$ and 4 mH for L .

$$\begin{aligned} v(t) &= \left(4\times10^{-3}\right)\frac{d}{dt}\left(-0.12\sin 2000\pi t \text{ mA}\right) \\ &= -\left(0.48\times10^{-3}\right)\frac{d}{dt}\left(\sin 2000\pi t\right) \text{ mV} \\ &= -\left(0.48\times10^{-3}\right)\left(2000\pi\right)\cdot\cos 2000\pi t \text{ mV} \\ &= -3.02\cos 2000\pi t \text{ mV} \end{aligned}$$

Thus, the expression for the current through the capacitor is $\boxed{-3.02\cos 2000\pi t \text{ mV}}$.

Step 3 of 3

Plot the waveform for voltage across the inductor.

Figure 1

Thus, the required voltage waveform is shown in Figure 1.

Step 1 of 7

The given circuit is,

Step 2 of 7

Step 3 of 7

Inductor value, $L = 2\text{H}$

a) $i(t) = 30\times10^{-3}\text{A}$ $\qquad 1 < t < 2\text{ms}$

$\therefore$ The energy stored in the inductor at $t = 1.5\text{ms}$:

$$w_L(t) = \frac{1}{2}Li^2(t)$$

$$W_L(1.5\text{ms}) = \frac{1}{2}\times2\times(30\times10^{-3})^2$$

$$W_L(1.5\text{ms}) = 9\times10^{-4}$$

$$\boxed{W_L(1.5\text{ms}) = 0.9\text{mJ}}$$

Step 4 of 7

b) $i(t) = 7.5\times10^{-3}\text{A}$ $\qquad t > 7\text{ms}$

$\therefore$ The energy stored in the inductor at $t = 6.25\text{ms}$:

$$w_L(t) = \frac{1}{2}Li^2(t)$$

$$W_L(6.25\text{ms}) = \frac{1}{2}\times2\times(7.5\times10^{-3})^2$$

$$W_L(6.25\text{ms}) = 5.625\times10^{-5}$$

$$\boxed{W_L(6.25\text{ms}) = 56.25\mu\text{J}}$$

Step 5 of 7

c) $i(t) = 30\times10^{-3}\text{A}$ $\qquad 1 < t < 2\text{ms}$

$\therefore$ $v_L(t)$ at $t = 1.5\text{ms}$:

$$v_L(t) = L\frac{di(t)}{dt}$$

$$v_L(1.5\text{ms}) = 2\frac{d}{dt}\left(30\times10^{-3}\right)$$

$$v_L(1.5\text{ms}) = 2(0)$$

$$\boxed{v_L(1.5\text{ms}) = 0\text{V}}$$

Step 6 of 7

d) $i(t) = \dfrac{17.5\times10^{-3}}{2\times10^{-3}}t - 53.75$ $\qquad 5\text{ms} < t < 7\text{ms}$

$\therefore$ $v_L(t)$ at $t = 6.25\text{ms}$:

$$v_L(t) = L\frac{di(t)}{dt}$$

$$v_L(6.25\text{ms}) = 2\frac{d}{dt}\left(\frac{17.5\times10^{-3}}{2\times10^{-3}}t - 53.75\right)$$

$$v_L(6.25\text{ms}) = 2(8.75)$$

$$\boxed{v_L(6.25\text{ms}) = 17.5\text{V}}$$

Step 7 of 7

e) $i(t) = \dfrac{-40\times10^{-3}}{2\times10^{-3}}t + 70$ $\qquad 2\text{ms} < t < 4\text{ms}$

$\therefore$ $v_L(t)$ at $t = 2.75\text{ms}$:

$$v_L(t) = L\frac{di(t)}{dt}$$

$$v_L(2.75\text{ms}) = 2\frac{d}{dt}\left(\frac{-40\times10^{-3}}{2\times10^{-3}}t + 70\right)$$

$$v_L(2.75\text{ms}) = 2(-20)$$

$$\boxed{v_L(2.75\text{ms}) = -40\text{V}}$$

Step 1 of 4

Refer to Figure P6.43 in the text book.

Since the circuit is connected with the dc current source, the capacitor is open-circuit and the inductor is short-circuited. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The current through the 50Ω resistor is equal to the current through the inductor.

Apply current division rule and calculate the current through the inductor.

$$\begin{aligned} i_L &= \frac{200}{200+50}(1\text{ A}) \\ &= 0.8\text{ A} \end{aligned}$$

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate energy stored in the inductor by substituting $0.8\text{ A for } i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}(L)(0.8)^2 \\ &= 0.32L\text{ J} \end{aligned}$$

Step 3 of 4

Apply current division rule and calculate the current through the 200Ω resistor.

$$\begin{aligned} i_{200} &= \frac{50}{200+50}(1\text{ A}) \\ &= 0.2\text{ A} \end{aligned}$$

Since 200Ω resistor is parallel to the capacitor, the voltage across the 200Ω resistor is equal to the voltage across the capacitor.

Write the expression for the voltage across the resistor.

$$v_C = i_{200}R$$

Calculate the voltage across the capacitor by by substituting $0.8\text{ A for } i(t)$ and $200\Omega.\text{ for } R$

$$\begin{aligned} v_C &= i_{200}R \\ &= (0.2\text{ A})(200\Omega) \\ &= 40\text{ V} \end{aligned}$$

Write the expression for the energy stored in the capacitor.

$$w_C(t) = \frac{1}{2}Cv^2(t)$$

Calculate energy stored in the capacitor by substituting $80\mu\text{F for } C$ and $40\text{ V for } v$

$$\begin{aligned} w_C(t) &= \frac{1}{2}Cv^2(t) \\ &= \frac{1}{2}(80\times10^{-6})(40)^2 \\ &= 64\text{ mJ} \end{aligned}$$

Step 4 of 4

Write the expression for the total energy.

$$\begin{aligned} w &= w_L(t) + w_C(t) \\ 80 &= 0.32L + 64 \\ L &= \frac{80\text{ mJ} - 64\text{ mJ}}{0.32} \\ &= 50\text{ mH} \end{aligned}$$

Therefore, the value of inductor is $\boxed{50\text{ mH}}$.

Step 1 of 4

Refer to Figure P6.44 in the text book.

Since the circuit is connected with the dc voltage source, the capacitor is open circuit and the inductor is short-circuited. Then the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 4

The current through the resistors is equal to the current through the inductor.

Apply ohm's law, calculate the current through the inductor.

$$\begin{aligned} i_L &= \frac{12\,\text{V}}{200\,\Omega + 100\,\Omega} \\ &= 0.04\,\text{A} \end{aligned}$$

Write the expression for the energy stored in the inductor.

$$w_L(t) = \frac{1}{2}Li^2(t)$$

Calculate energy stored in the inductor by substituting $0.04\,\text{A}$ for $i(t)$.

$$\begin{aligned} w_L(t) &= \frac{1}{2}Li^2(t) \\ &= \frac{1}{2}(0.1)(0.04)^2 \\ &= 80\,\mu\text{J} \end{aligned}$$

Step 3 of 4

Since $200\,\Omega$ resistor is parallel to the capacitor, the voltage across the $200\,\Omega$ resistor is equal to the voltage across the capacitor.

Write the expression for the voltage across the resistor.

$$v_C = i_{200}R$$

Calculate the voltage across the capacitor by substituting $0.04\,\text{A}$ for $i(t)$ and $200\,\Omega$. for R

$$\begin{aligned} v_C &= i_{200}R \\ &= (0.04\,\text{A})(200\,\Omega) \\ &= 8\,\text{V} \end{aligned}$$

Write the expression for the energy stored in the capacitor.

$$w_C(t) = \frac{1}{2}Cv^2(t)$$

Calculate energy stored in the capacitor by substituting $40\,\text{V}$ for v

$$\begin{aligned} w_C(t) &= \frac{1}{2}Cv^2(t) \\ &= \frac{1}{2}(C)(8)^2 \\ &= 32C\,\text{J} \end{aligned}$$

Step 4 of 4

The energy stored in the capacitor is equal to the energy stored in the inductor.

Equate both energies.

$$\begin{aligned} w_C(t) &= w_L(t) \\ 32C &= 80\,\mu\text{J} \\ C &= \frac{80\,\mu\text{J}}{32} \\ &= 2.5\,\mu\text{F} \end{aligned}$$

Therefore, the value of capacitor is $\boxed{2.5\,\mu\text{F}}$.

Step 1 of 8

The three capacitor values given are: $4\mu F, 6\mu F, 12\mu F$

We can obtain 8 different values by interconnecting the above capacitors,

1) When the capacitors $4\mu F, 6\mu F$ and $12\mu F$ are connected in series the equivalent capacitance is,

$$C_1 = 4\mu \| 6\mu \| 12\mu$$

$$C_1 = 4\mu \| \frac{6\mu \times 12\mu}{6\mu + 12\mu}$$

$$C_1 = 4\mu \| 4\mu$$

$$C_1 = \frac{4\mu \times 4\mu}{4\mu + 4\mu}$$

$$\boxed{C_1 = 2\mu F}$$

Step 2 of 8

2) When the capacitors $6\mu F, 12\mu F$ are connected in parallel and this is connected with the $4\mu F$ in series the equivalent capacitance is,

$$C_2 = (6\mu + 12\mu) \| 4\mu$$

$$C_2 = 18\mu \| 4\mu$$

$$C_2 = \frac{18\mu \times 4\mu}{18\mu + 4\mu}$$

$$\boxed{C_2 = 3.27\mu F}$$

Step 3 of 8

3) When the capacitors $12\mu F, 4\mu F$ are connected in parallel and this is connected with the $6\mu F$ in series the equivalent capacitance is,

$$C_3 = (12\mu + 4\mu) \| 6\mu$$

$$C_3 = 16\mu \| 6\mu$$

$$C_3 = \frac{16\mu \times 6\mu}{16\mu + 6\mu}$$

$$\boxed{C_3 = 4.36\mu F}$$

Step 4 of 8

4) When the capacitors $4\mu F, 6\mu F$ are connected in parallel and this is connected with the $12\mu F$ in series the equivalent capacitance is,

$$C_4 = (4\mu + 6\mu) \| 12\mu$$

$$C_4 = 10\mu \| 12\mu$$

$$C_4 = \frac{10\mu \times 12\mu}{10\mu + 12\mu}$$

$$\boxed{C_4 = 5.45\mu F}$$

Step 5 of 8

5) When the capacitors $6\mu F, 12\mu F$ are connected in series and this is connected with the $4\mu F$ in parallel the equivalent capacitance is,

$$C_5 = 4\mu + (6\mu \| 12\mu)$$

$$C_5 = 4\mu + \left(\frac{6\mu \times 12\mu}{6\mu + 12\mu}\right)$$

$$C_5 = 4\mu + 4\mu$$

$$\boxed{C_5 = 8\mu F}$$

Step 6 of 8

6) When the capacitors $12\mu F, 4\mu F$ are connected in series and this is connected with the $6\mu F$ in parallel the equivalent capacitance is,

$$C_6 = 6\mu + (12\mu \| 4\mu)$$

$$C_6 = 6\mu + \left(\frac{12\mu \times 4\mu}{12\mu + 4\mu}\right)$$

$$C_6 = 6\mu + 3\mu$$

$$\boxed{C_6 = 9\mu F}$$

Step 7 of 8

7) When the capacitors $4\mu F, 6\mu F$ are connected in series and this is connected with the $12\mu F$ in parallel the equivalent capacitance is,

$$C_7 = 12\mu + (4\mu \| 6\mu)$$

$$C_7 = 12\mu + \left(\frac{4\mu \times 6\mu}{4\mu + 6\mu}\right)$$

$$C_7 = 12\mu + 2.4\mu$$

$$\boxed{C_7 = 14.4\mu F}$$

Step 8 of 8

8) When the capacitors $4\mu F, 6\mu F$ and $12\mu F$ are connected in parallel the equivalent capacitance is,

$$C_8 = 4\mu + 6\mu + 12\mu$$

$$\boxed{C_8 = 22\mu F}$$

Step 1 of 2

6.040P

Four $2\mu F$ capacitors are given.

The maximum value of capacitance can be obtained by interconnecting these four capacitors in parallel combination.

$\therefore$ Equivalent capacitance in case of parallel combination

$$C_{max} = 2\mu + 2\mu + 2\mu + 2\mu$$

$$\boxed{C_{max} = 8\mu F}$$

Step 2 of 2

The minimum value of capacitance can be obtained by interconnecting these four capacitors in series combination.

$\therefore$ Equivalent capacitance in case of series combination

$$C_{min} = 2\mu \parallel 2\mu \parallel 2\mu \parallel 2\mu$$

$$C_{min} = \frac{2\mu \times 2\mu}{2\mu + 2\mu} \parallel \frac{2\mu \times 2\mu}{2\mu + 2\mu}$$

$$C_{min} = 1\mu \parallel 1\mu$$

$$C_{min} = \frac{1\mu \times 1\mu}{1\mu + 1\mu}$$

$$\boxed{C_{min} = 0.5\mu F}$$

Step 1 of 8

The three inductor values given are: 4mH,6mH,12mH

We can obtain 8 different values by interconnecting the above inductors,

1) When the inductors 4mH,6mH,12mH are connected in parallel the equivalent inductance is,

$$L_1 = 4\text{m}||6\text{m}||12\text{m}$$

$$L_1 = 4\text{m}||\frac{6\text{m}\times 12\text{m}}{6\text{m}+12\text{m}}$$

$$L_1 = 4\text{m}||4\text{m}$$

$$L_1 = \frac{4\text{m}\times 4\text{m}}{4\text{m}+4\text{m}}$$

$$\boxed{L_1 = 2\text{mH}}$$

Step 2 of 8

2) When the inductors 6mH,12mH are connected in series and this is connected with the 4mH in parallel the equivalent inductance is,

$$L_2 = (6\text{m}+12\text{m})||4\text{m}$$

$$L_2 = 18\text{m}\,||\,4\text{m}$$

$$L_2 = \frac{18\text{m}\times 4\text{m}}{18\text{m}+4\text{m}}$$

$$\boxed{L_2 = 3.27\text{mH}}$$

Step 3 of 8

3) When the inductors 12mH,4mH are connected in series and this is connected with the 6mH in parallel the equivalent inductance is,

$$L_3 = (12\text{m}+4\text{m})\,||\,6\text{m}$$

$$L_3 = 16\text{m}\,||\,6\text{m}$$

$$L_3 = \frac{16\text{m}\times 6\text{m}}{16\text{m}+6\text{m}}$$

$$\boxed{L_3 = 4.36\text{mH}}$$

Step 4 of 8

4) When the inductors 4mH,6mH are connected in series and this is connected with the 12mH in parallel the equivalent inductance is,

$$L_4 = (4\text{m}+6\text{m})\,||\,12\text{m}$$

$$L_4 = 10\text{m}\,||\,12\text{m}$$

$$L_4 = \frac{10\text{m}\times 12\text{m}}{10\text{m}+12\text{m}}$$

$$\boxed{L_4 = 5.45\text{mH}}$$

Step 5 of 8

5) When the inductors 6mH,12mH are connected in parallel and this is connected with the 4mH in series the equivalent inductance is,

$$L_5 = 4\text{m}+(6\text{m}||12\text{m})$$

$$L_5 = 4\text{m}+\left(\frac{6\text{m}\times 12\text{m}}{6\text{m}+12\text{m}}\right)$$

$$L_5 = 4\text{m}+4\text{m}$$

$$\boxed{L_5 = 8\text{mH}}$$

Step 6 of 8

6) When the inductors 12mH,4mH are connected in parallel and this is connected with the 6mH in series the equivalent inductance is,

$$L_6 = 6\text{m}+(12\text{m}||4\text{m})$$

$$L_6 = 6\text{m}+\left(\frac{12\text{m}\times 4\text{m}}{12\text{m}+4\text{m}}\right)$$

$$L_6 = 6\text{m}+3\text{m}$$

$$\boxed{L_6 = 9\text{mH}}$$

Step 7 of 8

7) When the inductors 4mH,6mH are connected in parallel and this is connected with the 12mH in series the equivalent inductance is,

$$L_7 = 12\text{m}+(4\text{m}||6\text{m})$$

$$L_7 = 12\text{m}+\left(\frac{4\text{m}\times 6\text{m}}{4\text{m}+6\text{m}}\right)$$

$$L_7 = 12\text{m}+2.4\text{m}$$

$$\boxed{L_7 = 14.4\text{mH}}$$

Step 8 of 8

8) When the inductors 4mH,6mH and 12mH are connected in series the equivalent inductance is,

$$L_8 = 4\text{m}+6\text{m}+12\text{m}$$

$$\boxed{L_8 = 22\text{mH}}$$

Step 1 of 2

6.042P

Four 4mH capacitors are given.
The maximum value of inductance can be obtained by interconnecting these four inductors in series combination.
∴ Equivalent inductance in case of series combination

$$L_{max} = 4m + 4m + 4m + 4m$$

$$\boxed{L_{max} = 16mH}$$

Step 2 of 2

The minimum value of inductance can be obtained by interconnecting these four inductors in parallel combination.
∴ Equivalent inductance in case of parallel combination

$$L_{min} = 4m \parallel 4m \parallel 4m \parallel 4m$$

$$L_{min} = \frac{4m \times 4m}{4m + 4m} \parallel \frac{4m \times 4m}{4m + 4m}$$

$$L_{min} = 2m \parallel 2m$$

$$L_{min} = \frac{2m \times 2m}{2m + 2m}$$

$$\boxed{L_{min} = 1mH}$$

Step 1 of 2

6.043P

The three inductors are of values: 6mH,9mH,18mH

Yes, these three inductors can be interconnected to obtain an equivalent 12mH inductor.

This is possible when the 9mH and 18mH inductors are connected in parallel combination and this parallel combination is then connected in series with the 6mH inductor.

In this case, the equivalent inductance,

$$L = 6\text{m} + \frac{9\text{m} \times 18\text{m}}{9\text{m} + 18\text{m}}$$

$$L = 6\text{m} + \frac{9\text{m} \times 18\text{m}}{27\text{m}}$$

$$L = 6\text{m} + 6\text{m}$$

$$L = 12\text{mH}$$

Step 2 of 2

The required circuit is shown below:

Step 1 of 5

Refer to Figure P6.45 in the text book.

For a DC source, the inductors are short-circuited and the capacitor is open-circuited. Apply superposition principle to the circuit, by acting only voltage source, the current source is open-circuited is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Ohms law, calculate the current through the 3Ω resistor.

$$I' = \frac{12\,\text{V}}{3\Omega + 6\Omega}$$
$$= 1.33\,\text{A}$$

Consider the current source and short-circuit the voltage source as shown in Figure 2.

Figure 2

Step 3 of 5

Apply current division rule, calculate the current through the 3Ω resistor.

$$I'' = \frac{6\Omega}{3\Omega + 6\Omega}(6\,\text{A})$$
$$= 4\,\text{A}$$

Write the expression for the current through 3Ω resistor.

$$I = I' - I''$$

Calculate the current I by substituting $1.33\,\text{A}$ for I' and $4\,\text{A}$ for I''.

$$I = I' - I''$$
$$= 1.33\,\text{A} - 4\,\text{A}$$
$$= -2.67\,\text{A}$$

Step 4 of 5

Write the expression for the power dissipated in the 3Ω resistor.

$$P = I^2(3\Omega)$$

Calculate the power dissipated in the 3Ω resistor by substituting $-2.67\,\text{A}$ for I.

$$P = (-2.67\,\text{A})^2(3\Omega)$$
$$= 21.38\,\text{W}$$

Therefore, the power dissipated in the 3Ω resistor is $\boxed{21.38\,\text{W}}$.

Step 5 of 5

Since the 2 H inductor is short-circuited, the voltage across the capacitor is 12 V.

Write the expression for the energy stored in the capacitor.

$$W = \frac{1}{2}CV_C^2$$

Calculate the energy stored in the capacitor by substituting $2\,\text{F}$ for C and $12\,\text{V}$ for V_C.

$$W = \frac{1}{2}(2\,\text{F})(12\,\text{V})^2$$
$$= 144\,\text{J}$$

Therefore, the energy stored in the capacitor is $\boxed{144\,\text{J}}$.

Step 1 of 7

Refer to the Figure P6.45 in the text book.

The capacitors $4\,\mu F$ and $2\,\mu F$ are in parallel.

$$\begin{aligned} C_{eq} &= 4\,\mu F + 2\,\mu F \\ &= 6\,\mu F \end{aligned}$$

The capacitors $4\,\mu F$ and $4\,\mu F$ are in series.

$$\begin{aligned} C_{eq} &= \frac{(4\,\mu F)(4\,\mu F)}{4\,\mu F + 4\,\mu F} \\ &= \frac{16\,\mu F}{8} \\ &= 2\,\mu F \end{aligned}$$

Step 2 of 7

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 7

From Figure 1, it is observed that, the capacitors $6\,\mu F$ and $3\,\mu F$ are in series.

$$\begin{aligned} C_{eq} &= \frac{(6\,\mu F)(3\,\mu F)}{6\,\mu F + 3\,\mu F} \\ &= \frac{18\,\mu F}{9} \\ &= 2\,\mu F \end{aligned}$$

Step 4 of 7

The modified circuit diagram of Figure 1is shown in Figure 2.

Figure 2

Step 5 of 7

From Figure 3, it is observed that the capacitors $2\,\mu F$ and $2\,\mu F$ are in parallel.

$$\begin{aligned} C_{eq} &= 2\,\mu F + 2\,\mu F \\ &= 4\,\mu F \end{aligned}$$

Step 6 of 7

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 7 of 7

From Figure 3, it is observed that the capacitors $3\,\mu F$ and $4\,\mu F$ are in series.

$$\begin{aligned} \frac{1}{C_T} &= \frac{1}{3\,\mu F} + \frac{1}{4\,\mu F} \\ &= \frac{7}{12\,\mu F} \end{aligned}$$

$$C_T = 1.714\,\mu F$$

Therefore, the total capacitance in the network is $\boxed{1.714\,\mu F}$.

Step 1 of 10

Refer to the Figure P6.46 in the text book.

The capacitors 12 and 6 are in series.

$$C_{eq} = \frac{(12)(6)}{12+6}$$
$$= \frac{72}{18}$$
$$= 4$$

The capacitors 8 and 4 are in parallel.

$$C_{eq} = 8+4$$
$$= 12$$

Step 2 of 10

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 10

Determine the equivalent capacitance between 4 and 12 using Figure 1.

The capacitors 4 and 12 are in series.

$$C_{eq} = \frac{(12)(4)}{12+4}$$
$$= \frac{48}{16}$$
$$= 3$$

Step 4 of 10

The modified circuit diagram of Figure 1is shown in Figure 2.

Figure 2

Step 5 of 10

Determine the equivalent capacitance between 3 and 3 using Figure 2.

The capacitors 3and 3 are in parallel.

$$C_{eq} = 3+3$$
$$= 6$$

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 6 of 10

Determine the equivalent capacitance between 6 and 3 using Figure 3.

The capacitors 6and 3 are in series.

$$C_{eq} = \frac{(6)(3)}{6+3}$$
$$= \frac{18}{9}$$
$$= 2$$

Step 7 of 10

The modified circuit diagram of Figure 3 is shown in Figure 4.

Figure 4

Step 8 of 10

Determine the equivalent capacitance between 4 and 2 using Figure 4.

The capacitors 4 and 2 are in parallel.

$$C_{eq} = 4+2$$
$$= 6$$

Step 9 of 10

The modified circuit diagram of Figure 4 is shown in Figure 5.

Figure 5

Step 10 of 10

Determine the equivalent capacitance between 6 and 6 using Figure 5.

The capacitors 6 and 6 are in series.

$$C_T = \frac{(6)(6)}{6+6}$$
$$= \frac{36}{12}$$
$$= 3$$

Therefore, the total capacitance in the network is $\boxed{3\mu F}$.

Step 1 of 3

6.047P

Refer to Figure P6.49 in the text book.

Identify the parallel branches in the circuit.

Figure 1

Calculate the equivalent value of parallel connected capacitors.

$$C_1 = 1\mu + 2\mu + 3\mu$$
$$= 6\mu F$$

Therefore, the equivalent value of the parallel connected capacitors is $6\mu F$.

Step 2 of 3

Then the simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 3

The capacitors $4\mu F$ and $6\mu F$ are in series and the resultant is in parallel with $12\mu F$ capacitor. Calculate the value of the total capacitance.

$$C_T = \frac{(4\mu)(6\mu)}{(4\mu)+(6\mu)} + 12\mu$$
$$= 2.4\mu F + 12\mu F$$
$$= 14.4\mu F$$

Therefore, the value of the total capacitance of the circuit is $\boxed{14.4\mu F}$.

Step 1 of 3

6.048P

Refer to Figure P6.51 in the text book.

When *N* numbers of capacitors are connected in parallel, write the expression for the equivalent capacitance.

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, write the expression for the equivalent capacitance.

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $6\mu F \text{ and } 3\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned}\frac{1}{C_{6,3}} &= \frac{1}{C_6} + \frac{1}{C_3} \\ &= \frac{1}{6} + \frac{1}{3} \\ &= \frac{1+2}{6} \\ C_{6,3} &= 2\mu F\end{aligned}$$

The capacitors $6\mu F \text{ and } 12\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned}\frac{1}{C_{6,12}} &= \frac{1}{C_6} + \frac{1}{C_{12}} \\ &= \frac{1}{6} + \frac{1}{12} \\ &= \frac{2+1}{12} \\ C_{6,12} &= 4\mu F\end{aligned}$$

This $4\mu F$ capacitor is in parallel with $8\mu F$ capacitor. Calculate their equivalent capacitance.

$$\begin{aligned}C_{4,8} &= C_4 + C_8 \\ &= 4 + 8 \\ &= 12\mu F\end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The capacitors $12\mu F \text{ and } 2\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned}\frac{1}{C_{12,2}} &= \frac{1}{C_{12}} + \frac{1}{C_2} \\ &= \frac{1}{12} + \frac{1}{2} \\ &= \frac{1+6}{12} \\ C_{12,2} &= \frac{12}{7}\mu F\end{aligned}$$

This $\frac{12}{7}\mu F$ capacitor is in parallel with $4\mu F$ capacitor. Calculate their equivalent capacitance.

$$\begin{aligned}C_T &= C_{\frac{12}{7}} + C_4 \\ &= \frac{12}{7} + 4 \\ &= \frac{12+28}{7} \\ &= 5.7\mu F\end{aligned}$$

Therefore, the total capacitance is $\boxed{5.7\mu F}$.

Step 1 of 3

Refer to Figure P6.53 in the text book.

When *N* numbers of capacitors are connected in parallel, the equivalent capacitance can be written as follows:

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, the equivalent capacitance can be written as follows:

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $6\,\mu\text{F and } 12\,\mu\text{F}$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned}\frac{1}{C_{6,12}} &= \frac{1}{C_6} + \frac{1}{C_{12}} \\ &= \frac{1}{6} + \frac{1}{12} \\ &= \frac{2+1}{12} \\ C_{6,12} &= 4\,\mu\text{F}\end{aligned}$$

The capacitors $6\,\mu\text{F and } 3\,\mu\text{F}$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned}\frac{1}{C_{6,3}} &= \frac{1}{C_6} + \frac{1}{C_3} \\ &= \frac{1}{6} + \frac{1}{3} \\ &= \frac{1+2}{6} \\ C_{6,3} &= 2\,\mu\text{F}\end{aligned}$$

This $2\,\mu\text{F}$ capacitor is in parallel with $5\,\mu\text{F}$ capacitor, their equivalent capacitance is as follows:

$$\begin{aligned}C_{2,5} &= C_2 + C_5 \\ &= 2+5 \\ &= 7\,\mu\text{F}\end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The $7\,\mu\text{F and } 11\,\mu\text{F}$ capacitors are in parallel, their equivalent total capacitance is as follows:

$$\begin{aligned}C_{7,11} &= C_7 + C_{11} \\ &= 7+11 \\ &= 18\,\mu\text{F}\end{aligned}$$

This $18\,\mu\text{F}$ capacitor is in series with $9\,\mu\text{F}$ capacitor, their equivalent capacitance is as follows:

$$\begin{aligned}\frac{1}{C_{18,9}} &= \frac{1}{C_{18}} + \frac{1}{C_9} \\ &= \frac{1}{18} + \frac{1}{9} \\ &= \frac{1+2}{18} \\ C_{18,9} &= 6\,\mu\text{F}\end{aligned}$$

This $6\,\mu\text{F}$ capacitor is in parallel with $4\,\mu\text{F}$ capacitor, their equivalent total capacitance is as follows:

$$\begin{aligned}C_T &= C_6 + C_4 \\ &= 6+4 \\ &= 10\,\mu\text{F}\end{aligned}$$

Therefore, the total capacitance C_T in the circuit is $\boxed{10\,\mu\text{F}}$.

Step 1 of 3

6.050P

Refer to Figure P6.54 in the text book.

When *N* numbers of capacitors are connected in parallel, write the expression for the equivalent capacitance.

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, write the expression for the equivalent capacitance.

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $3\mu F \text{ and } 4\mu F$ are connected in parallel. Calculate their equivalent capacitance.

$$\begin{aligned} C_{3,4} &= C_3 + C_4 \\ &= 3 + 4 \\ &= 7\mu F \end{aligned}$$

The capacitors $3\mu F \text{ and } 3\mu F$ are connected in parallel. Calculate their equivalent capacitance.

$$\begin{aligned} C_{3,3} &= C_3 + C_3 \\ &= 3 + 3 \\ &= 6\mu F \end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The capacitors $7\mu F \text{ and } 6\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned} \frac{1}{C_{7,6}} &= \frac{1}{C_7} + \frac{1}{C_6} \\ &= \frac{1}{7} + \frac{1}{6} \\ &= \frac{6+7}{42} \\ C_{7,6} &= 3.23\mu F \end{aligned}$$

The capacitors $12\mu F \text{ and } 6\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned} \frac{1}{C_{12,6}} &= \frac{1}{C_{12}} + \frac{1}{C_6} \\ &= \frac{1}{12} + \frac{1}{6} \\ &= \frac{1+2}{12} \\ C_{12,6} &= 4\mu F \end{aligned}$$

This $4\mu F$ capacitor is in parallel with $3.23\mu F$ capacitor. Calculate their equivalent capacitance.

$$\begin{aligned} C_T &= C_4 + C_{3.23} \\ &= 4 + 3.23 \\ &= 7.23\mu F \end{aligned}$$

Therefore, the total capacitance is $\boxed{7.23\mu F}$.

Step 1 of 3

6.051P

Refer to Figure P6.54 in the text book.

When *N* numbers of capacitors are connected in parallel, write the expression for the equivalent capacitance.

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, write the expression for the equivalent capacitance.

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $3\mu F \text{ and } 4\mu F$ are connected in parallel. Calculate their equivalent capacitance.

$$\begin{aligned} C_{3,4} &= C_3 + C_4 \\ &= 3 + 4 \\ &= 7\mu F \end{aligned}$$

The capacitors $3\mu F \text{ and } 3\mu F$ are connected in parallel. Calculate their equivalent capacitance.

$$\begin{aligned} C_{3,3} &= C_3 + C_3 \\ &= 3 + 3 \\ &= 6\mu F \end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The capacitors $7\mu F \text{ and } 6\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned} \frac{1}{C_{7,6}} &= \frac{1}{C_7} + \frac{1}{C_6} \\ &= \frac{1}{7} + \frac{1}{6} \\ &= \frac{6+7}{42} \\ C_{7,6} &= 3.23\mu F \end{aligned}$$

The capacitors $12\mu F \text{ and } 6\mu F$ are in series. Calculate their equivalent capacitance.

$$\begin{aligned} \frac{1}{C_{12,6}} &= \frac{1}{C_{12}} + \frac{1}{C_6} \\ &= \frac{1}{12} + \frac{1}{6} \\ &= \frac{1+2}{12} \\ C_{12,6} &= 4\mu F \end{aligned}$$

This $4\mu F$ capacitor is in parallel with $3.23\mu F$ capacitor. Calculate their equivalent capacitance.

$$\begin{aligned} C_T &= C_4 + C_{3.23} \\ &= 4 + 3.23 \\ &= 7.23\mu F \end{aligned}$$

Therefore, the total capacitance is $\boxed{7.23\mu F}$.

Step 1 of 7

6.052P

Refer to Figure P6.62 in the text book.

Identify the parallel branches in the circuit.

Figure 1

Step 2 of 7

Calculate the equivalent value of parallel connected capacitors.

$$C_1 = 4\mu F + 2\mu F$$
$$= 6\mu F$$

Therefore, the equivalent value of parallel connected capacitors is $6\mu F$.

Step 3 of 7

Identify the series branches in the circuit.

Figure 2

Step 4 of 7

Calculate the equivalent value of series connected capacitors.

$$C_2 = \frac{(12\mu F)(6\mu F)}{12\mu F + 6\mu F}$$
$$= 4\mu F$$

Therefore, the equivalent value of series connected capacitors is $4\mu F$.

Step 5 of 7

Consider the simplified circuit diagram shown in Figure 3.

Figure 3

Step 6 of 7

The capacitors $6\mu F$ and $4\mu F$ are in series. Calculate the equivalent capacitance.

$$C_3 = \frac{(6\mu F)(4\mu F)}{6\mu F + 4\mu F}$$
$$= 2.4\mu F$$

Therefore, the equivalent value of series connected capacitors is $2.4\mu F$.

The capacitors $8\mu F$ and $4\mu F$ are in parallel. Calculate the equivalent value of parallel connected capacitors.

$$C_4 = 8\mu F + 4\mu F$$
$$= 12\mu F$$

Therefore, the equivalent value of parallel connected capacitors is $12\mu F$.

Then the simplified circuit is shown in Figure 4.

Figure 4

Step 7 of 7

The capacitors $2.4\mu F$ and $12\mu F$ are in series. Calculate the equivalent capacitance.

$$C_5 = \frac{(2.4\mu F)(12\mu F)}{2.4\mu F + 12\mu F}$$
$$= 2\mu F$$

Therefore, the equivalent value of series connected capacitors is $2\mu F$.

This $2\mu F$ is in parallel with $2\mu F$ capacitor. Calculate the total capacitance of the network.

$$C_T = 2\mu F + 4\mu F$$
$$= 4\mu F$$

Therefore, the total capacitance of the circuit is $\boxed{4\mu F}$.

Step 1 of 3

6.053P

Refer to Figure P6.50 in the text book.

When N numbers of capacitors are connected in parallel, the equivalent capacitance can be written as follows:

$$C_p = C_1 + C_2 + ... + C_N$$

When N numbers of capacitors are connected in series, the equivalent capacitance can be written as follows:

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $6\mu F$ and $3\mu F$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned}\frac{1}{C_{6,3}} &= \frac{1}{C_6} + \frac{1}{C_3} \\ &= \frac{1}{6} + \frac{1}{3} \\ &= \frac{1+2}{6} \\ C_{6,3} &= 2\mu F\end{aligned}$$

This $2\mu F$ capacitor is in parallel with $4\mu F$ capacitor, their equivalent capacitance is as follows:

$$\begin{aligned}C_{2,4} &= C_2 + C_4 \\ &= 2+4 \\ &= 6\mu F\end{aligned}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

The capacitors $6\mu F$ and $6\mu F$ are in series, their equivalent capacitance is as follows:

$$\begin{aligned}\frac{1}{C_{6,6}} &= \frac{1}{C_6} + \frac{1}{C_6} \\ &= \frac{1}{6} + \frac{1}{6} \\ &= \frac{1+1}{6} \\ C_{6,6} &= 3\mu F\end{aligned}$$

This $3\mu F$ capacitor is in parallel with $3\mu F$ capacitor, their equivalent total capacitance is as follows:

$$\begin{aligned}C_T &= C_3 + C_3 \\ &= 3+3 \\ &= 6\mu F\end{aligned}$$

Therefore, the total capacitance C_T of the network is $\boxed{6\mu F}$.

Step 1 of 5

Refer to the Figure P6.54 in the text book.

The capacitors $4\,\mu F$ and $2\,\mu F$ are in parallel.

$$\begin{aligned} C_{eq} &= 4\,\mu F + 2\,\mu F \\ &= 6\,\mu F \end{aligned}$$

The capacitors $8\,\mu F$ and $3\,\mu F$ are in series.

$$\begin{aligned} C_{eq} &= \frac{(8\,\mu F)(3\,\mu F)}{8\,\mu F + 3\,\mu F} \\ &= \frac{24\,\mu F}{11} \\ &= 2.18\,\mu F \end{aligned}$$

The capacitors $4\,\mu F$, $4\,\mu F$ and $2\,\mu F$ are in series.

$$\begin{aligned} C_{eq} &= \frac{1}{\left(\frac{1}{4\,\mu F} + \frac{1}{4\,\mu F} + \frac{1}{2\,\mu F}\right)} \\ &= \frac{8\,\mu F}{8} \\ &= 1\,\mu F \end{aligned}$$

Step 2 of 5

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 5

From Figure 1, it is clear that the capacitors $2.18\,\mu F$ and $1\,\mu F$ are in parallel.

$$\begin{aligned} C_{eq} &= 2.18\,\mu F + 1\,\mu F \\ &= 3.18\,\mu F \end{aligned}$$

Step 4 of 5

The modified circuit diagram of Figure 1is shown in Figure 2.

Figure 2

Step 5 of 5

From Figure 2, it is observed that the capacitors $3.18\,\mu F$ and $6\,\mu F$ are in series.

$$\begin{aligned} C_{eq} &= \frac{(3.18\,\mu F)(6\,\mu F)}{3.18\,\mu F + 6\,\mu F} \\ &= \frac{19.08\,\mu F}{9.18} \\ &= 2.07\,\mu F \end{aligned}$$

Therefore, the total capacitance in the network is $\boxed{2.07\,\mu F}$.

Step 1 of 7

Consider Figure P6.63 from the text book.

(a)

When the switch is open, the circuit is labeled as shown in Figure 1.

Figure 1

Step 2 of 7

The capacitors C_1 and C_6 are in series. Calculate the equivalent capacitance by substituting $6\,\mu F$ for C_1 and $12\,\mu F$ for C_2.

$$C_{6,12} = \frac{(6\,\mu F)(12\,\mu F)}{6\,\mu F + 12\,\mu F}$$
$$= 4\,\mu F$$

Therefore, the equivalent value of series connected capacitors is $4\,\mu F$.

The capacitors C_2 and C_4 are in series. Calculate the equivalent capacitance by substituting $12\,\mu F$ for C_2 and $6\,\mu F$ for C_4.

$$C_{12,6} = \frac{(12\,\mu F)(6\,\mu F)}{12\,\mu F + 6\,\mu F}$$
$$= 4\,\mu F$$

Therefore, the equivalent value of series connected capacitors is $4\,\mu F$.

The capacitors C_3 and C_5 are in series. Calculate the equivalent capacitance by substituting $6\,\mu F$ for C_3 and $3\,\mu F$ for C_5.

$$C_{6,3} = \frac{(6\,\mu F)(3\,\mu F)}{6\,\mu F + 3\,\mu F}$$
$$= 2\,\mu F$$

Therefore, the equivalent value of series connected capacitors is $2\,\mu F$.

Then the simplified circuit is shown in Figure 2.

Figure 2

Step 3 of 7

The capacitors $4\,\mu F, 4\,\mu F$ and $2\,\mu F$ are in parallel. Calculate the equivalent value of parallel connected capacitors.

$$C_T = 4\,\mu F + 4\,\mu F + 2\,\mu F$$
$$= 10\,\mu F$$

Therefore, the value of the total capacitance is $\boxed{10\,\mu F}$.

Step 4 of 7

(b)

When the switch is closed, the circuit is labeled as shown in Figure 1.

Figure 3

Step 5 of 7

The capacitors C_1 and C_6 are in series. Calculate the equivalent capacitance by substituting $6\,\mu F$ for C_1 and $12\,\mu F$ for C_2.

$$C_{6,12} = \frac{(6\,\mu F)(12\,\mu F)}{6\,\mu F + 12\,\mu F}$$
$$= 4\,\mu F$$

Step 6 of 7

The capacitors C_2 and C_3 are in parallel. Calculate the equivalent value of parallel connected capacitors by substituting $12\,\mu F$ for C_2 and $6\,\mu F$ for C_3.

$$C = C_2 + C_3$$
$$= 12\,\mu F + 6\,\mu F$$
$$= 18\,\mu F$$

Therefore, the equivalent value of parallel connected capacitors is $18\,\mu F$.

The capacitors C_4 and C_5 are in parallel. Calculate the equivalent value of parallel connected capacitors by substituting $6\,\mu F$ for C_4 and $3\,\mu F$ for C_5.

$$C = C_4 + C_5$$
$$= 6\,\mu F + 3\,\mu F$$
$$= 9\,\mu F$$

Then the simplified circuit is shown in Figure 4.

Figure 4

Step 7 of 7

The capacitors $18\,\mu F$ and $9\,\mu F$ are in series. Calculate the equivalent capacitance.

$$C_{18,9} = \frac{(18\,\mu F)(9\,\mu F)}{18\,\mu F + 9\,\mu F}$$
$$= 6\,\mu F$$

This $6\,\mu F$ capacitor is in parallel with $4\,\mu F$ capacitor. Calculate the equivalent value of parallel connected capacitors.

$$C_T = C_4 + C_6$$
$$= 4\,\mu F + 6\,\mu F$$
$$= 10\,\mu F$$

Therefore, the value of the total capacitance is $\boxed{10\,\mu F}$.

Step 1 of 4

6.058P

Refer to Figure P6.60 in the text book.

When *N* numbers of capacitors are connected in parallel, the equivalent capacitance can be written as follows:

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, the equivalent capacitance can be written as follows:

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $10\mu\text{F and } 2\mu\text{F}$ are in parallel, their equivalent capacitance is as follows.

$$\begin{aligned} C_{10,2} &= C_{10} + C_2 \\ &= 10 + 2 \\ &= 12\mu\text{F} \end{aligned}$$

This $12\mu\text{F}$ is in series with capacitor *C*, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{12,C}} &= \frac{1}{12} + \frac{1}{C} \\ &= \frac{C+12}{12C} \\ C_{12,C} &= \frac{12C}{C+12} \end{aligned}$$

Step 2 of 4

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 4

The capacitance $\frac{12C}{C+12}$ and $3\mu\text{F}$ are in parallel, their equivalent capacitance is as follows.

$$\begin{aligned} C_{\frac{12c}{c+12},3} &= C_{\frac{12c}{c+12}} + C_3 \\ &= \frac{12C}{C+12} + 3 \\ &= \frac{12C + 3C + 36}{C+12} \\ &= \frac{15C + 36}{C+12} \end{aligned}$$

Step 4 of 4

This is in series with $12\mu\text{F}$. Their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{eq}} &= \frac{1}{\frac{15C+36}{C+12}} + \frac{1}{12} \\ &= \frac{C+12}{15C+36} + \frac{1}{12} \\ &= \frac{12C + 144 + 15C + 36}{180C + 432} \\ C_{eq} &= \frac{180C + 432}{27C + 180} \end{aligned}$$

Equate the total capacitance C_T to C_{eq}:

$$\begin{aligned} C_T &= C_{eq} \\ 4 &= \frac{180C + 432}{27C + 180} \\ 180C + 432 &= 108C + 720 \\ C &= 4\mu\text{F} \end{aligned}$$

Therefore, the value of capacitance C is $\boxed{4\mu\text{F}}$.

Step 1 of 2

Consider the circuit shown in Figure 1.

Figure 1

Step 2 of 2

Calculate the value of total capacitance.

$$\begin{aligned} C_T &= 4\mu \parallel (1\mu + 3\mu) \\ &= 4\mu \parallel 4\mu \\ &= \frac{(4\mu)(4\mu)}{4\mu + 4\mu} \\ &= 2\mu\text{F} \end{aligned}$$

Therefore, the total capacitance of the circuit is $\boxed{2\mu\text{F}}$.

Hence, the circuit diagram shown in Figure 1 satisfies the need of total capacitance to be $2\mu\text{F}$ by using $1\mu\text{F}$, $3\mu\text{F}$ and $4\mu\text{F}$.

Step 1 of 2

Refer to Figure P6.64 in the text book.

When *N* numbers of capacitors are connected in parallel, the equivalent capacitance can be writing as follows.

$$C_p = C_1 + C_2 + ... + C_N$$

When *N* numbers of capacitors are connected in series, the equivalent capacitance can be writing as follows.

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

The capacitors $8\mu\text{F and } 16\mu\text{F}$ are in parallel, their equivalent capacitance is as follows.

$$\begin{aligned} C_{8,16} &= C_8 + C_{16} \\ &= 8 + 16 \\ &= 24\mu\text{F} \end{aligned}$$

This $24\mu\text{F}$ is in series with capacitance *C*, their equivalent capacitance is as follows.

$$\begin{aligned} \frac{1}{C_{24,C}} &= \frac{1}{24} + \frac{1}{C} \\ &= \frac{C+24}{24C} \\ C_{24,C} &= \frac{24C}{C+24} \end{aligned}$$

Step 2 of 2

Equate the total capacitance C_T to $C_{24,C}$.

$$\begin{aligned} C_T &= C_{24,C} \\ 10 &= \frac{24C}{C+24} \\ 24C &= 10C + 240 \\ C &= \frac{120}{7}\mu\text{F} \end{aligned}$$

Therefore, the value of capacitance C is $\boxed{\frac{120}{7}\mu\text{F}}$.

Step 1 of 2

Consider Figure P6.65 from the text book.

Calculate the equivalent capacitance of the left branch.

$$C_1 = (1\mu F + 2\mu F) \parallel C$$
$$= \frac{(3\mu F)C}{3\mu F + C}$$

Calculate the equivalent capacitance of the right branch.

$$C_2 = (C + 1\mu F) \parallel C$$
$$= \frac{(C + 1\mu F)(1\mu F)}{(C + 1\mu F) + 1\mu F}$$
$$= \frac{C\mu F + 1pF}{C + 2\mu F}$$

Then the simplified circuit is shown in Figure 1.

Figure 1

Step 2 of 2

Since the capacitors C_1 and C_2 in parallel, calculate the equivalent capacitance.

$$C_T = C_1 + C_2$$
$$1\mu F = \frac{(3\mu F)C}{3\mu F + C} + \frac{C\mu F + 1pF}{C + 2\mu F}$$
$$= \frac{((3\mu F)C)(C + 2\mu F +) + (C\mu F + 1pF)(3\mu F + C)}{(3\mu F + C)(C + 2\mu F)}$$
$$(3\mu F + C)(C + 2\mu F)(1\mu F) = ((3\mu F)C)(C + 2\mu F +) + (C\mu F + 1pF)(3\mu F + C)$$

Further simplification

$$(3\mu F + C)(C + 2\mu F)(1\mu F) = ((3\mu F)C)(C + 2\mu F) + (C\mu F + 1pF)(3\mu F + C)$$
$$3C\,pF + 6\times10^{-18} + C^2\,\mu F + 2C\,pF = 3C^2\,\mu F + 6C\,pF + 3C\,pF + C^2\,\mu F + 3\times10^{-18} + C\,pF$$
$$3C^2\,\mu + 5C\,p - 3\times10^{-18} = 0$$
$$3C^2 + 5\mu C - 3p = 0$$

Further simplification

$$3C^2 + 5\mu C - 3p = 0$$
$$C = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$= \frac{-5\mu \pm \sqrt{(-5\mu)^2 - 4(3C)(-3p)}}{2(3C)}$$
$$= \frac{-5\mu \pm \sqrt{25p + 36p}}{6C}$$

Further simplification

$$C = \frac{-5\mu \pm 7.14\mu}{6}$$
$$= \frac{-5\mu + 7.14\mu}{6} \text{ or } \frac{-5\mu - 7.14\mu}{6}$$
$$= 0.356\,\mu F \text{ or } -2.023\,\mu F$$

Since capacitance value cannot be negative, hence, the capacitance is $0.356\,\mu F$.

Therefore, the value of the capacitance C is $\boxed{0.356\,\mu F}$.

Step 1 of 3

6.062P

Refer to Figure P6.68 in the text book.

Since the two branches are in parallel, the voltage across the first branch is 12 V.

$$V_1 + V_2 = 12\,\text{V}$$

The capacitors $8\,\mu\text{F and } 4\,\mu\text{F}$ are in series. Their equivalent capacitance is as follows.

$$\frac{1}{C_{8,4}} = \frac{1}{C_8} + \frac{1}{C_4}$$

$$\frac{1}{C_{8,4}} = \frac{1}{8} + \frac{1}{4}$$

$$\frac{1}{C_{8,4}} = \frac{1+2}{8}$$

$$\frac{1}{C_{8,4}} = \frac{3}{8}$$

$$C_{8,4} = \frac{8}{3}\,\mu\text{F}$$

Write the expression for the charge through the capacitor.

$$Q = CV$$

Calculate the charge through the first branch by substituting $12\,\text{V for } V \text{ and } \frac{8}{3}\,\mu\text{F for } C$.

$$\begin{aligned} Q &= CV \\ &= \left(\frac{8}{3}\times 10^{-6}\right)(12) \\ &= 32\,\mu\text{C} \end{aligned}$$

Since the capacitors are connected in series, same charge flow through the both capacitors.

Hence, the charge through the series capacitors is $32\,\mu\text{C}$.

Step 2 of 3

Calculate the voltage V_1 by substituting $8\,\mu\text{F for } C \text{ and } 32\,\mu\text{C for } Q$.

$$\begin{aligned} Q &= CV_1 \\ V_1 &= \frac{Q}{C} \\ &= \frac{32\times 10^{-6}}{8\times 10^{-6}} \\ &= 4\,\text{V} \end{aligned}$$

Therefore, the voltage V_1 is $\boxed{4\,\text{V}}$.

Step 3 of 3

Calculate the voltage V_2 by substituting $4\,\mu\text{F for } C \text{ and } 32\,\mu\text{C for } Q$.

$$\begin{aligned} Q &= CV_2 \\ V_2 &= \frac{Q}{C} \\ &= \frac{32\times 10^{-6}}{4\times 10^{-6}} \\ &= 8\,\text{V} \end{aligned}$$

Therefore, the voltage V_2 is $\boxed{8\,\text{V}}$.

Step 1 of 3

Refer to Figure P6.66 in the text book.

The capacitors $12\,\mu\text{F and } 4\,\mu\text{F}$ are in series. Calculate the equivalent capacitance.

$$C_1 = \frac{(12\,\mu\text{F})(4\,\mu\text{F})}{12\,\mu\text{F} + 4\,\mu\text{F}}$$
$$= 3\,\mu\text{F}$$

Therefore, the equivalent value of series connected capacitors is $\boxed{3\,\mu\text{F}}$.

Step 2 of 3

Calculate the value of the initial voltage at the terminals.

$$v_c(0) = -6\,\text{V} + 2\,\text{V}$$
$$= -4\,\text{V}$$

Therefore, the value of the initial voltage at the terminals is $\boxed{-4\,\text{V}}$.

Step 3 of 3

Calculate the value of the total energy stored in the network.

$$W = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$$

Substitute $12\,\mu\text{F}$ for C_1, $4\,\mu\text{F}$ for C_2, -6 V for V_1 and 2 V for V_2.

$$W = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$$
$$= \frac{1}{2}(12\,\mu\text{F})(-6\,\text{V})^2 + \frac{1}{2}(4\,\mu\text{F})(2\,\text{V})^2$$
$$= 216\,\text{J} + 8\,\text{J}$$
$$= 224\,\text{J}$$

Therefore, the total energy stored in the network is $\boxed{224\,\text{J}}$.

Step 1 of 2

6.064P

Refer to Figure P6.67 in the text book.

Write the expression for the charge through the capacitor.

$$Q = CV$$

Calculate the charge through the capacitor by substituting $16\,\text{V}$ for V and $4\,\mu\text{F}$ for C.

$$\begin{aligned} Q &= CV \\ &= \left(4\times10^{-6}\right)(16) \\ &= 64\,\mu\text{C} \end{aligned}$$

Since the capacitors are connected in series, same charge flow through the other capacitor also.

Hence, the charge through the other capacitor C_1 is $64\,\mu\text{C}$.

Step 2 of 2

Calculate the voltage V_0 by substituting $12\,\mu\text{F}$ for C and $64\,\mu\text{C}$ for Q.

$$\begin{aligned} Q &= CV_0 \\ V_0 &= \frac{Q}{C} \\ &= \frac{64\times10^{-6}}{12\times10^{-6}} \\ &= 5.33\,\text{V} \end{aligned}$$

Therefore, the voltage V_0 is $\boxed{5.33\,\text{V}}$.

Step 1 of 5

6.065P

Refer to Figure P6.69 in the text book.

When *N* numbers of inductors are connected in series, the equivalent inductance can be writing as follows.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, the equivalent inductance can be writing as follows.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors $2\,\text{mH and } 4\,\text{mH}$ are in series, their equivalent inductance is as follows:

$$\begin{aligned} L_{2,4} &= L_2 + L_4 \\ &= 2 + 4 \\ &= 6\,\text{mH} \end{aligned}$$

The inductors $4\,\text{mH and } 12\,\text{mH}$ are in parallel, their equivalent inductance is as follows:

$$\frac{1}{L_{4,12}} = \frac{1}{L_4} + \frac{1}{L_{12}}$$

$$\frac{1}{L_{4,12}} = \frac{1}{4} + \frac{1}{12}$$

$$\frac{1}{L_{4,12}} = \frac{3+1}{12}$$

$$L_{4,12} = \frac{12}{4}$$

$$L_{4,12} = 3\,\text{mH}$$

Step 2 of 5

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 5

The inductors $3\,\text{mH and } 3\,\text{mH}$ are in series. Their equivalent inductance is as follows:

$$\begin{aligned} L_{3,3} &= L_3 + L_3 \\ &= 3 + 3 \\ &= 6\,\text{mH} \end{aligned}$$

This $6\,\text{mH}$ inductor is in parallel with $6\,\text{mH}$ inductor. Their equivalent inductance is as follows:

$$\frac{1}{L_{6,6}} = \frac{1}{L_6} + \frac{1}{L_6}$$

$$\frac{1}{L_{6,6}} = \frac{1}{6} + \frac{1}{6}$$

$$\frac{1}{L_{6,6}} = \frac{1+1}{6}$$

$$L_{6,6} = \frac{6}{2}$$

$$L_{6,6} = 3\,\text{mH}$$

Step 4 of 5

Then the modified circuit is shown in Figure 2.

Figure 2

Step 5 of 5

The inductors $1\,\text{mH}, 3\,\text{mH and } 2\,\text{mH}$ are in series. Their equivalent inductance is as follows:

$$\begin{aligned} L_{eq} &= L_1 + L_3 + L_2 \\ &= 1 + 3 + 2 \\ &= 6\,\text{mH} \end{aligned}$$

Therefore, the equivalent inductance between the terminals *A-B* is $\boxed{6\,\text{mH}}$.

Step 1 of 8

Refer to the circuit diagram in Figure P6.66 in the textbook.

The Inductors $4\ \text{mH}$ and $5\ \text{mH}$ are in series.

The equivalent inductance of the two inductors is,

$$\begin{aligned} L_{eq1} &= 4\ \text{mH} + 5\ \text{mH} \\ &= 9\ \text{mH} \end{aligned}$$

Step 2 of 8

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 8

Determine the equivalent inductance of $9\ \text{mH}$ and $18\ \text{mH}$ inductors.

The inductors $9\ \text{mH}$ and $18\ \text{mH}$ are in parallel.

$$\begin{aligned} \frac{1}{L_{eq2}} &= \frac{1}{9\ \text{mH}} + \frac{1}{18\ \text{mH}} \\ &= \frac{9\ \text{mH} + 18\ \text{mH}}{(9\ \text{mH})(18\ \text{mH})} \end{aligned}$$

Rewrite the equation.

$$\begin{aligned} L_{eq2} &= \frac{(18\ \text{mH})(9\ \text{mH})}{9\ \text{mH} + 18\ \text{mH}} \\ &= \frac{162}{27}\ \text{mH} \\ &= 6\ \text{mH} \end{aligned}$$

Step 4 of 8

The modified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 8

Determine the equivalent inductance of $3\ \text{mH}$ and $6\ \text{mH}$ inductors.

The inductors $3\ \text{mH}$ and $6\ \text{mH}$ are in parallel.

$$\begin{aligned} \frac{1}{L_{eq3}} &= \frac{1}{3\ \text{mH}} + \frac{1}{6\ \text{mH}} \\ &= \frac{3\ \text{mH} + 6\ \text{mH}}{(3\ \text{mH})(6\ \text{mH})} \end{aligned}$$

Rewrite the equation.

$$\begin{aligned} L_{eq3} &= \frac{(3\ \text{mH})(6\ \text{mH})}{3\ \text{mH} + 6\ \text{mH}} \\ &= \frac{18}{9}\ \text{mH} \\ &= 2\ \text{mH} \end{aligned}$$

Step 6 of 8

Determine the equivalent inductance of $12\ \text{mH}$ and $6\ \text{mH}$ inductors.

$$\begin{aligned} \frac{1}{L_{eq4}} &= \frac{1}{12\ \text{mH}} + \frac{1}{6\ \text{mH}} \\ &= \frac{12\ \text{mH} + 6\ \text{mH}}{(12\ \text{mH})(6\ \text{mH})} \end{aligned}$$

Rewrite the equation.

$$\begin{aligned} L_{eq4} &= \frac{(12\ \text{mH})(6\ \text{mH})}{6\ \text{mH} + 12\ \text{mH}} \\ &= \frac{72}{18}\ \text{mH} \\ &= 4\ \text{mH} \end{aligned}$$

Step 7 of 8

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 8 of 8

Determine the equivalent inductance of $2\ \text{mH}$, $2\ \text{mH}$, $4\ \text{mH}$ and $1\ \text{mH}$ inductors.

The Inductors $2\ \text{mH}$, $2\ \text{mH}$, $4\ \text{mH}$ and $1\ \text{mH}$ are in series.

$$\begin{aligned} L_T &= 2\ \text{mH} + 2\ \text{mH} + 4\ \text{mH} + 1\ \text{mH} \\ &= 9\ \text{mH} \end{aligned}$$

Therefore, the total equivalent inductance of the circuit is $\boxed{9\ \text{mH}}$.

Step 1 of 6

Refer to the circuit diagram in Figure P6.67 in the textbook.

The inductors 18 and 9 are in parallel.

$$L_{eq} = \frac{(18)(9)}{18+9}$$
$$= \frac{162}{27}$$
$$= 6 \text{ mH}$$

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Determine the inductance of inductors 3 and 9.

The inductors 3 and 9 are in series.

$$L_{eq} = 3 \text{ mH} + 9 \text{ mH}$$
$$= 12 \text{ mH}$$

The modified circuit diagram of Figure 1 is shown in Figure 2.

Figure 2

Step 3 of 6

Determine the equivalent inductance of inductors 12 and 4.

The inductors 12 and 4 are in parallel.

$$L_{eq} = \frac{(12 \text{ mH})(4 \text{ mH})}{12 \text{ mH} + 4 \text{ mH}}$$
$$= 3 \text{ mH}$$

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 4 of 6

Determine the equivalent inductance of the inductors 3 and 6.
The inductors 3 and 6 are in parallel.

$$L_{eq} = \frac{(3 \text{ mH})(6 \text{ mH})}{3 \text{ mH} + 6 \text{ mH}}$$
$$= 2 \text{ mH}$$

The modified circuit diagram of Figure 3 is shown in Figure 4.

Figure 4

Step 5 of 6

Determine the equivalent inductance of 2 and 6 using Figure 4.

The inductors 2 and 6 are in series.

$$L_{eq} = 2 \text{ mH} + 6 \text{ mH}$$
$$= 8 \text{ mH}$$

The modified circuit diagram of Figure 4 is shown in Figure 5.

Figure 5

Step 6 of 6

Determine the equivalent inductance of 8 and 8 using Figure 5.

The inductors 8 and 8 are in series.

$$L_T = \frac{(8 \text{ mH})(8 \text{ mH})}{8 \text{ mH} + 8 \text{ mH}}$$
$$= 4 \text{ mH}$$

Therefore, the total inductance of the circuit is $\boxed{4 \text{ mH}}$.

Step 1 of 5

Refer to the circuit diagram in Figure P6.68 in the textbook.

From the figure, it is clear that the inductors 1, 2 and 3 are in series.

$$L_{eq} = 1\text{ mH} + 2\text{ mH} + 3\text{ mH}$$
$$= 6\text{ mH}$$

Similarly, inductors 1 and 2 aligned in left side of the circuit are also in series.

$$L_{eq} = 1\text{ mH} + 2\text{ mH}$$
$$= 3\text{ mH}$$

Step 2 of 5

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 5

Determine the equivalent inductance of inductors 12 and 4.

The inductors 12 and 4 are in parallel.

$$L_{eq} = \frac{(12\text{ mH})(4\text{ mH})}{12\text{ mH} + 4\text{ mH}}$$
$$= 3\text{ mH}$$

The modified circuit diagram of Figure 1 is shown in Figure 2.

Figure 2

Step 4 of 5

Determine the equivalent inductance of inductors 6,3 and 3.

The inductors 6, 3 and 3 are in series.

$$L_{eq} = 6\text{ mH} + 3\text{ mH} + 3\text{ mH}$$
$$= 12\text{ mH}$$

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 5 of 5

Determine the equivalent inductance of inductors 6 and 12.

The inductors 12 and 6 are in parallel.

$$L_T = \frac{(12\text{ mH})(6\text{ mH})}{12\text{ mH} + 6\text{ mH}}$$
$$= 4\text{ mH}$$

Therefore, the total inductance of the circuit is $\boxed{4\text{ mH}}$.

Step 1 of 5

6.069P

Refer to the circuit diagram in Figure P6.69 in the textbook.

From the figure, it is clear that the inductors 1, 2 and 3 are in series.

$$\begin{aligned} L_{eq} &= 1\text{ mH} + 2\text{ mH} + 3\text{ mH} \\ &= 6\text{ mH} \end{aligned}$$

Determine the equivalent inductance of inductors 12 and 4.

The inductors 12 and 4 are in parallel.

$$\begin{aligned} L_{eq} &= \frac{(12\text{ mH})(4\text{ mH})}{12\text{ mH} + 4\text{ mH}} \\ &= 3\text{ mH} \end{aligned}$$

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 5

Determine the equivalent inductance of inductors 3 and 9.

The inductors 3 and 9 are in series.

$$\begin{aligned} L_{eq} &= 3\text{ mH} + 9\text{ mH} \\ &= 12\text{ mH} \end{aligned}$$

The modified circuit diagram of Figure 1 is shown in Figure 2.

Figure 2

Step 3 of 5

Determine the equivalent inductance of inductors 12 and 6.

The inductors 12 and 6 are in parallel.

$$\begin{aligned} L_{eq} &= \frac{(12\text{ mH})(6\text{ mH})}{12\text{ mH} + 6\text{ mH}} \\ &= 4\text{ mH} \end{aligned}$$

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 4 of 5

Determine the equivalent inductance of inductors 4 and 2.
The inductors 4 and 2 are in series.

$$\begin{aligned} L_{eq} &= 4\text{ mH} + 2\text{ mH} \\ &= 6\text{ mH} \end{aligned}$$

The modified circuit diagram of Figure 3 is shown in Figure 4.

Figure 4

Step 5 of 5

Determine the equivalent inductance of inductors 6 and 6.

The inductors 6 and 6 are in parallel.

$$\begin{aligned} L_T &= \frac{(6\text{ mH})(6\text{ mH})}{6\text{ mH} + 6\text{ mH}} \\ &= 3\text{ mH} \end{aligned}$$

Therefore, the total inductance of the circuit is $\boxed{3\text{ mH}}$.

Step 1 of 4

6.070P

Refer to Figure P6.70 in the textbook.

Identify the parallel branches in the circuit.

Figure 1

Step 2 of 4

The inductor indicated in red dotted lines is shorted due to short in parallel with it.

Calculate the equivalent value of the parallel connected inductors.

$$\begin{aligned} L &= 12\text{ mH} \parallel 6\text{ mH} \\ &= \frac{(12\text{ mH})(6\text{ mH})}{12\text{ mH}+6\text{ mH}} \\ &= \frac{(12\text{ mH})(6\text{ mH})}{18\text{ mH}} \\ &= 4\text{ mH} \end{aligned}$$

Therefore, the value of equivalent value of the parallel inductors is 4 mH.

Step 3 of 4

Draw the simplified circuit diagram.

Figure 2

Step 4 of 4

Calculate the value of total inductance, L_T.

$$\begin{aligned} L_T &= 4\text{ mH} \parallel (2\text{ mH}+6\text{ mH}) \\ &= 4\text{ mH} \parallel 8\text{ mH} \\ &= \frac{(4\text{ mH})(8\text{ mH})}{(4\text{ mH})+(8\text{ mH})} \\ &= \frac{(4\text{ mH})(8\text{ mH})}{12\text{ mH}} \end{aligned}$$

$$L_T = \frac{8}{3}\text{ mH}$$

Therefore, the value of the total inductance, L_T is $\boxed{\frac{8}{3}\text{ mH}}$.

Step 1 of 3

6.071P

Refer to Figure P6.71 in the text book.

When *N* numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors $5\ \mu\text{H}$, $6\ \mu\text{H}$ and $7\ \mu\text{H}$ are shorted their equivalent inductance is zero.

$$L_{5,6,7} = 0\ \text{H}$$

Step 2 of 3

Then the modified circuit is shown in Figure 1.

Figure 1

Step 3 of 3

From the circuit shown in Figure 1, $2\ \mu\text{H}$ inductor and $4\ \mu\text{H}$ inductor are connected in series and this series is in parallel with $3\ \mu\text{H}$ inductor. Calculate the total inductance.

$$\begin{aligned}\frac{1}{L_T} &= \frac{1}{L_3} + \frac{1}{L_{2,4}} \\ &= \frac{1}{3\ \mu\text{H}} + \frac{1}{2\ \mu\text{H} + 4\ \mu\text{H}} \\ &= \frac{1}{3\ \mu\text{H}} + \frac{1}{6\ \mu\text{H}} \\ &= \frac{2+1}{6\ \mu\text{H}}\end{aligned}$$

$$L_T = 2\ \mu\text{H}$$

Therefore, the total inductance is $\boxed{2\ \mu\text{H}}$.

Step 1 of 10

Refer to Figure P6.78 in the text book.

When *N* numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

(a)

With the switch is open:

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 10

The inductors L_7 and L_8 are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{7,8} &= L_7 + L_8 \\ &= 12\text{ mH} + 12\text{ mH} \\ &= 24\text{ mH} \end{aligned}$$

This 24 mH inductor is in parallel with the L_6 inductor. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{6,7,8}} &= \frac{1}{L_6} + \frac{1}{L_{7,8}} \\ &= \frac{1}{12} + \frac{1}{24} \\ &= \frac{1+2}{24} \end{aligned}$$

$$L_{6,7,8} = 8\text{ mH}$$

The inductors L_2 and L_3 are in parallel. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{2,3}} &= \frac{1}{L_2} + \frac{1}{L_3} \\ &= \frac{1}{12\text{ mH}} + \frac{1}{12\text{ mH}} \\ &= \frac{1+1}{12} \end{aligned}$$

$$L_{2,3} = 6\text{ mH}$$

Step 3 of 10

Then the modified circuit is shown in Figure 2.

Figure 2

Step 4 of 10

The inductors 12 mH and 8 mH are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{eq1} &= 12\text{ mH} + 8\text{ mH} \\ &= 20\text{ mH} \end{aligned}$$

The inductors 12 mH and 6 mH are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{eq2} &= 6\text{ mH} + 12\text{ mH} \\ &= 18\text{ mH} \end{aligned}$$

Step 5 of 10

Then the modified circuit is shown in Figure 3.

Figure 3

Step 6 of 10

Calculate their equivalent inductance.

$$\begin{aligned} L_T &= 12\text{ mH} + (18\text{ mH}) \| (20\text{ mH}) \\ &= 12\text{ mH} + \frac{(18\text{ mH})(20\text{ mH})}{18\text{ mH} + 20\text{ mH}} \\ &= 12\text{ mH} + 9.47\text{ mH} \\ &= 21.47\text{ mH} \end{aligned}$$

Therefore, the total inductance is $\boxed{21.47\text{ mH}}$.

Step 7 of 10

(b)

With the switch is closed, the modified circuit is shown in Figure 4.

Figure 4

Step 8 of 10

The inductors L_7 and L_8 are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_{7,8} &= L_7 + L_8 \\ &= 12\text{ mH} + 12\text{ mH} \\ &= 24\text{ mH} \end{aligned}$$

This 24 mH inductor is in parallel with inductors L_5 and L_6. Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{eq3}} &= \frac{1}{L_5} + \frac{1}{L_6} + \frac{1}{L_{7,8}} \\ &= \frac{1}{12} + \frac{1}{12} + \frac{1}{24} \\ &= \frac{1+2+2}{24} \end{aligned}$$

$$L_{eq3} = 4.8\text{ mH}$$

The inductors L_2, L_3, and L_4 are in parallel, Calculate their equivalent inductance.

$$\begin{aligned} \frac{1}{L_{eq4}} &= \frac{1}{L_2} + \frac{1}{L_3} + \frac{1}{L_4} \\ &= \frac{1}{12\text{ mH}} + \frac{1}{12\text{ mH}} + \frac{1}{12\text{ mH}} \\ &= \frac{1+1+1}{12\text{ mH}} \\ &= \frac{3}{12\text{ mH}} \end{aligned}$$

$$L_{eq4} = 4\text{ mH}$$

Step 9 of 10

The modified circuit is shown in Figure 5.

Figure 5

Step 10 of 10

The inductors 4.8 mH, 4 mH and the 12 mH inductor are in series. Calculate their equivalent inductance.

$$\begin{aligned} L_T &= L_{4.8} + L_4 + L_{12} \\ &= 4.8\text{ mH} + 4\text{ mH} + 12\text{ mH} \\ &= 20.8\text{ mH} \end{aligned}$$

Therefore, the total inductance is $\boxed{20.8\text{ mH}}$.

Step 1 of 5

Refer to the circuit diagram in Figure P6.73 in the textbook.

The inductors 1 and 2 are in series.

$$L_{eq} = 1\text{ mH} + 2\text{ mH}$$
$$= 3\text{ mH}$$

The inductors 2 and 2 are in series.

$$L_{eq} = 2\text{ mH} + 2\text{ mH}$$
$$= 4\text{ mH}$$

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 5

Determine the equivalent inductance of inductors 3 and 6.

The inductors 3 and 6 are in parallel.

$$L_{eq} = \frac{(3\text{ mH})(6\text{ mH})}{3\text{ mH} + 6\text{ mH}}$$
$$= 2\text{ mH}$$

Determine the equivalent inductance of inductors 4 and 4.

The inductors 4 and 4 are in parallel.

$$L_{eq} = \frac{(4\text{ mH})(4\text{ mH})}{4\text{ mH} + 4\text{ mH}}$$
$$= 2\text{ mH}$$

The modified circuit diagram of Figure 1 is shown in Figure 2.

Figure 2

Step 3 of 5

Determine the equivalent inductance of inductors 2 and 2.

The inductors 2 and 2 are in series.

$$L_{eq} = 2\text{ mH} + 2\text{ mH}$$
$$= 4\text{ mH}$$

The modified circuit diagram of Figure 2 is shown in Figure 3.

Figure 3

Step 4 of 5

Determine the equivalent inductance of inductors 12 and 4.
The inductors 12 and 4 are in parallel.

$$L_{eq} = \frac{(12\text{ mH})(4\text{ mH})}{12\text{ mH} + 4\text{ mH}}$$
$$= 3\text{ mH}$$

The modified circuit diagram of Figure 3 is shown in Figure 4.

Figure 4

Step 5 of 5

Determine the equivalent inductance of inductors 1,3 and 1.

The inductors 1, 3 and 1 are in series.

$$L_T = 1\text{ mH} + 3\text{ mH} + 1\text{ mH}$$
$$= 5\text{ mH}$$

Therefore, the total inductance of the circuit is $\boxed{5\text{ mH}}$.

Step 1 of 9

The given circuit is,

Step 2 of 9

Inductors 4mH and 4mH are in parallel.

$$L_P = \frac{4\text{m} \times 4\text{m}}{4\text{m} + 4\text{m}}$$

$$L_P = \frac{16\text{m}}{8}$$

$$L_P = 2\text{mH}$$

Step 3 of 9

Therefore the circuit is reduced as,

Step 4 of 9

Now reducing the circuit

Step 5 of 9

Now 12mH and 12mH are in parallel

$$L_P = \frac{4\text{m} \times 4\text{m}}{4\text{m} + 4\text{m}}$$

$$L_P = \frac{16\text{m}}{8}$$

$$L_P = 2\text{mH}$$

Step 6 of 9

Therefore the circuit is reduced as,

Step 7 of 9

Now 4mH and 2mH are in series and this combination is in parallel with 4mH.

$$L_s = (4\text{m} + 2\text{m}) \| 4\text{m}$$

$$L_s = 6\text{m} \| 4\text{m}$$

$$L_s = \frac{6\text{m} \times 4\text{m}}{6\text{m} + 4\text{m}}$$

$$L_s = \frac{12}{5}\text{mH}$$

Step 8 of 9

Therefore the circuit is reduced as,

Step 9 of 9

$\frac{12}{5}$mH and 2mH are in series therefore the equivalent inductance is,

$$L_{eq} = \frac{12}{5}\text{m} + 2\text{m}$$

$$L_{eq} = \frac{12\text{m} + 10\text{m}}{5}$$

$$\boxed{L_{eq} = \frac{22}{5}\text{mH}}$$

Step 1 of 7

The given circuit is,

Step 2 of 7

The 4mH inductor is parallel to L,

$L_{p1} = 4\text{m} \parallel L$

$L_{p1} = \dfrac{(4\text{m})L}{4\text{m}+L}$

The inductors 2mH and 1mH are in series,

$L_{s1} = 1\text{m} + 2\text{m}$

$L_{s1} = 3\text{mH}$

Step 3 of 7

Therefore the circuit is modified as,

Step 4 of 7

The inductors 3mH and 6mH are in parallel,

$L_{p2} = 3\text{m} \parallel 6\text{m}$

$L_{p2} = \dfrac{3\text{m}\times 6\text{m}}{3\text{m}+6\text{m}}$

$L_{p2} = 2\text{mH}$

Step 5 of 7

Therefore the circuit is modified as,

Step 6 of 7

Hence the equivalent inductance is,

$L_T = L \parallel \left(2\text{m} + \dfrac{(4\text{m})L}{4\text{m}+L}\right)$

$L_T = L \parallel \left(\dfrac{2\text{m}(4\text{m}+L)+(4\text{m})L}{4\text{m}+L}\right)$

$L_T = L \parallel \left(\dfrac{8\mu+(6\text{m})L}{4\text{m}+L}\right)$

$L_T = \dfrac{L\left(\dfrac{8\mu+(6\text{m})L}{4\text{m}+L}\right)}{L+\left(\dfrac{8\mu+(6\text{m})L}{4\text{m}+L}\right)}$

$L_T = \dfrac{L(8\mu+(6\text{m})L)}{L^2+(10m)L+8\mu}$

Step 7 of 7

given $L_T = 2\text{mH}$

$2\text{m} = \dfrac{L(8\mu+(6\text{m})L)}{L^2+(10m)L+8\mu}$

$2\text{m}L^2 + 20\mu L + 16\text{n} = 8\mu L + 6\text{m}L^2$

$4\text{m}L^2 - 12\mu L - 16\text{n} = 0$

$L^2 - 3\text{m}L - 4\mu = 0$

solving the above quadratic equation we get,

$L_1 = 4\text{mH}$

$L_2 = -1\text{mH}$

neglecting the negative value,

$\boxed{L = 4\text{mH}}$

Step 1 of 4

Refer to Figure P6.73 in the textbook.

Represent the values of inductances on the circuit and identify the parallel branches.

Figure 1

Step 2 of 4

Calculate the equivalent inductance of the parallel branches.

$$L = 12\ \mu\text{H} \parallel 12\ \mu\text{H} \parallel 12\ \mu\text{H}$$
$$= \frac{(12\ \mu\text{H})(12\ \mu\text{H})(12\ \mu\text{H})}{(12\ \mu\text{H})(12\ \mu\text{H}) + (12\ \mu\text{H})(12\ \mu\text{H}) + (12\ \mu\text{H})(12\ \mu\text{H})}$$
$$= \frac{(12\ \mu\text{H})^3}{3(12\ \mu\text{H})^2}$$
$$= \frac{12\ \mu\text{H}}{3}$$
$$L = 4\ \mu\text{H}$$

Therefore, the value of equivalent value of the parallel inductors is $4\ \mu\text{H}$.

Step 3 of 4

Draw the simplified circuit diagram.

Figure 2

Step 4 of 4

Calculate the value of total inductance, L_T .

$$L_T = 4\ \mu\text{H} + (12\ \mu\text{H} \parallel 12\ \mu\text{H}) + 4\ \mu\text{H}$$
$$= 8\ \mu\text{H} + \frac{(12\ \mu\text{H})(12\ \mu\text{H})}{(12\ \mu\text{H}) + (12\ \mu\text{H})}$$
$$= 8\ \mu\text{H} + \frac{(12\ \mu\text{H})^2}{24\ \mu\text{H}}$$
$$= 8\ \mu\text{H} + 6\ \mu\text{H}$$
$$L_T = 14\ \mu\text{H}$$

Therefore, the value of the total inductance L_T is $\boxed{14\ \mu\text{H}}$.

Step 1 of 10

Refer to Figure P6.77 in the textbook.

Re-draw the circuit diagram with nodes.

Figure 1

Step 2 of 10

From Figure 1, the nodes C and D are same. The two inductors are in parallel.

Determine the equivalent inductance.

$$L_{eq1} = \frac{(6\text{ mH})(6\text{ mH})}{6\text{ mH}+6\text{ mH}}$$
$$= 3\text{ mH}$$

Step 3 of 10

Re-draw the circuit diagram.

Figure 2

Step 4 of 10

From Figure 2, between the nodes C and F, the inductors 3 mH and 6 mH are in series and between the nodes A and B, the inductors 6 mH and 6 mH are in series.

Re-draw the circuit diagram.

Figure 3

Step 5 of 10

From Figure 3, the inductors 12 mH and 6 mH are in parallel.

Determine the equivalent inductance.

$$L_{eq2} = \frac{(12\text{ mH})(6\text{ mH})}{12\text{ mH}+6\text{ mH}}$$
$$= 4\text{ mH}$$

Step 6 of 10

From Figure 3, the nodes B, C and F are same. There is a short circuit across 9 mH inductor.
Re-draw the circuit diagram.

Figure 4

Step 7 of 10

From Figure 4, the inductors 4 mH and 6 mH are in series.

Re-draw the circuit diagram.

Figure 5

Step 8 of 10

From Figure 5, there is short circuit between nodes H and I.

From Figure 5, between the nodes G and H, the inductors 6 mH and 6 mH are in parallel and between the J and L, the inductors 6 mH and 6 mH are in series.

Determine the parallel inductance.

$$L_{eq3} = \frac{(6\text{ mH})(6\text{ mH})}{6\text{ mH}+6\text{ mH}}$$
$$= 3\text{ mH}$$

Re-draw the circuit diagram.

Figure 6

Step 9 of 10

From Figure 6, the inductors 10 mH and 3 mH are in series.

Re-draw the circuit diagram.

Figure 7

Step 10 of 10

From Figure 7, there is a short across the 13 mH inductor.
Determine the value of total inductance.

$$L_T = 0\text{ H}$$

Therefore, the value of total inductance is $\boxed{0\text{ H}}$

Step 1 of 2

6.078P

Refer to Figure P6.74 in the textbook.

Calculate the value of the total inductance L_T .

$$L_T = 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(\begin{array}{l} \{4\ \mu\text{H} \parallel 4\ \mu\text{H}\} \\ +\{6\ \mu\text{H} \parallel [(6\ \mu\text{H} \parallel 12\ \mu\text{H}) + 2\ \mu\text{H}]\} \\ +1\ \mu\text{H} \end{array} \right) \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(\begin{array}{l} \{4\ \mu\text{H} \parallel 4\ \mu\text{H}\} \\ +\left\{6\ \mu\text{H} \parallel \left[\left(\dfrac{(6\ \mu\text{H})(12\ \mu\text{H})}{6\ \mu\text{H} + 12\ \mu\text{H}} \right) + 2\ \mu\text{H} \right] \right\} \\ +1\ \mu\text{H} \end{array} \right) \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(\begin{array}{l} \{4\ \mu\text{H} \parallel 4\ \mu\text{H}\} \\ +\left\{6\ \mu\text{H} \parallel \left[\left(\dfrac{(6\ \mu\text{H})(12\ \mu\text{H})}{18\ \mu\text{H}} \right) + 2\ \mu\text{H} \right] \right\} \\ +1\ \mu\text{H} \end{array} \right) \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(\begin{array}{l} \{4\ \mu\text{H} \parallel 4\ \mu\text{H}\} \\ +\{6\ \mu\text{H} \parallel [4\ \mu\text{H} + 2\ \mu\text{H}]\} \\ +1\ \mu\text{H} \end{array} \right) \right] \right\}$$

Step 2 of 2

Simplify the calculations.

$$L_T = 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(\left\{ \frac{(4\ \mu\text{H})(4\ \mu\text{H})}{4\ \mu\text{H} + 4\ \mu\text{H}} \right\} + \{6\ \mu\text{H} \parallel 6\ \mu\text{H}\} + 1\ \mu\text{H} \right) \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[12\ \mu\text{H} \parallel \left(2\ \mu\text{H} + \left\{ \frac{(6\ \mu\text{H})(6\ \mu\text{H})}{6\ \mu\text{H} + 6\ \mu\text{H}} \right\} + 1\ \mu\text{H} \right) \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + [12\ \mu\text{H} \parallel (2\ \mu\text{H} + 3\ \mu\text{H} + 1\ \mu\text{H})] \right\}$$

$$= 8\ \mu\text{H} \parallel \{5\ \mu\text{H} + [12\ \mu\text{H} \parallel 6\ \mu\text{H}]\}$$

Simplify the calculation further.

$$L_T = 8\ \mu\text{H} \parallel \left\{ 5\ \mu\text{H} + \left[\frac{(12\ \mu\text{H})(6\ \mu\text{H})}{12\ \mu\text{H} + 6\ \mu\text{H}} \right] \right\}$$

$$= 8\ \mu\text{H} \parallel \{5\ \mu\text{H} + 4\ \mu\text{H}\}$$

$$= 8\ \mu\text{H} \parallel 9\ \mu\text{H}$$

$$= \frac{(8\ \mu\text{H})(9\ \mu\text{H})}{8\ \mu\text{H} + 9\ \mu\text{H}}$$

$$L_T = \frac{72}{17}\ \mu\text{H}$$

Therefore, the value of the total inductance, L_T is $\boxed{\frac{72}{17}\ \mu\text{H}}$.

Step 1 of 5

Refer to Figure P6.75 in the textbook.

Identify the parallel branches in the circuit.

Figure 1

Step 2 of 5

Calculate the equivalent inductance of the parallel connected inductors.

$$L_1 = 12\ \mu H \| 6\ \mu H$$
$$= \frac{(12\ \mu H)(6\ \mu H)}{18\ \mu H}$$
$$= 4\ \mu H$$

Draw the simplified circuit and identify the series branch.

Figure 2

Step 3 of 5

Calculate the equivalent inductance of the series connected inductors.

$$L_2 = 4\ \mu H + 3\ \mu H$$
$$= 7\ \mu H$$

Draw the simplified circuit and identify the parallel branch.

Figure 3

Step 4 of 5

The parallel connected inductors in the circuit of Figure 3 are shorted due to shorted line across the inductors.

Draw the reduced circuit diagram.

Figure 4

Step 5 of 5

Calculate the value of the total inductance, L_T.

$$L_T = \left\{\left[\left(\{12\ \mu H \| 4\ \mu H\} + 3\ \mu H\right) \| 6\ \mu H\right] + 9\ \mu H\right\} \| 4\ \mu H$$
$$= \left\{\left[\left(\left\{\frac{(12\ \mu H)(4\ \mu H)}{12\ \mu H + 4\ \mu H}\right\} + 3\ \mu H\right) \| 6\ \mu H\right] + 9\ \mu H\right\} \| 4\ \mu H$$
$$= \left\{\left[(3\ \mu H + 3\ \mu H) \| 6\ \mu H\right] + 9\ \mu H\right\} \| 4\ \mu H$$
$$= \left\{\left[6\ \mu H \| 6\ \mu H\right] + 9\ \mu H\right\} \| 4\ \mu H$$

Simplify the calculation.

$$L_T = \left\{\left[\frac{(6\ \mu H) \| (6\ \mu H)}{6\ \mu H + 6\ \mu H}\right] + 9\ \mu H\right\} \| 4\ \mu H$$
$$= \{3\ \mu H + 9\ \mu H\} \| 4\ \mu H$$
$$= 12\ \mu H \| 4\ \mu H$$
$$= \frac{(12\ \mu H) \| (4\ \mu H)}{12\ \mu H + 4\ \mu H}$$

$$L_T = 3\ \mu H$$

Therefore, the value of the total inductance, L_T of the circuit is $\boxed{3\ \mu H}$.

Step 1 of 5

6.080P

Refer to Figure P6.77 in the textbook.

Identify the series connected inductors in the circuit.

Figure 1

Step 2 of 5

Calculate the equivalent inductance of the series connected inductors.

$$L_1 = 8\ \mu\text{H} + 4\ \mu\text{H}$$
$$= 12\ \mu\text{H}$$

Draw the simplified circuit and identify the parallel connected inductors.

Figure 2

Step 3 of 5

Calculate the equivalent inductance of the parallel connected inductors.

$$L_2 = L \| (18\ \mu\text{H} \| 9\ \mu\text{H} \| 12\ \mu\text{H})$$
$$= L \| \left(\frac{(18\ \mu\text{H})(9\ \mu\text{H})(12\ \mu\text{H})}{(18\ \mu\text{H})(9\ \mu\text{H}) + (9\ \mu\text{H})(12\ \mu\text{H}) + (18\ \mu\text{H})(12\ \mu\text{H})} \right)$$
$$= L \| \left(\frac{1944 \times 10^{-18}}{162 \times 10^{-12} + 108 \times 10^{-12} + 216 \times 10^{-12}} \right)$$
$$= L \| \left(\frac{1944 \times 10^{-18}}{486 \times 10^{-12}} \right)$$
$$L_2 = L \| (4\ \mu\text{H})$$

Draw the simplified circuit diagram.

Figure 3

Step 4 of 5

Write the expression for the total inductance, L_T .

$$L_T = 1\ \mu\text{H} + \{4\ \mu\text{H} \| [2\ \mu\text{H} + (L \| 4\ \mu\text{H})]\} + 3\ \mu\text{H}$$
$$= 4\ \mu\text{H} + \{4\ \mu\text{H} \| [2\ \mu\text{H} + (L \| 4\ \mu\text{H})]\}$$

Substitute $6\ \mu\text{H}$ for the total inductance, L_T .

$$6\ \mu\text{H} = 4\ \mu\text{H} + \{4\ \mu\text{H} \| [2\ \mu\text{H} + (L \| 4\ \mu\text{H})]\}$$
$$6\ \mu\text{H} - 4\ \mu\text{H} = 4\ \mu\text{H} \| [2\ \mu\text{H} + (L \| 4\ \mu\text{H})]$$
$$2\ \mu\text{H} = \frac{(4\ \mu\text{H})[2\ \mu\text{H} + (L \| 4\ \mu\text{H})]}{4\ \mu\text{H} + [2\ \mu\text{H} + (L \| 4\ \mu\text{H})]}$$
$$2\ \mu\text{H} = \frac{(4\ \mu\text{H})[2\ \mu\text{H} + (L \| 4\ \mu\text{H})]}{6\ \mu\text{H} + (L \| 4\ \mu\text{H})}$$
$$2\ \mu\text{H}[6\ \mu\text{H} + (L \| 4\ \mu\text{H})] = (4\ \mu\text{H})[2\ \mu\text{H} + (L \| 4\ \mu\text{H})]$$
$$6\ \mu\text{H} + (L \| 4\ \mu\text{H}) = 2[2\ \mu\text{H} + (L \| 4\ \mu\text{H})]$$
$$6\ \mu\text{H} + (L \| 4\ \mu\text{H}) = 4\ \mu\text{H} + 2(L \| 4\ \mu\text{H})$$

Step 5 of 5

Simplify the calculation further.

$$2(L \| 4\ \mu\text{H}) - (L \| 4\ \mu\text{H}) = 6\ \mu\text{H} - 4\ \mu\text{H}$$
$$L \| 4\ \mu\text{H} = 2\ \mu\text{H}$$
$$\frac{L(4\ \mu\text{H})}{L + 4\ \mu\text{H}} = 2\ \mu\text{H}$$
$$L(4\ \mu\text{H}) = 2\ \mu\text{H}(L + 4\ \mu\text{H})$$
$$2L = L + 4\ \mu\text{H}$$
$$2L - L = 4\ \mu\text{H}$$
$$L = 4\ \mu\text{H}$$

Therefore, the required value of the inductor L is $\boxed{4\ \mu\text{H}}$.

Step 1 of 7

Refer to Figure P6.79 in the text book.

When *N* numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

(a)

With the terminals *C-D* short-circuited, the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 7

The inductors $5\,\text{mH and } 20\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{5,20}} &= \frac{1}{L_5} + \frac{1}{L_{20}} \\ &= \frac{1}{5} + \frac{1}{20} \\ &= \frac{4+1}{20} \\ L_{5,20} &= 4\,\text{mH}\end{aligned}$$

Step 3 of 7

The inductors $6\,\text{mH and } 12\,\text{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{6,12}} &= \frac{1}{L_6} + \frac{1}{L_{12}} \\ &= \frac{1}{6} + \frac{1}{12} \\ &= \frac{2+1}{12} \\ L_{6,12} &= 4\,\text{mH}\end{aligned}$$

Step 4 of 7

The inductors $4\,\text{mH and } 4\,\text{mH}$ are in series. Calculate their equivalent inductance.

$$\begin{aligned}L_{A,B} &= L_{5,20} + L_{6,12} \\ &= 4 + 4 \\ &= 8\,\text{mH}\end{aligned}$$

Therefore, the inductance at terminals *A-B* is $\boxed{8\text{ mH}}$.

Step 5 of 7

(b)

With the terminals *A-B* open-circuited, the modified circuit is shown in Figure 2.

Figure 2

Step 6 of 7

The inductors $12\,\text{mH and } 6\,\text{mH}$ are in series. Calculate their equivalent inductance.

$$\begin{aligned}L_{12,6} &= L_{12} + L_6 \\ &= 12 + 6 \\ &= 18\,\text{mH}\end{aligned}$$

The inductors $20\,\text{mH and } 5\,\text{mH}$ are in series. Calculate their equivalent inductance.

$$\begin{aligned}L_{20,5} &= L_{20} + L_5 \\ &= 20 + 5 \\ &= 25\,\text{mH}\end{aligned}$$

Step 7 of 7

These $18\,\text{mH and } 25\,\text{mH}$ inductors are in parallel. Calculate their equivalent inductance is as follows.

$$\begin{aligned}\frac{1}{L_{C,D}} &= \frac{1}{L_{12,6}} + \frac{1}{L_{5,20}} \\ &= \frac{1}{18\text{ mH}} + \frac{1}{25\text{ mH}} \\ &= \frac{25+18}{450\text{ mH}} \\ L_{C,D} &= 10.46\text{ mH}\end{aligned}$$

Therefore, the inductance at terminals *C-D* is $\boxed{10.46\text{ mH}}$.

Step 1 of 3

6.082P

Refer to Figure P6.80 in the text book.

When *N* numbers of inductors are connected in series, write the expression for the equivalent inductance.

$$L_p = L_1 + L_2 + ... + L_N$$

When *N* numbers of inductors are connected in parallel, write the expression for the equivalent inductance.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors *L* and $6\,\mathrm{mH}$ are in parallel. Calculate their equivalent inductance.

$$\begin{aligned}\frac{1}{L_{L,6}} &= \frac{1}{L} + \frac{1}{L_6}\\ &= \frac{1}{L} + \frac{1}{6}\\ &= \frac{6+L}{6L}\\ L_{L,6} &= \frac{6L}{6+L}\,\mathrm{mH}\end{aligned}$$

Step 2 of 3

This $\frac{6L}{6+L}\,\mathrm{mH}$ inductor is in series with $2\,\mathrm{mH}$ inductor. Calculate their equivalent inductance is as follows.

$$\begin{aligned}L_S &= \frac{6L}{6+L} + 2\\ &= \frac{6L+12+2L}{6+L}\\ &= \frac{8L+12}{6+L}\,\mathrm{mH}\end{aligned}$$

Step 3 of 3

This $\frac{8L+12}{6+L}\,\mathrm{mH}$ inductor is in parallel with $4\,\mathrm{mH}$ inductor. Calculate their equivalent inductance is as follows.

$$\frac{1}{L_T} = \frac{1}{\frac{8L+12}{6+L}} + \frac{1}{4}$$

$$\frac{1}{2} = \frac{6+L}{8L+12} + \frac{1}{4}$$

$$\frac{1}{2} = \frac{24+4L+8L+12}{4(8L+12)}$$

$$32L + 48 = 24L + 72$$

$$L = 3\,\mathrm{mH}$$

Therefore, the inductance *L* is $\boxed{3\,\mathrm{mH}}$.

Step 1 of 2

6.083P

(a)

When N numbers of inductors are connected in series, the equivalent inductance can be writing as follows.

$$L_p = L_1 + L_2 + ... + L_N$$

When N numbers of inductors are connected in parallel, the equivalent inductance can be writing as follows.

$$\frac{1}{L_S} = \frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_N}$$

The inductors $20\ \text{mH}$ and $12\ \text{mH}$ are in series, calculate their equivalent inductance.

$$\begin{aligned} L_{eq} &= L_{20} + L_{12} \\ &= 20\ \text{mH} + 12\ \text{mH} \\ &= 32\ \text{mH} \end{aligned}$$

Therefore, the equivalent inductance is $\boxed{32\ \text{mH}}$.

Step 2 of 2

(b)

Since inductances are series, the current flows through both the inductors are the same.

Write the expression for the energy stored in inductor.

$$w_L(t) = \frac{1}{2} L i^2(t)$$

Calculate energy stored in the inductor $20\ \text{mH}$ by substitute $20\ \text{mH}$ for L and $1\ \text{A}$ for i in the equation.

$$\begin{aligned} w_L(t) &= \frac{1}{2} L i^2(t) \\ &= \frac{1}{2}\left(20 \times 10^{-3}\right)(1)^2 \\ &= 10\ \text{mJ} \end{aligned}$$

Calculate energy stored in the inductor $12\ \text{mH}$ by substitute $12\ \text{mH}$ for L and $1\ \text{A}$ for i in the equation.

$$\begin{aligned} w_L(t) &= \frac{1}{2} L i^2(t) \\ &= \frac{1}{2}\left(12 \times 10^{-3}\right)(1)^2 \\ &= 6\ \text{mJ} \end{aligned}$$

Calculate the total energy stored in both the inductors.

$$\begin{aligned} w_L(t) &= 10\ \text{mH} + 6\ \text{mH} \\ &= 16\ \text{mH} \end{aligned}$$

Therefore, the total energy stored in the inductors is $\boxed{16\ \text{mH}}$.

ts no current since the capacitor acts like an open

g voltage division.

acitor is $8\ \mathrm{V}$.

instantaneously, the voltage across the capacitor

shown in Figure 2.

gure 2.

0 .

n is,

r $t > 0$ is $\boxed{8e^{-\frac{t}{0.6}}\ \mathrm{V}}$.

Step 1 of 5

Refer to Figure P7.1 in the text book.

At $t > 0$, the switch is opened. So, the 12 V independent voltage source and $6\ \Omega$ resistor have no impact on the resulting circuit.

Redraw the network for $t > 0$.

Figure 1

Step 2 of 5

Apply Kirchhoff's Voltage Law to the Figure1.

$$2\frac{di(t)}{dt} + 6i(t) = 0$$

$$\frac{di(t)}{dt} + 3i(t) = 0$$

Write the general solution for the differential equation.

$$i(t) = K_2 e^{-3t}$$

Substitute 0 for t in the equation.

$$\begin{aligned} i(0) &= K_2 e^{-3(0)} \\ &= K_2(1) \\ &= K_2 \end{aligned}$$

Step 3 of 5

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Draw the modified circuit of Figure P7.1.

Figure 2

Step 4 of 5

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 5 of 5

From Figure 3, the value of current $i_L(0^-)$ is,

$$\begin{aligned} i_L(0^-) &= \frac{12}{6} \\ &= 2\ \text{A} \end{aligned}$$

The current flowing through the inductor cannot change in zero time.

$$i(0) = i_L(0^-) = i_L(0^+) = K_2 = 2\ \text{A}$$

The expression for $i(t)$ in Figure P7.1 is,

$$\begin{aligned} i(t) &= K_2 e^{-3t} \\ &= 2e^{-3t} \quad (\text{Since } K_2 = 2\ \text{A}) \end{aligned}$$

Thus, the expression for $i(t)$ at $t > 0$ is, $\boxed{2e^{-3t}\ \text{A}}$.

e P7.25 in the textbook.

›n for current is,

$K_2 e^{-t/\tau}$

ɜ circuit is in steady state and the capacitor acts as an open circuit. The capacitor is fully
ıo current flows through the capacitor before switch is closed.

s voltage law for the current $i_o(0-)$ is,

$(i_o(0-)) = 0$

$\frac{2\text{ V}}{\text{k}\Omega}$

.5 mA

age across the capacitor is,

$\text{k}\Omega \times i_o(0-)$

d the capacitor $\text{k}\Omega \times -1.5\text{ mA}$

capacitor befor 5 V

$i_o(0-)$ is, ıe switch is closed. The circuit is reduced to

Figure 1

Step 5 of 11

uit is reduced to

The Kirchhoff's voltage law equation for the current $i_o(0+)$ is,

$$-12 + (2\text{ k})(i_1) + (4\text{ k})(i_1 + i_2) = 0$$

$$(6\text{ k})(i_1) + (4\text{ k})(i_2) = 12 \text{ ..... (1)}$$

And

$$-6 + (4\text{ k})(i_2 + i_1) + (4\text{ k})(i_2) = 0$$

$$(4\text{ k})(i_1) + (8\text{ k})(i_2) = 6 \text{ ..... (2)}$$

Step 6 of 11

The solution of the above equations is,

$$i_1 = 2.25\text{ mA}, i_2 = -0.375\text{ mA}$$

The current at $t = 0+$ is,

$$\begin{aligned} i_o(0+) &= -(i_1 + i_2) \\ &= -1.875\text{ mA} \end{aligned}$$

Step 7 of 11

For $t > 5\tau$, the capacitor is again fully charged and it acts as an open circuit. The current $i_o(\infty)$ is given by

$$\begin{aligned} i_o(\infty) &= -\frac{12\text{ V}}{4\text{ k}\Omega + 2\text{ k}\Omega} \\ &= -2\text{ mA} \end{aligned}$$

Step 8 of 11

The Thevenin equivalent resistance, obtained by looking into the open-circuit terminals of the capacitor is given by

$$\begin{aligned} R_{Th} &= (4\text{ k}\Omega \| 4\text{ k}\Omega \| 4\text{ k}\Omega) + 4\text{ k}\Omega \\ &= 5.333\text{ k}\Omega \end{aligned}$$

Step 9 of 11

The time constant is,

$$\begin{aligned} \tau &= R_{Th}C \\ &= 5.333\text{ k}\Omega \times 200\ \mu\text{F} \\ &= 1.066\text{ s} \end{aligned}$$

Step 10 of 11

The constants are given by

$$K_1 = i_o(\infty) = -2\text{ mA}$$

$$\begin{aligned} K_2 &= i_o(0+) - i_o(\infty) \\ &= i_o(0+) - K_1 \\ &= -1.875\text{ mA} + 2\text{ mA} \\ &= 0.125\text{ mA} \end{aligned}$$

Step 11 of 11

Therefore the solution is,

$$\begin{aligned} i_o(t) &= i_o(\infty) + [i_o(0+) - i_o(\infty)]e^{-t/\tau} \\ &= -2 + 0.125e^{-0.938t}\text{ mA} \end{aligned}$$

Hence $i_o(t)$ for $t > 0$ is,

$$\boxed{i_o(t) = (-2 + 0.125e^{-0.938t})\text{ mA}}.$$

$$v_C(0^-)(3) = 12$$

$$v_C(0^-) = 4\ \text{V}$$

Therefore, the value of $v_C(0^-)$ is $4\ \text{V}$.

The value of $v_C(0)$ is equal to the values of $v_C(0^-)$. Therefore,

Step 3 of 6

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 6

Apply nodal analysis for the circuit diagram.

$$(100\ \mu)\frac{dv_C(t)}{dt} + \frac{v_C(t)}{6\ \text{k} + 6\ \text{k}} = 0$$

$$(100\ \mu)\frac{dv_C(t)}{dt} + \frac{v_C(t)}{12\ \text{k}} = 0$$

$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{1.2} = 0$$

The solution for the differential equation is,

$$v_C(t) = k_1 e^{-\frac{1}{1.2}t} \quad \text{..... (1)}$$

Step 5 of 6

Recall equation (1).

$$v_C(t) = k_1 e^{-\frac{1}{1.2}t}$$

Substitute 0 for t.

$$v_C(0) = k_1 e^{-\frac{1}{1.2}(0)}$$

$$v_C(0) = k_1$$

Substitute $4\ \text{V}$ for $v_C(0)$.

$$k_1 = 4\ \text{V}$$

Therefore, the value of the constant k_1 is $4\ \text{V}$.

Step 6 of 6

Recall equation (1).

$$v_C(t) = k_1 e^{-\frac{1}{1.2}t}$$

Substitute $4\ \text{V}$ for k_1 and 2 for t.

$$\begin{aligned} v_C(2) &= 4e^{-\frac{1}{1.2}(2)} \\ &= 4e^{-\frac{1}{0.6}} \\ &= 4(0.189) \\ &= 0.756\ \text{V} \end{aligned}$$

Therefore, the value of the voltage across the capacitor at $t = 2\ \text{s}$

Step 1 of 6

At $t = 0-$, the switch is open and the capacitor is fully charged by the voltage source 12 V.

Replace the capacitor $100\ \mu\text{F}$ as shown in Figure P7.2 in the text book with open circuit.

Draw the equivalent circuit at $t = 0-$.

Figure 1

Step 2 of 6

Determine the voltage across the capacitor $100\ \mu\text{F}$ at $t = 0-$.

$$\begin{aligned} v_C(0-) &= \frac{12\text{ V}}{(6\text{ k}\Omega + 6\text{ k}\Omega + 12\text{ k}\Omega)}(12\text{ k}\Omega) \\ &= \left(\frac{12}{24}\right)(12) \\ &= 6\text{ V} \\ &= v_C(0) \end{aligned}$$

Step 3 of 6

The switch is closed at $t = 0$.

Draw the equivalent circuit for $t > 0$.

Figure 2

Step 4 of 6

Apply Kirchhoff's current law at the node voltage v_C .

$$\frac{v_C}{6\text{ k}\Omega} + (100\ \mu\text{F})\frac{dv_C}{dt} + \frac{v_C}{12\text{ k}\Omega} = 0$$

$$2v_C + \left(100 \times 10^{-6} \times 12 \times 10^3\right)\frac{dv_C}{dt} + v_C = 0$$

$$1.2\frac{dv_C}{dt} + 3v_C = 0$$

$$\frac{dv_C}{dt} + 2.5v_C = 0$$

Step 5 of 6

Solve the differential equation.

$$\frac{dv_C(t)/dt}{v_C(t)} = -2.5$$

$$\frac{d}{dt}\left[\ln v_C(t)\right] = -2.5$$

$$\ln v_C(t) = -2.5t + c$$

$$v_C(t) = K_2 e^{-2.5t} \quad \text{..... (1)}$$

Substitute $t = 0$ in equation (1).

$$\begin{aligned} v_C(0) &= K_2 e^{-2.5(0)} \\ K_2 &= v_C(0) \\ &= 6\text{ V} \end{aligned}$$

The expression for the voltage across the capacitor is,

$$v_C(t) = 6e^{-2.5t}$$

Step 6 of 6

Write the expression of the current i_o for $t > 0$.

$$i_o = -\frac{v_C(t)}{6\text{ k}\Omega}$$

Substitute $6e^{-2.5t}$ for $v_C(t)$.

$$\begin{aligned} i_o &= -\frac{6e^{-2.5t}}{6\text{ k}\Omega} \\ &= -e^{-2.5t}\text{ mA} \end{aligned}$$

Thus, the expression for the current $i_o(t)$ for $t > 0$ is $\boxed{-e^{-2.5t}\text{ mA}}$.

Step 1 of 9

Refer to Fig. 7PFE-2 in textbook.

Initially for $t < 0$, the switch is in open position for a long time and the capacitor acts as an open circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

From Figure 1,

$$v_C(0^-) = 0\text{ V}$$

The voltage across the capacitor cannot change instantaneously.

$$\begin{aligned} v_C(0^-) &= v_C(0^+) \\ &= v_o(0) \\ &= 0\text{V} \end{aligned}$$

Step 3 of 9

At $t = \infty$, the circuit reaches steady state condition and the capacitor acts as an open circuit. The modified circuit is shown in Figure 2.

Figure 2

Step 4 of 9

Due to the open circuit, no current flows through the $4\text{k}\Omega$ resistor. Therefore, the voltage across the open circuit is equals to the voltage across the $12\text{k}\Omega$ resistor.

Apply voltage division rule to calculate the voltage, $v_o(\infty)$.

$$\begin{aligned} v_o(\infty) &= 12\left(\frac{12\text{k}}{12\text{k}+12\text{k}}\right) \\ &= 12\left(\frac{12\text{k}}{24\text{k}}\right) \\ &= 6\text{ V} \end{aligned}$$

Step 5 of 9

The Thevenin equivalent resistance R_{Th} is found by looking into the circuit from the capacitor terminal is shown in Figure 3.

Figure 3

Step 6 of 9

From Figure 3, the Thevenin equivalent resistance is,

$$\begin{aligned} R_{Th} &= (12\text{k}\|12\text{k}) + 4\text{k} \\ &= \left(\frac{12\text{k}\times 12\text{k}}{12\text{k}\times 12\text{k}}\right) + 4\text{k} \\ &= (6\text{k}) + 4\text{k} \\ &= 10\text{k}\Omega \end{aligned}$$

Step 7 of 9

Determine the value of time constant.

$$\tau = R_{Th}C$$

Substitute $10\text{k}\Omega$ for R_{Th} and $100\ \mu\text{F}$ for C in the equation.

$$\begin{aligned} \tau &= (10\times 10^3)(100\times 10^{-6}) \\ &= 1\text{ s} \end{aligned}$$

The solution for the output voltage is,

$$v_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Substitute 1 s for τ in the equation.

$$v_o(t) = K_1 + K_2 e^{\frac{-t}{1}}$$

$$v_o(t) = K_1 + K_2 e^{-t} \quad \text{..... (1)}$$

Step 8 of 9

Substitute ∞ for t in the equation (1), to determine the value of constant K_1.

$$v_o(\infty) = K_1 + K_2 e^{-(\infty)}$$

Substitute 6 V for $v_o(\infty)$ in the equation.

$$\begin{aligned} 6 &= K_1 + K_2(0) \\ K_1 &= 6 \end{aligned}$$

Substitute 0 for t in the equation (1), to determine the value of constant K_2.

$$v_o(0) = K_1 + K_2 e^{-(0)}$$

Substitute 0V for $v_o(0)$ in the equation.

$$\begin{aligned} 0 &= K_1 + K_2(1) \\ K_2 &= -K_1 \\ K_2 &= -6 \end{aligned}$$

Step 9 of 9

Derive the expression output voltage, $v_o(t)$.

$$v_o(t) = K_1 + K_2 e^{-t}$$

Substitute 6 for K_1 and -6 for K_2 in the equation.

$$v_o(t) = 6 - 6e^{-t}$$

Determine the value of output voltage, $v_o(t)$ at $t = 1\text{ s}$.

$$\begin{aligned} v_o(1) &= 6 - 6e^{-(1)} \\ &\approx 3.79\text{ V} \end{aligned}$$

Thus, the value of output voltage, $v_o(t)$ at $t = 1\text{ s}$ is $\boxed{3.79\text{ V}}$.

Hence, the correct option is $\boxed{(\text{d})}$.

Step 1 of 4

Refer to Figure E7.3 in the textbook.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RL* circuit,

$$x(t) = i_1(t)$$
$$K_1 = i_1(\infty)$$
$$K_2 = i_1(0^+) - i_1(\infty)$$
$$\tau = \frac{L}{R_{th}}$$

Substitute these values in equation $x(t)$.

$$i_1(t) = i_1(\infty) + \left[i_1(0^+) - i_1(\infty)\right]e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Step 2 of 4

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Redraw the circuit in Figure E7.3 at $t = 0^-$.

Figure 1

Step 3 of 4

In Figure 1 resistors are in parallel, hence the voltage across the $12\ \Omega$ resistor is 12 V.

Calculate the current $i_1(0^-)$, which is same as the $i_L(0^-)$.

$$i_1(0^-) = \frac{12}{12}$$
$$= 1\ \text{A}$$

At $t = 0^+$, the switch opens and the inductor is replaced by a current source. The current flowing throw the inductor cannot change in zero time. Hence, $i_L(0^-) = i_L(0^+)$.

Redraw the Figure E7.3 at $t = 0^+$.

Figure 2

In Figure 2, same current flow the circuit as it is a series circuit. Hence, $i_1(0^+) = 1\ \text{A}$.

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the inductor by a short circuit.

Redraw the Figure E7.3 at $t = \infty$.

Figure 3

There is no current flow in Figure 3. Hence, $i_1(\infty) = 0\ \text{A}$.

Redraw the Figure E7.3 to calculate the equivalent resistance.

Figure 4

Step 4 of 4

In Figure 4, resistors $6\ \Omega$ and $12\ \Omega$ are in series.

$$R_{th} = 12\ \Omega + 6\ \Omega$$
$$= 18\ \Omega$$

Calculate the time constant.

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{2}{18}$$
$$= \frac{1}{9}$$

Substitute 0 A for $i_1(\infty)$, 1 A for $i_1(0^+)$ and $\frac{1}{9}$ for τ.

$$i_1(t) = 0 + [1 - 0]e^{-\frac{t}{\left(\frac{1}{9}\right)}}$$
$$= 1e^{-9t}\ \text{A}$$

Thus, the current $i_1(t)$ for $t > 0$ is, $\boxed{1e^{-9t}\ \text{A}}$.

Step 1 of 6

The capacitor does not allow any sudden changes in voltage.

The voltage across the capacitor at $t = 0+$ is 0 V.

Replace the capacitor as shown in Figure P7.3 in the text book by a short circuit.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law at the node voltage $v_o(0)$ as shown in Figure 1.

$$\frac{v_o(0)-12}{6\text{ k}\Omega}+\frac{v_o(0)}{3\text{ k}\Omega}+\frac{v_o(0)}{2\text{ k}\Omega}=0$$
$$v_o(0)-12+2v_o(0)+3v_o(0)=0$$
$$6v_o(0)=12$$
$$v_o(0)=2\text{ V}$$

Step 3 of 6

Draw the equivalent circuit for $t > 0$.

Figure 2

Consider the node voltage v as shown in Figure 2.

The current passing through the capacitor is,

$$\frac{v_o}{2\text{ k}\Omega}=(200\ \mu\text{F})\frac{d}{dt}(v-v_o)$$
$$v_o=0.4\left(\frac{dv}{dt}-\frac{dv_o}{dt}\right)$$
$$0.4\frac{dv}{dt}=v_o+0.4\frac{dv_o}{dt}$$
$$\frac{dv}{dt}=2.5v_o+\frac{dv_o}{dt}\ \text{..... (1)}$$

Step 4 of 6

Apply Kirchhoff's current law at the node voltage v.

$$\frac{v-12}{6\text{ k}\Omega}+\frac{v}{3\text{ k}\Omega}+\frac{v_o}{2\text{ k}\Omega}=0$$
$$v-12+2v+3v_o=0$$
$$3v+3v_o=12$$
$$v+v_o=4\ \text{..... (2)}$$

Differentiate the equation (2) with respect to t on both sides.

$$\frac{d}{dt}(v+v_o)=\frac{d}{dt}(4)$$
$$\frac{dv}{dt}+\frac{dv_o}{dt}=0$$
$$\frac{dv}{dt}=-\frac{dv_o}{dt}$$

Step 5 of 6

Substitute $-\frac{dv_o}{dt}$ for $\frac{dv}{dt}$ in equation (1).

$$-\frac{dv_o}{dt}=2.5v_o+\frac{dv_o}{dt}$$
$$2\frac{dv_o}{dt}+2.5v_o=0$$
$$\frac{dv_o}{dt}+1.25v_o=0$$

Solve the differential equation.

$$\frac{dv_o(t)/dt}{v_o(t)}=-1.25$$
$$\frac{d}{dt}\left[\ln v_o(t)\right]=-1.25$$
$$\ln v_o(t)=-1.25t+c$$
$$v_o(t)=K_2e^{-1.25t}\ \text{..... (3)}$$

Step 6 of 6

Substitute $t = 0$ in equation (3).

$$v_o(0)=K_2e^{-1.25(0)}$$
$$K_2=v_o(0)$$
$$=2\text{ V}$$

Thus, the expression for the voltage $v_o(t)$ for $t > 0$ is $\boxed{2e^{-1.25t}}$.

Step 1 of 9

Refer to Fig. 7PFE-3 in the textbook.

Initially for $t < 0$, the switch is in closed position for a long time and the capacitor acts as an open circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Apply voltage division rule to determine the value of initial voltage.

$$v_C(0^-) = 12\left(\frac{6\text{ k}}{6\text{ k}+12\text{ k}}\right)$$
$$= 12\left(\frac{6}{18}\right)$$
$$= 4\text{ V}$$

The voltage across the capacitor cannot change instantaneously.

$$v_C(0^-) = v_C(0^+)$$
$$= v_C(0)$$
$$= 4\text{ V}$$

Step 3 of 9

At $t = \infty$, the circuit reaches steady state condition and the capacitor acts as an open circuit. The modified circuit is shown in Figure 2.

Figure 2

From Figure 2, the value of final voltage is,

$$v_C(\infty) = 0\text{ V}$$

Step 4 of 9

The Thevenin equivalent resistance R_{Th} is found by looking into the circuit from the capacitor terminal is shown in Figure 3.

Figure 3

From Figure 3, the Thevenin equivalent resistance is,

$$R_{Th} = 6\text{ k}\Omega$$

Step 5 of 9

Determine the value of time constant.

$$\tau = R_{Th}C$$

Substitute $6\text{ k}\Omega$ for R_{Th} and $100\ \mu\text{F}$ for C in the equation.

$$\tau = \left(6\times10^3\right)\left(100\times10^{-6}\right)$$
$$= 0.6\text{ s}$$

Step 6 of 9

The solution for the output voltage is,

$$v_C(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Substitute 0.6 s for τ in the equation.

$$v_C(t) = K_1 + K_2 e^{\frac{-t}{0.6}} \text{ ..... (1)}$$

Substitute ∞ for t in the equation (1), to determine the value of constant K_1.

$$v_C(\infty) = K_1 + K_2 e^{\frac{-\infty}{0.6}}$$

Substitute 0 V for $v_C(\infty)$ in the equation.

$$0 = K_1 + K_2(0)$$
$$K_1 = 0$$

Step 7 of 9

Substitute 0 for t in the equation (1), to determine the value of constant K_2.

$$v_C(0) = K_1 + K_2 e^{\frac{-0}{0.6}}$$

Substitute 4 V for $v_C(0)$ in the equation.

$$4 = K_1 + K_2(1)$$
$$K_2 = 4 - 0 \quad (\text{since } K_1 = 0)$$
$$K_2 = 4$$

Step 8 of 9

Derive the expression voltage across the capacitor, $v_C(t)$.

$$v_C(t) = K_1 + K_2 e^{\frac{-t}{0.6}}$$

Substitute 0 for K_1 and 4 for K_2 in the equation.

$$v_C(t) = 0 + 4e^{\frac{-t}{0.6}}$$

$$v_C(t) = 4e^{\frac{-t}{0.6}}$$

Step 9 of 9

Determine time required for the capacitor voltage to decay to its one half of its initial voltage.

$$\frac{v_C(0)}{2} = 4e^{\frac{-t}{0.6}}$$
$$\frac{4}{2} = 4e^{\frac{-t}{0.6}} \quad (\text{since } v_C(0) = 4\text{ V})$$
$$\frac{1}{2} = e^{\frac{-t}{0.6}}$$
$$2 = e^{\frac{t}{0.6}}$$
$$t = 0.6\ln(2)$$
$$t \approx 0.416\text{ s}$$

Thus, the time required for the capacitor voltage to decay to its one-half of its initial voltage is $\boxed{0.416\text{ s}}$.

Hence, the correct option is $\boxed{(\text{a})}$.

Step 1 of 8

Initially, before the switch is open, that is, at $t = 0^-$, the current through the inductor is to be determined. Inductor at this instant of time losses its significance and acts as a short circuit.

The circuit at $t = 0^-$ is as follows:

Figure1

Step 2 of 8

From Figure 1, the $2\text{k}\Omega$ resistor is in parallel with the short circuit and can be neglected in calculation.

Consider the node voltage as V.

Figure 2

Step 3 of 8

The equation for node voltage is,

$$\frac{V-12}{2\text{k}} + \frac{V+6}{3\text{k}} + i(0^-) = 0$$

The value of V is zero. The current equation is,

$$\frac{0-12}{2\text{k}} + \frac{0+6}{3\text{k}} + i(0^-) = 0$$

$$i(0^-) = 4\text{ mA}$$

The current through the inductor cannot change instantaneously.

$$\begin{aligned} i(0^-) &= i(0^+) \\ &= i(0) \\ &= 4\text{ mA} \end{aligned}$$

Step 4 of 8

When the switch is open at $t = 0$, the 12 V source along with resistor in series will be disconnected from the circuit.

Figure 3

Step 5 of 8

The circuit in Figure 3 can be redrawn as follows:

Figure 4

Write the Kirchhoff's current law equation for the current through the inductor.

$$\frac{V_L}{2\text{k}} + i(t) + \frac{V_L + 6}{3\text{k}} = 0$$

$$5V_L + 6\text{k}\,i(t) + 12 = 0 \text{ ..... (1)}$$

Step 6 of 8

The voltage across the inductor is,

$$\begin{aligned} V_L &= L\frac{di(t)}{dt} \\ &= 6\text{m}\frac{di(t)}{dt} \end{aligned}$$

Substitute the voltage across the inductor in equation (1).

$$5\left(6\text{m}\frac{di(t)}{dt}\right) + 6\text{k}(i(t)) + 12 = 0$$

$$\frac{di(t)}{dt} + 0.2\text{x}10^6(i(t)) + 0.4\text{x}10^3 = 0 \text{ ..... (2)}$$

Equation (2) is a first order differential equation.

Step 7 of 8

The solution of the first order differential equation is,

$$i(t) = K_1 + K_2 e^{\frac{-t}{\tau}} \text{ ..... (3)}$$

From Equation (2), the time constant τ is,

$$\begin{aligned} \tau &= \frac{1}{0.2\text{x}10^6} \\ &= 5\text{x}10^{-6}\text{ sec} \end{aligned}$$

The value of K_1 is the final value of the current in the circuit. The inductor will act as short circuit and K_1 can be expressed as,

$$\begin{aligned} K_1 &= \frac{-6}{3\text{k}} \\ &= -2\text{mA} \end{aligned}$$

Step 8 of 8

Substitute the values of τ and K_1 in equation (3).

$$i(t) = -2 + K_2 e^{\frac{-t}{5\text{x}10^{-6}}}\text{ mA} \text{ ..... (4)}$$

To find K_2, substitute the initial conditions in equation (4).

$$\begin{aligned} i(0) &= -2 + K_2 e^0 \\ 4\text{ m} &= -2\text{ m} + K_2 \\ K_2 &= 6\text{ mA} \end{aligned}$$

Hence, the value of $i(t)$ for $t > 0$ is, $\boxed{-2 + 6e^{\frac{-t}{5\text{x}10^{-6}}}\text{ mA}}$.

Step 1 of 5

Refer to Figure P7.2 in the text book.

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.2 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 5

Apply node analysis at v_1 .

$$4\text{ mA} = \frac{v_1}{6\text{ k}} + \frac{v_1}{3\text{ k}}$$

$$4\text{ mA} = \frac{v_1}{2\text{ k}}$$

$$v_1 = 8\text{ V}$$

Calculate initial voltage of the capacitor.

$$v_C(0^-) = 8\left(\frac{2\text{ k}}{1\text{ k} + 2\text{ k}}\right)$$

$$= \frac{16}{3}\text{ V}$$

Step 3 of 5

At $t > 0$, the switch is opened. Hence 4 mA independent current source and **4 kΩ, 4 kΩ, and 2 kΩ** resistors have no impact on the resulting circuit.

Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 4 of 5

Write the differential equation for the circuit.

$$\left(300 \times 10^{-6}\right)\frac{dv(t)}{dt} + \frac{v(t)}{2\text{ k}} = 0$$

$$\frac{dv(t)}{dt} + \frac{v(t)}{0.6} = 0$$

Write the general solution for the differential equation.

$$v(t) = K_2 e^{-\frac{t}{0.6}}$$

To evaluate the function use the initial conditions.

$$v(0) = K_2 e^{-\left(\frac{0}{0.6}\right)}$$

$$v(0) = K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v(0) = v_C(0^-) = v_C(0^+) = \frac{16}{3}\text{ V}$.

Thus, the complete solution of the circuit is, $v(t) = \frac{16}{3}e^{-\frac{t}{0.6}}\text{ V}$.

Step 5 of 5

Calculate $i_o(t)$ for $t > 0$.

$$i_o(t) = \frac{v(t)}{2\text{ k}}$$

$$= \frac{\frac{16}{3}e^{-\frac{t}{0.6}}}{2\text{ k}}$$

$$= \frac{8}{3}e^{-\frac{t}{0.6}}\text{ mA}$$

Thus, the current $i_o(t)$ for $t > 0$ is, $\boxed{\frac{8}{3}e^{-\frac{t}{0.6}}\text{ mA}}$.

Step 1 of 7

7.04FE

Refer to Figure 7PFE-4 in the textbook.

At $t<0$, the switch is in open condition. The inductor acts as a short circuit in steady state. Draw the circuit diagram for $t<0$.

Figure 1

Calculate the initial current through the inductor.

$$i_L(0^-)=\frac{10\text{ V}}{2\ \Omega}$$
$$=5\text{ A}$$

Step 2 of 7

Redraw the new circuit valid only for $t=0^+$.

Figure 2

The value of the current source that replaces the inductor is, $i_L(0^+)=5\text{ A}$.

Step 3 of 7

The switch stays in closed condition for long time. The inductor acts as a short circuit in steady state. Redraw the equivalent circuit valid for $t>5\tau$.

Figure 3

Step 4 of 7

The current through voltage source is,

$$I_1=\frac{10}{2}$$
$$=5\text{ A}$$

The current through current source is,

$$I_2=1\text{ A}$$

The current through inductor at $t=\infty$ is,

$$I_L(\infty)=I_1+I_2$$

Since $2\ \Omega$ and $2\ \Omega$ resistances are shorted in the circuit, no current flows through them. Therefore,

$$i_L(\infty)=5+1$$
$$=6\text{ A}$$

Step 5 of 7

The Thevenin's equivalent resistance, obtained by looking into the open circuit terminals of the inductor is,

Figure 4

Step 6 of 7

The Thevenin's equivalent resistance is,

$$R_{Th}=(2)\|(2)\|(2)$$
$$=\left[\frac{(2)(2)}{2+2}\right]\|(2)$$
$$=(1)\|(2)$$
$$=\frac{(1)(2)}{1+2}$$
$$R_{Th}=0.67\ \Omega$$

Therefore, the circuit time constant is

$$\tau=\frac{L}{R_{Th}}$$
$$=\frac{4\text{ H}}{0.67\ \Omega}$$
$$=6\text{ s}$$

Step 7 of 7

Consider the initial current value.

$$K_1=i_L(\infty)$$
$$=6\text{ A}$$

Consider the initial and final current values.

$$K_2=i_L(0^+)-i_L(\infty)$$
$$=5-6$$
$$=-1\text{ A}$$

Therefore, the current through inductor at $t>0$ is,

$$i_L(t)=K_1+K_2e^{-t/\tau}$$
$$=6+(-1)e^{-\frac{t}{6}}$$
$$=6-e^{-\frac{t}{6}}$$

Thus, the current through inductor for $t\geq 0$ is, $\boxed{i_L(t)=6-e^{-\frac{t}{6}}\text{ A}}$.

The **option (c)** is correct.

Step 1 of 6

Refer to Figure E7.5 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RC* circuit,

$$x(t) = v_o(t)$$
$$K_1 = v_o(\infty)$$
$$K_2 = v_o(0^+) - v_o(\infty)$$
$$\tau = R_{th}C$$

Substitute these values in equation $x(t)$.

$$v_o(t) = v_o(\infty) + \left[v_o(0^+) - v_o(\infty)\right]e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure E7.5 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 6

Apply KVL to the loop i_1.

$$-12 + i_1(1+2+2) - 2i_2 + 8 = 0$$
$$5i_1 - 2i_2 = 4$$

Apply KVL to the loop i_2.

$$-8 + i_2(2+2) - 2i_1 = 0$$
$$-i_1 + 2i_2 = 4$$

After solving loop equations, $i_1 = 2\text{ A}$.

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= 12 - 1(i_1) \\ &= 12 - 1(2) \\ &= 12 - 2 \\ &= 10\text{ V} \end{aligned}$$

Step 3 of 6

At $t = 0^+$, the switch is open and the capacitor is replaced by a voltage source. The voltage across the capacitor cannot change in zero time. Hence, $v_C(0^-) = v_C(0^+)$.

Redraw the Figure E7.5 at $t = 0^+$.

Figure 2: $t = 0^+$

Step 4 of 6

Calculate the voltage across the resistor $2\,\Omega$.

$$\begin{aligned} v_o(0^+) &= 10\left(\frac{2}{2+2}\right) \\ &= 10\left(\frac{1}{2}\right) \\ &= 5\text{ V} \end{aligned}$$

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the capacitor by a open circuit.

Redraw the Figure E7.5 at $t = \infty$.

Figure 3: $t = \infty$

Step 5 of 6

Calculate the voltage across $2\,\Omega$ resistor at $t = \infty$.

$$\begin{aligned} v_o(\infty) &= 12\left(\frac{2}{2+2+1}\right) \\ &= 12\left(\frac{2}{5}\right) \\ &= \frac{24}{5}\text{ V} \end{aligned}$$

Redraw the Figure E7.5 to calculate the equivalent resistance by looking into open terminals of the capacitor and replacing the voltage sources by short circuit.

Figure 4

Step 6 of 6

In Figure 4, resistors $2\,\Omega$ and $2\,\Omega$ are in series and the resultant is in parallel with $1\,\Omega$.

$$\begin{aligned} R_{th} &= (2\,\Omega + 2\,\Omega) \| 1\,\Omega \\ &= \frac{4(1)}{4+1} \\ &= \frac{4}{5}\,\Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{th}C \\ &= \frac{4}{5}(2) \\ &= \frac{8}{5} \end{aligned}$$

Substitute $\frac{24}{5}$ V for $v_o(\infty)$, 5 V for $v_o(0^+)$ and $\frac{8}{5}$ for τ.

$$\begin{aligned} v_o(t) &= \frac{24}{5} + \left[5 - \frac{24}{5}\right]e^{-\frac{t}{\left(\frac{8}{5}\right)}} \\ &= \frac{24}{5} + \frac{1}{5}e^{-\left(\frac{5}{8}\right)t}\text{ V} \end{aligned}$$

Thus, the voltage $v_o(t)$ for $t > 0$ is, $\boxed{\frac{24}{5} + \frac{1}{5}e^{-\left(\frac{5}{8}\right)t}\text{ V}}$.

Step 1 of 6

Refer to Figure P7.3 in the text book.

At $t = 0^-$, the switch is opened and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.3 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 6

At $t = 0^-$, there is no source in the circuit. Hence, $v_C(0^-) = 0\ \text{V}$.

At $t > 0$, the switch is closed. Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 3 of 6

Write the Kirchhoff's current law equation.

$$\frac{v_C(t) - 6}{12\ \text{k}} + \left(100 \times 10^{-6}\right)\frac{dv_C(t)}{dt} + \frac{v_C(t)}{(2\ \text{k} + 4\ \text{k})} = 0$$

$$\left(100 \times 10^{-6}\right)\frac{dv_C(t)}{dt} + v_C(t)\left[\frac{1}{12\ \text{k}} + \frac{1}{6\ \text{k}}\right] = \frac{1}{2\ \text{k}}$$

$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{\left(100 \times 10^{-6}\right)}\left[\frac{1}{4\ \text{k}}\right] = \frac{1}{2\ \text{k}\left(100 \times 10^{-6}\right)}$$

$$\frac{dv_C(t)}{dt} + 2.5 v_C(t) = 5$$

Write the general solution to the differential equation.

$$v_C(t) = \frac{5}{2.5} + K_2 e^{-2.5t}$$

$$v_C(t) = 2 + K_2 e^{-2.5t}$$

Step 4 of 6

To evaluate the function use the initial conditions.

$$v_C(0) = 2 + K_2 e^{-(2.5(0))}$$

$$v_C(0) = 2 + K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v(0) = v_C(0^-) = v_C(0^+) = 0\ \text{V}$.

Substitute 0 V for $v_C(0)$.

$$0 = 2 + K_2$$

$$K_2 = -2$$

Thus, the complete solution of the circuit is, $v_C(t) = 2 - 2e^{-2.5t}\ \text{V}$.

Step 5 of 6

Calculate $v_o(t)$ for $t > 0$.

$$v_o(t) = v_C(t)\left(\frac{4\ \text{k}}{4\ \text{k} + 2\ \text{k}}\right)$$

$$= \left(2 - 2e^{-2.5t}\right)\frac{2}{3}$$

$$= \frac{4}{3}\left(1 - e^{-2.5t}\right)\ \text{V}$$

Thus, the voltage $v_o(t)$ for $t > 0$ is, $\boxed{\frac{4}{3}\left(1 - e^{-2.5t}\right)\ \text{V}}$.

Step 6 of 6

Plot the response $v_o(t)$ for $t > 0$.

Figure 3

Thus, the response is drawn.

Step 1 of 6

Consider Figure 7PFE-5 from the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

Step 2 of 6

Calculate the value of the current $i_L(0^-)$.

$$i_L(0^-) = \frac{12}{3+(2\|4\|4)}$$
$$= \frac{12}{3+\frac{(2)(4)(4)}{(2)(4)+(2)(4)+(4)(4)}}$$
$$= \frac{12}{3+\frac{32}{8+8+16}}$$
$$= \frac{12}{3+\frac{32}{32}}$$

$$i_L(0^-) = \frac{12}{3+1}$$
$$= \frac{12}{4}$$
$$= 3\text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is 3 A .

The value of the $i_L(0)$ is equal to the value of $i_L(0^-)$. Therefore, the value of the $i_L(0)$ is 3 A .

Step 3 of 6

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 6

Apply mesh analysis in the Loop.

$$i(t)(2+3) + 3\frac{di(t)}{dt} = 12$$
$$3\frac{di(t)}{dt} + 5i(t) = 12$$
$$\frac{di(t)}{dt} + \left(\frac{5}{3}\right)i(t) = \frac{12}{3}$$
$$\frac{di(t)}{dt} + \left(\frac{5}{3}\right)i(t) = 4$$

The solution for the differential equation is

$$i_L(t)e^{\int \frac{5}{3}dt} = \int 4e^{\int \frac{5}{3}dt}dt + k_1$$
$$i_L(t)e^{\frac{5}{3}t} = 4\int e^{\frac{5}{3}t}dt + k_1$$
$$i_L(t)e^{\frac{5}{3}t} = \frac{4e^{\frac{5}{3}t}}{\frac{5}{3}} + k_1$$
$$i_L(t) = \frac{12}{5} + k_1 e^{-\frac{5}{3}t}$$
$$i_L(t) = 2.4 + k_1 e^{-\frac{5}{3}t} \quad \text{..... (1)}$$

Step 5 of 6

Recall equation (1).

$$i_L(t) = 2.4 + k_1 e^{-\frac{5}{3}t}$$

Substitute 0 for t .

$$i_L(0) = 2.4 + k_1 e^{-\frac{5}{3}(0)}$$
$$i_L(0) = 2.4 + k_1$$

Substitute 3 A for $i_L(0)$.

$$3 = 2.4 + k_1$$
$$k_1 = 3 - 2.4$$
$$k_1 = 0.6$$

Therefore, the value of the constant k_1 is 0.6 .

Step 6 of 6

Recall equation (1).

$$i_L(t) = 2.4 + k_1 e^{-\frac{5}{3}t}$$

Substitute 0.6 for k_1 .

$$i_L(t) = 2.4 + 0.6e^{-\frac{5}{3}t}\text{ A}$$

Therefore, the value of the current $i_L(t)$ is $\boxed{2.4 + 0.6e^{-\frac{5}{3}t}\text{ A}}$.

Step 1 of 6

Refer to Figure E7.6 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RL* circuit,

$$x(t) = v_o(t)$$
$$K_1 = v_o(\infty)$$
$$K_2 = v_o(0^+) - v_o(\infty)$$

Substitute these values in equation $x(t)$.

$$v_o(t) = v_o(\infty) + \left[v_o(0^+) - v_o(\infty)\right]e^{-\frac{t}{\tau}} \text{ ..... (1)}$$

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Redraw the circuit in Figure E7.6 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 6

Apply KVL to the loop i_1.

$$-12 + i_1(2+2) - 2i_2 - 4 = 0$$

$$4i_1 - 2i_2 = 16 \text{ ..... (2)}$$

Apply KVL to the loop i_2.

$$4 + i_2(2+2) - 2i_1 = 0$$
$$-i_1 + 2i_2 = -2$$
$$2i_2 = i_1 - 2$$

Substitute $i_1 - 2$ for $2i_2$ in equation (2).

$$4i_1 - (i_1 - 2) = 16$$
$$3i_1 = 14$$
$$i_1 = \frac{14}{3} \text{ and } i_2 = \frac{4}{3}$$

The current $i_L(0^-)$, which is same as the loop current i_2 is, $i_L(0^-) = \frac{4}{3}$ A.

Step 3 of 6

At $t = 0^+$, the switch opens and the inductor is replaced by a current source. The current flowing throw the inductor cannot change in zero time. Hence, $i_L(0^-) = i_L(0^+)$.

Redraw the Figure E7.6 at $t = 0^+$.

Figure 2: $t = 0^+$

Step 4 of 6

In Figure 2, same current flow the circuit as it is a series circuit.

Calculate the voltage across the resistor $2\,\Omega$.

$$v_o(0^+) = \frac{4}{3}(2)$$
$$= \frac{8}{3} \text{ V}$$

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the inductor by a short circuit.

Redraw the Figure E7.6 at $t = \infty$.

Figure 3: $t = \infty$

Step 5 of 6

Calculate the voltage across $2\,\Omega$ resistor at $t = \infty$.

$$v_o(\infty) = 12\left(\frac{2}{2+2}\right)$$
$$= 12\left(\frac{1}{2}\right)$$
$$= 6 \text{ V}$$

Redraw the Figure E7.6 to calculate the equivalent resistance by looking into open terminals of the inductor and replacing the voltage sources by short circuit.

Figure 4

Step 6 of 6

In Figure 4, resistors $6\,\Omega$ and $12\,\Omega$ are in series. Hence,

$$R_{th} = 2\,\Omega + 2\,\Omega$$
$$= 4\,\Omega$$

Calculate the time constant.

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{2}{4}$$
$$= \frac{1}{2}$$

Substitute for 6 V $v_o(\infty)$, $\frac{8}{3}$ V for $v_o(0^+)$ and $\frac{1}{2}$ for τ.

$$v_o(t) = 6 + \left[\frac{8}{3} - 6\right]e^{-\frac{t}{\left(\frac{1}{2}\right)}}$$
$$= 6 - \frac{10}{3}e^{-2t} \text{ V}$$

Thus, the voltage $v_o(t)$ for $t > 0$ is, $\boxed{6 - \frac{10}{3}e^{-2t} \text{ V}}$.

Step 1 of 6

Refer to Figure P7.6 in the text book.

At $t = 0^-$, the switch is opened and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.6 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 6

Apply Kirchhoff's current law at node $v_C(0^-)$.

$$\frac{v_C(0^-)-6}{4\text{ k}+2\text{ k}}+\frac{v_C(0^-)}{4\text{ k}+2\text{ k}}=0$$
$$\frac{1}{3\text{ k}}v_C(0^-)-\frac{6}{6\text{ k}}=0$$
$$v_C(0^-)=3\text{ V}$$

Thus, the initial voltage across the capacitor is, $v_C(0^-)=3\text{ V}$.

At $t > 0$, the switch is closed. Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 3 of 6

Write the Kirchhoff's current law equation.

$$\frac{v_C(t)}{4\text{ k}}+(100\times10^{-6})\frac{dv_C(t)}{dt}+\frac{v_C(t)}{4\text{ k}+2\text{ k}}=0$$
$$\frac{dv_C(t)}{dt}+\frac{v_C(t)}{(100\times10^{-6})}\left[\frac{1}{4\text{ k}}+\frac{1}{6\text{ k}}\right]=0$$
$$\frac{dv_C(t)}{dt}+\frac{25}{6}v_C(t)=0$$

Write the general solution to the differential equation.

$$v_C(t)=K_2e^{-\frac{25}{6}t}$$

Step 4 of 6

To evaluate the function use the initial conditions.

$$v_C(0)=K_2e^{-\frac{25}{6}(0)}$$
$$v_C(0)=K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v_C(0)=v_C(0^-)=v_C(0^+)=3\text{ V}$.

Substitute 3 V for $v_C(0)$.

$$K_2=3$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, $\boxed{3e^{-\frac{25}{6}t}\text{ V}}$.

Step 5 of 6

Draw the table to plot the response.

Table 1

t(sec)	0	0.5	1	1.5	2	2.5	3	3.5
$v_C(t)$	3	0.374	0.0465	0.0057	0.0007	0.000089	0.00001	0.000001

Step 6 of 6

Plot the response for voltage $v_C(t)$.

Figure 3

Thus, the response is drawn as shown in Figure 3.

Step 1 of 11

Refer to Figure E7.7 in the textbook.

Step 1:

For $t<0$, the switch is in closed position. The circuit is in steady-state condition. In steady state, the capacitor acts as open circuit.

Re-draw the circuit diagram:

Figure 1

Step 2 of 11

From Figure 1, apply Kirchhoff's current law in loop 1.

$$-24+(4\text{ k}\Omega)I_1+(6\text{ k}\Omega)I_1=0$$
$$(10\text{ k}\Omega)I_1=24$$
$$I_1=\frac{24}{10\text{ k}\Omega}$$
$$=2.4\text{ mA}$$

Step 3 of 11

From Figure 1, apply Kirchhoff's current law in loop 2.

$$12+(4\text{ k}\Omega)I_2+(6\text{ k}\Omega)I_2=0$$
$$(10\text{ k}\Omega)I_2=-12$$
$$I_2=\frac{-12}{10\text{ k}\Omega}$$
$$=-1.2\text{ mA}$$

Step 4 of 11

From Figure 1, determine the value of voltage, V .

$$V=I_1(6\text{ k}\Omega)+I_2(6\text{ k}\Omega)+12$$
$$=(2.4\text{ mA})(6\text{ k}\Omega)+(-1.2\text{ mA})(6\text{ k}\Omega)+12$$
$$=14.4-7.2+12$$
$$=19.2\text{ V}$$

From Figure 1, the voltage across capacitor is,

$$v_C(0^-)=V$$
$$=19.2\text{ V}$$

Step 5 of 11

Step 2:

For $t>0$, the switch is in open condition.

Re-draw the circuit diagram.

Figure 2

Step 6 of 11

From Figure 2, apply Kirchhoff's current law in loop 1.

$$(4\text{ k}\Omega)I_1+(6\text{ k}\Omega)(I_1-I_2)+12=0$$

$$(10\text{ k}\Omega)I_1-(6\text{ k}\Omega)I_2=-12 \text{ ..... (1)}$$

From Figure 2, apply Kirchhoff's current law in loop 2.

$$-(6\text{ k}\Omega)I_1+(6\text{ k}\Omega+3\text{ k}\Omega+6\text{ k}\Omega)I_2+19.2-12=0$$
$$-(6\text{ k}\Omega)I_1+(15\text{ k}\Omega)I_2+19.2-12=0$$

$$-(6\text{ k}\Omega)I_1+(15\text{ k}\Omega)I_2=-7.2 \text{ ..... (2)}$$

Step 7 of 11

Solve equation (1) and equation (2).

$$I_1=-1.96\text{ mA}$$
$$I_2=-1.263\text{ mA}$$

Determine the value of voltage $v_o(t)$.

$$v_o(t)=I_2(3\text{ k}\Omega)$$
$$=(-1.263\text{ mA})(3\text{ k}\Omega)$$
$$=-3.79\text{ V}$$

Step 8 of 11

Step 3:

For $t=\infty$, the circuit is in steady state. In steady-state the capacitor acts as open circuit.

Determine the value of voltage across resistor.

$$v_o(\infty)=0\text{ V (Since open circuit)}.$$

Step 9 of 11

Step 4:

Determine the value of time constant.

Re-draw the circuit diagram.

Figure 3

Step 10 of 11

From Figure 3, determine the equivalent resistance.

$$R_{eq}=(4\text{ k}\Omega\parallel 6\text{ k}\Omega)+6\text{ k}\Omega+3\text{ k}\Omega$$
$$=\frac{(4\text{ k}\Omega)(6\text{ k}\Omega)}{4\text{ k}\Omega+6\text{ k}\Omega}+6\text{ k}\Omega+3\text{ k}\Omega$$
$$=2.4\text{ k}\Omega+6\text{ k}\Omega+3\text{ k}\Omega$$
$$=11.4\text{ k}\Omega$$

Calculate the time constant of the circuit.

$$\tau=R_{eq}C$$
$$=(11.4\text{ k}\Omega)(5\ \mu\text{F})$$
$$=0.057\text{ s}$$

Step 11 of 11

Step 5:

Write the general expression for $v_o(t)$ for $t>0$.

$$v_o(t)=v_o(\infty)+\left[v_o(0^+)-v_o(t)\right]e^{-\frac{t}{\tau}}$$
$$=0+\left[-3.79-0\right]e^{-\frac{t}{0.057}}$$
$$=-3.79e^{-\frac{t}{0.057}}\text{ V}$$

Therefore, the value of voltage $v_o(t)$ for $t>0$ is, $\boxed{-3.79e^{-\frac{t}{0.057}}\text{ V}}$.

Step 1 of 7

Refer to Figure P7.8 in the text book.

At $t = 0^-$, the switch is opened and the capacitor is replaced by a open circuit.

Draw the modified circuit of Figure P7.8 at $t = 0^-$.

Figure 1

Step 2 of 7

Apply voltage division rule to determine the initial voltage across the capacitor.

$$v_C(0^-) = 6\left(\frac{12\text{ k}}{12\text{ k} + 12\text{ k}}\right)$$
$$= 6\left(\frac{1}{2}\right)$$
$$= 3\text{ V}$$

The voltage across the capacitor cannot change in zero time.

Hence, $v_C(0) = v_C(0^-) = v_C(0^+) = 3\text{ V}$.

Determine the value of initial current $i_o(t)$ at $t = 0^-$.

$$i_o(0^-) = \frac{v_C(0^-)}{12\text{ k}}$$
$$= \frac{3}{12\text{ k}}$$
$$= 0.25\text{ mA}$$

Thus, the output current $i_o(t)$ at $t = 0^-$ that is just prior to switch closing is, $\boxed{0.25\text{ mA}}$.

Step 3 of 7

At $t > 0$, the switch is closed.

Draw the modified circuit of Figure P7.8 at $t > 0$.

Figure 2

Step 4 of 7

Apply Kirchhoff's current Law at top node.

$$\frac{v_C(t) - 6}{12\text{ k}} + \left(200 \times 10^{-6}\right)\frac{dv_C(t)}{dt} + \frac{v_C(t)}{12\text{ k}} = 0$$
$$\left(200 \times 10^{-6}\right)\frac{dv_C(t)}{dt} + v_C(t)\left[\frac{1}{12\text{ k}} + \frac{1}{12\text{ k}}\right] = \frac{6}{12\text{ k}}$$
$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{\left(200 \times 10^{-6}\right)}\left[\frac{1}{6\text{ k}}\right] = \frac{1}{\left(200 \times 10^{-6}\right)(2\text{ k})}$$
$$\frac{dv_C(t)}{dt} + \frac{5}{6}v_C(t) = 2.5$$

Write the general solution to the differential equation.

$$v_C(t) = \frac{2.5(6)}{5} + K_2 e^{-\frac{5}{6}t}$$

$$v_C(t) = 3 + K_2 e^{-\frac{5}{6}t} \quad \text{..... (1)}$$

Substitute 0 for t in the equation.

$$v_C(0) = 3 + K_2^{-\frac{5}{6}(0)}$$
$$v_C(0) = 3 + K_2$$

Substitute 3 V for $v_C(0)$ in the equation.

$$3 = K_2 + 3$$
$$K_2 = 0$$

Step 5 of 7

Substitute 0 for K_2 in equation (1) to determine the expression for voltage, $v_C(t)$.

$$v_C(t) = 3 + (0)e^{-\frac{5}{6}t}$$
$$= 3\text{ V}$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, 3 V .

Step 6 of 7

Determine the expression for output current $i_o(t)$ at $t > 0$.

$$i_o(t) = \frac{v_C(t)}{12\text{ k}}$$

Substitute 3 V for $v_C(t)$ in the equation.

$$i_o(t) = \frac{3}{12\text{ k}}$$
$$= 0.25\text{ mA}$$

Thus, the expression for output current, $i_o(t)$ for $t > 0$ is, $\boxed{0.25\text{ mA}}$.

Step 7 of 7

Plot the response for current $i_o(t)$.

Figure 3

Thus, the response for current $i_o(t)$ is drawn as shown in Figure 3.

Step 1 of 11

Refer to Figure E7.8 in the textbook.

Step 1:

For $t<0$, the switch is in closed position. The circuit is in steady-state condition. In steady state, the inductor acts as short circuit.

Re-draw the circuit diagram.

Figure 1

Step 2 of 11

Determine the value of current $i_L(t)$.

Apply nodal analysis at node V_1.

$$\frac{V_1}{4}+\frac{V_1-12}{6}+\frac{V_1-V_2}{3}=0$$
$$V_1\left[\frac{1}{4}+\frac{1}{6}+\frac{1}{3}\right]-V_2\left[\frac{1}{3}\right]=\frac{12}{6}$$
$$V_1\left[\frac{3}{4}\right]-V_2\left[\frac{1}{3}\right]=2 \text{ ..... (1)}$$

Step 3 of 11

Apply nodal analysis at node V_2.

$$\frac{V_2-V_1}{3}+\frac{V_2}{3}-3=0$$
$$-V_1\left[\frac{1}{3}\right]+V_2\left[\frac{1}{3}+\frac{1}{3}\right]=3$$
$$-V_1\left[\frac{1}{3}\right]+V_2\left[\frac{2}{3}\right]=3 \text{ ..... (2)}$$

Step 4 of 11

Solve equation (1) and equation (2).

$$V_1=6\text{ V}$$
$$V_2=7.5\text{ V}$$

Determine the value of current i_L.

$$\begin{aligned} i_L &= \frac{V_1}{4} \\ &= \frac{6}{4} \\ &= 1.5\text{ A} \end{aligned}$$

Step 5 of 11

Step 2:

For $t>0$, the switch is in open condition.

Re-draw the circuit diagram.

Figure 2

Step 6 of 11

From Figure 2, determine the value of $i_o(0^+)$.

$$\begin{aligned} i_o(0^+) &= 3-1.5 \\ &= 1.5\text{ A} \end{aligned}$$

Step 7 of 11

Step 3:
For $t=\infty$, the circuit is in steady state. In steady-state the inductor acts as short circuit.

Re-draw the circuit diagram.

Figure 3

Step 8 of 11

Apply nodal analysis at node V_1.

$$\frac{V_1}{3+4}+\frac{V_1}{3}-3=0$$
$$V_1\left[\frac{1}{7}+\frac{1}{3}\right]=3$$
$$V_1\left[\frac{10}{21}\right]=3$$
$$\begin{aligned} V_1 &= (3)\left(\frac{21}{10}\right) \\ &= 6.3\text{ V} \end{aligned}$$

Step 9 of 11

Determine the value of $i_o(\infty)$.

$$\begin{aligned} i_o(\infty) &= \frac{V_1}{3} \\ &= \frac{6.3}{3} \\ &= 2.1\text{ A} \end{aligned}$$

Step 10 of 11

Step 4:

Determine the time constant of the circuit.

$$\tau=\frac{L}{R_{eq}}$$

Determine the value of equivalent resistance R_{eq}.

$$\begin{aligned} R_{eq} &= 4+3+3 \\ &= 10\ \Omega \end{aligned}$$

Calculate the time constant of the circuit.

$$\begin{aligned} \tau &= \frac{100\times10^{-3}}{10} \\ &= 0.01\text{ s} \end{aligned}$$

Step 11 of 11

Step 5:

Determine the expression for $i_o(t)$ for $t>0$.

$$\begin{aligned} i_o(t) &= i_o(\infty)+\left[i_o(0^+)-i_o(\infty)\right]e^{-\frac{t}{\tau}} \\ &= 2.1+\left[2.1-1.5\right]e^{-\frac{t}{0.01}} \\ &= 2.1-0.6e^{-\frac{t}{0.01}}\text{ A} \end{aligned}$$

Therefore, the expression for $i_o(t)$ for $t>0$ is $\boxed{2.1-0.6e^{-\frac{t}{0.01}}\text{ A}}$.

Step 1 of 7

Refer to Figure P7.9 in the text book.

Draw the circuit for $t<0^-$.

Figure 1

Step 2 of 7

Apply voltage division rule to calculate the initial capacitor voltage.

$$v_C(0^-)=\left(\frac{6\text{ k}}{6\text{ k}+6\text{ k}}\right)(12)$$
$$=\frac{1}{2}\times 12$$
$$=6\text{ V}$$

Draw the circuit for $t>0$.

Figure 2

Step 3 of 7

Redraw the Figure to simplify the circuit.

Figure 3

Step 4 of 7

Apply Kirchhoff's current law.

$$(100\mu)\frac{dv_C(t)}{dt}+\frac{v_C(t)}{6\text{ k}\Omega}+\frac{v_C(t)}{(6\text{ k}\Omega+6\text{ k}\Omega)}=0$$
$$\left(100\times10^{-6}\right)\frac{dv_C(t)}{dt}+\frac{v_C(t)}{4\times10^3}=0$$
$$\frac{dv_C(t)}{dt}+2.5v_C(t)=0 \quad \text{..... (1)}$$

The general solution for the differential equation is,

$$v_C(t)=Ae^{-\frac{t}{\tau}}$$

At $t=0$,

$$v_C(0)=Ae^0$$
$$A=v_C(0) \qquad \left[v_C(0)=6\text{ V}\right]$$
$$A=6$$

The resultant capacitor voltage is,

$$v_C(t)=6e^{-\frac{t}{\tau}}$$

Step 5 of 7

Substitute $6e^{-\frac{t}{\tau}}$ for $v_C(t)$ in equation (1).

$$\frac{d}{dt}\left[6e^{-\frac{t}{\tau}}\right]+2.5\left(6e^{-\frac{t}{\tau}}\right)=0$$
$$6e^{-\frac{t}{\tau}}\left(-\frac{1}{\tau}\right)+15e^{-\frac{t}{\tau}}=0$$

At $t=0$,

$$6e^0\left(-\frac{1}{\tau}\right)+15e^0=0$$
$$\frac{6}{\tau}=15$$
$$\tau=0.4\text{ s}$$

Step 6 of 7

Thus, the capacitor voltage is,

$$v_C(t)=6e^{-\frac{t}{0.4}}$$
$$=6e^{-2.5t}\text{ V}$$

Apply voltage division rule to calculate the output voltage.

$$v_o(t)=-\left(\frac{6\text{ k}\Omega}{6\text{ k}\Omega+6\text{ k}\Omega}\right)v_C(t)$$
$$=-\left(\frac{1}{2}\right)\left(6e^{-2.5t}\right)$$
$$=-3e^{-2.5t}\text{ V}$$

Thus, the output voltage is $\boxed{-3e^{-2.5t}\text{ V}}$.

Step 7 of 7

Draw the plot for the output voltage waveform.

Figure 2

Thus, the plot for the output voltage waveform is shown in Figure 2.

Step 1 of 9

Refer to Figure E7.9 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RC* circuit,

$$x(t) = v_o(t)$$
$$K_1 = v_o(\infty)$$
$$K_2 = v_o(0^+) - v_o(\infty)$$
$$\tau = R_{th}C$$

Substitute these values in equation $x(t)$.

$$v_o(t) = v_o(\infty) + \left[v_o(0^+) - v_o(\infty)\right]e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

At $t = 0^-$, the switch is opened and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure E7.9 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 9

The loop 1 is an open loop. Hence, no current flowing in the loop 1.

$$v_A = 4(3)$$
$$v_A = 12 \text{ V}$$

Apply KVL to the loop 2.

$$-v_A - 24 - 2v_A + v_C(0^-) = 0$$
$$v_C(0^-) = 24 + 3v_A$$
$$v_C(0^-) = 24 + 3(12)$$
$$v_C(0^-) = 60 \text{ V}$$

Step 3 of 9

At $t = 0^+$, the switch is closed and the capacitor is replaced by a voltage source. The voltage across the capacitor cannot change in zero time. Hence, $v_C(0^-) = v_C(0^+)$.

Redraw the Figure E7.9 at $t = 0^+$.

Figure 2: $t = 0^+$

Step 4 of 9

From Figure 2, the output voltage at $t = 0^+$ is, $v_o(0^+) = 60 \text{ V}$.

After a long time the switch is closed the circuit goes to steady state. In steady state $t = \infty$ replace the capacitor by a open circuit.

Redraw the Figure E7.9 at $t = \infty$.

Figure 3: $t = \infty$

Step 5 of 9

The loop at the output is an open loop, hence no current flows in this loop and in addition $v_A = 0 \text{ V}$.

Calculate the voltage at $t = \infty$.

$$-v_A - 24 - 2v_A + v_o(\infty) = 0$$
$$v_o(\infty) = 24 + 3v_A$$
$$v_o(\infty) = 24 + 3(0)$$
$$v_o(\infty) = 24 \text{ V}$$

Calculation of open circuit voltage:

Redraw the Figure E7.9 to calculate open circuit voltage by replacing the capacitor by open circuit.

Figure 4

Step 6 of 9

The loop at the output is an open loop, hence no current flows in this loop and in addition $v_A = 0 \text{ V}$.

Apply KVL to the circuit.

$$-v_A - 24 - 2v_A + v_{OC} = 0$$
$$v_{OC} = 24 + 3v_A$$
$$v_{OC} = 24 + 3(0)$$
$$v_{OC} = 24 \text{ V}$$

Step 7 of 9

Calculation of short circuit current:

Redraw the Figure E7.9 to calculate short circuit current by replacing the capacitor by short circuit.

Figure 5

Step 8 of 9

The voltage across the parallel resistors is same as the voltage across their equivalent resistor.

Redraw the circuit in Figure 5 after simplify.

Figure 6

The voltage across the $2\ \Omega$ resistor is, $v_A = -2i_{SC}$

Apply KVL to the circuit.

$$-v_A - 24 - 2v_A = 0$$
$$-24 - 3v_A = 0$$

Substitute $-2i_{SC}$ for v_A.

$$-24 - 3(-2i_{SC}) = 0$$
$$6i_{SC} = 24$$
$$i_{SC} = 4 \text{ A}$$

Step 9 of 9

Calculate the Thevenin's equivalent resistance.

$$R_{th} = \frac{v_{OC}}{i_{SC}}$$
$$= \frac{24}{4}$$
$$= 6\ \Omega$$

Calculate the time constant.

$$\tau = R_{th}C$$
$$= 6(2)$$
$$= 12$$

Substitute 24 V for $v_o(\infty)$, 50 V for $v_o(0^+)$ and 12 for τ.

$$v_o(t) = 24 + [50 - 24]e^{-\frac{t}{12}}$$
$$= 24 + 36e^{-\frac{t}{12}} \text{ V}$$

Thus, the voltage $v_o(t)$ for $t > 0$ is, $\boxed{24 + 36e^{-\frac{t}{12}} \text{ V}}$

Step 1 of 4

Refer to Figure P7.4 in the text book.

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.4 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 4

Apply Kirchhoff's current law at node v_1 .

$$\frac{v_1}{3\text{ k}} + \frac{v_1 - 12}{6\text{ k}} = 0$$
$$3v_1 - 12 = 0$$
$$v_1 = 4\text{ V}$$

Thus, the initial voltage across the capacitor is, $v_C(0^-) = 4\text{ V}$.

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 3 of 4

Write the Kirchhoff's current law equation.

$$\frac{v_C(t) - 12}{6\text{ k}} + \left(100\times10^{-6}\right)\frac{dv_C(t)}{dt} = 0$$
$$\left(100\times10^{-6}\right)\frac{dv_C(t)}{dt} + v_C(t)\left[\frac{1}{6\text{ k}}\right] = \frac{2}{1\text{ k}}$$
$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{\left(100\times10^{-6}\right)}\left[\frac{1}{6\text{ k}}\right] = \frac{2}{1\text{ k}\left(100\times10^{-6}\right)}$$
$$\frac{dv_C(t)}{dt} + \frac{5}{3}v_C(t) = 20$$

Write the general solution to the differential equation.

$$v_C(t) = \frac{20}{\left(\frac{5}{3}\right)} + K_2 e^{-\frac{5}{3}t}$$
$$v_C(t) = 12 + K_2 e^{-\frac{5}{3}t}$$

Step 4 of 4

To evaluate the function use the initial conditions.

$$v_C(0) = 12 + K_2 e^{-\frac{5}{3}(0)}$$
$$v_C(0) = 12 + K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v_C(0) = v_C(0^-) = v_C(0^+) = 4\text{ V}$.

Substitute 4 V for $v_C(0)$.

$$4 = 12 + K_2$$
$$K_2 = -8$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, $\boxed{12 - 8e^{-\frac{5}{3}t}\text{ V}}$.

Step 1 of 18

Refer to Figure E7.10 in the textbook.

Step 1:

For $t < 0$, the switch is in closed position. The circuit is in steady-state condition. In steady state, the capacitor acts as open circuit.

Re-draw the circuit diagram.

Figure 1

Step 2 of 18

From Figure 1, there is a short circuit across $6\ \text{k}\Omega$ resistor. Re-draw the circuit diagram.

Figure 2

Step 3 of 18

From Figure 2, determine the value of current i_A .

$$i_A = \frac{12 - V_1}{6\ \text{k}\Omega}$$

Apply nodal analysis at node V_1 .

$$\frac{V_1 - 12}{6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} - 2i_A = 0$$

Substitute $\frac{12 - V_1}{6\ \text{k}\Omega}$ for i_A in the equation

$$\frac{V_1 - 12}{6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} - 2\left[\frac{12 - V_1}{6\ \text{k}\Omega}\right] = 0$$

$$\frac{V_1 - 12}{6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} + 2\left[\frac{V_1 - 12}{6\ \text{k}\Omega}\right] = 0$$

$$\frac{V_1}{4\ \text{k}\Omega} + 3\left[\frac{V_1 - 12}{6\ \text{k}\Omega}\right] = 0$$

$$V_1\left[\frac{1}{4\ \text{k}\Omega} + \frac{3}{6\ \text{k}\Omega}\right] = \frac{36}{6\ \text{k}\Omega}$$

$$V_1\left[\frac{1}{4} + \frac{3}{6}\right] = \frac{36}{6}$$

$$V_1\left[\frac{3}{4}\right] = 6$$

$$V_1 = (6)\left(\frac{4}{3}\right)$$
$$= 8\ \text{V}$$

Step 4 of 18

Determine the value of current i_A .

$$i_A = \frac{12 - 8}{6\ \text{k}\Omega}$$
$$= \frac{4}{6}\ \text{mA}$$

From Figure 2, determine the value of voltage across capacitor $v_C(t)$.

$$v_C(t) = V_1 - (-2I_A)(6\ \text{k}\Omega)$$

Substitute $\frac{4}{6}$ mA for I_A and 8 V for V_1 in the equation.

$$v_C(t) = 8 - (-2)\left(\frac{4}{6}\ \text{mA}\right)(6\ \text{k}\Omega)$$
$$= 8 + 8$$
$$= 16\ \text{V}$$

Step 5 of 18

Step 2:

For $t > 0$, the switch is in open condition

Re-draw the circuit diagram.

Figure 3

Step 6 of 18

From Figure 3, determine the value of current i_A .

$$i_A = \frac{12 - V_1}{6\ \text{k}\Omega + 6\ \text{k}\Omega}$$
$$= \frac{12 - V_1}{12\ \text{k}\Omega}$$

Apply nodal analysis at node V_1 .

$$\frac{V_1 - 12}{6\ \text{k}\Omega + 6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} + \frac{V_1 - V_2}{6\ \text{k}\Omega} = 0$$

$$V_1\left[\frac{1}{12\ \text{k}\Omega} + \frac{1}{4\ \text{k}\Omega} + \frac{1}{6\ \text{k}\Omega}\right] - V_2\left[\frac{1}{6\ \text{k}\Omega}\right] = \frac{12}{12\ \text{k}\Omega}$$

$$V_1\left[\frac{1}{12} + \frac{1}{4} + \frac{1}{6}\right] - V_2\left[\frac{1}{6}\right] = \frac{12}{12}$$

$$V_1\left[\frac{1}{2}\right] - V_2\left[\frac{1}{6}\right] = 1 \quad \ldots\ldots (1)$$

Step 7 of 18

Apply nodal analysis at node V_2 .

$$\frac{V_2 - V_1}{6\ \text{k}\Omega} - 2i_A + \frac{V_2 - 16}{3\ \text{k}\Omega} = 0$$

Substitute $\frac{12 - V_1}{12\ \text{k}\Omega}$ for i_A in the equation.

$$\frac{V_2 - V_1}{6\ \text{k}\Omega} - 2\left[\frac{12 - V_1}{12\ \text{k}\Omega}\right] + \frac{V_2 - 16}{3\ \text{k}\Omega} = 0$$

$$\frac{V_2 - V_1}{6} - \left[\frac{12 - V_1}{6}\right] + \frac{V_2 - 16}{3} = 0$$

$$V_1\left[\frac{1}{6} - \frac{1}{6}\right] + V_2\left[\frac{1}{6} + \frac{1}{3}\right] = 2 + \frac{16}{3}$$

$$V_2\left[\frac{1}{2}\right] = \frac{22}{3}$$

$$V_2 = \left(\frac{22}{3}\right)(2)$$
$$= 14.67\ \text{V}$$

Step 8 of 18

From equation (1), determine the value of voltage V_1 .

Substitute 14.67 V for V_2 in equation (1).

$$V_1\left[\frac{1}{2}\right] - (14.67)\left[\frac{1}{6}\right] = 1$$

$$V_1\left[\frac{1}{2}\right] - 2.445 = 1$$

$$V_1 = 6.89\ \text{V}$$

Step 9 of 18

Determine the value of $i_o(0^+)$.

$$i_o(0^+) = \frac{V_1}{4\ \text{k}\Omega}$$
$$= \frac{6.89}{4\ \text{k}\Omega}$$
$$= 1.723\ \text{mA}$$

Step 10 of 18

Step 3:

For $t = \infty$, the circuit is in steady state. In steady-state the capacitor acts as open circuit.

Re-draw the circuit diagram.

Figure 5

Step 11 of 18

From Figure 4, determine the value of current i_A .

$$i_A = \frac{12 - V_1}{6\ \text{k}\Omega + 6\ \text{k}\Omega}$$
$$= \frac{12 - V_1}{12\ \text{k}\Omega}$$

Apply nodal analysis at node V_1 .

$$\frac{V_1 - 12}{6\ \text{k}\Omega + 6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} - 2i_A = 0$$

Substitute $\frac{12 - V_1}{6\ \text{k}\Omega}$ for i_A in the equation.

$$\frac{V_1 - 12}{12\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} - 2\left[\frac{12 - V_1}{12\ \text{k}\Omega}\right] = 0$$

$$\frac{V_1 - 12}{12\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} + 2\left[\frac{V_1 - 12}{12\ \text{k}\Omega}\right] = 0$$

$$\frac{V_1}{4\ \text{k}\Omega} + 3\left[\frac{V_1 - 12}{12\ \text{k}\Omega}\right] = 0$$

$$V_1\left[\frac{1}{4\ \text{k}\Omega} + \frac{3}{12\ \text{k}\Omega}\right] = \frac{36}{12\ \text{k}\Omega}$$

$$V_1\left[\frac{1}{4} + \frac{3}{12}\right] = \frac{36}{12}$$

$$V_1\left[\frac{1}{2}\right] = 3$$

$$V_1 = (3)(2)$$
$$= 6\ \text{V}$$

Step 12 of 18

Determine the value of $i_o(\infty)$.

$$i_o(\infty) = \frac{V_1}{4\ \text{k}\Omega}$$
$$= \frac{6}{4\ \text{k}\Omega}$$
$$= 1.5\ \text{mA}$$

Step 13 of 18

Determine the time constant of the circuit.

From figure 4, determine the value of i_A .

$$i_A = \frac{12 - V_1}{6\ \text{k}\Omega + 6\ \text{k}\Omega}$$
$$= \frac{12 - 6}{12\ \text{k}\Omega}$$
$$= 0.5\ \text{mA}$$

From figure 4, determine the value of v_{OC} .

$$v_{OC} = V_1 - (-2I_A)(6\ \text{k}\Omega)$$
$$= 6 + (2)(0.5\ \text{mA})(6\ \text{k}\Omega)$$
$$= 6 + 6$$
$$= 12\ \text{V}$$

Step 14 of 18

Determine the value of short circuit current i_{SC} .

Re-draw the circuit diagram.

Figure 6

Step 15 of 18

From Figure 6, determine the value of current i_A .

$$i_A = \frac{12 - V_1}{6\ \text{k}\Omega + 6\ \text{k}\Omega}$$
$$= \frac{12 - V_1}{12\ \text{k}\Omega}$$

Apply nodal analysis at node V_1 .

$$\frac{V_1 - 12}{6\ \text{k}\Omega + 6\ \text{k}\Omega} + \frac{V_1}{4\ \text{k}\Omega} + \frac{V_1 - V_2}{6\ \text{k}\Omega} = 0$$

$$V_1\left[\frac{1}{12\ \text{k}\Omega} + \frac{1}{4\ \text{k}\Omega} + \frac{1}{6\ \text{k}\Omega}\right] - V_2\left[\frac{1}{6\ \text{k}\Omega}\right] = \frac{12}{12\ \text{k}\Omega}$$

$$V_1\left[\frac{1}{12} + \frac{1}{4} + \frac{1}{6}\right] - V_2\left[\frac{1}{6}\right] = \frac{12}{12}$$

$$V_1\left[\frac{1}{2}\right] - V_2\left[\frac{1}{6}\right] = 1 \quad \ldots\ldots (2)$$

Step 16 of 18

Apply nodal analysis at node V_2 .

$$\frac{V_2 - V_1}{6\ \text{k}\Omega} - 2i_A + \frac{V_2}{3\ \text{k}\Omega} = 0$$

Substitute $\frac{12 - V_1}{12\ \text{k}\Omega}$ for i_A in the equation.

$$\frac{V_2 - V_1}{6\ \text{k}\Omega} - 2\left[\frac{12 - V_1}{12\ \text{k}\Omega}\right] + \frac{V_2}{3\ \text{k}\Omega} = 0$$

$$\frac{V_2 - V_1}{6} - \left[\frac{12 - V_1}{6}\right] + \frac{V_2}{3} = 0$$

$$V_1\left[\frac{1}{6} - \frac{1}{6}\right] + V_2\left[\frac{1}{6} + \frac{1}{3}\right] = 2$$

$$V_2\left[\frac{1}{2}\right] = 2$$

$$V_2 = (2)(2)$$
$$= 4\ \text{V}$$

From figure 6, determine the value of short circuit current i_{SC} .

$$i_{SC} = \frac{V_2}{3\ \text{k}\Omega}$$
$$= \frac{4}{3\ \text{k}\Omega}$$
$$= 1.33\ \text{mA}$$

Step 17 of 18

Determine the value of Thevenin's resistance.

$$R_{th} = \frac{v_{OC}}{i_{SC}}$$
$$= \frac{12}{1.33\ \text{mA}}$$
$$= 9.023\ \text{k}\Omega$$

Calculate the time constant of the circuit.

$$\tau = R_{th}C$$
$$= (9.023\ \text{k}\Omega)(100\ \mu\text{F})$$
$$= 0.9023\ \text{s}$$

Step 18 of 18

Write the general expression for $i_o(t)$ for $t > 0$.

$$i_o(t) = i_o(\infty) + \left[i_o(0^+) - i_o(t)\right]e^{-\frac{t}{\tau}}$$

$$= 1.5\ \text{mA} + \left[1.723\ \text{mA} - 1.5\ \text{mA}\right]e^{-\frac{t}{0.9023}}$$

$$= \left(1.5 + 0.223^{-\frac{t}{0.9023}}\right)\ \text{mA}$$

Therefore, the value of voltage $i_o(t)$ for $t > 0$ is $\boxed{\left(1.5 + 0.223^{-\frac{t}{0.9023}}\right)\ \text{mA}}$

Step 1 of 4

Refer to Figure P7.5 in the text book.

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.5 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 4

Apply Kirchhoff's current law at node $v_C(0^-)$.

$$\frac{v_C(0^-)}{3\text{ k}+9\text{ k}} + \frac{v_C(0^-)-6}{4\text{ k}} = 0$$
$$4v_C(0^-) - 18 = 0$$
$$v_C(0^-) = 4.5\text{ V}$$

Thus, the initial voltage across the capacitor is, $v_C(0^-) = 4.5\text{ V}$.

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 3 of 4

Write the Kirchhoff's current law equation.

$$\frac{v_C(t)}{12\text{ k}} + (100\times10^{-6})\frac{dv_C(t)}{dt} = 0$$
$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{(100\times10^{-6})}\left[\frac{1}{12\text{ k}}\right] = 0$$
$$\frac{dv_C(t)}{dt} + \frac{5}{6}v_C(t) = 0$$

Write the general solution to the differential equation.

$$v_C(t) = K_2 e^{-\frac{5}{6}t}$$

Step 4 of 4

To evaluate the function use the initial conditions.

$$v_C(0) = K_2 e^{-\frac{5}{6}(0)}$$
$$v_C(0) = K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v_C(0) = v_C(0^-) = v_C(0^+) = 4.5\text{ V}$

.

Substitute 4.5 V for $v_C(0)$.

$$K_2 = 4.5$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, $\boxed{4.5e^{-\frac{5}{6}t}\text{ V}}$.

Step 1 of 12

Consider Figure E7.11 from the text book.

Consider the value of the source voltage.

$$v(t)=\begin{cases}0\text{ V} & t<0\\ 12\text{ V} & 0<t<1\\ 0\text{ V} & t>1\end{cases}$$

Step 2 of 12

Consider the circuit diagram at $t<0$.

Figure 1

As the value of the source voltage is 0 V, the value of the current $i_L(0)$ is 0 A. Therefore, the value of the output voltage is 0 V.

Step 3 of 12

Consider the circuit diagram at $0<t<1$.

Figure 2

Step 4 of 12

Apply Kirchhoff's Voltage Law in Loop-2.

$$i_2(t)(2)+(i_2(t)-i_1(t))(2)+2\frac{di_2(t)}{dt}=0$$

$$i_2(t)+i_2(t)-i_1(t)+\frac{di_2(t)}{dt}=0$$

$$2i_2(t)-i_1(t)+\frac{di_2(t)}{dt}=0$$

$$i_1(t)=2i_2(t)+\frac{di_2(t)}{dt}$$

Therefore, the expression for the current $i_1(t)$ is $2i_2(t)+\frac{di_2(t)}{dt}$.

Step 5 of 12

Apply Kirchhoff's Voltage Law in Loop-1.

$$-12+i_1(t)(2)+(i_1(t)-i_2(t))(2)=0$$

$$-6+i_1(t)+i_1(t)-i_2(t)=0$$

$$-6+2i_1(t)-i_2(t)=0$$

Substitute $2i_2(t)+\frac{di_2(t)}{dt}$ for $i_1(t)$.

$$-6+2\left(2i_2(t)+\frac{di_2(t)}{dt}\right)-i_2(t)=0$$

$$-6+4i_2(t)+2\frac{di_2(t)}{dt}-i_2(t)=0$$

$$2\frac{di_2(t)}{dt}+3i_2(t)=6$$

$$\frac{di_2(t)}{dt}+\left(\frac{3}{2}\right)i_2(t)=\frac{6}{2}$$

$$\frac{di_2(t)}{dt}+\left(\frac{3}{2}\right)i_2(t)=3$$

The value of the current $i_2(t)$ is equal to the current $i_L(t)$.

$$\frac{di_L(t)}{dt}+\left(\frac{3}{2}\right)i_L(t)=3$$

The differential equation of the network is $\frac{di_L(t)}{dt}+\left(\frac{3}{2}\right)i_L(t)=3$.

The solution for the differential equation is,

$$i_L(t)i_2(t)e^{\frac{3}{2}t}=3\int e^{\frac{3}{2}t}dt+k_1$$

$$i_L(t)e^{\frac{3}{2}t}=\frac{3e^{\frac{3}{2}t}}{\frac{3}{2}}+k_1$$

$$i_L(t)e^{\frac{3}{2}t}=2e^{\frac{3}{2}t}+k_1$$

$$i_L(t)=2+k_1e^{-\frac{3}{2}t}\text{ ..... (1)}$$

Substitute 0 for t.

$$i_L(0)=2+k_1e^{-\frac{3}{2}(0)}$$

$$i_L(0)=2+k_1$$

Substitute 0 A for $i_2(0)$.

$$0=2+k_1$$

$$k_1=-2$$

Therefore, the value of the constant is k_1 is -2.

Step 6 of 12

Recall equation (1).

$$i_L(t)=2+k_1e^{-\frac{3}{2}t}$$

Substitute -2 for k_1.

$$i_L(t)=2-2e^{-\frac{3}{2}t}$$

$$=2\left(1-e^{-\frac{3}{2}t}\right)\text{ A}$$

Therefore, the value of the current $i_L(t)$ is $2\left(1-e^{-\frac{3}{2}t}\right)\text{ A}$.

Step 7 of 12

Calculate the value of the output voltage for $0<t<1$.

$$v_o(t)=2i_L(t)$$

Substitute $2\left(1-e^{-\frac{3}{2}t}\right)\text{ A}$ for $i_L(t)$.

$$v_o(t)=2\left(2\left(1-e^{-\frac{3}{2}t}\right)\right)$$

$$v_o(t)=4\left(1-e^{-\frac{3}{2}t}\right)\text{ V ..... (2)}$$

Therefore, the value of the output voltage for $0<t<1$ is $4\left(1-e^{-\frac{3}{2}t}\right)\text{ V}$.

Step 8 of 12

Consider the circuit diagram at $t>1$.

Figure 3

Step 9 of 12

Calculate the value of output voltage at $t=1$.

$$v_o(t)=4\left(1-e^{-\frac{3}{2}t}\right)$$

Substitute 1 for t.

$$v_o(1)=4\left(1-e^{-\frac{3}{2}}\right)$$

$$=4\left(1-e^{-\frac{3}{2}}\right)$$

$$=4(1-0.223)$$

$$=4(0.777)$$

$$v_o(1)=3.11\text{ V}$$

Therefore, the value of the output voltage at $t=1$ is 3.11 V.

0 V voltage source represents the shorted terminals.

Apply Kirchhoff's Voltage Law in the Loop.

$$2\frac{di_L(t)}{dt}+(2+2\|2)i_L(t)=0$$

$$2\frac{di_L(t)}{dt}+(2+1)i_L(t)=0$$

$$\frac{di_L(t)}{dt}+\left(\frac{3}{2}\right)i_L(t)=0$$

Therefore, the differential equation is $\frac{di_L(t)}{dt}+\left(\frac{3}{2}\right)i_L(t)=0$.

Step 10 of 12

The solution of the differential equation is,

$$i_L(t)=k_2e^{\int\frac{3}{2}dt}$$

$$i_L(t)=k_2e^{\frac{3}{2}t}$$

Therefore, the expression for the current at $t>1$ is $k_2e^{\frac{3}{2}t}$.

Step 11 of 12

Calculate the value of the output voltage at $t>1$.

$$v_o(1)=2i_L(t)$$

Substitute $k_2e^{\frac{3}{2}t}$ for $i_L(t)$.

$$v_o(1)=2k_2e^{\frac{3}{2}t}\text{ ..... (3)}$$

Substitute 1 for t.

$$v_o(1)=2k_2e^{\frac{3}{2}(1)}$$

Substitute 3.11 for $v_o(1)$.

$$3.11=2k_2e^{\frac{3}{2}}$$

$$k_2=\frac{3.11}{2}e^{-\frac{3}{2}}$$

Therefore, the value of the constant k_2 is $\frac{3.11}{2}e^{-\frac{3}{2}}$.

Step 12 of 12

Recall equation (3).

$$v_o(t)=2k_2e^{\frac{3}{2}t}$$

Substitute $\frac{3.11}{2}e^{-\frac{3}{2}}$ for k_2.

$$v_o(t)=2\left(\frac{3.11}{2}e^{-\frac{3}{2}}\right)e^{\frac{3}{2}t}$$

$$=3.11e^{-\frac{3}{2}(t-1)}\text{ A}$$

Therefore, the value of the output voltage is $3.11e^{-\frac{3}{2}(t-1)}\text{ V}$.

Therefore, the values of the output voltage at different intervals is

$$\boxed{v_o(t)=\begin{cases}0\text{ V} & t<0\\ 4\left(1-e^{-\frac{3}{2}t}\right)\text{ V} & 0<t<1\\ 3.11e^{-\frac{3}{2}(t-1)}\text{ V} & 1<t\end{cases}}$$

Step 1 of 11

Refer to Figure P7.7 in the text book.

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.7 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 11

Apply Kirchhoff's voltage law to the loop i_1 .

$$i_1(4\text{ k}+12\text{ k})-i_2(12\text{ k})=0$$
$$i_1(16\text{ k})-i_2(12\text{ k})=0$$
$$4i_1-3i_2=0 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law to the loop i_2 .

$$i_2(12\text{ k}+12\text{ k})-i_1(12\text{ k})-i_3(12\text{ k})-12=0$$
$$i_2(24\text{ k})-i_1(12\text{ k})-i_3(12\text{ k})-12=0$$
$$2i_2-i_1-i_3=1\times10^{-3} \text{ ..... (2)}$$

Apply Kirchhoff's voltage law to the loop i_3 .

$$i_3(12\text{ k}+12\text{ k})-i_2(12\text{ k})=0$$
$$2i_3-i_2=0$$
$$i_3=\frac{i_2}{2}$$

Step 3 of 11

Substitute $\frac{i_2}{2}$ for i_3 in equation (2).

$$2i_2-i_1-\frac{i_2}{2}=1\times10^{-3}$$
$$3i_2-2i_1=2\times10^{-3}$$
$$3i_2=2i_1+2\times10^{-3}$$

Substitute $2i_1+2\times10^{-3}$ for $3i_2$ in equation (1).

$$4i_1-\left(2i_1+2\times10^{-3}\right)=0$$
$$2i_1=2\times10^{-3}$$
$$i_1=1\text{ mA}$$

Thus, the output current i_o for $t = 0^-$ that is just prior to switch opening is,

$$\boxed{i(0^-)=-i_1=-1\text{ mA}}.$$

Step 4 of 11

Calculate the initial voltage across the capacitor.

$$\begin{aligned}v_C(0^-)&=-4\text{ k}(-i_1)\\&=4\text{ k}(i_1)\\&=4\text{ k}(1\text{ mA})\\&=4\text{ V}\end{aligned}$$

Thus, the initial voltage across the capacitor is, $v_C(0^-)=4\text{ V}$.

Step 5 of 11

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 2: $t > 0$

Step 6 of 11

Apply Kirchhoff's voltage law to the loop i_1 .

$$i_1(3\text{ k}+4\text{ k})+v_C(t)-i_2(4\text{ k})=0$$
$$i_1(7\text{ k})+v_C(t)-i_2(4\text{ k})=0 \text{ ..... (3)}$$

Step 7 of 11

Apply Kirchhoff's voltage law to the loop i_2 .

$$i_2(4\text{ k}+12\text{ k})-i_1(4\text{ k})=0$$
$$i_2(16\text{ k})-i_1(4\text{ k})=0$$
$$i_2=\frac{i_1}{4}$$

Substitute $\frac{i_1}{4}$ for i_2 in equation (3).

$$i_1(7\text{ k})+v_C(t)-\frac{i_1}{4}(4\text{ k})=0$$
$$i_1(6\text{ k})+v_C(t)=0$$

From the Figure 2, it is clear that $i_1=\left(50\times10^{-6}\right)\frac{dv_C(t)}{dt}$

$$\left(50\times10^{-6}\right)\frac{dv_C(t)}{dt}(6\text{ k})+v_C(t)=0$$
$$\frac{dv_C(t)}{dt}+\frac{10}{3}v_C(t)=0$$

Write the general solution to the differential equation.

$$v_C(t)=K_2e^{-\frac{10}{3}t}$$

Step 8 of 11

To evaluate the function use the initial conditions.

$$v_C(0)=K_2e^{-\frac{10}{3}(0)}$$
$$v_C(0)=K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v_C(0)=v_C(0^-)=v_C(0^+)=4\text{ V}$.

Substitute 4 V for $v_C(0)$.

$$K_2=4$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, $4e^{-\frac{10}{3}t}\text{ V}$.

Step 9 of 11

Calculate the current i_1 .

$$\begin{aligned}i_1&=\left(50\times10^{-6}\right)\frac{d\left[4e^{-\frac{10}{3}t}\right]}{dt}\\&=\left(50\times10^{-6}\right)\left(4\left(-\frac{10}{3}\right)e^{-\frac{10}{3}t}\right)\\&=-\frac{200\times10^{-6}}{3}e^{-\frac{10}{3}t}\text{ A}\end{aligned}$$

Calculate the current i_2 .

$$\begin{aligned}i_2&=\frac{i_1}{4}\\&=-\frac{200\times10^{-6}}{3(4)}e^{-\frac{10}{3}t}\\&=-\frac{50\times10^{-6}}{3}e^{-\frac{10}{3}t}\text{ A}\end{aligned}$$

Step 10 of 11

Now calculate the output current, i_o .

$$\begin{aligned}i_o&=i_1-i_2\\&=-\frac{200\times10^{-6}}{3}e^{-\frac{10}{3}t}-\left(-\frac{50\times10^{-6}}{3}e^{-\frac{10}{3}t}\right)\\&=-0.5e^{-\frac{10}{3}t}\text{ mA}\end{aligned}$$

Thus, the output current i_o for $t > 0$ is, $\boxed{-0.5e^{-\frac{10}{3}t}\text{ mA}}$.

Step 11 of 11

Draw the table to plot the response.

Table 1

$t(\text{sec})$	0^-	0	0.5	1	1.5	2
$i_o(\text{mA})$	−1	−0.5	−0.094	−0.0178	−0.0034	−0.00063

Plot the response for current $i_o(t)$.

Figure 3

Thus, the response is drawn as shown in Figure 3.

Step 1 of 6

Consider Figure E7.12 from the text book.

Figure 1

Step 2 of 6

Apply nodal analysis.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=i(t)$$

Assume the current source to be a constant value. Apply derivative with respect to t .

$$\frac{1}{R}\frac{d(v(t))}{dt}+C\frac{d^2(v(t))}{dt^2}+\frac{1}{L}(v(t))=0$$

$$\frac{d^2(v(t))}{dt^2}+\frac{1}{RC}\frac{d(v(t))}{dt}+\frac{1}{LC}(v(t))=0 \quad \text{..... (1)}$$

Step 3 of 6

Consider the characteristic equation for equation (1).

$$s^2+\left(\frac{1}{RC}\right)s+\frac{1}{LC}=0$$

Substitute $1\,\Omega$ for R , 2 H for L for 2 F for C .

$$s^2+\left(\frac{1}{(1)(2)}\right)s+\frac{1}{(2)(2)}=0$$

$$s^2+\left(\frac{1}{2}\right)s+\frac{1}{4}=0$$

$$s^2+0.5s+0.25=0 \quad \text{..... (2)}$$

Solve the characteristic equation.

$$(s-0.25-j0.433)(s-0.25-j0.433)=0$$

The roots are $s_1=0.25+j0.433$ and $s_2=0.25-j0.433$.

The roots are complex. Hence, the circuit exhibits under damped characteristics.

Step 4 of 6

Recall equation (1).

$$s^2+0.5s+0.25=0$$

Compare with $s^2+2\xi\omega_o s+\omega_o{}^2=0$.

$$\omega_o{}^2=0.25 \quad \text{..... (3)}$$

and

$$2\xi\omega_o=0.5 \quad \text{..... (4)}$$

Step 5 of 6

Recall equation (3).

$$\omega_o{}^2=0.25$$

$$\omega_o=\sqrt{0.25}$$

$$\omega_o=0.5\text{ rad/sec}$$

Therefore, the value of the under damped natural frequency is $\boxed{0.5\text{ rad/sec}}$.

Step 6 of 6

Recall equation (4).

$$2\xi\omega_o=0.5$$

Substitute 0.5 rad/sec for ω_o .

$$2\xi(0.5)=0.5$$

$$\xi=0.5$$

Therefore, the value of the damping ratio is $\boxed{0.5}$.

Step 1 of 6

Refer to Figure P7.10 in the text book.

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Draw the modified circuit of Figure P7.10 at $t = 0^-$.

Figure 1

Step 2 of 6

In Figure 1, the resistors $4\ \Omega$ and $12\ \Omega$ are in parallel.

$$\begin{aligned}(12\ \Omega \| 4\ \Omega) &= \frac{(12)(4)}{12+4} \\ &= \frac{48}{16} \\ &= 3\ \Omega\end{aligned}$$

The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 3 of 6

Apply current division rule to determine the value of current, $i_L(0^-)$.

$$\begin{aligned}i_L(0^-) &= 2\left(\frac{3}{3+6}\right) \\ &= \frac{2}{3}\ \text{A}\end{aligned}$$

The current flowing through the inductor cannot change in zero time.

Hence, $i_o(0) = i_L(0^-) = i_L(0^+) = i_L(0) = \frac{2}{3}$ A .

Step 4 of 6

At $t > 0$, the switch is opened. So, 2 A independent current source and $12\ \Omega$ resistor have no impact on the resulting circuit.

Draw the modified circuit of Figure P7.10 at $t > 0$.

Figure 3

Step 5 of 6

Apply Kirchhoff's Voltage Law to Figure 3.

$$2\frac{di_L(t)}{dt} + (6+4)i_L(t) = 0$$

$$\frac{di_L(t)}{dt} + 5i_L(t) = 0$$

Write the general solution for the differential equation.

$i_L(t) = K_2 e^{-5t}$ ..... (1)

Substitute **0** for t in the equation.

$$\begin{aligned}i_L(0) &= K_2 e^{-5(0)} \\ &= K_2 \\ &= \frac{2}{3} \qquad \left(\text{since } i_L(0) = \frac{2}{3}\ \text{A}\right)\end{aligned}$$

Step 6 of 6

Substitute $\frac{2}{3}$ A for K_2 in equation (1).

$$i_L(t) = \frac{2}{3}e^{-5t}$$

Thus, the expression for current, $i_o(t)$ for the network at $t > 0$ is, $\boxed{\frac{2}{3}e^{-5t}\ \text{A}}$.

Step 1 of 6

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Apply mesh analysis in the loop.

$$i(t)(R)+L\frac{di(t)}{dt}+\frac{1}{C}\int i(t)dt=v(t)$$

Assume the voltage source to be a constant value. Apply derivative with respect to t.

$$R\frac{di(t)}{dt}+L\frac{d^2i(t)}{dt^2}+\frac{1}{C}i(t)=0$$

$$\frac{d^2i(t)}{dt^2}+\frac{R}{L}\frac{di(t)}{dt}+\frac{1}{LC}i(t)=0 \text{ ..... (1)}$$

Step 3 of 6

Consider the characteristic equation for equation (1).

$$s^2+\left(\frac{R}{L}\right)s+\frac{1}{LC}=0$$

Substitute $2\,\Omega$ for R, $1\,\text{H}$ for L.

$$s^2+\left(\frac{2}{1}\right)s+\frac{1}{(1)C}=0$$

$$s^2+2s+\frac{1}{C}=0 \text{ ..... (2)}$$

Step 4 of 6

(a)

Recall equation (2).

$$s^2+2s+\frac{1}{C}=0$$

Substitute $\frac{1}{2}\,\text{F}$ for C.

$$s^2+2s+\frac{1}{\left(\frac{1}{2}\right)}=0$$

$$s^2+2s+2=0$$

Solve the characteristic equation.

$$(s+1-j1)(s+1+j1)=0$$

The roots are $s_1=-1+j1$ and $s_2=-1-j1$.

The roots are complex. Hence, the circuit exhibits **under damped** characteristics at $C=\frac{1}{2}\,\text{F}$.

Step 5 of 6

(b)

Recall equation (2).

$$s^2+2s+\frac{1}{C}=0$$

Substitute $1\,\text{F}$ for C.

$$s^2+2s+\frac{1}{1}=0$$

$$s^2+2s+1=0$$

Solve the characteristic equation.

$$(s+1)(s+1)=0$$

The roots are $s_1=-1$ and $s_2=-1$.

The roots are real and equal. Hence, the circuit exhibits **critically damped** characteristics at $C=1\,\text{F}$.

Step 6 of 6

(c)

Recall equation (2).

$$s^2+2s+\frac{1}{C}=0$$

Substitute $2\,\text{F}$ for C.

$$s^2+2s+\frac{1}{2}=0$$

$$s^2+2s+0.5=0$$

Solve the characteristic equation.

$$(s+0.293)(s+1.71)=0$$

The roots are $s_1=-0.293$ and $s_2=-1.71$.

The roots are real and unequal. Hence, the circuit exhibits **over damped** characteristics at $C=2\,\text{F}$.

Step 1 of 7

Replace the inductor with short circuit at $t = 0-$.

Draw the equivalent circuit at $t = 0-$.

Figure 1

Step 2 of 7

Apply Kirchhoff's voltage law at the node voltage $v_o(0-)$.

$$\frac{v_o(0-)}{2} - 4 + \frac{v_o(0-)}{4} + \frac{v_o(0-)}{4} = 0$$

$$4v_o(0-) = 16$$

$$v_o(0-) = 4 \text{ V}$$

$$v_o(0) = 4 \text{ V}$$

Step 3 of 7

Determine the initial current passing through the inductor.

$$\begin{aligned} i_L(0-) &= \frac{v_o(0-)}{4} \\ &= \frac{4}{4} \\ &= 1 \text{ A} \end{aligned}$$

Step 4 of 7

Draw the equivalent circuit for $t > 0$.

Figure 2

Apply Kirchhoff's voltage law in the loop as shown in Figure 2.

$$4i_L + 4\frac{di_L}{dt} + 4i_L = 0$$

$$\frac{di_L}{dt} + 2i_L = 0$$

Step 5 of 7

Find the complementary solution of the inductor current i_L .

$$\frac{di_L(t)/dt}{i_L(t)} = -2$$

$$\frac{d}{dt}\left[\ln i_L(t)\right] = -2$$

$$\ln i_L(t) = -2t + c$$

$$i_L(t) = K_2 e^{-2t}$$

Step 6 of 7

Substitute $t = 0$ in the expression of $i_L(t)$.

$$i_L(0) = K_2 e^{-2(0)}$$

$$K_2 = i_L(0)$$

Substitute 1 A for $i_L(0)$.

$$K_2 = 1$$

The expression for the inductor current for $t > 0$ is,

$$i_L(t) = e^{-2t}$$

Step 7 of 7

Write the expression of the voltage $v_o(t)$.

$$v_o(t) = 4i_L(t)$$

Substitute e^{-2t} for $i_L(t)$.

$$v_o(t) = 4e^{-2t} \text{ V}$$

Thus, the expression of the voltage $v_o(t)$ for $t > 0$ is $\boxed{4e^{-2t} \text{ V}}$.

Step 1 of 9

Consider the Figure E7.14 from the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

Step 2 of 9

Calculate the value of the current $i_L(0^-)$.

$$i_L(0^-) = \frac{12}{6}$$
$$= 2 \text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is 2 A .

The value of the current $i_L(0)$ for $i_L(0^-)$.

The value of the voltage $v_C(0^-)$ is 0 V since the terminals are shorted.

Step 3 of 9

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 9

Apply Kirchhoff's Voltage Law in the Loop.

$$2\frac{di(t)}{dt} + \frac{1}{1}\int i(t)\,dt + 3i(t) = 0$$

$$\frac{di(t)}{dt} + \frac{1}{2}\int i(t)\,dt + \frac{3}{2}i(t) = 0$$

Take derivative with respect to t .

$$\frac{d^2i(t)}{dt^2} + \frac{3}{2}\frac{di(t)}{dt} + \frac{1}{2}i(t) = 0$$

$$\frac{d^2i(t)}{dt^2} + (1.5)\frac{di(t)}{dt} + (0.5)i(t) = 0 \quad \text{..... (1)}$$

Step 5 of 9

Consider the characteristic equation of the differential equation.

$$s^2 + (1.5)s + 0.5 = 0$$

Solve for the characteristic equation.

$$(s+1)(s+0.5) = 0$$

The roots of the characteristic equation are $s_1 = -1$ and $s_2 = -0.5$.

The roots the real and unequal, hence the circuit exhibits over damped characteristics.

Step 6 of 9

Recall equation (1).

$$\frac{d^2i(t)}{dt^2} + (1.5)\frac{di(t)}{dt} + (0.5)i(t) = 0$$

The solution for the differential equation is

$$i(t) = C_1e^{-t} + C_2e^{-t/2} \quad \text{..... (2)}$$

Substitute 0 for t .

$$i(0) = C_1e^{-(0)} + C_2e^{-(0)/2}$$
$$i(0) = C_1 + C_2$$

Substitute 2 A for $i(0)$.

$$2 = C_1 + C_2$$

$$C_1 = 2 - C_2 \quad \text{..... (3)}$$

Therefore, the expression for the constant C_1 is $2 - C_2$.

Step 7 of 9

Recall equation (2).

$$i(t) = C_1e^{-t} + C_2e^{-t/2}$$

Take derivative with respect to t .

$$\frac{di(t)}{dt} = C_1\frac{de^{-t}}{dt} + C_2\frac{de^{-t/2}}{dt}$$
$$= -C_1e^{-t} - \frac{1}{2}C_2e^{-t/2}$$

Substitute 0 for t .

$$\frac{di(0)}{dt} = -C_1e^{-(0)} - \frac{1}{2}C_2e^{-(0)/2}$$
$$= -C_1 - \frac{1}{2}C_2$$

Substitute $2 - C_2$ for C_1 and 2 A for $i(0)$.

$$\frac{d(2)}{dt} = -(2 - C_2) - \frac{1}{2}C_2$$
$$-2 + C_2 - \frac{1}{2}C_2 = 0$$
$$C_2\left(1 - \frac{1}{2}\right) = 2$$
$$C_2\left(\frac{1}{2}\right) = 2$$
$$C_2 = 4$$

Therefore, the value of the constant C_2 is 4 .

Step 8 of 9

Recall equation (3).

$$C_1 = 2 - C_2$$

Substitute 4 for C_2 .

$$C_1 = 2 - 4$$
$$= -2$$

Therefore, the value of the constant C_1 is -2 .

Step 9 of 9

Recall equation (2).

$$i(t) = C_1e^{-t} + C_2e^{-t/2}$$

Substitute 4 for C_2 and -2 for C_1 .

$$i(t) = -2e^{-t} + 4e^{-t/2} \text{ A}$$

Therefore, the value of the current $i(t)$ is $\boxed{-2e^{-t} + 4e^{-t/2} \text{ A}}$.

Step 1 of 6

Refer to Figure P7.11 in the text book.

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Redraw the circuit in Figure P7.11 at $t = 0^-$.

Figure 1: $t = 0^-$

Step 2 of 6

The resistors $12\ \Omega$ and $6\ \Omega$ are in parallel. Calculate the equivalent resistance.

$$12\ \Omega \| 6\ \Omega = \frac{12(6)}{12+6} = \frac{72}{18} = 4\ \Omega$$

Using source transformation technique, simplify the Figure 1.

Redraw the Figure 1 after simplifying.

Figure 2

Step 3 of 6

Calculate the current $i_L(0^-)$, using current division formula.

$$i_L(0^-) = \frac{3}{2}\left(\frac{4\|6}{4\|6+3}\right) = \frac{3}{2}\left(\frac{\frac{4(6)}{10}}{\frac{4(6)}{10}+3}\right) = \frac{3}{2}\left(\frac{2.4}{5.4}\right) = \frac{2}{3}\ \text{A}$$

The current flowing through the inductor cannot change in zero time. Hence,

$$i_o(0) = i_L(0^-) = i_L(0^+) = i_L(0) = \frac{2}{3}\ \text{A}$$

Step 4 of 6

At $t > 0$, the switch is opened. Hence 6 V independent voltage source and $12\ \Omega$ and $6\ \Omega$ resistor have no impact on the resulting circuit.

Redraw the network for $t > 0$.

Figure 3: $t > 0$

Step 5 of 6

Write the KVL to the circuit.

$$2\frac{di_L(t)}{dt} + (6+3)i_L(t) = 0$$

$$\frac{di_L(t)}{dt} + 4.5i_L(t) = 0$$

Write the general solution for the differential equation.

$$i_L(t) = K_2 e^{-4.5t}$$

To evaluate the function use the initial conditions.

$$i_L(0) = K_2 e^{-4.5(0)}$$

$$i_L(0) = K_2$$

Substitute $\frac{2}{3}$ A for $i_L(0)$.

$$K_2 = \frac{2}{3}$$

Thus, the current $i_L(t)$ for the network at $t > 0$ is, $\boxed{\frac{2}{3}e^{-4.5t}\ \text{A}}$.

Step 6 of 6

Draw the table to plot the response.

Table 1

t(sec)	0	0.2	0.4	0.6	0.8	1	1.2	1.4
$i_L(t)$	0.666	0.271	0.11	0.0448	0.018	0.007	0.003	0.001

Plot the response $i_L(t)$, including thee time intervals just prior to the switch opening.

Figure 4

Thus, the response is drawn.

Step 1 of 8

Consider the Figure E7.15 from the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

The value of the current $i_L(0^-)$ is -2 A and the value of the voltage $v_C(0^-)$ is 0 V .

Step 2 of 8

Consider the circuit diagram at $t > 0$.

Figure 2

Step 3 of 8

Apply Kirchhoff's Voltage Law in the Loop.

$$\frac{1}{2}\frac{di(t)}{dt} + \frac{1}{\left(\frac{2}{3}\right)}\int i(t)dt + 2i(t) = 0$$

$$\frac{di(t)}{dt} + 3\int i(t)dt + 4i(t) = 0$$

Take derivative with respect to t .

$$\frac{d^2i(t)}{dt^2} + 4\frac{di(t)}{dt} + 3i(t) = 0 \text{ ..... (1)}$$

Step 4 of 8

Consider the characteristic equation of the differential equation.

$$s^2 + 4s + 3 = 0$$

Solve for the characteristic equation.

$$(s+1)(s+3) = 0$$

The roots of the characteristic equation are $s_1 = -1$ and $s_2 = -3$.

The roots the real and unequal, hence the circuit exhibits over damped characteristics.

Step 5 of 8

Recall equation (1).

$$\frac{d^2i(t)}{dt^2} + 4\frac{di(t)}{dt} + 3i(t) = 0$$

The solution for the differential equation is

$$i(t) = C_1e^{-t} + C_2e^{-3t} \text{ ..... (2)}$$

Substitute 0 for t .

$$i(0) = C_1e^{-(0)} + C_2e^{-3(0)}$$
$$i(0) = C_1 + C_2$$

Substitute -2 A for $i(0)$.

$$-2 = C_1 + C_2$$

$$C_1 = -2 - C_2 \text{ ..... (3)}$$

Therefore, the expression for the constant C_1 is $-2 - C_2$.

Step 6 of 8

Recall equation (2).

$$i(t) = C_1e^{-t} + C_2e^{-3t}$$

Take derivative with respect to t .

$$\frac{di(t)}{dt} = C_1\frac{de^{-t}}{dt} + C_2\frac{de^{-t/2}}{dt}$$
$$= -C_1e^{-t} - 3C_2e^{-3t}$$

Substitute 0 for t .

$$\frac{di(0)}{dt} = -C_1e^{-(0)} - \frac{1}{2}C_2e^{-3(0)}$$
$$= -C_1 - 3C_2$$

Substitute $-2 - C_2$ for C_1 and -2 A for $i(0)$.

$$\frac{d(-2)}{dt} = -(-2 - C_2) - 3C_2$$
$$2 + C_2 - 3C_2 = 0$$
$$C_2(1-3) = -2$$
$$C_2(-2) = -2$$

$$C_2 = 1$$

Therefore, the value of the constant C_2 is 1 .

Step 7 of 8

Recall equation (3).

$$C_1 = -2 - C_2$$

Substitute 1 for C_2 .

$$C_1 = -2 - 1$$
$$= -3$$

Therefore, the value of the constant C_1 is -3 .

Step 8 of 8

Recall equation (2).

$$i(t) = C_1e^{-t} + C_2e^{-3t}$$

Substitute 1 for C_2 and -3 for C_1 .

$$i(t) = e^{-t} - 3e^{-3t} \text{ A}$$

Therefore, the value of the current is $e^{-t} - 3e^{-3t}$ A .

Calculate the value of the output voltage.

$$v_o(t) = i(t)(2)$$

Substitute $e^{-t} - 3e^{-3t}$ A for $i(t)$.

$$v_o(t) = 2\left(e^{-t} - 3e^{-3t}\right) \text{ V}$$

Therefore, the value of the output voltage is $\boxed{2\left(e^{-t} - 3e^{-3t}\right) \text{ V}}$.

Step 1 of 7

Refer to Figure P7.13 in the text book.

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Redraw the circuit in Figure P7.13 at $t = 0^-$.

Figure 1

Step 2 of 7

Redraw Figure 1 after simplify.

Figure 2

From Figure 2, total source current flows through the short wire. Hence, $i(0) = 5\text{ mA}$.

Thus, the output current i for $t = 0^-$ that is just prior to switch opening is,

$$\boxed{i(0^-) = i(0) = 5\text{ mA}}.$$

Step 3 of 7

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 3

Step 4 of 7

Reduce the network by calculating the equivalent resistance of the resistance from the right hand side of the network.

$$\begin{aligned} R_{eq} &= \left((1\text{ k} + 1\text{ k}) \| 2\text{ k}\right) + 2\text{ k} \\ &= \left((2\text{ k}) \| 2\text{ k}\right) + 2\text{ k} \\ &= 1\text{ k} + 2\text{ k} \\ &= 3\text{ k} \end{aligned}$$

Redraw the Figure 3 after reducing the network.

Figure 4

Step 5 of 7

Apply KVL to the circuit.

$$\left(1\times10^{-3}\right)\frac{di(t)}{dt} + \left(1\text{ k} \| 3\text{ k}\right) i(t) = 0$$

$$\left(1\times10^{-3}\right)\frac{di(t)}{dt} + \left(\frac{3}{4}\text{ k}\right) i(t) = 0$$

$$\frac{di(t)}{dt} + \left(\frac{3}{4\left(\left(1\times10^{-3}\right)\right)}\text{ k}\right) i(t) = 0$$

$$\frac{di(t)}{dt} + \frac{3\times10^{6}}{4} i(t) = 0$$

Write the general solution to the differential equation.

$$i(t) = K_2 e^{-\frac{3\times10^{6}}{4}t}$$

$$i(t) = K_2 e^{-\frac{3}{4\times10^{-6}}t}$$

Step 6 of 7

To evaluate the function use the initial conditions.

$$i(0) = K_2 e^{-\frac{3\times10^{6}}{4}(0)}$$

$$i(0) = K_2$$

The current flowing through the inductor cannot change in zero time. Hence,

$$i(0) = i(0^-) = i(0^+) = 5\text{ mA}.$$

Substitute 5 mA for $i(0)$.

$$K_2 = 5\times10^{-3}$$

Thus, the output current i for $t > 0$ is, $\boxed{5e^{-\frac{3}{4\times10^{-6}}t}\text{ mA}}$.

Draw the table to plot the response.

Table 1

$t(\mu s)$	0	1	2	3	4	5	6	7
$i(\text{mA})$	5	2.36	1.11	0.52	0.24	0.11	0.055	0.026

Step 7 of 7

Plot the response for current $i(t)$.

Figure 5

Thus, the response is drawn as shown in Figure 5.

Step 1 of 5

Refer to Figure E7.16 in the text book for the circuit.

The switch is closed for $t < 0$. Inductor acts as a short circuit and capacitor acts as an open circuit. Draw the circuit for $t < 0$.

Figure 1

$$i_L(0) = \frac{12}{5+1}$$
$$= 2 \text{ A}$$
$$v_C(0) = -12 + (5)(2) + 24$$
$$= 22 \text{ V}$$

Step 2 of 5

The switch is open for $t > 0$. The circuit is a series *RLC* circuit.

Draw the circuit for $t > 0$.

Figure 2

Step 3 of 5

Apply Kirchhoff's voltage law to the loop.

$$v_C(t) + i_L(t) + 0.25\frac{di_L(t)}{dt} = 24$$

The inductor current is,

$$i_L(t) = i_C(t) = C\frac{dv_C(t)}{dt}$$
$$= 0.8\frac{dv_C(t)}{dt}$$

$$v_C(t) + 0.8\frac{dv_C(t)}{dt} + 0.2\frac{d^2v_C(t)}{dt^2} = 24$$
$$\frac{d^2v_C(t)}{dt^2} + 4\frac{dv_C(t)}{dt} + 5v_C(t) = 120$$

The particular solution is,

$$v_{cp}(t) = \frac{120}{5}$$
$$= 24 \text{ V}$$

Step 4 of 5

Obtain the complementary solution of the differential equation,

$$\frac{d^2v_C(t)}{dt^2} + 4\frac{dv_C(t)}{dt} + 5v_C(t) = 0$$

The characteristic equation is

$$s^2 + 4s + 5 = 0$$

The roots of the characteristic equation are,

$$s_1 = -2 + j$$
$$s_2 = -2 - j$$

As the roots are complex, the circuit is underdamped and the expression for $v_C(t)$ is,

$$v_C(t) = K_1e^{-2t}\cos t + K_2e^{-2t}\sin t$$

The complete response is,

$$v_C(t) = K_1e^{-2t}\cos t + K_2e^{-2t}\sin t + 24$$

Apply initial condition, $v_C(0) = 0$.

$$v_C(0) = K_1 + 24 = 22$$
$$K_1 = -2$$

The complete solution is the sum of complementary and particular solutions.

$$v_C(t) = -2e^{-2t}\cos t + K_2e^{-2t}\sin t + 24$$

The capacitor current,

$$i_C(t) = 0.8\frac{dv_C}{dt}$$
$$= 0.8\frac{d}{dt}\left[-2e^{-2t}\cos t + K_2e^{-2t}\sin t + 24\right]$$
$$= 0.8\left[4e^{-2t}\cos t - 2e^{-2t}\sin t - 2K_2e^{-2t}\sin t + K_2e^{-2t}\cos t\right]$$
$$i_C(0) = i_L(0) = 2 \text{ A}$$
$$i_C(0) = 0.8[4 + K_2] = 2$$
$$K_2 = -1.5$$

Step 5 of 5

The complete solution is,

$$v_C(t) = -2e^{-2t}\cos t - 1.5e^{-2t}\sin t + 24$$

Thus, the capacitor voltage, $v_C(t)$ is $\boxed{-2e^{-2t}\cos t - 1.5e^{-2t}\sin t + 24}$.

Step 1 of 6

Refer to Figure P7.14 in the text book.

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Redraw the circuit in Figure P7.14 at $t = 0^-$.

Figure 1

Apply KVL to the left hand side loop.

$$-12 + 6i_1 + 4(i_1 - i_2) = 0$$
$$-12 + 10i_1 - 4i_2 = 0$$

$5i_1 - 2i_2 = 6$ ..... (1)

Apply KVL to the right hand side loop.

$$-6 + 12i_2 + 4(i_2 - i_1) = 0$$
$$-6 + 16i_2 - 4i_1 = 0$$
$$2i_1 + 8i_2 = 3$$

Substitute $\frac{3-2i_1}{4}$ for $2i_2$ in equation (1).

$$5i_1 - \frac{3+2i_1}{4} = 6$$
$$18i_1 = 27$$
$$i_1 = \frac{3}{2}\text{ A}$$
$$i_2 = \frac{3}{4}\text{ A}$$

Thus, the output current i_o for $t = 0^-$ that is just prior to switch opening is,

$$i_o(0^-) = i_2 = \frac{3}{4}\text{ A}.$$

Step 2 of 6

Calculate the inductor current, $i_L(0^-)$.

$$i_L(0^-) = i_1 - i_2$$
$$= \frac{3}{2} - \frac{3}{4}$$
$$= \frac{3}{4}\text{ A}$$

Step 3 of 6

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 2

Step 4 of 6

Apply KVL to the circuit.

$$2\frac{di_L(t)}{dt} + (4+12)i_L(t) + 6 = 0$$
$$2\frac{di_L(t)}{dt} + 16i_L(t) + 6 = 0$$
$$\frac{di_L(t)}{dt} + 8i_L(t) = -3$$

Write the general solution to the differential equation.

$$i_L(t) = \frac{-3}{8} + K_2 e^{-8t}$$

To evaluate the function use the initial conditions.

$$i_L(0) = \frac{-3}{8} + K_2 e^{-8(0)}$$
$$i_L(0) = \frac{-3}{8} + K_2$$

Step 5 of 6

The current flowing through the inductor cannot change in zero time. Hence,

$i_L(0) = i_L(0^-) = i_L(0^+) = \frac{3}{4}$ A .

Substitute $\frac{3}{4}$ A for $i_L(0)$.

$$\frac{3}{4} = \frac{-3}{8} + K_2$$
$$K_2 = \frac{3}{4} + \frac{3}{8}$$
$$K_2 = \frac{9}{8}$$

Thus, the current is, $i_L(t) = \frac{-3}{8} + \frac{9}{8}e^{-8t}$ A

From the circuit,

$$i_o(t) = -i_L(t)$$
$$= \frac{3}{8} - \frac{9}{8}e^{-8t}\text{ A}$$

Thus, the output current $i_o(t)$ for $t > 0$ is, $\boxed{\frac{3}{8} - \frac{9}{8}e^{-8t}\text{ A}}$.

Step 6 of 6

Draw the table to plot the response.

Table 1

t(sec)	0	0.25	0.5	0.75	1	1.25	1.5	1.75
i(A)	0.75	0.22	0.35	0.372	0.374	0.374	0.374	0.374

Plot the response for current $i_o(t)$.

Figure 3

Thus, the response is drawn as shown in Figure 3.

Step 1 of 8

Refer to Figure E7.17 in text book.

Redraw the circuit for $t = 0^-$. At $t = 0^-$ the circuit is under steady state condition. Capacitor acts as open circuit.

Figure 1

Step 2 of 8

Apply Kirchhoff's Voltage Law for the circuit.

$$-24+6i+18i+12=0$$
$$-12+24i=0$$
$$24i=12$$
$$i=\frac{12}{24}$$
$$=\frac{1}{2}\text{ A}$$
$$i(0^-)=i(0^+)$$
$$\frac{1}{2}\text{ A}$$

Step 3 of 8

Redraw the circuit for $t = 0^+$.

Figure 2

Step 4 of 8

Apply Kirchhoff's Voltage Law for the circuit.

$$-4+12+\frac{1}{C}\int i\,dt+L\frac{di}{dt}+18i=0$$
$$8+\frac{1}{C}\int i\,dt+L\frac{di}{dt}+18i=0$$
$$\frac{1}{C}+L\frac{d^2i}{dt}+18\frac{di}{dt}=0$$
$$\frac{d^2i}{dt}+\frac{18}{L}\frac{di}{dt}+\frac{1}{LC}=0$$
$$\frac{d^2i}{dt}+\frac{18}{2}\frac{di}{dt}+\frac{1}{2\left(\frac{1}{36}\right)}=0$$
$$\frac{d^2i}{dt}+9\frac{di}{dt}+18=0$$
$$s^2+9s+18=0$$
$$s^2+6s+3s+18=0$$
$$s(s+6)+3(s+6)=0$$
$$(s+6)(s+3)=0$$
$$s=-6, s=-3$$

Step 5 of 8

The expression for the current through inductor is,

$i_0(t)=k_1e^{-6t}+k_2e^{-3t}$ ..... (1)

Determine constant values.

At $t=0$,

$\frac{1}{2}=k_1+k_2$ ..... (1)

Apply Kirchhoff's Voltage Law to the circuit.

$$-4+V_c+V_L+9+12=0$$
$$-4+0+V_L+9+12=0$$
$$V_L=-17$$
$$L\frac{di}{dt}=-17$$
$$\frac{di}{dt}=\frac{-17}{2}$$

Step 6 of 8

Differentiate equation (1).

$$\frac{di}{dt}=\frac{d}{dt}\left(k_1e^{-6t}+k_2e^{-3t}\right)$$
$$=-6k_1e^{-6t}-3k_2e^{-3t}$$
$$\frac{-17}{2}=-6k_1e^{-6t}-3k_2e^{-3t}$$
$$\frac{-17}{2}=-6k_1-3k_2$$
$$-3k_1=\frac{-17}{2}+\frac{3}{2}$$
$$k_1=\frac{-14}{(-3)2}$$
$$=\frac{14}{6}$$

Step 7 of 8

Substitute value of k_1 in equation (1).

$$\frac{1}{2}=k_1+k_2$$
$$\frac{1}{2}=\frac{14}{6}+k_2$$
$$k_2=\frac{1}{2}-\frac{14}{6}$$
$$=\frac{-11}{6}$$

Substitute the values of k_1 and k_2 in equation (2).

$$i_0(t)=\frac{14}{6}e^{-6t}-\frac{11}{6}e^{-3t}\text{ A}$$

Thus, the current through inductor, $i_0(t)$ for $t>0$ is $\boxed{\frac{14}{6}e^{-6t}-\frac{11}{6}e^{-3t}\text{ A}}$.

Step 8 of 8

Determine voltage, $v_0(t)$.

$$v_0(t)=12+Ri_0(t)$$
$$=12+18\left[\left(\frac{14}{6}e^{-6t}\right)-\left(\frac{11}{6}e^{-3t}\right)\right]$$
$$=12+42e^{-6t}-33e^{-3t}\text{ V}$$

Thus, the output voltage, $v_0(t)$ for $t>0$ is $\boxed{12+42e^{-6t}-33e^{-3t}\text{ V}}$.

Step 1 of 6

Refer to Figure P7.12 in the text book.

At $t = 0^-$, the switch is closed and the capacitor is replaced by a open circuit.

Redraw the circuit in Figure P7.12 at $t = 0^-$.

Figure 1

Step 2 of 6

Calculate the initial voltage across the capacitor.

$$v_C(0^-) = 6\left(\frac{12\text{ k}}{12\text{ k}+8\text{ k}}\right)$$
$$= 6\left(\frac{12}{20}\right)$$
$$= 3.6\text{ V}$$

Thus, the initial voltage across the capacitor is, $v_C(0^-) = 3.6\text{ V}$.

At $t > 0$, the switch is opened. Redraw the network for $t > 0$.

Figure 2

Step 3 of 6

Write the KCL equation at node 1.

$$\frac{v_C(t)-12}{8\text{ k}+4\text{ k}} + \left(100\times10^{-6}\right)\frac{dv_C(t)}{dt} + \frac{v_C(t)}{12\text{ k}} = 0$$
$$\left(100\times10^{-6}\right)\frac{dv_C(t)}{dt} + v_C(t)\left[\frac{1}{12\text{ k}}+\frac{1}{12\text{ k}}\right] = \frac{12}{12\text{ k}}$$
$$\frac{dv_C(t)}{dt} + \frac{v_C(t)}{\left(100\times10^{-6}\right)}\left[\frac{1}{6\text{ k}}\right] = \frac{1}{\left(100\times10^{-6}\right)(1\text{ k})}$$
$$\frac{dv_C(t)}{dt} + \frac{5}{3}v_C(t) = 10$$

Write the general solution to the differential equation.

$$v_C(t) = \frac{10(3)}{5} + K_2 e^{-\frac{5}{3}t}$$
$$v_C(t) = 6 + K_2 e^{-\frac{5}{3}t}$$

Step 4 of 6

To evaluate the function use the initial conditions.

$$v_C(0) = 6 + K_2^{-\frac{5}{3}(0)}$$
$$v_C(0) = 6 + K_2$$

The voltage across the capacitor cannot change in zero time. Hence, $v_C(0) = v_C(0^-) = v_C(0^+) = 3.6\text{ V}$.

Substitute 3.6 V for $v_C(0)$.

$$3.6 = K_2 + 6$$
$$K_2 = -2.4$$

Thus, the voltage $v_C(t)$ for $t > 0$ is, $6 - 2.4e^{-\frac{5}{3}t}$.

Step 5 of 6

Calculate the output voltage, $v_o(t)$.

$$v_o(t) = \left(12 - v_C(t)\right)\frac{8\text{ k}}{4\text{ k}+8\text{ k}}$$
$$= \left(12 - \left(6 - 2.4e^{-\frac{5}{3}t}\right)\right)\left(\frac{2}{3}\right)$$
$$= 4 + 1.6e^{-\frac{5}{3}t}\text{ V}$$

Thus, the output voltage, $v_o(t)$ for $t > 0$ is, $\boxed{4 + 1.6e^{-\frac{5}{3}t}\text{ V}}$.

Draw the table to plot the response.

Table 1

$t(\text{sec})$	0	0.2	0.4	0.5	1	2	3	4
$v_o(t)$	5.6	5.14	4.82	4.69	4.3	4.05	4.01	4.002

Plot the response $v_o(t)$, including thee time intervals just prior to the switch opening.

Step 6 of 6

Plot the response for output voltage $v_o(t)$.

Figure 4

Thus, the response is drawn as shown in Figure 4.

Step 1 of 5

Refer to Figure E7.18 in the text book for the circuit.

The switch is open for $t < 0$. Inductor acts as a short circuit and capacitor acts as an open circuit.

Draw the circuit for $t < 0$.

Figure 1

The initial current is,

$$i(0) = \frac{10}{10}$$
$$= 1 \text{ A}$$

The initial inductor voltage, $v(0) = 0$

Step 2 of 5

The switch is closed for $t > 0$. Draw the circuit for $t > 0$.

Figure 2

Apply Kirchhoff's current law to the top node.

$$\frac{v(t)-10}{10} + \frac{v(t)-20}{10} + i(t) + 0.01\frac{dv(t)}{dt}$$
$$0.01\frac{dv(t)}{dt} + 0.2v(t) + i(t) = 3$$

The inductor voltage is,

$$v(t) = 2\frac{di(t)}{dt}$$

The differential equation describing the circuit is,

$$0.02\frac{d^2i(t)}{dt^2} + 0.4\frac{di(t)}{dt} + i(t) = 3$$
$$\frac{d^2i(t)}{dt^2} + 20\frac{di(t)}{dt} + 50i(t) = 150$$

The particular solution is,

$$i_p(t) = \frac{150}{50}$$
$$= 3 \text{ A}$$

Step 3 of 5

Obtain the complementary solution of the differential equation,

$$\frac{d^2i(t)}{dt^2} + 20\frac{di(t)}{dt} + 50i(t) = 0$$

The characteristic equation is

$$s^2 + 20s + 50 = 0$$

The roots of the characteristic equation are,

$$s_1 = -2.93$$
$$s_2 = -17.07$$

As the roots are real and unequal, the circuit is overdamped and $i(t)$ is of the form,

$$i(t) = K_1e^{-2.93t} + K_2e^{-17.07t}$$

The complete solution is the sum of complementary and particular solutions.

$$i(t) = K_1e^{-2.93t} + K_2e^{-17.07t} + 3$$

Apply initial condition.

$$i(0) = K_1 + K_2 + 3$$

$K_1 + K_2 = -2$ ..... (1)

Step 4 of 5

From the response equation,

$$\frac{di(t)}{dt} = \frac{d}{dt}\left[K_1e^{-2.93t} + K_2e^{-17.07t} + 3\right]$$
$$= -2.93K_1e^{-2.93t} - 17.07K_2e^{-2.93t}$$

$$\frac{di(0)}{dt} = -2.93K_1 - 17.07K_2$$

$$\frac{di(0)}{dt} = \frac{v(0)}{L} = 0$$

$2.93K_1 + 17.07K_2 = 0$ ..... (2)

Step 5 of 5

Solve equations (1) and (2) to get the values of constants.

$$K_1 = -2.414$$
$$K_2 = 0.414$$

$$i(t) = -2.414e^{-2.93t} + 0.414e^{-17.07t} + 3 \text{ A}$$

Thus, the inductor current, $i(t)$ is $\boxed{-2.414e^{-2.93t} + 0.414e^{-17.07t} + 3 \text{ A}}$.

Step 1 of 8

Refer to Figure P7.15 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RC* circuit,

$$x(t) = i_o(t)$$
$$K_1 = i_o(\infty)$$
$$K_2 = i_o(0^+) - i_o(\infty)$$
$$\tau = R_{th}C$$

Substitute these values in equation $x(t)$.

$$i_o(t) = i_o(\infty) + \left[i_o(0^+) - i_o(\infty)\right]e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Step 2 of 8

At $t = 0^-$, the switch is open and the capacitor is replaced by a open circuit.

Draw the modified circuit diagram of Figure P7.15 at $t = 0^-$.

Figure 1

Step 3 of 8

Apply voltage division rule to determine the initial voltage across the capacitor.

$$v_C(0^-) = 12\left(\frac{4\text{ k}+6\text{ k}}{4\text{ k}+6\text{ k}+2\text{ k}}\right)$$
$$= 12\left(\frac{10\text{ k}}{12\text{ k}}\right)$$
$$= 10\text{ V}$$

The voltage across the capacitor cannot change in zero time.

Hence, $v_C(0^-) = v_C(0^+) = 10\text{ V}$.

Step 4 of 8

At $t = 0^+$, the switch is closed and the capacitor is replaced by a voltage source.

Draw the modified circuit diagram of Figure P7.15 at $t = 0^+$.

Figure 2

Determine the value of current in Figure 2.

$$i_o(0^+) = \frac{10}{4\text{ k}}$$
$$= 2.5\text{ mA}$$

Step 5 of 8

After a long time the switch is closed the circuit goes to steady state. In steady state $t = \infty$ replace the capacitor by an open circuit.

Draw the modified circuit diagram of Figure P7.15 at $t = \infty$.

Figure 3

Determine the value of current in Figure 3.

$$i_o(\infty) = \frac{12}{2\text{ k}+4\text{ k}}$$
$$= 2\text{ mA}$$

Step 6 of 8

Redraw the Figure P7.15 to calculate the equivalent resistance by looking into open terminals of the capacitor and replacing the voltage sources by short circuit.

Figure 4

Step 7 of 8

In Figure 4, the resistor $4\text{ k}\Omega$ is in parallel with $2\text{ k}\Omega$.

$$R_{th} = (4\text{ k}\Omega)\|(2\text{ k}\Omega)$$
$$= \frac{(4)(2)}{4+2}\text{ k}$$
$$= \frac{4}{3}\text{ k}\Omega$$

Determine the value of time constant.

$$\tau = R_{th}C$$

Substitute $\frac{4}{3}\text{ k}\Omega$ for R_{th} and $200\ \mu\text{F}$ for C in the equation.

$$\tau = \left(\frac{4}{3}\text{ k}\right)\left(200\times10^{-6}\right)$$
$$= 0.267\text{ s}$$

Step 8 of 8

Substitute 2 mA for $i_o(\infty)$, 2.5 mA for $i_o(0^+)$ and 0.267 for τ in equation (1).

$$v_o(t) = 2 + [2.5 - 2]e^{-\frac{t}{0.267}}\text{ mA}$$
$$= 2 + 0.5e^{-\frac{t}{0.267}}\text{ mA}$$

Thus, the expression for current, $i_o(t)$ for $t > 0$ is, $\boxed{2 + 0.5e^{-\frac{t}{0.267}}\text{ mA}}$.

Step 1 of 9

Refer to circuit diagram in Figure P7.19 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the current in the circuit.

$$(3\text{ k}\Omega + 6\text{ k}\Omega + 9\text{ k}\Omega)i_o(0^-) = 6\text{ V} - 24\text{ V}$$
$$(18\text{ k}\Omega)i_o(0^-) = -18\text{ V}$$
$$i_o(0^-) = -1\text{ mA}$$

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= 6\text{ V} - (3\text{ k}\Omega)i_o(0^-) \\ &= 6\text{ V} - (3\text{ k}\Omega)(-1\text{ mA}) \\ &= 6\text{ V} + 3\text{ V} \\ &= 9\text{ V} \end{aligned}$$

Step 3 of 9

At $t = 0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Apply Kirchhoff's voltage law to middle loop.

$$(6\text{ k}\Omega)i_o(0^+) = 9\text{ V}$$

$$\begin{aligned} i_o(0^+) &= \frac{9\text{ V}}{6\text{ k}\Omega} \\ &= 1.5\text{ mA} \end{aligned}$$

The initial current through current through $6\text{ k}\Omega$ resistor is 1.5 mA .

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= (3\text{ k}\Omega) \| [6\text{ k}\Omega + (0 \| 9\text{ k}\Omega)] \\ &= (3\text{ k}\Omega) \| [6\text{ k}\Omega + 0\ \Omega] \\ &= \frac{(3\text{ k}\Omega)(6\text{ k}\Omega)}{3\text{ k}\Omega + 6\text{ k}\Omega} \\ &= 2\text{ k}\Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (2\text{ k}\Omega)(200\ \mu\text{F}) \\ &= 0.4\text{ s} \end{aligned}$$

Step 7 of 9

For $t = \infty$, the switch in the circuit is closed and circuit reaches steady state. At steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the final current through $6\text{ k}\Omega$ resistor.

$$(3\text{ k}\Omega + 6\text{ k}\Omega)i_o(\infty) = 6\text{ V}$$
$$(9\text{ k}\Omega)i_o(\infty) = 6\text{ V}$$

$$\begin{aligned} i_o(\infty) &= \frac{6\text{ V}}{9\text{ k}\Omega} \\ &= 0.67\text{ mA} \end{aligned}$$

Therefore, the final current through $6\text{ k}\Omega$ resistor is 0.67 mA .

Step 9 of 9

Write the expression for current through $6\text{ k}\Omega$ resistor for $t > 0$.

$$i_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1 .

$$\begin{aligned} K_1 &= i_o(\infty) \\ &= 0.67\text{ mA} \end{aligned}$$

Calculate the value of K_2 .

$$\begin{aligned} K_2 &= i_o(0^+) - i_o(\infty) \\ &= 1.5\text{ mA} - 0.67\text{ mA} \\ &= 0.83\text{ mA} \end{aligned}$$

Calculate the current through $6\text{ k}\Omega$ resistor for $t > 0$.

$$\begin{aligned} i_o(t) &= 0.67\text{ mA} + 0.83\text{ mA}e^{\frac{-t}{0.4\text{ s}}} \\ &= 0.67 + 0.83e^{-2.5t}\text{ mA} \end{aligned}$$

Therefore, the current, $i_o(t)$ through $6\text{ k}\Omega$ resistor for $t > 0$ is $\boxed{0.67 + 0.83e^{-2.5t}\text{ mA}}$.

Step 1 of 9

Refer to circuit diagram in Figure P7.20 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the current in the circuit.

$$(4\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega + 1\text{ k}\Omega)i_o(0^-) = 12\text{ V}$$
$$(9\text{ k}\Omega)i_o(0^-) = 12\text{ V}$$
$$i_o(0^-) = 1.33\text{ mA}$$

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= (4\text{ k}\Omega + 2\text{ k}\Omega)i_o(0^-) \\ &= (4\text{ k}\Omega + 2\text{ k}\Omega)(1.33\text{ mA}) \\ &= (6\text{ k}\Omega)(1.33\text{ mA}) \\ &= 8\text{ V} \end{aligned}$$

Step 3 of 9

At $t = 0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Apply Kirchhoff's voltage law to middle loop.

$$(4\text{ k}\Omega + 2\text{ k}\Omega)i_o(0^+) = 8\text{ V}$$
$$(6\text{ k}\Omega)i_o(0^+) = 8\text{ V}$$

$$\begin{aligned} i_o(0^+) &= \frac{8\text{ V}}{6\text{ k}\Omega} \\ &= 1.33\text{ mA} \end{aligned}$$

The initial current through current through $4\text{ k}\Omega$ resistor is 1.33 mA.

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= (4\text{ k}\Omega + 2\text{ k}\Omega) \| [2\text{ k}\Omega + (0 \| 1\text{ k}\Omega)] \\ &= (6\text{ k}\Omega) \| [2\text{ k}\Omega + 0\ \Omega] \\ &= \frac{(6\text{ k}\Omega)(2\text{ k}\Omega)}{6\text{ k}\Omega + 2\text{ k}\Omega} \\ &= 1.5\text{ k}\Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (1.5\text{ k}\Omega)(100\ \mu\text{F}) \\ &= 0.15\text{ s} \end{aligned}$$

Step 7 of 9

For $t = \infty$, the switch in the circuit is closed and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the final current through $4\text{ k}\Omega$ resistor.

$$(4\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega)i_o(\infty) = 0\text{ V}$$
$$(9\text{ k}\Omega)i_o(\infty) = 0\text{ V}$$
$$i_o(\infty) = 0\text{ A}$$

Therefore, the final current through $4\text{ k}\Omega$ resistor is 0 A.

Step 9 of 9

Write the expression for current through $4\text{ k}\Omega$ resistor for $t > 0$.

$$i_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$\begin{aligned} K_1 &= i_o(\infty) \\ &= 0\text{ A} \end{aligned}$$

Calculate the value of K_2.

$$\begin{aligned} K_2 &= i_o(0^+) - i_o(\infty) \\ &= 1.33\text{ mA} - 0\text{ A} \\ &= 1.33\text{ mA} \end{aligned}$$

Calculate the current through $4\text{ k}\Omega$ resistor for $t > 0$.

$$\begin{aligned} i_o(t) &= 0\text{ A} + 1.33\text{ mA}e^{\frac{-t}{0.15\text{ s}}} \\ &= 1.33e^{-6.67t}\text{ mA} \end{aligned}$$

Therefore, the current, $i_o(t)$ through $4\text{ k}\Omega$ resistor for $t > 0$ is $\boxed{1.33e^{-6.67t}\text{ mA}}$.

Step 1 of 8

Refer to Figure P7.19 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RL* circuit,

$$x(t) = i_o(t)$$
$$K_1 = i_o(\infty)$$
$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute these values in equation $x(t)$.

$$i_o(t) = i_o(\infty) + \left[i_o(0^+) - i_o(\infty)\right] e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Step 2 of 8

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Draw the modified circuit diagram of Figure P7.19 at $t = 0^-$.

Figure 1

Step 3 of 8

There is no current flow in the $6\ \Omega$ resistor. Thus, the current $i_o(0^-) = 0\ \text{A}$.

Determine the initial current flowing through the inductor.

$$i_L(0^-) = \frac{24}{6}$$
$$= 4\ \text{A}$$

The current flowing throw the inductor cannot change in zero time.

Hence, $i_L(0^-) = i_L(0^+) = 4\ \text{A}$.

Step 4 of 8

At $t = 0^+$, the switch opens and the inductor is replaced by a current source.

Draw the modified circuit diagram of Figure P7.19 at $t = 0^+$.

Figure 2

In Figure 2, the same current flow through the circuit as it is a series circuit.

$$i_o(0^+) = -4\ \text{A}$$

Step 5 of 8

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the inductor by a short circuit.

Draw the modified circuit diagram of Figure P7.19 at $t = \infty$.

Figure 3

There is no source in Figure 3. Hence, the value of final current is, $i_o(\infty) = 0\ \text{A}$

Step 6 of 8

Redraw the Figure P7.19 to calculate the equivalent resistance by looking into open terminals of the capacitor and replacing the voltage sources by short circuit.

Figure 4

Step 7 of 8

Determine the thevenin equivalent resistance.

$$R_{th} = 6\ \Omega$$

Determine the value of time constant.

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{2}{6}$$
$$= \frac{1}{3}$$

Step 8 of 8

Substitute 0 A for $i_o(\infty)$, $-4\ \text{A}$ for $i_o(0^+)$ and $\frac{1}{3}$ for τ in the equation (1).

$$i_o(t) = 0 + [-4 - 0] e^{-\frac{t}{\left(\frac{1}{3}\right)}}\ \text{A}$$
$$= -4e^{-3t}\ \text{A}$$

Thus, the expression for current, $i_o(t)$ for $t > 0$ is, $\boxed{-4e^{-3t}\ \text{A}}$.

Step 1 of 8

Refer to Figure P7.20 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RC* circuit,

$$x(t) = i_o(t)$$
$$K_1 = i_o(\infty)$$
$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute these values in equation $x(t)$.

$$i_o(t) = i_o(\infty) + \left[i_o(0^+) - i_o(\infty)\right]e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Step 2 of 8

At $t = 0^-$, the switch is closed and the capacitor is replaced by an open circuit.

Draw the modified circuit diagram of Figure P7.20 at $t = 0^-$.

Figure 1

Step 3 of 8

Determine the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= (12\times10^{-3})(6\text{ k}\|12\text{ k}) \\ &= (12\times10^{-3})\left(\frac{(6\text{ k})(12\text{ k})}{6\text{ k}+12\text{ k}}\right) \\ &= (12\times10^{-3})(4\times10^{3}) \\ &= 48\text{ V} \end{aligned}$$

The voltage across the capacitor cannot change in zero time.

Hence, $v_C(0^-) = v_C(0^+) = 48\text{ V}$.

Step 4 of 8

At $t = 0^+$, the switch is open and the capacitor is replaced by a voltage source.

Draw the modified circuit diagram of Figure P7.20 at $t = 0^+$.

Figure 2

In Figure 2, same current flow through the circuit as it is a series circuit.

$$\begin{aligned} i_o(0^+) &= \frac{48}{12\text{ k}+6\text{ k}} \\ &= \frac{48}{18\text{ k}} \\ &= \frac{8}{3}\text{ mA} \end{aligned}$$

Step 5 of 8

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the capacitor by an open circuit.

Draw the modified circuit diagram of Figure P7.20 at $t = \infty$.

Figure 3

There is no source in the Figure 3. Hence, $i_o(\infty) = 0\text{ A}$

Step 6 of 8

Redraw the Figure P7.20 to calculate the equivalent resistance by looking into open terminals of the capacitor and replacing the voltage sources by short circuit.

Figure 4

Step 7 of 8

Determine the Thevenin equivalent resistance.

$$\begin{aligned} R_{th} &= 12\text{ k}\Omega + 6\text{ k}\Omega \\ &= 18\text{ k}\Omega \end{aligned}$$

Determine the time constant.

$$\begin{aligned} \tau &= R_{th}C \\ &= (18\text{ k})(200\times10^{-6}) \\ &= 3.6 \end{aligned}$$

Step 8 of 8

Substitute 0 A for $i_o(\infty)$, $\frac{8}{3}\text{ mA}$ for $i_o(0^+)$ and 3.6 for τ in equation (1).

$$\begin{aligned} i_o(t) &= 0 + \left[\frac{8}{3} - 0\right]e^{-\frac{t}{(3.6)}}\text{ mA} \\ &= \frac{8}{3}e^{-\frac{t}{3.6}}\text{ mA} \end{aligned}$$

Thus, the expression for current $i_o(t)$ for $t > 0$ is, $\boxed{\frac{8}{3}e^{-\frac{t}{3.6}}\text{ mA}}$.

Step 1 of 11

Refer to Figure P7.25 in the textbook.

The expression for current is,

$$i_o(t) = K_1 + K_2 e^{-t/\tau}$$

At $t = 0-$ the circuit is in steady state and the capacitor acts as an open circuit. The capacitor is fully charged and no current flows through the capacitor before switch is closed.

Step 2 of 11

The Kirchhoff's voltage law for the current $i_o(0-)$ is,

$$12 + (8\ \text{k}\Omega)(i_o(0-)) = 0$$

$$\begin{aligned} i_o(0-) &= -\frac{12\ \text{V}}{8\ \text{k}\Omega} \\ &= -1.5\ \text{mA} \end{aligned}$$

Step 3 of 11

The initial voltage across the capacitor is,

$$\begin{aligned} v_C(0-) &= 4\ \text{k}\Omega \times i_o(0-) \\ &= 4\ \text{k}\Omega \times -1.5\ \text{mA} \\ &= -6\ \text{V} \end{aligned}$$

Step 4 of 11

At $t = 0+$, the switch is closed. The circuit is reduced to

Figure 1

Step 5 of 11

The Kirchhoff's voltage law equation for the current $i_o(0+)$ is,

$$-12 + (2\ \text{k})(i_1) + (4\ \text{k})(i_1 + i_2) = 0$$

$$(6\ \text{k})(i_1) + (4\ \text{k})(i_2) = 12 \quad \text{..... (1)}$$

And

$$-6 + (4\ \text{k})(i_2 + i_1) + (4\ \text{k})(i_2) = 0$$

$$(4\ \text{k})(i_1) + (8\ \text{k})(i_2) = 6 \quad \text{..... (2)}$$

Step 6 of 11

The solution of the above equations is,

$$i_1 = 2.25\ \text{mA},\ i_2 = -0.375\ \text{mA}$$

The current at $t = 0+$ is,

$$\begin{aligned} i_o(0+) &= -(i_1 + i_2) \\ &= -1.875\ \text{mA} \end{aligned}$$

Step 7 of 11

For $t > 5\tau$, the capacitor is again fully charged and it acts as an open circuit. The current $i_o(\infty)$ is given by

$$\begin{aligned} i_o(\infty) &= -\frac{12\ \text{V}}{4\ \text{k}\Omega + 2\ \text{k}\Omega} \\ &= -2\ \text{mA} \end{aligned}$$

Step 8 of 11

The Thevenin equivalent resistance, obtained by looking into the open-circuit terminals of the capacitor is given by

$$\begin{aligned} R_{Th} &= (4\ \text{k}\Omega \| 4\ \text{k}\Omega \| 4\ \text{k}\Omega) + 4\ \text{k}\Omega \\ &= 5.333\ \text{k}\Omega \end{aligned}$$

Step 9 of 11

The time constant is,

$$\begin{aligned} \tau &= R_{Th} C \\ &= 5.333\ \text{k}\Omega \times 200\ \mu\text{F} \\ &= 1.066\ \text{s} \end{aligned}$$

Step 10 of 11

The constants are given by

$$K_1 = i_o(\infty) = -2\ \text{mA}$$

$$\begin{aligned} K_2 &= i_o(0+) - i_o(\infty) \\ &= i_o(0+) - K_1 \\ &= -1.875\ \text{mA} + 2\ \text{mA} \\ &= 0.125\ \text{mA} \end{aligned}$$

Step 11 of 11

Therefore the solution is,

$$\begin{aligned} i_o(t) &= i_o(\infty) + [i_o(0+) - i_o(\infty)] e^{-t/\tau} \\ &= -2 + 0.125 e^{-0.938t}\ \text{mA} \end{aligned}$$

Hence $i_o(t)$ for $t > 0$ is,

$$\boxed{i_o(t) = (-2 + 0.125 e^{-0.938t})\ \text{mA}}.$$

Step 1 of 11

The voltage $v_o(t) = K_1 + K_2 e^{-t/\tau}$

Step 2 of 11

At $t = 0-$ the circuit is in steady state and the capacitor acts as an open circuit. The capacitor is fully charged and no current flows through the capacitor before switch is closed.

Step 3 of 11

The current division rule for the current through the $6\ \text{k}\Omega$ resistor is $6\ \text{mA}$.

Step 4 of 11

The initial voltage across the capacitor is given by

$$\begin{aligned} v_C(0-) &= 6\ \text{k}\Omega \times i_o(0-) \\ &= 6\ \text{k}\Omega \times 6\ \text{mA} \\ v_C(0-) &= 36\ \text{V} \end{aligned}$$

Step 5 of 11

At $t = 0+$, the switch is opened. The circuit will be

The voltage $v_o(0+) = 36\ \text{V}$

Step 6 of 11

For $t > 5\tau$, the capacitor is fully discharged. Since no source is connected to it, the voltage across the capacitor is zero.

$$v_C(\infty) = 0\ \text{V}$$

Step 7 of 11

The Thevenin equivalent resistance, obtained by looking into the open-circuit terminals of the capacitor is given by

$$R_{Th} = 6\ \text{k}\Omega$$

Step 8 of 11

The time constant is

$$\begin{aligned} \tau &= R_{Th} C \\ &= 6\ \text{k}\Omega \times 100\ \mu\text{F} \\ \tau &= 0.6\ \text{s} \end{aligned}$$

Step 9 of 11

The constants are given by

$$\begin{aligned} K_1 &= v_o(\infty) = 0\ \text{V} \\ K_2 &= v_o(0+) - v_o(\infty) \\ &= 36\ \text{V} \end{aligned}$$

Step 10 of 11

Therefore the solution is

$$\begin{aligned} v_o(t) &= v_o(\infty) + \left[v_o(0+) - v_o(\infty)\right] e^{-t/\tau} \\ &= 36 e^{-1.666t}\ \text{V} \end{aligned}$$

Step 11 of 11

Hence $v_o(t)$ for $t > 0$ is

$$\boxed{v_o(t) = 36 e^{-1.666t}\ \text{V}}$$

Step 1 of 8

Refer to Figure P7.32 in the textbook.

Find the output voltage, $v_o(t)$ in the circuit using step-by-step method.

Step 1: Write the general form of the output voltage.

$$v_o(t) = k_1 + k_2 e^{\frac{-t}{\tau}}$$

Here, $k_1 = v_o(\infty)$.

The final value of the output voltage is $v_o(\infty)$.

And $k_2 = v_o(0^+) - v_o(\infty)$.

The value of the output voltage just after the switch open condition is $v_o(0^+)$.

Step 2 of 8

Step 2: The switch is in closed condition for long time for $t = 0^-$. The inductor acts as short circuit in steady-state. Draw the modified circuit for $t < 0$ to calculate the initial current through the inductor.

Figure 1

Step 3 of 8

The $4\ \Omega$ resistor vanishes since it is in parallel with a short circuit. Simplify and draw the circuit.

Figure 2

Find the value of $i_L(0^-)$.

$$i_L(0^-) = \frac{12\text{ V}}{2\ \Omega} = 6\text{ A}$$

The current through the inductor does not change instantaneously. Therefore,

$$i_L(0^+) = i_L(0^-) = 6\text{ A}$$

Step 4 of 8

Step 3: Replace the inductor with current source and draw the new valid circuit for $t > 0$.

Figure 3

Step 5 of 8

Apply mesh analysis to top (first) loop in the circuit.

$I_1 = 6\text{ A}$

Apply Kirchhoff's voltage law to the bottom (second) mesh.

$$12 + 2I_2 + 4(I_2 - I_1) + 2I_2 = 0$$
$$8I_2 - 4I_1 + 12 = 0$$

Substitute 6 a for I_1.

$$8I_2 - 4(6\text{ A}) + 12 = 0$$
$$8I_2 - 24 + 12 = 0$$
$$8I_2 - 12 = 0$$
$$8I_2 = 12$$

Therefore,

$$I_2 = \frac{12}{8} = 1.5\text{ A}$$

Use Ohm's law to find the output voltage.

$$v_o(0^+) = 2I_2$$

Substitute 1.5 A for I_2.

$$v_o(0^+) = 2(1.5) = 3\text{ V}$$

Step 6 of 8

Step 4: The switch is in open condition for long time for $t = 5\tau$. The inductor acts as short circuit in steady-state. Draw the modified circuit for $t = 5\tau$ to calculate the final value of the output voltage.

Figure 4

Use voltage division method to find the final value of the output voltage.

$$V_0(\infty) = (-12\text{ V})\left(\frac{2\ \Omega}{2\ \Omega + 2\ \Omega}\right) = (-12\text{ V})(0.5) = -6\text{ V}$$

Step 7 of 8

Step 5: Deactivate the circuit sources and draw the circuit to find the equivalent resistance of the circuit.

Figure 5

Step 8 of 8

Find the equivalent resistance of the circuit.

$$R_{th} = 4\ \Omega \| (2\ \Omega + 2\ \Omega) = 4\ \Omega \| 4\ \Omega = 2\ \Omega$$

Therefore, the circuit time constant is,

$$\tau = \frac{L}{R_{th}} = \frac{\frac{1}{3}}{\frac{2}{1}} = \frac{1}{6} = 0.167\text{ s}$$

Step 6: Find the values of k_1 and k_2.

$$k_1 = v_o(\infty) = -6\text{ V}$$

$$k_2 = v_o(0^+) - v_o(\infty) = 3 - (-6) = 9\text{ V}$$

The output voltage expression is,

$$v_o(t) = -6 + 9e^{-\frac{t}{0.167}}\text{ V} = -6 + 9e^{-6t}\text{ V}$$

Thus, the final expression for the output voltage, $v_o(t)$ is, $\boxed{-6 + 9e^{-6t}\text{ V}}$.

Step 1 of 5

Write the expression for voltage across capacitor,

$$v_C(t) = K_1 + K_2 e^{-t/\tau}$$

At $t = 0-$ the circuit is in steady state and the capacitor acts as an open circuit. The capacitor is fully charged and no current flows through the capacitor before switch is opened.

The initial voltage across the capacitor is,

$$v_C(0-) = 12 \text{ V}$$

Step 2 of 5

At $t = 0+$, the switch is opened. The voltage across the capacitor is,

$$v_C(0-) = v_C(0+)$$

For $t > 5\tau$, the capacitor is fully discharged. Since no source is connected to it, the voltage across the capacitor is zero.

$$v_C(\infty) = 0 \text{ V}$$

Step 3 of 5

The Thevenin equivalent resistance, obtained by looking into the open-circuit terminals of the capacitor is,

$$R_{Th} = 6 \text{ k}\Omega$$

Determine the time constant.

$$\begin{aligned}\tau &= R_{Th}C \\ &= 6 \text{ k}\Omega \times 100 \ \mu\text{F} \\ &= 0.6 \text{ s}\end{aligned}$$

Step 4 of 5

The constants are given by

$$K_1 = v_C(\infty) = 0 \text{ V}$$

$$\begin{aligned}K_2 &= v_C(0+) - v_C(\infty) \\ &= 12 \text{ V}\end{aligned}$$

Step 5 of 5

Determine the solution is,

$$\begin{aligned}v_C(t) &= v_C(\infty) + \left[v_C(0+) - v_C(\infty)\right]e^{-t/\tau} \\ &= 12e^{1.666t} \text{ V}\end{aligned}$$

Hence $v_C(t)$ for $t > 0$ is,

$$\boxed{v_C(t) = 12e^{-1.666t} \text{ V}}.$$

Step 1 of 11

Write the expression for the voltage,

$$v_o(t) = K_1 + K_2 e^{-t/\tau}$$

At $t = 0-$ the circuit is in steady state and the capacitor acts as an open circuit. The capacitor is fully charged and no current flows through the capacitor before switch is opened.

From the circuit, the initial voltage across the capacitor is given by

$$v_C(0-) = 24 \text{ V}$$

Step 2 of 11

At $t = 0+$, the switch is closed. The circuit will be

Figure 1

Step 3 of 11

The voltage $v_C(0+) = v_C(0-) = 24 \text{ V}$

The Kirchhoff's voltage law equations for the voltage $v_o(t)$ is,

$$(2 \text{ k}\Omega \times i_1) + 24 \text{ V} + (4 \text{ k}\Omega \times i_1) + (4 \text{ k}\Omega \times (i_1 - i_2)) - 24 \text{ V} = 0$$

$$(10 \text{ k}\Omega \times i_1) - (4 \text{ k}\Omega \times i_2) = 0 \text{ ..... (1)}$$

And

$$24 \text{ V} + (4 \text{ k}\Omega \times (i_2 - i_1)) - 12 \text{ V} + (2 \text{ k}\Omega \times i_2) = 0$$

$$(4 \text{ k}\Omega \times i_1) - (6 \text{ k}\Omega \times i_2) = 12 \text{ ..... (2)}$$

Step 4 of 11

Solve the equations (1) and (2) , we get

$i_1 = -1.1 \text{ mA}$ and $i_2 = -2.727 \text{ mA}$

Step 5 of 11

The voltage $v_o(t)$ is given by

$$\begin{aligned} v_o(0+) &= 4 \text{ k}\Omega \times i_1 \\ &= -4.4 \text{ V} \end{aligned}$$

Step 6 of 11

For $t > 5\tau$, the capacitor is again fully charged. Since no current flows through it, the voltage $v_o(\infty)$ is zero.

$$v_o(\infty) = 0 \text{ V}$$

Step 7 of 11

The Thevenin equivalent resistance, obtained by looking into the open-circuit terminals of the capacitor is given by

$$\begin{aligned} R_{Th} &= (4 \text{ k}\Omega \| 2 \text{ k}\Omega) + 2 \text{ k}\Omega + 4 \text{ k}\Omega \\ &= 7.33 \text{ k}\Omega \end{aligned}$$

Step 8 of 11

The time constant is,

$$\begin{aligned} \tau &= R_{Th} C \\ &= 7.33 \text{ k}\Omega \times 50 \ \mu\text{F} \\ &= 0.3665 \text{ s} \end{aligned}$$

Step 9 of 11

The constants are given by

$$\begin{aligned} K_1 &= v_o(\infty) = 0 \text{ V} \\ K_2 &= v_o(0+) - v_o(\infty) \\ &= -4.4 \text{ V} \end{aligned}$$

Step 10 of 11

Therefore the solution is,

$$\begin{aligned} v_o(t) &= v_o(\infty) + [v_o(0+) - v_o(\infty)] e^{-t/\tau} \\ &= -4.4 e^{-2.73t} \text{ V} \end{aligned}$$

Step 11 of 11

Hence $v_o(t)$ for $t > 0$ is

$$\boxed{v_o(t) = -4.4 e^{-2.73t} \text{ V}}.$$

Step 1 of 8

Refer to Figure P7.36 in the textbook.

Step1: The expression for the current $i_0(t)$ is of the form $k_1 + k_2 e^{\frac{-t}{\tau}}$.

Step2: Note that for $t < 0$ the switch is in open condition from long time and hence the circuit is in steady state. The capacitor acts as an open circuit in steady state. Draw the modified circuit for $t < 0$ and calculate the initial voltage across the capacitor $V_C(0^-)$ from the circuit.

Figure 1

Step 2 of 8

There is no current flow through $2\ \text{k}\Omega$ resistance in the circuit due to the open at the capacitor, hence the voltage across the capacitor is same as the voltage across $4\ \text{k}\Omega$ resistance.

Use voltage division method to find the voltage across the open capacitor.

$$\begin{aligned} V_C(0^-) &= \left[\frac{4\ \text{k}\Omega}{4\ \text{k}\Omega + 4\ \text{k}\Omega + 4\ \text{k}\Omega}\right](24) \\ &= \left(\frac{4}{12}\right)(24) \\ &= 8\ \text{V} \end{aligned}$$

Step 3 of 8

Step3: draw the new circuit valid for $t = 0^+$.

Figure 2

Step 4 of 8

The portion of the circuit across the short circuit line vanishes. Draw the modified circuit.

Figure 3

Step 5 of 8

Calculate the total resistance in the circuit.

$$\begin{aligned} R_{eq} &= 2\ \text{k}\Omega + (4\ \text{k}\Omega \| 4\ \text{k}\Omega) \\ &= 2\ \text{k}\Omega + \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega)}{4\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Calculate the total current in the circuit.

$$\begin{aligned} I &= \frac{V}{R_{eq}} \\ &= \frac{8\ \text{V}}{4\ \text{k}\Omega} \\ &= 2\ \text{mA} \end{aligned}$$

Use current division method to find the current through the $4\ \text{k}\Omega$ resistance.

$$\begin{aligned} i_0(0^+) &= \left(\frac{4\ \text{k}\Omega}{4\ \text{k}\Omega + 4\ \text{k}\Omega}\right)(2\ \text{mA}) \\ &= \left(\frac{1}{2}\right)(2\ \text{mA}) \\ &= 1\ \text{mA} \end{aligned}$$

Step 6 of 8

Step 4: draw the new equivalent circuit valid for $t > 5\tau$.

Figure 4

Step 7 of 8

The current, $i_o(0^+)$ is zero due to no source available in the circuit.

$$i_o(0^+) = 0$$

Step 5: Find the Thevenin's equivalent resistance of the circuit with respect to open connection at capacitor.

$$\begin{aligned} R_{th} &= 2\ \text{k}\Omega + (4\ \text{k}\Omega \| 4\ \text{k}\Omega) \\ &= 2\ \text{k}\Omega + \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega)}{4\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Calculate the circuit time constant.

$$\begin{aligned} \tau &= R_{th}C \\ &= (4\ \text{k}\Omega)(200\ \mu\text{F}) \\ &= 0.8\ \text{s} \end{aligned}$$

Step 8 of 8

Step 6: Find the values of constants, k_1 and k_2 in the expression of $i_o(t)$.

$$\begin{aligned} k_1 &= i_o(\infty) \\ &= 0 \end{aligned}$$

$$\begin{aligned} k_2 &= i_o(0^+) - i_o(\infty) \\ &= 1 - 0 \\ &= 1\ \text{mA} \end{aligned}$$

Substitute these values in the expression of $i_o(t)$.

$$\begin{aligned} i_o(t) &= 0 + (1\ \text{mA})e^{\frac{-t}{0.8\ \text{s}}} \\ &= e^{-1.25t}\ \text{mA} \end{aligned}$$

Therefore, the expression $i_o(t)$ is, $\boxed{e^{-1.25t}\ \text{mA}}$.

Step 1 of 8

Refer to Figure P7.37 in textbook for the circuit.

Step1: The expression for the current $v_o(t)$ is of the form $k_1 + k_2 e^{\frac{-t}{\tau}}$.

Step2: Note that for $t < 0$ the switch is in open condition from long time and hence the circuit is in steady state. The capacitor acts as an open circuit in steady state. Draw the modified circuit for $t < 0$ and calculate the initial voltage across the capacitor $V_C(0^-)$ from the circuit.

Figure 1

Step 2 of 8

There is no current flow through $2\ \text{k}\Omega$ resistance in the circuit due to the open at the capacitor, hence the voltage across the capacitor is same as the voltage across $4\ \text{k}\Omega$ resistance.

Use voltage division method to find the voltage across the open capacitor.

$$\begin{aligned} V_C(0^-) &= \left[\frac{4\ \text{k}\Omega}{4\ \text{k}\Omega + 4\ \text{k}\Omega + 4\ \text{k}\Omega}\right](24) \\ &= \left(\frac{4}{12}\right)(24) \\ &= 8\ \text{V} \end{aligned}$$

Step 3 of 8

Step3: draw the new circuit valid for $t = 0^+$.

Figure 2

Step 4 of 8

The portion of the circuit across the short circuit line vanishes. Draw the modified circuit.

Figure 3

Step 5 of 8

The output volatge is,

$$\begin{aligned} v_o(0^+) &= \frac{(2\ \text{k})}{(2\ \text{k} + 2\ \text{k})}(-8) \\ &= \frac{(2\ \text{k})}{4\ \text{k}}(-8) \\ &= -4\ \text{V} \end{aligned}$$

Step 6 of 8

Step4: draw the new circuit valid for $t = \infty$.

Figure 4

Step 7 of 8

Figure 4 is source free network. So, the voltage is,

$$v_o(\infty) = 0\ \text{V}$$

Step 5: Find the Thevenin's equivalent resistance of the circuit with respect to open connection at capacitor.

$$\begin{aligned} R_{th} &= 2\ \text{k}\Omega + (4\ \text{k}\Omega \| 4\ \text{k}\Omega) \\ &= 2\ \text{k}\Omega + \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega)}{4\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega + 2\ \text{k}\Omega \\ &= 4\ \text{k}\Omega \end{aligned}$$

Step 8 of 8

Calculate the circuit time constant.

$$\begin{aligned} \tau &= R_{th}C \\ &= (4\ \text{k}\Omega)(200\ \mu\text{F}) \\ &= 0.8\ \text{s} \end{aligned}$$

Step 6: Calculate the constants K_1 and K_2

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= 0 \\ K_2 &= v_o(0^+) - 0 \\ &= -4 - 0 \\ &= -4\ \text{V} \end{aligned}$$

Therefore,

$$\begin{aligned} v_o(t) &= 0 - 4e^{-t/0.8} \\ &= -4e^{-1.25t}\ \text{V} \end{aligned}$$

Therefore, the output voltage is, $\boxed{-4e^{-1.25t}\ \text{V}}$.

Step 1 of 6

Refer to Figure P7.38 in textbook for the circuit.

At $t = 0^-$ circuit is under steady state condition. Capacitor acts as open circuit. Redraw the circuit at $t = 0^-$.

Figure 1

Step 2 of 6

Determine initial capacitor voltage, $v_C(0^-)$.

$$v_C(0^-) = \left(\frac{4\text{ k}}{4\text{ k}+4\text{ k}}\right)(-12)$$
$$= \left(\frac{1}{2}\right)(-12)$$
$$= -6\text{ V}$$

From the circuit, observe that the capacitor voltage is,

$$v_o(0^-) = -v_C(0^-)$$
$$= 6\text{ V}$$

Step 3 of 6

Redraw the circuit at $t = 0^+$.

Figure 2

Step 4 of 6

Redraw the circuit at $t = \infty$.

Figure 3

Step 5 of 6

Observe that the circuit in Figure 3 is a source free network. So, the voltage is,

$$v_o(\infty) = 0\text{ V}$$

Calculate the constants K_1 and K_2

$$K_1 = v_o(\infty)$$
$$= 0$$
$$K_2 = v_o(0) - v_o(\infty)$$
$$= 6 - 0$$
$$= 6\text{ V}$$

Therefore,

$$v_o(t) = K_1 + K_2 e^{-t/\tau}$$
$$= 0 + 6e^{-t/\tau}$$
$$= 6e^{-t/\tau}\text{ V}$$

Step 6 of 6

Calculate the time constant.

$$\tau = R_{eq}C$$
$$= \left(\frac{(12\text{ k})(4\text{ k})}{16\text{ k}}\right)(50\times10^{-6})$$
$$= (3\text{ k})(50\times10^{-6})$$
$$= 0.15\text{ s}$$

Therefore the output voltage is,

$$v_o(t) = 6e^{-t/0.15}\text{ V}$$

Thus, the voltage $v_o(t)$ for $t > 0$ is, $\boxed{6e^{-6.67t}\text{ V}}$.

Step 1 of 10

Refer to Figure P7.46 in the textbook for the circuit diagram.

Step 1:

$i_o(t)$ is of the form $k_1 + k_2 e^{-t/\tau}$

Step 2:

At $t = 0^-$ the switch has been opened and the capacitor is open circuited. Draw the circuit to calculate the initial voltage across the capacitor.

Figure 1

Step 2 of 10

Apply voltage division rule.

$$v_C(0^-) = 12\left(\frac{2k}{2k+2k+2k}\right)$$
$$= 4\text{ V}$$

Step 3:

The circuit for $t = 0^+$ is shown in Figure 2.

Figure 2

Step 3 of 10

The resistors $2\text{ k}\Omega$ and $2\text{ k}\Omega$ are in series and this combination in parallel with $4\text{ k}\Omega$. Determine the equivalent resistance.

$$R_{eq} = (2k + 2k) \| 4k$$
$$= 4k \| 4k$$
$$= 2\text{ k}\Omega$$

Step 4 of 10

The modified circuit is shown in Figure 3.

Figure 3

Step 5 of 10

Apply Kirchhoff's current law to the top node.

$$\frac{V-12}{2k} + \frac{V}{2k} + \frac{V-4}{2k} = 0$$
$$3V - 16 = 0$$
$$V = \frac{16}{3}\text{ V}$$

Step 6 of 10

Determine the output current for $t = 0^+$.

$$i_o(0+) = \frac{V}{2k}$$
$$= \frac{\left(\frac{16}{3}\right)}{2k}$$
$$= \frac{8}{3}\text{ mA}$$

Step 4:

Draw the equivalent circuit for $t > 5\tau$.

Figure 4

Step 7 of 10

Determine the output current $t = \infty$.

$$i_o(\infty) = \frac{12}{2k + (4k \| (2k + 2k))}$$
$$= \frac{12}{2k(4k \| 4k)}$$
$$= \frac{12}{2k + 2k}$$
$$= 3\text{ mA}$$

Step 8 of 10

Step 5:

The Thevenin equivalent resistance can be found by looking into the open circulated terminals of the capacitor.

Figure 5

Step 9 of 10

Determine the Thevenin resistance.

$$R_{Th} = 2k + \{2k \| [4k \| (2k + 2k)]\}$$
$$= 2k + \{2k \| [4k \| 4k]\}$$
$$= 2k + (2k \| 2k)$$
$$= 3\text{ k}$$

Determine the circuit time constant.

$$\tau = R_{Th}C$$
$$= (3 \times 10^3)(200 \times 10^{-6})$$
$$= 0.6\text{ s}$$

Step 10 of 10

Step 6:

Determine the constants.

$$k_1 = i_o(\infty)$$
$$k_1 = 3\text{ mA}$$
$$k_2 = i_o(0+) - i_o(\infty)$$
$$k_2 = \frac{8}{3} - 3$$
$$k_2 = -\frac{1}{3}\text{ mA}$$

Thus, the output current for $t > 0$ is, $\boxed{i_o(t) = \left(3 - \frac{1}{3}e^{-\frac{t}{0.6}}\right)u(t)\text{ mA}}$.

Step 1 of 10

Refer to Figure P7.55 in the textbook.

Step1: The expression for the voltage $v_o(t)$ is of the form $k_1 + k_2 e^{\frac{-t}{\tau}}$.

Step2: Note that for $t < 0$ the switch is in open condition from long time and hence the circuit is in steady state. The capacitor acts as an open circuit in steady state. Draw the modified circuit for $t < 0$ and calculate the initial voltage across the capacitor $V_C(0^-)$ from the circuit.

Figure 1

Step 2 of 10

Simplify and redraw the circuit carefully.

Figure 2

Step 3 of 10

Use voltage division method to find the voltage across the open capacitor.

$$V_C(0^-) = \left[\frac{6\text{ k}\Omega}{6\text{ k}\Omega + 6\text{ k}\Omega}\right](-12\text{ V})$$
$$= \left(\frac{1}{2}\right)(-12)$$
$$= -6\text{ V}$$

Step3: draw the new circuit valid for $t = 0^+$.

Figure 3

Step 4 of 10

Simplify and redraw the circuit.

Figure 4

Step 5 of 10

Use voltage division method to find the output voltage.

$$V_o(0^+) = \left[\frac{6\text{ k}\Omega}{6\text{ k}\Omega + (6\text{ k}\Omega \| 6\text{ k}\Omega)}\right](-6\text{ V})$$
$$= \left[\frac{6\text{ k}\Omega}{6\text{ k}\Omega + 3\text{ k}\Omega}\right](-6\text{ V})$$
$$= \left(\frac{2}{3}\right)(-6)$$
$$= -4\text{ V}$$

Step 6 of 10

Step 4: Draw the new equivalent circuit valid for $t > 5\tau$.

Figure 5

Step 7 of 10

The voltage, $v_o(\infty)$ is zero due to no source available in the circuit.

$$v_o(\infty) = 0$$

Step 5: Find the Thevenin's equivalent resistance of the circuit.

Figure 6

Step 8 of 10

Simplify and redraw the circuit.

Figure 7

Step 9 of 10

Find the Thevenin's equivalent resistance

$$R_{th} = 6\text{ k}\Omega \| [6\text{ k}\Omega + (6\text{ k}\Omega \| 6\text{ k}\Omega)]$$
$$= 6\text{ k}\Omega \| [6\text{ k}\Omega + 3\text{ k}\Omega]$$
$$= 6\text{ k}\Omega \| 9\text{ k}\Omega$$
$$= 3.6\text{ k}\Omega$$

Calculate the circuit time constant.

$$\tau = R_{th}C$$
$$= (3.6\text{ k}\Omega)(50\ \mu\text{F})$$
$$= 0.18\text{ s}$$

Step 10 of 10

Step 6: Find the values of constants, k_1 and k_2 in the expression of $i_o(t)$.

$$k_1 = V_o(\infty)$$
$$= 0$$

$$k_2 = V_o(0^+) - V_o(\infty)$$
$$= -4 - 0$$
$$= -4\text{ V}$$

Substitute these values in the expression of $i_o(t)$.

$$v_o(t) = 0 + (-4\text{ V})e^{\frac{-t}{0.18\text{ s}}}$$
$$= -4e^{-5.56t}\text{ V}$$

Therefore, the expression $v_o(t)$ is, $\boxed{-4e^{-5.56t}\text{ V}}$.

Step 1 of 15

Consider the Figure P7.59 from the text book.

Step-1:

Let the value of the capacitor voltage $v_c(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 15

Calculate the value of the current $i_1(t)$ using current division rule.

$$i_1(t) = (6)\left(\frac{20+10}{20+10+5+10}\right)$$
$$= (6)\left(\frac{30}{45}\right)$$
$$= (6)\left(\frac{2}{3}\right)$$
$$= 4\text{ A}$$

Therefore, the value of the current $i_1(t)$ is 4 A .

Step 3 of 15

Calculate the value of the current $i_2(t)$.

$$i_2(t) = 6 - i_1(t)$$

Substitute 4 A for $i_1(t)$.

$$i_2(t) = 6 - 4$$
$$= 2\text{ A}$$

Therefore, the value of the current $i_2(t)$ is 2 A .

Step 4 of 15

Calculate the value of the voltage $v_C(0^-)$.

$$v_C(0^-) = i_2(t)(10) - i_1(t)(10)$$

Substitute 2 A for $i_2(t)$ and 4 A for $i_1(t)$.

$$v_C(0^-) = (2)(10) - (4)(10)$$
$$= 20 - 40$$
$$= -20\text{ V}$$

Therefore, the value of the voltage $v_C(0^-)$ is -20 V .

Step 5 of 15

Step-3:

The value of the capacitor voltage at $t = 0^+$ is equal to the value of the voltage $v_C(0^-)$. Therefore, the value of the voltage $v_C(0^+)$ is -20 V .

Step 6 of 15

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

Step 7 of 15

Calculate the value of the current $i_1(t)$ using current division rule.

$$i_1(t) = (6)\left(\frac{10}{10+5+10}\right)$$
$$= (6)\left(\frac{10}{25}\right)$$
$$= (6)\left(\frac{2}{5}\right)$$
$$= 2.4\text{ A}$$

Therefore, the value of the current $i_1(t)$ is 2.4 A .

Step 8 of 15

Calculate the value of the current $i_2(t)$.

$$i_2(t) = 6 - i_1(t)$$

Substitute 2.4 A for $i_1(t)$.

$$i_2(t) = 6 - 2.4$$
$$= 3.6\text{ A}$$

Therefore, the value of the current $i_2(t)$ is 3.6 A .

Step 9 of 15

Calculate the value of the voltage $v_C(\infty)$.

$$v_C(\infty) = i_2(t)(10) - i_1(t)(10)$$

Substitute 3.6 A for $i_2(t)$ and 2.4 A for $i_1(t)$.

$$v_C(\infty) = (3.6)(10) - (2.4)(10)$$
$$= 36 - 24$$
$$= 12\text{ V}$$

Therefore, the value of the voltage $v_C(\infty)$ is 12 V .

Step 10 of 15

Consider the circuit diagram shown in Figure 3 to calculate the equivalent resistance as seen from the opened terminals of the capacitor.

Figure 3

Step 11 of 15

Calculate the value of the equivalent resistance R_{eq} .

$$R_{eq} = 5 \parallel (10+10)$$
$$= 5 \parallel 20$$
$$= \frac{(5)(20)}{5+20}$$
$$= \frac{100}{25}$$
$$R_{eq} = 5 \parallel (10+10)$$
$$= 5 \parallel 20$$
$$= \frac{(5)(20)}{5+20}$$
$$= 4\ \Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $4\ \Omega$.

Step 12 of 15

Step-5:

Calculate the value of the time constant τ .

$$\tau = R_{eq} \cdot C$$

Substitute $4\ \Omega$ for R_{eq} and 0.5 F for C .

$$\tau = (4)\cdot(0.5)$$
$$= 2\text{ s}$$

Therefore, the value of the time constant τ is 2 s .

Step 13 of 15

Step-6:

Calculate the value of the constant K_1 .

$$K_1 = v_c(\infty)$$

Substitute 12 V for $v_O(\infty)$.

$$K_1 = 12\text{ V}$$

Therefore, the value of the constant K_1 is 12 V .

Step 14 of 15

Calculate the value of the constant K_2 .

$$K_2 = v_c(0^+) - v_c(\infty)$$

Substitute -12 V for $v_O(\infty)$ and 12 V for $v_c(0^+)$.

$$K_2 = -20 - 12$$
$$= -32\text{ V}$$

Therefore, the value of the constant K_2 is -32 V .

Step 15 of 15

Recall equation (1).

$$v_c(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 2 s for τ . -32 V for K_2 and 12 V for K_1 .

$$v_c(t) = 12 - 32\, e^{-t/2}\text{ V}$$

Therefore, the value of the voltage $v_c(t)$ is $\boxed{12 - 32\, e^{-t/2}\text{ V}}$.

Step 1 of 9

7.034P

Refer to circuit diagram in Figure P7.34 in the textbook.

Initially switch in the circuit is closed, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law at node $v_C(0^-)$.

$$\frac{v_C(0^-)-12}{2\text{ k}\Omega}+\frac{v_C(0^-)}{1\text{ k}\Omega}+\frac{v_C(0^-)+6}{2\text{ k}\Omega}=0$$

$$\left(\frac{1}{2\text{ k}\Omega}+\frac{1}{1\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}\right)v_C(0^-)=\frac{12}{2\text{ k}\Omega}-\frac{6}{2\text{ k}\Omega}$$

$$\left(\frac{1+2+1}{2\text{ k}\Omega}\right)v_C(0^-)=\frac{12-6}{2\text{ k}\Omega}$$

$$4v_C(0^-)=6$$

$$v_C(0^-)=1.5\text{ V}$$

Step 3 of 9

At $t=0^+$, the switch in the circuit is open and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Calculate the initial current through current through $1\text{ k}\Omega$ resistor.

$$i_o(0^+)=\frac{1.5\text{ V}}{1\text{ k}\Omega}$$
$$=1.5\text{ mA}$$

The initial current through current through $1\text{ k}\Omega$ resistor is 1.5 mA.

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$R_{eq}=(2\text{ k}\Omega)\|(1\text{ k}\Omega)$$
$$=\frac{(2\text{ k}\Omega)(1\text{ k}\Omega)}{2\text{ k}\Omega+1\text{ k}\Omega}$$
$$=\frac{2\text{ k}\Omega}{3}$$
$$=667\ \Omega$$

Calculate the time constant.

$$\tau=R_{eq}C$$
$$=(667\ \Omega)(100\ \mu\text{F})$$
$$=66.7\text{ ms}$$

Step 7 of 9

For $t=\infty$, the switch in the circuit is open and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the final current through $1\text{ k}\Omega$ resistor.

$$(2\text{ k}\Omega+1\text{ k}\Omega)i_o(\infty)=-6\text{ V}$$
$$(3\text{ k}\Omega)i_o(\infty)=-6\text{ V}$$
$$i_o(\infty)=-2\text{ mA}$$

Therefore, the final current through $1\text{ k}\Omega$ resistor is -2 mA.

Step 9 of 9

Write the expression for current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=K_1+K_2e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$K_1=i_o(\infty)$$
$$=-2\text{ mA}$$

Calculate the value of K_2.

$$K_2=i_o(0^+)-i_o(\infty)$$
$$=1.5\text{ mA}-(-2\text{ mA})$$
$$=3.5\text{ mA}$$

Calculate the current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=-2\text{ mA}+3.5\text{ mA}e^{\frac{-t}{66.7\text{ ms}}}$$
$$=-2+3.5e^{-15t}\text{ mA}$$

Therefore, the current, $i_o(t)$ through $1\text{ k}\Omega$ resistor for $t>0$ is $\boxed{-2+3.5e^{-15t}\text{ mA}}$.

Step 1 of 9

Refer to circuit diagram in Figure P7.35 in the textbook.

Initially switch in the circuit is closed, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= 6\text{ V} - \left(\frac{1\text{ k}\Omega}{1\text{ k}\Omega + 1\text{ k}\Omega}\right)(6\text{ V}) \\ &= 6\text{ V} - (0.5)(6\text{ V}) \\ &= 6\text{ V} - 3\text{ V} \\ &= 3\text{ V} \end{aligned}$$

Step 3 of 9

At $t = 0^+$, the switch in the circuit is open and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

From the circuit, a voltage source is between nodes v_1 and $v_o(0^+)$ and it forms supernode. Write the voltage expression.

$$v_1 - v_o(0^+) = 3\text{ V}$$

$$v_1 = v_o(0^+) + 3\text{ V} \quad \text{..... (1)}$$

Apply Kirchhoff's current law at node $v_o(0^+)$.

$$\frac{v_1}{1\text{ k}\Omega} + \frac{v_o(0^+)}{1\text{ k}\Omega} + \frac{v_o(0^+) - 6\text{ V}}{1\text{ k}\Omega} = 0$$

Substitute $v_o(0^+) + 3\text{ V}$ for v_1 in the equation.

$$\begin{aligned} \frac{v_o(0^+) + 3\text{ V}}{1\text{ k}\Omega} + \frac{v_o(0^+)}{1\text{ k}\Omega} + \frac{v_o(0^+) - 6\text{ V}}{1\text{ k}\Omega} &= 0 \\ \left(\frac{1}{1\text{ k}\Omega} + \frac{1}{1\text{ k}\Omega} + \frac{1}{1\text{ k}\Omega}\right) v_o(0^+) &= \frac{6\text{ V}}{1\text{ k}\Omega} - \frac{3\text{ V}}{1\text{ k}\Omega} \\ 3v_o(0^+) &= 3\text{ V} \\ v_o(0^+) &= 1\text{ V} \end{aligned}$$

The initial voltage across the $1\text{ k}\Omega$ resistor is 1 V .

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= \left[(1\text{ k}\Omega) \| (1\text{ k}\Omega)\right] + 1\text{ k}\Omega \\ &= \frac{(1\text{ k}\Omega)(1\text{ k}\Omega)}{1\text{ k}\Omega + 1\text{ k}\Omega} + 1\text{ k}\Omega \\ &= 0.5\text{ k}\Omega + 1\text{ k}\Omega \\ &= 1.5\text{ k}\Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (1.5\text{ k}\Omega)(100\ \mu\text{F}) \\ &= 0.15\text{ ms} \end{aligned}$$

Step 7 of 9

For $t = \infty$, the switch in the circuit is open and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the final voltage across the $1\text{ k}\Omega$ resistor.

$$\begin{aligned} v_C(\infty) &= \left(\frac{1\text{ k}\Omega}{1\text{ k}\Omega + 1\text{ k}\Omega}\right)(6\text{ V}) \\ &= \left(\frac{1\text{ k}\Omega}{2\text{ k}\Omega}\right)(6\text{ V}) \\ &= (0.5)(6\text{ V}) \\ &= 3\text{ V} \end{aligned}$$

Therefore, the final voltage across the $1\text{ k}\Omega$ resistor is 3 V .

Step 9 of 9

Write the expression for voltage across $1\text{ k}\Omega$ resistor for $t > 0$.

$$v_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1 .

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= 3\text{ V} \end{aligned}$$

Calculate the value of K_2 .

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= 1\text{ V} - 3\text{ V} \\ &= -2\text{ V} \end{aligned}$$

Calculate the voltage across $1\text{ k}\Omega$ resistor for $t > 0$.

$$\begin{aligned} v_o(t) &= 3\text{ V} + (-2\text{ V})e^{\frac{-t}{0.15\text{ s}}} \\ &= 3 - 2e^{-6.67t}\text{ V} \end{aligned}$$

Therefore, the voltage, $v_o(t)$ across $1\text{ k}\Omega$ resistor for $t > 0$ is $\boxed{3 - 2e^{-6.67t}\text{ V}}$.

Refer to circuit diagram in Figure P7.36 in the textbook.

Initially switch in the circuit is closed, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff's current law at node v_1 .

$$\frac{v_1}{3\text{ k}\Omega+9\text{ k}\Omega}+\frac{v_1}{2\text{ k}\Omega+4\text{ k}\Omega+6\text{ k}\Omega}=12\text{ mA}$$

$$\frac{v_1}{12\text{ k}\Omega}+\frac{v_1}{12\text{ k}\Omega}=12\text{ mA}$$

$$2v_1=144\text{ V}$$

$$v_1=72\text{ V}$$

Calculate the initial voltage across the capacitor.

$$\begin{aligned}v_C(0^-)&=\left(\frac{4\text{ k}\Omega+6\text{ k}\Omega}{2\text{ k}\Omega+4\text{ k}\Omega+6\text{ k}\Omega}\right)(72\text{ V})\\&=\left(\frac{10\text{ k}\Omega}{12\text{ k}\Omega}\right)(72\text{ V})\\&=60\text{ V}\end{aligned}$$

Step 3 of 8

At $t=0^+$, the switch in the circuit is open and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 8

Calculate the voltage across the $6\text{ k}\Omega$ resistor at $t=0^+$.

$$\begin{aligned}v_o(0^+)&=\left(\frac{6\text{ k}\Omega}{4\text{ k}\Omega+6\text{ k}\Omega}\right)(60\text{ V})\\&=\left(\frac{6\text{ k}\Omega}{10\text{ k}\Omega}\right)(60\text{ V})\\&=(6)(6\text{ V})\\&=36\text{ V}\end{aligned}$$

Step 5 of 8

To calculate the equivalent resistance from the terminals of the capacitor, open circuit the current source and the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 8

Calculate the equivalent resistance.

$$\begin{aligned}R_{eq}&=4\text{ k}\Omega+6\text{ k}\Omega\\&=10\text{ k}\Omega\end{aligned}$$

Calculate the time constant.

$$\begin{aligned}\tau&=R_{eq}C\\&=(10\text{ k}\Omega)(60\ \mu\text{F})\\&=0.6\text{ s}\end{aligned}$$

Step 7 of 8

For $t=\infty$, the switch in the circuit is open and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 8

Calculate the final voltage across the $6\text{ k}\Omega$ resistor.

$$\begin{aligned}v_C(\infty)&=(6\text{ k}\Omega)(12\text{ mA})\\&=72\text{ V}\end{aligned}$$

Write the expression for voltage across $6\text{ k}\Omega$ resistor for $t>0$.

$$v_o(t)=K_1+K_2e^{\frac{-t}{\tau}}$$

Calculate the value of K_1 .

$$\begin{aligned}K_1&=v_o(\infty)\\&=72\text{ V}\end{aligned}$$

Calculate the value of K_2 .

$$\begin{aligned}K_2&=v_o(0^+)-v_o(\infty)\\&=36\text{ V}-72\text{ V}\\&=-36\text{ V}\end{aligned}$$

Calculate the voltage across $6\text{ k}\Omega$ resistor for $t>0$.

$$\begin{aligned}v_o(t)&=72\text{ V}+(-36\text{ V})e^{\frac{-t}{0.6\text{ s}}}\\&=72-36e^{-1.67t}\text{ V}\end{aligned}$$

Therefore, the voltage, $v_o(t)$ across $6\text{ k}\Omega$ resistor for $t>0$ is $\boxed{72-36e^{-1.67t}\text{ V}}$.

Step 1 of 9

7.037P

Refer to circuit diagram in Figure P7.37 in the textbook.

Initially switch in the circuit is closed, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

From the circuit, loop 3 is not a closed loop. So, current in the loop 3 is zero.

$$i_3 = 0$$

Apply Kirchhoff's voltage law to loop 1.

$$(4\ \text{k}\Omega)i_1 + (3\ \text{k}\Omega)(i_1 - i_2) = 36\ \text{V}$$
$$(7\ \text{k}\Omega)i_1 - (3\ \text{k}\Omega)i_2 = 36\ \text{V}$$
$$(7\ \text{k}\Omega)i_1 = 36\ \text{V} + (3\ \text{k}\Omega)i_2$$

$$i_1 = 5.143\ \text{mA} + 0.428i_2 \quad \text{..... (1)}$$

Step 3 of 9

Apply Kirchhoff's voltage law to loop 2.

$$(3\ \text{k}\Omega)(i_2 - i_1) + (3\ \text{k}\Omega)i_2 + (3\ \text{k}\Omega)(i_2 - 0) = 0$$
$$-i_1 + 3i_2 = 0$$

Substitute $5.143\ \text{mA} + 0.428i_2$ for i_1 in the equation.

$$-(5.143\ \text{mA} + 0.428i_2) + 3i_2 = 0$$
$$2.572i_2 = 5.143\ \text{mA}$$
$$i_2 = 2\ \text{mA}$$

Apply Kirchhoff's voltage law to loop 2.

$$(3\ \text{k}\Omega)(0 - i_2) + v_C(0^-) + 12\ \text{V} = 0$$
$$(3\ \text{k}\Omega)(-2\ \text{mA}) + v_C(0^-) + 12\ \text{V} = 0$$
$$-6\ \text{V} + v_C(0^-) + 12\ \text{V} = 0$$
$$v_C(0^-) = -6\ \text{V}$$

Step 4 of 9

At $t = 0^+$, the switch in the circuit is open and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 9

Apply Kirchhoff's current law at node v_1.

$$\frac{v_1}{3\ \text{k}\Omega + 3\ \text{k}\Omega} + \frac{v_1}{3\ \text{k}\Omega} + \frac{v_1 + 6\ \text{V} - 12\ \text{V}}{2\ \text{k}\Omega} = 0$$
$$\frac{v_1}{6\ \text{k}\Omega} + \frac{v_1}{3\ \text{k}\Omega} + \frac{v_1}{2\ \text{k}\Omega} = \frac{6\ \text{V}}{2\ \text{k}\Omega}$$
$$\frac{v_1 + 2v_1 + 3v_1}{6} = 3\ \text{V}$$
$$v_1 = \frac{18\ \text{V}}{6}$$

$$v_1 = 3\ \text{V}$$

Calculate the initial current, $i_o(0^+)$ $t = 0^+$.

$$i_o(0^+) = \frac{v_1}{3\ \text{k}\Omega}$$
$$= \frac{3\ \text{V}}{3\ \text{k}\Omega}$$
$$= 1\ \text{mA}$$

Step 6 of 9

To calculate the equivalent resistance from the terminals of the capacitor, open circuit the current source and the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 9

Calculate the equivalent resistance.

$$R_{eq} = \left[(3\ \text{k}\Omega) \| (3\ \text{k}\Omega + 3\ \text{k}\Omega)\right] + 2\ \text{k}\Omega$$
$$= \left[\frac{(3\ \text{k}\Omega)(6\ \text{k}\Omega)}{3\ \text{k}\Omega + 6\ \text{k}\Omega}\right] + 2\ \text{k}\Omega$$
$$= 2\ \text{k}\Omega + 2\ \text{k}\Omega$$
$$= 4\ \text{k}\Omega$$

Calculate the time constant.

$$\tau = R_{eq}C$$
$$= (4\ \text{k}\Omega)(150\ \mu\text{F})$$
$$= 0.6\ \text{s}$$

Step 8 of 9

For $t = \infty$, the switch in the circuit is open and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 9 of 9

Calculate the final current $i_o(\infty)$.

$$i_o(\infty) = 0\ \text{A}$$

Write the expression for current through resistor for $t > 0$.

$$i_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$K_1 = i_o(\infty)$$
$$= 0\ \text{A}$$

Calculate the value of K_2.

$$K_2 = i_o(0^+) - i_o(\infty)$$
$$= 1\ \text{mA} - 0\ \text{A}$$
$$= 1\ \text{mA}$$

Calculate the current through resistor for $t > 0$.

$$i_o(t) = 0\ \text{A} + (1\ \text{mA})e^{\frac{-t}{0.6\ \text{s}}}$$
$$= 1e^{-1.67t}\ \text{mA}$$

Therefore, the current through resistor for $t > 0$ is $\boxed{1e^{-1.67t}\ \text{mA}}$.

Step 1 of 8

7.038P

Refer to circuit diagram in Figure P7.38 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff's current law.

$$\frac{v_C(0^-)-18\text{ V}}{3\text{ k}\Omega}+\frac{v_C(0^-)-6\text{ V}}{6\text{ k}\Omega+3\text{ k}\Omega}=0$$

$$\frac{v_C(0^-)-18\text{ V}}{3\text{ k}\Omega}+\frac{v_C(0^-)-6\text{ V}}{9\text{ k}\Omega}=0$$

$$\left(\frac{3+1}{9\text{ k}\Omega}\right)v_C(0^-)=\frac{54\text{ V}+6\text{ V}}{9\text{ k}\Omega}$$

$$4v_C(0^-)=60\text{ V}$$

$$v_C(0^-)=15\text{ V}$$

Step 3 of 8

At $t=0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 8

Calculate the initial voltage across the $6\text{ k}\Omega$ resistor at $t=0^+$.

$$v_o(0^+)=15\text{ V}$$

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources. The circuit diagram is shown in Figure 3.

Figure 3

Step 5 of 8

Calculate the equivalent resistance.

$$\begin{aligned}R_{eq}&=(3\text{ k}\Omega)\|(6\text{ k}\Omega)\\&=\frac{(3\text{ k}\Omega)(6\text{ k}\Omega)}{3\text{ k}\Omega+6\text{ k}\Omega}\\&=\frac{18\text{ k}\Omega}{9}\\&=2\text{ k}\Omega\end{aligned}$$

Calculate the time constant.

$$\begin{aligned}\tau&=R_{eq}C\\&=(2\text{ k}\Omega)(200\ \mu\text{F})\\&=0.4\text{ s}\end{aligned}$$

Step 6 of 8

For $t=\infty$, the switch in the circuit is closed and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 7 of 8

Calculate the voltage across the $6\text{ k}\Omega$ resistor at $t=\infty$.

$$\begin{aligned}v_o(\infty)&=\left(\frac{6\text{ k}\Omega}{3\text{ k}\Omega+6\text{ k}\Omega}\right)(18\text{ V})\\&=\left(\frac{6\text{ k}\Omega}{9\text{ k}\Omega}\right)(18\text{ V})\\&=(6)(2\text{ V})\\&=12\text{ V}\end{aligned}$$

Step 8 of 8

Write the expression for voltage across the $6\text{ k}\Omega$ resistor for $t>0$.

$$v_o(t)=K_1+K_2e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$\begin{aligned}K_1&=v_o(\infty)\\&=12\text{ V}\end{aligned}$$

Calculate the value of K_2.

$$\begin{aligned}K_2&=v_o(0^+)-v_o(\infty)\\&=15\text{ V}-12\text{ V}\\&=3\text{ V}\end{aligned}$$

Calculate the voltage across the $6\text{ k}\Omega$ resistor for $t>0$.

$$\begin{aligned}v_o(t)&=12\text{ V}+(3\text{ V})e^{\frac{-t}{0.4\text{ s}}}\\&=12+3e^{-2.5t}\text{ V}\end{aligned}$$

Therefore, the voltage across the $6\text{ k}\Omega$ resistor for $t>0$ is $\boxed{12+3e^{-2.5t}\text{ V}}$.

Step 1 of 9

7.039P

Refer to circuit diagram in Figure P7.39 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law.

$$\frac{v_C(0^-)-24\text{ V}}{2\text{ k}\Omega+1\text{ k}\Omega}+\frac{v_C(0^-)}{3\text{ k}\Omega}=4\text{ mA}$$

$$\frac{v_C(0^-)-24\text{ V}}{3\text{ k}\Omega}+\frac{v_C(0^-)}{3\text{ k}\Omega}=4\text{ mA}$$

$$v_C(0^-)-24\text{ V}+v_C(0^-)=12\text{ V}$$

$$2v_C(0^-)=36\text{ V}$$

$$v_C(0^-)=18\text{ V}$$

Step 3 of 9

At $t=0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Calculate the initial current through $1\text{ k}\Omega$ resistor at $t=0^+$.

$$i_o(0^+)=\frac{18\text{ V}}{1\text{ k}\Omega}$$
$$=18\text{ mA}$$

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, open circuit the current source. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$R_{eq}=(3\text{ k}\Omega)\|(1\text{ k}\Omega)$$
$$=\frac{(3\text{ k}\Omega)(1\text{ k}\Omega)}{3\text{ k}\Omega+1\text{ k}\Omega}$$
$$=\frac{3\text{ k}\Omega}{4}$$
$$=750\ \Omega$$

Calculate the time constant.

$$\tau=R_{eq}C$$
$$=(750\ \Omega)(100\ \mu\text{F})$$
$$=0.075\text{ s}$$

Step 7 of 9

For $t=\infty$, the switch in the circuit is closed and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the current through $1\text{ k}\Omega$ resistor at $t=\infty$.

$$i_o(\infty)=\left(\frac{3\text{ k}\Omega}{3\text{ k}\Omega+1\text{ k}\Omega}\right)(-4\text{ mA})$$
$$=\left(\frac{3\text{ k}\Omega}{4\text{ k}\Omega}\right)(-4\text{ mA})$$
$$=(0.75)(-4\text{ mA})$$
$$=-3\text{ mA}$$

Step 9 of 9

Write the expression for current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=K_1+K_2e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$K_1=i_o(\infty)$$
$$=-3\text{ mA}$$

Calculate the value of K_2.

$$K_2=i_o(0^+)-i_o(\infty)$$
$$=18\text{ mA}-(-3\text{ mA})$$
$$=21\text{ mA}$$

Calculate the current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=-3\text{ mA}+(21\text{ mA})e^{\frac{-t}{0.075\text{ s}}}$$
$$=-3+21e^{-13.33t}\text{ mA}$$

Therefore, the current through $1\text{ k}\Omega$ resistor for $t>0$ is $\boxed{-3+21e^{-13.33t}\text{ mA}}$.

Step 1 of 9

Refer to circuit diagram in Figure P7.40 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law at node v_1.

$$\frac{v_1}{2\text{ k}\Omega}+\frac{v_1-v_C(0^-)}{1\text{ k}\Omega}=12\text{ mA}$$
$$0.5v_1+v_1-v_C(0^-)=12\text{ V}$$
$$1.5v_1=12\text{ V}+v_C(0^-)$$
$$v_1=\frac{12\text{ V}+v_C(0^-)}{1.5}$$

Apply Kirchhoff's current law at node $v_C(0^-)$.

$$\frac{v_C(0^-)-12\text{ V}}{3\text{ k}\Omega}+\frac{v_C(0^-)-v_1}{1\text{ k}\Omega}=0$$
$$v_C(0^-)-12\text{ V}+3\left(v_C(0^-)-v_1\right)=0$$
$$4v_C(0^-)-3v_1=12\text{ V}$$

Substitute $\frac{12\text{ V}+v_C(0^-)}{1.5}$ for v_1 in the equation.

$$4v_C(0^-)-3\left(\frac{12\text{ V}+v_C(0^-)}{1.5}\right)=12\text{ V}$$
$$4v_C(0^-)-24\text{ V}-2v_C(0^-)=12\text{ V}$$
$$2v_C(0^-)=36\text{ V}$$
$$v_C(0^-)=18\text{ V}$$

Step 3 of 9

At $t=0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Calculate the initial current through $1\text{ k}\Omega$ resistor at $t=0^+$.

$$i_o(0^+)=\frac{18\text{ V}}{1\text{ k}\Omega}$$
$$=18\text{ mA}$$

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, open circuit the current source and short circuit the voltage source. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$R_{eq}=(3\text{ k}\Omega)\|(1\text{ k}\Omega)$$
$$=\frac{(3\text{ k}\Omega)(1\text{ k}\Omega)}{3\text{ k}\Omega+1\text{ k}\Omega}$$
$$=\frac{3\text{ k}\Omega}{4}$$
$$=750\ \Omega$$

Calculate the time constant.

$$\tau=R_{eq}C$$
$$=(750\ \Omega)(100\ \mu\text{F})$$
$$=0.075\text{ s}$$

Step 7 of 9

For $t=\infty$, the switch in the circuit is closed and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the current through $1\text{ k}\Omega$ resistor at $t=\infty$.

$$i_o(\infty)=\frac{-12\text{ V}}{3\text{ k}\Omega+1\text{ k}\Omega}$$
$$=\frac{-12\text{ V}}{4\text{ k}\Omega}$$
$$=-3\text{ mA}$$

Step 9 of 9

Write the expression for current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=K_1+K_2e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$K_1=i_o(\infty)$$
$$=-3\text{ mA}$$

Calculate the value of K_2.

$$K_2=i_o(0^+)-i_o(\infty)$$
$$=18\text{ mA}-(-3\text{ mA})$$
$$=21\text{ mA}$$

Calculate the current through $1\text{ k}\Omega$ resistor for $t>0$.

$$i_o(t)=-3\text{ mA}+(21\text{ mA})e^{\frac{-t}{0.075\text{ s}}}$$
$$=-3+21e^{-13.33t}\text{ mA}$$

Therefore, the current through $1\text{ k}\Omega$ resistor for $t>0$ is $\boxed{-3+21e^{-13.33t}\text{ mA}}$.

Step 1 of 9

Refer to circuit diagram in Figure P7.41 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= \left(\frac{1\text{ k}\Omega}{2\text{ k}\Omega + 1\text{ k}\Omega}\right)(-6\text{ V}) \\ &= \left(\frac{1\text{ k}\Omega}{3\text{ k}\Omega}\right)(-6\text{ V}) \\ &= (0.333)(-6\text{ V}) \\ &= -2\text{ V} \end{aligned}$$

Step 3 of 9

At $t = 0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Calculate the initial current through current through $1\text{ k}\Omega$ resistor.

$$\begin{aligned} i_o(0^+) &= \frac{-2\text{ V}}{1\text{ k}\Omega} \\ &= -2\text{ mA} \end{aligned}$$

The initial current through current through $1\text{ k}\Omega$ resistor is -2 mA.

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= (2\text{ k}\Omega) \| (1\text{ k}\Omega) \| (2\text{ k}\Omega) \\ &= \frac{1}{\frac{1}{2\text{ k}\Omega} + \frac{1}{1\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}} \\ &= \frac{2\text{ k}\Omega}{1+2+1} \\ &= 500\ \Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (500\ \Omega)(100\ \mu\text{F}) \\ &= 50\text{ ms} \end{aligned}$$

Step 7 of 9

For $t = \infty$, the switch in the circuit is closed and circuit reaches steady state. Under steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Apply Kirchhoff's current law at node v_1.

$$\frac{v_1 - 12\text{ V}}{2\text{ k}\Omega} + \frac{v_1}{1\text{ k}\Omega} + \frac{v_1 + 6\text{ V}}{2\text{ k}\Omega} = 0$$

$$\left(\frac{1}{2\text{ k}\Omega} + \frac{2}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}\right)v_1 = \frac{12\text{ V}}{2\text{ k}\Omega} - \frac{6\text{ V}}{2\text{ k}\Omega}$$

$$4v_1 = 6\text{ V}$$

$$v_1 = 1.5\text{ V}$$

Calculate the final current through $1\text{ k}\Omega$ resistor.

$$\begin{aligned} i_o(\infty) &= \frac{1.5\text{ V}}{1\text{ k}\Omega} \\ &= 1.5\text{ mA} \end{aligned}$$

Therefore, the final current through $1\text{ k}\Omega$ resistor is 1.5 mA.

Step 9 of 9

Write the expression for current through $1\text{ k}\Omega$ resistor for $t > 0$.

$$i_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$\begin{aligned} K_1 &= i_o(\infty) \\ &= 1.5\text{ mA} \end{aligned}$$

Calculate the value of K_2.

$$\begin{aligned} K_2 &= i_o(0^+) - i_o(\infty) \\ &= -2\text{ mA} - 1.5\text{ mA} \\ &= -3.5\text{ mA} \end{aligned}$$

Calculate the current through $1\text{ k}\Omega$ resistor for $t > 0$.

$$\begin{aligned} i_o(t) &= 1.5\text{ mA} - 3.5\text{ mA}e^{\frac{-t}{50\text{ ms}}} \\ &= 1.5 - 3.5e^{-20t}\text{ mA} \end{aligned}$$

Therefore, the current, $i_o(t)$ through $1\text{ k}\Omega$ resistor for $t > 0$ is $\boxed{1.5 - 3.5e^{-20t}\text{ mA}}$.

Step 1 of 6

Step 1:

Refer to Figure P7.42 in the textbook.

The output voltage, $v_o(t)$ is of the form, $K_1 + K_2 e^{\frac{-t}{\tau}}$.

Step 2:

For $t = 0^-$, the switch is in closed condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as open circuit.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law at output node.

$$\frac{v_o(0^-) - 12\text{ V}}{1\,\Omega + 2\,\Omega} + \frac{v_o(0^-) - 8\text{ V}}{2\,\Omega} + \frac{v_o(0^-)}{2\,\Omega} = 0$$

Simplify the expression for $v_o(0^-)$.

$$v_o(0^-)\left(\frac{1}{3} + \frac{1}{2} + \frac{1}{2}\right) = \frac{12}{3} + \frac{8}{2}$$

$$v_o(0^-)\left(\frac{8}{6}\right) = 4 + 4$$

$$v_o(0^-) = 6\text{ V}$$

Apply Kirchhoff's current law to calculate the voltage across the capacitor.

$$\frac{v_C(0^-) - 12\text{ V}}{1\,\Omega} + \frac{v_C(0^-) - v_o(0^-)}{2\,\Omega} = 0$$

$$\frac{v_C(0^-) - 12\text{ V}}{1\,\Omega} + \frac{v_C(0^-) - 6\text{ V}}{2\,\Omega} = 0$$

Simplify the expression for $v_C(0^-)$.

$$v_C(0^-)\left(1 + \frac{1}{2}\right) = 12 + \frac{6}{2}$$

$$v_C(0^-)\left(\frac{3}{2}\right) = 15$$

$$v_C(0^-) = 10\text{ V}$$

Step 3 of 6

Step 3:

For $t = 0^+$, the switch is in open condition, therefore, the 8 V source is not connected to the circuit and the capacitor is replaced with a voltage source.

The value of the voltage source that replaces the capacitor is, $v_C(0^+)$.

The voltage across the capacitor does not change instantaneously. Therefore,

$$\begin{aligned} v_C(0^+) &= v_C(0^-) \\ &= 10\text{ V} \end{aligned}$$

The equivalent circuit for $t = 0^+$ is,

Figure 2

Apply voltage division to find the voltage at output node.

$$\begin{aligned} v_o(0^+) &= v_C(0^+)\left(\frac{2\,\Omega}{2\,\Omega + 2\,\Omega}\right) \\ &= (10\text{ V})\left(\frac{2\,\Omega}{4\,\Omega}\right) \\ &= 5\text{ V} \end{aligned}$$

Step 4 of 6

Step 4:

For $t > 0$, the switch stays in open condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as open circuit.

Figure 3

Use voltage division method to calculate the final value of output voltage, $v_o(\infty)$.

$$\begin{aligned} v_o(\infty) &= (12\text{ V})\left(\frac{2\,\Omega}{2\,\Omega + 1\,\Omega + 2\,\Omega}\right) \\ &= (12\text{ V})\left(\frac{2\,\Omega}{5\,\Omega}\right) \\ &= 4.8\text{ V} \end{aligned}$$

Step 5 of 6

Step 5:

Replace the voltage sources with short circuit to calculate the equivalent resistance seen by the capacitor.

Figure 4

Calculate the value of R_{eq}.

$$\begin{aligned} R_{eq} &= 1\,\Omega \,\|\, (2\,\Omega + 2\,\Omega) \\ &= 1\,\Omega \,\|\, 4\,\Omega \\ &= \frac{(1\,\Omega)(4\,\Omega)}{1\,\Omega + 4\,\Omega} \\ &= 0.8\,\Omega \end{aligned}$$

Calculate the time constant of the circuit.

$$\begin{aligned} \tau &= R_{eq} C \\ &= (0.8\,\Omega)(2\text{ F}) \\ &= 1.6\text{ s} \end{aligned}$$

Step 6 of 6

Step 6:

Find the final equation for the output voltage, $v_o(t)$.

The value of K_1 is,

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= 4.8\text{ V} \end{aligned}$$

The value of K_2 is,

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= 5\text{ V} - 4.8\text{ V} \\ &= 0.2\text{ V} \end{aligned}$$

Therefore,

$$\begin{aligned} v_o(t) &= K_1 + K_2 e^{-\frac{t}{\tau}} \\ &= 4.8 + 0.2 e^{-\frac{t}{1.6}} \\ &= 4.8 + 0.2 e^{-0.625t} \end{aligned}$$

Thus, the expression for the output voltage, $v_o(t)$ is, $\boxed{v_o(t) = 4.8 + 0.2e^{-0.625t}\text{ V}}$.

Step 1 of 9

7.043P

Refer to circuit diagram in Figure P7.19 in the textbook.

Initially switch in the circuit is open, capacitor in the circuit acts as open. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the current in the circuit.

$$(3\text{ k}\Omega + 6\text{ k}\Omega + 9\text{ k}\Omega)i_o(0^-) = 6\text{ V} - 24\text{ V}$$
$$(18\text{ k}\Omega)i_o(0^-) = -18\text{ V}$$
$$i_o(0^-) = -1\text{ mA}$$

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= 6\text{ V} - (3\text{ k}\Omega)i_o(0^-) \\ &= 6\text{ V} - (3\text{ k}\Omega)(-1\text{ mA}) \\ &= 6\text{ V} + 3\text{ V} \\ &= 9\text{ V} \end{aligned}$$

Step 3 of 9

At $t = 0^+$, the switch in the circuit is closed and capacitor in the circuit is replaced with initial value. The circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 9

Apply Kirchhoff's voltage law to middle loop.

$$(6\text{ k}\Omega)i_o(0^+) = 9\text{ V}$$

$$\begin{aligned} i_o(0^+) &= \frac{9\text{ V}}{6\text{ k}\Omega} \\ &= 1.5\text{ mA} \end{aligned}$$

The initial current through current through $6\text{ k}\Omega$ resistor is 1.5 mA.

Step 5 of 9

To calculate the equivalent resistance from the terminals of the capacitor, short circuit the voltage sources and open circuit the capacitor. The circuit diagram is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= (3\text{ k}\Omega) \| [6\text{ k}\Omega + (0 \| 9\text{ k}\Omega)] \\ &= (3\text{ k}\Omega) \| [6\text{ k}\Omega + 0\ \Omega] \\ &= \frac{(3\text{ k}\Omega)(6\text{ k}\Omega)}{3\text{ k}\Omega + 6\text{ k}\Omega} \\ &= 2\text{ k}\Omega \end{aligned}$$

Calculate the time constant.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (2\text{ k}\Omega)(200\ \mu\text{F}) \\ &= 0.4\text{ s} \end{aligned}$$

Step 7 of 9

For $t = \infty$, the switch in the circuit is closed and circuit reaches steady state. At steady state capacitor acts as open circuit. The circuit diagram is shown in Figure 4.

Figure 4

Step 8 of 9

Calculate the final current through $6\text{ k}\Omega$ resistor.

$$(3\text{ k}\Omega + 6\text{ k}\Omega)i_o(\infty) = 6\text{ V}$$
$$(9\text{ k}\Omega)i_o(\infty) = 6\text{ V}$$

$$\begin{aligned} i_o(\infty) &= \frac{6\text{ V}}{9\text{ k}\Omega} \\ &= 0.67\text{ mA} \end{aligned}$$

Therefore, the final current through $6\text{ k}\Omega$ resistor is 0.67 mA.

Step 9 of 9

Write the expression for current through $6\text{ k}\Omega$ resistor for $t > 0$.

$$i_o(t) = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Calculate the value of K_1.

$$\begin{aligned} K_1 &= i_o(\infty) \\ &= 0.67\text{ mA} \end{aligned}$$

Calculate the value of K_2.

$$\begin{aligned} K_2 &= i_o(0^+) - i_o(\infty) \\ &= 1.5\text{ mA} - 0.67\text{ mA} \\ &= 0.83\text{ mA} \end{aligned}$$

Calculate the current through $6\text{ k}\Omega$ resistor for $t > 0$.

$$\begin{aligned} i_o(t) &= 0.67\text{ mA} + 0.83\text{ mA}e^{\frac{-t}{0.4\text{ s}}} \\ &= 0.67 + 0.83e^{-2.5t}\text{ mA} \end{aligned}$$

Therefore, the current, $i_o(t)$ through $6\text{ k}\Omega$ resistor for $t > 0$ is $\boxed{0.67 + 0.83e^{-2.5t}\text{ mA}}$.

Step 1 of 9

Step 1:

Refer to Figure P7.44 in the textbook.

The output voltage, $v_o(t)$ is of the form, $K_1 + K_2 e^{\frac{-t}{\tau}}$.

Step 2:

For $t = 0^-$, the switch is in open condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law at output node.

$$\frac{v_o(0^-) - 12\text{ V}}{6\text{ k}\Omega + 12\text{ k}\Omega} + \frac{v_o(0^-) - 12\text{ V}}{3\text{ k}\Omega + 6\text{ k}\Omega} + \frac{v_o(0^-)}{6\text{ k}\Omega} = 0$$

Simplify the expression for $v_o(0^-)$.

$$v_o(0^-)\left(\frac{1}{18000} + \frac{1}{9000} + \frac{1}{6000}\right) = \frac{12}{18000} + \frac{12}{9000}$$

$$v_o(0^-)\left(\frac{6}{18000}\right) = \frac{36}{18000}$$

$$v_o(0^-) = 6\text{ V}$$

Apply Kirchhoff's current law to calculate the voltage across the capacitor.

$$\frac{v_C(0^-) - 12\text{ V}}{6\text{ k}\Omega} + \frac{v_C(0^-) - v_o(0^-)}{3\text{ k}\Omega} = 0$$

$$\frac{v_C(0^-) - 12\text{ V}}{6\text{ k}\Omega} + \frac{v_C(0^-) - 6\text{ V}}{3\text{ k}\Omega} = 0$$

Simplify the expression for $v_C(0^-)$.

$$v_C(0^-)\left(\frac{1}{6000} + \frac{1}{3000}\right) = \frac{12}{6000} + \frac{6}{3000}$$

$$v_C(0^-)\left(\frac{3}{6000}\right) = \frac{24}{6000}$$

$$v_C(0^-) = 8\text{ V}$$

Step 3 of 9

Step 3:

For $t = 0^+$, the switch moves to closed position. Replace the capacitor with a voltage source. The value of the voltage source that replaces the capacitor is, $v_C(0^+)$.

The voltage across the capacitor does not change instantaneously. Therefore,

$$\begin{aligned} v_C(0^+) &= v_C(0^-) \\ &= 8\text{ V} \end{aligned}$$

The equivalent circuit for $t = 0^+$ is,

Figure 2

Step 4 of 9

Find the equivalent resistance of parallel combination of $3\text{ k}\Omega$ and $6\text{ k}\Omega$ resistances.

$$\begin{aligned} (3\text{ k}\Omega \| 6\text{ k}\Omega) &= \frac{(3\text{ k}\Omega)(6\text{ k}\Omega)}{3\text{ k}\Omega + 6\text{ k}\Omega} \\ &= \frac{18\text{ M}\Omega}{9\text{ k}\Omega} \\ &= 2\text{ k}\Omega \end{aligned}$$

Apply voltage division to find the voltage at output node.

$$\begin{aligned} v_o(0^+) &= v_C(0^+)\left(\frac{6\text{ k}\Omega}{2\text{ k}\Omega + 6\text{ k}\Omega}\right) \\ &= (8\text{ V})\left(\frac{6\text{ k}\Omega}{8\text{ k}\Omega}\right) \\ &= 6\text{ V} \end{aligned}$$

Step 5 of 9

Step 4:

For $t > 0$, the switch stays in closed condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 3

Step 6 of 9

Find the equivalent resistance of parallel combination of $6\text{ k}\Omega$ and $12\text{ k}\Omega$ resistances.

$$\begin{aligned} (6\text{ k}\Omega \| 12\text{ k}\Omega) &= \frac{(6\text{ k}\Omega)(12\text{ k}\Omega)}{6\text{ k}\Omega + 12\text{ k}\Omega} \\ &= \frac{74\text{ M}\Omega}{18\text{ k}\Omega} \\ &= 4\text{ k}\Omega \end{aligned}$$

The equivalent resistance of parallel combination of $3\text{ k}\Omega$ and $6\text{ k}\Omega$ resistances is, $2\text{ k}\Omega$.

Use voltage division method to calculate the final value of output voltage, $v_o(\infty)$.

$$\begin{aligned} v_o(\infty) &= (12\text{ V})\left(\frac{6\text{ k}\Omega}{4\text{ k}\Omega + 2\text{ k}\Omega + 6\text{ k}\Omega}\right) \\ &= (12\text{ V})\left(\frac{6\text{ k}\Omega}{12\text{ k}\Omega}\right) \\ &= 6\text{ V} \end{aligned}$$

Step 7 of 9

Step 5:

Replace the voltage sources with short circuit to calculate the equivalent resistance seen by the capacitor.

Figure 4

Step 8 of 9

Calculate the value of R_{eq}.

$$\begin{aligned} R_{eq} &= (12\text{ k}\Omega \| 6\text{ k}\Omega) \| \left[(3\text{ k}\Omega \| 6\text{ k}\Omega) + 6\text{ k}\Omega\right] \\ &= 4\text{ k}\Omega \| (2\text{ k}\Omega + 6\text{ k}\Omega) \\ &= \frac{(4\text{ k}\Omega)(8\text{ k}\Omega)}{4\text{ k}\Omega + 8\text{ k}\Omega} \\ &= 2.67\text{ k}\Omega \end{aligned}$$

Calculate the time constant of the circuit.

$$\begin{aligned} \tau &= R_{eq} C \\ &= (2.67\text{ k}\Omega)(100\ \mu\text{F}) \\ &= 0.267\text{ s} \end{aligned}$$

Step 9 of 9

Step 6:

Find the final equation for the output voltage, $v_o(t)$.

The value of K_1 is,

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= 6\text{ V} \end{aligned}$$

The value of K_2 is,

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= 6\text{ V} - 6\text{ V} \\ &= 0 \end{aligned}$$

Therefore,

$$\begin{aligned} v_o(t) &= K_1 + K_2 e^{\frac{-t}{\tau}} \\ &= 6 + 0e^{\frac{-t}{0.267}} \\ &= 6 \end{aligned}$$

Thus, the expression for the output voltage, $v_o(t)$ is, $\boxed{v_o(t) = 6\text{ V}}$.

Step 1 of 8

Step 1:

Refer to Figure P7.45 in the textbook.

The output current, $i_o(t)$ is of the form, $K_1 + K_2 e^{\frac{-t}{\tau}}$.

Step 2:

For $t = 0^-$, the switch is in open condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 1

Since there is an open circuit, there is no current flow in the circuit. Apply Kirchhoff's voltage law to the circuit to find the voltage across the capacitor.

$$v_C(0^-) + (2\text{ k}\Omega)(0) + 12\text{ V} + (3\text{ k}\Omega)(0) = 0$$
$$v_C(0^-) + 12\text{ V} = 0$$
$$v_C(0^-) = -12\text{ V}$$

Step 2 of 8

Step 3:

For $t = 0^+$, the switch moves to closed position. Replace the capacitor with a voltage source. The value of the voltage source that replaces the capacitor is, $v_C(0^+)$.

The voltage across the capacitor does not change instantaneously. Therefore,

$$v_C(0^+) = v_C(0^-)$$
$$= -12\text{ V}$$

The equivalent circuit for $t = 0^+$ is,

Figure 2

Step 3 of 8

Apply mesh analysis to the circuit in Figure 2 to find the output current.

Apply Kirchhoff's voltage law to the first mesh.

$$-12\text{ V} + (2\text{ k}\Omega)i_1 + 12\text{ V} + (3\text{ k}\Omega)(i_1 - i_2) = 0$$
$$(2\text{ k}\Omega)i_1 + (3\text{ k}\Omega)i_1 - (3\text{ k}\Omega)i_2 = 0$$
$$(5\text{ k}\Omega)i_1 = (3\text{ k}\Omega)i_2$$
$$i_1 = 0.6i_2$$

Apply Kirchhoff's voltage law to the middle mesh.

$$(3\text{ k}\Omega)(i_2 - i_1) + (3\text{ k}\Omega)i_2 + (3\text{ k}\Omega)(i_2 - i_3) = 0$$
$$(3\text{ k}\Omega)i_2 - (3\text{ k}\Omega)0.6i_2 + (3\text{ k}\Omega)i_2 + (3\text{ k}\Omega)i_2 - (3\text{ k}\Omega)i_3 = 0\ (\text{since, } i_1 = 0.6i_2)$$
$$(7.2\text{ k}\Omega)i_2 = (3\text{ k}\Omega)i_3$$

$$i_2 = 0.4167i_3$$

Apply Kirchhoff's voltage law to the third mesh.

$$(3\text{ k}\Omega)(i_3 - i_2) + (4\text{ k}\Omega)i_3 + 36 = 0$$
$$(3\text{ k}\Omega)i_3 - (3\text{ k}\Omega)0.4167i_3 + (4\text{ k}\Omega)i_3 = -36\ (\text{since, } i_2 = 0.4167i_3)$$
$$(5.75\text{ k}\Omega)i_3 = -36$$

$$i_3 = -6.26\text{ mA}$$

Therefore,

$$i_2 = 0.4167(-6.26\text{ mA})$$
$$= -2.6\text{ mA}$$

And

$$i_1 = 0.6(-2.6\text{ mA})$$
$$= -1.565\text{ mA}$$

Calculate the output current, $i_o(0^+)$.

$$i_o(0^+) = i_1 - i_2$$
$$= -1.565\text{ mA} - (-2.6\text{ mA})$$
$$= 1.04\text{ mA}$$

Step 4 of 8

Step 4:

For $t > 0$, the switch stays in closed condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 3

Step 5 of 8

Apply mesh analysis to the circuit in Figure 3 to find the final value of output current.

Apply Kirchhoff's voltage law to the first mesh.

$$(3\text{ k}\Omega)i_1 + (3\text{ k}\Omega)i_1 + (3\text{ k}\Omega)(i_1 - i_2) = 0$$
$$(3\text{ k}\Omega)i_1 + (3\text{ k}\Omega)i_1 + (3\text{ k}\Omega)i_1 - (3\text{ k}\Omega)i_2 = 0$$
$$(9\text{ k}\Omega)i_1 = (3\text{ k}\Omega)i_2$$
$$i_1 = 0.34i_2$$

Apply Kirchhoff's voltage law to the second mesh.

$$(3\text{ k}\Omega)(i_2 - i_1) + (4\text{ k}\Omega)i_2 + 36 = 0$$
$$(3\text{ k}\Omega)i_2 - (3\text{ k}\Omega)0.34i_2 + (4\text{ k}\Omega)i_2 = -36 \quad (\text{since, } i_1 = 0.34i_2)$$
$$(6\text{ k}\Omega)i_2 = -36$$

$$i_2 = -6\text{ mA}$$

Therefore,

$$i_1 = 0.34(-6\text{ mA})$$
$$= -2\text{ mA}$$

Calculate the output current, $i_o(\infty)$.

$$i_o(\infty) = -i_1$$
$$= -(-2\text{ mA})$$
$$= 2\text{ mA}$$

Step 6 of 8

Step 5:

Replace the voltage sources with short circuit to calculate the equivalent resistance seen by the capacitor.

Figure 4

Step 7 of 8

Calculate the value of R_{eq}.

$$R_{eq} = \left\{\left[(4\text{ k}\Omega \| 3\text{ k}\Omega) + 3\text{ k}\Omega\right] \| 3\text{ k}\Omega\right\} + 2\text{ k}\Omega$$
$$= (4.714\text{ k}\Omega \| 3\text{ k}\Omega) + 2\text{ k}\Omega$$
$$= 1.834\text{ k}\Omega + 2\text{ k}\Omega$$
$$= 3.834\text{ k}\Omega$$

Calculate the time constant of the circuit.

$$\tau = R_{eq}C$$
$$= (3.834\text{ k}\Omega)(150\ \mu\text{F})$$
$$= 0.575\text{ s}$$

Step 8 of 8

Step 6:

Find the final equation for the output current, $i_o(t)$.

The value of K_1 is,

$$K_1 = i_o(\infty)$$
$$= 2\text{ mA}$$

The value of K_2 is,

$$K_2 = i_o(0^+) - i_o(\infty)$$
$$= 1.04\text{ mA} - 2\text{ mA}$$
$$= -0.96\text{ mA}$$

Therefore,

$$i_o(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$
$$= 2 - 0.96e^{-\frac{t}{0.575}}\text{ mA}$$
$$= 2 - 0.96e^{-1.74t}\text{ mA}$$

Thus, the expression for the output current, $i_o(t)$ is, $\boxed{i_o(t) = 2 - 0.95e^{-1.74t}\text{ mA}}$.

Step 1 of 9

Step 1:

Refer to Figure P7.46 in the textbook.

The output voltage, $v_o(t)$ is of the form, $K_1 + K_2 e^{\frac{-t}{\tau}}$.

Step 2:

For $t = 0^-$, the switch is in closed position for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 1

Step 2 of 9

Apply Kirchhoff's voltage law to the first loop in the circuit.

$$-24\text{V} + 12\text{ V} + (12\text{ k}\Omega)(i_1 + i_2) = 0$$
$$(12\text{ k}\Omega)(i_1 + i_2) = 12\text{ V}$$
$$i_1 + i_2 = 1\text{ mA}$$

Apply Kirchhoff's voltage law to the second loop in the circuit.

$$-24\text{ V} + (16\text{ k}\Omega)i_2 + (4\text{ k}\Omega)i_2 + (12\text{ k}\Omega)(i_2 + i_1) = 0$$
$$(20\text{ k}\Omega)i_2 + (12\text{ k}\Omega)(1\text{ mA}) = 24\text{ V} \quad (\text{since, } i_1 + i_2 = 1\text{ mA})$$
$$(20\text{ k}\Omega)i_2 = 24\text{ V} - 12\text{ V}$$
$$i_2 = 0.6\text{ mA}$$

Calculate the value of $v_C(0^-)$.

$$\begin{aligned} v_C(0^-) &= (16\text{ k}\Omega)i_2 \\ &= (16\text{ k}\Omega)(0.6\text{ mA}) \\ &= 9.6\text{ V} \end{aligned}$$

Step 3 of 9

Step 3:

For $t = 0^+$, the switch moves to open position. Replace the capacitor with a voltage source. The value of the voltage source that replaces the capacitor is, $v_C(0^+)$.

The voltage across the capacitor does not change instantaneously. Therefore,

$$\begin{aligned} v_C(0^+) &= v_C(0^-) \\ &= 9.6\text{ V} \end{aligned}$$

The equivalent circuit for $t = 0^+$ is,

Figure 2

Step 4 of 9

Apply mesh analysis to the circuit in Figure 2 to find the output voltage.
Apply Kirchhoff's voltage law to the first mesh.

$$(16\text{ k}\Omega)i_1 + 9.6\text{ V} + (16\text{ k}\Omega)(i_1 - i_2) = 0$$

$$(32\text{ k}\Omega)i_1 - (16\text{ k}\Omega)i_2 = -9.6\text{ V} \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the second mesh.

$$(12\text{ k}\Omega)i_2 - 24\text{ V} + (16\text{ k}\Omega)(i_2 - i_1) + (4\text{ k}\Omega)i_2 = 0$$

$$-(16\text{ k}\Omega)i_1 + (32\text{ k}\Omega)i_2 = 24\text{ V} \quad \text{..... (2)}$$

Multiply equation (2) with 2 and add it to equation (1) to get the value of i_2.

$$(32\text{ k}\Omega)i_1 - (16\text{ k}\Omega)i_2 + 2\left[-(16\text{ k}\Omega)i_1 + (32\text{ k}\Omega)i_2\right] = -9.6\text{ V} + 2(24\text{ V})$$
$$(32\text{ k}\Omega)i_1 - (16\text{ k}\Omega)i_2 - (32\text{ k}\Omega)i_1 + (64\text{ k}\Omega)i_2 = -9.6\text{ V} + 48\text{ V}$$
$$(48\text{ k}\Omega)i_2 = 38.4\text{ V}$$
$$i_2 = 0.8\text{ mA}$$

Calculate the output voltage, $v_o(0^+)$.

$$\begin{aligned} v_o(0^+) &= -(12\text{ k}\Omega)i_2 \\ &= -(12\text{ k}\Omega)(0.8\text{ mA}) \\ &= -9.6\text{ V} \end{aligned}$$

Step 5 of 9

Step 4:

For $t > 0$, the switch stays in open condition for long time, therefore, the circuit is in steady state and hence the capacitor acts as an open circuit.

Figure 3

Step 6 of 9

Apply Kirchhoff's voltage law to the circuit in Figure 3.

$$(12\text{ k}\Omega)i_1 - 24\text{ V} + (16\text{ k}\Omega)i_1 + (4\text{ k}\Omega)i_1 = 0$$
$$(32\text{ k}\Omega)i_1 = 24\text{ V}$$
$$i_1 = 0.75\text{ mA}$$

Calculate the output voltage, $v_o(\infty)$.

$$\begin{aligned} v_o(\infty) &= -(12\text{ k}\Omega)i_1 \\ &= -(12\text{ k}\Omega)(0.75\text{ mA}) \\ &= -9\text{ V} \end{aligned}$$

Step 7 of 9

Step 5:

Replace the voltage sources with short circuit to calculate the equivalent resistance seen by the capacitor.

Figure 4

Step 8 of 9

Calculate the value of R_{eq}.

$$\begin{aligned} R_{eq} &= \left[(12\text{ k}\Omega + 4\text{ k}\Omega) \| 16\text{ k}\Omega\right] + 16\text{ k}\Omega \\ &= (16\text{ k}\Omega \| 16\text{ k}\Omega) + 16\text{ k}\Omega \\ &= 8\text{ k}\Omega + 16\text{ k}\Omega \\ &= 24\text{ k}\Omega \end{aligned}$$

Calculate the time constant of the circuit.

$$\begin{aligned} \tau &= R_{eq}C \\ &= (24\text{ k}\Omega)(10\ \mu\text{F}) \\ &= 0.24\text{ s} \end{aligned}$$

Step 9 of 9

Step 6:

Find the final equation for the output voltage, $v_o(t)$.

The value of K_1 is,

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= -9\text{ V} \end{aligned}$$

The value of K_2 is,

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= -9.6\text{ V} - (-9\text{ V}) \\ &= -0.6\text{ V} \end{aligned}$$

Therefore,

$$\begin{aligned} v_o(t) &= K_1 + K_2 e^{-\frac{t}{\tau}} \\ &= -9 - 0.6e^{-\frac{t}{0.24}} \\ &= -9 - 0.6e^{-4.17t}\text{ V} \end{aligned}$$

Thus, the expression for the output voltage, $v_o(t)$ is, $\boxed{v_o(t) = -9 - 0.6e^{-4.17t}\text{ V}}$.

Step 1 of 7

The initial value of current through the $2\,\text{k}\Omega$ resistor for the time $t<0$ and the circuit for this position of switch is as follows:

Figure 1

In this position of switch, the capacitor is working as open circuit and the current through $2\,\text{k}\Omega$ resistor is,

Apply current division rule to calculate this.

$$\begin{aligned} i_0(0^-) &= -\frac{(6\,\text{mA})(4\,\text{k}\Omega)}{4\,\text{k}\Omega+2\,\text{k}\Omega+10\,\text{k}\Omega} \\ &= -1.5\,\text{mA} \end{aligned}$$

Step 2 of 7

The voltage drop across the capacitor is,

$$\begin{aligned} v_{150\mu F} &= (-1.5\text{mA})(2\,\text{k}\Omega)+(4.5\text{mA})(4\,\text{k}\Omega) \\ &= 15\,\text{V} \end{aligned}$$

Step 3 of 7

When the switch is open at time t = 0 the capacitor start working as voltage source with voltage of 15 V then the total current through the resistor is,

Figure 2

Find the current due to capacitor initial voltage at $t>0$.

Figure 3

Obtain current thorough resistor using Ohm's law.

$$\begin{aligned} i_{01} &= \frac{15\,\text{V}}{6\,\text{k}\Omega} \\ &= 2.5\,\text{mA} \end{aligned}$$

Step 4 of 7

The current through the resistor because of current source is obtained using current division rule and it is.

$$\begin{aligned} i_{02} &= (-6\,\text{mA})\left(\frac{4\,\text{k}\Omega}{2\text{k}\Omega+4\text{k}\Omega}\right) \\ &= -4\,\text{mA} \end{aligned}$$

The total current through the resistor will be equal to summation of the two current.

$$\begin{aligned} i_0(0) &= -4\,\text{mA}+2.5\text{mA} \\ &= -1.5\,\text{mA} \end{aligned}$$

The current through the resistor in steady state will be obtained using the concept that the capacitor voltage will discharged in the circuit and final current will be the current because of current source which is

$$\begin{aligned} i_0(f) &= -6\,\text{mA}\times\frac{4\,\text{k}\Omega}{2\text{k}\Omega+4\text{k}\Omega+10\text{k}\Omega} \\ &= -1.5\,\text{mA} \end{aligned}$$

Step 5 of 7

Therefore the condition of transient circuit shows that the equation of transient state is.

$$i_0(t) = i_0(f) + Ae^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Put time t = 0 in equation (1) and get the value of constant A to get the finale time dependent equation of output current.

$$\begin{aligned} i_0(0) &= i_0(f) + Ae^{-\frac{0}{\tau}} \\ -3.5\,\text{mA} &= -1.5\,\text{mA} + A \quad \text{..... (2)} \\ A &= -2\,\text{mA} \end{aligned}$$

Step 6 of 7

The time constant of the circuit is obtained using the circuit given below and it is equal to multiplication of equivalent resistor and capacitor.

Figure 4

Find the time constant of the circuit.

$$\begin{aligned} \tau &= R_{eq}C \\ &= \left[(2\text{k}\Omega+4\text{k}\Omega)\|10\text{k}\Omega\right]\cdot(150\mu\text{F}) \\ &= (3.75\text{k}\Omega)\cdot(150\mu\text{F}) \\ &= 0.5625\ \text{sec} \end{aligned}$$

Step 7 of 7

Now put the value of A from equation (2) in equation (1) and we get get the final equation of output current through $2\,\text{k}\Omega$ resistor.

$$\begin{aligned} i_o(t) &= -1.5-2e^{-\frac{t}{1.44}}\ \text{mA} \\ &= -\left(1.5+2e^{-0.6944t}\right)\text{mA} \end{aligned}$$

The time dependent current through the $2\,\text{k}\Omega$ resistor $i_o(t)$ is $\boxed{-\left(1.5+2e^{-0.6944t}\right)\text{mA}}$.

Step 1 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 5 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 6 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 7 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 8 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 9 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 10 of 10

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 8

Refer to Figure P7.49 in the textbook.

For $t < 0$, the switch is in open position. Draw the modified circuit diagram and find the initial voltage across the capacitor.

Figure 1

Step 2 of 8

Apply Kirchhoff's voltage law around the loop and find the value of current.

$$6ki_1 - 4 + 8ki_1 + 4ki_1 = 0$$
$$18ki_1 = 4$$
$$i_1 = \frac{4}{18k}$$
$$= \frac{2}{9}\text{mA}$$

Calculate the initial voltage across capacitor.

$$v_C(0^-) = (8k)(i_1) + (4k)(i_1)$$
$$= (8)\left(\frac{2}{9}\right) + (4)\left(\frac{2}{9}\right)$$
$$= \frac{8}{3}\text{V}$$

The voltage across the capacitor cannot change instantaneously, therefore,

$$v_C(0^-) = v_C(0^+)$$
$$= \frac{8}{3}\text{V}$$

Step 3 of 8

At $t = 0$, switch is closed. Draw the modified circuit diagram for $t = 0^+$.

Figure 2

Step 4 of 8

The voltage across the $4\,\text{k}\Omega$ resistor is same as $\frac{8}{3}\text{V}$

Therefore, $v_o(0^+) = \frac{8}{3}\text{V}$

Draw the equivalent circuit valid for $t > 5\tau$.

Figure 3

Step 5 of 8

As $8\,\text{k}\Omega$ is parallel to short circuit, its value can be neglected.
Apply Kirchhoff's voltage law around the loop and find the value of current.

$$6ki_1 - 4 + 4ki_1 = 0$$
$$10ki_1 = 4$$
$$i_1 = \frac{4}{10k}$$
$$i_1 = 0.4\,\text{mA}$$

Find the final voltage across capacitor.

$$v_o(\infty) = (i_1)(4k)$$
$$= (0.4)(4)$$
$$= 1.6\,\text{V}$$

Step 6 of 8

The Thevenin equivalent resistance is obtained by looking into the open circuit terminals of the capacitor. Draw the modified circuit diagram.

Figure 4

Step 7 of 8

From the circuit in Figure 4, it is clear that the resistors $9\,\text{k}\Omega$ and $8\,\text{k}\Omega$ are shorted together. Calculate the equivalent resistance.

$$R_{Th} = \frac{6k \times 4k}{6k + 4k}$$
$$= 2.4\,\text{k}\Omega$$

Determine the time constant of the circuit.

$$\tau = R_{eq} \times C$$
$$= 2.4k \times 200\mu$$
$$= 0.48\text{s}$$

Step 8 of 8

Write the expression for output voltage of the circuit.

$$v_o(t) = v_o(\infty) + Ae^{-\frac{t}{\tau}}$$

Substitute $t = 0$ in the expression.

$$v_o(0) = v_o(\infty) + Ae^{-\frac{0}{\tau}}$$

$$A = v_o(0) - v_o(\infty)$$
$$= \frac{8}{3} - 1.6$$
$$= 1.066$$

Determine the expression for $v_o(t)$ by substituting the known values.

$$v_o(t) = v_o(\infty) + Ae^{-\frac{t}{\tau}}$$
$$= 1.6 + 1.066e^{-\frac{t}{0.48}}$$
$$= 1.6 + 1.066e^{-2.08t}\ \text{V}$$

Therefore, the output voltage is $\boxed{1.6 + 1.066e^{-2.08t}\ \text{V}}$.

7.050E

Refer to Figure P7.50 in the textbook.

For $t < 0$, the switch is open. Draw the modified circuit diagram and calculate the initial voltage across the capacitor.

Figure 1

Step 2 of 13

Apply Kirchhoff's current law at node v_x.

$$\frac{v_x - 12}{3k} + \frac{v_x - v_o}{6k} = 0$$

$$2v_x - 24 + v_x - v_o = 0$$

$$4v_x - 3v_o = 24 \text{ ..... (1)}$$

Apply Kirchhoff's current law at node v_o.

$$\frac{v_o}{3k} + \frac{v_o - 12}{6k + 12k} + \frac{v_o - v_x}{6k} = 0$$

$$6v_o + v_o - 12 + 3v_o - 3v_x = 0$$

$$-3v_x + 10v_o = 12 \text{ ..... (2)}$$

Step 3 of 13

Solve equations (1) and (2).

$$v_x = 9.33\text{ V}$$
$$v_o = 4\text{ V}$$

Therefore, the initial voltage across the capacitor is,

$$\begin{aligned} v_C(0^-) &= v_x \\ &= v_C(0^+) \\ &= 9.33\text{ V} \end{aligned}$$

Step 4 of 13

Draw the circuit diagram for $t = 0^+$.

Figure 2

Step 5 of 13

Apply Kirchhoff's voltage law to loop 1.

$$12i_1 + 6(i_1 - i_2) = 0$$

$$18i_1 - 6i_2 = 0 \text{ ..... (3)}$$

Apply Kirchhoff's voltage law to loop 2.

$$6(i_2 - i_1) + 3i_2 = 9$$

$$-6i_1 + 9i_2 = 9.33 \text{ ..... (4)}$$

Solve equations (3) and (4).

$$i_1 = 0.44\text{ A}$$
$$i_2 = 1.33\text{ A}$$

Step 6 of 13

Calculate the value of $v_o(0^+)$.

$$\begin{aligned} v_o(0^+) &= (i_2)(3k) \\ &= (1.33)(3) \\ &= 4\text{ V} \end{aligned}$$

Step 7 of 13

Draw the equivalent circuit valid for $t > 5\tau$.

Figure 3

Step 8 of 13

Apply Kirchhoff's voltage law to loop 1.

$$6i_1 + 3(i_1 - i_3) = 0$$

$$9i_1 - 3i_3 = 0 \text{ ..... (5)}$$

Apply Kirchhoff's voltage law to loop 2.

$$12i_2 + 6(i_2 - i_3) = 0$$

$$18i_2 - 6i_3 = 0 \text{ ..... (6)}$$

Apply Kirchhoff's voltage law to loop 3.

$$3(i_3 - i_1) + 6(i_3 - i_2) + 3i_3 = 12$$

$$-3i_1 - 6i_2 + 12i_3 = 12 \text{ ..... (7)}$$

Step 9 of 13

Solve equations (5), (6) and (7).

$$i_1 = 0.44\text{ A}$$
$$i_2 = 0.44\text{ A}$$
$$i_3 = 1.33\text{ A}$$

Calculate the value of $v_o(\infty)$.

$$\begin{aligned} v_o(\infty) &= (i_3)(3k) \\ &= (1.33)(3) \\ &= 4\text{ V} \end{aligned}$$

Step 10 of 13

The Thevenin's equivalent resistance is obtained by looking into the open circuit terminals of the capacitor. Draw the modified circuit diagram.

Figure 4

Step 11 of 13

In the circuit shown in figure 4, the resistors $6\text{ k}\Omega$ and $3\text{ k}\Omega$ are connected in parallel. Its equivalent resistance is,

$$\frac{(6\text{k}\Omega)(3\text{k}\Omega)}{6\text{k}\Omega + 3\text{k}\Omega} = 2\text{ k}\Omega$$

Similarly, the resistors $6\text{ k}\Omega$ and $12\text{ k}\Omega$ are connected in parallel. Its equivalent resistance is,

$$\frac{(6\text{k}\Omega)(12\text{k}\Omega)}{6\text{k}\Omega + 12\text{k}\Omega} = 4\text{ k}\Omega$$

This $4\text{ k}\Omega$ is series with $3\text{ k}\Omega$. Therefore,

$$4\text{ k}\Omega + 3\text{ k}\Omega = 7\text{ k}\Omega$$

The resultant $7\text{ k}\Omega$ is in parallel with $2\text{ k}\Omega$ resistor. Calculate the equivalent resistance.

$$\begin{aligned} R_{Th} &= \frac{(7\text{k}\Omega)(2\text{k}\Omega)}{7\text{k}\Omega + 2\text{k}\Omega} \\ &= \frac{14}{9}\text{ k}\Omega \\ R_{Th} &= 1.55\text{ k}\Omega \end{aligned}$$

Step 12 of 13

Calculate the circuit time constant.

$$\begin{aligned} \tau &= R_{Th}C \\ &= (1.55\times10^3)(160\times10^{-6}) \\ \tau &= 0.249\text{ s} \end{aligned}$$

The expression for $v_o(t)$ is,

$$v_o(t) = K_1 + K_2 e^{-t/\tau}$$

Here,

$$K_1 = v_o(\infty)$$
$$K_1 = 4\text{ V}$$

Step 13 of 13

The value of K_2 is,

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= 4\text{ V} - 4\text{ V} \\ &= 0\text{ V} \end{aligned}$$

Determine the expression for voltage, $v_o(t)$.

$$\begin{aligned} v_o(t) &= K_1 + K_2 e^{-t/\tau} \\ &= 4 + (0)e^{-t/\tau} \\ &= 4\text{ V} \end{aligned}$$

Therefore, the output voltage is $\boxed{4\text{ V}}$.

Step 1 of 7

Refer to Figure P7.52 in the textbook.

The expression for the voltage, $v_o(t)$ is of the form $K_1 + K_2 e^{-t/\tau}$.

Note that the switch is in open condition for $t < 0$ and hence the circuit is in steady state. The capacitor acts as an open circuit in steady state. Draw the circuit for $t < 0$ and calculate the initial voltage across the capacitor.

Figure 1

Step 2 of 7

The resistors $2\ \text{k}\Omega$ and $4\ \text{k}\Omega$ are in series and resultant is parallel with $3\ \text{k}\Omega$.

Calculate the equivalent resistance.

$$\begin{aligned} R_{eq} &= (2\ \text{k}\Omega + 4\ \text{k}\Omega) \| 3\ \text{k}\Omega \\ &= 6\ \text{k}\Omega \| 3\ \text{k}\Omega \\ &= \frac{(6\ \text{k}\Omega)(3\ \text{k}\Omega)}{6\ \text{k}\Omega + 3\ \text{k}\Omega} \\ &= 2\ \text{k}\Omega \end{aligned}$$

Represent the equivalent resistance in the circuit and apply Kirchhoff's voltage law to the circuit.

$$(2\ \text{k}\Omega)i + (1\ \text{k}\Omega)i + 6\ \text{V} + (4\ \text{k}\Omega)i = 12\ \text{V}$$
$$(7\ \text{k}\Omega)i = 12\ \text{V} - 6\ \text{V}$$

$$\begin{aligned} i &= \frac{6\ \text{V}}{7\ \text{k}\Omega} \\ &= 0.85\ \text{mA} \end{aligned}$$

Find the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= (1\ \text{k}\Omega)i + 6\ \text{V} \\ &= (1\ \text{k}\Omega)(0.85\ \text{mA}) + 6\ \text{V} \\ &= 0.85\ \text{V} + 6\ \text{V} \\ &= 6.85\ \text{V} \end{aligned}$$

Step 3 of 7

Replace the capacitor value with the following voltage source:

$$\begin{aligned} v_C(0^-) &= v_C(0^+) \\ &= 6.85\ \text{V} \end{aligned}$$

Draw the new circuit valid only for $t = 0^+$.

Figure 2

Observe that the output voltage $v_o(0^+)$ is in parallel with 6.85 V voltage source, therefore, the output voltage is,

$$v_o(0^+) = 6.85\ \text{V}$$

Step 4 of 7

Draw the equivalent circuit valid only for $t > 5\tau$.

Figure 3

Step 5 of 7

Write mesh equations for the circuit.

$$(1\ \text{k}\Omega)i_1 + 6\ \text{V} + (4\ \text{k}\Omega)i_1 = 0$$
$$(5\ \text{k}\Omega)i_1 = -6\ \text{V}$$

$$\begin{aligned} i_1 &= \frac{-6\ \text{V}}{5\ \text{k}\Omega} \\ &= -1.2\ \text{mA} \end{aligned}$$

Find the final value of the voltage.

$$\begin{aligned} v_o(\infty) &= (i_1)(4\ \text{k}\Omega) \\ &= (-1.2\ \text{mA})(4\ \text{k}\Omega) \\ &= -4.8\ \text{V} \end{aligned}$$

Step 6 of 7

Draw the circuit to find the value of Thevenin's equivalent resistance.

Figure 4

Step 7 of 7

Calculate the Thevenin's equivalent resistance by looking into the open circuit terminals of the capacitor.

$$\begin{aligned} R_{Th} &= 1\ \text{k}\Omega \| 4\ \text{k}\Omega \\ &= \frac{(1\ \text{k}\Omega)(4\ \text{k}\Omega)}{1\ \text{k}\Omega + 4\ \text{k}\Omega} \\ &= 800\ \Omega \end{aligned}$$

Calculate the circuit time constant.

$$\begin{aligned} \tau &= R_{Th}C \\ &= (800\ \Omega)(100\ \mu\text{F}) \\ &= 0.08\ \text{s} \end{aligned}$$

Calculate the values of constants K_1 and K_2 in the expression of $v_o(t)$.

$$\begin{aligned} K_1 &= v_o(\infty) \\ &= -4.8\ \text{V} \end{aligned}$$

$$\begin{aligned} K_2 &= v_o(0^+) - v_o(\infty) \\ &= -6.85 - (-4.8) \\ &= -2.05\ \text{V} \end{aligned}$$

Substitute these values in the expression of $v_o(t)$.

$$\begin{aligned} v_o(t) &= K_1 + K_2 e^{-t/\tau} \\ &= -4.8 - 2.05e^{-t/0.08} \\ &= -4.8 - 2.05e^{-12.5t}\ \text{V} \end{aligned}$$

Thus, the expression for the output voltage $v_o(t)$ is $\boxed{-4.8 - 2.05e^{-12.5t}\ \text{V}}$.

Step 1 of 17

Consider the Figure P7.56 from the text book. Identify the series and parallel connected resistors in the circuit diagram.

Figure 1

Step 2 of 17

Calculate the value of the resistance R_1.

$$\begin{aligned} R_1 &= 12\text{ k} \parallel (2\text{k} + 4\text{k}) \\ &= 12\text{ k} \parallel (2\text{k} + 4\text{k}) \\ &= 12\text{ k} \parallel 6\text{k} \\ &= \frac{(12\text{ k})(6\text{ k})}{12\text{ k} + 6\text{ k}} \end{aligned}$$

$$\begin{aligned} R_1 &= \frac{72\text{ k}^2}{18\text{ k}} \\ &= 4\text{ k}\Omega \end{aligned}$$

Therefore, the value of the resistance R_1 is $4\text{ k}\Omega$.

Step 3 of 17

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 4 of 17

Step-1:

Let the value of the output current $i_o(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 3

Step 5 of 17

The value of the current $i_1(t)$ is 4 mA.

Apply the Kirchhoff's Voltage Law in loop-2.

$$\begin{aligned} &(i_2(t) - i_1(t))(2\text{ k} + 2\text{ k}) + i_2(t)(4\text{ k}) = 0 \\ &i_2(t)(2\text{ k} + 2\text{ k} + 4\text{ k}) - i_1(t)(2\text{ k} + 2\text{ k}) = 0 \\ &i_2(t)(8\text{ k}) - i_1(t)(4\text{ k}) = 0 \\ &i_2(t)(8\text{ k}) = i_1(t)(4\text{ k}) \end{aligned}$$

$$i_2(t) = i_1(t)\left(\frac{4\text{ k}}{8\text{ k}}\right)$$

$$i_2(t) = i_1(t)\left(\frac{1}{2}\right)$$

Substitute 4 mA for $i_1(t)$.

$$\begin{aligned} i_2(t) &= (4\text{ m})\left(\frac{1}{2}\right) \\ &= 2\text{ mA} \end{aligned}$$

Therefore, the value of the current $i_2(t)$ is 2 mA.

Step 6 of 17

Apply Kirchhoff's Voltage Law in Loop-1.

$$\begin{aligned} &v_C(0^-) + i_1(t)(2\text{ k}) + (i_1(t) - i_2(t))(2\text{ k}) + 4 = 0 \\ &v_C(0^-) + i_1(t)(2\text{ k} + 2\text{ k}) - i_2(t)(2\text{ k}) + 4 = 0 \\ &v_C(0^-) + i_1(t)(4\text{ k}) - i_2(t)(2\text{ k}) + 4 = 0 \end{aligned}$$

Substitute 2 mA for $i_2(t)$ and 4 mA for $i_1(t)$.

$$\begin{aligned} v_C(0^-) &= -(4\text{ m})(4\text{ k}) + (2\text{ m})(2\text{ k}) - 4 \\ &= -16 + 4 - 4 \\ &= -16\text{ V} \end{aligned}$$

Therefore, the value of the voltage $v_C(0^-)$ is -16 V.

Step 7 of 17

Step-3:

Consider the circuit diagram at $t = 0^+$

Figure 4

Step 8 of 17

Calculate the value of the current $i_o(0^+)$.

$$\begin{aligned} i_o(0^+) &= \frac{-16}{2\text{ k}} \\ &= -8\text{ mA} \end{aligned}$$

Therefore, the value of the current $i_o(0^+)$ is -8 mA.

Step 9 of 17

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 5

Step 10 of 17

The value of the current $i_1(t)$ is 4 mA.

Apply the Kirchhoff's Voltage Law in loop-2.

$$\begin{aligned} &(i_2(t) - i_1(t))(2\text{ k} + 2\text{ k}) + i_2(t)(4\text{ k}) = 0 \\ &i_2(t)(2\text{ k} + 2\text{ k} + 4\text{ k}) - i_1(t)(2\text{ k} + 2\text{ k}) = 0 \\ &i_2(t)(8\text{ k}) - i_1(t)(4\text{ k}) = 0 \\ &i_2(t)(8\text{ k}) = i_1(t)(4\text{ k}) \end{aligned}$$

$$i_2(t) = i_1(t)\left(\frac{4\text{ k}}{8\text{ k}}\right)$$

$$i_2(t) = i_1(t)\left(\frac{1}{2}\right)$$

Substitute 4 mA for $i_1(t)$.

$$\begin{aligned} i_2(t) &= (4\text{ m})\left(\frac{1}{2}\right) \\ &= 2\text{ mA} \end{aligned}$$

Therefore, the value of the current $i_2(t)$ is 2 mA.

Step 11 of 17

Calculate the value of the voltage $i_o(\infty)$.

$$i_o(\infty) = i_2(t) - i_1(t)$$

Substitute 4 mA for $i_1(t)$ and 2 mA for $i_2(t)$.

$$\begin{aligned} i_o(\infty) &= 2\text{ m} - 4\text{ m} \\ &= -2\text{ mA} \end{aligned}$$

Therefore, the value of the voltage $i_o(\infty)$ is -2 mA.

Step 12 of 17

Consider the circuit diagram shown in Figure 6 to calculate the equivalent resistance as seen from the opened terminals of the capacitor.

Figure 6

Step 13 of 17

Calculate the value of the equivalent resistance R_{eq}.

$$\begin{aligned} R_{eq} &= 2\text{ k} \parallel [2\text{ k} + 4\text{ k}] \\ &= 2\text{ k} \parallel 6\text{ k} \\ &= \frac{(2\text{ k})(6\text{ k})}{2\text{ k} + 6\text{ k}} \\ &= \frac{12\text{ k}^2}{8\text{ k}} \end{aligned}$$

$$\begin{aligned} R_{eq} &= \frac{3\text{ k}}{2} \\ &= 1.5\text{ k}\Omega \end{aligned}$$

Therefore, the value of the equivalent resistance R_{eq} is $1.5\text{ k}\Omega$.

Step 14 of 17

Step-5:

Calculate the value of the time constant τ.

$$\tau = R_{eq} \cdot C$$

Substitute $1.5\text{ k}\Omega$ for R_{eq} and $100\ \mu\text{F}$ for C.

$$\begin{aligned} \tau &= (1.5\text{ k}) \cdot (100\ \mu) \\ &= 0.15\text{ s} \end{aligned}$$

Therefore, the value of the time constant τ is 0.15 s.

Step 15 of 17

Step-6:

Calculate the value of the constant K_1.

$$K_1 = i_o(\infty)$$

Substitute -2 mA for $i_o(\infty)$.

$$K_1 = -2\text{ mA}$$

Therefore, the value of the constant K_1 is -2 mA.

Step 16 of 17

Calculate the value of the constant K_2.

$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute -2 mA for $i_o(\infty)$ and -8 mA for $i_o(0^+)$.

$$\begin{aligned} K_2 &= -8\text{ m} - (-2\text{ m}) \\ &= -6\text{ mA} \end{aligned}$$

Therefore, the value of the constant K_2 is -6 mA.

Step 17 of 17

Recall equation (1).

$$i_o(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0.15 s for τ, -6 mA for K_2 and -2 mA for K_1.

$$i_o(t) = -2 - 6\,e^{-t/0.15}\text{ mA}$$

Therefore, the value of the output current $i_o(t)$ is $\boxed{-2 - 6\,e^{-t/0.15}\text{ mA}}$.

Step 1 of 18

Consider the Figure P7.58 from the text book.

Step-1.

Let the value of the output current $i_o(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2.

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 18

Apply the Kirchhoff's Voltage Law in loop-2.

$$(i_1(t)+i_2(t))(1\,\text{k}) + i_1(t)(3\,\text{k}) - 6 = 0$$
$$i_1(t)(1\,\text{k}+3\,\text{k}) + i_2(t)(1\,\text{k}) - 6 = 0$$
$$i_1(t)(4\,\text{k}) = 6 - i_2(t)(1\,\text{k})$$
$$i_1(t) = \frac{6 - i_2(t)(1\,\text{k})}{4\,\text{k}}$$
$$i_1(t) = 1.5\,\text{m} - 0.25 i_2(t)$$

Therefore, the expression for the current $i_1(t)$ is $1.5\,\text{m} - 0.25 i_2(t)$.

Step 3 of 18

Apply Kirchhoff's Voltage Law in Loop-2.

$$i_2(t)(4\,\text{k}+2\,\text{k}) + (i_1(t)+i_2(t))(1\,\text{k}) - 6 = 0$$
$$i_1(t)(6\,\text{k}+1\,\text{k}) + i_2(t)(1\,\text{k}) - 6 = 0$$
$$i_2(t)(7\,\text{k}) + i_2(t)(1\,\text{k}) - 6 = 0$$

Substitute $1.5\,\text{m} - 0.25 i_2(t)$ for $i_1(t)$.

$$i_2(t)(7\,\text{k}) + (1.5\,\text{m} - 0.25 i_2(t))(1\,\text{k}) - 6 = 0$$
$$i_2(t)(7\,\text{k}) + 1.5 - i_2(t)(0.25\,\text{k}) - 6 = 0$$
$$i_2(t)(7\,\text{k} - 0.25\,\text{k}) - 4.5 = 0$$
$$i_2(t)(6.75\,\text{k}) = 4.5$$
$$i_2(t) = \frac{4.5}{6.75\,\text{k}}$$
$$i_2(t) = 0.667\,\text{mA}$$

Therefore, the value of the current $i_2(t)$ is $0.667\,\text{mA}$.

Step 4 of 18

Calculate the value of the current $v_C(0^-)$.

$$v_C(0^-) = 6 - i_2(t)(2\,\text{k})$$

Substitute $0.667\,\text{mA}$ for $i_2(t)$.

$$v_C(0^-) = 6 - (0.667\,\text{m})(2\,\text{k})$$
$$= 4.666\,\text{V}$$

Therefore, the value of the voltage $v_C(0^-)$ is $4.666\,\text{V}$.

Step 5 of 18

Step-3:

Consider the circuit diagram at $t = 0^+$.

Figure 2

Step 6 of 18

Apply Kirchhoff's Voltage law in loop-1.

$$-6 + i_1(t)(3\,\text{k}) + (i_1(t)+i_2(t))(1\,\text{k}) = 0$$
$$-6 + i_1(t)(3\,\text{k}+1\,\text{k}) + i_2(t)(1\,\text{k}) = 0$$
$$-6 + i_1(t)(4\,\text{k}) + i_2(t)(1\,\text{k}) = 0$$
$$i_1(t)(4\,\text{k}) = 6 - i_2(t)(1\,\text{k})$$
$$i_1(t) = \frac{6 - i_2(t)(1\,\text{k})}{(4\,\text{k})}$$
$$i_1(t) = 1.5\,\text{m} - i_2(t)(0.25)$$

Therefore, the expression for the current $i_1(t)$ is $1.5\,\text{m} - i_2(t)(0.25)$.

Step 7 of 18

Apply Kirchhoff's Voltage law in loop-2

$$-4.666 + (i_2(t)+i_1(t))(1\,\text{k}) + (i_2(t)+i_4(t))(4\,\text{k}) = 0$$
$$-4.666 + i_2(t)(1\,\text{k}+4\,\text{k}) + i_1(t)(1\,\text{k}) + i_4(t)(4\,\text{k}) = 0$$
$$-4.666 + i_2(t)(5\,\text{k}) + i_1(t)(1\,\text{k}) + i_4(t)(4\,\text{k}) = 0$$

Substitute $1.5\,\text{m} - i_2(t)(0.25)$ for $i_1(t)$.

$$-4.666 + i_2(t)(5\,\text{k}) + (1.5\,\text{m} - i_2(t)(0.25))(1\,\text{k}) + i_4(t)(4\,\text{k}) = 0$$
$$-4.666 + i_2(t)(5\,\text{k}) + 1.5 - i_2(t)(0.25\,\text{k}) + i_4(t)(4\,\text{k}) = 0$$
$$-3.166 + i_2(t)(5\,\text{k}) - i_2(t)(0.25\,\text{k}) + i_4(t)(4\,\text{k}) = 0$$
$$i_2(t)(4.75\,\text{k}) = 3.166 - i_4(t)(4\,\text{k})$$
$$i_2(t) = \frac{3.166 - i_4(t)(4\,\text{k})}{4.75\,\text{k}}$$
$$i_2(t) = 0.667\,\text{m} - i_4(t)(0.211)$$

Therefore, the expression for the current $i_2(t)$ is $0.667\,\text{m} - i_4(t)(0.211)$.

Step 8 of 18

Apply Kirchhoff's Voltage law in loop-3.

$$-6 + 4.666 + (i_3(t)+i_4(t))(2\,\text{k}) = 0$$
$$-1.334 + i_3(t)(2\,\text{k}) + i_4(t)(2\,\text{k}) = 0$$
$$i_3(t)(2\,\text{k}) = 1.334 - i_4(t)(2\,\text{k})$$
$$i_3(t) = \frac{1.334 - i_4(t)(2\,\text{k})}{2\,\text{k}}$$
$$i_3(t) = \frac{1.334 - i_4(t)(2\,\text{k})}{2\,\text{k}}$$
$$i_3(t) = 0.667\,\text{m} - i_4(t)$$

Therefore, the expression for the current $i_3(t)$ is $0.667\,\text{m} - i_4(t)$ ..... (2)

Step 9 of 18

Apply Kirchhoff's Voltage law in loop-4.

$$(i_2(t)+i_4(t))(4\,\text{k}) + (i_1(t)+i_2(t))(2\,\text{k}) = 0$$
$$(i_2(t)(4\,\text{k}) + i_4(t)(2\,\text{k}) + i_4(t)(4\,\text{k}+2\,\text{k}) = 0$$
$$i_2(t)(4\,\text{k}) + i_4(t)(2\,\text{k}) = 0$$

Substitute $0.667\,\text{m} - i_4(t)$ for $i_4(t)$ and $0.667\,\text{m} - i_4(t)(0.211)$ for $i_2(t)$.

$$(0.667\,\text{m} - i_4(t)(0.211))(4\,\text{k}) + (0.667\,\text{m} - i_4(t))(2\,\text{k}) + i_4(t)(6\,\text{k}) = 0$$
$$2.668 - i_4(t)(0.844\,\text{k}) + 1.334 - i_4(t)(2\,\text{k}) + i_4(t)(6\,\text{k}) = 0$$
$$4.002 + i_4(t)(6\,\text{k} - 2\,\text{k} - 0.844\,\text{k}) = 0$$
$$4.002 + i_4(t)(3.156\,\text{k}) = 0$$
$$i_4(t)(3.156\,\text{k}) = -4.002$$
$$i_4(t) = \frac{-4.002}{3.156\,\text{k}}$$
$$i_4(t) = -0.789\,\text{mA}$$

Therefore, the value of the current $i_4(t)$ is $-0.789\,\text{mA}$.

Step 10 of 18

Recall equation (2).

$$i_3(t) = 0.667\,\text{m} - i_4(t)$$

Substitute $-0.789\,\text{mA}$ for $i_4(t)$.

$$i_3(t) = 0.667\,\text{m} - (-0.789\,\text{m})$$
$$= 0.667\,\text{m} + 0.789\,\text{m}$$
$$= 1.456\,\text{mA}$$

Therefore, the value of the current $i_3(t)$ is $1.456\,\text{mA}$.

Step 11 of 18

Calculate the value of the current $i_o(0^+)$.

$$i_o(0^+) = i_3(t) + i_4(t)$$

Substitute $1.456\,\text{mA}$ for $i_3(t)$ and $-0.789\,\text{mA}$ for $i_4(t)$.

$$i_o(0^+) = 1.456\,\text{m} - 0.789\,\text{m}$$
$$= 0.667\,\text{mA}$$

Therefore, the value of the current $i_o(0^+)$ is $0.667\,\text{mA}$.

Step 12 of 18

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 3

The value of the current $i_o(\infty)$ is $0\,\text{A}$ since the series combination of the resistors of $2\,\text{k}\Omega$ and $4\,\text{k}\Omega$ is shorted.

Step 13 of 18

Consider the circuit diagram shown in Figure 4 to calculate the equivalent resistance as seen from the opened terminals of the capacitor.

Figure 4

Step 14 of 18

The resistors $3\,\text{k}\Omega$ and $1\,\text{k}\Omega$ are shorted.

Calculate the value of the equivalent resistance R_{eq} .

$$R_{eq} = 4\,\text{k} \parallel 2\,\text{k}$$
$$= \frac{(4\,\text{k})(2\,\text{k})}{4\,\text{k}+2\,\text{k}}$$
$$= \frac{8\,\text{k}^2}{6\,\text{k}}$$
$$= \frac{4}{3}\,\text{k}\Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $\frac{4}{3}\,\text{k}\Omega$.

Step 15 of 18

Step-5:

Calculate the value of the time constant τ .

$$\tau = R_{eq} \cdot C$$

Substitute $\frac{4}{3}\,\text{k}\Omega$ for R_{eq} and $150\,\mu\text{F}$ for C .

$$\tau = \left(\frac{4}{3}\,\text{k}\right)(150\,\mu)$$
$$= 0.2\,\text{s}$$

Therefore, the value of the time constant τ is $0.2\,\text{s}$.

Step 16 of 18

Step-6

Calculate the value of the constant K_1 .

$$K_1 = i_o(\infty)$$

Substitute $0\,\text{mA}$ for $i_o(\infty)$.

$$K_1 = 0\,\text{mA}$$

Therefore, the value of the constant K_1 is $0\,\text{mA}$.

Step 17 of 18

Calculate the value of the constant K_2

$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute $0\,\text{mA}$ for $i_o(\infty)$ and $0.667\,\text{mA}$ for $i_o(0^+)$.

$$K_2 = 0 + 0.667\,\text{m}$$
$$= 0.667\,\text{mA}$$

Therefore, the value of the constant K_2 is $0.667\,\text{mA}$.

Step 18 of 18

Recall equation (1)

$$i_o(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute $0.2\,\text{s}$ for τ , $0.667\,\text{mA}$ for K_2 and $0\,\text{mA}$ for K_1 .

$$i_o(t) = 0 - 0.667\, e^{-t/0.2}\,\text{mA}$$
$$= -0.667\, e^{-t/0.2}\,\text{mA}$$

Therefore, the value of the output current $i_o(t)$ is $\boxed{-0.667\, e^{-t/0.2}\,\text{mA}}$

Step 1 of 16

The given circuit is,

Fig (a)

Step 2 of 16

Step 1: 600μF and 300μF Capacitors are in series which together are in parallel with 200μF capacitor replace with equivalent capacitor C as in Fig (b)

$$C = 200\mu + \frac{600\mu \times 300\mu}{600\mu + 300\mu}$$
$$C = 200\mu + 200\mu$$
$$C = 400\mu F$$

Step 3 of 16

Now we have circuit with only one energy storing element

Fig (b)

Step 2: $i_0(t)$ is of the form $K_1 + K_2 e^{\frac{-t}{\tau}}$.

Step 4 of 16

Step 3: At $t = 0-$, circuit is as shown is Fig (c), the circuit is in steady state prior to time $t = 0$ therefore the capacitor acts as open circuit,

Fig (c)

Step 5 of 16

By source transformation of 1mA and 4kΩ in fig (c)

$$V = (1m)(4k)$$
$$V = 4V$$

Step 6 of 16

Fig (d)

Linearly adding voltage sources 12V + 4V in Fig (d) we obtain Fig (e)

Step 7 of 16

Fig (e)

Step 8 of 16

From Fig (e), by voltage division,

$$v_c(0-) = (16)\frac{4}{4+4}$$
$$v_c(0-) = 8V$$

Step 9 of 16

Step 4: Fig (f) is the new circuit valid only at $t = 0+$,

Fig (f)

Step 10 of 16

In fig (f),

$$V_2 - V_1 = 12V$$

And

$$V_2 = 8V$$
$$\therefore V_1 = V_2 - 12V$$
$$V_1 = 8 - 12V$$
$$V_1 = -4V$$
$$\therefore i_0(0+) = \frac{V_1}{2k}$$
$$i_0(0+) = -\frac{4}{2k}$$
$$i_0(0+) = -2mA$$

Step 11 of 16

Step 5: The equivalent circuit, valid for $t > 5\tau$, is shown in fig (g) at $t = \infty$

Fig (g)

Step 12 of 16

By KCL at node 1,

$$1m + I = I + \frac{V_1}{2k} + \frac{V_1}{4k}$$
$$3V_1 = (4k)(1m)$$
$$\therefore V_1 = \frac{4}{3}V$$
$$\therefore i_0(\infty) = \frac{V_1}{2k}$$
$$i_0(\infty) = \frac{2}{3}mA$$

Step 13 of 16

Step 6: The Thevenin equivalent resistance R_{Th} as seen into the open circuit terminals of the capacitor,

Fig (h)

Step 14 of 16

4k and 2k are in parallel and 2k is shorted

$$\therefore R_{Th} = 4k \| 2k + (2k) \| 0$$
$$R_{Th} = \frac{4k \times 2k}{4k + 2k}$$
$$R_{Th} = \frac{4}{3}\ k\Omega$$

Step 15 of 16

Therefore the time constant is,

$$\therefore \tau = R_{Th}C$$
$$\tau = \left(\frac{4}{3}k\right)(400\mu)$$
$$\tau = \frac{8}{15}s$$

Step 16 of 16

Step 7: $K_1 = i_0(\infty)$

$$K_1 = \frac{2}{3}mA$$
$$K_2 = i_0(0+) - i_0(\infty)$$
$$K_2 = -2mA - \frac{2}{3}mA$$
$$K_2 = -\frac{8}{3}mA$$
$$\therefore i_0(t) = \frac{2}{3}m - \left(\frac{8}{3}m\right)e^{-\frac{15t}{8}}$$

$$\boxed{i_0(t) = \left(\frac{2}{3} - \frac{8}{3}e^{-1.875t}\right)mA}$$

Step 1 of 11

The given circuit is,

Fig (a)

Step 2 of 11

Step 1: 50μF and 150μF Capacitors are in parallel which together are in series with 200μF capacitor, replace with equivalent capacitor C as in Fig (b)

$$C=\frac{200\mu(50\mu+150\mu)}{200\mu+(50\mu+150\mu)}$$

$$C=\frac{200\mu\times200\mu}{400\mu}$$

$$C=100\,\mu F$$

Step 3 of 11

Now we have single energy storing element in circuit.

Fig (b)

Step 2: $i_0(t)$ is of the form $K_1+K_2e^{\frac{-t}{\tau}}$.

Step 4 of 11

Step 3: At $t=0-$, circuit is as shown is Fig (c), the circuit is in steady state prior to time $t=0$ therefore the capacitor acts as open circuit,

Fig (c)

Step 5 of 11

By KCL at the top node,

$$\frac{12-v_c(0-)}{3k}+\frac{6-v_c(0-)}{2k}=\frac{v_c(0-)}{6k}$$

$$2(12)-2v_c(0-)+3(6)-3v_c(0-)=v_c(0-)$$

$$6v_c(0-)=42V$$

$$\therefore v_c(0-)=7V$$

Step 6 of 11

Step 4: Fig (e) is the new circuit valid only at $t=0+$,

Fig (e)

Step 7 of 11

By Ohm's law,

$$i_0(0+)=\frac{7V}{6k}$$

$$i_0(0+)=\frac{7}{6}mA$$

Step 5: The equivalent circuit, valid for $t>5\tau$, is shown in fig (f) at $t=\infty$

Fig (f)

Step 8 of 11

By KCL at node 'a'

$$\frac{12-V_1}{3k}-\frac{V_1}{6k}-\frac{V_1}{2k}+\frac{6-V_1}{2k}=0$$

$$2(12)-2V_1-V_1-3V_1+3(6)-3V_1=0$$

$$9V_1=42$$

$$V_1=\frac{42}{9}V$$

$$\therefore i_0(\infty)=\frac{V_1}{6k}$$

$$i_0(\infty)=\frac{42}{9\times6k}$$

$$i_0(\infty)=\frac{7}{9}mA$$

Step 9 of 11

Step 6: The Thevenin equivalent resistance R_{Th} as seen into the open circuit terminals of the capacitor,

Fig (g)

Step 10 of 11

$$R_{Th}=(3k\|6k)\|(2k\|2k)$$

$$R_{Th}=\left(\frac{3k\times6k}{3k+6k}\right)\|\left(\frac{2k\times2k}{2k+2k}\right)$$

$$R_{Th}=(2k)\|(1k)$$

$$R_{Th}=\frac{2k\times1k}{2k+1k}$$

$$R_{Th}=\frac{2}{3}k\Omega$$

Therefore the time constant is,

$$\tau=R_{Th}C$$

$$\tau=\left(\frac{2}{3}k\right)(100\mu)$$

$$\tau=\frac{0.2}{3}s$$

Step 11 of 11

Step 7: $K_1=i_0(\infty)$

$$K_1=\frac{7}{9}mA$$

$$K_2=i_0(0+)-i_0(\infty)$$

$$K_2=\frac{7}{6}m-\frac{7}{9}m$$

$$K_2=\frac{7}{18}mA$$

$$\therefore i_0(t)=\frac{7}{9}m+\left(\frac{7}{18}m\right)e^{-\frac{3t}{0.2}}$$

$$\boxed{i_0(t)=\left(\frac{7}{9}+\frac{7}{18}e^{-15t}\right)mA}$$

Step 1 of 8

Refer to Figure P7.16 in the text book.

Write the general form of solution for the first order circuits.

$$x(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$

For the *RL* circuit,

$$x(t) = i_o(t)$$
$$K_1 = i_o(\infty)$$
$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute these values in equation $x(t)$.

$$i_o(t) = i_o(\infty) + \left[i_o(0^+) - i_o(\infty)\right] e^{-\frac{t}{\tau}} \quad \text{..... (1)}$$

Step 2 of 8

At $t = 0^-$, the switch is closed and the inductor is replaced by a short circuit.

Draw the modified circuit diagram of Figure P7.16 at $t = 0^-$.

Figure 1

Step 3 of 8

There is no current flow in the $6\ \text{k}\Omega$ resistor. Therefore, the current $i_o(0^-) = 0\ \text{A}$

Determine the initial current flowing through the inductor.

$$i_L(0^-) = \frac{12}{2\ \text{k}}$$
$$= 6\ \text{mA}$$

The current flowing throw the inductor cannot change in zero time.

Hence, $i_L(0^-) = i_L(0^+) = 6\ \text{mA}$.

Step 4 of 8

At $t = 0^+$, the switch opens and the inductor is replaced by a current source.

Draw the modified circuit diagram of Figure P7.16 at $t = 0^+$.

Figure 2

In Figure 2, same current flow through the circuit as it is a series circuit.

$$i_o(0^+) = -6\ \text{mA}$$

Step 5 of 8

After a long time the switch is opened the circuit goes to steady state. In steady state $t = \infty$ replace the inductor by a short circuit.

Draw the modified circuit diagram of Figure P7.16 at $t = \infty$.

Figure 3

There is no source in Figure 3. Hence, the value of final current is, $i_o(\infty) = 0\ \text{A}$

Step 6 of 8

Redraw the Figure P7.16 to calculate the equivalent resistance by looking into open terminals of the inductor and replacing the voltage sources by short circuit.

Figure 4

Step 7 of 8

Determine the thevenin equivalent resistance.

$$R_{th} = 6\ \text{k}\Omega$$

Determine the value of time constant.

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{2}{6\ \text{k}}$$
$$= \frac{1}{3} \times 10^{-3}$$

Step 8 of 8

Substitute 0 mA for $i_o(\infty)$, $-6\ \text{mA}$ for $i_o(0^+)$ and $\frac{1}{3} \times 10^{-3}$ for τ in equation (1).

$$i_o(t) = 0 + [-6 - 0] e^{-\frac{t}{\left(\frac{1}{3} \times 10^{-3}\right)}}\ \text{mA}$$
$$= -6e^{-3000t}\ \text{mA}$$

Thus, the expression for current, $i_o(t)$ for $t > 0$ is $\boxed{-6e^{-3000t}\ \text{mA}}$.

Step 1 of 11

Refer to Figure P7.57 in the text book.

For $t < 0$, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 11

For $t < 0$, Calculate the current through the inductor .

Calculate the source current.

From Figure 1, the source current is,

$$i_s = \frac{V_s}{R_1 + (R_L \| (R_2 + R_3))}$$

Substitute $3\ \Omega$ for R_1 , $3\ \Omega$ for R_2 , $3\ \Omega$ for R_3 , $3\ \Omega$ for R_L and 30 V for V_s in equation.

$$\begin{aligned} i_s(0^-) &= \frac{30}{3 + (3 \| (3+3))} \\ &= \frac{30}{3 + (3 \| 6)} \\ &= \frac{30}{3 + \frac{(3 \times 6)}{(3+6)}} \\ &= 6\ \text{A} \end{aligned}$$

Step 3 of 11

For $t < 0$, the current through the inductor is,

$i_L = \left(\frac{R_3 + R_2}{R_L + R_2 + R_3}\right) i_s$ Substitute $3\ \Omega$ for R_2 , $3\ \Omega$ for R_3 , $3\ \Omega$ for R_L and 6 A for i_s in equation.

$$\begin{aligned} i_L(0^-) &= \left(\frac{3+3}{3+3+3}\right)(6) \\ &= \left(\frac{2}{3}\right)(6) \\ &= 4\ \text{A} \end{aligned}$$

Step 4 of 11

Inductor does not allow sudden changes current.

Therefore, $i_L(0^-) = i_L(0^+)$.

At $t = 0^+$, the resultant circuit is shown in Figure 2.

Step 5 of 11

Step 6 of 11

Figure 2

Step 7 of 11

From Figure 2, it is clear that the initial voltage across the $3\ \Omega$ resistance is,

$$\begin{aligned} v_o(0^+) &= -i_L(0^+)(3) \\ &= -4(3) \\ &= -12\ \text{V} \end{aligned}$$

Step 8 of 11

For $t > 0$, Calculate the time constant of the circuit.
The Thevinen's equivalent resistance circuit is shown in Figure 3.

Figure 3

Step 9 of 11

The Thevinen's equivalent resistance is,

$$R_{th} = R_L + R_2 + R_3$$

Substitute $3\ \Omega$ for R_1 , $3\ \Omega$ for R_2 , $3\ \Omega$ for R_3 , $3\ \Omega$ for R_L and in equation.

$$\begin{aligned} R_{th} &= 3 + 3 + 3 \\ &= 9\ \Omega \end{aligned}$$

The time constant of the circuit is,

$$\begin{aligned} \tau &= \frac{L}{R_{th}} \\ &= \frac{3}{9} \\ &= 0.333\ \text{sec} \end{aligned}$$

Step 10 of 11

At $t = \infty$, the resultant circuit is shown in Figure 4.

Figure 4

Step 11 of 11

From Figure 4, it is clear that the final voltage across the $3\ \Omega$ resistor is 0 V.

$$v(\infty) = 0\ \text{V}$$

Calculate the voltage across $3\ \Omega$ resistor is,

$$v_o(t) = v_o(0^+) e^{-t/\tau}\ \text{V}$$

Substitute $-12\ \text{V}$ for $v_o(0^+)$ and $0.333\ \text{sec}$ for τ in equation.

$$\begin{aligned} v_o(t) &= -12 e^{-t/(0.333)}\ \text{V} \\ &= -12 e^{-3t}\ \text{V} \end{aligned}$$

Thus, the output voltage across $3\ \Omega$ resistor is $\boxed{-12 e^{-3t}\ \text{V}}$.

Step 1 of 12

Refer to Figure P7.58 in the text book.

For $t < 0$, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 12

Under steady state conditions inductor acts as a short circuit.

At $t = 0^-$, the current through the inductor is same as current through the $2\ \Omega$ resistor.

Calculate the initial current through the $2\ \Omega$ resistor.

From Figure 1, the current through the inductor is,

$$i_L(0^-) = \frac{V_{s1}}{R_o}$$

Substitute $2\ \Omega$ for R_o , and 6 V for V_s in equation.

$$i_L(0^-) = \frac{6}{2}$$
$$= 3\ \text{A}$$

Inductor does not allow sudden changes current.

Therefore, at t= 0+ the current through inductor or resistor is,

$$i_L(0^+) = i_L(0^-)$$
$$= 3\ \text{A}$$

Step 3 of 12

At $t = 0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 4 of 12

Apply Kirchhoff's current law at node a.

$$\frac{v_a - (-9)}{3} + \frac{v_a - v_b}{4} + i_L(0^+) = 0$$

Substitute $3\ \text{A}$ for $i_L(0^+)$ in equation.

$$\frac{v_a + 9}{3} + \frac{v_a - v_b}{4} + 3 = 0$$
$$v_a\left(\frac{1}{3} + \frac{1}{4}\right) - \frac{v_b}{4} = -3 - 3$$
$$\frac{7v_a}{12} - \frac{v_b}{4} = -6 \quad \text{..... (1)}$$

Step 5 of 12

Apply Kirchhoff's current law at node a.

$$\frac{v_b}{2} + \frac{v_b - v_a}{4} = i_L(0^+)$$

Substitute $3\ \text{A}$ for $i_L(0^+)$ in equation.

$$\frac{v_b}{2} + \frac{v_b - v_a}{4} = 3$$
$$v_b\left(\frac{1}{2} + \frac{1}{4}\right) - \frac{v_a}{4} = 3$$
$$\left(\frac{6}{8}\right)v_b - \frac{v_a}{4} = 3$$
$$-\frac{v_a}{4} + \frac{3v_b}{4} = 3 \quad \text{..... (2)}$$

Step 6 of 12

Solve equations (1) and (2).

Consider equation (2).

$$-\frac{v_a}{4} + \frac{3v_b}{4} = 3$$
$$-v_a + 3v_b = 12$$
$$v_a = 3v_b - 12$$

Substitute $3v_b - 12$ for v_a in equation (1).

$$\frac{7(3v_b - 12)}{12} - \frac{v_b}{4} = -6$$
$$\frac{21v_b - 84}{12} - \frac{v_b}{4} = -6$$
$$21v_b - 84 - 3v_b = -6(12)$$
$$v_b = \frac{-72 + 84}{18}$$

$$v_b = \frac{12}{18}$$
$$= \frac{2}{3}\ \text{V}$$

Step 7 of 12

The initial current through the R_o is,

$$i_o(0^+) = \frac{v_b}{R_o}$$

Substitute $2\ \Omega$ for R_o and $\frac{2}{3}$ V for v_b in equation.

$$i_o(0^+) = \frac{\frac{2}{3}}{2}$$
$$= \frac{1}{3}$$
$$= 0.3333\ \text{A}$$

Step 8 of 12

At $t = \infty$, the circuit reaches steady state and the resultant circuit is shown in Figure 2.

Figure 2

Step 9 of 12

Under steady state conditions the inductor acts as a short circuit.

At $t = \infty$, the current through the inductor is same as the current through the $2\ \Omega$ resistor.

For t<0, the current through the inductor is,

$i(\infty) = \frac{V_{s2}}{R_o + R_2}$ Substitute $2\ \Omega$ for R_o , $3\ \Omega$ for R_2 , -9 V for V_{s2} in equation.

$$i(\infty) = \frac{-9}{2+3}$$
$$= -1.8\ \text{A}$$

Step 10 of 12

For $t > 0$, Calculate the time constant of circuit.

The Thevinen's equivalent resistance circuit is shown in Figure 3.

Figure 3

Step 11 of 12

Calculate the Thevinen's resistance.

$$R_{th} = R_1 \| (R_o + R_2)$$

Substitute $4\ \Omega$ for R_1 , $3\ \Omega$ for R_2 , $2\ \Omega$ for R_o in equation.

$$R_{th} = 4 \| (2+3)$$
$$= \frac{4(5)}{4+5}$$
$$= 2.222\ \Omega$$

The time constant of the circuit is,

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{0.5}{2.222}$$
$$= 0.225\ \text{sec}$$

Step 12 of 12

The general solution for current $i(t)$ is,

$$i(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1

$$K_1 = i(\infty)$$

Substitute -1.8 A for $i(\infty)$ in equation.

$$K_1 = -1.8\ \text{A}$$

Calculate the value of K_2 .

$$K_2 = \left(i(0^+) - i(\infty)\right)$$

Substitute -1.8 A for $i(\infty)$ and $0.3333\ \text{A}$ for $i(0^+)$ in equation.

$$K_2 = (0.3333 - (-1.8))$$
$$= 2.1333\ \text{A}$$

Substitute $-1.8\ \text{A}$ for K_1 and $2.1333\ \text{A}$ for K_2 in equation (1).

$$i(t) = -1.8 + 2.1333e^{-t/(0.225)}$$
$$= -1.8 + 2.1333e^{-4.444t}\ \text{A}$$

Thus, the output current is $\boxed{-1.8 + 2.1333e^{-4.444t}\ \text{A}}$.

Step 1 of 7

Refer to Figure P7.59 in the text book.

For t<0, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 7

Under steady state conditions inductor acts as a short circuit.

At $t = 0^-$, the current through the inductor is same as current through the $6\ \text{k}\Omega$ resistor.

Calculate the initial current through the $6\ \text{k}\Omega$ resistor.

From Figure 1, the current through the inductor is,

$$i_L(0^-) = \frac{V_{s1}}{R_4}$$

Substitute $6\ \text{k}\Omega$ for R_4, and -12 V for V_{s1} in equation.

$$\begin{aligned} i_L(0^-) &= \frac{-12}{6} \\ &= -2\ \text{mA} \end{aligned}$$

Inductor does not allow sudden changes current.

Therefore, at t= 0^+ the current through inductor is,

$$\begin{aligned} i_L(0^+) &= i_L(0^-) \\ &= -2\ \text{mA} \end{aligned}$$

Step 3 of 7

At $t = \infty$, the circuit reaches steady state and the resultant circuit is shown in Figure 2.

Figure 2

Step 4 of 7

Under steady state conditions the inductor acts as a short circuit.

Calculate the current, $i_{s2}(\infty)$.

$$i_{s2}(\infty) = \frac{V_{s2}}{R_4 + R_2}$$

Substitute 30 V for V_{s2} , $4\ \text{k}\Omega$ for R_1 and $2\ \text{k}\Omega$ for R_2

$$\begin{aligned} i_{s2}(\infty) &= \frac{30}{4+2} \\ &= 5\ \text{mA} \end{aligned}$$

Calculate the current $i_{s1}(\infty)$.

$$i_{s1}(\infty) = \frac{V_{s1}}{R_4}$$

Substitute $6\ \text{k}\Omega$ for R_4 , and -12 V for V_{s1} in equation.

$$\begin{aligned} i_{s1}(\infty) &= \frac{-12}{6} \\ &= -2\ \text{mA} \end{aligned}$$

At $t = \infty$, the current through the inductor is,

$$\begin{aligned} i_L(\infty) &= i_{s1}(\infty) + i_{s2}(\infty) \\ &= -2\ \text{mA} + 5\ \text{mA} \\ &= 3\ \text{mA} \end{aligned}$$

Step 5 of 7

For $t > 0$, calculate the time constant of the circuit.

The Thevenin equivalent resistance circuit is shown in Figure 3.

Figure 3

Step 6 of 7

Calculate the Thevenin resistance.

$$R_{th} = (R_1 + R_2) \parallel R_3 \parallel R_4$$

Substitute $4\ \text{k}\Omega$ for R_1 , $2\ \text{k}\Omega$ for R_2 , $12\ \text{k}\Omega$ for R_3 $6\ \text{k}\Omega$ for R_4 in equation.

$$\begin{aligned} R_{th} &= (4\text{k} + 2\text{k}) \parallel 6\text{k} \parallel 12\text{k} \\ &= 6\text{k} \parallel 6\text{k} \parallel 12\text{k} \\ &= 3\text{k} \parallel 12\text{k} \\ &= 2.4\ \text{k}\Omega \end{aligned}$$

The time constant of the circuit is,

$$\begin{aligned} \tau &= \frac{L}{R_{th}} \\ &= \frac{12\ \text{mH}}{2.4\ \text{k}\Omega} \\ &= 5\ \mu\text{s} \end{aligned}$$

Step 7 of 7

The general solution for current $i_L(t)$ is.

$$i(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1 .

$$K_1 = i_L(\infty)$$

Substitute 3 mA for $i_L(\infty)$ in the equation.

$$K_1 = 3\ \text{mA}$$

Calculate the value of K_2 .

$$K_2 = \left(i_L(0^+) - i_L(\infty)\right)$$

Substitute 3 mA for $i_L(\infty)$ and $-2\ \text{mA}$ for $i_L(0^+)$ in the equation.

$$\begin{aligned} K_2 &= (-2\ \text{mA} - 3\ \text{mA}) \\ &= -5\ \text{mA} \end{aligned}$$

Substitute $3\ \text{mA}$ for K_1 and $-5\ \text{mA}$ for K_2 in equation (1).

$$\begin{aligned} i_L(t) &= 3 - 5e^{-t/5\times10^{-6}} \\ &= 3 - 5e^{-0.2\times10^6 t}\ \text{A} \end{aligned}$$

Thus, the output current, $i_L(t)$ is $\boxed{3 - 5e^{-0.2\times10^6 t}\ \text{A}}$.

Step 1 of 11

7.060P

Refer to Figure P7.60 in the text book.

For $t < 0$, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 11

For $t < 0$, Calculate the current passes through the $20\ \text{V}$ source.

From Figure 1, the source current is,

$$\begin{aligned} i_s &= \frac{20}{5\text{ k} + 3\text{ k} + (6\text{ k} \| 3\text{ k})} \\ &= \frac{20}{5\text{ k} + 3\text{ k} + \left(\frac{6\text{ k}(3\text{ k})}{6\text{ k} + 3\text{ k}}\right)} \\ &= \frac{20}{8\text{ k} + 2\text{ k}} \\ &= 2\text{ mA} \end{aligned}$$

Step 3 of 11

At $t = 0^-$, the current through the $6\ \text{k}\Omega$ resistor is,

$$\begin{aligned} i_L(0^-) &= \left(\frac{6\text{ k}}{6\text{ k} + 3\text{ k}}\right)(2\text{ m}) \\ &= \frac{4}{3} \\ &= 1.333\text{ mA} \end{aligned}$$

Step 4 of 11

At $t = 0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 5 of 11

Apply Kirchhoff's Current Law at node 1.

$$\frac{v_1 - (-12)}{3\text{ k}} + \frac{v_1}{6\text{ k}} + 1.3333 = 0$$

$$\frac{v_1 + 12}{3\text{ k}} + \frac{v_1}{6\text{ k}} + 1.3333\text{ m} = 0$$

$$2(v_1 + 12) + v_1 + 8 = 0$$

$$3v_1 + 24 + 8 = 0$$

$$3v_1 = -32$$

$$v_1 = -10.6666$$

Step 6 of 11

The initial current $i_R(0^+)$ is ,

$$i_R(0^+) = \frac{v_1}{6\text{ k}}$$

Substitute -10.666 V for v_1 in equation.

$$\begin{aligned} i_R(0^+) &= \frac{-10.666}{6\text{ k}} \\ &= -1.6666\text{ mA} \end{aligned}$$

Step 7 of 11

At $t = \infty$, the circuit reaches steady state and the resultant circuit is shown in Figure 3.

Figure 3

Step 8 of 11

At $t = \infty$, Calculate the current passes through the $-12\ \text{V}$ source. Calculate the source current.

From Figure 3, the source current is,

$$\begin{aligned} i_{s2} &= \frac{-12}{3\text{ k} + (6\text{ k} \| 3\text{ k})} \\ &= \frac{-12}{3\text{ k} + 2\text{ k}} \\ &= -2.4\text{ mA} \end{aligned}$$

Step 9 of 11

At $t = \infty$, the current through the $6\ \text{k}\Omega$ resistor is,

$$\begin{aligned} i_R(\infty) &= \left(\frac{3\text{ k}}{6\text{ k} + 3\text{ k}}\right)(-2.4\text{ m}) \\ &= \frac{-2.4\text{ m}}{3} \\ &= -0.8\text{ mA} \end{aligned}$$

The Thevinen's equivalent resistance circuit is shown in Figure 4.

Figure 4

Step 10 of 11

Calculate the Thevinen's resistance.

$$\begin{aligned} R_{th} &= 3 + (3 \| 6) \\ &= 3 + \frac{3(6)}{3 + 6} \\ &= 5\text{ k}\Omega \end{aligned}$$

The time constant of the circuit is,

$$\tau = \frac{L}{R_{th}}$$

Substitute 5 mH for L and $5\ \text{k}\Omega$ for R_{th} in equation.

$$\begin{aligned} \tau &= \frac{5\text{ m}}{5\text{ k}} \\ &= 1\ \mu\text{sec} \end{aligned}$$

Step 11 of 11

The general solution for current $i_R(t)$ is,

$$i(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1.

$$K_1 = i_R(\infty)$$

Substitute -0.8 mA for $i_R(\infty)$ in the equation.

$$K_1 = -0.8\text{ mA}$$

Calculate the value of K_2.

$$K_2 = \left(i_R(0^+) - i_R(\infty)\right)$$

Substitute -0.8 mA for $i_R(\infty)$ and -1.666 mA for $i_R(0^+)$ in the equation.

$$\begin{aligned} K_2 &= (-1.666 - (-0.8)) \\ &= -0.866\text{ mA} \end{aligned}$$

Substitute -0.8 mA for K_1 and -0.866 mA for K_2 in equation (1).

$$\begin{aligned} i_R(t) &= \left(-0.8 - 0.866\, e^{-\frac{t}{1\times10^{-4}}}\right)\text{ m} \\ &= \left(-0.8 - 0.866\, e^{-10^4 t}\right)\text{ mA} \end{aligned}$$

Thus, the output current is $\boxed{\left(-0.8 - 0.866\, e^{-10^4 t}\right)\text{ mA}}$.

Step 1 of 9

Refer to Figure P7.60 in the text book.

For $t < 0$, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 9

At $t = 0^-$, Calculate the current passes through the $-24\ \mathrm{V}$ source.

From Figure 1, the source current is,

$$\begin{aligned} i_s &= \frac{-24}{2\ \mathrm{k} + 6\ \mathrm{k} + (6\ \mathrm{k} \| 12\ \mathrm{k})} \\ &= \frac{-24}{8\ \mathrm{k} + 4\ \mathrm{k}} \\ &= \frac{-24}{12\ \mathrm{k}} \\ &= -2\ \mathrm{mA} \end{aligned}$$

Step 3 of 9

At $t = 0^-$, the current through the $20\ \mathrm{mH}$ inductor is,

$$\begin{aligned} i_L(0^-) &= \left(\frac{12}{6\ \mathrm{k} + 12\ \mathrm{k}}\right)(-2) \\ &= \frac{-24}{18\ \mathrm{k}} \\ &= -1.333\ \mathrm{mA} \end{aligned}$$

The inductor does not allow sudden change in current.

Therefore , the current through the inductor after switching is,

$$\begin{aligned} i_L(0^+) &= i_L(0^-) \\ &= -1.333\ \mathrm{mA} \end{aligned}$$

Step 4 of 9

At $t = \infty$, the circuit reaches steady state and the resultant circuit is shown in Figure 2.

Figure 2

Step 5 of 9

At $t = \infty$, Calculate the current passes through the $6\ \mathrm{V}$ source.

Calculate the source current.

From Figure 1, the source current is,

$$i_{s2} = \frac{V_{s2}}{R_2 + R_3 + (R_4 \| R_5)}$$

Substitute $12\ \mathrm{k\Omega}$ for R_5 , $6\ \mathrm{k\Omega}$ for R_2 , $6\ \mathrm{k\Omega}$ for R_3 , $6\ \mathrm{k\Omega}$ for R_4 and 16 V for V_s in equation.

$$\begin{aligned} i_{s2} &= \frac{16}{6 + 6 + (6 \| 12)} \\ &= \frac{16}{12 + 4} \\ &= 1\ \mathrm{mA} \end{aligned}$$

Step 6 of 9

At $t = \infty$, the current through the $20\ \mathrm{mH}$ inductor is,

$$i_L(\infty) = \left(\frac{R_5}{R_4 + R_5}\right) i_{s2}$$ Substitute $12\ \mathrm{k\Omega}$ for R_5 , $6\ \mathrm{k\Omega}$ for R_4 and 1 mA for i_s in equation.

$$\begin{aligned} i_L(\infty) &= \left(\frac{12}{6\ \mathrm{k} + 12\ \mathrm{k}}\right)(1) \\ &= \frac{2}{3\ \mathrm{k}} \\ &= 0.666\ \mathrm{mA} \end{aligned}$$

Step 7 of 9

The Thevenin equivalent resistance circuit is shown in Figure 3.

Figure 3

Step 8 of 9

Calculate the Thevenin resistance.

$$R_{th} = (R_5 \| (R_2 + R_3)) + R_4$$

Substitute $6\ \mathrm{k\Omega}$ for R_3 , $6\ \mathrm{k\Omega}$ for R_2 , $6\ \mathrm{k\Omega}$ for R_4 and $12\ \mathrm{k\Omega}$ for R_5 in equation.

$$\begin{aligned} R_{th} &= (12\ \mathrm{k} \| (6\ \mathrm{k} + 6\ \mathrm{k})) + 6\ \mathrm{k} \\ &= 6\ \mathrm{k} + \frac{12\ \mathrm{k}(12\ \mathrm{k})}{12\ \mathrm{k} + 12\ \mathrm{k}} \\ &= 6\ \mathrm{k} + 6\ \mathrm{k} \\ &= 12\ \mathrm{k\Omega} \end{aligned}$$

The time constant of the circuit is,

$$\tau = \frac{L}{R_{th}}$$

Substitute $20\ \mathrm{mH}$ for L and $12\ \mathrm{k\Omega}$ for R_{th} in the equation.

$$\begin{aligned} \tau &= \frac{20\ \mathrm{m}}{12\ \mathrm{k}} \\ &= 1.666\ \mu\mathrm{sec} \end{aligned}$$

Step 9 of 9

The general solution for current $i_L(t)$ is,

$$i_L(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1 .

$$K_1 = i_L(\infty)$$

Substitute 0.666 mA for $i_L(\infty)$ in the equation.

$$K_1 = 0.666\ \mathrm{mA}$$

Calculate the value of K_2 .

$$K_2 = \left(i_L(0^+) - i_L(\infty)\right)$$

Substitute 0.666 mA for $i_L(\infty)$ and $-1.333\ \mathrm{mA}$ for $i_L(0^+)$ in the equation.

$$\begin{aligned} K_2 &= ((-1.333) - 0.666) \\ &= -2\ \mathrm{mA} \end{aligned}$$

Substitute $0.6666\ \mathrm{mA}$ for K_1 and $2\ \mathrm{mA}$ for K_2 in equation (1).

$$\begin{aligned} i_L(t) &= \left(0.666 - 2e^{\frac{-t}{1.666 \times 10^{-6}}}\right) \mathrm{m} \\ &= 0.6666 - 2e^{-600240t}\ \mathrm{mA} \end{aligned}$$

Thus, the output current is $\boxed{0.6666 - 2e^{-600240t}\ \mathrm{mA}}$.

Step 1 of 7

This is a resistance inductor circuit which is initially closed and the current through the inductor before opening of the switch can be calculated using Ohm's law.

Figure-1

The inductor is shorted in this condition because of inductor which shows short circuit in steady state. Now apply current division theorem to get the current through $6\,k\Omega$ resistance.

$$i_1 = \frac{(6\,A)(4\Omega)}{4\Omega + 6\Omega + 6\Omega}$$
$$= 1.5\,A$$

Now apply current division to get the value of current through the inductor and it is.

$$i_L(0) = 6\,A - 1.5\,A$$
$$= 4.5\,A$$

Step 2 of 7

Now the position of switch has changed and it is in closed condition so the inductor will work as current source and calculate the output voltage in this condition.

Figure-2

Apply superposition theorem to calculate the value of output current through output resistance.

For the 6 A current source replace the inductor as open circuited and then calculate the value of current through output terminal.

Figure-3

$$i_1 = 6\,A$$

Step 3 of 7

Calculate the current through output resistance because of 4.5 A source assuming 6 A current source as open circuit.

Figure-4

$$i_2 = -4.5\,A$$

The total output current is the summation of the two current and.

$$i_0 = 6\,A - 4.5\,A$$
$$= 1.5\,A$$

Step 4 of 7

Calculate the output voltage in this circuit at time $t = 0$ using Ohm's law.

$$v_0(0) = (1.5\,A)(6\Omega)$$
$$= 9\,V$$

The voltage on the output resistance at the time of closing of switch is 9 V.

Step 5 of 7

The output voltage at steady state is calculated by using the delta-star transform assuming the inductor is shorted in steady state and then using current division.

Figure-5

$$v_0(f) = 18\,V$$

Therefore the condition of transient circuit shows that the equation of transient state is.

$$v_0(t) = v_0(f) + Ae^{-\frac{t}{\tau}} \quad \text{..... (i)}$$

Put time t=0 in equation (i) and get the value of A to find the time dependent equation output current.

$$v_0(0) = v_0(f) + Ae^{-\frac{0}{\tau}}$$
$$11.636\,V = 0 + A \quad \text{..... (ii)}$$
$$A = 11.636\,V$$

Step 6 of 7

The time constant of the circuit in steady state is equal to the ratio of inductor and resistance value where the resistance is the equivalent resistance of the circuit.

Figure-6

Step 7 of 7

The time constant of the circuit is,

$$\tau = \frac{L}{R_{eq}}$$
$$= \frac{(2\,H)}{(3\Omega \| 6\Omega) + 4\Omega + 6\Omega}$$
$$= \frac{(2\,H)}{12\Omega}$$
$$= 0.1666\,sec.$$

Now put the value of A from equation (ii) in equation (i) and you get the final equation of output voltage across $2\,k\Omega$ resistance

$$v_0(t) = \left(18 - 9e^{-\frac{t}{0.166\,sec}}\right) V$$

Therefore, the voltage across the output terminal is $\boxed{9\left(2 - e^{-6t}\right) V}$.

Step 1 of 8

Refer to Figure P7.42 in the text book.

The current flowing through the inductor, $i(t)$ is of the form,

$$i(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Initially the switch has been closed for long time and the inductor acts a short circuit.

Figure 1

Step 2 of 8

Apply Kirchhoff's current law at node v_x.

$$\frac{v_x - 10}{1\text{k}} + \frac{v_x}{2\text{k}} + \frac{v_x}{2\text{k}} = 0$$

$$\frac{2v_x - 20 + v_x + v_x}{2\text{k}} = 0$$

$$4v_x = 20$$

$$v_x = 5 \text{ V}$$

From Figure 1, the initial inductor current is,

$$\begin{aligned} i(0^-) &= \frac{v_x}{2\text{k}} \\ &= \frac{v_x}{2\text{k}} \\ &= 2.5 \text{ mA} \end{aligned}$$

Step 3 of 8

Draw the circuit diagram at $t = 0$.

Figure 2

Step 4 of 8

The current flowing through the inductor cannot change instantaneously.

Therefore,

$$\begin{aligned} i(0) &= i(0^+) \\ &= i(0^-) \\ &= 2.5 \text{ mA} \end{aligned}$$

Draw the circuit diagram at $t = \infty$.

Figure 3

Step 5 of 8

Apply Kirchhoff's current law at node v_1.

$$\frac{v_1 - 30}{1\text{k} + 1\text{k}} + \frac{v_1}{2\text{k}} + \frac{v_1}{2\text{k}} = 0$$

$$v_1 - 30 + v_1 + v_1 = 0$$

$$3v_1 = 30$$

$$v_1 = 10 \text{ V}$$

From Figure 3, the final current through inductor is,

$$\begin{aligned} i(\infty) &= \frac{v_1}{2\text{k}} \\ &= \frac{10}{2\text{k}} \\ &= 5 \text{ mA} \end{aligned}$$

Step 6 of 8

The Thevenin equivalent resistance is found by looking into the inductor terminals. This circuit is shown in Figure 4.

Figure 4

Step 7 of 8

From Figure 4, the Thevenin equivalent resistance is,

$$\begin{aligned} R_{Th} &= \left[(1\text{k} + 1\text{k}) \| (2\text{k})\right] + 2\text{k} \\ &= \left[\frac{(2\text{k})(2\text{k})}{2\text{k} + 2\text{k}}\right] + 2\text{k} \\ &= 1\text{k} + 2\text{k} \\ &= 3 \text{ k}\Omega \end{aligned}$$

Therefore, the time constant is,

$$\begin{aligned} \tau &= \frac{L}{R_{Th}} \\ &= \frac{0.3}{3 \times 10^3} \\ &= 0.1 \text{ ms} \end{aligned}$$

Step 8 of 8

Write the general solution of the inductor current.

$$i(t) = i(\infty) + \left(i(0) - i(\infty)\right) e^{-t/\tau} \quad \text{..... (2)}$$

Compare equation (1) with equation (2).

$$\begin{aligned} K_1 &= i_L(\infty) \\ &= 5 \text{ mA} \end{aligned}$$

And,

$$\begin{aligned} K_2 &= i_L(0) - i_L(\infty) \\ &= 2.5 \text{ mA} - 5 \text{ mA} \\ &= -2.5 \text{ mA} \end{aligned}$$

Substitute 5 mA for K_1 and -2.5 mA for K_2 in equation (1).

$$\begin{aligned} i(t) &= (5 \text{ mA}) - (2.5 \text{ mA}) e^{-t/(0.1 \times 10^{-3})} \\ &= 5 - 2.5 e^{-10000t} \text{ mA} \end{aligned}$$

Therefore, the current flowing through the inductor for $t > 0$, $i(t)$ is $\boxed{5 - 2.5 e^{-10000t} \text{ mA}}$.

Step 1 of 17

Consider the Figure P7.67 from the text book.

Step-1:

Let the value of the output voltage $v_O(t)$ be $K_1 + K_2 e^{-xt}$ . . . . . (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 17

Calculate the value of the current $i_1(t)$.

$$i_1(t) = \frac{12}{2}$$
$$= 6\text{ A}$$

Therefore, the value of the current $i_1(t)$ is 6 A .

Step 3 of 17

Calculate the value of the current $i_2(t)$.

$$i_2(t) = \frac{12}{2}$$
$$= 6\text{ A}$$

Therefore, the value of the current $i_2(t)$ is 6 A .

Step 4 of 17

Calculate the value of the current $i_L(0^-)$.

$$i_L(0^-) = -i_1(t) - i_2(t)$$

Substitute 6 A for $i_2(t)$ and $i_1(t)$.

$$i_L(0^-) = -6 - 6$$
$$= -12\text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is -12 A .

Step 5 of 17

Step-3:

Consider the circuit diagram at $t = 0^-$

Figure 2

Step 6 of 17

Identify the parallel connected resistors in the circuit.

Calculate the equivalent resistance for the parallel connected resistors.

$$R_1 = 3 \| 6$$
$$= \frac{(3)(6)}{3+6}$$
$$= \frac{18}{9}$$
$$= 2\,\Omega$$

Therefore, the value of the parallel connected resistors is $2\,\Omega$

Step 7 of 17

Redraw the circuit diagram. Identify the parallel connected resistors.

Figure 4

Step 8 of 17

Calculate the equivalent resistance for the parallel connected resistors.

$$R_2 = 2 \| 2$$
$$= \frac{(2)(2)}{2+2}$$
$$= \frac{4}{4}$$
$$= 1\,\Omega$$

Therefore, the value of the parallel connected resistors is $1\,\Omega$.

Step 9 of 17

Redraw the circuit diagram.

Figure 5

Step 10 of 17

Calculate the value of the voltage $v_O(0^+)$.

$$v_O(0^-) = -i_1(t)(1)$$

Substitute -12 A for $i_1(t)$.

$$v_O(0^+) = -(-12)(1)$$
$$= 12\text{ V}$$

Therefore, the value of the voltage $v_O(0^+)$ is 12 V .

Step 11 of 17

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 6

The value of the voltage $v(\infty)$ is 0 V since no source is present in the circuit.

Step 12 of 17

Consider the circuit diagram shown in Figure 7 to calculate the equivalent resistance as seen from the opened terminals of the inductor.

Figure 7

Step 13 of 17

Calculate the value of the equivalent resistance R_{eq} .

$$R_{eq} = (2 \| 2) + (3 \| 6)$$
$$= \frac{(2)(2)}{2+2} + \frac{(3)(6)}{3+6}$$
$$= \frac{4}{4} + \frac{18}{9}$$
$$= 1 + 2$$

$$R_{eq} = 3\,\Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $3\,\Omega$.

Step 14 of 17

Step-5:

Calculate the value of the time constant τ .

$$\tau = \frac{L}{R_{eq}}$$

Substitute $3\,\Omega$ for R_{eq} and 2 H for L .

$$\tau = \frac{2}{3}$$
$$= 0.667\text{ s}$$

Therefore, the value of the time constant τ is 0.667 s .

Step 15 of 17

Step-6:

Calculate the value of the constant K_1 .

$$K_1 = v_O(\infty)$$

Substitute 0 V for $v_O(\infty)$.

$$K_1 = 0\text{ V}$$

Therefore, the value of the constant K_1 is 0 V .

Step 16 of 17

Calculate the value of the constant K_2

$$K_2 = v_O(0^-) - v_O(\infty)$$

Substitute 0 V for $v_O(\infty)$ and 12 V for $v_O(0^-)$.

$$K_2 = 12 - 0$$
$$= 12\text{ V}$$

Therefore, the value of the constant K_2 is 12 V .

Step 17 of 17

Recall equation (1).

$$v_O(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0.667 s for τ , 12 V for K_2 and 0 V for K_1 .

$$v_O(t) = 0 + 12e^{-t/0.667}\text{ V}$$
$$= 12e^{-t/0.667}\text{ V}$$

Therefore, the value of the output voltage $v_O(t)$ is $\boxed{12e^{-t/0.667}\text{ V}}$

Step 1 of 13

Consider the Figure P7.60 from the text book.

Step-1:

Let the value of the current $i(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 13

Apply nodal analysis at node-1.

$$\frac{v_1(t)+30}{5}+\frac{v_1(t)}{2}+\frac{v_1(t)}{2}=0$$

$$v_1(t)\left(\frac{1}{5}+\frac{1}{2}+\frac{1}{2}\right)+\frac{30}{5}=0$$

$$v_1(t)\left(\frac{2}{10}+\frac{5}{10}+\frac{5}{10}\right)+\frac{60}{10}=0$$

$$v_1(t)\left(\frac{12}{10}\right)+\frac{60}{10}=0$$

$$v_1(t)(12)+60=0$$

$$v_1(t)(12)=-60$$

$$v_1(t)=-\frac{60}{12}$$

$$v_1(t)=-5\text{ V}$$

Therefore, the value of the voltage $v_1(t)$ is -5 V .

Step 3 of 13

Calculate the value of the current $i_L(0^-)$.

$$i_L(0^-)=\frac{v_1(t)}{2}$$

Substitute -5 V for $v_1(t)$.

$$i_L(0^-)=-\frac{5}{2}$$
$$=-2.5\text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is -2.5 A .

Step 4 of 13

Step-3:

The value of the current through the inductor at $t = 0^+$ is equal to the value of the current $i_L(0^-)$.

Therefore, the value of the current $i_L(0^+)$ is -2.5 A .

Step 5 of 13

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

Step 6 of 13

Apply nodal analysis at node-1.

$$\frac{v_1(t)-30}{2}+\frac{v_1(t)}{2}+\frac{v_1(t)}{2}=0$$

$$v_1(t)\left(\frac{1}{2}+\frac{1}{2}+\frac{1}{2}\right)-\frac{30}{2}=0$$

$$v_1(t)\left(\frac{3}{2}\right)=\frac{30}{2}$$

$$v_1(t)=10\text{ V}$$

Therefore, the value of the voltage $v_1(t)$ is 10 V .

Step 7 of 13

Calculate the value of the current $i_L(\infty)$.

$$i_L(\infty)=-\frac{v_1(t)}{2}$$

Substitute 10 V for $v_1(t)$.

$$i_L(\infty)=-\frac{10}{2}$$
$$=-5\text{ A}$$

Therefore, the value of the current $i_L(\infty)$ is -5 A .

The value of the current $i(\infty)$ is equal to -5 A .

Step 8 of 13

Consider the circuit diagram shown in Figure 3 to calculate the equivalent resistance as seen from the opened terminals of the inductor.

Figure 3

Step 9 of 13

Calculate the value of the equivalent resistance R_{eq} .

$$R_{eq}=6\parallel\left(2+(2\parallel 2)\right)$$
$$=6\parallel\left(2+\frac{(2)(2)}{2+2}\right)$$
$$=6\parallel\left(2+\frac{4}{4}\right)$$
$$=6\parallel(2+1)$$

$$R_{eq}=6\parallel 3$$
$$=\frac{(6)(3)}{6+3}$$
$$=\frac{18}{9}$$
$$=2\,\Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $2\,\Omega$.

Step 10 of 13

Step-5:

Calculate the value of the time constant τ .

$$\tau=\frac{L}{R_{eq}}$$

Substitute $2\,\Omega$ for R_{eq} and 0.5 H for L .

$$\tau=\frac{0.5}{2}$$
$$=0.25\text{ s}$$

Therefore, the value of the time constant τ is 0.25 s .

Step 11 of 13

Step-6:

Calculate the value of the constant K_1 .

$$K_1=i(\infty)$$

Substitute -5 A for $i(\infty)$.

$$K_1=-5\text{ A}$$

Therefore, the value of the constant K_1 is -5 A .

Step 12 of 13

Calculate the value of the constant K_2 .

$$K_2=i(0^+)-i(\infty)$$

Substitute -5 A for $i(\infty)$ and -2.5 A for $i(0^+)$.

$$K_2=-2.5-(-5)$$
$$=-2.5+5$$
$$=2.5\text{ A}$$

Therefore, the value of the constant K_2 is 2.5 A .

Step 13 of 13

Recall equation (1).

$$i(t)=K_1+K_2e^{-t/\tau}$$

Substitute 0.25 s for τ , 2.5 A for K_2 and -5 A for K_1 .

$$i(t)=-5+2.5\,e^{-t/0.25}\text{ A}$$

Therefore, the value of the current $i(t)$ is $\boxed{-5+2.5\,e^{-t/0.25}\text{ A}}$.

Step 1 of 23

Consider the Figure P7.64 from the textbook

Step 1:

List the value of the current: $i_L(t)$ for $K_1 + K_2 e^{-6.5t}$ (1)

Step 2:

Consider the circuit diagram at $t = 0^-$

Figure 1

Step 2 of 23

Apply Kirchhoff's Voltage Law in Loop-1

$$-105 + i_L(t)(12) + i_L(t) - i_L(t)(18) + i_L(t) + i_L(t) + i_L(t)(6) = 0$$

$$i_L(t)(12 + 18 + 6) - i_L(t)(10) + i_L(t)(6) = 105$$

$$i_L(t)(28) = 105 + i_L(t)(18) - i_L(t)(6)$$

$$i_L(t) = \frac{105 - i_L(t)(18) - i_L(t)(6)}{28}$$

Therefore, the expression for the current $i_L(t)$ is $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$.

Step 3 of 23

Apply Kirchhoff's Voltage Law in Loop-2

$$i_L(t)(15) + i_L(t) - i_L(t)(10) = 0$$

$$i_L(t)(15 + 10) - i_L(t)(10) = 0$$

$$i_L(t)(25) - i_L(t)(10) = 0$$

Substitute $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$ for $i_L(t)$.

$$i_L(t)(25) - \left(\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}\right)(10) = 0$$

$$i_L(t)(25) - \left(\frac{1050 + i_L(t)(180) - i_L(t)(60)}{28}\right) = 0$$

$$i_L(t)(25)(28) - 1050 - i_L(t)(180) + i_L(t)(60) = 0$$

$$i_L(t)(700 - 180) + i_L(t)(60) - 1050 = 0$$

$$i_L(t)(600) + i_L(t)(60) = 1050$$

$$i_L(t)(600 + 60) = 1050$$

$$i_L(t)(660) = 1050$$

$$i_L(t) = \frac{1050 - i_L(t)(60)}{660}$$

$$i_L(t) = \frac{35 - i_L(t)(2)}{28} \quad \text{.....(2)}$$

Therefore, the expression for the current $i_L(t)$ is $\frac{35 - i_L(t)(2)}{20}$.

Step 4 of 23

Apply Kirchhoff's Voltage Law in Loop-3

$$i_L(t)(6) + (i_L(t) + i_L(t))(6) = 0$$

$$i_L(t) + i_L(t) + i_L(t) = 0$$

$$2i_L(t) + i_L(t) = 0$$

Substitute $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$ for $i_L(t)$.

$$2i_L(t) + \frac{105 + i_L(t)(10) - i_L(t)(6)}{28} = 0$$

$$i_L(t)(56) + 105 + i_L(t)(10) - i_L(t)(6) = 0$$

$$i_L(t)(56 + 10 - 6) + i_L(t)(18) + 105 = 0$$

$$i_L(t)(58) + i_L(t)(18) + 105 = 0$$

Step 5 of 23

Substitute $\frac{35 - i_L(t)(2)}{20}$ for $i_L(t)$.

$$i_L(t)(58) + \left(\frac{35 - i_L(t)(2)}{20}\right)(18) + 105 = 0$$

$$i_L(t)(58) + \left(\frac{35 - i_L(t)(2)}{2}\right) + 105 = 0$$

$$i_L(t)(100) + 35 - i_L(t)(2) + 210 = 0$$

$$i_L(t)(100 - 2) + 245 = 0$$

$$i_L(t)(98) = -245$$

$$i_L(t) = -\frac{245}{98}$$

$$i_L(t) = -2.5 \text{ A}$$

Therefore, the value of the current $i_L(t)$ is -2.5 A.

Step 6 of 23

Recall equation (2):

$$i_L(t) = \frac{35 - i_L(t)(2)}{28}$$

Substitute -2.5 A for $i_L(t)$

$$i_L(t) = \frac{35 - (-2.5)(2)}{20}$$

$$= \frac{35 + 5}{20}$$

$$= \frac{40}{20}$$

$$= 2 \text{ A}$$

Therefore, the value of the current $i_L(t)$ is 2 A.

Step 7 of 23

Calculate the value of the current $i_L(0^-)$.

$$i_L(0^-) = i_L(t) + i_L(t)$$

Substitute 2 A for $i_L(t)$ and -2.5 A for $i_L(t)$.

$$i_L(0^-) = -2.5 + 2$$

$$= -0.5 \text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is -0.5 A.

Step 8 of 23

Step-3:

The value of the current through the inductor at $t = 0^-$ is equal to the value of the current at $t = 0^-$.

Therefore, the value of the current $i_L(0^-)$ is -0.5 A.

Step 9 of 23

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

Identify that 15 Ω resistor is shorted.

Apply Kirchhoff's Voltage Law in Loop-1

$$-105 + i_L(t)(12) + i_L(t) - i_L(t)(18) + i_L(t) + i_L(t)(6) = 0$$

$$i_L(t)(12 + 18 + 6) - i_L(t)(10) + i_L(t)(6) = 105$$

$$i_L(t)(28) = 105 + i_L(t)(18) - i_L(t)(6)$$

$$i_L(t) = \frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$$

Therefore, the expression for the current $i_L(t)$ is $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$.

Step 10 of 23

Apply Kirchhoff's Voltage Law in Loop-2

$$i_L(t) - i_L(t)(18) = 0$$

$$i_L(t) - i_L(t) = 0$$

Substitute $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$ for $i_L(t)$.

$$i_L(t) - \left(\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}\right) = 0$$

$$i_L(t)(28) - (105 + i_L(t)(18) - i_L(t)(6)) = 0$$

$$i_L(t)(28) - 105 - i_L(t)(18) + i_L(t)(6) = 0$$

$$i_L(t)(28) - 18) - 105 + i_L(t)(6) = 0$$

$$i_L(t)(18) = 105 - i_L(t)(4)$$

$$i_L(t) = \frac{105 - i_L(t)(4)}{18}$$

$$i_L(t) = \frac{35 - i_L(t)(2)}{6} \quad \text{(3)}$$

Therefore, the expression for the current $i_L(t)$ is $\frac{35 - i_L(t)(2)}{6}$.

Step 11 of 23

Apply Kirchhoff's Voltage Law in Loop-3

$$i_L(t)(6) = (i_L(t) + i_L(t))(6) = 0$$

$$i_L(t) + i_L(t) + i_L(t) = 0$$

$$2i_L(t) + i_L(t) = 0$$

Substitute $\frac{105 + i_L(t)(18) - i_L(t)(6)}{28}$ for $i_L(t)$.

$$2i_L(t) + \frac{105 + i_L(t)(10) - i_L(t)(6)}{28} = 0$$

$$i_L(t)(56) + 105 + i_L(t)(10) - i_L(t)(6) = 0$$

$$i_L(t)(56 + 10 - 6) + i_L(t)(18) + 105 = 0$$

$$i_L(t)(58) + i_L(t)(18) + 105 = 0$$

Step 12 of 23

Substitute $\frac{35 - i_L(t)(2)}{6}$ for $i_L(t)$.

$$i_L(t)(58) + \left(\frac{35 - i_L(t)(2)}{6}\right)(10) + 105 = 0$$

$$i_L(t)(58) + \left(\frac{350 - i_L(t)(20)}{6}\right) + 105 = 0$$

$$i_L(t)(58)(6) + 350 - i_L(t)(20) + (105)(6) = 0$$

$$i_L(t)(348) + 350 - i_L(t)(20) + 630 = 0$$

$$i_L(t)(300 - 20) + 980 = 0$$

$$i_L(t)(280) = -980$$

$$i_L(t) = -\frac{980}{280}$$

$$i_L(t) = -3.5 \text{ A}$$

Therefore, the value of the current $i_L(t)$ is -3.5 A.

Step 13 of 23

Recall equation (3):

$$i_L(t) = \frac{35 - i_L(t)(2)}{6}$$

Substitute -3.5 A for $i_L(t)$

$$i_L(t) = \frac{35 - (-3.5)(2)}{6}$$

$$= \frac{35 + 7}{6}$$

$$= \frac{43}{6}$$

$$= 7 \text{ A}$$

Therefore, the value of the current $i_L(t)$ is 7 A.

Step 14 of 23

Calculate the value of the current $i_L(\infty)$.

$$i_L(\infty) = i_L(t) + i_L(t)$$

Substitute 2 A for $i_L(t)$ and -3.5 A for $i_L(t)$.

$$i_L(\infty) = -3.5 + 7$$

$$= 3.5 \text{ A}$$

Therefore, the value of the current $i_L(\infty)$ is 3.5 A.

Step 14 of 23

Consider the circuit diagram shown in Figure 3 to calculate the equivalent resistance as seen from the opened terminals of the inductor. Identify the delta connection in the circuit.

Figure 3

Step 16 of 23

Calculate the value of the resistance R_1

$$R_1 = \frac{(12)(10)}{12 + 10 + 6}$$

$$= \frac{120}{28}$$

$$= 4.286 \ \Omega$$

Therefore, the value of the resistance R_1 is 4.286Ω

Step 18 of 23

Calculate the value of the resistance R_2

$$R_2 = \frac{(10)(6)}{12 + 10 + 6}$$

$$= \frac{60}{28}$$

$$= 2.143 \ \Omega$$

Therefore, the value of the resistance R_2 is $2.143 \ \Omega$

Step 17 of 23

Calculate the value of the resistance R_3

$$R_3 = \frac{(12)(6)}{12 + 10 + 6}$$

$$= \frac{72}{28}$$

$$= 2.571 \ \Omega$$

Therefore, the value of the resistance R_3 is $2.571 \ \Omega$

Step 18 of 23

Redraw the circuit using wye connected resistors in place of delta connected resistors.

Figure 4

Step 19 of 23

Calculate the value of the equivalent resistance R_{eq}

$$R_{eq} = 2.143 + (4.286)(2.571 + 6)$$

$$= 2.143 + (4.286)(8.571)$$

$$= 2.143 + \left(\frac{(4.286)(8.571)}{4.286 + 8.571}\right)$$

$$= 2.143 + \left(\frac{36.7353}{12.857}\right)$$

$$R_{eq} = 2.143 + 2.857$$

$$= 5 \ \Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $5 \ \Omega$.

Step 20 of 23

Step-5

Calculate the value of the time constant τ.

$$\tau = \frac{L}{R_{eq}}$$

Substitute $5 \ \Omega$ for R_{eq} and 1 H for L.

$$\tau = \frac{1}{5}$$

$$= 0.2 \text{ s}$$

Therefore, the value of the time constant τ is 0.2 s.

Step 21 of 23

Step-6:

Calculate the value of the constant K_1

$$K_1 = i(\infty)$$

Substitute 3.5 A for $i(\infty)$

$$K_1 = 3.5 \text{ A}$$

Therefore, the value of the constant K_1 is 3.5 A.

Step 22 of 23

Calculate the value of the constant K_2.

$$K_2 = i(0^+) - i(\infty)$$

Substitute 3.5 A for $i(\infty)$ and -0.5 A for $i(0^+)$

$$K_2 = -0.5 - 3.5$$

$$= -4 \text{ A}$$

Therefore, the value of the constant K_2 is -4 A.

Step 23 of 23

Recall equation (1):

$$i(t) = K_1 + K_2 e^{-6.5t}$$

Substitute 0.2 s for t, -4 A for K_2 and 3.5 A for K_1.

$$i(t) = 3.5 - 4e^{-6.5 \times 0.2}$$

Therefore, the value of the current $i(t)$ is $\boxed{3.5 - 4e^{-1.3} \text{ A}}$

Step 1 of 8

Refer to Figure P7.68 in the text book.

For t<0, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 8

At $t = 0^+$, Calculate the current through the $4\,\Omega$ resistor.

Calculate the source current.

From Figure 1, the source current is,

$$i_s(0^+) = \frac{V_s}{R_1 + (R_4 \| (R_2 \| R_3))}$$

Substitute $2\,\Omega$ for R_1 , $6\,\Omega$ for R_2 , $12\,\Omega$ for R_3 , $4\,\Omega$ for R_4 and 12 V for V_s in equation.

$$\begin{aligned} i_s(0^+) &= \frac{12}{2+(6\|(12\|4))} \\ &= \frac{12}{2+(3\|6)} \\ &= \frac{12}{2+2} \\ &= 3\text{ A} \end{aligned}$$

Step 3 of 8

For t<0, the current through the $4\,\Omega$ resistor,

$i_4(0^+) = \left(\frac{R_3 \| R_2}{R_4 + (R_3 \| R_2)}\right) i_s$ Substitute $6\,\Omega$ for R_2 , $12\,\Omega$ for R_3 , $4\,\Omega$ for R_4 and 3 A for i_s in equation.

$$\begin{aligned} i_4(0^+) &= \left(\frac{6\|12}{4+(12\|6)}\right)(3) \\ &= \left(\frac{\frac{6\times12}{6+12}}{4+\frac{6\times12}{6+12}}\right)(3) \\ &= \left(\frac{4}{4+4}\right)(3) \\ &= 1.5\text{ A} \end{aligned}$$

Step 4 of 8

The initial voltage across the R_4 is,

$$\begin{aligned} v_o(0^+) &= i_{R_4}(0^+) R_4 \\ &= (1.5)(4) \\ &= 6\text{ V} \end{aligned}$$

Step 5 of 8

for t>0 , Calculate the time constant of the circuit.

The Thevinen's equivalent resistance circuit is shown in Figure 2.

Figure 2

Step 6 of 8

The Thevinen's equivalent resistance is,

$$R_{th} = R_4 + (R_2 \| R_3)$$

Substitute $6\,\Omega$ for R_2 , $12\,\Omega$ for R_3 , $4\,\Omega$ for R_4 in equation.

$$\begin{aligned} R_{th} &= 4 + (12\|6) \\ &= 4 + \frac{12\times6}{12+6} \\ &= 4 + (4) \\ &= 8\,\Omega \end{aligned}$$

Step 7 of 8

The time constant of the circuit is,

$$\begin{aligned} \tau &= \frac{L}{R_{th}} \\ &= \frac{2}{8} \\ &= 0.25\text{ sec} \end{aligned}$$

Step 8 of 8

Calculate the voltage across $4\,\Omega$ resistor is,

$$v_o(t) = v_o(0^+) e^{-t/\tau}\text{ V}$$

Substitute 6 V for $v_o(0^+)$ and 0.25 sec for τ in equation.

$$\begin{aligned} v_o(t) &= 6e^{-t/(0.25)}\text{ V} \\ &= 6e^{-4t}\text{ V} \end{aligned}$$

Thus, the output voltage across $4\,\Omega$ resistor is $\boxed{6e^{-4t}\text{ V}}$.

Step 1 of 10

7.069P

Refer to Figure P7.69 in the text book.

For t<0, calculate the current passing through the inductor.

At $t = 0^-$, the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c}{3} + v_c + \frac{v_c - 12}{3} = 0$$

$$\frac{5v_c}{3} - 4 = 0$$

$$\frac{5v_c}{3} = 4$$

$$v_c = 2.4 \text{ V}$$

At t=0⁻ , The current passing through the inductor is,

$$i_L(0^-) = \frac{v_c}{1}$$

Substitute 2.4 V for v_c in the equation.

$$i_L(0^-) = \frac{2.4}{1}$$
$$= 2.4 \text{ A}$$

Step 3 of 10

At $t = 0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 4 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c(0^+)}{3} + \frac{v_c(0^+) - 12}{3} = -2.4$$

$$\frac{2v_c(0^+)}{3} - 4 = -2.4$$

$$\frac{2v_c(0^+)}{3} = 1.6$$

$$v_c(0^+) = 2.4 \text{ V}$$

The initial voltage, $v_o(0^+)$ is,

$$v_o(0^+) = 12 - v_c(0^+)$$

Substitute 2.4 V for $v_c(0^+)$ in equation.

$$v_o(0^+) = 12 - 2.4$$
$$= 9.6 \text{ V}$$

Step 5 of 10

At $t = \infty$, Calculate the current passing through the inductor.

The resultant circuit is shown in Figure 3.

Figure 3

Step 6 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c(\infty)}{3} + \frac{v_c(\infty) - 12}{3} = -2.4$$

$$\frac{2v_c(\infty)}{3} - 4 = -2.4$$

$$\frac{2v_c(\infty)}{3} = 1.6$$

$$v_c(\infty) = 2.4 \text{ V}$$

Step 7 of 10

The initial voltage, $v_o(\infty)$ is,

$$v_o(\infty) = 12 - v_c(\infty)$$

Substitute 2.4 V for $v_c(\infty)$ in equation.

$$v_o(\infty) = 12 - 2.4$$
$$= 9.6 \text{ V}$$

Step 8 of 10

for t>0 , Calculate the time constant of the circuit.

The Thevinen's equivalent resistance circuit is shown in Figure 4.

Figure 4

Step 9 of 10

Thevinen's equivalent resistance is,

$$R_{th} = R_4 + (R_3 \parallel R_5)$$

Substitute **1 Ω for R_4** , **3 Ω for R_3** , **3 Ω for R_5** in equation.

$$R_{th} = 1 + (3 \parallel 3)$$
$$= 2.5\ \Omega$$

The time constant of the circuit is,

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{5}{2.5}$$
$$= 2 \text{ sec}$$

Step 10 of 10

The general solution for current $v_o(t)$ is,

$$v_o(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1 .

$$K_1 = v_o(\infty)$$

Substitute 9.6 V for $v_o(\infty)$ in the equation.

$$K_1 = 9.6 \text{ V}$$

Calculate the value of K_2 .

$$K_2 = (v_o(0^+) - v_o(\infty))$$

Substitute 9.6 V for $v_o(\infty)$ and 9.6 V for $v_o(0^+)$ in the equation.

$$K_2 = (9.6 - 9.6)$$
$$= 0 \text{ V}$$

Substitute **9.6 V** for K_1 and **0 V** for K_2 in equation (1).

$$v_o(t) = 9.6 + (0)e^{-t/2}$$
$$= 9.6 \text{ V}$$

Thus, the output current is $\boxed{9.6 \text{ V}}$.

Step 1 of 9

7.070P

Refer to Figure P7.70 in the text book.

Calculate the equivalent inductance.

$$L_{eq} = L_1 \parallel L_2$$
$$= \frac{L_1 L_2}{L_1 + L_2}$$

Substitute 4 mH for L_1 and 12 mH for L_2 in equation.

$$L_{eq} = \frac{4(12)}{4+12}$$
$$= 3\ \text{mH}$$

Redraw the circuit as shown in Figure 1.

Figure 1

Step 2 of 9

For t<0, the circuit reaches steady state and the resultant circuit is shown in Figure 1.

Figure 2

Step 3 of 9

At $t = 0^-$. Calculate the current passes through the inductor.

From Figure 1, it is clear that is, the entire source current is passing through the inductor.

Therefore,

$$i_s = i_L(0^-)$$
$$= 10\ \text{mA}$$

An inductor does not allow sudden change in current.

$$i_L(0^+) = i_L(0^-)$$
$$= 10\ \text{mA}$$

Step 4 of 9

Redraw the circuit at $t = 0^+$ is shown in Figure 3.

Figure 3

Calculate the initial current $i_o(0^+)$.

From Figure 3, it is clear that is, 10 mA current is passing through the $10\ \text{k}\Omega$ resistor.

Therefore,

$$i_L(0^+) = i_o(0^+)$$
$$i_o(0^+) = 10\ \text{mA}$$

Step 5 of 9

At $t = \infty$, the circuit reaches steady state and the resultant circuit is shown in Figure 4.

Figure 4

Step 6 of 9

At $t = \infty$, Calculate the current passes through the $10\ \text{k}\Omega$ resistor.

Calculate the current , $i_o(\infty)$.

From Figure 1, the source current is,

$$i_o(\infty) = \left(\frac{R_1}{R_1 + R_2}\right) i_s$$

Substitute, $10\ \text{k}\Omega$ for R_1 , $10\ \text{k}\Omega$ for R_2 , and 10 mA for i_s in equation.

$$i_o(\infty) = \left(\frac{10}{10+10}\right)(10)$$
$$= \frac{10}{2}$$
$$= 5\ \text{mA}$$

Step 7 of 9

The Thevinen's equivalent resistance circuit is shown in Figure 3.

Figure 5

Step 8 of 9

Calculate the Thevinen's resistance.

$$R_{th} = R_2 + R_1$$

Substitute $10\ \text{k}\Omega$ for R_1 , $10\ \text{k}\Omega$ for R_2 in equation.

$$R_{th} = 10 + 10$$
$$= 20\ \text{k}\Omega$$

The time constant of the circuit is,

$$\tau = \frac{L_{eq}}{R_{th}}$$
$$= \frac{3}{20}$$
$$= 0.15\ \mu\text{sec}$$

Step 9 of 9

The general solution for current $i_o(t)$ is,

$$i_o(t) = K_1 + K_2 e^{-t/\tau} \text{ ..... (1)}$$

Calculate the value of K_1 .

$$K_1 = i_o(\infty)$$

Substitute 5 mA for $i_o(\infty)$ in the equation.

$$K_1 = 5\ \text{mA}$$

Calculate the value of K_2 .

$$K_2 = \left(i_o(0^+) - i_o(\infty)\right)$$

Substitute 5 mA for $i_o(\infty)$ and $10\ \text{mA}$ for $i_o(0^+)$ in the equation.

$$K_2 = (5 - 10)$$
$$= -5\ \text{mA}$$

Substitute $5\ \text{mA}$ for K_1 and $-5\ \text{mA}$ for K_2 in equation (1).

$$i_o(t) = 5 - 5e^{-t/(0.15\times10^{-6})}$$
$$= \left(5 - 5e^{-6.666\times10^6 t}\right)\ \text{mA}$$

Thus, the output current is $\boxed{\left(5 - 5e^{-6.666\times10^6 t}\right)\ \text{mA}}$.

Step 1 of 14

Refer to Figure P7.71 in the text book.

For t<0, the circuit reaches steady state condition. So replace the inductor with short circuit.

Redraw the circuit diagram as shown in Figure 1.

Figure 1

Step 2 of 14

Apply Kirchhoff's current law at node 1.

$$\frac{v_a-12}{6}+\frac{v_a}{12}+\frac{v_a}{3}=0$$

$$v_a\left(\frac{1}{6}+\frac{1}{12}+\frac{1}{3}\right)=2$$

$$v_a\left(\frac{14}{24}\right)=2$$

$$v_a=3.428\text{ V}$$

Step 3 of 14

At $t=0^-$. Calculate the current through the resistor, R_3.

$$i_o(0^-)=\frac{v_a}{R_3}$$

Substitute 3.428 V for v_a and 3 Ω for R_3 .

$$i_o(0^-)=\frac{3.428}{3}$$
$$=1.14\text{ A}$$

Step 4 of 14

At $t=0^-$. Calculate the current through the resistor, R_4

$$i_4(0^-)=\frac{V_{s2}}{R_4}$$

Substitute -6 V for V_{s2} and 3 Ω for R_4

$$i_4(0^-)=\frac{-6}{3}$$
$$=-2\text{ A}$$

Step 5 of 14

The initial current through the inductor is,

$$i_L(0^-)=i_4(0^-)+i_o(0^-)$$

Substitute -2 A for $i_4(0^-)$ and 1.14 A for $i_o(0^-)$ in equation.

$$i_L(0^-)=-2+1.14$$
$$=-0.86\text{ A}$$

Step 6 of 14

The inductor does not allow sudden change in current.

Therefore, the current is,

$$i_L(0^+)=i_L(0^-)$$
$$=-0.86\text{ A}$$

Step 7 of 14

At $t=0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 8 of 14

From Figure 2, it is clear that is the initial current $i_o(0^-)$ is,

$$i_o(0^+)=i_L(0^+)$$
$$=-0.86\text{ A}$$

At $t=\infty$, the resultant circuit is shown in Figure 3.

Figure 3

Step 9 of 14

Calculate the stead state current, $i_o(\infty)$.

$$i_s(\infty)=\frac{V_{s1}}{R_1+(R_2\parallel R_3)}$$

Substitute 3 Ω for R_3 , 6 Ω for R_1 , 12 Ω for R_2 in equation.

$$i_s(\infty)=\frac{12}{6+(12\parallel 3)}$$
$$=\frac{12}{6+2.4}$$
$$=1.4285\ \Omega$$

Step 18 of 14

The steady state current $i_o(\infty)$ is,

$$i_o(\infty)=\left(\frac{R_2}{(R_2+R_3)}\right)i_s(\infty)$$

Substitute 3 Ω for R_3 , 12 Ω for R_2 and 1.4285 for $i_s(\infty)$ in equation.

$$i_o(\infty)=\left(\frac{12}{12+3}\right)(1.4285)$$
$$=1.1428\text{ A}$$

Step 11 of 14

The Thevinen's equivalent resistance circuit is shown in Figure 4.

Figure 4

Step 12 of 14

Calculate the Thevinen's resistance.

$$R_{th}=(R_2\parallel R_1)+R_3$$

Substitute 3 Ω for R_3 , 6 Ω for R_1 , 12 Ω for R_2 in equation.

$$R_{th}=(6\parallel 12)+3$$
$$=\frac{6\times 12}{6+12}+3$$
$$=4+3$$
$$=7\ \Omega$$

The time constant of the circuit is,

$$\tau=\frac{L_{eq}}{R_{th}}$$
$$=\frac{0.2}{7}$$
$$=0.02875\text{ sec}$$

Step 13 of 14

The general solution for current $i_o(t)$ is,

$$i_o(t)=K_1+K_2e^{-t/\tau}\ \text{.....}\ (1)$$

Calculate the value of K_1 .

$$K_1=i_o(\infty)$$

Substitute 1.1428 A for $i_o(\infty)$ in the equation.

$$K_1=1.1428\text{ mA}$$

Step 14 of 14

Calculate the value of K_2 .

$$K_2=\left(i_o(0^+)-i_o(\infty)\right)$$

Substitute 1.1428 A for $i_o(\infty)$ and -0.86 A for $i_o(0^+)$ in the equation.

$$K_2=(-0.86-1.1428)$$
$$=-2.0028\text{ A}$$

Substitute 1.1428 A for K_1 and -2.0028 A for K_2 in equation (1).

$$i_o(t)=1.1428-2.0028e^{-t/0.02875}$$
$$=\left(1.1428-2.0028e^{-34.782t}\right)\text{ A}$$

Thus, the output current is $\boxed{\left(1.1428-2.0028e^{-34.782t}\right)\text{ A}}$

Step 1 of 10

7.072P

Refer to Figure P7.69 in the text book.

For t<0, calculate the current passing through the inductor.

At $t = 0^-$, the resultant circuit is shown in Figure 1.

Figure 1

Step 2 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c}{3} + v_c + \frac{v_c - 12}{3} = 0$$

$$\frac{5v_c}{3} - 4 = 0$$

$$\frac{5v_c}{3} = 4$$

$$v_c = 2.4 \text{ V}$$

At t=0⁻ , The current passing through the inductor is,

$$i_L(0^-) = \frac{v_c}{1}$$

Substitute 2.4 V for v_c in the equation.

$$i_L(0^-) = \frac{2.4}{1}$$
$$= 2.4 \text{ A}$$

Step 3 of 10

At $t = 0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 4 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c(0^+)}{3} + \frac{v_c(0^+) - 12}{3} = -2.4$$

$$\frac{2v_c(0^+)}{3} - 4 = -2.4$$

$$\frac{2v_c(0^+)}{3} = 1.6$$

$$v_c(0^+) = 2.4 \text{ V}$$

The initial voltage, $v_o(0^+)$ is,

$$v_o(0^+) = 12 - v_c(0^+)$$

Substitute 2.4 V for $v_c(0^+)$ in equation.

$$v_o(0^+) = 12 - 2.4$$
$$= 9.6 \text{ V}$$

Step 5 of 10

At $t = \infty$, Calculate the current passing through the inductor.

The resultant circuit is shown in Figure 3.

Figure 3

Step 6 of 10

Apply Kirchhoff's current law at node a.

$$\frac{v_c(\infty)}{3} + \frac{v_c(\infty) - 12}{3} = -2.4$$

$$\frac{2v_c(\infty)}{3} - 4 = -2.4$$

$$\frac{2v_c(\infty)}{3} = 1.6$$

$$v_c(\infty) = 2.4 \text{ V}$$

Step 7 of 10

The initial voltage, $v_o(\infty)$ is,

$$v_o(\infty) = 12 - v_c(\infty)$$

Substitute 2.4 V for $v_c(\infty)$ in equation.

$$v_o(\infty) = 12 - 2.4$$
$$= 9.6 \text{ V}$$

Step 8 of 10

for t>0 , Calculate the time constant of the circuit.

The Thevinen's equivalent resistance circuit is shown in Figure 4.

Figure 4

Step 9 of 10

Thevinen's equivalent resistance is,

$$R_{th} = R_4 + (R_3 \| R_5)$$

Substitute $1\ \Omega$ for R_4 , $3\ \Omega$ for R_3 , $3\ \Omega$ for R_5 in equation.

$$R_{th} = 1 + (3 \| 3)$$
$$= 2.5\ \Omega$$

The time constant of the circuit is,

$$\tau = \frac{L}{R_{th}}$$
$$= \frac{5}{2.5}$$
$$= 2 \text{ sec}$$

Step 10 of 10

The general solution for current $v_o(t)$ is,

$$v_o(t) = K_1 + K_2 e^{-t/\tau} \quad \text{..... (1)}$$

Calculate the value of K_1 :

$$K_1 = v_o(\infty)$$

Substitute 9.6 V for $v_o(\infty)$ in the equation.

$$K_1 = 9.6 \text{ V}$$

Calculate the value of K_2 .

$$K_2 = \left(v_o(0^+) - v_o(\infty)\right)$$

Substitute 9.6 V for $v_o(\infty)$ and 9.6 V for $v_o(0^+)$ in the equation.

$$K_2 = (9.6 - 9.6)$$
$$= 0 \text{ V}$$

Substitute 9.6 V for K_1 and 0 V for K_2 in equation (1).

$$v_o(t) = 9.6 + (0)e^{-t/2}$$
$$= 9.6 \text{ V}$$

Thus, the output current is $\boxed{9.6 \text{ V}}$.

Step 1 of 14

Refer to Figure P7.71 in the text book.

For t<0, the circuit reaches steady state condition. So replace the inductor with short circuit.

Redraw the circuit diagram as shown in Figure 1.

Figure 1

Step 2 of 14

Apply Kirchhoff's current law at node 1.

$$\frac{v_a-12}{6}+\frac{v_a}{12}+\frac{v_a}{3}=0$$

$$v_a\left(\frac{1}{6}+\frac{1}{12}+\frac{1}{3}\right)=2$$

$$v_a\left(\frac{14}{24}\right)=2$$

$$v_a=3.428\text{ V}$$

Step 3 of 14

At $t=0^-$. Calculate the current through the resistor, R_3.

$$i_o(0^-)=\frac{v_a}{R_3}$$

Substitute 3.428 V for v_a and 3 Ω for R_3 .

$$i_o(0^-)=\frac{3.428}{3}$$
$$=1.14\text{ A}$$

Step 4 of 14

At $t=0^-$. Calculate the current through the resistor, R_4.

$$i_4(0^-)=\frac{V_{s2}}{R_4}$$

Substitute -6 V for V_{s2} and 3 Ω for R_4 .

$$i_4(0^-)=\frac{-6}{3}$$
$$=-2\text{ A}$$

Step 5 of 14

The initial current through the inductor is,

$$i_L(0^-)=i_4(0^-)+i_o(0^-)$$

Substitute -2 A for $i_4(0^-)$ and 1.14 A for $i_o(0^-)$ in equation.

$$i_L(0^-)=-2+1.14$$
$$=-0.86\text{ A}$$

Step 6 of 14

The inductor does not allow sudden change in current.

Therefore, the current is,

$$i_L(0^+)=i_L(0^-)$$
$$=-0.86\text{ A}$$

Step 7 of 14

At $t=0^+$, the resultant circuit is shown in Figure 2.

Figure 2

Step 8 of 14

From Figure 2, it is clear that is the initial current $i_o(0^+)$ is,

$$i_o(0^+)=i_L(0^+)$$
$$=-0.86\text{ A}$$

At $t=\infty$, the resultant circuit is shown in Figure 3.

Figure 3

Step 9 of 14

Calculate the stead state current, $i_o(\infty)$.

$$i_s(\infty)=\frac{V_{s1}}{R_1+(R_2\parallel R_3)}$$

Substitute 3 Ω for R_3 , 6 Ω for R_1 , 12 Ω for R_2 in equation.

$$i_s(\infty)=\frac{12}{6+(12\|3)}$$
$$=\frac{12}{6+2.4}$$
$$=1.4285\ \Omega$$

Step 10 of 14

The steady state current $i_o(\infty)$ is,

$$i_o(\infty)=\left(\frac{R_2}{(R_2+R_3)}\right)i_s(\infty)$$

Substitute 3 Ω for R_3 , 12 Ω for R_2 and 1.4285 for $i_s(\infty)$ in equation.

$$i_o(\infty)=\left(\frac{12}{12+3}\right)(1.4285)$$
$$=1.1428\text{ A}$$

Step 11 of 14

The Thevinen's equivalent resistance circuit is shown in Figure 4.

Figure 4

Step 12 of 14

Calculate the Thevinen's resistance.

$$R_{th}=(R_2\|R_1)+R_3$$

Substitute 3 Ω for R_3 , 6 Ω for R_1 , 12 Ω for R_2 in equation.

$$R_{th}=(6\|12)+3$$
$$=\frac{6\times12}{6+12}+3$$
$$=4+3$$
$$=7\ \Omega$$

The time constant of the circuit is,

$$\tau=\frac{L_{eq}}{R_{th}}$$
$$=\frac{0.2}{7}$$
$$=0.02875\text{ sec}$$

Step 13 of 14

The general solution for current $i_o(t)$ is,

$$i_o(t)=K_1+K_2e^{-t/\tau}\ \text{.....}\ (1)$$

Calculate the value of K_1 .

$$K_1=i_o(\infty)$$

Substitute 1.1428 A for $i_o(\infty)$ in the equation.

$$K_1=1.1428\text{ mA}$$

Step 14 of 14

Calculate the value of K_2 .

$$K_2=\left(i_o(0^+)-i_o(\infty)\right)$$

Substitute 1.1428 A for $i_o(\infty)$ and -0.86 A for $i_o(0^+)$ in the equation.

$$K_2=(-0.86-1.1428)$$
$$=-2.0028\text{ A}$$

Substitute 1.1428 A for K_1 and -2.0028 A for K_2 in equation (1).

$$i_o(t)=1.1428-2.0028e^{-t/0.02875}$$
$$=\left(1.1428-2.0028e^{-34.782t}\right)\text{ A}$$

Thus, the output current is $\boxed{\left(1.1428-2.0028e^{-34.782t}\right)\text{ A}}$.

Step 1 of 7

Refer to Figure P7.74 in the textbook.

For $t < 0$, the switch is opened and the inductor acts as short circuit at $t = 0^-$ due to steady state.

Draw the modified circuit to calculate the initial current through the inductor.

Figure 1

Step 2 of 7

Apply nodal analysis at the node V_1.

$$\frac{V_1-12}{3}+\frac{V_1}{6}+\frac{V_1-V_2}{2}=0$$

$$V_1\left(\frac{1}{3}+\frac{1}{6}+\frac{1}{2}\right)-V_2\left(\frac{1}{2}\right)=\frac{12}{3}$$

$$V_1\left(\frac{2+3+1}{6}\right)-V_2\left(\frac{1}{2}\right)=\frac{12}{3}$$

$$2V_1-V_2=8$$

$V_2=2V_1-8$ ..... (1)

Apply nodal analysis at the node V_1.

$$\frac{V_2}{4}+\frac{V_2-V_1}{2}=4$$

$$V_2\left(\frac{1}{4}+\frac{1}{2}\right)-V_1\left(\frac{1}{2}\right)=4$$

$$\frac{3V_2-2V_1}{4}=4$$

$3V_2-2V_1=16$ ..... (2)

Step 3 of 7

Substitute $2V_1-8$ for V_2 in equation (2).

$$3(2V_1-8)-2V_1=16$$

$$4V_1=16+24$$

$$V_1=10\text{ V}$$

Substitute 10 V for V_1 in equation (1).

$$\begin{aligned}V_2&=2V_1-8\\&=2(10)-8\\&=12\text{ V}\end{aligned}$$

Calculate the value of the initial current through the inductor, $i_L(0)$.

$$\begin{aligned}i_L(0)&=\frac{V_1-V_2}{2}\\&=\frac{10-12}{2}\\&=-1\text{ A}\end{aligned}$$

Step 4 of 7

For $t > 0$, the switch is closed. Replace the inductor with current source and calculate the initial output current.

Draw the modified circuit to calculate the initial output current.

Figure 2

Apply nodal analysis at the output node to calculate the initial value.

$$i(0^+)-4+1=0$$

$$i(0^+)=3\text{ A}$$

Step 5 of 7

At $t=\infty$, inductor is at steady state and acts as short circuit.
Draw the modified circuit to calculate the final output current.

Figure 3

The source current flows through the shorted switch because of negligible resistance. The current through the $4\ \Omega$ resistor is zero.

$$i(\infty)=0\text{ A}$$

Step 6 of 7

Open the current source and short the voltage source and look into the opened inductor to calculate the equivalent resistance for time constant.

Draw the modified circuit to calculate the equivalent resistance for time constant.

Figure 4

The equivalent resistance is,

$$\begin{aligned}R_{Th}&=0+4\\&=4\ \Omega\end{aligned}$$

Step 7 of 7

Calculate the value of time constant, τ.

$$\tau=\frac{L}{R_{Th}}$$

Substitute $4\ \Omega$ for R_{Th} and 1 H for L.

$$\begin{aligned}\tau&=\frac{1}{4}\\&=0.25\text{ s}\end{aligned}$$

Calculate the expression for output current.

$$i_o(t)=i(\infty)+\left[i(0)-i(\infty)\right]e^{-\frac{t}{\tau}}$$

Substitute 0 A for $i(\infty)$, 3 A for $i(0^+)$ and 0.25 s for τ.

$$\begin{aligned}i_o(t)&=0+[3-0]e^{-\frac{t}{0.25}}\\&=3e^{-4t}\text{ A}\end{aligned}$$

Thus, the expression for the output current, $i_o(t)$ is $\boxed{3e^{-4t}\text{ A}}$.

Step 1 of 9

Refer to Figure P7.65 in the textbook.

Step-1:

The expression of the current $i_o(t)$ is,

$K_1 + K_2 e^{-6t}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 9

Apply Kirchhoff's voltage law to loop-1.

$$6 + (i_1(t) - i_2(t))(6) = 0$$
$$1 + i_1(t) - i_2(t) = 0$$
$$i_2(t) = i_1(t) + 1$$

Therefore, the expression for the current $i_2(t)$ is $i_1(t) + 1$.

Apply Kirchhoff's voltage law to loop-2.

$$i_2(t)(2+4) + (i_2(t) - i_1(t))(6) - 6 = 0$$
$$i_2(t)(2+4+6) - i_1(t)(6) - 6 = 0$$
$$i_2(t)(12) - i_1(t)(6) - 6 = 0$$
$$i_2(t)(2) - i_1(t) - 1 = 0$$

Substitute $i_1(t) + 1$ for $i_2(t)$

$$(i_1(t) + 1)(2) - i_1(t) - 1 = 0$$
$$2i_1(t) + 2 - i_1(t) - 1 = 0$$
$$i_1(t) + 1 = 0$$
$$i_1(t) = -1 \text{ A}$$

Therefore, the value of the current $i_1(t)$ is -1 A.

Therefore, the value of the current $i_L(0^-)$ is -1 A.

Step 3 of 9

Step-3:

Consider the circuit diagram at $t = 0^+$.

Figure 2

Step 4 of 9

Apply Kirchhoff's voltage law to loop-1.

$$(i_1(t) - (-1))(6) + i_1(t)(2) = 0$$
$$i_1(t)(6+2) + 6 = 0$$
$$i_1(t)(8) = -6$$
$$i_1(t) = -\frac{6}{8}$$
$$i_1(t) = -0.75 \text{ A}$$

Therefore, the value of current $i_1(t)$ is -0.75 A.

Step 5 of 9

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 3

Step 6 of 9

Apply Kirchhoff's voltage law to loop-1.

$$-6 + [i_1(t) + i_2(t)](6) = 0$$
$$i_1(t) + i_2(t) = 1$$
$$i_1(t) = 1 - i_2(t)$$

Therefore, the expression for the current $i_1(t)$ is $1 - i_2(t)$.

Apply Kirchhoff's voltage law to loop-2.

$$i_2(t)(2) + (i_2(t) + i_1(t))(6) = 0$$
$$i_2(t)(2+6) + i_1(t)(6) = 0$$
$$i_2(t)(8) + i_1(t)(6) = 0$$
$$i_2(t)(4) + i_1(t)(3) = 0$$

Substitute $1 - i_2(t)$ for $i_1(t)$.

$$i_2(t)(4) + (1 - i_2(t))(3) = 0$$
$$i_2(t)(4) + 3 - i_2(t)(3) = 0$$
$$i_2(t)(4-3) = -3$$
$$i_2(t) = -3 \text{ A}$$

Therefore, the value of the current $i_1(t)$ is -3 A.

Therefore, the value of the current $i_L(\infty)$ is -3 A.

Step 7 of 9

Consider the circuit diagram shown in Figure 4 to calculate the equivalent resistance as seen from the opened terminals of the inductor.

Figure 4

Step 8 of 9

Notice that $4\ \Omega$ resistor is shorted.

Calculate the value of the equivalent resistance R_{eq}

$$R_{eq} = 6 \| 2$$
$$= \frac{(2)(6)}{2+6}$$
$$= \frac{12}{8}$$
$$= \frac{3}{2}$$
$$= 1.5\ \Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $1.5\ \Omega$.

Step-5:

Calculate the value of the time constant τ.

$$\tau = \frac{L}{R_{eq}}$$

Substitute $1.5\ \Omega$ for R_{eq} and 2 H for L.

$$\tau = \frac{2}{1.5}$$
$$= \frac{4}{3}$$
$$= 1.34 \text{ s}$$

Therefore, the value of the time constant τ is 1.34 s.

Step 9 of 9

Step-6:

Calculate the value of the constant K_1.

$$K_1 = i_o(\infty)$$

Substitute -3 A for $i_o(\infty)$.

$$K_1 = -3 \text{ A}$$

Therefore, the value of the constant K_1 is -3 A.

Calculate the value of the constant K_2.

$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute -3 A for $i_o(\infty)$ and -0.75 A for $i_o(0^+)$

$$K_2 = -0.75 - (-3)$$
$$= -0.75 + 3 \text{ A}$$
$$= 2.25 \text{ A}$$

Therefore, the value of the constant K_2 is 2.25 A.

Recall equation (1).

$$i_o(t) = K_1 + K_2 e^{-6t}$$

Substitute 1.34 s for τ, 2.25 A for K_2 and -3 A for K_1.

$$i_o(t) = -3 + 2.25e^{-t/1.5} \text{ A}$$
$$= -3 + 2.25e^{-0.75t} \text{ A}$$

Therefore, the value of the current $i_o(t)$ is $\boxed{-3 + 2.25e^{-0.75t} \text{ A}}$.

rt circuit and capacitor acts as an open circuit. Draw

LC circuit.

equation,

and the expression for $v_C(t)$ is,

nd particular solutions.

$+ K_2 e^{-2t} \cos t]$

$1.5e^{-2t} \sin t + 24]$

Step 1 of 13

Refer to Figure P7.77 in the textbook

For $t < 0$, one switch is opened and other switch is closed and the inductor acts as short circuit at $t = 0^-$ due to steady state

Draw the modified circuit to calculate the initial current through the inductor

Figure 1

Step 2 of 13

From the super node shown in Figure 1,

$V_2 - V_1 = 12$

$V_2 = 12 + V_1$

Apply nodal analysis at the super node

$$\frac{V_1}{6} + \frac{V_1}{3} + \frac{V_1 - V_2}{2} + \frac{V_1}{2+2} + \frac{V_2 - V_1}{2} = 0$$

$$V_1\left(\frac{1}{6} + \frac{1}{3}\right) + V_1\left(\frac{1}{4}\right) = 0$$

$$2V_1 + V_2 = 0$$

Substitute $12 + V_1$ for V_2.

$$2V_1 + 12 + V_1 = 0$$

$$3V_1 = -12$$

$$V_1 = -4 \text{ V}$$

Substitute -4 V for V_1 in $V_2 = 12 + V_1$.

$$V_2 = 12 - 4$$
$$= 8 \text{ V}$$

Step 3 of 13

Apply nodal analysis at the node V_1 to calculate the value of the initial current through the inductor, $i_L(0)$.

$$i_L(0) = -\frac{V_1}{6} - \frac{V_1 - V_2}{2}$$

Substitute -4 V for V_1 and 8 V for V_2.

$$i_L(0) = \frac{4}{6} - \frac{-4-8}{2}$$
$$= \frac{2}{3} + 6$$
$$= \frac{20}{3} \text{ A}$$

Step 4 of 13

For $t > 0$, one switch is opened and other switch is closed. Replace the inductor with current source and calculate the initial output voltage

Draw the modified circuit to calculate the initial output voltage.

Figure 2

Step 5 of 13

From Figure 2, it is clear that,

$$I_4 = -2 \text{ A}$$

$$I_2 - I_1 = \frac{20}{3}$$

$$I_1 = I_2 - \frac{20}{3}$$

Apply Kirchhoff's voltage law to loop 3.

$$(2+2)(I_3 - I_4) + 3(I_3 - I_2) - 12 = 0$$

$$4(I_3 + 2) + 3(I_3 - I_2) = 12$$

$$-3I_2 + 7I_3 = 4$$

$$I_3 = \frac{7}{3}I_2 - \frac{4}{3}$$

Step 6 of 13

Apply Kirchhoff's voltage law to loop 1 and loop 2 together.

$$2I_1 + 6I_2 + 3(I_2 - I_3) + 12 = 0$$

$$2I_1 + 9I_2 - 3I_3 = -12$$

Substitute $I_2 - \frac{20}{3}$ for I_1.

$$2\left(I_2 - \frac{20}{3}\right) + 9I_2 - 3I_3 = -12$$

$$11I_2 - 3I_3 = -12 + \frac{40}{3}$$

$$11I_2 - 3I_3 = \frac{4}{3} \quad \text{..... (1)}$$

Step 7 of 13

Substitute $\frac{7}{3}I_2 - \frac{4}{3}$ for I_3 in equation (1).

$$11\left(\frac{7}{3}I_2 - \frac{4}{3}\right) - 3I_2 = \frac{4}{3}$$

$$\left(\frac{77}{3} - 3\right)I_2 = \frac{4}{3} + \frac{44}{3}$$

$$68I_2 = 48$$

$$I_2 = 0.706 \text{ A}$$

Apply Ohm's law calculate the initial value.

$$v(0^+) = 2(I_2 - I_4)$$

Substitute 0.706 A for I_2 and -2 A for I_4.

$$v(0^+) = 2(0.706 + 2)$$
$$= 5.412 \text{ V}$$

Step 8 of 13

At $t = \infty$, inductor is at steady state and acts as short circuit.

Draw the modified circuit to calculate the final output current

Figure 3

Step 9 of 13

From the super node shown in Figure 1.

$$V_y - V_x = 12$$

$$V_y = 12 + V_x$$

Apply nodal analysis at the super node.

$$\frac{V_x}{6} + \frac{V_x}{3} + \frac{V_x - V_y}{2} + \frac{V_x}{2+2} + \frac{V_y - V_x}{2} = 2 = 0$$

$$V_x\left(\frac{1}{6} + \frac{1}{3}\right) + V_x\left(\frac{1}{4}\right) = 2$$

$$2V_x + V_y = 8$$

Substitute $12 + V_x$ for V_y.

$$2V_x + 12 + V_x = 8$$

$$3V_x = -4$$

$$V_x = -\frac{4}{3} \text{ V}$$

Step 10 of 13

Substitute $-\frac{4}{3}$ V for V_x in $V_y = 12 + V_x$.

$$V_y = 12 - \frac{4}{3}$$
$$= \frac{32}{3} \text{ V}$$

Apply voltage division rule to calculate the final value of output voltage.

$$v(\infty) = \left(\frac{2}{2+2}\right)V_y$$
$$= \frac{1}{2} \times \frac{32}{3}$$
$$= 5.334 \text{ V}$$

Open the current source and short the voltage source and look into the opened inductor to calculate the equivalent resistance for time constant.

Draw the modified circuit to calculate the equivalent resistance for time constant

Figure 4

Step 11 of 13

Draw the mod

Figure 5

Step 12 of 13

The equivalent resistance is,

$$R_{Th} = 2 \| \{6 + [3 \| (2+2)]\}$$
$$= 2 \| [6 + (3 \| 4)]$$
$$= 2 \| \left[6 + \left(\frac{3 \times 4}{3+4}\right)\right]$$
$$= 2 \| \left[6 + \frac{12}{7}\right]$$
$$= 2 \| \frac{54}{7}$$
$$= \frac{2 \times \frac{54}{7}}{2 + \frac{54}{7}}$$
$$= \frac{108}{14 + 54}$$
$$= 1.588 \ \Omega$$

Step 13 of 13

Calculate the value of time constant, τ.

$$\tau = \frac{L}{R_{Th}}$$

Substitute $1.588 \ \Omega$ for R_{Th} and 2 H for L.

$$\tau = \frac{2}{1.588}$$
$$= 1.26 \text{ s}$$

Calculate the expression for output voltage, $v_o(t)$.

$$v_o(t) = v(\infty) + \left[v(0^+) - v(\infty)\right]e^{-\frac{t}{\tau}}$$

Substitute 5.334 V for $v(\infty)$, 5.412 V for $v(0^+)$ and 1.26 s for τ.

$$v_o(t) = 5.334 + (5.412 - 5.334)e^{-\frac{t}{1.26}}$$
$$= 5.334 + 0.078e^{-0.79t} \text{ V}$$

Thus, the expression for the output voltage, $v_o(t)$ is $\boxed{5.334 + 0.078e^{-0.79t} \text{ V}}$.

Step 1 of 13

Refer to Figure P7.78 in the textbook.

Draw the circuit to make single inductance.

ce.

equivalent inductance.

$$L = 2 \| 3$$
$$= \frac{2\times 3}{2+3}$$
$$= 1.2\ \text{H}$$

Draw the modified circuit diagram.

Figure 2

Step 3 of 13

For $t < 0$, switch is opened and the inductor acts as short circuit at $t = 0^-$ due to steady state.

Draw the modified circuit to calculate the initial current through the inductor.

Figure 3

Step 4 of 13

Apply nodal analysis at the node, V_1.

$$\frac{V_1 - 12}{4} + \frac{V_1}{4} = 3$$
$$V_1\left(\frac{1}{4} + \frac{1}{4}\right) = 3 + 3$$
$$V_1 = 12\ \text{V}$$

Apply nodal analysis at the node, $0\ \text{V}$.

$$\frac{0 - V_1}{4} + \frac{0}{6} + i_L(0) = 0$$
$$i_L(0) = \frac{V_1}{4}$$

Substitute $12\ \text{V}$ for V_1.

$$i_L(0) = \frac{12}{4}$$
$$= 3\ \text{A}$$

Step 5 of 13

For $t > 0$, switch is closed. Replace the inductor with current source and calculate the initial output current.

Draw the modified circuit to calculate the initial output voltage.

Figure 4

Step 6 of 13

Apply nodal analysis at the node, V_x.

$$\frac{V_x - 12}{4} + \frac{V_x - V_z}{4} + \frac{V_x - V_y}{6} + \frac{V_x}{12} = 3$$
$$V_x\left(\frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{12}\right) - V_z\left(\frac{1}{4}\right) - V_y\left(\frac{1}{6}\right) = 3 + 3$$
$$V_x\left(\frac{9}{12}\right) - V_z\left(\frac{5}{12}\right) = 6$$
$$9V_x - 5V_z = 72 \quad \ldots\ldots (1)$$

Apply nodal analysis at the node, V_y.

$$\frac{V_y - V_z}{4} + \frac{V_y - V_x}{6} = 3$$
$$V_y\left(\frac{1}{4} + \frac{1}{6}\right) - V_z\left(\frac{1}{4}\right) - V_x\left(\frac{1}{6}\right) = 3$$
$$V_y\left(\frac{5}{12}\right) - V_z\left(\frac{5}{12}\right) = 3$$
$$-5V_x + 5V_y = 36 \quad \ldots\ldots (2)$$

Add equation (1) and equation (2).

$$4V_x = 108$$
$$V_x = 27\ \text{V}$$

Step 7 of 13

Substitute $27\ \text{V}$ for V_x in equation (1).

$$9(27) - 5V_z = 72$$
$$5V_z = 171$$
$$V_z = 34.2\ \text{V}$$

Apply Ohm's law calculate the initial value.

$$i(0^+) = \frac{V_x - V_z}{6}$$

Substitute $27\ \text{V}$ for V_x and $34.2\ \text{V}$ for V_z.

$$i(0^+) = \frac{27 - 34.2}{6}$$
$$= -1.2\ \text{A}$$

Step 8 of 13

At $t = \infty$, inductor is at steady state and acts as short circuit.

Draw the modified circuit to calculate the final output current.

Figure 5

Step 9 of 13

Apply nodal analysis at the node, V_a.

$$\frac{V_a - 12}{4} + \frac{V_a - 0}{4} + \frac{V_a - 0}{6} + \frac{V_a}{12} = 3$$
$$V_a\left(\frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{12}\right) = 3 + 3$$
$$V_a\left(\frac{9}{12}\right) = 6$$
$$V_a = 8\ \text{V}$$

Apply Ohm's law calculate the final value.

$$i(\infty) = \frac{V_a - 0}{6}$$
$$= 1.334\ \text{A}$$

Step 10 of 13

Open the current source and short the voltage source and look into the opened inductor to calculate the equivalent resistance for time constant.

Draw the modified circuit to calculate the equivalent resistance for time constant.

Figure 6

Step 11 of 13

Draw the modified circuit diagram.

Figure 7

Step 12 of 13

The equivalent resistance is.

$$R_{Th} = (12 \| 4) + (6 \| 4)$$
$$= \left(\frac{12\times 4}{12+4}\right) + \left(\frac{6\times 4}{6+4}\right)$$
$$= 3 + 2.4$$
$$= 5.4\ \Omega$$

Calculate the value of time constant, τ.

$$\tau = \frac{L}{R_{Th}}$$

Substitute $5.4\ \Omega$ for R_{Th} and $1.2\ \text{H}$ for L.

$$\tau = \frac{1.2}{5.4}$$
$$= 0.222\ \text{s}$$

Step 13 of 13

Calculate the expression for output current

$$i_o(t) = i(\infty) + \left[i(0^+) - i(\infty)\right]e^{-\frac{t}{\tau}}$$

Substitute $1.334\ \text{A}$ for $i(\infty)$, $-1.2\ \text{A}$ for $i(0^+)$ and $0.222\ \text{s}$ for τ.

$$i_o(t) = 1.334 + \left(-1.2 - 1.334\right)e^{-\frac{t}{0.222}}$$
$$= 1.334 - 2.534e^{-4.5t}\ \text{A}$$

Thus, the expression for the output current, $i_o(t)$ is $\boxed{1.334 - 2.534e^{-4.5t}\ \text{A}}$

Step 1 of 15

Consider the Figure P7.71 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 15

Calculate the value of the capacitance C_{eq}.

$$C_{eq} = 6\,\mu \| (6\,\mu + 6\,\mu)$$
$$= 6\,\mu \| 12\,\mu$$
$$= \frac{(6\,\mu)(12\,\mu)}{6\,\mu + 12\,\mu}$$
$$= \frac{(6\,\mu)(12\,\mu)}{18\,\mu}$$
$$C_{eq} = 4\,\mu F$$

Therefore, the value of the equivalent capacitance C_{eq} is $4\,\mu F$

Step 3 of 15

Redraw the circuit diagram as shown in Figure 2.

Figure 2

Step 4 of 15

Step-1:

Let the value of the capacitor voltage $v_O(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step 5 of 15

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 3

Step 6 of 15

Calculate the value of the voltage $v_C(0^-)$.

$$v_C(0^-) = (12)\left(\frac{2\text{ k} + 4\text{ k}}{2\text{ k} + 4\text{ k} + 6\text{ k}}\right)$$
$$= (12)\left(\frac{6\text{ k}}{12\text{ k}}\right)$$
$$= (12)\left(\frac{1}{2}\right)$$
$$= 6\text{ V}$$

Therefore, the value of the voltage $v_C(0^-)$ is 6 V.

Step 7 of 15

Step-3:

Figure 4

Step 8 of 15

Calculate the value of the voltage $v_O(0^+)$.

$$v_O(0^+) = (6)\left(\frac{4\text{ k}}{2\text{ k} + 4\text{ k}}\right)$$
$$= (6)\left(\frac{4\text{ k}}{6\text{ k}}\right)$$
$$= (6)\left(\frac{2}{3}\right)$$
$$= 4\text{ V}$$

Therefore, the value of the voltage $v_O(0^+)$ is 4 V.

Step 9 of 15

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 5

The value of the voltage $v_O(\infty)$ is 0 V since no source is present in the circuit.

Step 10 of 15

Consider the circuit diagram shown in Figure 6 to calculate the equivalent resistance as seen from the opened terminals of the capacitor.

Figure 6

Step 11 of 15

Calculate the value of the equivalent resistance R_{eq}.

$$R_{eq} = 4\text{ k} + 2\text{ k}$$
$$= 6\text{ k}\Omega$$

Therefore, the value of the equivalent resistance R_{eq} is $6\text{ k}\Omega$.

Step 12 of 15

Step-5:

Calculate the value of the time constant τ.

$$\tau = R_{eq} \cdot C$$

Substitute $6\text{ k}\Omega$ for R_{eq} and $4\,\mu$F for C.

$$\tau = (6\text{ k}) \cdot (4\,\mu)$$
$$= 0.024\text{ s}$$

Therefore, the value of the time constant τ is 0.024 s.

Step 13 of 15

Step-6:

Calculate the value of the constant K_1.

$$K_1 = v_O(\infty)$$

Substitute 0 V for $v_O(\infty)$.

$$K_1 = 0\text{ V}$$

Therefore, the value of the constant K_1 is 0 V.

Step 14 of 15

Calculate the value of the constant K_2.

$$K_2 = v_O(0^+) - v_O(\infty)$$

Substitute 4 V for $v_O(\infty)$ and 0 V for $v_O(0^+)$

$$K_2 = 4 - 0$$
$$= 4\text{ V}$$

Therefore, the value of the constant K_2 is 4 V.

Step 15 of 15

Recall equation (1).

$$v_O(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0.024 s for τ, 4 V for K_2 and 0 V for K_1.

$$v_O(t) = 0 + 4\,e^{-t/0.024}$$
$$= 4\,e^{-t/0.024}\text{ V}$$

Therefore, the value of the voltage $v_O(t)$ is $\boxed{4\,e^{-t/0.024}\text{ V}}$.

Step 1 of 12

Consider the Figure P7.72 from the text book.

Step-1:

Let the value of the output current $i_L(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 12

The value of the voltage $v_1(t)$ is $10\ \text{V}$.

Apply the Kirchhoff's Voltage Law in the loop.

$$-v_1(t) + i_L(0^-)(12) - 5v_1(t) = 0$$
$$i_L(0^-)(12) = 6v_1(t)$$
$$i_L(0^-) = \frac{6v_1(t)}{12}$$
$$i_L(0^-) = \frac{v_1(t)}{2}$$

Substitute $10\ \text{V}$ for $v_1(t)$.

$$i_L(0^-) = \frac{10}{2}$$
$$= 5\ \text{A}$$

Therefore, the value of the current $i_L(0^-)$ is $5\ \text{A}$.

Step 3 of 12

Step-3:

The value of the current $i_L(0^+)$ is equal to the value of $i_L(0^-)$. Therefore, the value of the current is $5\ \text{A}$.

Step 4 of 12

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

Apply the Kirchhoff's Voltage Law in the loop.

$$-i_1(t)(2) + i_L(\infty)(12) - 5v_1(t) = 0$$

Substitute $i_1(t)(2)$ for $v_1(t)$.

$$-i_1(t)(2) + i_L(\infty)(12) - 5(i_1(t)(2)) = 0$$
$$-i_1(t)(2) + i_L(\infty)(12) - 10i_1(t) = 0$$
$$i_L(\infty)(12) - i_1(t)(12) = 0$$
$$i_L(\infty) = i_1(t)$$

Therefore, the expression for the current $i_L(\infty)$ is $i_1(t)$.

Step 5 of 12

Consider the nodal equation at node-1.

$$i_1(t) + i_L(\infty) = 4$$

Substitute $i_L(\infty)$ for $i_1(t)$.

$$i_L(\infty) + i_L(\infty) = 4$$
$$2i_L(\infty) = 4$$
$$i_L(\infty) = 2\ \text{A}$$

Therefore, the value of the current $i_L(\infty)$ is $2\ \text{A}$.

Step 6 of 12

Consider the circuit diagram shown in Figure 4 to calculate the open circuit voltage as seen from the opened terminals of the inductor.

Figure 3

Step 7 of 12

Since no current flows through 12Ω .

$$v_1(t) = (4)(2)$$
$$v_1(t) = 8\text{V}$$

Calculate the value of the voltage v_{OC} .

$$v_{OC} = v_1(t) + 5v_1(t)$$
$$v_{OC} = 6v_1(t)$$
$$v_{OC} = 48\text{V}$$

Therefore, the value of the open circuit voltage is $48\ \text{V}$.

The value of the short circuit current i_{SC} is equal to the value of $i_L(\infty)$, that is $2\ \text{A}$.

Step 8 of 12

Calculate the value of the Thevenin resistance R_{Th} .

$$R_{Th} = \frac{v_{OC}}{i_{SC}}$$

Substitute $2\ \text{A}$ for i_{SC} and $48\ \text{V}$ for v_{OC} .

$$R_{Th} = \frac{48}{2}$$
$$= 24\,\Omega$$

Therefore, the value of the Thevenin resistance R_{Th} is $24\,\Omega$.

Step 9 of 12

Step-5:

Calculate the value of the time constant τ .

$$\tau = \frac{L}{R_{Th}}$$

Substitute $24\,\Omega$ for R_{eq} and $2\ \text{H}$ for L .

$$\tau = \frac{2}{24}$$
$$= \frac{1}{12}\ \text{s}$$

Therefore, the value of the time constant τ is $\frac{1}{12}\ \text{s}$.

Step 10 of 12

Step-6:

Calculate the value of the constant K_1 .

$$K_1 = i_L(\infty)$$

Substitute $2\ \text{A}$ for $i_L(\infty)$.

$$K_1 = 2\ \text{A}$$

Therefore, the value of the constant K_1 is $2\ \text{A}$.

Step 11 of 12

Calculate the value of the constant K_2 .

$$K_2 = i_L(0^+) - i_L(\infty)$$

Substitute $5\ \text{A}$ for $i_L(\infty)$ and $2\ \text{A}$ for $i_L(0^+)$.

$$K_2 = 5 - 2$$
$$= 3\ \text{A}$$

Therefore, the value of the constant K_2 is $3\ \text{A}$.

Step 12 of 12

Recall equation (1).

$$i_L(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute $0.5\ \text{s}$ for τ , $3\ \text{A}$ for K_2 and $2\ \text{A}$ for K_1

$$i_L(t) = 2 + 3e^{-t/\left(\frac{1}{12}\right)}\ \text{A}$$
$$= 2 + 3e^{-12t}\ \text{A}$$

Therefore, the value of the current $i_L(t)$ is $\boxed{2 + 3e^{-12t}\ \text{A}}$.

Step 1 of 6

Consider the Figure P7.73 from the text book.

Step-1:

Let the value of the output current $i_o(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 6

Calculate the value of the current $i_L(0^-)$ using current division rule.

$$\begin{aligned} i_L(0^-) &= (10\text{ m})\left(\frac{2\text{ k}}{2\text{ k}+2\text{ k}}\right) \\ &= (10\text{ m})\left(\frac{2\text{ k}}{4\text{ k}}\right) \\ &= (10\text{ m})\left(\frac{1}{2}\right) \\ &= 5\text{ mA} \end{aligned}$$

Therefore, the value of the current $i_L(0^-)$ is 5 mA .

The value of the current $i_o(0^-)$ is equal to 5 mA since $i_o(0^-) = i_L(0^-)$.

The value of the constant K_1 is equal to 5 mA .

Step 3 of 6

Step-3:

The value of the current $i_L(0^+)$ is equal to the value of $i_L(0^-)$. Therefore, the value of the current $i_o(0^+)$ is 5 mA .

Step 4 of 6

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

The part of the circuit shown in dotted lines will be shorted and does not effect the value of the current through the inductor at $t = \infty$.

Therefore, the value of the current is $i_o(\infty)$ is 5 mA .

Step 5 of 6

Calculate the value of the constant K_2 .

$$K_2 = i_o(0^+) - i_o(\infty)$$

Substitute 5 mA for $i_o(\infty)$ and 2 A for $i_o(0^+)$.

$$\begin{aligned} K_2 &= 5\text{ m} - 5\text{ m} \\ &= 0\text{ A} \end{aligned}$$

Therefore, the value of the constant K_2 is 0 A .

As the value of the constant K_2 is 0 A , there is no need to find the value of the time constant.

Step 6 of 6

Step-5:

Recall equation (1).

$$i_o(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0 A for K_2 and 5 mA for K_1 .

$$\begin{aligned} i_o(t) &= 5\text{ mA} + (0)\, e^{-t/\tau} \\ &= 5\text{ mA} \end{aligned}$$

Therefore, the value of the output current $i_o(t)$ is $\boxed{5\text{ mA}}$.

placed by a short circuit.

ge in zero time. Hence,

^{3t} A .

25	1.5	1.75
374	0.374	0.374

or $t > 0$.

to switch opening is,

Step 1 of 13

Refer to Figure P7.78 in the textbook.

Draw the circuit to make single inductance.

Figure 1

Step 2 of 13

Calculate the equivalent inductance.

$$L = 2 \| 3$$
$$= \frac{2 \times 3}{2+3}$$
$$= 1.2 \text{ H}$$

Draw the modified circuit diagram.

Figure 2

Step 3 of 13

For $t < 0$, switch is opened and the inductor acts as short circuit at $t = 0^-$ due to steady state.

Draw the modified circuit to calculate the initial current through the inductor.

Figure 3

Step 4 of 13

Apply nodal analysis at the node, V_1 :

$$\frac{V_1 - 12}{4} + \frac{V_1}{4} = 3$$
$$V_1\left(\frac{1}{4} + \frac{1}{4}\right) = 3 + 3$$
$$V_1 = 12 \text{ V}$$

Apply nodal analysis at the node, 0 V .

$$\frac{0 - V_1}{4} + \frac{0}{6} + i_L(0) = 0$$
$$i_L(0) = \frac{V_1}{4}$$

Substitute 12 V for V_1 .

$$i_L(0) = \frac{12}{4}$$
$$= 3 \text{ A}$$

Step 5 of 13

For $t > 0$, switch is closed. Replace the inductor with current source and calculate the initial output current.

Draw the modified circuit to calculate the initial output voltage.

Figure 4

Step 6 of 13

Apply nodal analysis at the node, V_x .

$$\frac{V_x - 12}{4} + \frac{V_x - V_y}{4} + \frac{V_x - V_y}{6} + \frac{V_x}{12} = 3$$
$$V_x\left(\frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{12}\right) - V_y\left(\frac{1}{4} + \frac{1}{6}\right) = 3 + 3$$
$$V_x\left(\frac{9}{12}\right) - V_y\left(\frac{5}{12}\right) = 6$$
$$9V_x - 5V_y = 72 \text{ ..... (1)}$$

Apply nodal analysis at the node, V_y .

$$\frac{V_y - V_x}{4} + \frac{V_y - V_x}{6} = 3$$
$$V_y\left(\frac{1}{4} + \frac{1}{6}\right) - V_x\left(\frac{1}{4} + \frac{1}{6}\right) = 3$$
$$V_y\left(\frac{5}{12}\right) - V_x\left(\frac{5}{12}\right) = 3$$
$$-5V_x + 5V_y = 36 \text{ ..... (2)}$$

Add equation (1) and equation (2).

$$4V_x = 108$$
$$V_x = 27 \text{ V}$$

Step 7 of 13

Substitute 27 V for V_x in equation (1).

$$9(27) - 5V_y = 72$$
$$5V_y = 171$$
$$V_y = 34.2 \text{ V}$$

Apply Ohm's law calculate the initial value.

$$i(0^+) = \frac{V_x - V_y}{6}$$

Substitute 27 V for V_x and 34.2 V for V_y .

$$i(0^+) = \frac{27 - 34.2}{6}$$
$$= -1.2 \text{ A}$$

Step 8 of 13

At $t = \infty$, inductor is at steady state and acts as short circuit.

Draw the modified circuit to calculate the final output current.

Figure 5

Step 9 of 13

Apply nodal analysis at the node, V_a .

$$\frac{V_a - 12}{4} + \frac{V_a - 0}{4} + \frac{V_a - 0}{6} + \frac{V_a}{12} = 3$$
$$V_a\left(\frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{12}\right) = 3 + 3$$
$$V_a\left(\frac{9}{12}\right) = 6$$
$$V_a = 8 \text{ V}$$

Apply Ohm's law calculate the final value.

$$i(\infty) = \frac{V_a - 0}{6}$$
$$= 1.334 \text{ A}$$

Step 10 of 13

Open the current source and short the voltage source and look into the opened inductor to calculate the equivalent resistance for time constant.

Draw the modified circuit to calculate the equivalent resistance for time constant.

Figure 6

Step 11 of 13

Draw the modified circuit diagram.

Figure 7

Step 12 of 13

The equivalent resistance is,

$$R_{Th} = (12 \| 4) + (6 \| 4)$$
$$= \left(\frac{12 \times 4}{12 + 4}\right) + \left(\frac{6 \times 4}{6 + 4}\right)$$
$$= 3 + 2.4$$
$$= 5.4 \ \Omega$$

Calculate the value of time constant, τ .

$$\tau = \frac{L}{R_{Th}}$$

Substitute $5.4 \ \Omega$ for R_{Th} and 1.2 H for L .

$$\tau = \frac{1.2}{5.4}$$
$$= 0.222 \text{ s}$$

Step 13 of 13

Calculate the expression for output current.

$$i_o(t) = i(\infty) + \left[i(0^+) - i(\infty)\right]e^{-\frac{t}{\tau}}$$

Substitute 1.334 A for $i(\infty)$, -1.2 A for $i(0^+)$ and 0.222 s for τ .

$$i_o(t) = 1.334 + (-1.2 - 1.334)e^{-\frac{t}{0.222}}$$
$$= 1.334 - 2.534e^{-4.5t} \text{ A}$$

Thus, the expression for the output current, $i_o(t)$ is $\boxed{1.334 - 2.534e^{-4.5t} \text{ A}}$.

Refer figure P7.76b in text book.

7.084P

For $t < 0$ there is no source is applied.

At $t = 0^-$

$i(t) = 0$

$v_c = 0$

Step 2 of 19

Redraw the circuit at $t = 0^+$

Figure 1.

Step 3 of 19

At $t = 0^+$, capacitor acts as a short circuit. No charge has accumulated on the capacitor.

Therefore

At $t = 0^+$

$v_c = 0$

Determine the value of i_b.

$$i_b = (i)\left(\frac{R_1}{R_1 + R_2}\right)$$
$$= (6)\left(\frac{2}{(2+2)}\right)$$
$$= (6)\left(\frac{2}{4}\right)$$
$$= 3 \text{ A}$$

Step 4 of 19

Determine constant values.

Current expression at $t = 0^+$

$$i_b = K_1 + K_2 e^{-\frac{t}{\tau}}$$

But at $t = 0^+$

$i_b = 3$ A

Therefore,

$3 = K_1 + K_2 e^0$

$3 = K_1 + K_2$ ..... (1)

Step 5 of 19

Determine constant values at $t = 0^+$.

Voltage expression at $t = 0^+$

$$v_C(t) = K_3 + K_4 e^{-\frac{t}{\tau}}$$

But at $t = 0^+$

$v_c = 0$

Therefore,

$0 = K_3 + K_4 e^0$

$0 = K_3 + K_4$ ..... (2)

Step 6 of 19

Determine constant values at $t = \infty$.

At $t = \infty$

$i_C = 0$ A

Current expression at $t = \infty$

$$i_b = K_1 + K_2 e^{-\frac{t}{\tau}}$$

But at $t = \infty$

$i_b = 6$ A

Therefore

$6 = K_1 + K_2 e^\infty$

$6 = K_1$

Step 7 of 19

Determine $v_C(t)$ at $t = \infty$.

$$v_C(t) = i_b R$$
$$= 6(2)$$
$$= 12 \text{ V}$$

Step 8 of 19

Determine constant values.

$$v_C(t) = K_3 + K_4 e^{-\frac{t}{\tau}}$$

$$12 = K_3 + K_4 e^\infty$$
$$= K_3 + 0$$
$$= K_3$$

Step 9 of 19

From equation (1), determine the value of K_2.

$3 = K_1 + K_2$

But

$K_1 = 6$

Therefore

$3 = K_1 + K_2$

$3 = 6 + K_2$

$-3 = K_2$

Step 10 of 19

From equation (2)

$0 = K_3 + K_4$

But

$K_3 = 12$

Therefore

$0 = K_3 + K_4$

$0 = 12 + K_4$

$-12 = K_4$

Step 11 of 19

Determine time constant.

$$\tau = R_{eqv} C$$
$$= (2+2)2$$
$$= 8 \text{ s}$$

Step 12 of 19

Determine current expression.

$$i_b(t) = K_1 + K_2 e^{-\frac{t}{\tau}}$$
$$= 6 - 3e^{-\frac{t}{8}} \text{ A}$$

Current $i_b(t)$ for $0 \le t \le 4.5$ s is $\boxed{6 - 3e^{-\frac{t}{8}} \text{ A}}$.

Step 13 of 19

Determine voltage expression.

$$v_C(t) = K_3 + K_4 e^{-\frac{t}{\tau}}$$
$$= 12 - 12e^{-\frac{t}{8}} \text{ V.}$$

Determine $v_C(t)$ at $t = 4.5$ s.

$$v_C(t) = 12 - 12e^{-\frac{4.5}{8}}$$
$$= 5.16 \text{ V}$$

Step 14 of 19

Redraw the circuit with equivalent capacitor voltage.

Figure 2.

Step 15 of 19

Determine i_b at $t = 4.5^+$ s.

$$i_b = K_5 + K_6 e^{-\frac{(t-4.5)}{\tau}}$$

$t = 4.5^+$

$$i_b = \frac{5.16}{(2+2)}$$
$$= 1.29 \text{ A}$$

$1.29 = K_5 + K_6 e^0$

$1.29 = K_5 + K_6$

Step 18 of 19

Redraw he circuit at $t = \infty$.

Figure 3.

Step 17 of 19

Determine constants at $t = \infty$.

At $t = \infty$

$i_b = 0$ A

$i_b = K_5 + K_6 e^\infty$

$= K_5 + 0$

$= K_5$

$1.29 = K_5 + K_6$

$1.29 = 0 + K_6$

$= K_6$

Step 18 of 19

Determine time constant.

$$\tau = R_{eqv} C$$
$$= C(R_1 + R_2)$$
$$= 2(2+2)$$
$$= 8 \text{ s}$$

Step 19 of 19

Determine current expression.

$$i_b(t) = K_5 + K_6 e^{-\frac{(t-4.5)}{\tau}}$$
$$= 0 + 1.29e^{-\frac{(t-4.5)}{8}}$$
$$= 1.29e^{-\frac{(t-4.5)}{8}} \text{ A}$$

Therefore, the current $i_b(t)$ for $t > 4.5$ s is $\boxed{1.29e^{-\frac{(t-4.5)}{8}} \text{ A}}$

Step 1 of 5

(a)

Refer Figure P7.77b in text book.

Determine energy is stored in inductor at $t = 3s$.

Energy stored in the inductor is $W_L = \frac{1}{2}Li_L^2$

But

$$i_L(t) = \frac{1}{L}\int v_L dt$$

At $t = 3$ s determine $i_L(t)$.

$$\begin{aligned} i_L(3) &= \frac{1}{L}\int v_L dt \\ &= \frac{1}{2}\int_0^2 10dt + \frac{1}{2}\int_2^3 -10dt \\ &= \frac{1}{2}[10t]_0^2 - \frac{1}{2}[10t]_2^3 \end{aligned}$$

Simplify further.

$$\begin{aligned} i_L(3) &= \left(\frac{1}{2}[10(2)] - \frac{1}{2}[10(0)]\right) - \left(\frac{1}{2}[10(3)] - \frac{1}{2}[10(2)]\right) \\ &= 10 - 0 - 15 + 10 = 20 - 15 \\ &= 5 \text{ A} \end{aligned}$$

Energy stored in inductor is,

$$\begin{aligned} W_L &= \frac{1}{2}Li_L^2 \\ &= \frac{1}{2}(2)(5)^2 \\ &= 25 \text{ J} \end{aligned}$$

Therefore, the energy is stored in inductor at $t = 3s$ is $\boxed{25 \text{ J}}$.

Step 2 of 5

(b)

Determine power is supplied by the source at $t = 4s$.

Power supplied by the source is,

$$\begin{aligned} P_S(t) &= v(t)i(t) \\ &= v(t)\left[i_L(t) + \frac{v(t)}{R}\right] \end{aligned}$$

But

$$\begin{aligned} i_L(t) &= \frac{1}{L}\int v_L dt i_L(4) \\ &= \frac{1}{2}\int_0^2 10dt + \frac{1}{2}\int_2^4 -10dt = \frac{1}{2}[10t]_0^2 - \frac{1}{2}[10t]_2^4 \\ &= \left(\frac{1}{2}[10(2)] - \frac{1}{2}[10(0)]\right) - \left(\frac{1}{2}[10(4)] - \frac{1}{2}[10(2)]\right) \end{aligned}$$

Simplify further.

$$\begin{aligned} i_L(t) &= 10 - 0 - 10 - 0 \\ &= 0 \text{ A} \end{aligned}$$

Then

$$\begin{aligned} P_S(t) &= v(t)\left[i_L(t) + \frac{v(t)}{R}\right] \\ &= v(t)\left[0 + \frac{v(t)}{R}\right] \\ &= \frac{v(t)^2}{R} \end{aligned}$$

Simplify further.

$$\begin{aligned} P_S(t) &= \frac{10^2}{2} \\ &= \frac{100}{2} \\ &= 50 \text{ W} \end{aligned}$$

Therefore, the power is supplied by the source at $t = 4s$ is $\boxed{50 \text{ W}}$.

Step 3 of 5

(c)

Determine current $i(t)$ at $t = 6s$.

$$i(t) = i_R + i_L$$

At $t = 6s$ the current through resister is zero.

$$i_L(t) = \frac{1}{L}\int v_L dt$$

$$\begin{aligned} i_L(6) &= \frac{1}{2}\int v_L dt \\ &= \frac{1}{2}\int_0^2 10dt + \frac{1}{2}\int_2^5 -10dt \\ &= \frac{1}{2}[10t]_0^2 - \frac{1}{2}[10t]_2^5 \end{aligned}$$

Step 4 of 5

Simplify further.

$$\begin{aligned} i_L(6) &= \left(\frac{1}{2}[10(2)] - \frac{1}{2}[10(0)]\right) - \left(\frac{1}{2}[10(5)] - \frac{1}{2}[10(2)]\right) \\ &= 10 - 0 - 25 + 10 \\ &= 20 - 25 \\ &= -5 \text{ A} \end{aligned}$$

$$i_L(6) = -5 \text{ A}$$

Determine total current.

$$\begin{aligned} i(t) &= i_R + i_L \\ &= 0 + (-5) \\ &= -5 \text{ A} \end{aligned}$$

Therefore, the current $i(t)$ at $t = 6s$ is $\boxed{-5 \text{ A}}$.

Step 5 of 5

(d)

Determine power is absorbed by inductor.

$$P_L = v(t)i_L(t)$$

$$\begin{aligned} i_L(3) &= \frac{1}{L}\int v_L dt \\ &= \frac{1}{2}\int_0^2 10dt + \frac{1}{2}\int_2^3 -10dt \\ &= \frac{1}{2}[10t]_0^2 - \frac{1}{2}[10t]_2^3 \end{aligned}$$

Simplify further.

$$\begin{aligned} &= \left(\frac{1}{2}[10(2)] - \frac{1}{2}[10(0)]\right) - \left(\frac{1}{2}[10(3)] - \frac{1}{2}[10(2)]\right) \\ &= 10 - 0 - 15 + 10 \\ &= 20 - 15 \\ &= 5 \text{ A} \end{aligned}$$

And

$$v(3) = -10$$

Then power absorbed by the inductor is,

$$\begin{aligned} P_L(3) &= v(t)i_L(t) \\ &= (-10)(5) \\ &= -50 \text{ W} \end{aligned}$$

$$P_L(3) = -50 \text{ W}$$

Thus, the power is absorbed by the inductor at $t = 3s$ is $\boxed{50 \text{ W}}$.

Step 1 of 6

Refer figure P7.79 in textbook.

At $t = (0^-)$ the circuit is in open circuit condition.

Redraw the Figure at $t = (0^+)$ the circuit is in closed position.

Figure 1

Step 2 of 6

Determine equivalent capacitance.

$$C_{equ} = C_1 + C_2$$
$$= \frac{(2)(4)}{(2+4)}$$
$$= \frac{8}{6}\ \text{F}$$

Step 3 of 6

Redraw the Figure with equivalent capacitance.

Figure 2

Step 4 of 6

Determine total voltage across the circuit.

$$V = -10 - 20$$
$$= -30\ \text{V}$$

Determine time constant.

$$\tau = RC$$
$$= 4\left(\frac{8}{6}\right)$$
$$= 5.33\ \text{s}$$

Step 5 of 6

Determine voltage $\text{v}(t)$.

$$\text{v}(t) = Ve^{\frac{-t}{\tau}}$$
$$= -30e^{\frac{-t}{\tau}}$$
$$= -30e^{-0.1875t}\ \text{V}$$

Step 6 of 6

Determine current $i(t)$.

$$i(t) = \frac{\text{v}(t)}{R}$$
$$= \frac{-30e^{-0.1875t}}{4}$$
$$= -7.5e^{-0.1875t}\ \text{A}$$

Thus, the expression for current $i(0^+)$ is $\boxed{-7.5e^{-0.1875t}\ \text{A}}$.

Step 1 of 8

Refer to Figure P7.81 in text book. Redraw the circuit at $t = (0^-)$.

Figure 1

Step 2 of 8

Determine current through inductor at $t = (0^-)$.

$$i_L = \left(\frac{-v_R}{R}\right)$$
$$= \left(\frac{-100}{100}\right)$$
$$= -1 \text{ A}$$

Step 3 of 8

Determine inductance value.

$$\tau = \frac{L}{R}$$

$$\frac{1}{400} = \frac{L}{100}$$
$$L = \frac{1}{4} \text{ H}$$

Step 4 of 8

Redraw the circuit at $t = (0^+)$

Figure 2

Step 5 of 8

Determine time constant.

At $t = (0^+)$

$$\tau = \frac{L}{R_{equi}}$$

But

$$R_{equi} = \frac{R_1 R_2}{R_1 + R_2}$$
$$= \frac{25(100)}{(25+100)}$$
$$= \frac{2500}{125}$$
$$= 20\ \Omega$$

Therefore

$$\tau = \frac{L}{R_{equi}}$$
$$= \frac{\frac{1}{4}}{20}$$
$$= \frac{1}{(4)(20)}$$
$$= \frac{1}{80} \text{ s}$$

Step 6 of 8

Determine voltage across the inductor $v_L(0^+)$.

$$v_L(0^+) = -i_L\left(\frac{25(100)}{25+100}\right)$$
$$= -(-1)\left(\frac{2500}{125}\right)$$
$$= 20 \text{ V}$$

Step 7 of 8

Determine voltage expression.

$$v(t) = k_1 + k_2 e^{\frac{-t}{\tau}}$$

But

At $t = 0^+$ $v_L(t)$ is 20 V.

Therefore

$$v_L(0^+) = k_1 + k_2 e^0$$

$$20 = k_1 + k_2 \text{ ..... (1)}$$

Step 8 of 8

Determine voltage expression.
At $t = \infty$

$$v(t) = k_1 + k_2 e^{\frac{-t}{\tau}}$$

But

At $t = \infty$, $v_L(t)$ is 0 V.

Therefore

$$v(t) = k_1 + k_2 e^{\frac{-t}{\tau}}$$

$$0 = k_1 + k_2 e^{\infty}$$
$$= k_1 + 0$$
$$= k_1$$

Substitute value of k_1 in equation (1)

Then

$$20 = k_1 + k_2$$
$$= 0 + k_2$$
$$= k_2$$

The voltage expression for $t \geq 0^+$ is

$$v_L(t) = 0 + 20e^{\frac{-t}{\frac{1}{80}}}$$
$$= 20e^{-80t}$$

The voltage across the inductor is same as the voltage across the resistor, as both are in parallel.

Therefore, the voltage $v_R(t)$ for $t \geq 0^+$ is $\boxed{20e^{-80t} \text{ V}}$.

Step 1 of 8

Refer to Figure P7.78 in text book for the circuit diagram.

The input voltage is,

$$v_i(t) = 5[u(t) - u(t-0.05)] \text{ V}$$

At $t = 0^-$ there is no voltage applied (according to the step function). That is,

$$\begin{aligned} v_i(0) &= 5[u(0) - u(0-0.05)] \\ &= 5[0] \\ &= 0 \end{aligned}$$

Therefore, the circuit becomes source free network. So the output voltage is zero. That is,

$$\begin{aligned} v_O(0^-) &= v_C(0^-) \\ &= 0 \text{ V} \end{aligned}$$

Step 2 of 8

At $t = 0^+$ the source is applied but initially the capacitor acts as short circuit and there is no voltage appear across capacitor. Therefore,

$$v_C(0) = 0$$

When the capacitor voltage zero, the output voltage becomes input voltage.

$$\begin{aligned} v_O &= v_i \\ &= 5 \text{ V} \end{aligned}$$

The standard expression for the output voltage or capacitor voltage between $0 \le t \le 50 \text{ ms}$ is,

$$v_O = K_1 + K_2 e^{\frac{-t}{\tau}}$$

Here, the final voltage is, $v_C(\infty) = K_1$ and $K_2 = v_C(0^-) - v_C(\infty)$

Therefore, $v_C(0^-) = 5 \text{ V}$

The output voltage at $t = 0$ is,

$$\begin{aligned} v_O(0) &= K_1 + K_2 e^{\frac{-0}{\tau}} \\ 5 &= K_1 + K_2 \end{aligned}$$

Step 3 of 8

At $t = \infty$, the source voltage applied is zero and voltage across capacitor is discharged and therefore no voltage is appeared across capacitor.

$$\begin{aligned} v_C(\infty) &= 0 \\ &= K_1 \end{aligned}$$

Solve the expressions.

$$\begin{aligned} 5 &= K_1 + K_2 \\ 5 &= 0 + K_2 \\ &= K_2 \end{aligned}$$

Step 4 of 8

Determine time constant.

$$\begin{aligned} \tau &= RC \\ &= (100 \times 10^3)(1 \times 10^{-6}) \\ &= 0.1 \text{ s} \end{aligned}$$

Determine the voltage v_o for $0 \le t \le 50 \text{ ms}$.

$$\begin{aligned} v_O &= K_1 + K_2 e^{\frac{-t}{\tau}} \\ &= 0 + 5e^{\frac{-t}{0.1}} \\ &= 5e^{-10t} \text{ V} \end{aligned}$$

Thus, the voltage v_o for $0 \le t \le 50 \text{ ms}$ is, $\boxed{5e^{-10t} \text{ V}}$.

Step 5 of 8

Determine voltage v_o for $t > 50 \text{ ms}$. That is, the output voltage at $t = 50 \text{ ms}$ is,

$$\begin{aligned} v_O &= 5e^{-10t} \\ &= 5e^{-10(50 \times 10^{-3})} \\ &= 5(0.6065) \\ &= 3.03 \text{ V} \end{aligned}$$

Determine voltage across capacitor.

$$\begin{aligned} v_C &= v_i - v_O \\ &= 5 - 3.03 \\ &= 1.97 \text{ V} \end{aligned}$$

Step 6 of 8

Determine voltage v_o for $t = 50^+ \text{ ms}$.

$$v_O = v_i - v_C$$

At $t = 50^+ \text{ ms}$, the input voltage is,

$$v_i = 0$$

Calculate the output voltage.

$$\begin{aligned} v_O &= v_i - v_C \\ &= 0 - 1.97 \\ &= -1.97 \text{ V} \end{aligned}$$

Step 7 of 8

Determine voltage v_o for $t > 50 \text{ ms}$.
At $t = \infty$, the output voltage is,

$$\begin{aligned} v_O &= 0 \\ &= K_3 \end{aligned}$$

The standard expression for the output voltage or capacitor voltage between $t \ge 50 \text{ ms}$ is,

$$v_O = K_3 + K_4 e^{\frac{-(t-0.05)}{\tau}}$$

Solve the expressions.

$$\begin{aligned} -1.97 &= K_3 + K_4 \\ -1.97 &= 0 + K_4 \\ &= K_4 \end{aligned}$$

Step 8 of 8

Determine the voltage v_o for $t \ge 50 \text{ ms}$.

$$\begin{aligned} v_O &= K_3 + K_4 e^{\frac{-(t-0.05)}{\tau}} \\ &= -1.97 e^{-10(t-0.05)} \text{ V} \end{aligned}$$

Thus, the voltage v_o for $t \ge 50 \text{ ms}$ is, $\boxed{-1.97 e^{-10(t-0.05)} \text{ V}}$.

Step 1 of 5

Refer Figure P7.80 in text book.

At $t = 0^-$

$$\begin{aligned} v_{c2}(0^-) &= -v_{c1}(0^-) \\ &= -(-10) \\ &= 10 \text{ V} \end{aligned}$$

Step 2 of 5

Determine equivalent capacitance.

$$\begin{aligned} C_{equi} &= \frac{C_1 C_2}{C_1 + C_2} \\ &= \frac{(0.3)(0.6)}{0.3 + 0.6} \\ &= \frac{0.18}{0.9} \\ &= 0.2 \text{ F} \end{aligned}$$

Step 3 of 5

Redraw the figure with equivalent capacitor.

Figure 1

Step 4 of 5

Determine $\frac{d}{dt}(v(t))$.

For $t > 0$

$$\begin{aligned} v(t) &= 10e^{-5t} \\ \frac{d}{dt}(v(t)) &= \frac{d}{dt}(10e^{-5t}) \\ &= 10\delta(t) - 50e^{-5t} \text{ V} \end{aligned}$$

Step 5 of 5

Determine $i(t)$ at $t > 0$.

$$\begin{aligned} i(t) &= c\frac{dv}{dt} \\ &= (0.2)\left[10\delta(t) + (-50e^{-5t})\right] \\ &= 2\delta(t) - 10e^{-5t} \end{aligned}$$

Current $i(t)$ for $t \geq 0$ is $\boxed{2\delta(t) - 10e^{-5t} \text{ A}}$.

Thus, the voltage $v_{c2}(0^-)$ is $\boxed{10 \text{ V}}$.

Step 1 of 5

Refer to Figure P7.82 in text book for the circuit diagram.

The initial current $i_1(0^-)$ is 2 A.

Redraw the circuit at $t=(0^-)$

Figure 1

Step 2 of 5

The inductor current does not change instantaneously. Therefore,

$$\begin{aligned} i_1(0^-) &= i_1(0^+) \\ &= 2\text{ A} \end{aligned}$$

Redraw the circuit at $i_2(0^+)$.

Figure 2

Step 3 of 5

Determine the current $i_2(0^+)$.

$$\begin{aligned} i_2(0^-) &= i_2(0^+) \\ &= 0\text{ A} \end{aligned}$$

Thus, the current $i_2(0^+)$ is, $\boxed{0\text{ A}}$.

Determine the voltage $v_R(0^+)$.

$$\begin{aligned} v_R(0^+) &= -i_1(0^+)(4) \\ &= -2(4) \\ &= -8\text{ V} \end{aligned}$$

Thus, the voltage $v_R(0^+)$ for $t \geq 0^+$ is, $\boxed{-8\text{ V}}$.

Step 4 of 5

Draw the circuit at $t=\infty$.

Figure 3

Step 5 of 5

From Figure 3, determine current i_1 at $t=(\infty)$.

$$i_1(\infty) = 0\text{ A}$$

Therefore, the current $i_1(\infty)$ is, $\boxed{0\text{ A}}$.

Step 1 of 9

Consider Figure P7.84 from the text book.

Consider the value of the current.

$i(t) = 2.5 + 1.5e^{-4t}$ ..... (1)

Calculate the value of current at $t = 0$.

$$\begin{aligned} i(0) &= 2.5 + 1.5e^{-4(0)} \\ &= 2.5 + 1.5 \\ &= 4\ \text{A} \end{aligned}$$

Therefore, the value of the current $i(0)$ is $4\ \text{A}$.

Step 2 of 9

Calculate the value of current at $t = \infty$.

$$\begin{aligned} i(\infty) &= 2.5 + 1.5e^{-4(\infty)} \\ &= 2.5 + 0 \\ &= 2.5\ \text{A} \end{aligned}$$

Therefore, the value of the current $i(\infty)$ is $2.5\ \text{A}$.

Step 3 of 9

Consider the circuit diagram at $t < 0$.

Figure 1

Step 4 of 9

Calculate the value of the current $i(0^-)$.

$$i(0^-) = \frac{20}{R_2}$$

The value of the current $i(0^-)$ is equal to the value of the current $i(0)$.

$$i(0) = \frac{20}{R_2}$$

Substitute $4\ \text{A}$ for $i(0)$.

$$\begin{aligned} 4 &= \frac{20}{R_2} \\ R_2 &= \frac{20}{4} \\ R_2 &= 5\ \Omega \end{aligned}$$

Therefore, the value of the resistor R_2 is $\boxed{5\ \Omega}$.

Step 5 of 9

Consider the circuit diagram at $t = \infty$.

Figure 2

Step 6 of 9

Calculate the value of the current $i(\infty)$.

$$i(\infty) = \frac{20}{R_1 + R_2}$$

Substitute $2.5\ \text{A}$ for $i(\infty)$ and $5\ \Omega$ for R_2.

$$\begin{aligned} 2.5 &= \frac{20}{R_1 + 5} \\ R_1 + 5 &= \frac{20}{2.5} \\ R_1 + 5 &= 8 \\ R_1 &= 3\ \Omega \end{aligned}$$

Therefore, the value of the resistor R_1 is $\boxed{3\ \Omega}$.

Step 7 of 9

Consider the circuit diagram at $t > 0$.

Figure 3

Step 8 of 9

Apply Kirchhoff's Voltage Law in Loop.

$$i(t)[R_1 + R_2] + L\frac{di(t)}{dt} = v(t)$$

$$\frac{di(t)}{dt} + i(t)\left[\frac{R_1 + R_2}{L}\right] = v(t)$$

The solution of differential equation is equal to

$$i(t) = k_1 + k_2 e^{-\left(\frac{t}{\frac{L}{R_1+R_2}}\right)} \quad \text{..... (2)}$$

Here, $k_1 = \dfrac{v(t)}{R_1 + R_2}$ and $k_2 = v(t)\left(\dfrac{1}{R_1 + R_2} - \dfrac{1}{R_2}\right)$.

Step 9 of 9

Compare the time constants of the equations (1) and (2).

$$\frac{1}{4} = \frac{L}{R_1 + R_2}$$

Substitute $5\ \Omega$ for R_2 and $3\ \Omega$ for R_1.

$$\begin{aligned} 4 &= \frac{1}{\frac{L}{5+3}} \\ 4 &= \frac{1}{\frac{L}{8}} \\ 4 &= \frac{8}{L} \\ L &= \frac{8}{4} \\ L &= 2\ \text{H} \end{aligned}$$

Therefore, the value of the inductor L is $\boxed{2\ \text{H}}$.

Step 1 of 8

Given circuit diagram:

Step 2 of 8

Given voltage across the capacitor for $t > 0$ is

$v_C(t) = 20 - 8e^{-0.05t}$ V ..... (1)

The voltage across the capacitor for $t > 0$ is

$v_C(t) = v_C(\infty) + \left(v_C(0^-) - v_C(\infty)\right)e^{-t/\tau}$

$v_C(t) = k_1 + k_2 e^{-t/\tau}$ ..... (2)

Step 3 of 8

Comparing the equation (1) and equation (2), we have

$v_C(\infty) = k_1 = 20$ ..... (3)

$v_C(0^-) - v_C(\infty) = k_2 = -8$ ..... (4)

$\tau = \dfrac{1}{0.05} = 20$ ..... (5)

Step 4 of 8

For $t = 0^-$ the above circuit can be modified as shown below.

Step 5 of 8

The capacitive voltage for $t = 0^-$ is

$v_C(0^-) = 2(R_1 \| R_2)$

$v_C(0^-) = 2\left[\dfrac{R_1 R_2}{R_1 + R_2}\right]$

Capacitor voltage can not change instantaneously, thus we have below relation

$v_C(0^-) = v_C(0^+)$

$v_C(0^+) = 2\left[\dfrac{R_1 R_2}{R_1 + R_2}\right]$ ..... (6)

Step 6 of 8

For $t > 5\tau$ the given circuit can be modified as shown below.

Step 7 of 8

The capacitive voltage for $t > \infty$ is

$v_C(\infty) = 2R_1$

$20 = 2R_1$ $\quad$ $\left(\text{since } v_C(\infty) = k_1 = 20\right)$

$R_1 = 10\,\Omega$

Therefore the value of R_1 is $\boxed{R_1 = 10\,\Omega}$

Step 8 of 8

To find Thevenin's resistance across the capacitor terminals, replace voltage source and capacitor with open circuit as shown below

Step 1 of 10

Consider Figure P7.85 from the text book.

Consider the value of the current $i(t)$.

$i(t)=13.33e^{-t}-8.33e^{-0.5t}$ A ..... (1)

(a)

Consider the circuit diagram at $t<0$. At $t<0$, the capacitor is open circuited.

Figure 1

Step 2 of 10

Calculate the value of the capacitor voltage at $t<0$.

$v_C(0^-)=40e^{-(0^-)}u(0^-)$

The value of the unit function is zero for $t<0$. Hence,

$$v_C(0^-)=40e^{-(0^-)}(0)$$
$$=0\text{ V}$$

The value of the voltage $v_C(0^-)$ is equal to $v_C(0)$.

$v_C(0)=0\text{ V}$

Therefore, the value of the voltage $v_C(0)$ is $\boxed{0\text{ V}}$.

Step 3 of 10

(b)

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 4 of 10

Consider the Kirchhoff's Voltage Law in the Loop.

$$i(t)[4+2]+\frac{1}{C}\int i(t)dt=40e^{-t}u(t)$$
$$i(t)(6)+\frac{1}{C}\int i(t)dt=40e^{-t}$$

Take derivative with respect to 't'.

$$\frac{di(t)}{dt}(6)+\frac{1}{C}i(t)=-40e^{-t}$$
$$\frac{di(t)}{dt}+\frac{1}{6C}i(t)=-\frac{40}{6}e^{-t}$$

The solution for the above linear differential equation is equal to

$$i(t)e^{\int\frac{1}{6C}dt}=\int-\frac{40}{6}e^{-t}e^{\int\frac{1}{6C}dt}dt+k_1$$

Step 5 of 10

Solve for the expression of $i(t)$.

$$i(t)e^{\left(\frac{1}{6C}\right)t}=\int-\frac{40}{6}e^{-t}e^{\left(\frac{1}{6C}\right)t}dt+k_1$$
$$i(t)e^{\left(\frac{1}{6C}\right)t}=-\frac{40}{6}\int e^{\left(\frac{1}{6C}-1\right)t}dt+k_1$$
$$i(t)e^{\left(\frac{1}{6C}\right)t}=-\frac{40}{6\left(\frac{1}{6C}-1\right)}e^{\left(\frac{1}{6C}-1\right)t}+k_1$$
$$i(t)=-\frac{40}{6\left(\frac{1}{6C}-1\right)}\frac{e^{\left(\frac{1}{6C}-1\right)t}}{e^{\left(\frac{1}{6C}\right)t}}+\frac{k_1}{e^{\left(\frac{1}{6C}\right)t}}$$
$$i(t)=-\frac{40e^{-t}}{6\left(\frac{1}{6C}-1\right)}+k_1e^{-\left(\frac{1}{6C}\right)t}\quad\text{..... (2)}$$

Step 6 of 10

Compare the value of the time constants from equations (1) and (2).

$$0.5=\frac{1}{6C}$$
$$C=\frac{1}{6(0.5)}$$
$$C=\frac{1}{3}\text{ F}$$

Therefore, the value of the capacitor C is $\frac{1}{3}$ F .

Step 7 of 10

Consider the expression for the voltage across the capacitor.

$$v_C(t)=\frac{1}{C}\int i(t)dt$$

Substitute $13.33e^{-t}-8.33e^{-0.5t}$ A for $i(t)$ and $\frac{1}{3}$ F for C .

$$v_C(t)=\frac{1}{\left(\frac{1}{3}\right)}\int 13.33e^{-t}-8.33e^{-0.5t}dt$$
$$=(3)\left(-13.33e^{-t}-8.33(-0.5)e^{-0.5t}\right)+k_2$$
$$v_C(t)=(3)\left(-13.33e^{-t}+16.66e^{-0.5t}\right)+k_2\quad\text{..... (3)}$$

Step 8 of 10

Recall equation (3).

$$v_C(t)=(3)\left(-13.33e^{-t}+16.66e^{-0.5t}\right)+k_2$$

Substitute 0 for t .

$$v_C(0)=(3)\left(-13.33e^{-(0)}+16.66e^{-0.5(0)}\right)+k_2$$
$$v_C(0)=(3)(-13.33(1)+16.66(1))+k_2$$
$$v_C(0)=(3)(3.33)+k_2$$
$$v_C(0)=9.99+k_2$$

Substitute 0 V for $v_C(0)$.

$$0=9.99+k_2$$
$$k_2=-9.99$$

Therefore, the value of the constant k_2 is -9.99 .

Step 9 of 10

Recall equation (3).

$$v_C(t)=(3)\left(-13.33e^{-t}+16.66e^{-0.5t}\right)+k_2$$

Substitute 0 for t and -9.99 for k_2 .

$$v_C(1)=(3)\left(-13.33e^{-1}+16.66e^{-0.5}\right)-9.99$$
$$=(3)(-13.33(0.368)+16.66(0.607))-9.99$$
$$=(3)(-4.91+10.11)-9.99$$
$$=(3)(5.2)-9.99$$
$$v_C(1)=15.6-9.99$$
$$=5.61\text{ V}$$

Therefore, the value of the voltage $v_C(t)$ at $t=1$ sec is $\boxed{5.61\text{ V}}$.

Step 10 of 10

(c)

The value of the capacitor is calculated to be $\boxed{\frac{1}{3}\text{ F}}$ in section (b).

Step 1 of 7

The given circuit is,

Fig (a)

Step 2 of 7

For t < 0 , the circuit is in steady state and therefore the inductor acts as a short circuit,

Fig (b)

Hence the initial current through the inductor is,

$$i_1 = \frac{10}{R_1}$$

$$i_L(0-) = \frac{10}{R_1} \qquad \because i_1 = i_L(0-)$$

$$i_L(0+) = \frac{10}{R_1} \qquad \because i_L(0-) = i_L(0+)$$

Step 3 of 7

For t > 0, the circuit is modified as,

Step 4 of 7

Writing KVL equation across the loop,

$$L\frac{di_L(t)}{dt} + R_2 i_L(t) = 0$$

$$\frac{di_L(t)}{dt} + \frac{R_2}{L} i_L(t) = 0$$

Hence the solution for this differential equation is of the form,

$$i_L(t) = K_1 e^{-\frac{R_2}{L}t}$$

Where K_1 is determined by the initial condition,

$$i_L(0) = K_1$$

$$K_1 = \frac{10}{R_1}$$

$$\therefore i_L(t) = \frac{10}{R_1} e^{-\frac{R_2}{L}t}$$

Step 5 of 7

Now the voltage $v_0(t)$ is given by,

$$v_0(t) = L\frac{di_L(t)}{dt}$$

$$v_0(t) = L\frac{d}{dt}\left(\frac{10}{R_1} e^{-\frac{R_2}{L}t}\right)$$

$$v_0(t) = L\left(\frac{10}{R_1}\right)\left(-\frac{R_2}{L}\right)\left(e^{-\frac{R_2}{L}t}\right)$$

$$v_0(t) = -10\frac{R_2}{R_1} e^{-\frac{R_2}{L}t}$$

Step 6 of 7

Comparing the output voltage with the given equation,

$$v_0(t) = -20e^{-10^6 t} \text{ V}$$

$$10\frac{R_2}{R_1} = 20$$

$$R_2 = 2R_1 \qquad \text{.....(1)}$$

$$\frac{R_2}{L} = 10^6 \qquad \text{.....(2)}$$

Step 7 of 7

Given that the current $i_1 \le 1\text{A}$

$$i_1 = \frac{10}{R_1}$$

Therefore we have $R_1 \ge 10\Omega$

Choosing $R_1 = 20\Omega$

We have $R_2 = 40\Omega \qquad (\because R_2 = 2R_1)$

$$L = \frac{R_2}{10^6}$$

$$L = \frac{40}{10^6}$$

$$L = 40\mu\text{H}$$

One solution of many possible solutions is,

$$\boxed{R_1 = 20\Omega, R_2 = 40\Omega, L = 40\mu\text{H}}$$

Step 1 of 3

The given circuit is,

Fig (a)

Step 2 of 3

For $t > 0$, The Thevenin equivalent resistance R_{Th} as seen into the open circuit terminals of the capacitor,

Fig (b)

Step 3 of 3

$$R_{Th} = (2k + 7k) \| (18k)$$

$$R_{Th} = \frac{9k \times 18k}{9k + 18k}$$

$$R_{Th} = \frac{9k \times 18k}{27k}$$

$$R_{Th} = 6k\Omega$$

$\therefore$ Time constant of the circuit is,

$$\tau = R_{Th}C$$

$$120 \times 10^{-6} = (6 * 10^3)C$$

$$C = \frac{120 \times 10^{-6}}{6 \times 10^3}$$

$$C = 20 \times 10^{-9}\text{F}$$

$$\boxed{C = 20\text{nF}}$$

Step 1 of 3

(a)

The differential response that describes the second order circuit is as given below.

$$\frac{d^2 i_0(t)}{dt} + 6\frac{di_0(t)}{dt} + 4i_0(t) = 0$$

Apply Laplace transform on the given second order differential equation and we will get a second order characteristic equation.

$$s^2 I(s) + 6sI(s) + 4I(s) = 0$$

The characteristic equation of the circuit in simplest form is only the Laplace transform.

$$s^2 + 6s + 4 = 0$$

The roots of the characteristic equation are

$$s_1 = -0.7639$$
$$s_2 = -5.23$$

The characteristic equation of the differential equation is $\boxed{s^2 + 6s + 4 = 0}$.

Step 2 of 3

(b)

Equate the above given characteristic equation with the general equation of second order characteristic equation.

$$s^2 + 2\xi\omega_o s + \omega_o^2 = 0$$

After equating it you get two values one is the natural frequency of the circuit.

$$\omega_o = 2\text{ rad/sec}$$

The natural frequency of the circuit is $\boxed{2\text{ rad/sec}}$.

Step 3 of 3

(c)

The roots of the characteristic equation are real and unequal so the circuit is overdamped and then its general equation is.

$$\begin{aligned} i_o(t) &= k_1 e^{s_1 t} + k_2 e^{s_2 t} \\ &= k_1 e^{-0.7639t} + k_2 e^{-5.23t} \end{aligned}$$

The general expression of output current is $\boxed{i_o(t) = k_1 e^{-0.7639t} + k_2 e^{-5.23t}}$.

Step 1 of 4

Given equation

$$\frac{d^2 i_o(t)}{dt} + 8\frac{di_0(t)}{dt} + 16 i_0(t) = 0$$

Step 2 of 4

a) The characteristic equation of the network is

$$\boxed{s^2 + 8s + 16 = 0}$$

Step 3 of 4

b) $s^2 + 8s + 16 = 0$ is the characteristic equation comparing with the original equation

$$s^2 + 2\zeta\omega_o s + \omega_0^2 = 0$$

$$\omega_0^2 = 16$$

$$\boxed{\omega_0 = 4 \text{ rad/sec}}$$

$$2\zeta\omega_0 = 8$$

$$\boxed{\zeta = 1}$$

Step 4 of 4

c) Since $\zeta = 1$, the network is critically damped.

$$s = \frac{-8 \pm \sqrt{64 - 64}}{2}$$

$$s = -4$$

Therefore the equation for $i_0(t)$ is

$$\boxed{i_0(t) = k_1 e^{-4t} + k_2 t e^{-4t} \text{ A}}$$

Step 1 of 3

(a)

The differential equation is,

$$\frac{d^2v_1(t)}{dt^2}+2\left[\frac{dv_1(t)}{dt}\right]+5v_1(t)=0$$

Apply Laplace transforms to calculate the characteristic equation of the network.

$$s^2+2s+5=0$$

Thus, the characteristic equation of the network is $\boxed{s^2+2s+5=0}$.

Step 2 of 3

(b)

The characteristic equation is,

$$s^2+2s+5=0$$

Compare the characteristic equation with its generalized characteristic equation.

$$s^2+2\zeta\omega_0 s+\omega_0{}^2=0$$

The natural frequencies are,

$$\omega_0=\sqrt{5}=\pm 2.236 rad/s$$

Thus, the natural frequencies of the network are $\boxed{\pm 2.236 \text{ rad/s}}$.

Step 3 of 3

(c)

The characteristic equation is,

$$s^2+2s+5=0$$

The roots of the characteristic equation are,

$$s_1=-1+2i$$
$$s_2=-1-2i$$

Since the roots are complex, the circuit is underdamped and the expression for $v_1(t)$ is,

$$v_1(t)=K_1e^{-t}\cos 2t+K_2e^{-t}\sin 2t$$

Thus, the expression for $v_1(t)$ is $\boxed{K_1e^{-t}\cos 2t+K_2e^{-t}\sin 2t}$.

Step 1 of 5

Consider the following differential equation.

$$\frac{d^2v_o(t)}{dt^2}+8\frac{dv_o(t)}{dt}+10\,v_o(t)=0$$

Step 2 of 5

(a) Consider the second-order differential equation.

$$\frac{d^2x(t)}{dt^2}+2\zeta\omega_0\frac{dv_o(t)}{dt}+\omega_0^2v_o(t)=0$$

The characteristic equation of this differential equation is,

$$s^2+2\zeta\omega_0 s+\omega_0^2=0$$

Thus the characteristic equation of the circuit is $\boxed{s^2+8s+10=0}$.

Step 3 of 5

(b) Compare the two characteristic equations.

$$s^2+2\zeta\omega_0 s+\omega_0^2=0$$
$$s^2+8s+10=0$$
$$\omega_0^2=10$$
$$\omega_0=3.16\text{ rad/s}$$

Thus, the undamped natural frequency of the network is, $\boxed{\omega_0=3.16\text{ rad/s}}$.

Step 4 of 5

Also,

$$2\zeta\omega_n=8$$
$$(2)(\zeta)(3.16)=8$$
$$\zeta=\frac{8}{(2)(3.16)}$$
$$\zeta=1.266$$

For $\zeta>1$, the roots of the characteristic equation are also called the natural frequencies.

Determine the roots of the characteristic equation.

$$s_{1,2}=\frac{-8\pm\sqrt{64-40}}{2}$$
$$=\frac{-8\pm\sqrt{24}}{2}$$
$$=-4\pm\sqrt{6}$$
$$=-1.55,-6.45$$

Thus, the natural frequencies of the circuit are,

$$\boxed{\begin{array}{l}-1.55\text{ rad/s}\\-6.45\text{ rad/s}\end{array}}.$$

Step 5 of 5

(c) Since $\zeta>1$, the network is over damped.

The solution of the second-order differential equation is of the form,

$$v_o(t)=K_1e^{s_1t}+K_2e^{s_2t}$$
$$=K_1e^{-1.55t}+K_2e^{-6.45t}$$

Thus, the equation for $v_o(t)$ is $\boxed{K_1e^{-1.55t}+K_2e^{-6.45t}}$.

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Apply nodal analysis.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=i(t)$$

Assume the current source to be a constant value. Apply derivative with respect to t.

$$\frac{1}{R}\frac{d(v(t))}{dt}+C\frac{d^2(v(t))}{dt^2}+\frac{1}{L}(v(t))=0$$

$$\frac{d^2(v(t))}{dt^2}+\frac{1}{RC}\frac{d(v(t))}{dt}+\frac{1}{LC}(v(t))=0$$

Compare with $\frac{d^2(v(t))}{dt^2}+2\xi\omega_o\frac{d(v(t))}{dt}+\omega_o^2(v(t))=0$.

$$\omega_o^2=\frac{1}{LC} \quad \text{..... (1)}$$

and

$$2\xi\omega_o=\frac{1}{RC} \quad \text{..... (2)}$$

Step 3 of 3

Recall equation (1).

$$\omega_o^2=\frac{1}{LC}$$

$$\omega_o=\frac{1}{\sqrt{LC}}$$

Recall equation (2).

$$2\xi\omega_o=\frac{1}{RC}$$

Substitute $\frac{1}{\sqrt{LC}}$ for ω_o and 1 for ξ

$$2(1)\left(\frac{1}{\sqrt{LC}}\right)=\frac{1}{RC}$$

$$(2)^2\left(\frac{1}{\sqrt{LC}}\right)^2=\left(\frac{1}{RC}\right)^2$$

$$\frac{4}{LC}=\frac{1}{R^2C^2}$$

$$\frac{4}{L}=\frac{1}{R^2C}$$

$$C=\frac{L}{4R^2}$$

Substitute $1\,\Omega$ for R and $2\,\text{H}$ for L.

$$C=\frac{2}{4(1)^2}$$

$$=\frac{1}{2}\,\text{F}$$

Therefore, the required value of the capacitor is $\boxed{\frac{1}{2}\,\text{F}}$.

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Apply mesh analysis in the loop.

$$i(t)(R)+L\frac{di(t)}{dt}+\frac{1}{C}\int i(t)dt=v(t)$$

Assume the voltage source to be a constant value. Apply derivative with respect to t.

$$R\frac{di(t)}{dt}+L\frac{d^2i(t)}{dt^2}+\frac{1}{C}i(t)=0$$

$$\frac{d^2i(t)}{dt^2}+\frac{R}{L}\frac{di(t)}{dt}+\frac{1}{LC}i(t)=0$$

Compare with $\frac{d^2(i(t))}{dt^2}+2\xi\omega_o\frac{d(i(t))}{dt}+\omega_o^2(i(t))=0$.

$$\omega_o^2=\frac{1}{LC} \text{ ..... (1)}$$

And,

$$2\xi\omega_o=\frac{R}{L} \text{ ..... (2)}$$

Step 3 of 3

Recall equation (1).

$$\omega_o^2=\frac{1}{LC}$$

$$\omega_o=\frac{1}{\sqrt{LC}}$$

Recall equation (2).

$$2\xi\omega_o=\frac{R}{L}$$

Substitute $\frac{1}{\sqrt{LC}}$ for ω_o and 1 for ξ

$$2(1)\left(\frac{1}{\sqrt{LC}}\right)=\frac{R}{L}$$

$$(2)^2\left(\frac{1}{\sqrt{LC}}\right)^2=\left(\frac{R}{L}\right)^2$$

$$\frac{4}{LC}=\frac{R^2}{L^2}$$

$$\frac{4}{C}=\frac{R^2}{L}$$

$$L=\frac{R^2C}{4}$$

Substitute $2\,\Omega$ for R and $\frac{1}{2}$ F for C.

$$L=\frac{(2)^2\left(\frac{1}{2}\right)}{4}$$

$$=\frac{1}{2}\text{ H}$$

Therefore, the required value of the inductor is $\boxed{\frac{1}{2}\text{ H}}$.

Step 1 of 2

The differential equation for a parallel RLC circuit is

$$\frac{d^2V}{dt^2}+\frac{1}{RC}\frac{dV}{dt}+\frac{V}{LC}=0$$

Given

$R=1\Omega$

$L=\frac{1}{2}\text{H}$

$C=\frac{1}{2}\text{F}$

Step 2 of 2

Substituting these we obtain

$$\frac{d^2V}{dt^2}+2\frac{dV}{dt}+4V=0$$

The characteristic equation is

$s^2+2s+4=0$

Comparing with the original equation

$s^2+2\zeta\omega_0 s+\omega_0^2=0$

$\omega_0^2=4$

$\omega_0=2$

$2\zeta\omega_0=2$

$\zeta=\frac{1}{2}$

$\boxed{\zeta=0.5}$

Since ζ is less than 1, the circuit exhibits $\boxed{\text{under damping}}$

Step 1 of 5

Consider Figure P7.91 in the text book.

Apply nodal analysis.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=0 \text{ ..... (1)}$$

Apply derivative with respect to t.

$$\frac{1}{R}\frac{d(v(t))}{dt}+C\frac{d^2(v(t))}{dt^2}+\frac{1}{L}(v(t))=0$$

$$\frac{d^2(v(t))}{dt^2}+\frac{1}{RC}\frac{d(v(t))}{dt}+\frac{1}{LC}(v(t))=0 \text{ ..... (2)}$$

Step 2 of 5

Consider the characteristic equation for the equation (2).

$$s^2+\left(\frac{1}{RC}\right)s+\frac{1}{LC}=0$$

Substitute $10\ \Omega$ for R, $4\ \text{H}$ for L and $0.01\ \Omega$ for C.

$$s^2+\left(\frac{1}{(10)(0.01)}\right)s+\frac{1}{(4)(0.01)}=0$$

$$s^2+\left(\frac{1}{0.1}\right)s+\frac{1}{0.04}=0$$

$$s^2+10s+25=0$$

Solve for the values of s.

$$s=\frac{-(10)\pm\sqrt{(10)^2-4(1)(25)}}{2(1)}$$

$$=\frac{-10\pm\sqrt{100-100}}{2}$$

$$=-5$$

The natural frequency values are $s_1=-5\ \text{rad/sec}$ and $s_2=-5\ \text{rad/sec}$.

Step 3 of 5

The roots of the characteristic equation are real and equal, hence, the circuit exhibits critical damping. Therefore, the solution for the value of the voltage is

$$v(t)=B_1e^{st}+B_2te^{st}$$

Substitute -5 for s.

$$v(t)=B_1e^{-5t}+B_2te^{-5t} \text{ ..... (3)}$$

Let $t=0$. At $t=0$, the value of the voltage $v(t)$ is equal to $v_C(0)$.

$$v_C(0)=B_1e^{-5(0)}+B_2(0)e^{-5(0)}$$

$$v_C(0)=B_1$$

Substitute $5\ \text{V}$ for $v_C(0)$.

$$B_1=5$$

Therefore, the value of the constant B_1 is 5.

Step 4 of 5

Recall equation (1).

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=0$$

Substitute $i_L(t)$ for $\frac{1}{L}\int v(t)dt$.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+i_L(t)=0$$

$$i_L(t)=-\frac{v(t)}{R}-C\frac{d(v(t))}{dt}$$

Let $t=0$.

$$i_L(0)=-\frac{v(0)}{R}-C\frac{d(v(t))}{dt}\bigg|_{t=0}$$

Substitute $B_1e^{-5t}+B_2te^{-5t}$ for $v(t)$, $5\ \text{V}$ for $v_C(0)$, $2\ \text{A}$ for $i_L(0)$, $10\ \Omega$ for R and $0.01\ \text{F}$ for C.

$$2=-\frac{5}{10}-(0.01)\frac{d(B_1e^{-5t}+B_2te^{-5t})}{dt}\bigg|_{t=0}$$

$$2=-\frac{1}{2}-(0.01)\left[(-5)B_1e^{-5t}+(-5)B_2te^{-5t}+B_2e^{-5t}\right]_{t=0}$$

$$2+\frac{1}{2}=-(0.01)\left[(-5)B_1e^{-5(0)}+(-5)B_2(0)e^{-5(0)}+B_2e^{-5(0)}\right]$$

$$\frac{5}{2}=-(0.01)[-5B_1+0+B_2]$$

$$\frac{500}{2}=5B_1-B_2$$

$$250=5B_1-B_2$$

Substitute 5 for B_1.

$$250=5(5)-B_2$$

$$B_2=25-250$$

$$B_2=-225$$

Therefore, the value of the constant B_2 is -255.

Step 5 of 5

Recall equation (3).

$$v(t)=B_1e^{-5t}+B_2te^{-5t}$$

Substitute 5 for B_1 and -225 for B_2.

$$v(t)=5e^{-5t}-225te^{-5t}\ \text{V}$$

Therefore, the value of the voltage $v(t)$ is $\boxed{5e^{-5t}-225te^{-5t}\ \text{V}}$.

Step 1 of 9

Consider Figure P7.93 form the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

Step 2 of 9

Calculate the value of the voltage across the open circuited capacitor.

$$v_C(0) = (1)(8)$$
$$= 8\text{ V}$$

Therefore, the value of the voltage across the capacitor is 8 V .

The value of the current through the inductor is 0 A since no current flows through it.

Step 3 of 9

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 9

Apply nodal analysis.

$$\frac{v(t)}{R} + C\frac{d(v(t))}{dt} + \frac{1}{L}\int v(t)dt = 0 \quad \text{..... (1)}$$

Apply derivative with respect to t .

$$\frac{1}{R}\frac{d(v(t))}{dt} + C\frac{d^2(v(t))}{dt^2} + \frac{1}{L}(v(t)) = 0$$

$$\frac{d^2(v(t))}{dt^2} + \frac{1}{RC}\frac{d(v(t))}{dt} + \frac{1}{LC}(v(t)) = 0 \quad \text{..... (2)}$$

Step 5 of 9

Consider the characteristic equation for the equation (2).

$$s^2 + \left(\frac{1}{RC}\right)s + \frac{1}{LC} = 0$$

Substitute $8\,\Omega$ for R , 1 H for L and $0.04\,\Omega$ for C .

$$s^2 + \left(\frac{1}{(8)(0.04)}\right)s + \frac{1}{(1)(0.04)} = 0$$

$$s^2 + \left(\frac{1}{0.32}\right)s + \frac{1}{(0.04)} = 0$$

$$s^2 + 3.125s + 25 = 0$$

Solve for the values of s .

$$s = \frac{-(3.125) \pm \sqrt{(3.125)^2 - 4(1)(25)}}{2(1)}$$
$$= \frac{-3.125 \pm \sqrt{9.766 - 100}}{2}$$
$$= \frac{-3.125 \pm \sqrt{-90.234}}{2}$$
$$= \frac{-3.125 \pm j9.5}{2}$$

$$s = -1.5625 \pm j4.75$$

The natural frequency values are $s_1 = -1.5625 + j4.75\ \text{rad/sec}$ and $s_2 = -1.5625 - j4.75\ \text{rad/sec}$.

Step 6 of 9

The roots of the characteristic equation are complex, hence, the circuit exhibits under damping. Therefore, the solution for the value of the voltage is

$$v(t) = e^{-\sigma t}\left(A_1 \cos\omega_d t + A_2 \sin\omega_d t\right)$$

Substitute 1.5625 for σ and 4.75 for ω_d .

$$v(t) = e^{-1.5625t}\left(A_1 \cos 4.75t + A_2 \sin 4.75t\right) \quad \text{..... (3)}$$

Let $t = 0$. At $t = 0$, the value of the voltage $v(t)$ is equal to $v_C(0)$.

$$v_C(0) = e^{-1.5625(0)}\left(A_1 \cos 4.75(0) + A_2 \sin 4.75(0)\right)$$
$$v_C(0) = A_1(1) + A_2(0)$$
$$v_C(0) = A_1$$

Substitute 8 V for $v_C(0)$.

$$A_1 = 8$$

Therefore, the value of the constant A_1 is 8 .

Step 7 of 9

Recall equation (1).

$$\frac{v(t)}{R} + C\frac{d(v(t))}{dt} + \frac{1}{L}\int v(t)dt = 0$$

Substitute $i_L(t)$ for $\frac{1}{L}\int v(t)dt$.

$$\frac{v(t)}{R} + C\frac{d(v(t))}{dt} + i_L(t) = 0$$

$$i_L(t) = -\frac{v(t)}{R} - C\frac{d(v(t))}{dt}$$

Let $t = 0$.

$$i_L(0) = -\frac{v(0)}{R} - C\frac{d(v(t))}{dt}\bigg|_{t=0}$$

Step 8 of 9

On further simplification:

Substitute $e^{-1.5625t}\left(A_1 \cos 4.75t + A_2 \sin 4.75t\right)$ for $v(t)$, 8 V for $v_C(0)$, 0 A for $i_L(0)$, $8\,\Omega$ for R and 0.04 F for C .

$$0 = -\frac{8}{8} - (0.04)\frac{d\left(e^{-1.5625t}\left(A_1 \cos 4.75t + A_2 \sin 4.75t\right)\right)}{dt}\bigg|_{t=0}$$

$$0 = -1 - (0.04)\left[\begin{pmatrix} e^{-1.5625t}\left(-4.75A_1 \sin 4.75t + 4.75A_2 \cos 4.75t\right) - \\ (1.5625)e^{-1.5625t}\left(A_1 \cos 4.75t + A_2 \sin 4.75t\right) \end{pmatrix}\right]\bigg|_{t=0}$$

$$1 = -(0.04)\left[\begin{pmatrix} e^{-1.5625(0)}\left(-4.75A_1 \sin 4.75(0) + 4.75A_2 \cos 4.75(0)\right) \\ -(1.5625)e^{-1.5625(0)}\left(A_1 \cos 4.75(0) + A_2 \sin 4.75(0)\right) \end{pmatrix}\right]$$

$$25 = -\left(\left(-4.75A_1(0) + 4.75A_2(1)\right) - (1.5625)\left(A_1(1) + A_2(0)\right)\right)$$

$$25 = -\left(4.75A_2 - 1.5625A_1\right)$$
$$25 = -4.75A_2 + 1.5625A_1$$

Substitute 8 for A_1 .

$$25 = -4.75A_2 + 1.5625(8)$$
$$25 = -4.75A_2 + 12.5$$
$$4.75A_2 = 12.5$$
$$A_2 = \frac{12.5}{4.75}$$
$$A_2 = -2.63$$

Therefore, the value of the constant A_2 is -2.63 .

Step 9 of 9

Recall equation (3).

$$v(t) = e^{-1.5625t}\left(A_1 \cos 4.75t + A_2 \sin 4.75t\right)$$

Substitute 10 for A_1 and -40 for A_2 .

$$v(t) = e^{-1.5625t}\left(8\cos 4.75t - 2.63\sin 4.75t\right)\text{ V}$$

Therefore, the value of the voltage $v(t)$ is $\boxed{e^{-1.5625t}\left(8\cos 4.75t - 2.63\sin 4.75t\right)\text{ V}}$.

Step 1 of 10

Refer to Figure P7.95 in textbook.

Redraw the circuit at $t=(0^-)$. Before the switch is open the circuit is in steady state condition .Therefore the capacitor acts as open circuit and inductor acts as short circuit.

Figure 1

Step 2 of 10

Determine voltage across capacitor at $t=(0^-)$.

$$v_c(0^-)=12\text{ V}$$

And $v_c(0^+)=12$

$$i_c(0^-)=0\text{ A}$$

And $i_c(0^+)=0\text{ A}$

Step 3 of 10

At $t=(0)$ the switch is closed and redraw the circuit.

Figure 2

Step 4 of 10

This is a parallel *RLC* circuit.

At $t=(0^+)$, determine current through resister.

$$\begin{aligned} i_R &= \frac{v_R}{R} \\ &= \frac{12}{10} \\ &= 1.2\text{ A} \end{aligned}$$

Determine current through capacitor.

$$\begin{aligned} i_C &= -i_L - i_R \\ &= -0-1.2 \\ &= -1.2\text{ A} \\ &= i_C(0^+) \end{aligned}$$

Step 5 of 10

Determine rate of change of voltage.

$$C\frac{dv}{dt}=i_C$$

$$\begin{aligned} \frac{dv}{dt} &= \frac{i_C}{C} \\ &= \frac{-1.2}{\frac{1}{400}} \\ &= -1.2(400) \\ &= -480\ \text{V}/s \end{aligned}$$

Step 6 of 10

Determine the value of α .

$$\begin{aligned} \alpha &= \frac{1}{2RC} \\ &= \frac{1}{2(10)\left(\frac{1}{400}\right)} \\ &= \frac{400}{20} \\ &= 20\ \text{rad/s} \end{aligned}$$

Step 7 of 10

Determine the value of ω_o .

$$\begin{aligned} \omega_o &= \frac{1}{\sqrt{LC}} \\ &= \frac{1}{\sqrt{1\left(\frac{1}{400}\right)}} \\ &= 20\ \text{rad/s} \end{aligned}$$

$\alpha=\omega_o$. Therefore it is critically damped circuit.

Step 8 of 10

Determine expression for voltage.

$$\begin{aligned} v_0(t) &= V_{SS}+(A_1+A_2t)e^{-\alpha t} \\ &= 0+(A_1+A_2t)e^{-20t} \end{aligned}$$

At $t=(0^+)$

$$\begin{aligned} v_0(t) &= (A_1+A_2 0)e^0 \\ &= A_1 \end{aligned}$$

But,

$$v_0(0)=10\text{ V}$$

Therefore,

$$A_1=12\text{ V}$$

Step 9 of 10

Determine $\frac{dv}{dt}$.

$$\begin{aligned} \frac{dv_0}{dt} &= \frac{d}{dt}\left(V_{SS}+(A_1+A_2t)e^{-20t}\right) \\ &= 0+-20A_1e^{-20t}+-20A_2te^{-20t}+A_2e^{-20t} \end{aligned}$$

At $t=(0^+)$

$$\frac{dv_0}{dt}=-20A_1+A_2$$

But, $\frac{dv_0}{dt}=-480\ V/s$

Therefore,

$$\begin{aligned} -480 &= -20A_1+A_2 \\ -480 &= -20(12)+A_2 \\ -480 &= -240+A_2 \\ -240 &= A_2 \end{aligned}$$

$$v_0(t)=12e^{-20t}-240te^{-20t}\text{ V}$$

Thus, the expression for voltage at $t>0$ is $\boxed{12e^{-20t}-240te^{-20t}\text{ V}}$.

Step 10 of 10

Plot the graph between voltage and time.

Step 1 of 9

Refer Figure P7.97 in text book.

At $t = 0^-$ circuit is under steady state condition. Capacitor acts as open circuit. Inductor acts as short circuit.

Determine current flow through the inductor.

Apply Kirchhoff's Current Law to the circuit.

$$-12 - 6 + 6i_1 = 0$$
$$-18 + 6i_1 = 0$$
$$18 = 6i_1$$

$$i_1 = \frac{18}{6}$$
$$= 3 \text{ A}$$

$$i_L(0^-) = 3 \text{ A}$$
$$i_L(0^+) = 3 \text{ A}$$
$$v_c(0^-) = -6 \text{ V}$$
$$v_c(0^+) = -6 \text{ V}$$

Step 2 of 9

Redraw the figure with equivalent resistance.

Figure 1

Step 3 of 9

Determine α at $t > 0$.

It is series RLC circuit.

$$\alpha = \frac{R_{eq}}{2L}$$
$$= \frac{6 + 1.5}{2(1.25)}$$
$$= \frac{7.5}{2(1.25)}$$
$$= 3$$

Step 4 of 9

Determine ω_0 at $t > 0$.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$
$$= \frac{1}{\sqrt{(1.25)(0.1)}}$$
$$= \frac{1}{(0.3535)}$$
$$= 2{,}828 \text{ rad/s}$$

$$\alpha > \omega_0$$

Therefore circuit is over damped.

Step 5 of 9

Determine poles s_1 and s_2.

$$v(t) = \left(A_1 e^{-s_1 t} + A_2 e^{-s_2 t}\right)$$
$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$
$$= -3 \pm \sqrt{3^2 - 2.828^2}$$
$$= -3 \pm 1$$

$$s_1 = -4$$
$$s_2 = -2$$

Step 6 of 9

Determine voltage $v(t)$.

$$i(t) = K_1 e^{-4t} + K_2 e^{-2t}$$
$$i(0) = K_1 e^0 + K_2 e^0$$

$$3 = K_1 + K_2 \text{ ..... (1)}$$

Step 7 of 9

Determine voltage $v(t)$ at $t = 0$.

$$t = (0^+)$$
$$12 = 7.5(3) + v_C + v_L$$
$$= 22.5 - 6 + v_L$$
$$v_L = -4.5$$

Step 8 of 9

Determine rate of change of current.

$$v_L = L\frac{di}{dt}$$
$$\frac{di}{dt} = \frac{-4.5}{L}$$
$$= \frac{-4.5}{1.25}$$
$$= -3.6$$

Step 9 of 9

Determine K_1 and K_2 values.

$$i(t) = K_1 e^{-4t} + K_2 e^{-2t}$$

$$\frac{di}{dt} = \frac{d}{dt}\left(K_1 e^{-4t} + K_2 e^{-2t}\right)$$
$$= -4K_1 e^{-4t} - 2K_2 e^{-2t}$$

But $\frac{di}{dt}$ at $t = 0$

$$-3.6 = -4K_1 - 2K_2 \text{ ..... (2)}$$

Solve equation (1) and (2).

$$K_1 = -1.2$$

Substitute value of K_1 in equation (1)

$$K_1 + K_2 = 3$$
$$K_2 = 3 - K_1$$
$$K_2 = 3 - (-1.2)$$
$$K_2 = 4.2$$

Then the current expression is $i(t) = -1.2e^{-4t} + 4.2e^{-2t}$ A

Thus, the current expression for is $i(t)$ at $t > 0$ is $\boxed{-1.2e^{-4t} + 4.2e^{-2t} \text{ A}}$.

Step 1 of 11

Refer Figure P7.99P in text book. Redraw the Figure at $t = 0$.

Figure 1

Step 2 of 11

At $t = 0^-$ there is no source.

Therefore,

$$i_c(0^-) = 0 \text{ A}$$
$$i_c(0^+) = 0 \text{ A}$$
$$v_c(0^-) = 0 \text{ V}$$
$$v_c(0^+) = 0 \text{ V}$$

Step 3 of 11

Redraw the Figure at $t = 0^+$ switch is closed.

Figure 2

Inductance acts like open circuit. Capacitor acts like short circuit.

Therefore,

Total voltage appears across inductor. But under steady state condition inductor acts like short circuit and capacitor acts like open circuit.

Step 4 of 11

Redraw the circuit at $t = \infty$.

Figure 3

Step 5 of 11

Determine voltage across capacitor at $t = \infty$.

$$i = \frac{v}{R}$$
$$= \frac{8}{2}$$
$$= 4 \text{ A}$$

Voltage across capacitor is 8 V.

Step 6 of 11

Apply Kirchhoff's Current Law to the circuit.

Figure 4

Step 7 of 11

Apply nodal analysis.

$$i_L = i_R + i_c$$
$$= \frac{v}{R} + C\frac{dv}{dt} \text{ ..... (1)}$$

Apply Kirchhoff's Voltage Law for loop 1.

$$L\frac{di}{dt} + v = 0 \text{ ..... (2)}$$

Substitute equation (1) in (2).

$$L\frac{d}{dt}\left(\frac{v}{R} + C\frac{dv}{dt}\right) + v = 0$$
$$\frac{L}{R}\frac{dv}{dt} + LC\frac{d^2v}{dt^2} + v = 0$$
$$LC\frac{d^2v}{dt^2} + \frac{L}{R}\frac{dv}{dt} = -v$$
$$LC\left(\frac{d^2v}{dt^2} + \frac{1}{RC}\frac{dv}{dt}\right) = -v$$

Step 8 of 11

Separate $\frac{dv}{dt}$ terms.

$$\left(\frac{d^2v}{dt^2} + \frac{1}{RC}\frac{dv}{dt}\right) = -\frac{v}{LC}$$
$$\left(\frac{d^2v}{dt^2} + \frac{1}{RC}\frac{dv}{dt}\right) + \frac{v}{LC} = 0$$
$$\left(\frac{d^2v}{dt^2} + \frac{1}{2\left(\frac{1}{12}\right)}\frac{dv}{dt}\right) + \frac{v}{\left(\frac{1}{12}\right)\left(\frac{12}{5}\right)} = 0$$
$$\left(\frac{d^2v}{dt^2} + 6\frac{dv}{dt}\right) + 5v = 0$$

Step 9 of 11

Determine poles s_1 and s_2.

$$s^2 + 6s + 5 = 0$$
$$= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$= \frac{-6 \pm \sqrt{6^2 - 4(1)(5)}}{2(1)}$$
$$= \frac{-6 \pm 4}{2}$$
$$= -3 \pm 2$$
$$s_1 = -5$$
$$s_2 = -1$$

Step 10 of 11

Determine $v(t)$.

$$v(t) = v_{ss} + Ae^{-5t} + Be^{-t}$$
$$= 8 + Ae^{-5t} + Be^{-t}$$

Step 11 of 11

Determine $v(t)$ at $t = 0$.

$$v(t) = v_{ss} + Ae^{-5t} + Be^{-t}$$
$$= 8 + Ae^{-5t} + Be^{-t}$$
$$0 = 8 + A + B$$
$$A + B = -8 \text{ ..... (1)}$$

At $t = 0$, the switch is closed. But the inductor opposes the sudden changes in the current.

Therefore at $t = 0$.

$$i_L = 0$$
$$i_R = 0$$
$$i_C = 0$$

But

$$i_C = C\frac{dv}{dt}$$
$$\frac{dv}{dt} = \frac{i_C}{C}$$
$$= \frac{0}{C}$$
$$= 0 \text{ V} \text{ ..... (2)}$$
$$\frac{dv(t)}{dt} = 0 - 5Ae^{-5t} - Be^{-t}$$

But from equation (2), $\frac{dv(t)}{dt} = 0$.

Therefore,

$$0 = -5A - B$$
$$A = -\frac{B}{5} \text{ ..... (3)}$$

Substitute equation (3) in (1).

$$A + B = -8$$
$$-\frac{B}{5} + B = -8$$
$$-B + 5B = -40$$
$$4B = -40$$
$$B = -10$$
$$A = \frac{-B}{5}$$
$$= -\left(-\frac{10}{5}\right)$$
$$= 2$$

$$v(t) = v_{ss} + Ae^{-5t} + Be^{-t}$$
$$= 8 + 2e^{-5t} - 10e^{-t} \text{ V}$$

Thus, voltage $v(t)$ for $t > 0$ is $\boxed{8 + 2e^{-5t} - 10e^{-t} \text{ V}}$.

Step 1 of 9

Refer to Figure P7.102 in text book.

At $t = 0^-$ the circuit is under steady state condition.

Therefore, capacitor acts as open circuit. And inductor acts as short circuit. Redraw the circuit at $t = 0^-$.

Figure 1

Step 2 of 9

Determine voltage across capacitor at $t = 0^-$.

$$i = \frac{v}{R}$$
$$= \frac{(10)(10)}{10+10}$$
$$= 5 \text{ A}$$

The initial voltage across the capacitor is,

$$v_c(0) = iR$$
$$= 5(10)$$
$$= 50 \text{ V}$$

The initial current through the inductor is,

$$i_L(0^-) = i_L(0^-)$$
$$= 0 \text{ A}$$

Step 3 of 9

Redraw the circuit at $t = 0^+$.

Figure 2

Step 4 of 9

Determine the rate of change of voltage.

At $t = 0$

$$v = L\frac{di}{dt}$$
$$i_L = i_c$$
$$C\frac{dv}{dt} = 0$$
$$\frac{dv}{dt} = 0 \text{ V}$$

Step 5 of 9

Determine damping ratio α.

$$\alpha = \frac{R}{2L}$$
$$= \frac{2(1000)}{2(100\times10^{-3})}$$
$$= 10000$$
$$\alpha^2 = 100{,}000{,}000 \text{ rad/s}$$

Determine natural frequency ω_0.

$$\omega_0^2 = \frac{1}{RC}$$
$$= \frac{1}{(100\times10^{-3})(10\times10^{-6})}$$
$$= 10^6 \text{ rad/s}$$

Step 6 of 9

Determine poles .

$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$
$$= -10000 \pm \sqrt{100{,}000{,}000 - 10^6}$$
$$= -10000 \pm 9{,}949.874$$
$$s_1 = -19{,}949.874$$
$$s_2 = -50.126$$

Step 7 of 9

Determine voltage across capacitor.

$$v_c(t) = v_{ss} + A_1e^{s_1t} + A_2e^{s_2t}$$
$$= 0 + A_1e^{-19{,}949.874t} + A_2e^{-50.126t}$$

$v_c(t)$ at $t = 0$

$$v_c(t) = v_{ss} + A_1e^{s_1t} + A_2e^{s_2t}$$
$$= 0 + A_1e^{-19{,}949.874t} + A_2e^{-50.126t}$$
$$50 = 0 + A_1 + A_2$$

$A_1 + A_2 = 50$ …… (1)

Determine rate of change of voltage.

$\frac{dv_c(t)}{dt}$ at $t = 0$.

$0 = -19{,}949.874A_1 - 50.126A_2$ …… (2)

Solve equations (1) and (2).

$$A_1 = -0.126$$
$$A_2 = 50.126$$

Therefore, the output voltage is,

$$v(t) = 50.126e^{-50.126t} - 0.126e^{-19949.874t} \text{ V}$$

Thus, voltage $v(t)$ for $t > 0$ is $\boxed{50.126e^{-50.126t} - 0.126e^{-19949.874t} \text{ V}}$.

Step 8 of 9

Consider the following MATLAB command to the plot the graph of output voltage and time.

```
>> t=0:0.001:1;

>> v=50.129.*exp(-50.126.*t)-0.126.*exp(-19949.874.*t);

>> plot(t,v)
```

Step 9 of 9

Consider the plot of output voltage versus time shown in Figure 3.

Therefore, the required plot is shown in Figure 3.

Step 1 of 10

Refer to Figure P7.103 in text book.

At $t = 0^-$ the circuit is under steady state condition.

Therefore, capacitor acts as open circuit.

Redraw the circuit at $t = 0^-$.

Figure 1

Step 2 of 10

Determine voltage across capacitor.

$$v_c(0^-) = v_c(0^+)$$
$$= 12 \text{ V}$$

At $t = 0^+$

$$v_L = v_c$$

Because no drop in the resistance.

Step 3 of 10

Redraw the circuit at $t = 0$.

Figure 2

Step 4 of 10

Determine at $\frac{di}{dt}\ t = 0$.

This is a series RLC circuit.

$$i_L = i_c$$

$$v_c = L\frac{di}{dt}$$
$$12 = L\frac{di}{dt}$$

$$\frac{di}{dt} = \frac{12}{L}$$
$$= \frac{12}{10^{-3}}$$
$$= 12000 \text{ A/s}$$

Step 5 of 10

Determine α for series RLC circuit.

$$\alpha = \frac{R}{2L}$$
$$= \frac{1000}{2(10^{-3})}$$
$$= (0.5)(10^6)$$

$$\alpha^2 = 2.5\times10^{11} \text{ rad/s}$$

Step 6 of 10

Determine frequency.

$$\omega_0^2 = \frac{1}{LC}$$
$$= \frac{1}{(10^{-3})(6.25\times10^{-9})}$$
$$= \frac{10^{12}}{6.25}$$
$$= 1.6\times10^{11} \text{ rad/s}$$

$$\alpha^2 > \omega_0^2$$

Therefore, the circuit is over damped.

Step 7 of 10

Determine poles.

$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$
$$= -0.5\times10^6 \pm \sqrt{2.5\times10^{11} - 1.6\times10^{11}}$$
$$= -500{,}000 \pm 300{,}000$$

$$s_1 = -200{,}000$$
$$s_2 = -800{,}000$$

Step 8 of 10

Determine current.

$$i(t) = i_1 + A_1e^{s_1t} + A_2e^{s_2t}$$
$$0 = 0 + A_1e^{-200{,}000t} + A_2e^{-800{,}000t}$$
$$0 = A_1 + A_2$$

$A_1 = -A_2$ …… (1)

Determine rate of change of current.

$$\frac{di(t)}{dt} = 0 - 200{,}000A_1e^{-200{,}000t} - 800{,}000A_2e^{-800{,}000t}$$
$$12000 = -200{,}000A_1 - 800{,}000A_2$$

Substitute $-A_2$ for A_1 in the equation.

$$12000 = -200{,}000(-A_2) - 800{,}000A_2$$
$$12000 = 200{,}000A_2 - 800{,}000A_2$$
$$12000 = -600{,}000A_2$$

$$A_2 = \frac{12000}{-600{,}000}$$
$$= -0.02$$

And,

$$A_1 = 0.02$$

Step 9 of 10

Therefore current equation is.

$$i(t) = 0.02e^{-200{,}000t} - 0.02e^{-800{,}000t} \text{ A}$$

Determine voltage $v_o(t)$ for $t > 0$.

$$v_o(t) = i(t)(R)$$
$$= 1000\left[0.02e^{-200{,}000t} - 0.02e^{-800{,}000t}\right]$$
$$= 20e^{-200{,}000t} - 20e^{-800{,}000t} \text{ V}$$

Thus, voltage $v_o(t)$ for $t > 0$ is $\boxed{20e^{-200{,}000t} - 20e^{-800{,}000t} \text{ V}}$.

Step 10 of 10

Plot the grape between voltage and time.

Figure 3

Therefore, the required plot is shown in Figure 3.

Step 1 of 6

Consider Figure P7.92 form the text book.

Apply nodal analysis.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=0 \text{ ..... (1)}$$

Apply derivative with respect to t.

$$\frac{1}{R}\frac{d(v(t))}{dt}+C\frac{d^2(v(t))}{dt^2}+\frac{1}{L}(v(t))=0$$

$$\frac{d^2(v(t))}{dt^2}+\frac{1}{RC}\frac{d(v(t))}{dt}+\frac{1}{LC}(v(t))=0 \text{ ..... (2)}$$

Step 2 of 6

Consider the characteristic equation for the equation (2).

$$s^2+\left(\frac{1}{RC}\right)s+\frac{1}{LC}=0$$

Substitute $5\ \Omega$ for R, $2\ \text{H}$ for L and $\frac{1}{40}\ \Omega$ for C.

$$s^2+\left(\frac{1}{(5)\left(\frac{1}{40}\right)}\right)s+\frac{1}{(2)\left(\frac{1}{40}\right)}=0$$

$$s^2+8s+20=0$$

Solve for the values of s.

$$s=\frac{-(8)\pm\sqrt{(8)^2-4(1)(20)}}{2(1)}$$

$$=\frac{-8\pm\sqrt{64-80}}{2}$$

$$=\frac{-8\pm\sqrt{-16}}{2}$$

$$=\frac{-8\pm j4}{2}$$

$$s=-4\pm j2$$

The natural frequency values are $s_1=-4+j2\ \text{rad/sec}$ and $s_2=-4-j2\ \text{rad/sec}$.

Step 3 of 6

The roots of the characteristic equation are complex, hence, the circuit exhibits under damping. Therefore, the solution for the value of the voltage is

$$v(t)=e^{-\sigma t}\left(A_1\cos\omega_d t+A_2\sin\omega_d t\right)$$

Substitute 4 for σ and 2 for ω_d.

$$v(t)=e^{-4t}\left(A_1\cos 2t+A_2\sin 2t\right) \text{ ..... (3)}$$

Let $t=0$. At $t=0$, the value of the voltage $v(t)$ is equal to $v_C(0)$.

$$v_C(0)=e^{-4(0)}\left(A_1\cos 2(0)+A_2\sin 2(0)\right)$$

$$=A_1(1)+A_2(0)$$

$$=A_1$$

Substitute $10\ \text{V}$ for $v_C(0)$.

$$A_1=10$$

Therefore, the value of the constant A_1 is 10.

Step 4 of 6

Recall equation (1).

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=0$$

Substitute $i_L(t)$ for $\frac{1}{L}\int v(t)dt$.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+i_L(t)=0$$

$$i_L(t)=-\frac{v(t)}{R}-C\frac{d(v(t))}{dt}$$

Let $t=0$.

$$i_L(0)=-\frac{v(0)}{R}-C\frac{d(v(t))}{dt}\bigg|_{t=0}$$

Substitute $e^{-4t}\left(A_1\cos 2t+A_2\sin 2t\right)$ for $v(t)$, $10\ \text{V}$ for $v_C(0)$, $1\ \text{A}$ for $i_L(0)$, $5\ \Omega$ for R and $\frac{1}{40}\ \text{F}$ for C.

$$1=-\frac{10}{5}-\left(\frac{1}{40}\right)\frac{d\left(e^{-4t}\left(A_1\cos 2t+A_2\sin 2t\right)\right)}{dt}\bigg|_{t=0}$$

$$1=-2-\left(\frac{1}{40}\right)\left(e^{-4t}\left(-2A_1\sin 2t+2A_2\cos 2t\right)-4e^{-4t}\left(A_1\cos 2t+A_2\sin 2t\right)\right)\bigg|_{t=0}$$

$$1+2=-\left(\frac{1}{40}\right)\left(e^{-4(0)}\left(-2A_1\sin 2(0)+2A_2\cos 2(0)\right)-4e^{-4(0)}\left(A_1\cos 2(0)+A_2\sin 2(0)\right)\right)$$

$$3(40)=-\left(\frac{1}{40}\right)\left(\left(-2A_1(0)+2A_2(1)\right)-4\left(A_1(1)+A_2(0)\right)\right)$$

$$120=-2A_2+4A_1$$

Step 5 of 6

Substitute 10 for A_1.

$$120=-2A_2+4(10)$$

$$2A_2=40-120$$

$$2A_2=-80$$

$$A_2=\frac{-80}{2}$$

$$A_2=-40$$

Therefore, the value of the constant A_2 is -40.

Step 6 of 6

Recall equation (3).

$$v(t)=e^{-4t}\left(A_1\cos 2t+A_2\sin 2t\right)$$

Substitute 10 for A_1 and -40 for A_2.

$$v(t)=e^{-4t}\left(10\cos 2t-40\sin 2t\right)\ \text{V}$$

Therefore, the value of the voltage $v(t)$ is $\boxed{e^{-4t}\left(10\cos 2t-40\sin 2t\right)\ \text{V}}$.

Step 1 of 9

Determine rate of change of voltage.

$$v(t) = 12 + A_1 e^{(-8,872.9833)t} + A_2 e^{(-1,127.0167)t}$$

$$\frac{dv(t)}{dt} = 0 + A_1(-8,872.9833)e^{(-8,872.9833)t} + (-1,127.0167)A_2 e^{(-1,127.0167)t}$$

But at $t = 0$

From equation (1),

$$\frac{dv(t)}{dt} = 0 \text{ V}$$

$$0 = A_1(-8,872.9833) + (-1,127.0167)A_2 \quad \text{..... (3)}$$

Solve equations (2) and (3).

We get,

$$A_1 = 1.746$$
$$A_2 = -13.746$$

$$v_C(t) = 12 + 1.746e^{(-8,872.9833)t} - 13.746e^{(-1,127.0167)t} \text{ V}$$

Thus, voltage $v_C(t)$ for $t > 0$ is $\boxed{12 + 1.746e^{(-8,872.9833)t} - 13.746e^{(-1,127.0167)t} \text{ V}}$.

Step 2 of 9

Refer Figure P.7.94 in text book. Redraw the circuit at $t = 0$.

At $t = 0^-$ no source is applied.

Therefore,

$v_C = 0$ V and $i_L = 0$ A

Figure 1

Step 3 of 9

Determine Neper frequency.

$$\alpha = \frac{R}{2L}$$
$$= \frac{1000}{2(100\times10^{-3})}$$
$$= \frac{5}{10^{-3}}$$
$$= 5000 \text{ rad/s}$$

Step 4 of 9

Determine resonance radiant frequency.

$$\omega_0^2 = \frac{1}{LC}$$
$$= \frac{1}{(100\times10^{-3})(10^{-6})}$$
$$= 10^7 \text{ rad/s}$$

Step 5 of 9

Determine poles.

$$S_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$
$$= -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$
$$= -\frac{1000}{2(100\times10^{-3})} \pm \sqrt{\left(\frac{1000}{2(100\times10^{-3})}\right)^2 - \frac{1}{(100\times10^{-3})(1\times10^{-6})}}$$
$$= -5000 \pm \sqrt{25,000,000 - 10,000,000}$$
$$= -5000 \pm 3,872.9833$$
$$S_1 = -8,872.9833$$
$$S_2 = -1,127.0167$$

Roots are real and different.

Therefore it is over damped.

Step 6 of 9

Determine voltage.

$$v(t) = v_{ss} + A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

Initially there is no source at $t = 0^-$.

$$i_L(0^-) = 0$$
$$i_L(0^+) = 0$$
$$v_c(0) = 0$$
$$v_c(0^+) = 0$$

$$i_L(0^-) = 0$$

As it is series circuit same current flows through the circuit.

Therefore,

$$i_L = i_c$$

But, the capacitor voltage is,

$$i_c = C\frac{dv}{dt}$$

$$\frac{dv}{dt} = \frac{i_c}{C}$$
$$= \frac{0}{C}$$
$$= 0 \text{ V}$$

$$\frac{dv}{dt} = 0 \quad \text{..... (1)}$$

Step 7 of 9

Redraw the Figure at $t = \infty$.

Figure 2

Step 8 of 9

Determine voltage across capacitor

$$v_C(t) = v_{ss} + A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

But at $t = 0$.

$$v_C(t) = 0 \text{ V}$$

Therefore

$$v(t) = v_{ss} + A_1 e^{s_1 t} + A_2 e^{s_2 t}$$
$$0 = 12 + A_1 + A_2$$

$$A_1 + A_2 = -12 \quad \text{..... (2)}$$

Step 9 of 9

Determine rate of change of voltage.

$$v(t) = 12 + A_1 e^{(-8,872.9833)t} + A_2 e^{(-1,127.0167)t}$$

$$\frac{dv(t)}{dt} = 0 + A_1(-8,872.9833)e^{(-8,872.9833)t} + (-1,127.0167)A_2 e^{(-1,127.0167)t}$$

But at $t = 0$

From equation (1),

$$\frac{dv(t)}{dt} = 0 \text{ V}$$

$$0 = A_1(-8,872.9833) + (-1,127.0167)A_2 \quad \text{..... (3)}$$

Solve equations (2) and (3).

We get,

$$A_1 = 1.746$$
$$A_2 = -13.746$$

$$v_C(t) = 12 + 1.746e^{(-8,872.9833)t} - 13.746e^{(-1,127.0167)t} \text{ V}$$

Thus, voltage $v_C(t)$ for $t > 0$ is $\boxed{12 + 1.746e^{(-8,872.9833)t} - 13.746e^{(-1,127.0167)t} \text{ V}}$.

Step 1 of 9

Refer to Figure P7.96 in textbook.

Redraw the Figure at $t=(0^-)$. The circuit is under steady state condition. Inductor acts as short circuit and capacitor acts as open circuit.

Figure 1

Step 2 of 9

Determine the value of $i(0^-)$.

$$20+10=10i$$
$$30=10i$$
$$i=\frac{30}{10}$$
$$=3\text{ A}$$

$$i(0^-)=i(0^+)$$
$$=3\text{ A}$$

Determine voltage at $t=(0^-)$.

$$V(0^-)=15-10$$
$$=5\text{ V}$$
$$=V(0^+)$$

Step 3 of 9

Draw the circuit diagram at $t=(0^+)$.

Figure 2

Step 4 of 9

Determine the value of α.

$$\alpha=\frac{R}{2L}$$
$$=\frac{10}{2(1)}$$
$$=5\text{ rad/s}$$

Step 5 of 9

Determine the value of ω_o.

$$\omega_o=\frac{1}{\sqrt{LC}}$$
$$=\frac{1}{\sqrt{\frac{1}{1(0.04)}}}$$
$$=\sqrt{25}$$
$$=5\text{ rad/s}$$

Step 6 of 9

Since $\alpha=\omega_o$, the system is critically damped circuit. The response of the circuit is,

$$i(t)=(B_1+B_2t)e^{-5t}\text{ ..... (1)}$$

Determine constants B_1 and B_2.

At $t=0$,

$$i(0)=(B_1+B_2(0))e^0$$
$$3=B_1$$
$$B_1=3\text{ A}$$

$$i_L(0^-)=i_L(0^+)$$
$$=3\text{ A}$$

Step 7 of 9

Determine the inductor voltage.

$$v_c=-10+Ri(0^+)+v_L$$
$$5=-10+10(3)+v_L$$
$$5+10-30=v_L$$
$$-15=v_L$$

Determine the value of $\frac{di}{dt}$.

$$v_L=L\frac{di}{dt}$$

$$\frac{di}{dt}=\frac{v_L}{L}$$
$$=\frac{-15}{1}$$
$$=-15\text{ A}$$

$$i(t)=(B_1+B_2t)e^{-5t}$$

Step 8 of 9

Differentiate equation (1) with respect to "t".

$$\frac{di}{dt}=\frac{d}{dt}\left[(B_1+B_2t)e^{-5t}\right]$$
$$=-5B_1e^{-5t}-5B_2te^{-5t}+B_2e^{-5t}$$

At $t=0$,

$$\frac{di}{dt}=-5B_1+B_2$$
$$-15=-5(3)+B_2$$
$$B_2=15-15$$
$$B_2=0$$

Step 9 of 9

Substitute the values of B_1 and B_2 in equation (1).

$$i(t)=(B_1+B_2t)e^{-5t}$$
$$=(3+0(t))e^{-5t}$$
$$=3e^{-5t}\text{ A}$$

Therefore, the current expression $i(t)$ for $t>0$ is $\boxed{3e^{-5t}\text{ A}}$.

Step 1 of 13

Determine current at $t=(0^-)$.

$$i_L(0^-)=0\text{ A}$$
$$=i_L(0^+)$$

Determine voltage $V_0(0^-)$.

$$V_C(0^-)=6\left(\frac{6}{18}\right)$$
$$=2\text{ V}$$
$$=V_C(0^+)$$

Step 2 of 13

Determine equivalent resistance and redraw the circuit.

Step 3 of 13

Figure 2

Step 4 of 13

Determine equivalent resistance.

$$R_{equ}=\frac{(8+4)(6)}{8+4+6}$$
$$=\frac{72}{18}$$
$$=4\ \Omega$$

Determine equivalent resistance.

$$R_{equ}=4+1$$
$$=5\ \Omega$$

Step 5 of 13

Determine equivalent inductance.

$$L_{equ}=L_1+L_2$$
$$=\frac{1}{8}+\frac{1}{8}$$
$$=\frac{1}{4}\text{ H}$$

Step 6 of 13

At $t=(0^+)$ redraw the circuit.

Figure 3

Step 7 of 13

Determine damping ratio α.

$$\alpha=\frac{R}{2L}$$
$$=\frac{5}{2\left(\frac{1}{4}\right)}$$
$$=10\text{ rad/s}$$

Determine natural frequency ω_0.

$$\omega_0=\frac{1}{\sqrt{LC}}$$
$$=\frac{1}{\sqrt{\frac{1}{4}\left(\frac{1}{25}\right)}}$$
$$=\frac{1}{\sqrt{\frac{1}{100}}}$$
$$=10$$

$\alpha=\omega_0$, therefore it is critically damped.

Step 8 of 13

Redraw the circuit at $t=(\infty)$.

Figure 4

Step 9 of 13

Determine voltage across capacitor at $t=(\infty)$.

$$V_C=2\text{ V}$$

At $t=(0^+)$ the voltage across capacitor is equal to inductor, as there is no drop in resistor in zero time.

Therefore $V_L=V_C$.

But

$$V_L=L\frac{di}{dt}$$

$$\frac{di}{dt}=\frac{V_L}{L}$$
$$=\frac{2}{\frac{1}{4}}$$
$$=8$$

Step 10 of 13

Determine $i(t)$.

$\frac{di}{dt}$ at $t=0$.

Current expression

$$i(t)=I+(A_1+A_2t)e^{-10t}$$

At $t=0$ current expression is,

$$0+(A_1+A_2o)e^{-10}=0$$
$$A_1=0$$

Determine $\frac{di}{dt}$ at $t=0$.

$$\frac{di}{dt}=\frac{d}{dt}\left(I+(A_1+A_2t)e^{-10t}\right)$$
$$=0-10A_1e^{-10t}-10A_2te^{-10t}+A_2e^{-10t}$$

At $t=0$

$$\frac{di}{dt}=A_2e^{-10t}-10A_1te^{-10t}$$

$$8=A_2-10A_1$$
$$8=A_2-10(0)$$
$$A_2=8$$

Step 11 of 13

The total current expression is,

$$i(t)=I+(A_1+A_2t)e^{-10t}$$
$$=0+(0+8t)e^{-10t}$$
$$=8te^{-10t}\text{ A}$$

Calculate the output voltage.

$$v_o(t)=Ri(t)$$
$$=(1)8te^{-10t}$$
$$=8te^{-10t}\text{ V}$$

Thus, the output voltage, $v_o(t)$ is $\boxed{8te^{-10t}\text{ V}}$.

Step 12 of 13

Consider the following MATLAB command to the plot the graph of output voltage and time.

```
>> t=0:0.001:1;

>> v=8.*t.*exp(-10.*t);

>> plot(t,v)
```

Step 13 of 13

Consider the plot of output voltage versus time shown in Figure 5.

Therefore, the required plot is shown in Figure 5.

Step 1 of 9

Refer to Figure P7.114 in the textbook.

Initially for $t < 0$, the switch is closed for long time, the capacitor acts as an open circuit and inductor acts as a short circuit.

The circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law at node 1.

$$-2+\frac{V_1-12}{2}+\frac{V_1}{6}+\frac{V_1-V_2}{4}=0$$

$$\frac{-24+6V_1-72+2V_1+3V_1-3V_2}{12}=0$$

$$11V_1-3V_2=96 \text{ ..... (1)}$$

Apply Kirchhoff's current law at node 2.

$$\frac{V_2-V_1}{4}+\frac{V_2}{2}=0$$

$$\frac{V_2-V_1+2V_2}{4}=0$$

$$-V_1+3V_2=0$$

$$V_1=3V_2 \text{ ..... (2)}$$

Substitute $3V_2$ for V_1 in equation (1).

$$11(3V_2)-3V_2=96$$

$$30V_2=96$$

$$V_2=3.2\text{ V}$$

From Figure 1, the initial voltage across the capacitor is,

$$v_C(0^-)=V_2$$
$$=3.2\text{ V}$$

The voltage across the capacitor cannot change instantaneously. Therefore,

$$v_C(0)=v_C(0^-)$$
$$=3.2\text{ V}$$

Calculate the initial current flowing through the inductor.

$$i_L(0^-)=\frac{V_2}{2}$$
$$=\frac{3.2}{2}$$
$$=1.6\text{ A}$$

The current flowing through inductor cannot change instantaneously.

Therefore,

$$i_L(0)=i_L(0^-)$$
$$=1.6\text{ V}$$

Step 3 of 9

Draw the circuit diagram for $t > 0$.

Figure 2

Step 4 of 9

Apply Kirchhoff's voltage law for loop 1.

$$-2i_L-2\frac{di_L}{dt}+\frac{1}{1}\int(2-i_L)dt=0$$

Differentiate the equation with respect to t.

$$-2\frac{di_L}{dt}-2\frac{d^2i_L}{dt^2}+2-i_L=0$$

$$\frac{di_L}{dt}+\frac{d^2i_L}{dt^2}-1+0.5i_L=0$$

$$\frac{d^2i_L}{dt^2}+\frac{di_L}{dt}+0.5i_L=1 \text{ ..... (3)}$$

The solution to the differential equation shown in equation (3) is,

$$i_L(t)=i_{Lp}(t)+i_{Lc}(t)$$

Here,

$i_{Lp}(t)$ is the particular solution of the equation (1).

$i_{Lc}(t)$ is the complementary solution of the homogeneous equation

$$\frac{d^2i_L}{dt^2}+\frac{di_L}{dt}+0.5i_L=0$$

Step 5 of 9

From the differential equation, the particular solution is,

$$i_{Lp}(t)=\frac{1}{0.5}$$
$$=2\text{ A}$$

Write the characteristic equation from the homogeneous equation.

$$s^2+s+0.5=0$$

Calculate the roots of the characteristic equation.

$$s_{1,2}=\frac{-1\pm\sqrt{1-2}}{2}$$
$$=\frac{-1\pm j}{2}$$
$$=-0.5\pm j0.5$$

Since the roots are complex, the circuit is underdamped, and the expression for $i_{Lc}(t)$ is,

$$i_{Lc}(t)=K_1e^{-0.5t}\cos(0.5t)+K_2e^{-0.5t}\sin(0.5t)$$

Therefore, the complete solution is,

$$i_L(t)=i_{Lp}(t)+i_{Lc}(t)$$

$$i_L(t)=2+K_1e^{-0.5t}\cos(0.5t)+K_2e^{-0.5t}\sin(0.5t) \text{ ..... (4)}$$

Substitute 0 for t.

$$i_{Lc}(0)=2+K_1e^{-0.5(0)}\cos(0.5(0))+K_2e^{-0.5(0)}\sin(0.5(0))$$

$$1.6=2+K_1+K_2(0)$$

$$K_1=-0.4$$

Step 6 of 9

Apply Kirchhoff's voltage law for loop 1 in Figure 2.

$$-2i_L(t)-2\frac{di_L(t)}{dt}+v_C(t)=0$$

Substitute 0 for t.

$$-2i_L(0)-2\frac{di_L(0)}{dt}+v_C(0)=0$$

$$-2(1.6)-2\frac{di_L(0)}{dt}+3.2=0$$

$$\frac{di_L(0)}{dt}=0$$

Differentiate the equation (4) with respect to t.

$$\frac{di_{Lc}(t)}{dt}=\begin{bmatrix}-0.5K_1e^{-0.5t}\sin 0.5t-0.5K_1e^{-0.5t}\cos 0.5t+0.5K_2e^{-0.5t}\cos 0.5t-\\0.5K_2e^{-0.5t}\sin 0.5t\end{bmatrix}$$

Substitute 0 for t.

$$\frac{di_{Lc}(0)}{dt}=\begin{bmatrix}-0.5K_1e^{-0.5(0)}\sin 0.5(0)-0.5K_1e^{-0.5(0)}\cos 0.5(0)+0.5K_2e^{-0.5(0)}\cos 0.5(0)-\\0.5K_2e^{-0.5(0)}\sin 0.5(0)\end{bmatrix}$$

$$0=[-0.5K_1+0.5K_2]$$

$$-0.5K_1+0.5K_2=0$$

$$0.5K_2=0.5K_1$$

$$K_2=K_1$$

$$K_2=1.6$$

Step 7 of 9

Substitute -0.4 for K_1 and -0.4 for K_2 in equation (4)

$$i_L(t)=2-0.4e^{-0.5t}\cos(0.5t)-0.4e^{-0.5t}\sin(0.5t)$$
$$=2-0.4e^{-0.5t}[\cos(0.5t)+\sin(0.5t)]\text{ A}$$

Therefore, the current flowing through the inductor is,

$$i_L(t)=2-0.4e^{-0.5t}[\cos(0.5t)+\sin(0.5t)]\text{ A}$$

Step 8 of 9

Calculate the voltage across $2\,\Omega$ resistor.

$$v_o(t)=2i_L(t)$$
$$=2[2-0.4e^{-0.5t}[\cos(0.5t)+\sin(0.5t)]]$$
$$=4-0.8e^{-0.5t}[\cos(0.5t)+\sin(0.5t)]\text{ V}$$

Therefore, the voltage across the $2\,\Omega$ resistor is,

$$v_o(t)=4-0.8e^{-0.5t}[\cos(0.5t)+\sin(0.5t)]\text{ V}$$

Step 9 of 9

Draw the plot for $v_o(t)$ over a 10 s interval.

Figure 3

Hence, the plot, $v_o(t)$ is drawn.

7.115P

We don't have the solution to this problem yet.

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7.116P

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Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Apply nodal analysis.

$$\frac{v(t)}{R}+C\frac{d(v(t))}{dt}+\frac{1}{L}\int v(t)dt=i(t)$$

Assume the current source to be a constant value. Apply derivative with respect to t.

$$\frac{1}{R}\frac{d(v(t))}{dt}+C\frac{d^2(v(t))}{dt^2}+\frac{1}{L}(v(t))=0$$

$$\frac{d^2(v(t))}{dt^2}+\frac{1}{RC}\frac{d(v(t))}{dt}+\frac{1}{LC}(v(t))=0 \quad \text{..... (1)}$$

Step 3 of 5

Consider the characteristic equation for equation (1).

$$s^2+\left(\frac{1}{RC}\right)s+\frac{1}{LC}=0$$

Compare with $s^2+4\times10^7 s+4\times10^{14}=0$.

$$\frac{1}{LC}=4\times10^{14} \quad \text{..... (2)}$$

and

$$\frac{1}{RC}=4\times10^{7} \quad \text{..... (3)}$$

Step 4 of 5

Divide equation (2) by (1).

$$\frac{\frac{1}{RC}}{\frac{1}{LC}}=\frac{4\times10^7}{4\times10^{14}}$$

$$\frac{L}{R}=10^{-7}$$

Assume the value of the R to be $10\ \text{k}\Omega$.

$$\frac{L}{10\ \text{k}}=10^{-7}$$

$$L=(10^{-7})(10\ \text{k})$$

$$L=1\ \text{mH}$$

Therefore, the value of the inductor is $0.1\ \text{mH}$.

Step 5 of 5

Consider equation (1).

$$\frac{1}{LC}=4\times10^{14}$$

Substitute $1\ \text{mH}$ for L in the equation.

$$\frac{1}{(1\ \text{m})C}=4\times10^{14}$$

$$C=\frac{1}{(1\ \text{m})(4\times10^{14})}$$

$$=2.5\ \text{nF}$$

Therefore, the value of the capacitor is $2.5\ \text{nF}$.

Therefore, the values of the resistor, inductor and capacitor are $\boxed{10\ \text{k}\Omega}$, $\boxed{1\ \text{mH}}$ and $\boxed{2.5\ \text{nF}}$ respectively.

Step 1 of 3

The characteristic equation is,

$$s^2 + 4\times10^7 s + 3\times10^{14} = 0 \quad \text{..... (1)}$$

Draw the parallel *RLC* circuit.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law at node v_C.

$$\frac{v_C}{R} + \frac{1}{L}\int v_C dt + C\frac{dv_C}{dt} = 0$$

Differentiate the equation with respect to t.

$$\frac{1}{R}\frac{dv_C}{dt} + \frac{v_C}{L} + C\frac{dv_C^2}{dt^2} = 0$$

$$\frac{dv_C^2}{dt^2} + \frac{1}{RC}\frac{dv_C}{dt} + \frac{1}{LC}v_C = 0$$

From the differential equation, the characteristic equation is,

$$s^2 + \left(\frac{1}{RC}\right)s + \frac{1}{LC} = 0 \quad \text{..... (2)}$$

Compare equation (2) with equation (1).

$$RC = \frac{1}{4\times10^7} \quad \text{..... (3)}$$

$$LC = \frac{1}{3\times10^{14}} \quad \text{..... (4)}$$

Step 3 of 3

Substitute $R \geq 1\text{k}\Omega$ in equation (3).

$$C = \frac{1}{4\times10^7 R}$$

$$C \leq \frac{1}{4\times10^7(1\text{k})}$$

$$\leq 25\ \text{pF}$$

From equation (4),

$$L = \frac{1}{3\times10^{14}C}$$

$$L \geq \frac{1}{3\times10^{14}\left(25\times10^{-12}\right)}$$

$$\geq 0.133\ \text{mH}$$

Therefore, the designed parameters are,

$$\boxed{C \leq 25\ \text{pF},\ L \geq 0.133\ \text{mH}}.$$

Step 1 of 2

Write the expression for the frequency f in hertz.

$$f = \frac{\omega}{2\pi}$$

Here ω is the angular frequency.

Calculate the frequency in hertz by substituting 314 for ω.

$$\begin{aligned} f &= \frac{\omega}{2\pi} \\ &= \frac{314}{2\pi} \\ &= 50\,\text{Hz} \end{aligned}$$

Therefore, the frequency in hertz is $\boxed{50\,\text{Hz}}$.

Step 2 of 2

The phase angle is $\frac{\pi}{4}$.

The phase in degrees is as follows:

$$\begin{aligned} \text{Phase in degrees} &= \frac{\pi}{4} \\ &= \frac{180^\circ}{4} \\ &= 45^\circ \end{aligned}$$

Therefore, the phase in degrees is $\boxed{45^\circ}$.

Step 1 of 2

Write the expression for the frequency *f* in hertz.

$$f = \frac{\omega}{2\pi}$$

Here ω is the angular frequency.

Calculate the frequency in hertz by substitute $400\ \text{Hz}$ for ω in the equation.

$$\begin{aligned} f &= \frac{\omega}{2\pi} \\ &= \frac{400}{2\pi} \\ &= 63.7\ \text{Hz} \end{aligned}$$

Therefore, the frequency in hertz is $\boxed{63.7\ \text{Hz}}$.

Step 2 of 2

Write the expression for the period *T*.

$$T = \frac{1}{f}.$$

Calculate the period of the current by substitute $63.7\ \text{Hz}$ for f in the equation.

$$\begin{aligned} T &= \frac{1}{f} \\ &= \frac{1}{63.7} \\ &= 0.0157\,\text{s} \end{aligned}$$

Therefore, the period of the current is $\boxed{0.0157\ \text{s}}$.

Step 1 of 7

Refer to Figure 8PFE-1 in the textbook.

Apply source transformation to convert the current source with parallel resistance to voltage source with a series resistance.

Determine the value of voltage.

$$V = IZ$$

Substitute $2\angle 0^\circ\ \text{A}$ for I, and 2Ω for Z.

$$\begin{aligned} V &= (2\angle 0^\circ\ \text{A})(2\Omega) \\ &= 4\angle 0^\circ\ \text{V} \end{aligned}$$

Step 2 of 7

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 7

Determine the value of equivalent voltage.

$$\begin{aligned} V &= (12\angle 0^\circ\ \text{V}) + (4\angle 0^\circ\ \text{V}) \\ &= 16\angle 0^\circ\ \text{V} \end{aligned}$$

Apply source transformation to convert the voltage source with series resistance to current source with a parallel resistance.

Determine the value of current.

$$I = \frac{V}{Z}$$

Substitute $16\angle 0^\circ\ \text{V}$ for V, and 2Ω for Z.

$$\begin{aligned} I &= \frac{16\angle 0^\circ\ \text{V}}{2\Omega} \\ &= 8\angle 0^\circ\ \text{A} \end{aligned}$$

Step 4 of 7

The modified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 7

Determine the value of equivalent impedance.

$$\begin{aligned} Z &= 2 \| (-j1) \\ &= \frac{(2)(-j1)}{2 - j1} \\ &= \frac{-j2}{2 - j1} \\ &= (0.4 - j0.8)\Omega \end{aligned}$$

Apply source transformation to convert the current source with parallel resistance to voltage source with a series resistance.

Determine the value of voltage.

$$V = IZ$$

Substitute $8\angle 0^\circ\ \text{A}$ for I, and $(0.4 - j0.8)\Omega$ for Z.

$$\begin{aligned} V &= (8\angle 0^\circ\ \text{A})(0.4 - j0.8) \\ &= 3.2 - 6.4j \\ &= 7.155\angle -63.435^\circ\ \text{V} \end{aligned}$$

Step 6 of 7

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 7

Apply voltage-division rule to determine the value of V_0.

$$\begin{aligned} V_0 &= \left(\frac{1}{1 + j1 + (0.4 - j0.8)}\right)(7.155\angle -63.435^\circ\ \text{V}) \\ &= \left(\frac{1}{1.4 + j0.2}\right)(7.155\angle -63.435^\circ\ \text{V}) \\ &= 1.6 - j4.8 \\ &= 5.06\angle -71.6^\circ\ \text{V} \end{aligned}$$

Thus, the value of voltage, V_0 is $\boxed{5.06\angle -71.6^\circ\ \text{V}}$.

Therefore, the correct option is $\boxed{\text{d}}$.

The current equations are to be expressed as sine waves with positive amplitudes.

$$i_1(t) = 2\sin(377t + 45^\circ)\,\text{A}$$

$$\begin{aligned} i_2(t) &= 0.5\cos(377t + 10^\circ)\,\text{A} \\ &= 0.5\sin(377t + 100^\circ)\,\text{A} \end{aligned}$$

$$\begin{aligned} i_3(t) &= -0.25\sin(377t + 60^\circ)\,\text{A} \\ &= 0.25\sin(377t - 120^\circ)\,\text{A} \end{aligned}$$

The phase angle between $i_1(t)$ and $i_2(t)$ is $45^\circ - 100^\circ = -55^\circ$; that is $i_1(t)$ leads $i_2(t)$ by $\boxed{-55^\circ}$.

The phase angle between $i_1(t)$ and $i_3(t)$ is $45^\circ - (-120^\circ) = 165^\circ$; that is $i_1(t)$ leads $i_3(t)$ by $\boxed{165^\circ}$

The phase relationships of the two waves are,

$$v_1 = 10\cos(377t - 30°)\ \text{V}$$

$$v_2 = 10\cos(377t + 90°)\ \text{V}$$

Since the both voltages of the same frequency are expressed as cosine waves with positive amplitude. Calculate the phase angle between $v_2(t)$ and $v_1(t)$.

$$90° - (-30°)$$
$$\Rightarrow 90° + 30°$$
$$\Rightarrow 120°$$

This means that voltage $v_2(t)$ leads voltage $v_1(t)$ by $120°$ or voltage $v_1(t)$ lags voltage $v_2(t)$ by $120°$.

Therefore, the voltage $v_2(t)$ leads voltage $v_1(t)$ by $\boxed{120°}$.

Step 1 of 6

Refer to Figure 8PFE-2 in the textbook.

The circuit diagram of Figure 8PFE-2 with node representation as shown in Figure 1.

Figure 1

Step 2 of 6

Determine the value of V_2 .

From the circuit,

$$V_2 = 12\angle 0^\circ \text{ V}$$

Step 3 of 6

Apply Kirchhoff's Current Law at node-1.

$$\frac{V_1 - V_2}{1} + \frac{V_1}{-j1} + 2I_x = 0$$

Substitute $12\angle 0^\circ$ V for V_2 .

$$V_1 - 12\angle 0^\circ + j1V_1 + 2I_x = 0$$

$$(1 + j1)V_1 - 12\angle 0^\circ + 2I_x = 0 \text{ ..... (1)}$$

Step 4 of 6

Determine the value of V_1 .

$$I_x = \frac{V_1}{-j1}$$

$$V_1 = -j1I_x$$

Step 5 of 6

Determine the value of I_x .

Substitute $-j1I_x$ for V_1 in equation (1).

$$(1 + j1)(-j1I_x) - 12\angle 0^\circ + 2I_x = 0$$

$$-j1I_x + I_x - 12 + 2I_x = 0$$

$$(3 - j1)I_x = 12$$

$$I_x = \frac{12}{3 - j1}$$

$$= (3.6 + j1.2)\text{A}$$

Step 6 of 6

Apply Kirchhoff's Current Law at node-3.

$$\frac{V_2 - V_0}{2} + 2I_x + 2\angle 0^\circ = 0$$

$$V_2 - V_0 + 4I_x + 4\angle 0^\circ = 0$$

Substitute $12\angle 0^\circ$ V for V_2 , $(3.6 + j1.2)$A for I_x .

$$12\angle 0^\circ - V_0 + 4(3.6 + j1.2) + 4\angle 0^\circ = 0$$

$$12 - V_0 + 14.4 + j4.8 + 4 = 0$$

$$V_0 = 30.4 + j4.8$$

$$= 30.8\angle 8.97^\circ \text{ V}$$

Therefore, the value of voltage, V_0 is $\boxed{30.8\angle 8.97^\circ \text{ V}}$.

Hence, the correct option is $\boxed{\text{c}}$.

Step 1 of 2

The function in time domain $A\cos(\omega t \pm \theta)$ is equivalent to the function $A\angle \pm \theta$ in the frequency domain.

$$A\cos(\omega t \pm \theta) = A\angle \pm \theta$$

The voltage function in time domain can be expressed in frequency domain is as follows.

$$v_1(t) = 12\cos(377t - 425°)\,\text{V}$$
$$\text{V}_1 = 12\angle -425°\,\text{V}$$

Therefore, the phasor of the voltage function is $\boxed{12\angle -425°\,\text{V}}$.

Step 2 of 2

The voltage function in time domain can be expressed in frequency domain is as follows.

$$\begin{aligned} v_2(t) &= 18\sin(2513t + 4.2°)\,\text{V} \\ &= 18\cos(2513t + 4.2° - 90°)\,\text{V} \\ &= 18\cos(2513t - 85.8°)\,\text{V} \\ \text{V}_2 &= 18\angle -85.8°\,\text{V} \end{aligned}$$

Therefore, the phasor of the voltage function is $\boxed{18\angle -85.8°\,\text{V}}$.

Convert the current source in sine function in to cosine function.

$$\begin{aligned} i(t) &= 5\sin(377t - 20^\circ)\ \text{A} \\ &= 5\cos(377t - 20^\circ - 90^\circ)\ \text{A} \\ &= 5\cos(377t - 110^\circ)\ \text{A} \end{aligned}$$

The voltage function is,

$$v(t) = 10\cos(377t + 30^\circ)\text{V}$$

Since the both current and voltages of same frequency and are expressed as cosine waves with positive amplitude. Calculate the phase angle between $v(t)$ and $i(t)$.

$$\begin{aligned} &30^\circ - (-110^\circ) \\ &\Rightarrow 30^\circ + 110^\circ \\ &\Rightarrow 140^\circ \end{aligned}$$

This means that voltage $v(t)$ leads current $i(t)$ by 140° or current $i(t)$ lags voltage $v(t)$ by 140° .

Therefore, the voltage $v(t)$ leads current $i(t)$ by $\boxed{140^\circ}$.

Step 1 of 5

Refer to Figure 8PFE-3 in the textbook.

The circuit diagram of Figure 8PFE-3 with loops as shown in Figure 1.

Figure 1

Step 2 of 5

From Figure 1,

$$V_0 = 4I_2$$

Apply Kirchhoff's Voltage Law in loop-1.

$$-12\angle 0^\circ + 2I_1 + j2(I_1 - I_2) + 2V_0$$
$$(2+j2)I_1 - j2I_2 + 2V_0 = 12\angle 0^\circ$$

Substitute $4I_2$ for V_0.

$$(2+j2)I_1 - j2I_2 + 2(4I_2) = 12\angle 0^\circ$$
$$(2+j2)I_1 - j2I_2 + 8I_2 = 12\angle 0^\circ$$

$$(2+j2)I_1 + (8-j2)I_2 = 12 \quad \text{..... (1)}$$

Step 3 of 5

Apply Kirchhoff's Voltage Law in loop-2.

$$-j1I_2 + V_0 - 2V_0 + j2(I_2 - I_1) = 0$$
$$-j1I_2 - V_0 + j2(I_2 - I_1) = 0$$

Substitute $4I_2$ for V_0.

$$-j1I_2 - 4I_2 + j2I_2 - j2I_1 = 0$$
$$(-4+j1)I_2 - j2I_1 = 0$$
$$(-4+j1)I_2 = j2I_1$$

$$I_1 = \frac{(-4+j1)I_2}{j2}$$
$$= (0.5+j2)I_2$$

Step 4 of 5

Determine the value of I_2.

Substitute $(0.5+j2)I_2$ for I_1 in equation (1).

$$(2+j2)(0.5+j2)I_2 + (8-j2)I_2 = 12$$
$$(-3+j5)I_2 + (8-j2)I_2 = 12$$
$$(5+j3)I_2 = 12$$

$$I_2 = \frac{12}{5+j3}$$
$$= 2.058\angle -30.96^\circ \text{ A}$$

Step 5 of 5

Determine the value of V_0.

$$V_0 = 4I_2$$

Substitute $2.058\angle -30.96^\circ$ A for I_2.

$$V_0 = 4(2.058\angle -30.96^\circ)$$
$$= 8.232\angle -30.96^\circ \text{ V}$$

Therefore, the value of voltage, V_0 is $\boxed{8.232\angle -30.96^\circ \text{ V}}$.

Hence, the correct option is $\boxed{\text{a}}$.

Step 1 of 2

The function $A\angle\pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t\pm\theta)$ in the time domain.

$$A\angle\pm\theta = A\cos(\omega t\pm\theta)$$

Write the expression for the angular frequency.

$$\omega = 2\pi f$$

Calculate the angular frequency by substituting $400\,\text{Hz}$ for f.

$$\begin{aligned}\omega &= 2\pi f\\ &= 2\pi(400)\\ &= 800\pi\end{aligned}$$

The voltage function in phasor can be expressed in time domain is as follows.

$$\begin{aligned}\mathbf{V}_1 &= 10\angle 20^\circ\,\text{V}\\ v_1(t) &= 10\cos(800t+20^\circ)\,\text{V}\end{aligned}$$

Therefore, the voltage function in the time domain is $\boxed{10\cos(800\pi t+20^\circ)\,\text{V}}$.

Step 2 of 2

The voltage function in phasor can be expressed in time domain is as follows.

$$\begin{aligned}\mathbf{V}_1 &= 12\angle -60^\circ\,\text{V}\\ v_1(t) &= 12\cos(800t-60^\circ)\,\text{V}\end{aligned}$$

Therefore, the voltage function in the time domain is $\boxed{12\cos(800\pi t-60^\circ)\,\text{V}}$.

8.004P

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Step 1 of 5

Refer to Figure 8PFE-4 in the textbook.

At mid-point impedance of capacitors, Z_C is small. So, it can be neglected.

In Figure 8PFE-4, the resistors $6\,\text{k}\Omega$ and $12\,\text{k}\Omega$ are in parallel.

Determine the equivalent resistance.

$$\begin{aligned} R_{eq} &= \frac{(6\,\text{k}\Omega)(12\,\text{k}\Omega)}{(6\,\text{k}\Omega)+(12\,\text{k}\Omega)} \\ &= \frac{72}{18}\,\text{k}\Omega \\ &= 4\,\text{k}\Omega \end{aligned}$$

Step 2 of 5

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 5

Apply voltage division rule in left loop to determine the value of V_S.

$$\begin{aligned} V_x &= \left(\frac{5\,\text{k}\Omega}{5\,\text{k}\Omega + 1\,\text{k}\Omega}\right)V_S \\ V_S &= \left(\frac{6}{5}\right)V_x \end{aligned}$$

Step 4 of 5

Determine the value of V_0.

$$\begin{aligned} V_0 &= (4\,\text{k}\Omega)\left(-40\times10^{-3}V_x\right) \\ &= \left(4\times10^{3}\right)\left(-40\times10^{-3}V_x\right) \\ &= -160V_x \end{aligned}$$

Step 5 of 5

The mid-band gain of the single-stage transistor amplifier is,

$$\begin{aligned} \text{gain} &= \frac{\text{output voltage}}{\text{input voltage}} \\ &= \frac{V_0}{V_S} \end{aligned}$$

Substitute $-160V_x$ for V_0, and $\left(\frac{6}{5}\right)V_x$ for V_S.

$$\begin{aligned} \frac{V_0}{V_S} &= \frac{-160V_x}{\left(\frac{6}{5}\right)V_x} \\ &= \frac{(-160)(5)}{6} \\ &= -133.33 \end{aligned}$$

Thus, the midband gain of the single-stage transistor amplifier is $\boxed{-133.33\ \text{V/V}}$.

Therefore, the correct option is $\boxed{\text{b}}$.

Step 1 of 2

The function $A\angle\pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t\pm\theta)$ in the time domain.

$$A\angle\pm\theta = A\cos(\omega t\pm\theta)$$

Write the expression for the angular frequency.

$$\omega = 2\pi f$$

Calculate the angular frequency by substituting $4\,\text{kHz}$ for f.

$$\begin{aligned}\omega &= 2\pi f\\ &= 2\pi(4000)\\ &= 8000\pi\end{aligned}$$

Step 2 of 2

Determine the current in time domain.

$$\begin{aligned}\mathbf{I}_1 &= 12\angle 60^\circ\,\text{A}\\ i_1(t) &= 12\cos(8000\pi t + 60^\circ)\,\text{A}\end{aligned}$$

Apply Ohm's law, write the expression for the voltage across the resistor.

$$v(t) = Ri(t)$$

Calculate the voltage across the resistor.

Substitute 4Ω for R and $12\cos(8000\pi t + 60^\circ)\,\text{A}$ for $i(t)$ in the equation.

$$\begin{aligned}v(t) &= Ri(t)\\ &= (4)(12\cos(8000\pi t + 60^\circ))\\ &= 48\cos(8000\pi t + 60^\circ)\,\text{V}\end{aligned}$$

Therefore, the voltage across the resistor is $\boxed{48\cos(8000\pi t + 60^\circ)\,\text{V}}$.

Step 1 of 2

(a) Given:

$V_1(t) = 10\cos(377t + 180°)\text{V}$

In phase form

$V_1 = 10\angle 180°\text{ V}$

$$\therefore I = \frac{V_1}{R}$$

$$= \frac{10\angle 180°}{2}$$

$I = \boxed{5\angle 180°\text{ A}}$

In time domain

$\boxed{i(t) = 5\cos(377t + 180°)\text{ A}}$

Step 2 of 2

(b) Given:

$V_2(t) = 12\sin(377t + 45°)\text{ V}$

$V_2(t) = 12\cos(377t - 45°)\text{V}$

In phasor from $V_2 = 12\angle -45°$

$$\therefore I = \frac{V_2}{R}$$

$$= \frac{12\angle -45°}{2}$$

$\boxed{I = 6\angle -45°\text{ A}}$

In time domain $\boxed{i(t) = 6\cos(377t - 45°)\text{ A}}$

Step 1 of 8

8.05FE

Refer to Figure 8PFE-5 in the textbook.

Apply source transformation to convert the voltage source with series resistance to current source with a parallel resistance.

Determine the value of current.

$$I = \frac{V}{Z}$$

Substitute $6\angle 0^\circ\ \text{V}$ for V, 3Ω for Z.

$$\begin{aligned} I &= \frac{6\angle 0^\circ\ \text{V}}{3\Omega} \\ &= 2\angle 0^\circ\ \text{A} \end{aligned}$$

Step 2 of 8

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 8

Determine the value of equivalent impedance.

$$\begin{aligned} Z_{eq} &= 3 \| (1 + j3) \\ &= \frac{3(1 + j3)}{3 + (1 + j3)} \\ &= \frac{3 + j9}{4 + j3} \\ &= (1.56 + j1.08)\Omega \end{aligned}$$

Step 4 of 8

The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 8

In Figure 2, the current source $2\angle 0^\circ\ \text{A}$ with parallel impedance of $(1.56 + j1.08)\Omega$ is exchanged with voltage source of with series impedance.

Determine the value of voltage.

Determine the value of voltage.

$$V = IZ$$

Substitute $2\angle 0^\circ\ \text{A}$ for I, and $(1.56 + j1.08)\Omega$ for Z.

$$\begin{aligned} V &= (2\angle 0^\circ\ \text{A})(1.56 + j1.08)\Omega \\ &= (3.12 + j2.16)\ \text{V} \\ &= 3.795\angle 34.695^\circ\ \text{V} \end{aligned}$$

Step 6 of 8

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 8

Apply voltage-division rule to determine the value of V_0.

$$\begin{aligned} V_0 &= \left(\frac{1}{1 + 1.56 + j1.08 - j1}\right)(3.795\angle 34.695^\circ\ \text{V}) \\ &= \left(\frac{1}{2.56 + j0.08}\right)(3.795\angle 34.695^\circ\ \text{V}) \\ &= 1.48\angle 32.91^\circ\ \text{V} \end{aligned}$$

Step 8 of 8

Determine the value of I_0.

$$I_0 = (1\Omega)(V_0)$$

Substitute $1.48\angle 32.91^\circ\ \text{V}$ for V_0.

$$\begin{aligned} I_0 &= (1\Omega)(1.48\angle 32.91^\circ\ \text{V}) \\ &= 1.48\angle 32.91^\circ\ \text{A} \end{aligned}$$

Therefore, the value of I_0 is $\boxed{1.48\angle 32.91^\circ\ \text{A}}$.

Hence, the correct option is $\boxed{\text{c}}$.

Step 1 of 2

The function $A\angle\pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t\pm\theta)$ in the time domain.

$$A\angle\pm\theta = A\cos(\omega t\pm\theta)$$

Write the expression for the angular frequency.

$$\omega = 2\pi f$$

Calculate the angular frequency by substituting $60\,\text{Hz}$ for f.

$$\begin{aligned}\omega &= 2\pi f\\ &= 2\pi(60)\\ &= 120\pi\\ &= 377\end{aligned}$$

Step 2 of 2

The current in phasor can be expressed in time domain is as follows.

$$\begin{aligned}\mathrm{I} &= 4\angle -30^\circ\,\text{A}\\ i(t) &= 4\cos(377t-30^\circ)\,\text{A}\end{aligned}$$

Write the expression for the current through the inductor in phasor notation..

$$\mathrm{I} = \frac{\mathrm{V}}{j\omega L}$$

Calculate the voltage across the inductor by substituting $0.05\,\text{H}$ for L, 377 for ω and $4\cos(377t-30^\circ)\,\text{A}$ for I.

$$\begin{aligned}\mathrm{I} &= \frac{\mathrm{V}}{j\omega L}\\ \mathrm{V} &= (j\omega L)(\mathrm{I})\\ &= (377)(0.05\angle 90^\circ)(4\cos(377t-30^\circ))\\ &= 75.4\cos(377t+60^\circ)\,\text{V}\end{aligned}$$

Therefore, the voltage across the inductor is $\boxed{75.4\cos(377t+60^\circ)\,\text{V}}$.

Step 1 of 4

Refer to Figure P8.5 in the text book.

(a)

Convert the voltage in time domain in to frequency domain.

$$v_1(t) = 10\cos(377t - 30°)\text{A}$$
$$\mathbf{V}_1 = 10\angle -30°\text{ A}$$

Write the expression for the current through the capacitor in phasor notation.

$$\mathbf{I} = j\omega C\mathbf{V}$$

Calculate the current through the capacitor by substitute $1\ \mu\text{F}$ for C, 377 for ω, $10\angle -30°\text{ V}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{I} &= j\omega C\mathbf{V}\\ &= (1\angle 90°)(377)(1\times 10^{-6})(10\angle -30°)\\ &= 3.77\angle 60°\text{ mA}\end{aligned}$$

Therefore, the current through the capacitor in frequency domain is $\boxed{3.77\angle 60°\text{ mA}}$.

Step 2 of 4

The function $A\angle \pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t \pm \theta)$ in the time domain.

$$A\angle \pm\theta = A\cos(\omega t \pm \theta)$$

Convert the current into time domain.

$$\begin{aligned}\mathbf{I} &= 3.77\angle 60°\text{ mA}\\ &= 3.77\cos(377t + 60°)\text{ mA}\end{aligned}$$

Therefore, the current through the capacitor in time domain is $\boxed{3.77\cos(377t + 60°)\text{ mA}}$.

Step 3 of 4

(b)

Convert the voltage in time domain in to frequency domain.

$$\begin{aligned}v_2(t) &= 12\sin(377t + 60°)\text{ V}\\ &= 12\cos(377t + 60° - 90°)\text{ V}\\ &= 12\cos(377t - 30°)\text{ V}\end{aligned}$$

$$\mathbf{V}_2 = 12\angle -30°\text{ V}$$

Write the expression for the current through the capacitor in phasor notation.

$$\mathbf{I} = j\omega C\mathbf{V}$$

Calculate the current through the capacitor by substitute $1\ \mu\text{F}$ for C, 377 for ω, $12\angle -30°\text{ V}$ for $\mathbf{V}_2$ in the equation.

$$\begin{aligned}\mathbf{I} &= j\omega C\mathbf{V}\\ &= (1\angle 90°)(377)(1\times 10^{-6})(12\angle -30°)\\ &= 4.524\angle 60°\text{ mA}\end{aligned}$$

Therefore, the current through the capacitor in frequency domain is $\boxed{4.524\angle 60°\text{ mA}}$.

Step 4 of 4

The function $A\angle \pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t \pm \theta)$ in the time domain.

$$A\angle \pm\theta = A\cos(\omega t \pm \theta)$$

Convert the current into time domain.

$$\begin{aligned}\mathbf{I} &= 4.524\angle 60°\text{ mA}\\ &= 4.524\cos(377t + 60°)\text{ mA}\end{aligned}$$

Therefore, the current through capacitor in time domain is $\boxed{4.524\cos(377t + 60°)\text{ mA}}$.

Step 1 of 2

The function $A\angle\pm\theta$ in the frequency domain is equivalent to the function $A\cos(\omega t\pm\theta)$ in the time domain.

$$A\angle\pm\theta = A\cos(\omega t\pm\theta)$$

Write the expression for the angular frequency.

$$\omega = 2\pi f$$

Calculate the angular frequency by substituting $60\,\text{Hz}$ for f.

$$\begin{aligned}\omega &= 2\pi f\\ &= 2\pi(60)\\ &= 120\pi\\ &= 377\end{aligned}$$

Step 2 of 2

The current in phasor can be expressed in time domain is as follows.

$$\mathbf{I} = 3.6\angle -145^\circ\,\text{A}$$
$$i(t) = 3.6\cos(377t - 145^\circ)\,\text{A}$$

Write the expression for the current through the capacitor in phasor notation..

$$\mathbf{I} = j\omega C\mathbf{V}$$

Calculate the voltage across the capacitor.

Substitute $150\,\mu\text{F}$ for C, 377 for ω, and $3.6\cos(377t - 145^\circ)\,\text{A}$ for $\mathbf{I}$ in the equation.

$$\mathbf{I} = j\omega C\mathbf{V}$$

$$\begin{aligned}\mathbf{V} &= \frac{\mathbf{I}}{j\omega C}\\ &= \frac{3.6\cos(377t - 145^\circ)}{(377)(150\times10^{-6}\angle 90^\circ)}\\ &= 63.66\cos(377t - 235^\circ)\,\text{V}\end{aligned}$$

Therefore, the voltage across the capacitor is $\boxed{63.66\cos(377t - 235^\circ)\,\text{V}}$.

8.007P

The voltage and current equations are to be expressed as sine waves with positive amplitudes.

$$v_1(t) = 4\sin(377t + 25^\circ)\,\text{V}$$

$$\begin{aligned} i_1(t) &= 0.05\cos(377t - 20^\circ)\,\text{A} \\ &= 0.05\sin(377t + 70^\circ)\,\text{A} \end{aligned}$$

$$\begin{aligned} i_2(t) &= -0.1\sin(377t + 45^\circ)\,\text{A} \\ &= 0.1\sin(377t - 135^\circ)\,\text{A} \end{aligned}$$

The phase angle between $v_1(t)$ and $i_1(t)$ is $25^\circ - 70^\circ = -45^\circ$; that is $v_1(t)$ leads $i_1(t)$ by $\boxed{-45^\circ}$.

The phase angle between $v_1(t)$ and $i_2(t)$ is $25^\circ - (-135^\circ) = 160^\circ$; that is $v_1(t)$ leads $i_2(t)$ by $\boxed{160^\circ}$.

Step 1 of 4

Refer to Figure E8.8 in the text book.

The impedances of the individual elements are as follows:

$$Z_R = 20\Omega$$

From the voltage source, the angular frequency is 377.

Write the expression for the frequency.

$$f = \frac{\omega}{2\pi}$$

Calculate the frequency by substituting 377 for ω.

$$\begin{aligned} f &= \frac{\omega}{2\pi} \\ &= \frac{377}{2\pi} \\ &= 60\,\text{Hz} \end{aligned}$$

Step 2 of 4

The impedance of the inductance is as follows:

$$Z_L = j\omega L$$

Calculate the inductance impedance by substituting $60\,\text{Hz}$ for f and $40\,\text{mH}$ for L.

$$\begin{aligned} Z_L &= j\omega L \\ &= j(2\pi)(60)(40\times10^{-3}) \\ &= j15.07\,\Omega \end{aligned}$$

The impedance of the capacitance is as follows:

$$Z_C = \frac{-j}{\omega C}$$

Calculate the capacitance impedance by substituting $60\,\text{Hz}$ for f and $50\,\mu\text{H}$ for C.

$$\begin{aligned} Z_C &= \frac{-j}{\omega C} \\ &= \frac{-j}{2\pi(60)(50\times10^{-6})} \\ &= -j53.07\,\Omega \end{aligned}$$

Step 3 of 4

Write the expression for the equivalent impedance.

$$Z = (Z_R + Z_L) \| Z_C$$

Calculate the equivalent impedance.

Substitute $20\,\Omega$ for Z_R, $j15.07\,\Omega$ for Z_L and $-j53.07\,\Omega$ for Z_C in the equation.

$$\begin{aligned} Z &= (Z_R + Z_L) \| Z_C \\ &= (20 + j15.07) \| (-j53.07) \\ &= \frac{799.76 - j1061.4}{20 - j38} \\ &= \frac{1328.97\angle -53^\circ}{42.94\angle -62.24^\circ} \\ &= 30.94\angle 9.24^\circ\,\Omega \end{aligned}$$

The voltage source is as follows:

$$\begin{aligned} v(t) &= 120\sin(377t + 60^\circ)\,\text{V} \\ &= 120\cos(377t + 60^\circ - 90^\circ)\,\text{V} \\ &= 120\cos(377t - 30^\circ)\,\text{V} \\ &= 120\angle -30^\circ\,\text{V} \end{aligned}$$

Step 4 of 4

Write the expression for the current in the circuit.

$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}}$$

Calculate the current in the circuit.

Substitute $120\angle -30^\circ$ for $\mathbf{V}$ and $30.94\angle 9.24^\circ$ for $\mathbf{Z}$ in the equation.

$$\begin{aligned} \mathbf{I} &= \frac{\mathbf{V}}{\mathbf{Z}} \\ &= \frac{120\angle -30^\circ}{30.94\angle 9.2^\circ} \\ &= 3.88\angle -39.2\,\text{A} \end{aligned}$$

Convert the current in phasor form to time domain.

$$i(t) = 3.88\cos(377t - 39.2^\circ)\,\text{A}$$

Therefore, the current in the circuit is $\boxed{3.88\cos(377t - 39.2^\circ)\,\text{A}}$.

8.008P

Refer to Figure P8.6 in the text book.

The impedances of the individual elements are as follows:

$$Z_R = 3\Omega$$
$$Z_L = j4\Omega$$

Since the resistor and inductor are connected in parallel, write the expression for the equivalent impedance.

$$Z = \frac{Z_R Z_L}{Z_R + Z_L}$$

Calculate the equivalent impedance by substitute $3\ \Omega$ for Z_R and $j4\ \Omega$ for Z_L in the equation.

$$\begin{aligned} Z &= \frac{Z_R Z_L}{Z_R + Z_L} \\ &= \frac{(3)(j4)}{3 + j4} \\ &= \frac{j12}{3 + j4} \\ &= 1.92 + j1.44\ \Omega \end{aligned}$$

Therefore, the frequency domain impedance is $\boxed{1.92 + j1.44\ \Omega}$.

Step 1 of 3

8.009E

Refer to Figure E8.9 in the text book.

The admittance of the impedance Z_R is as follows:

$$Y_R = \frac{1}{Z_R}$$

Calculate the admittance of the impedance Z_R by substituting 2Ω for Z_R.

$$\begin{aligned} Y_R &= \frac{1}{Z_R} \\ &= \frac{1}{2} \\ &= 0.5\text{S} \end{aligned}$$

Calculate the admittance of the impedance Z_L by substituting $j2\Omega$ for Z_L.

$$\begin{aligned} Y_L &= \frac{1}{Z_L} \\ &= \frac{1}{j2} \\ &= -j0.5\text{S} \end{aligned}$$

Step 2 of 3

Calculate the admittance of the impedance Z_C by substituting $-j1\Omega$ for Z_C.

$$\begin{aligned} Y_C &= \frac{1}{Z_C} \\ &= \frac{1}{-j1} \\ &= j1\text{S} \end{aligned}$$

Calculate the admittance of the impedance Z_R by substituting 4Ω for Z_R.

$$\begin{aligned} Y_R &= \frac{1}{Z_R} \\ &= \frac{1}{4} \\ &= 0.25\text{S} \end{aligned}$$

Step 3 of 3

When admittances $Y_1, Y_2, Y_3, \ldots Y_n$ are connected in series, the equivalent admittance is equal to the sum of all the admittances.

$$Y_p = Y_1 + Y_2 + Y_3 + \ldots + Y_n$$

Calculate the total admittance by substituting 0.5S for Y_{R1}, $-j0.5\text{S}$ for Y_L, $j1\text{S}$ for Y_C and 0.25S for Y_{R2}.

$$\begin{aligned} Y &= Y_{R1} + Y_L + Y_C + Y_{R2} \\ &= 0.5 - j0.5 + j1 + 0.25 \\ &= 0.75 + j0.5 \\ &= 0.901\angle 33.7^\circ\text{S} \end{aligned}$$

Write the expression for the current in the network.

$$I = YV$$

Calculate the current in the network by substituting $10\angle 20^\circ\text{ V}$ for V and $0.901\angle 33.7^\circ\text{S}$ for Y.

$$\begin{aligned} I &= YV \\ &= (0.901\angle -33.7^\circ)(10\angle 20^\circ) \\ &= 9.01\angle 53.7^\circ\text{ A} \end{aligned}$$

Therefore, the current in the network is $\boxed{9.01\angle 53.7^\circ\text{ A}}$.

Step 1 of 5

The following is the given circuit diagram:

Figure 1

Step 2 of 5

(a) It is given that,

The voltage input is, $v_1(t) = 10\cos(377t + 45°)\text{V}$

Convert the voltage in phasor form.

$$V_1 = 10\angle 45°$$

The frequency of operation of the circuit is,

$$\omega = 377\text{rad/sec}$$

Step 3 of 5

Calculate the current in the circuit for the voltage applied.

$$\begin{aligned} I &= \frac{V_1}{j\omega L} \\ &= \frac{V_1}{\omega L\angle 90°} \\ &= \frac{10\angle 45°}{(377)(1\times 10^{-3})\angle 90°} \\ &= \frac{10}{0.377}\angle(45° - 90°) \end{aligned}$$

Thus, the current in the circuit in the phasor domain is, $\boxed{26.53\angle -45°\text{ A}}$.

Thus, the time domain expression of the current is, $\boxed{26.53\cos(377t - 45°)\text{A}}$.

Step 4 of 5

(b) It is given that,

The voltage input is, $v_2(t) = 5\sin(377t - 90°)\text{V}$

Convert the voltage into the cosine form.

From the trigonometric properties

$$\sin(377t - 90°) = \cos(377t - 90° - 90°)$$

$$\sin(377t - 90°) = \cos(377t - 180°)$$

Convert the voltage into the phasor form.

$$V_1 = -5\angle 180°$$

The frequency of operation of the circuit is,

$$\omega = 377\text{rad/sec}$$

Step 5 of 5

Calculate the current in the circuit for the voltage applied.

$$\begin{aligned} I &= \frac{V_2}{j\omega L} \\ &= \frac{V_2}{\omega L\angle 90°} \\ &= \frac{5\angle -180°}{(377)(1\times 10^{-3})\angle 90°} \\ &= \frac{5}{0.377}\angle(-180° - 90°) \\ &= 13.26\angle -270°\text{ A} \end{aligned}$$

Convert the current expression into the time domain expression.

$$i(t) = 13.26\cos(377t - 270°)\text{A}$$

$$i(t) = 13.26\cos((377t - 180°) - 90°)\text{A}$$

Thus, the current in the circuit is, $\boxed{13.26\sin(377t - 180°)\text{A}}$.

Step 1 of 2

Refer to Figure E8.10 in the text book.

Draw the equivalent impedance model for the circuit.

Figure 1

Step 2 of 2

The impedances $\mathbf{Z}_2$ and $\mathbf{Z}_3$ are connected in parallel.

Calculate the equivalent admittance for $\mathbf{Z}_2$ and $\mathbf{Z}_3$.

$$\begin{aligned}\mathbf{Y}_{23} &= \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3} \\ &= \frac{1}{2+j2} + \frac{1}{4+j6-j4} \\ &= (0.25 - j0.25) + (0.2 - j0.1) \\ &= 0.45 - j0.35\end{aligned}$$

Calculate the equivalent impedance for $\mathbf{Z}_2$ and $\mathbf{Z}_3$.

$$\begin{aligned}\mathbf{Z}_{23} &= \frac{1}{\mathbf{Y}_{23}} \\ &= \frac{1}{0.45 - j0.35} \\ &= 1.38 + j1.08\ \Omega\end{aligned}$$

Calculate the overall equivalent impedance.

$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_{23} \\ &= 2 + (1.38 + j1.08) \\ &= 3.38 + j1.08\ \Omega\end{aligned}$$

Thus, the overall equivalent impedance, $\mathbf{Z}_T$ is $\boxed{3.38 + j1.08\ \Omega}$.

Step 1 of 2

The given circuit is,

Step 2 of 2

Let, $Z_R = 1\Omega$

$Z_L = j1\Omega$ and

$Z_C = -j2\Omega$

The impedance Z_L and Z_C are in parallel, therefore the equivalent impedance is,

$$Z_{LC} = \frac{Z_L \times Z_C}{Z_L + Z_C}$$

$$Z_{LC} = \frac{j1 \times (-j2)}{j1 - j2}$$

$$Z_{LC} = j2\Omega$$

Now the impedance Z_{LC} is in series with Z_R,

∴ The impedance Z in the network shown above is:

$$Z = Z_R + Z_{LC}$$

$$Z = (1 + j2)\Omega$$

$$\boxed{Z = 2.236\angle 63.435^\circ \Omega}$$

Step 1 of 7

Refer to Figure

The resistor $(4+j2)\ \Omega$ is in parallel with $-j3\ \Omega$, the equivalent resistance is;

$$(4+j2)\|(-j3)=\frac{(4+j2)(-j3)}{(4+j2-j3)}$$

$$=\frac{6-j12}{4-j1}$$

$$=\frac{13.416\angle-63.43^\circ}{4.123\angle-14.04^\circ}$$

$$=3.25\angle-49.39^\circ$$

Simply further.

$$(4+j2)\|(-j3)=2.12-j2.47$$

Step 2 of 7

Also the resistors 4Ω & $j3\Omega$ are in parallel.

$$4\|j3=\frac{4\times j3}{4+j3}$$

$$=\frac{j12}{4+j3}$$

$$=\frac{12\angle90^\circ}{5\angle36.87^\circ}$$

$$=2.4\angle53.13^\circ$$

Simplify further.

$$4\|j3=1.44+j1.9$$

Step 3 of 7

Draw the equivalent circuit.

Figure 1

Step 4 of 7

In the circuit in Figure 1; $2\Omega, 1.44\Omega$ and $j1.9\Omega$ are in series.

$$2+1.44+j1.9=3.44+j1.9$$

And 5Ω is in parallel with $(2.12-j2.47+j3)\ \Omega$, hence the equivalent resistance is;

$$5\|(2.12-j2.47+j3)=\frac{(5)(2.12-j2.47+j3)}{5+2.12-j2.47+j3}$$

$$=\frac{10.6+j2.65}{7.12+j0.53}$$

$$=\frac{10.93\angle14.04^\circ}{7.14\angle4.26^\circ}$$

$$=\frac{10.93\angle14.04^\circ}{7.14\angle4.26^\circ}$$

$$=1.53\angle9.78^\circ$$

Simplify further.

$$5\|(2.12-j2.47+j3)=1.51+j0.26$$

Step 5 of 7

Draw the equivalent circuit.

Figure 2

In the circuit of Figure 2; $(3.44+j1.9)\Omega$ and $(1.51+j0.26)\Omega$ are in series.

$$3.44+j1.9+1.51+j0.26=4.95+j2.16$$

Step 6 of 7

Draw the equivalent circuit.

Figure 3

Step 7 of 7

In the circuit of Figure 3, 3Ω is in parallel with $(4.95+j2.16)\ \Omega$.

$$Z=3\|(4.95+j2.16)$$

$$=\frac{(3)(4.95+j2.16)}{3+4.95+j2.16}$$

$$=\frac{14.85+j6.48}{7.95+j2.16}$$

$$=\frac{16.2\angle23.57^\circ}{8.24\angle15.2^\circ}$$

Simplify further.

$$Z=1.966\angle8.37^\circ$$

$$=1.95+j0.29$$

Therefore the equivalent resistance Z is $\boxed{(1.95+j0.29)\ \Omega}$.

Refer to Figure P8.11 in the textbook.

Calculate the impedance of the circuit, from right to left of the circuit.

$$
\begin{aligned}
Z &= \left\{\left[\left[\left((j2-j1)\|2\right)\|2\right]+1\right]\|j2\right\}+2 \\
&= \left\{\left[\left[\left((j1)\|2\right)\|2\right]+1\right]\|j2\right\}+2 \\
&= \left\{\left[\left[\left(\frac{(j1)2}{(j1)+2}\right)\|2\right]+1\right]\|j2\right\}+2 \\
&= \left\{\left[\left[(0.4+j0.8)\|2\right]+1\right]\|j2\right\}+2
\end{aligned}
$$

$$
\begin{aligned}
Z &= \left\{\left[\left[\frac{(0.4+j0.8)2}{(0.4+j0.8)+2}\right]+1\right]\|j2\right\}+2 \\
&= \left\{\left[\left[\frac{(0.8+j1.6)}{(2.4+j0.8)}\right]+1\right]\|j2\right\}+2 \\
&= \left\{\left[0.5+j0.5+1\right]\|j2\right\}+2 \\
&= \left\{\left[1.5+j0.5\right]\|j2\right\}+2
\end{aligned}
$$

Simplify the expression further.

$$
\begin{aligned}
Z &= \left[\frac{(1.5+j0.5)\,j2}{(1.5+j0.5)+j2}\right]+2 \\
&= \left[\frac{-1+j3}{(1.5+j2.5)}\right]+2 \\
&= 0.705+j0.823+2 \\
&= 2.705+j0.823
\end{aligned}
$$

$$Z = 2.82\angle 16.92^\circ$$

Therefore, the impedance of the circuit is $\boxed{2.82\angle 16.92^\circ\ \Omega}$.

Step 1 of 6

Refer the circuit in Figure E.8.12 in the textbook.

Determine the value of $\mathbf{I}_2$.

Apply current-division rule.

Step 2 of 6

Determine the value of $\mathbf{I}_1$.

Apply current-division rule.

$$\begin{aligned}\mathbf{I}_1 &= \left(\frac{-j4}{2-j4}\right)\left(4\angle 45^\circ\right)\\ &= \left(0.8-j0.4\right)\left(4\angle 45^\circ\right)\\ &= 3.39+j1.13\\ &= 3.58\angle 18.43^\circ \text{ A}\end{aligned}$$

Step 3 of 6

Current source with parallel impedance is transformed to voltage source with series impedance.

Determine the value of voltage.

From ohms law,

$$V = \mathbf{IZ}$$

Substitute $4\angle 45^\circ \text{ A}$ for I, 2Ω for $\mathbf{Z}$.

$$\begin{aligned}V &= \left(4\angle 45^\circ\right)\left(2\right)\\ &= 8\angle 45^\circ \text{ V}\end{aligned}$$

Step 4 of 6

The equivalent circuit is represented by Figure 1.

Figure-1

Step 5 of 6

Determine the value of V.

Apply voltage division rule.

$$\begin{aligned}\mathbf{V} &= \left(\frac{-j4}{2-j4}\right)\left(8\angle 45^\circ\right)\\ &= \left(0.8-j0.4\right)\left(8\angle 45^\circ\right)\\ &= 6.78+j2.26\\ &= 7.15\angle 18.43^\circ \text{ V}\end{aligned}$$

Step 6 of 6

The phasor diagram that represents all currents and voltages is represented by Figure 2.

Figure-2

Thus, the phasor diagram illustrates all currents and voltages in Figure E8.12.

Step 1 of 2

Refer to Figure P8.12 in the text book.

The impedances of the individual elements are as follows:

$$Z_{R1} = 1\Omega$$
$$Z_{R2} = 2\Omega$$

The impedance of the inductance is as follows:

$$Z_L = j\omega L$$

Calculate the inductance impedance.

Substitute $400\ \text{Hz}$ for f and $10\ \text{mH}$ for L in the equation.

$$\begin{aligned} Z_L &= j\omega L \\ &= j(2\pi)(400)(10\times10^{-3}) \\ &= j25.12\Omega \end{aligned}$$

The impedance of the capacitance is,

$$Z_C = \frac{-j}{\omega C}$$

Calculate the capacitance impedance.

Substitute $400\ \text{Hz}$ for f and $10\ \mu\text{F}$ for C in the equation.

$$\begin{aligned} Z_C &= \frac{-j}{\omega C} \\ &= \frac{-j}{2\pi(400)(10\times10^{-6})} \\ &= -j39.8\Omega \end{aligned}$$

Step 2 of 2

Write the expression for the equivalent impedance.

$$Z = \left[(Z_{R2} + Z_C) \| Z_{R1}\right] + Z_L$$

Calculate the equivalent impedance.

Substitute 1Ω for Z_{R1}, 2Ω for Z_{R2}, $j25.12\Omega$ for Z_L and $-j39.8\Omega$ for Z_C in the equation.

$$\begin{aligned} Z &= \left[(Z_{R2} + Z_C) \| Z_{R1}\right] + Z_L \\ &= \left[(2 - j39.8) \| 1\right] + j25.12 \\ &= \left[\frac{39.85\angle-87.12^\circ}{39.91\angle-85.68^\circ}\right] + j25.12 \\ &= 0.998\angle-1.44^\circ + j25.12 \end{aligned}$$

$$\begin{aligned} &= 0.998\angle-1.44^\circ + j25.12 \\ &= 0.997 - j0.025 + j25.12 \\ &= 0.997 + j25.09 \\ &= 25.1\angle87.72^\circ\Omega \end{aligned}$$

Therefore, the impedance of the circuit is $\boxed{25.1\angle87.72^\circ\Omega}$.

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Step 1 of 3

The given circuit is,

Step 2 of 3

As the given network is a parallel network, we first convert all the impedances to their respective admittances,

$$Y_R = \frac{1}{Z_R}$$

$$Y_R = \frac{1}{2}\text{S}$$

$$Y_L = \frac{1}{Z_L}$$

$$Y_L = \frac{1}{j1}$$

$$Y_L = -j1\text{ S}$$

$$Y_C = \frac{1}{Z_C}$$

$$Y_C = \frac{1}{-j2}$$

$$Y_C = \frac{j}{2}\text{ S}$$

Step 3 of 3

∴ Equivalent admittance Y for the given network is:

$$Y = Y_R + Y_L + Y_C$$

$$Y = \left(\frac{1}{2} - j1 + \frac{j}{2}\right)$$

$$Y = \left(\frac{1}{2} - \frac{j}{2}\right)\text{S}$$

∴ The impedance Z in the network shown above is:

$$Z = \frac{1}{Y}$$

$$Z = \frac{2}{1 - j1}$$

$$Z = \frac{2(1 + j1)}{(1)^2 + (1)^2}$$

$$Z = (1 + j1)$$

$$\boxed{Z = 1.414\angle 45^\circ\Omega}$$

Step 1 of 6

Refer to Figure E8.14 in the textbook for the circuit diagram.

The voltage $60\cos(50t+20)$ in phasor form is $60\angle 20°$

The voltage $100\cos 50t$ in phasor form is $100\angle 0°$

Calculate the impedance of inductor, 0.05 H at $\omega = 50$

$$\begin{aligned} Z_L &= j\omega L \\ &= j(50)(0.05) \\ &= j2.5\,\Omega \end{aligned}$$

Calculate the impedance of inductor, 0.1 H at $\omega = 50$

$$\begin{aligned} Z_L &= j\omega L \\ &= j(50)(0.1) \\ &= j5\,\Omega \end{aligned}$$

Step 2 of 6

Calculate the impedance of capacitor, 0.01 F at $\omega = 50$

$$\begin{aligned} Z_C &= \frac{1}{j\omega C} \\ &= \frac{1}{j(50)0.01} \\ &= -j2\,\Omega \end{aligned}$$

Calculate the impedance of capacitor, 0.005 F at $\omega = 50$

$$\begin{aligned} Z_C &= \frac{1}{j\omega C} \\ &= \frac{1}{j(50)(0.005)} \\ &= -j4\,\Omega \end{aligned}$$

Step 3 of 6

Draw the frequency domain circuit.

Figure 1

Step 4 of 6

Apply Kirchhoff's voltage law to the circuit.

$$60\angle 20° - 2\mathbf{I} - (j2\mathbf{I}) - 2.5j - 100\angle 0° - (-4j\mathbf{I}) + 5\mathbf{I} + j5\mathbf{I} = 0$$

$$60\angle 20° - 100\angle 0° - 7\mathbf{I} + j6\mathbf{I} - 7.5j\mathbf{I} = 0$$

$$60\angle 20° - 100\angle 0° - 7\mathbf{I} - j1.5\mathbf{I} = 0$$

$$7\mathbf{I} + j1.5\mathbf{I} = 60\angle 20° - 100\angle 0°$$

$$\begin{aligned} \mathbf{I} &= \frac{48.2046\angle 154.804°}{7 + j1.5} \\ &= \frac{48.2046\angle 154.804°}{7.1589\angle 12.095°} \\ &= 6.7335\angle 142.709°\text{ A} \end{aligned}$$

Step 5 of 6

Draw the circuit to calculate the voltage, $\mathbf{V}_A$

Figure 2

Step 6 of 6

Apply Kirchhoff's voltage law to the circuit.

$$60\angle 20° - 2\mathbf{I} - \mathbf{V}_A - j5\mathbf{I} = 0$$

$$60\angle 20° - (2 + j5)\mathbf{I} = \mathbf{V}_A$$

$$\begin{aligned} \mathbf{V}_A &= 60\angle 20° - (2 + j5)\mathbf{I} \\ &= 60\angle 20° - (5.385\angle 68.1986°)(6.7335\angle 142.709°) \\ &= 60\angle 20° - 36.2599\angle 210.908° \\ &= 95.85\angle 24.10° \end{aligned}$$

Therefore, the voltage in time domain is, $\boxed{95.85\cos(50t + 24.10°)\text{ V}}$.

Step 1 of 2

Refer to Figure P8.7 in the text book.

The impedances of the individual elements are as follows:

$$Z_{R1} = 1\ \Omega$$
$$Z_{R2} = 2\ \Omega$$

The impedance of the inductance is as follows:

$$Z_L = j\omega L$$

Calculate the inductance impedance by substitute $60\ \text{Hz}$ for f and $10\ \text{mH}$ for L in the equation.

$$\begin{aligned} Z_L &= j\omega L \\ &= j2\pi fL \\ &= j(2\pi)(60)(10\times10^{-3}) \\ &= j3.77\ \Omega \end{aligned}$$

The impedance of the capacitance is as follows:

$$Z_C = \frac{-j}{\omega C}$$

Calculate the capacitance impedance by substitute $60\ \text{Hz}$ for f and $10\ \mu\text{H}$ for C in the equation.

$$\begin{aligned} Z_C &= \frac{-j}{\omega C} \\ &= \frac{-j}{2\pi(60)(10\times10^{-6})} \\ &= -j265.25\ \Omega \end{aligned}$$

Step 2 of 2

Write the expression for the equivalent impedance.

$$Z = \left[(Z_{R2} + Z_C) \| Z_{R1}\right] + Z_L$$

Calculate the equivalent impedance by substitute $1\ \Omega$ for Z_{R1}, $2\ \Omega$ for Z_{R2}, $j3.77\ \Omega$ for Z_L, and $-j265.25\ \Omega$ for Z_C in the equation.

$$\begin{aligned} Z &= \left[(2 - j265.25) \| 1\right] + j3.77 \\ &= \frac{(2 - j265.25)(1)}{2 - j265.25 + 1} + j3.77 \\ &= \frac{2 - j265.25}{3 - j265.25} + j3.77 \\ &= 0.999 - j0.00377 + j3.77 \end{aligned}$$

$$\begin{aligned} &= 0.999 + j3.766 \\ &= 3.89\angle 75.13^\circ\ \Omega \end{aligned}$$

Therefore, the impedance of the circuit is $\boxed{3.89\angle 75.13^\circ\ \Omega}$.

Step 1 of 5

Refer the circuit in Figure E8.15 in the textbook.

Determine the value of equivalent impedance.

$$\begin{aligned} Z_{eq} &= (j2) \| (4-j2) \\ &= \frac{(j2)(4-j2)}{(j2)+(4-j2)} \\ &= \frac{4+j8}{4} \\ &= (1+j2)\Omega \end{aligned}$$

Step 2 of 5

The circuit is represented by Figure-1.

Figure-1

Step 3 of 5

Transform the current source with parallel impedance into voltage source with series impedance.

Determine the value of voltage using Ohms law.

$$V = IZ$$

Substitute $2\angle 0^\circ \text{ A}$ for *I*, $(1+j2)\Omega$ for *Z*.

$$\begin{aligned} V &= (2\angle 0^\circ \text{ A})(1+j2)\Omega \\ &= (2+j4)\text{V} \end{aligned}$$

Step 4 of 5

The circuit in Figure-1 is represented by Figure-2.

Figure-2

Step 5 of 5

Determine the value of V_0 by applying voltage division rule.

$$\begin{aligned} V_0 &= \left(\frac{-j2}{1+j2+2-j2}\right)\left[-(2+j4)\right] \\ &= \left(\frac{-8+j4}{3}\right) \\ &= -2.66+j1.33 \\ &= 2.97\angle 153^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{2.97\angle 153^\circ \text{ V}}$.

Step 1 of 5

The given circuit is,

Step 2 of 5

As the given circuit is a series circuit first convert the admittances to their equivalent impedances,

$$Z_{R_1} = \frac{1}{Y_{R_1}}$$

$$Z_{R_1} = 1\Omega$$

$$Z_{C_1} = \frac{1}{Y_{C_1}}$$

$$Z_{C_1} = \frac{1}{j1}$$

$$Z_{C_1} = -j1\Omega$$

Step 3 of 5

$$Z_{L_1} = \frac{1}{Y_{L_1}}$$

$$Z_{L_1} = \frac{1}{-j2}$$

$$Z_{L_1} = j0.5\Omega$$

$$Z_{R_2} = \frac{1}{Y_{R_2}}$$

$$Z_{R_2} = \frac{1}{2}$$

$$Z_{R_2} = 0.5\Omega$$

Step 4 of 5

$$Z_{L_2} = \frac{1}{Y_{L_2}}$$

$$Z_{L_2} = \frac{1}{-j1}$$

$$Z_{L_2} = j1\Omega$$

$$Z_{R_3} = \frac{1}{Y_{R_3}}$$

$$Z_{R_3} = \frac{1}{2}$$

$$Z_{R_3} = 0.5\Omega$$

Step 5 of 5

$$Z_{C_2} = \frac{1}{Y_{C_2}}$$

$$Z_{C_2} = \frac{1}{j2}$$

$$Z_{C_2} = -j0.5\Omega$$

∴ Impedance Z for the given network is:

$$Z = Z_{R_1} + Z_{C_1} + Z_{L_1} + Z_{R_2} + Z_{L_2} + Z_{R_3} + Z_{C_2}$$

$$Z = 1 - j1 + j0.5 + 0.5 + j1 + 0.5 - j0.5$$

$$Z = 2\Omega$$

∴ Admittance Y for the given network is:

$$Y = \frac{1}{Z}$$

$$Y = \frac{1}{2}$$

$$\boxed{Y = 0.5\text{S}}$$

Step 1 of 4

Refer the circuit in Figure E.8.16 in the textbook.

The circuit is represented by Figure-1.

Figure-1

Step 2 of 4

Apply Kirchhoff's current law at node-1.

$$\mathbf{I}_1 = \mathbf{I}_2 + \mathbf{I}_3$$

$$\frac{\mathbf{V}_S - \mathbf{V}_1}{2} = \frac{\mathbf{V}_1}{j2} + \frac{\mathbf{V}_1 - \mathbf{V}_o}{-j2}$$

$$\mathbf{V}_S - \mathbf{V}_1 = -j1\mathbf{V}_1 + j1\mathbf{V}_1 - j1\mathbf{V}_o$$

$$\mathbf{V}_S - \mathbf{V}_1 = -j1\mathbf{V}_o$$

Substitute $8\angle 45^\circ\ \mathrm{V}$ for $\mathbf{V}_o$.

$$\begin{aligned}\mathbf{V}_S - \mathbf{V}_1 &= -j1\left(8\angle 45^\circ\ \mathrm{V}\right)\\ &= 5.65 - j5.65\\ &= 8\angle -45^\circ\end{aligned}$$

$$\mathbf{V}_S = \mathbf{V}_1 + 8\angle -45^\circ \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's current law at node-2.

$$\mathbf{I}_3 = \mathbf{I}_o$$

$$\frac{\mathbf{V}_1 - \mathbf{V}_o}{-j2} = \frac{\mathbf{V}_o}{2}$$

$$j1\mathbf{V}_1 - j1\mathbf{V}_o = \mathbf{V}_o$$

$$j1\mathbf{V}_1 = \left(1 + j1\right)\mathbf{V}_o$$

Substitute $8\angle 45^\circ\ \mathrm{V}$ for $\mathbf{V}_o$.

$$\begin{aligned}\mathbf{V}_1 &= \left(\frac{1+j1}{j1}\right)\left(8\angle 45^\circ\right)\\ &= \left(1 - j1\right)\left(8\angle 45^\circ\right)\\ &= 11.3\ \mathrm{V}\end{aligned}$$

Step 4 of 4

Determine the value of $\mathbf{V}_S$.

Substitute 11.3 V for $\mathbf{V}_1$ in equation (1).

$$\begin{aligned}\mathbf{V}_S &= 11.3 + 8\angle -45^\circ\\ &= 16.95 - j5.65\\ &= 17.86\angle -18.43^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_S$ is $\boxed{17.86\angle -18.43^\circ\ \mathrm{V}}$.

Step 1 of 2

Refer to Figure P8.9 in the textbook.

Modify the circuit with equivalent impedances.

Figure 1

Step 2 of 2

Determine the values of impedances.

$$\begin{aligned} Z_2 &= (8-j8)\ \Omega \parallel j5\ \Omega \\ &= \frac{(8-j8)(j5)}{(8-j8)+(j5)} \\ &= \frac{40+j40}{8-j3} \\ &= (2.739+j6.027)\ \Omega \end{aligned}$$

$$\begin{aligned} Z_3 &= -j2\Omega + 4\Omega \\ &= (4-j2)\Omega \end{aligned}$$

Impedances Z_2 and Z_3 are in series.

$$\begin{aligned} Z_{23} &= Z_2 + Z_3 \\ &= 2.739 + j6.027 + 4 - j2 \\ &= (6.739 + j4.027)\Omega \end{aligned}$$

Impedances Z_1 and Z_{23} are in parallel.

$$\begin{aligned} Z_{123} &= Z_1 \parallel Z_{23} \\ &= \frac{(j10)(6.739+j4.027)}{(j10)+(6.739+j4.027)} \\ &= \frac{-40.27+j67.39}{6.739+j14.027} \\ &= (2.782+j4.207)\Omega \end{aligned}$$

Determine the value of impedance of the circuit.

$$\begin{aligned} Z_{eq} &= 10\Omega + Z_{123} \\ &= 10\Omega + (2.782+j4.207)\Omega \\ &= 12.782 + j4.207 \\ &= (13.46\angle 18.23^\circ)\Omega \end{aligned}$$

Therefore, equivalent impedance is $\boxed{(13.46\angle 18.23^\circ)\ \Omega}$.

Step 1 of 4

Refer the circuit in Figure E.8.17 in the textbook.

The circuit is represented by Figure-1.

Figure-1

Step 2 of 4

Apply Kirchhoff's voltage law at node 1.

$$\frac{12\angle 30^\circ - \mathbf{V}_1}{2} = \frac{\mathbf{V}_1}{1} + \frac{\mathbf{V}_1}{j2} + \frac{\mathbf{V}_1 - \mathbf{V}_o}{-j1}$$

$$6\angle 30^\circ - 0.5\mathbf{V}_1 = \mathbf{V}_1 - j0.5\mathbf{V}_1 + j1\mathbf{V}_1 - j1\mathbf{V}_o$$

$$6\angle 30^\circ = 1.5\mathbf{V}_1 + j0.5\mathbf{V}_1 - j1\mathbf{V}_o$$

$$6\angle 30^\circ = (1.5 + j0.5)\mathbf{V}_1 - j1\mathbf{V}_o \text{ ..... (1)}$$

Step 3 of 4

Apply Kirchhoff's voltage law at node 2.

$$\frac{\mathbf{V}_1 - \mathbf{V}_o}{-j1} = \frac{\mathbf{V}_o}{1}$$

$$j1\mathbf{V}_1 - j1\mathbf{V}_o = \mathbf{V}_o$$

$$\mathbf{V}_1 = \left(\frac{1 + j1}{j1}\right)\mathbf{V}_o$$

$$= (1 - j1)\mathbf{V}_o$$

Step 4 of 4

Determine the value of $\mathbf{V}_o$.

Substitute $(1 - j1)\mathbf{V}_o$ for $\mathbf{V}_1$ in equation (1).

$$6\angle 30^\circ = (1.5 + j0.5)(1 - j1)\mathbf{V}_o - j1\mathbf{V}_o$$

$$= (2 - j1)\mathbf{V}_o - j1\mathbf{V}_o$$

$$= (2 - j2)\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{6\angle 30^\circ}{(2 - j2)}$$

$$= 0.55 + j2.05$$

$$= 2.12\angle 75^\circ \text{ V}$$

Therefore, the value of $\mathbf{V}_o$ is, $\boxed{2.12\angle 75^\circ \text{ V}}$.

Step 1 of 2

Refer to Figure P8.10 in the textbook.

Modify the circuit with the equivalent impedances.

Figure 1

Step 2 of 2

Determine the values of impedances.

$$\begin{aligned} Z_1 &= (1\ \Omega) \| (-j1\ \Omega) \\ &= \frac{(1\ \Omega)(-j1\ \Omega)}{(1\ \Omega)+(-j1\ \Omega)} \\ &= \frac{-j1}{1-j1} \\ &= (0.5-j0.5)\ \Omega \end{aligned}$$

$$\begin{aligned} Z_2 &= (j2\ \Omega) \| (-j2\ \Omega) \\ &= \frac{(j2\ \Omega)(-j2\ \Omega)}{(j2\ \Omega)+(-j2\ \Omega)} \\ &= \frac{4}{j2-j2} \\ &= \infty \end{aligned}$$

Determine the value of impedance.

$$\begin{aligned} \overline{Z} &= 2\ \Omega + Z_1 + Z_2 \\ &= 2\ \Omega + 0.5 - j0.5 + \infty \\ &= \infty \end{aligned}$$

Therefore, the frequency domain impedance of the circuit is, $\boxed{\infty}$.

Step 1 of 4

Refer to Figure E8.18 in the textbook for the circuit diagram.

Draw the circuit with node voltages, $\mathbf{V}_1$ and $\mathbf{V}_2$.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node voltage, $\mathbf{V}_1$

$$\frac{\mathbf{V}_1-12\angle 0^\circ}{3+j2}+\frac{\mathbf{V}_1-6\angle 0^\circ}{j3}+\frac{\mathbf{V}_1-\mathbf{V}_2}{4}=0 \text{ ..... (1)}$$

Apply Kirchhoff's current law at node voltage, $\mathbf{V}_2$

$$\frac{\mathbf{V}_2}{-j2}-\left(\frac{\mathbf{V}_1-\mathbf{V}_2}{4}\right)-3\angle 10^\circ=0 \text{ ..... (2)}$$

$$\frac{\mathbf{V}_2}{-j2}-\left(\frac{\mathbf{V}_1-\mathbf{V}_2}{4}\right)-3\angle 10^\circ=0$$

$$-0.5\mathbf{V}_2\angle -90^\circ+0.25\mathbf{V}_2=3\angle 10^\circ+0.25\mathbf{V}_1$$

$$j0.5\mathbf{V}_2+0.25\mathbf{V}_2=3\angle 10^\circ+0.25\mathbf{V}_1$$

$$\mathbf{V}_2=\frac{3\angle 10^\circ+0.25\mathbf{V}_1}{0.25+0.5j}$$

Step 3 of 4

Substitute $\mathbf{V}_2$ in equation (1).

$$\frac{\mathbf{V}_1-12\angle 0^\circ}{3+j2}+\frac{\mathbf{V}_1-6\angle 0^\circ}{j3}+\frac{\mathbf{V}_1}{4}-\frac{1}{4}\left(\frac{3\angle 10^\circ+0.25\mathbf{V}_1}{0.25+0.5j}\right)=0$$

$$\left\{\begin{array}{l}0.277\angle -33.69^\circ(\mathbf{V}_1-12\angle 0^\circ)+0.33\angle -90^\circ(\mathbf{V}_1-6\angle 0^\circ)\\+0.25\mathbf{V}_1-0.25(1.789\angle -63.43^\circ)(3\angle 10^\circ+0.25\mathbf{V}_1)\end{array}\right\}=0$$

$$\left\{\begin{array}{l}0.277\mathbf{V}_1\angle -33.69^\circ-3.324\angle -33.69^\circ+0.33\mathbf{V}_1\angle -90^\circ-1.998\angle -90^\circ\\+0.25\mathbf{V}_1-1.342\angle -53.43-0.1118\mathbf{V}_1\angle -63.43^\circ=0\end{array}\right\}$$

Simplify further.

$$0.5786\mathbf{V}_1\angle -41.93^\circ=6.0756\angle -54.068^\circ$$

$$\begin{aligned}\mathbf{V}_1&=\frac{6.0756\angle -54.068^\circ}{0.5786\angle -41.93^\circ}\\&=10.5\angle -12.138^\circ\end{aligned}$$

Step 4 of 4

Calculate the current, $\mathbf{I}_1$

$$\begin{aligned}\mathbf{I}_1&=\frac{\mathbf{V}_1-12\angle 0^\circ}{3+j2}\\&=\frac{10.5\angle -12.138^\circ-12\angle 0^\circ}{3+2j}\\&=0.277\angle -33.69^\circ(10.5\angle -12.138^\circ-12\angle 0^\circ)\\&=0.778\angle -161.847^\circ\end{aligned}$$

Therefore, the current is, $\mathbf{I}_1$ is, $\boxed{0.778\angle -161.847^\circ \text{ A}}$.

Step 1 of 2

Refer to Figure P8.13 in the text book.

The impedances of the individual elements are as follows:

$$Z_{R1} = 2\Omega$$
$$Z_{R2} = 4\Omega$$

The impedance of the inductance is,

$$Z_L = j\omega L$$

Calculate the inductance impedance.

Substitute 60 Hz for f and 10 mH for L in the equation.

$$\begin{aligned} Z_L &= j\omega L \\ &= j(2\pi)(60)(10\times10^{-3}) \\ &= j3.768\Omega \end{aligned}$$

The impedance of the capacitance is,

$$Z_C = \frac{-j}{\omega C}$$

Calculate the capacitance impedance.

Substitute 60 Hz for f and $500\ \mu\text{F}$ for C in the equation.

$$\begin{aligned} Z_C &= \frac{-j}{\omega C} \\ &= \frac{-j}{2\pi(60)(500\times10^{-6})} \\ &= -j5.3\Omega \end{aligned}$$

Step 2 of 2

Write the expression for the equivalent impedance.

$$Z = \left[(Z_{R2} + Z_C) \| Z_L\right] + Z_{R1}$$

Calculate the equivalent impedance.

Substitute $2\ \Omega$ for Z_{R1}, $4\ \Omega$ for Z_{R2}, $j3.768\Omega$ for Z_L and $-j5.3\Omega$ for Z_C in the equation.

$$\begin{aligned} Z &= \left[(Z_{R2} + Z_C) \| Z_L\right] + Z_{R1} \\ &= \left[(4 - j5.3) \| j3.768\right] + 2 \\ &= \frac{19.97 + j15.07}{4 - j1.53} + 2 \\ &= \frac{25.01\angle37.03^\circ}{4.28\angle-20.93^\circ} + 2 \end{aligned}$$

$$\begin{aligned} &= \frac{25.01\angle37.03^\circ}{4.28\angle-20.93^\circ} + 2 \\ &= 5.84\angle57.96^\circ + 2 \\ &= 3.09 + j4.95 + 2 \\ &= 5.09 + j4.95 \\ &= 7.1\angle44.2^\circ\Omega \end{aligned}$$

Therefore, the impedance of the circuit is $\boxed{7.1\angle44.2^\circ\Omega}$.

Step 1 of 9

(a)

Refer to circuit diagram in Figure E8.19 in the textbook.

Draw the circuit with node notations.

Figure 1

Step 2 of 9

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1}{4}+\frac{\mathbf{V}_1-\mathbf{V}_2}{j2}+\frac{\mathbf{V}_1+24\angle 0^\circ-\mathbf{V}_3}{4}=0$$

$$\mathbf{V}_1\left(\frac{1}{4}+\frac{1}{j2}+\frac{1}{4}\right)-\frac{\mathbf{V}_2}{j2}+\frac{24\angle 0^\circ}{4}-\frac{\mathbf{V}_3}{4}=0$$

$$\mathbf{V}_1(0.25-j0.5+0.25)+j0.5(10\angle 0^\circ)+6-\mathbf{V}_3(0.25)=0 \qquad \because(\mathbf{V}_2=10\angle 0^\circ)$$

$$\mathbf{V}_1(0.5-j0.5)+j5+6-\mathbf{V}_3(0.25)=0$$

$$\mathbf{V}_1(0.5-j0.5)-\mathbf{V}_3(0.25)=-6-j5 \quad \text{..... (1)}$$

Step 3 of 9

Apply Kirchhoff's current law at node 3.

$$\frac{\mathbf{V}_3}{3-j2}+\frac{\mathbf{V}_3-\mathbf{V}_2}{j4}+\frac{\mathbf{V}_3-24\angle 0^\circ-\mathbf{V}_1}{4}=0$$

$$\mathbf{V}_3\left(\frac{1}{3-j2}+\frac{1}{j4}+\frac{1}{4}\right)-\frac{\mathbf{V}_2}{j4}-\frac{24\angle 0^\circ}{4}-\frac{\mathbf{V}_1}{4}=0$$

$$\mathbf{V}_1(0.23+j0.154-j0.25+0.25)+j0.25(10\angle 0^\circ)-6-\mathbf{V}_1(0.25)=0$$

$$\mathbf{V}_1(0.48-j0.096)+j2.5-6-\mathbf{V}_1(0.25)=0$$

$$\mathbf{V}_3(0.48-j0.096)-\mathbf{V}_1(0.25)=6-j2.5$$

$$\mathbf{V}_1=\frac{\mathbf{V}_3(0.48-j0.096)-6+j2.5}{(0.25)}$$

$$\mathbf{V}_1=\mathbf{V}_3(1.92-j0.384)-24+j10 \quad \text{..... (2)}$$

Step 4 of 9

Substitute equation (2) in equation (1).

$$\left[\mathbf{V}_3(1.92-j0.384)-24+j10\right](0.5-j0.5)-\mathbf{V}_3(0.25)=-6-j5$$

$$\mathbf{V}_3(0.768-j1.152)-7+j17-\mathbf{V}_3(0.25)=-6-j5$$

$$\mathbf{V}_3(0.768-j1.152-0.25)=-6-j5+7-j17$$

$$\mathbf{V}_3(0.518-j1.152)=1-j22$$

$$\mathbf{V}_3=\frac{(1-j22)}{(0.518-j1.152)}$$

$$=17.44\angle -21.61^\circ \text{ V}$$

From the circuit, the voltage, $\mathbf{V}_x$ is

$$\mathbf{V}_x=\mathbf{V}_3$$

$$=17.44\angle -21.61^\circ \text{ V}$$

Therefore, the voltage V_x of the circuit is $\boxed{17.44\angle -21.61^\circ \text{ V}}$.

Step 5 of 9

(b)

Draw the circuit with mesh notations.

Step 6 of 9

Apply Kirchhoff's voltage law to loop 1.

$$-24\angle 0^\circ+4\mathbf{I}_1+j4(\mathbf{I}_1-\mathbf{I}_3)+j2(\mathbf{I}_1-\mathbf{I}_2)=0$$

$$\mathbf{I}_1(4+j4+j2)-\mathbf{I}_2(j2)-\mathbf{I}_3(j4)=24\angle 0^\circ$$

$$\mathbf{I}_1(4+j6)-\mathbf{I}_2(j2)-\mathbf{I}_3(j4)=24 \quad \text{..... (3)}$$

Apply Kirchhoff's voltage law to loop 2.

$$4\mathbf{I}_2+j2(\mathbf{I}_2-\mathbf{I}_1)+10\angle 0^\circ=0$$

$$-\mathbf{I}_1(j2)+\mathbf{I}_2(4+j2)=-10\angle 0^\circ \quad \text{..... (4)}$$

Step 7 of 9

Apply Kirchhoff's voltage law to loop 3.

$$-10\angle 0^\circ+j4(\mathbf{I}_3-\mathbf{I}_1)+3\mathbf{I}_3-j2\mathbf{I}_3=0$$

$$\mathbf{I}_3(j4+3-j2)-\mathbf{I}_1(j4)=10\angle 0^\circ$$

$$-\mathbf{I}_1(j4)+\mathbf{I}_3(3+j2)=10\angle 0^\circ \quad \text{..... (3)}$$

Write equations (1), (2), and (3) in matrix-form.

$$\begin{bmatrix}4+j6 & -j2 & -j4\\ -j2 & 4+j2 & 0\\ -j4 & 0 & 3+j2\end{bmatrix}\begin{bmatrix}\mathbf{I}_1\\ \mathbf{I}_2\\ \mathbf{I}_3\end{bmatrix}=\begin{bmatrix}24\\ -10\\ 10\end{bmatrix}$$

$$\Delta=\begin{bmatrix}4+j6 & -j2 & -j4\\ -j2 & 4+j2 & 0\\ -j4 & 0 & 3+j2\end{bmatrix}$$

$$=[4+j6]\left[(4+j2)(3+j2)-(0)(0)\right]-[-j2]\left[(-j2)(3+j2)-(0)(-j4)\right]$$
$$+[-j4]\left[(-j2)(0)-(-j4)(4+j2)\right]$$

$$=[4+j6][8+j14-0]+[j2][4-j6-0]-[j4][0-8+j16]$$

$$=[4+j6][8+j14]+[j2][4-j6]-[j4][-8+j16]$$

$$=-52+j104+12+j8+64+j32$$

$$=24+j144$$

Step 8 of 9

Calculate the current Δ_3.

$$\Delta_3=\begin{bmatrix}4+j6 & -j2 & 24\\ -j2 & 4+j2 & -10\\ -j4 & 0 & 10\end{bmatrix}$$

$$=[4+j6]\left[(4+j2)(10)-(-10)(0)\right]-[-j2]\left[(-j2)(10)-(-10)(-j4)\right]$$
$$+[24]\left[(-j2)(0)-(-j4)(4+j2)\right]$$

$$=[4+j6][40+j20]-[-j2][-j20-j40]+[24][j16-8]$$

$$=[40+j320+120-192+j384]$$

$$=-32+j704$$

Step 9 of 9

Calculate the current $\mathbf{I}_3$.

$$\mathbf{I}_3=\frac{\Delta_3}{\Delta}$$

$$=\frac{-32+j704}{24+j144}$$

$$=4.72+j1.01$$

$$=4.83\angle 12.08^\circ \text{ A}$$

Calculate the voltage $\mathbf{V}_x$.

$$\mathbf{V}_x=(3-j2)(\mathbf{I}_3)$$

$$=(3.606\angle -33.69^\circ)(4.83\angle 12.08^\circ)$$

$$=17.41\angle -21.61^\circ \text{V}$$

Therefore, the voltage V_x of the circuit is $\boxed{17.44\angle -21.61^\circ \text{ V}}$.

Step 1 of 2

Refer to Figure P8.14 in the textbook.

Modify the circuit with the equivalent impedances.

Figure 1

Step 2 of 2

Determine the values of impedances.

$$\begin{aligned} Z_1 &= (1+j1)\,||\,2 \\ &= \frac{(1+j1)2}{(1+j1)+2} \\ &= \frac{2+j2}{3+j1} \\ &= 0.8+j0.4 \end{aligned}$$

$$\begin{aligned} Z_2 &= (4+j2)\,||\,(j2-j1) \\ &= \frac{(4+j2)(j1)}{(4+j2)+(j1)} \\ &= \frac{-2+j4}{4+j3} \\ &= 0.16+j0.88 \end{aligned}$$

Determine the impedance of the circuit.

$$\begin{aligned} Z &= 6+Z_1+Z_2+j4 \\ &= 6+(0.8+j0.4)+(0.16+j0.88)+j4 \\ &= (6.96+j5.28)\ \Omega \end{aligned}$$

Therefore, the frequency domain impedance is $\boxed{(6.96+j5.28)\ \Omega}$.

Step 1 of 7

(a)

Refer to Figure E8.20 in the textbook.

From the Figure it is clear that, there is a current source between mesh 1 and 2, hence there is super mesh exists between these two meshes.

Write the super mesh equation to the circuit.

$$-24\angle 0^\circ + 2\mathbf{I}_1 - j2\mathbf{I}_2 + 2\mathbf{I}_2 = 0$$

$$2\mathbf{I}_1 + (-j2+2)\mathbf{I}_2 = 24\angle 0^\circ \quad \text{..... (1)}$$

Write the current constraint equation.

$$\mathbf{I}_2 - \mathbf{I}_1 = 2\angle 90^\circ$$

$$\mathbf{I}_2 = 2\angle 90^\circ + \mathbf{I}_1 \quad \text{..... (2)}$$

Step 2 of 7

Substitute $2\angle 90^\circ + \mathbf{I}_1$ for $\mathbf{I}_2$ in equation (1).

$$2\mathbf{I}_1 + (-j2+2)(2\angle 90^\circ + \mathbf{I}_1) = 24\angle 0^\circ$$
$$2\mathbf{I}_1 + (4+j4) + (-j2+2)\mathbf{I}_1 = 24\angle 0^\circ$$
$$(2-j2+2)\mathbf{I}_1 = 20 - j4$$

$$\begin{aligned}\mathbf{I}_1 &= \frac{20-j4}{4-j2}\\ &= 4.4 + j1.2\\ &= 4.56\angle 15.255^\circ\end{aligned}$$

Find the value of mesh current $\mathbf{I}_2$ using equation (2).

$$\begin{aligned}\mathbf{I}_2 &= 2\angle 90^\circ + 4.56\angle 15.255^\circ\\ &= 5.44\angle 36^\circ \text{ A}\end{aligned}$$

Step 3 of 7

Determine the output voltage, $\mathbf{V}_o$.

$$\begin{aligned}\mathbf{V}_o &= 2\mathbf{I}_2\\ &= 2(5.44\angle 36^\circ)\\ &= 10.88\angle 36^\circ \text{ V}\end{aligned}$$

Therefore, the output voltage using mesh equations is $\boxed{10.88\angle 36^\circ \text{ V}}$.

Step 4 of 7

(b)

To find Thevenin's voltage open circuit the load resistance $2\ \Omega$ and draw the modified circuit diagram.

Figure 2

Step 5 of 7

Apply Kirchhoff's voltage law to the outer loop.

$$V_{oc} - 2(2\angle 90^\circ) = 24\angle 0^\circ$$
$$V_{oc} = 24 + j4$$

Therefore, the Thevenin voltage is $24j + 4$ V.

To find the Thevenin's resistance short circuit the voltage source open circuit the voltage source. Draw the modified circuit diagram.

Figure 3

Step 6 of 7

The Thevenin's resistance of the circuit is $(2-j2)\ \Omega$.
Draw the Thevenin's equivalent of the circuit.

Step 7 of 7

Find the ouput volatge, $\mathbf{V}_o$.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{24+4j}{2-j2+2}\right)(2)\\ &= (5.44\angle 36^\circ)(2)\\ &= 10.88\angle 36^\circ \text{ V}\end{aligned}$$

Therefore, the output voltage using Thevenin's theorem is $\boxed{10.88\angle 36^\circ \text{ V}}$.

Refer to Figure P8.15 in the textbook.

Determine the impedance of capacitor.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 1000 for ω , and $100\times10^{-6}\,\mathrm{F}$ for *C*.

$$\begin{aligned} Z_C &= \frac{1}{j(1000)(100\times10^{-6}\,\mathrm{F})} \\ &= -j10\,\Omega \end{aligned}$$

Determine the impedance of inductor.

$$Z_L = j\omega L$$

Substitute 1000 for ω .

$$Z_L = j(1000)L.$$

Consider that the current is in phase with source voltage in the circuit.

$$\begin{aligned} &Z_L + Z_C = 0 \\ &-j10 + j1000L = 0 \\ &1000L = 10 \end{aligned}$$

Find the value of inductance.

$$\begin{aligned} L &= \frac{10}{1000} \\ &= 0.01\,\mathrm{H} \\ &= 10\,\mathrm{mH} \end{aligned}$$

Therefore, the value of inductance, L is $\boxed{10\text{ mH}}$.

Step 1 of 5

Refer to circuit shown in Figure E8.21 in the textbook. The circuit with mesh direction is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's voltage law to the mesh 1.

$$24 - I_1(4) - j4(I_1 - I_2) - j2(I_1 - I_3) = 0$$

$$24 - I_1(4 + j6) + j4I_2 + j2I_3 = 0 \text{ ..... (1)}$$

From the figure 1,

$$V_A = -4I_3$$

Apply Kirchhoff's voltage law to the mesh 2.

$$-(I_3 - I_2)6 - 2V_A - 4I_3 - j2(I_3 - I_1) = 0$$
$$-(I_3 - I_2)6 - 2(-4I_3) - 4I_3 - j2(I_3 - I_1) = 0$$
$$-j2I_1 + 6I_2 + (-10 - j2 + 8)I_3 = 0$$

$$-j2I_1 + 6I_2 + (-2 - j2)I_3 = 0 \text{ ..... (2)}$$

Apply Kirchhoff's voltage law to the mesh 3.

$$-I_2(3) - I_2(-j2) + 2V_A - (I_2 - I_3)6 - j4(I_2 - I_1) = 0$$
$$-I_2(3) - I_2(-j2) + 2(-4I_3) - (I_2 - I_3)6 - j4(I_2 - I_1) = 0$$
$$j4I_1 + I_2(-3 + j2 - 6 - j4) + (6 - 8)I_3 = 0$$

$$j4I_1 + I_2(-9 - j2) - 2I_3 = 0 \text{ ..... (3)}$$

Step 3 of 5

Multiply equation (2) with 2 and subtract from equation (3).

$$j4I_1 + I_2(-9 - j2) - 2I_3 - 2\left[2jI_1 + 6I_2 + I_3(-2 - j2)\right] = 0$$
$$I_2(-21 - j2) + I_3(2 + j4) = 0$$

$$I_3 = I_2\left(\frac{21 + j2}{2 + j4}\right) \text{ ..... (4)}$$

Recall equation (2).

$$-j2I_1 + 6I_2 + (-2 - j2)I_3 = 0$$

Substitute $I_2\left(\frac{21 + j2}{2 + j4}\right)$ for I_3 in the equation.

$$j2I_1 + 6I_2 + I_2\left(\frac{21 + j2}{2 + j4}\right)(-2 - j2) = 0$$

$$2jI_1 + I_2\left(\frac{12 + j24 - 38 - 46j}{2 + j4}\right) = 0$$

$$2jI_1 = I_2\left(\frac{26 + 22j}{2 + j4}\right)$$

$$I_1 = I_2\left(\frac{26 + 22j}{(2 + j4)2j}\right) \text{ ..... (5)}$$

Step 4 of 5

Recall equation (1).

$$24 - I_1(4 + j6) + j4I_2 + j2I_3 = 0$$

Substitute $I_2\left(\frac{26 + 22j}{(2 + j4)2j}\right)$ for I_1, $I_2\left(\frac{21 + j2}{2 + j4}\right)$ for I_3 in the equation.

$$24 - I_2\left(\frac{(26 + j22)(4 + j6)}{2j(2 + 4j)}\right) + j4I_2 + j2\left(\frac{21 + j2}{2 + j4}\right) = 0$$

$$24 - \frac{I_2}{2 + j4}\left(\frac{(26 + j22)(4 + j6)}{j2} - j4(2 + j4) - j2(21 + j2)\right) = 0$$

$$24 - \frac{I_2}{2 + j4}(78 + 66j - 52j + 44 - 8j + 20 - 42j) = 0$$

$$24 - \frac{I_2}{2 + j4}(142 - 36j) = 0$$

$$I_2 = 24\left(\frac{2 + j4}{142 - 36j}\right) \text{ A}$$

Step 5 of 5

Calculate the output voltage.

$$\mathbf{V}_o = -j2I_2$$
$$= -j2\left(\frac{24(2 + j4)}{142 - 36j}\right)$$
$$= -j2(0.7327\angle 77.66°)$$
$$= 1.4654\angle -12.34° \text{ V}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{1.4654\angle -12.34° \text{ V}}$.

Step 1 of 2

Refer to Figure P8.16 in the textbook.

Determine the impedance of inductor.

$$\begin{aligned} Z_L &= j\omega L \\ &= j(2\pi f)L \end{aligned}$$

Substitute 60 Hz for *f*, $5\times10^{-3}\ \text{H}$ for *L*.

$$\begin{aligned} Z_L &= j(2\pi(60))(5\times10^{-3}\ \text{H}) \\ &= j1.885\ \Omega \end{aligned}$$

Determine the impedance of capacitor.

$$\begin{aligned} Z_C &= \frac{1}{j\omega C} \\ &= \frac{1}{j(2\pi f)C} \end{aligned}$$

Substitute 60 Hz for *f*.

$$\begin{aligned} Z_C &= \frac{1}{j(2\pi(60))C} \\ &= \frac{2.65\times10^{-3}}{jC}\ \Omega \end{aligned}$$

Step 2 of 2

Consider that the impedance in the circuit is purely resistive. Therefore,

$$Z_L + Z_C = 0$$

$$j1.885 + \frac{2.65\times10^{-3}}{jC} = 0$$

$$\frac{2.65\times10^{-3}}{jC} = -j1.885$$

Find the value of capacitance, C .

$$\begin{aligned} C &= \frac{2.65\times10^{-3}}{j(-j1.885)} \\ &= \frac{2.65\times10^{-3}}{1.885} \\ &= 1.4\times10^{-3}\ \text{F} \\ &= 1.4\ \text{mF} \end{aligned}$$

Therefore, the value of capacitance, C is, $\boxed{1.4\ \text{mF}}$.

Step 1 of 12

Consider the Figure P7.72 from the text book.

Step-1:

Let the value of the output current $i_L(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 12

The value of the voltage $v_1(t)$ is 10 V .

Apply the Kirchhoff's Voltage Law in the loop.

$$-v_1(t) + i_L(0^-)(12) - 5v_1(t) = 0$$
$$i_L(0^-)(12) = 6v_1(t)$$
$$i_L(0^-) = \frac{6v_1(t)}{12}$$
$$i_L(0^-) = \frac{v_1(t)}{2}$$

Substitute 10 V for $v_1(t)$.

$$i_L(0^-) = \frac{10}{2}$$
$$= 5\text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is 5 A .

Step 3 of 12

Step-3:

The value of the current $i_L(0^+)$ is equal to the value of $i_L(0^-)$. Therefore, the value of the current is 5 A .

Step 4 of 12

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

Apply the Kirchhoff's Voltage Law in the loop.

$$-i_1(t)(2) + i_L(\infty)(12) - 5v_1(t) = 0$$

Substitute $i_1(t)(2)$ for $v_1(t)$.

$$-i_1(t)(2) + i_L(\infty)(12) - 5(i_1(t)(2)) = 0$$
$$-i_1(t)(2) + i_L(\infty)(12) - 10i_1(t) = 0$$
$$i_L(\infty)(12) - i_1(t)(12) = 0$$
$$i_L(\infty) = i_1(t)$$

Therefore, the expression for the current $i_L(\infty)$ is $i_1(t)$.

Step 5 of 12

Consider the nodal equation at node-1.

$$i_1(t) + i_L(\infty) = 4$$

Substitute $i_L(\infty)$ for $i_1(t)$.

$$i_L(\infty) + i_L(\infty) = 4$$
$$2i_L(\infty) = 4$$
$$i_L(\infty) = 2\text{ A}$$

Therefore, the value of the current $i_L(\infty)$ is 2 A .

Step 6 of 12

Consider the circuit diagram shown in Figure 4 to calculate the open circuit voltage as seen from the opened terminals of the inductor.

Figure 3

Step 7 of 12

Since no current flows through 12Ω .

$$v_1(t) = (4)(2)$$
$$v_1(t) = 8\text{V}$$

Calculate the value of the voltage v_{OC} .

$$v_{OC} = v_1(t) + 5v_1(t)$$
$$v_{OC} = 6v_1(t)$$
$$v_{OC} = 48\text{V}$$

Therefore, the value of the open circuit voltage is 48 V .

The value of the short circuit current i_{SC} is equal to the value of $i_L(\infty)$, that is 2 A .

Step 8 of 12

Calculate the value of the Thevenin resistance R_{Th} .

$$R_{Th} = \frac{v_{OC}}{i_{SC}}$$

Substitute 2 A for i_{SC} and 48 V for v_{OC} .

$$R_{Th} = \frac{48}{2}$$
$$= 24\,\Omega$$

Therefore, the value of the Thevenin resistance R_{Th} is $24\,\Omega$.

Step 9 of 12

Step-5:

Calculate the value of the time constant τ .

$$\tau = \frac{L}{R_{Th}}$$

Substitute $24\,\Omega$ for R_{eq} and 2 H for L .

$$\tau = \frac{2}{24}$$
$$= \frac{1}{12}\text{ s}$$

Therefore, the value of the time constant τ is $\frac{1}{12}\text{ s}$.

Step 10 of 12

Step-6:

Calculate the value of the constant K_1 .

$$K_1 = i_L(\infty)$$

Substitute 2 A for $i_L(\infty)$.

$$K_1 = 2\text{ A}$$

Therefore, the value of the constant K_1 is 2 A .

Step 11 of 12

Calculate the value of the constant K_2 .

$$K_2 = i_L(0^+) - i_L(\infty)$$

Substitute 5 A for $i_L(\infty)$ and 2 A for $i_L(0^+)$.

$$K_2 = 5 - 2$$
$$= 3\text{ A}$$

Therefore, the value of the constant K_2 is 3 A .

Step 12 of 12

Recall equation (1).

$$i_L(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0.5 s for τ , 3 A for K_2 and 2 A for K_1 .

$$i_L(t) = 2 + 3\,e^{-t/\left(\frac{1}{12}\right)}\text{ A}$$
$$= 2 + 3\,e^{-12t}\text{ A}$$

Therefore, the value of the current $i_L(t)$ is $\boxed{2 + 3\,e^{-12t}\text{ A}}$.

Step 1 of 4

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 4

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 4

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 4

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 15

(a)

Refer to Figure P8.23 in the textbook.

Use the superposition method to find the output voltage, $\mathbf{V}_o$.

Consider only the $24\angle 0^\circ$ V voltage source in the circuit and remove the other sources by shorting voltage sources and opening current sources.

Draw the modified circuit.

Figure 1

Step 2 of 15

The impedances $-j2\ \Omega$ and $2\ \Omega$ are in series. Find the equivalent impedance.

$$Z_1 = (2-j2)\ \Omega$$

This equivalent impedance is in parallel with $j2\ \Omega$. Find the equivalent impedance.

$$\begin{aligned} Z_2 &= (2-j2)\|(j2) \\ &= \frac{(2-j2)(j2)}{2-j2+j2} \\ &= \frac{4+j4}{2} \\ &= 2+j2 \end{aligned}$$

This equivalent impedance is in series with $2\ \Omega$. Find the equivalent impedance.

$$\begin{aligned} Z_{eq} &= 2+j2+2 \\ &= (4+j2)\ \Omega \end{aligned}$$

Step 3 of 15

Find the total current in the circuit.

$$\begin{aligned} \mathbf{I}_T &= \frac{24\text{ V}}{4+j2\ \Omega} \\ &= 4.8-j2.4\text{ A} \end{aligned}$$

Use current division method to find the current flow through $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{I}_1 &= \mathbf{I}_T\left(\frac{j2}{j2+2-j2}\right) \\ &= (4.8-j2.4)\left(\frac{j2}{2}\right) \\ &= (2.4+j4.8)\text{ A} \end{aligned}$$

Calculate the voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{V}_{oa} &= \mathbf{I}_1(2\ \Omega) \\ &= (2.4+j4.8)(2\ \Omega) \\ &= 4.8+j9.6\text{ V} \end{aligned}$$

Step 4 of 15

Consider only the $12\angle 0^\circ$ V voltage source in the circuit and remove the other sources by shorting voltage sources and opening current sources.

Draw the new modified circuit.

Figure 2

Step 5 of 15

The impedances $-j2\ \Omega$ and $2\ \Omega$ are in series. Find the equivalent impedance.

$$Z_1 = (2-j2)\ \Omega$$

This equivalent impedance is in parallel with $2\ \Omega$. Find the equivalent impedance.

$$\begin{aligned} Z_2 &= (2-j2)\|(2) \\ &= \frac{(2-j2)(2)}{2-j2+2} \\ &= \frac{4-j4}{4-j2} \end{aligned}$$

This equivalent impedance is in series with $j2\ \Omega$. Find the equivalent impedance.

$$\begin{aligned} Z_{eq} &= \frac{4-j4}{4-j2}+j2 \\ &= \frac{4-j4+j2(4-j2)}{4-j2} \\ &= \frac{4-j4+j8+4}{4-j2} \\ &= \frac{8+j4}{4-j2}\ \Omega \end{aligned}$$

Step 6 of 15

Find the total current in the circuit.

$$\begin{aligned} \mathbf{I}_T &= \frac{12\text{ V}}{\frac{8+j4}{4-j2}\ \Omega} \\ &= \frac{12(4-j2)}{8+j4} \\ &= \frac{48-j24}{8+j4} \\ &= 3.6-j4.8\text{ A} \end{aligned}$$

Use current division method to find the current flow through $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{I}_2 &= \mathbf{I}_T\left(\frac{2}{2+2-j2}\right) \\ &= (3.6-j4.8)\left(\frac{2}{4-j2}\right) \\ &= (2.4-j1.2)\text{ A} \end{aligned}$$

Step 7 of 15

Calculate the voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{V}_{ob} &= \mathbf{I}_2(2\ \Omega) \\ &= (2.4-j1.2)(2\ \Omega) \\ &= 4.8-j2.4\text{ V} \end{aligned}$$

Calculate the total voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{V}_o &= \mathbf{V}_{oa}-\mathbf{V}_{ob} \\ &= 4.8+j9.6-(4.8-j2.4) \\ &= 0+j12 \\ &= 12\angle 90^\circ\text{ V} \end{aligned}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{12\angle 90^\circ\text{ V}}$.

Step 8 of 15

(b)

Use the source transformation method to find the output voltage, $\mathbf{V}_o$.

Change the voltage source in series with the impedance into a current source with parallel impedance.

The current source equal to the $24\angle 0^\circ$ V voltage source is,

$$\begin{aligned} \mathbf{I}_{s1} &= \frac{24\angle 0^\circ\text{ V}}{2\ \Omega} \\ &= 12\angle 0^\circ\text{ A} \end{aligned}$$

The current source equal to the $12\angle 0^\circ$ V voltage source is,

$$\begin{aligned} \mathbf{I}_{s2} &= \frac{12\angle 0^\circ\text{ V}}{j2\ \Omega} \\ &= 6\angle -90^\circ\text{ A} \end{aligned}$$

Draw the equivalent circuit after source transformation.

Figure 3

Step 9 of 15

The total current in the circuit is,

$$\begin{aligned} \mathbf{I}_T &= \mathbf{I}_{s1}-\mathbf{I}_{s2} \\ &= 12\angle 0^\circ-6\angle -90^\circ \\ &= (12+j6)\text{ A} \end{aligned}$$

The impedances $2\ \Omega$ and $j2\ \Omega$ are in parallel. Find the equivalent impedance.

$$\begin{aligned} Z_1 &= (2)\|(j2) \\ &= \frac{(2)(j2)}{2+j2} \\ &= \frac{j4}{2+j2} \\ &= (1+j1)\ \Omega \end{aligned}$$

This equivalent impedance is in parallel with series combination of $2-j2\ \Omega$.

Use current division method to find the current flow through $(2-j2)\ \Omega$ impedance.

$$\begin{aligned} \mathbf{I}_T &= \mathbf{I}_2\left(\frac{1+j1}{1+j1+2-j2}\right) \\ &= (12+j6)\left(\frac{1+j1}{3-j1}\right) \\ &= j6\text{ A} \end{aligned}$$

Calculate the voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{V}_o &= \mathbf{I}_T(2\ \Omega) \\ &= (j6)(2\ \Omega) \\ &= j12 \\ &= 12\angle 90^\circ\text{ V} \end{aligned}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{12\angle 90^\circ\text{ V}}$.

Step 10 of 15

(c)

Use the Norton's theorem to find the output voltage, $\mathbf{V}_o$.

Show the resistance through which the current has to be found and represent the loop currents.

Draw the modified circuit.

Figure 4

Step 11 of 15

Apply Kirchhoff's voltage law to the loop 1.

$$\begin{aligned} &24\angle 0^\circ-2\mathbf{I}_1-(-j2)(\mathbf{I}_1-\mathbf{I}_o)+12\angle 0^\circ-0 \\ &36\angle 0^\circ-2\mathbf{I}_1-j2\mathbf{I}_1+j2\mathbf{I}_o=0 \\ &36-2\mathbf{I}_1(1+j)+j2\mathbf{I}_o=0 \end{aligned}$$

Apply Kirchhoff's voltage law to the loop 2.

$$\begin{aligned} &-12\angle 0^\circ-(-j2)(\mathbf{I}_o-\mathbf{I}_1)-(-j2)\mathbf{I}_o=0 \\ &-12\angle 0^\circ-(j2)\mathbf{I}_o-(j2)\mathbf{I}_1+(j2)\mathbf{I}_o=0 \\ &-12+(j2)\mathbf{I}_1=0 \\ &j2\mathbf{I}_1=12 \\ &\mathbf{I}_1=\frac{12}{j2} \\ &=-j6\text{ A} \end{aligned}$$

Substitute this value in the KVL equation of loop 1.

$$\begin{aligned} &36-2\mathbf{I}_1(1+j)+j2\mathbf{I}_o=0 \\ &36-2(-j6)(1+j)+j2\mathbf{I}_o=0 \\ &36+j12-12+j2\mathbf{I}_o=0 \\ &24+j12+j2\mathbf{I}_o=0 \\ &\mathbf{I}_o=\frac{24+j12}{-j2} \\ &=-6+j12\text{ A} \end{aligned}$$

Step 12 of 15

Find the Norton equivalent impedance.

Eliminate the sources in the circuit by shorting the voltage sources and opening the current sources.

Draw the modified circuit.

Figure 5

Step 13 of 15

Measure the equivalent impedance across the load resistance.

$$\begin{aligned} Z_N &= (2\|j2)+(-j2) \\ &= \frac{2(j2)}{2+j2}-j2 \\ &= \frac{j4}{2+j2}-j2 \\ &= \frac{j4-j2(2+j2)}{2+j2} \end{aligned}$$

Simplify the calculation further.

$$\begin{aligned} Z_N &= \frac{j4-j4+4}{2+j2} \\ &= \frac{4}{2+j2} \\ &= (1-j1)\ \Omega \end{aligned}$$

Step 14 of 15

Draw the Norton's equivalent circuit.

Figure 6

Step 15 of 15

Use current division method to find the current flow through $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{I} &= (-6+j12)\left(\frac{1-j1}{1-j1+2}\right) \\ &= (-6+j12)\left(\frac{1-j1}{3-j1}\right) \\ &= j6\text{ A} \end{aligned}$$

Calculate the voltage drop across $2\ \Omega$ resistor.

$$\begin{aligned} \mathbf{V}_o &= \mathbf{I}_T(2\ \Omega) \\ &= (j6)(2\ \Omega) \\ &= j12 \\ &= 12\angle 90^\circ\text{ V} \end{aligned}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{12\angle 90^\circ\text{ V}}$.

Hence, the output voltage calculated by all the methods is same

Step 1 of 2

The admittance at 500 rad/sec is,

$$Y = (0.1 + j0.2)\text{S} \quad \text{..... (1)}$$

The general form of admittance is,

$$Y = \frac{1}{R_{eq}} + \frac{1}{X_{C(eq)}} \quad \text{..... (2)}$$

Compare equations (1) and (2).

Determine the value of resistance.

$$\frac{1}{R_{eq}} = 0.1$$

$$\begin{aligned} R_{eq} &= \frac{1}{0.1} \\ &= 10\ \Omega \end{aligned}$$

Calculate the value of capacitance.

$$\frac{1}{X_{C(eq)}} = j0.2$$

$$\frac{1}{\frac{1}{j\omega C_{eq}}} = j0.2$$

$$j\omega C_{eq} = j0.2$$

$$\omega C_{eq} = 0.2$$

$$C_{eq} = \frac{0.2}{\omega}$$

Substitute 500 rad/sec for ω.

$$\begin{aligned} C_{eq} &= \frac{0.2}{500} \\ &= 4\times10^{-4}\ \text{F} \\ &= 400\ \mu\text{F} \end{aligned}$$

Step 2 of 2

The admittance of the circuit at 300 rad/sec is,

$$\overline{Y} = \frac{1}{R_{eq}} + \frac{1}{X_{C(eq)}}$$

Substitute $\frac{1}{j\omega C_{eq}}$ for $X_{C(eq)}$.

$$\begin{aligned} \overline{Y} &= \frac{1}{R_{eq}} + \frac{1}{\frac{1}{j\omega C_{eq}}} \\ &= \frac{1}{R_{eq}} + j\omega C_{eq} \end{aligned}$$

Substitute 10Ω for R_{eq}, 300 rad/sec for ω, and 4×10^{-4} F for C_{eq}.

$$\begin{aligned} \overline{Y} &= \frac{1}{10} + j(300)(4\times10^{-4}) \\ &= (0.1 + j0.12)\text{S} \end{aligned}$$

Determine the impedance of the circuit.

$$\begin{aligned} \overline{Z} &= \frac{1}{\overline{Y}} \\ &= \frac{1}{0.1 + j0.12} \\ &= (4.1 - j4.92)\Omega \end{aligned}$$

Therefore, the impedance at 300 rad/sec is $\boxed{(4.1 - j4.92)\ \Omega}$.

Step 1 of 16

The given circuit is,

Step 2 of 16

Calculating Thevenin's open circuit voltage:
Removing the $-j2\Omega$ capacitor the circuit will be

Step 3 of 16

From the circuit,

$\mathbf{V_A} = -4\mathbf{I_2}$

Applying loop analysis to the loop (1) we have,

$-24 + 4\mathbf{I_1} + j4\mathbf{I_1} + j2(\mathbf{I_1} - \mathbf{I_2}) = 0$

$\mathbf{I_1}(4 + j6) - \mathbf{I_2}(j2) = 24$ ..... (1)

Step 4 of 16

Applying loop analysis to the loop (2) we have,

$$4\mathbf{I_2} + j2(\mathbf{I_2} - \mathbf{I_1}) + 6\mathbf{I_2} + 2\mathbf{V_A} = 0$$
$$\mathbf{I_2}(4 + j2 + 6) - \mathbf{I_1}(j2) + 2(-4\mathbf{I_2}) = 0$$
$$-\mathbf{I_1}(j2) + \mathbf{I_2}(10 + j2 - 8) = 0$$
$$-\mathbf{I_1}(j2) + \mathbf{I_2}(2 + j2) = 0$$
$$\mathbf{I_1}(j2) = \mathbf{I_2}(2 + j2)$$
$$\mathbf{I_1} = \mathbf{I_2}\left(\frac{2 + j2}{j2}\right)$$
$$\mathbf{I_1} = \mathbf{I_2}(1 - j1)$$

Step 5 of 16

Substituting $\mathbf{I_1}$ in equation (1) we have

$\mathbf{I_2}(1 - j1)(4 + j6) - \mathbf{I_2}(j2) = 24$

$\mathbf{I_2}(10 + j2) - \mathbf{I_2}(j2) = 24$

$\mathbf{I_2}(10) = 24$

$\therefore \mathbf{I_2} = 2.4\ \mathbf{A}$

Now,

$\mathbf{I_1} = \mathbf{I_2}(1 - j1)$

$\mathbf{I_1} = 2.4(1 - j1)$

$\therefore \mathbf{I_1} = (2.4 - j2.4)\ \mathbf{A}$

Step 6 of 16

Now from the circuit,

$\mathbf{V_{oc}} = j4(\mathbf{I_1}) + 6\mathbf{I_2} + 2\mathbf{V_A}$

$\mathbf{V_{oc}} = j4(2.4 - j2.4) + 6(2.4) + 2(-4\mathbf{I_2})$

$\mathbf{V_{oc}} = 9.6 + j9.6 + 14.4 + 2(-4 \times 2.4)$

$\mathbf{V_{oc}} = 9.6 + j9.6 + 14.4 - 19.2$

$\mathbf{V_{oc}} = 4.8 + j9.6$

$\therefore \mathbf{V_{oc}} = 10.733\angle 63.43^\circ\ \mathrm{V}$

Step 7 of 16

Calculating the Thevenin's resistance:
Removing the $-j2\Omega$ resistor, short circuiting the terminals and for finding short circuit current the circuit will be,

Step 8 of 16

From the circuit,

$\mathbf{V_A} = -4\mathbf{I_2}$

$\mathbf{I_3} = \mathbf{I_{sc}}$

Applying loop analysis to the loop (1) we have,

$-24 + 4\mathbf{I_1} + j4\mathbf{I_1} + j2(\mathbf{I_1} - \mathbf{I_2}) = 0$

$\mathbf{I_1}(4 + j6) - \mathbf{I_2}(j2) = 24$ .....(2)

Step 9 of 16

Applying loop analysis to the loop (2) we have,

$4\mathbf{I_2} + j2(\mathbf{I_2} - \mathbf{I_1}) + 6(\mathbf{I_2} - \mathbf{I_3}) + 2\mathbf{V_A} = 0$

$\mathbf{I_2}(4 + j2 + 6) - \mathbf{I_1}(j2) - \mathbf{I_3}(6) + 2(-4\mathbf{I_2}) = 0$

$-\mathbf{I_1}(j2) + \mathbf{I_2}(10 + j2 - 8) - \mathbf{I_3}(6) = 0$

$-\mathbf{I_1}(j2) + \mathbf{I_2}(2 + j2) - \mathbf{I_3}(6) = 0$ .....(3)

Applying loop analysis to the loop (3) we have,

$-2\mathbf{V_A} + 6(\mathbf{I_3} - \mathbf{I_2}) + j4(\mathbf{I_3} - \mathbf{I_1}) + 3\mathbf{I_3} = 0$

$-2(-4\mathbf{I_2}) - \mathbf{I_1}(j4) - \mathbf{I_2}(6) + \mathbf{I_3}(6 + j4 + 3) = 0$

$8\mathbf{I_2} - \mathbf{I_1}(j4) - \mathbf{I_2}(6) + \mathbf{I_3}(9 + j4) = 0$

$\mathbf{I_1}(j4) + \mathbf{I_2}(2) + \mathbf{I_3}(9 + j4) = 0$ .....(4)

Writing the equations (1), (2) and (3) in matrix form we get,

$$\begin{bmatrix} 4 + j6 & -j2 & -j4 \\ -j2 & 2 + j2 & -6 \\ -j4 & 2 & 9 + j4 \end{bmatrix} \begin{bmatrix} \mathbf{I_1} \\ \mathbf{I_2} \\ \mathbf{I_3} \end{bmatrix} = \begin{bmatrix} 24 \\ 0 \\ 0 \end{bmatrix}$$

Step 10 of 16

$$\Delta = \begin{bmatrix} 4 + j6 & -j2 & -j4 \\ -j2 & 2 + j2 & -6 \\ -j4 & 2 & 9 + j4 \end{bmatrix}$$

$$\Delta = 4 + j6[(2 + j2)(9 + j4) - (2)(-6)] - (-j2)[(-j2)(9 + j4) - (-j4)(-6)]$$
$$+ (-j4)[(-j2)(2) - (-j4)(2 + j2)]$$

$\Delta = 4 + j6[10 + j26 + 12] + j2[8 - j18 - j24] - j4[-j4 - 8 + j8]$

$\Delta = 4 + j6[22 + j26] + j2[8 - j42] - j4[-8 + j4]$

$\Delta = -68 + j236 + 84 + j16 + 16 + j32$

$\therefore \Delta = 32 + j284$

Step 11 of 16

$$\Delta_3 = \begin{bmatrix} 4 + j6 & -j2 & 24 \\ -j2 & 2 + j2 & 0 \\ -j4 & 2 & 0 \end{bmatrix}$$

$$\Delta_3 = 4 + j6[(2 + j2)(0) - (2)(0)] - (-j2)[(-j2)(0) - (-j4)(0)]$$
$$+ 24[(-j2)(2) - (-j4)(2 + j2)]$$

$\Delta_3 = 4 + j6[0] + j2[0] + 24[-j4 - 8 + j8]$

$\Delta_3 = 24[-8 + j4]$

$\Delta_3 = -192 + j96$

Step 12 of 16

Current, $\mathbf{I_3} = \dfrac{\Delta_3}{\Delta}$

$\mathbf{I_3} = \dfrac{-192 + j96}{32 + j284}$

$\mathbf{I_3} = 0.2586 + j0.7052$

$\mathbf{I_3} = 0.751\angle 69.86^\circ\ \mathrm{A}$

$\therefore \mathbf{I_{sc}} = 0.751\angle 69.86^\circ\ \mathrm{A}$

Step 13 of 16

Now Thevenin's impedance,

$\mathbf{Z_{Th}} = \dfrac{\mathbf{V_{oc}}}{\mathbf{I_{sc}}}$

$\mathbf{Z_{Th}} = \dfrac{10.733\angle 63.43^\circ}{0.751\angle 69.86^\circ}$

$\mathbf{Z_{Th}} = 14.29\angle -6.43^\circ\ \Omega$

$\therefore \mathbf{Z_{Th}} = (14.2 - j1.6)\ \Omega$

Step 14 of 16

Now the Thevenin's equivalent circuit will be

Step 15 of 16

From the Thevenin's equivalent circuit the output voltage is
By voltage-division rule

Step 18 of 16

$\mathbf{V_o} = 10.733\angle 63.43^\circ \times \dfrac{-j2}{14.2 - j1.6 - j2}$

$\mathbf{V_o} = 10.733\angle 63.43^\circ \times \dfrac{2\angle -90^\circ}{14.2 - j3.6}$

$\mathbf{V_o} = 10.733\angle 63.43^\circ \times \dfrac{2\angle -90^\circ}{14.65\angle -14.23^\circ}$

$\therefore \boxed{\mathbf{V_o} = 1.465\angle -12.34^\circ\ \mathrm{V}}$

Step 1 of 2

The impedance at 1000 rad/sec is,

$$Z = (5 + j4)\Omega \text{ ..... (1)}$$

The general form of impedance is,

$$Z = R + Z_L \text{ ..... (2)}$$

Compare equations (1) and (2).

The value of resistance is 5Ω .

Calculate the value of inductance.

$$Z_L = j4\Omega$$

Substitute $j\omega L$ for Z_L .

$$j\omega L = j4$$
$$\omega L = 4$$
$$L = \frac{4}{\omega}$$

Substitute 1000 rad/sec for ω .

$$L = \frac{4}{1000}$$
$$= 4\times10^{-3}\,\text{H}$$
$$= 4\,\text{mH}$$

Step 2 of 2

The impedance at 1300 rad/sec is,

$$Z = R + Z_L$$

Substitute $j\omega L$ for Z_L .

$$Z = R + j\omega L$$

Substitute 5Ω for *R*, 1300 rad/sec for ω , and $4\times10^{-3}\,\text{H}$ for *L*.

$$Z = 5 + j(1300)\left(4\times10^{-3}\right)$$
$$= (5 + j5.2)\ \Omega$$

Therefore, the impedance at 1300 rad/sec is $\boxed{(5 + j5.2)\ \Omega}$.

Step 1 of 6

Refer to Figure P8.26 in the text book.

Calculate the phasor parameters.

The expression for the current signal, $i_1(t)$ is,

$$i_1(t) = 200\cos\left(10^5 t + 60^\circ\right)\text{mA}$$

The phasor form of $i_2(t)$ is,

$$\begin{aligned} I_1 &= 200\angle 60^\circ \text{ mA} \\ &= 0.2\angle 60^\circ \text{ A} \end{aligned}$$

The expression for the current signal, $i_2(t)$ is,

$$\begin{aligned} i_2(t) &= 100\sin\left(10^5 t + 90^\circ\right)\text{mA} \\ &= 100\cos\left(10^5 t + 90^\circ - 90^\circ\right)\text{mA} \\ &= 100\cos\left(10^5 t\right)\text{mA} \end{aligned}$$

The phasor form of $i_2(t)$ is,

$$\begin{aligned} I_2 &= 100\angle 0^\circ \text{ mA} \\ &= 0.1\angle 0^\circ \text{ A} \end{aligned}$$

Step 2 of 6

The expression for the voltage signal, $v_s(t)$ is,

$$\begin{aligned} v_s(t) &= 10\sin\left(10^5 t\right) \text{ V} \\ &= 10\cos\left(10^5 t - 90^\circ\right) \text{ V} \end{aligned}$$

The phasor form of $v_s(t)$ is,

$$V_S = 10\angle -90^\circ \text{ V}$$

The value of angular frequency is,

$$\omega = 10^5 \text{ rad/sec}$$

Calculate the impedance of capacitor in frequency domain.

$$\begin{aligned} Z_C &= \frac{-j}{\omega C} \\ &= \frac{-j}{\left(10^5\right)\left(250\times 10^{-9}\right)} \\ &= -j40\ \Omega \end{aligned}$$

Step 3 of 6

Draw the circuit in frequency-domain network.

Figure 1

Thus, the frequency-domain network is shown in Figure 1.

Step 4 of 6

Apply nodal analysis at the node V_o.

$$\frac{V_O}{30} + \frac{V_O - V_S}{-j40} + I_2 - I_1 = 0$$

$$\frac{V_O}{30} + \frac{V_O - 10\angle -90^\circ}{-j40} + 0.1\angle 0^\circ - 0.2\angle 60^\circ = 0$$

$$V_O\left(\frac{1}{30} + \frac{j}{40}\right) = 0.2\angle 60^\circ - 0.1\angle 0^\circ + \frac{10\angle -90^\circ}{40\angle -90^\circ}$$

$$V_O\left(0.033 + j0.025\right) = 0.1 + j0.173 - 0.1 + 0.25$$

$$\begin{aligned} V_O &= \frac{0.25 + j0.173}{0.033 + j0.025} \\ &= 7.29 - j0.278 \\ &= 7.29\angle -2.18^\circ \text{ V} \end{aligned}$$

The output voltage in time domain is,

$$v_o(t) = 7.29\cos\left(10^5 t - 2.18^\circ\right) \text{ V}$$

Thus, the output voltage is $\boxed{7.29\cos\left(10^5 t - 2.18^\circ\right) \text{ V}}$.

Step 5 of 6

Apply Kirchhoff's voltage law to right side loop.

$$\begin{aligned} -V_C + V_S - V_O &= 0 \\ V_C &= V_S - V_O \end{aligned}$$

Substitute $7.29\angle -2.18^\circ \text{ V}$ for V_O and $10\angle -90^\circ \text{ V}$ for V_S.

$$\begin{aligned} V_C &= 10\angle -90^\circ - 7.29\angle -2.18^\circ \\ &= -j10 - 7.29 + j0.278 \\ &= -7.29 - j9.722 \\ &= 12.15\angle -126.86^\circ \end{aligned}$$

The capacitor voltage in time domain is,

$$v_C(t) = 12.15\cos\left(10^5 t - 126.86^\circ\right) \text{ V}$$

Thus, the capacitor voltage, $v_C(t)$ is $\boxed{12.15\cos\left(10^5 t - 126.86^\circ\right) \text{ V}}$.

Step 6 of 6

Draw the phasor diagram.

Figure 2

Thus, the phasor diagram is shown in Figure 2.

Step 1 of 2

Refer to Figure P8.26 in the textbook.

Calculate the value of angular frequency, ω .

$$\omega = 2\pi f$$

Substitute 60 Hz for f .

$$\begin{aligned}\omega &= 2\pi(60)\\ &= 120\pi\\ &= 377\text{ rad/s}\end{aligned}$$

The impedance of the inductor is,

$$\begin{aligned}Z_L &= j\omega L\\ &= j377L\end{aligned}$$

The impedance of the capacitor is,

$$\begin{aligned}Z_C &= \frac{1}{j\omega C}\\ &= \frac{1}{j(377)(10\times10^{-3})}\\ &= -j0.265\end{aligned}$$

Step 2 of 2

Calculate the total impedance of the circuit.

$$\begin{aligned}\mathbf{Z} &= R\,\|\,(Z_L + Z_C)\\ &= (2)\,\|\,(j377L - j0.265)\\ &= \frac{(2)(j377L - j0.265)}{(2)+(j377L - j0.265)}\\ &= \frac{(j2)(377L - 0.265)}{2 + j(377L - 0.265)} \times \frac{2 - j(377L - 0.265)}{2 - j(377L - 0.265)}\end{aligned}$$

$$\mathbf{Z} = \left[\frac{2(377L - 0.265)^2}{2^2 + (377L - 0.265)^2}\right] + j\left[\frac{4(377L - 0.265)}{2^2 + (377L - 0.265)^2}\right]$$

The impedance of the circuit is real. So, equate the imaginary part to zero to calculate the value of inductor.

$$\begin{aligned}&\frac{4(377L - 0.265)}{2^2 + (377L - 0.265)^2} = 0\\ &377L - 0.265 = 0\\ &377L = 0.265\\ &L = 0.7\text{ mH}\end{aligned}$$

Thus, the value of inductor for the real impedance is $\boxed{0.7\text{ mH}}$.

Refer the circuit in figure P8.19 in the textbook.

The condition for purely resistive circuit is,

$$\frac{1}{\omega L} = \omega C$$

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

Substitute $5\times10^{-3}\,\mathrm{H}$ for *L*, $1\times10^{-3}\,\mathrm{F}$ for *C*.

$$\begin{aligned}\omega &= \frac{1}{\sqrt{\left(5\times10^{-3}\,\mathrm{H}\right)\left(1\times10^{-3}\,\mathrm{F}\right)}}\\ &= 447.21\,\mathrm{rad/sec}\end{aligned}$$

Substitute $2\pi f$ for ω .

$$\begin{aligned}2\pi f &= 447.21\\ f &= \frac{447.21}{2\pi}\\ &= 71.2\,\mathrm{Hz}\end{aligned}$$

Therefore, the frequency of the circuit is $\boxed{71.2\,\mathrm{Hz}}$.

Step 1 of 3

The given circuit is,

Step 2 of 3

The voltage across the capacitor is,

$$v_C(t) = 80\cos\left(1000t - 60^\circ\right)\text{V}$$

$$V_C = 80\angle -60^\circ\text{V}$$

Therefore the current in the circuit is,

$$I = \frac{V_C}{\left(\frac{1}{j\omega C}\right)}$$

$$I = (j\omega C)V_C$$

$$I = \left(j1000 \times 25 \times 10^{-6}\right)\left(80\angle -60^\circ\right)$$

$$I = \left(25 \times 10^{-3}\angle 90^\circ\right)\left(80\angle -60^\circ\right)$$

$$I = 2\angle 30^\circ\text{A}$$

Step 3 of 3

Hence the voltage across the source is given by,

$$V_S = I\left(40 + \frac{1}{j1000 \times 25 \times 10^{-6}}\right)$$

$$V_s = \left(2\angle 30^\circ\right)(40 - j40)$$

$$V_s = \left(2\angle 30^\circ\right)\left(56.5685\angle -45^\circ\right)$$

$$V_s = 113.14\angle -15^\circ\text{V}$$

Therefore in the time domain the source voltage is,

$$\therefore \boxed{v_s(t) = 113.14\cos(1000t - 15^\circ)\text{V}}$$

Step 1 of 6

Refer to Figure P8.29 in the textbook.

The expression for the source voltage is,

$$v_s(t) = 15\sin(10000t)$$

Compare the source voltage with $V_m \sin(\omega t + \phi)$ for Phasor representation.

$$\begin{aligned}\mathbf{V}_S &= V_m\angle\phi^\circ \\ &= 15\angle 0^\circ \text{ V}\end{aligned}$$

$$\omega = 10000 \text{ rad/s}$$

The impedance of the capacitor is,

$$\begin{aligned}\mathbf{Z}_C &= \frac{1}{j\omega C} \\ &= \frac{1}{j(10000)(66.67\times10^{-6})} \\ &= -j1.5\end{aligned}$$

Step 2 of 6

Draw the frequency domain network.

Figure 1

Step 3 of 6

Apply Kirchhoff's voltage law to calculate the current through the circuit.

$$\mathbf{I}(R + Z_C) = V_S$$

$$\mathbf{I}(20 - j1.5) = 15\angle 0^\circ$$

$$\mathbf{I} = \frac{15\angle 0^\circ}{(20 - j1.5)}$$

$$\mathbf{I} = 0.7479\angle 4.289^\circ$$

Convert the phasor form to time domain expression.

$$i(t) = 0.7479\sin(10000t + 4.289^\circ)$$

Thus, the expression for the current through the circuit is $\boxed{0.7479\sin(10000t + 4.289^\circ)}$.

Step 4 of 6

Calculate the value of voltage across the capacitor.

$$\begin{aligned}\mathbf{V}_C &= \mathbf{I}\mathbf{Z}_C \\ &= (0.7479\angle 4.289^\circ)(-j1.5) \\ &= 1.12\angle -85.71^\circ\end{aligned}$$

Calculate the value of voltage across the resistor.

$$\begin{aligned}\mathbf{V}_R &= \mathbf{I}\mathbf{Z}_R \\ &= (0.7479\angle 4.289^\circ)(20) \\ &= 14.958\angle 4.289^\circ\end{aligned}$$

Step 5 of 6

Draw the Phasor diagram.

Figure 2

Step 6 of 6

From the Phasor diagram in Figure 2,

$$\begin{aligned}\mathbf{V}_C + \mathbf{V}_R &= (1.12\angle -85.71^\circ) + (14.958\angle 4.289^\circ) \\ &= (0.08378 - j1.1168) + (14.91 + j1.1186) \\ &= 15 + j1.8 \\ &= 15\angle 0^\circ \text{ V}\end{aligned}$$

Convert the Phasor form to time domain expression.

$$\begin{aligned}v_C(t) + v_R(t) &= 15\sin(10000t) \\ &= v_S(t)\end{aligned}$$

Thus, the expression $v_C(t) + v_R(t) = v_S(t)$ is proved.

Step 1 of 6

Refer to Figure P8.30 in the textbook.

The expression for the source current is,

$$i_S(t) = 1\cos(2500t - 45°)$$

Compare the source voltage with $I_m \cos(\omega t + \phi)$ for Phasor representation.

$$\begin{aligned}\mathbf{I}_S &= I_m \angle \phi° \\ &= 1\angle -45°\end{aligned}$$

$$\omega = 2500 \text{ rad/s}$$

The impedance of the capacitor is,

$$\begin{aligned}\mathbf{Z}_C &= \frac{1}{j\omega C} \\ &= \frac{1}{j(2500)(20\times10^{-6})} \\ &= -j20\end{aligned}$$

Step 2 of 6

Draw the frequency domain network.

Figure 1

Step 3 of 6

Apply nodal analysis at the node.

$$\frac{\mathbf{V}_O}{-j20} + \frac{\mathbf{V}_O}{10} = 1\angle -45°$$

$$\mathbf{V}_O(0.1 + j0.05) = 1\angle -45°$$

$$\begin{aligned}\mathbf{V}_O &= \frac{1\angle -45°}{0.1 + j0.05} \\ &= 2.828 - j8.485 \\ &= 8.944\angle -71.56°\end{aligned}$$

Convert the Phasor form to time domain expression.

$$v_o(t) = 8.944\cos(2500t - 71.56°)$$

Thus, the expression for the output voltage is $\boxed{8.944\cos(2500t - 71.56°)}$.

Step 4 of 6

Calculate the value of current through the capacitor.

$$\begin{aligned}\mathbf{I}_C &= \frac{\mathbf{V}_O}{\mathbf{Z}_C} \\ &= \frac{8.944\angle -71.56°}{-j20} \\ &= 0.424 + j0.141 \\ &= 0.447\angle 18.43°\end{aligned}$$

Calculate the value of current through the resistor.

$$\begin{aligned}\mathbf{I}_R &= \frac{\mathbf{V}_O}{\mathbf{Z}_R} \\ &= \frac{8.944\angle -71.56°}{10} \\ &= 0.8944\angle -71.56°\end{aligned}$$

Step 5 of 6

Draw the phasor diagram.

Figure 2

Step 6 of 6

From the Phasor diagram in Figure 2,

$$\begin{aligned}\mathbf{I}_C + \mathbf{I}_R &= (0.8944\angle -71.56°) + (0.447\angle 18.43°) \\ &= (0.2829 - j0.8485) + (0.424 + j0.141) \\ &= 0.707 - j0.707 \\ &= 1\angle -45°\end{aligned}$$

Convert the phasor form to time domain expression.

$$\begin{aligned}i_C(t) + i_R(t) &= 1\cos(2500t - 45°) \\ &= i_S(t)\end{aligned}$$

Thus, the expression $i_C(t) + i_R(t) = i_S(t)$ is proved.

Step 1 of 6

The given circuit is,

Step 2 of 6

$v(t)=120\cos(5000t)\text{V}$

$V=120\angle 0^\circ\text{V}$

$\omega=5000$ rad/s

Therefore the impedances in frequency domain,

$X_L=j\omega L$

$X_L=j(5000)(16\times10^{-3})$

$X_L=j80\Omega$

$X_C=\dfrac{1}{j\omega C}$

$X_C=\dfrac{1}{j(5000)(2.5\times10^{-6})}$

$X_C=-j80\Omega$

Step 3 of 6

Therefore the circuit in frequency domain,

Step 4 of 6

$I_C=\dfrac{V}{-j80}$

$I_C=\dfrac{120\angle 0^\circ}{80\angle -90^\circ}$

$I_C=1.5\angle 90^\circ\text{A}$

Therefore in the time domain,

$\boxed{i_c(t)=1.5\cos(5000t+90^\circ)\text{A}}$

Step 5 of 6

Now the current through the resistor and inductor combination is,

$I_1=\dfrac{V}{R+jX_L}$

$I_1=\dfrac{120\angle 0^\circ}{60+j80}$

$I_1=\dfrac{120\angle 0^\circ}{100\angle 53.13^\circ}$

$I_1=1.2\angle -53.13^\circ\text{A}$

Step 6 of 6

Writing KCL at the top node,

$I=I_C+I_1$

$I=1.5\angle 90^\circ+1.2\angle -53.13^\circ$

$I=j1.5+0.72-j0.96$

$I=0.72+j0.54$

$I=0.9\angle 36.87^\circ\text{A}$

Therefore in the time domain,

$\boxed{i(t)=0.9\cos(5000t+36.87^\circ)\text{A}}$

Step 1 of 4

The given circuit is,

Step 2 of 4

Given $v_s(t) = 20\cos 5t$ V

$\therefore V_s = 20\angle 0^\circ$V

$\omega = 5$rad/s

$X_L = j\omega L$

$X_L = j(5)(0.5)$

$X_L = j2.5\Omega$

The impedance on the right side of the circuit is simplified as,

$$Z = \frac{1}{\frac{1}{j\omega L} + \frac{1}{R} + j\omega C}$$

$$Z = \frac{1}{\frac{1}{j5} + \frac{1}{10} + j5 \times 0.02}$$

$$Z = \frac{1}{0.1 - j0.1}$$

$$Z = \frac{0.1 + j0.1}{0.1^2 + 0.1^2}$$

$Z = 5 + j5\Omega$

$Z = 7.07\angle 45^\circ\Omega$

Step 3 of 4

Hence the given network represented in frequency domain is,

Step 4 of 4

Therefore the current in the network is,

$$I = \frac{V_s}{3 + j2.5 + 5 + j5}$$

$$I = \frac{20\angle 0^\circ}{8 + j7.5}$$

$I = 1.82\angle -43.15^\circ$A

Hence the output voltage is,

$V_0 = IZ$

$V_0 = (1.82\angle -43.15^\circ)(7.07\angle 45^\circ)$

$V_0 = 12.87\angle 1.85^\circ$V

Therefore in the time domain,

$$\boxed{v_0(t) = 12.87\cos(5t + 1.85^\circ)\text{V}}$$

Step 1 of 7

The given circuit is,

Step 2 of 7

The input voltage is given as,

$v_1(t) = 170\cos 377t \text{ V}$

$\therefore V_I = 170\angle 0^\circ \text{V}$

$\omega = 377 \text{ rad/s}$

Therefore the impedances in the frequency domain,

$X_{L1} = j\omega L_1$

$X_{L1} = j(377)(20\times 10^{-3})$

$X_{L1} = j7.54\Omega$

$X_{C1} = \dfrac{1}{j\omega C_1}$

$X_{C1} = \dfrac{1}{j(377)(200\times 10^{-6})}$

$X_{C1} = -j13.26\Omega$

Step 3 of 7

$X_{L2} = j\omega L_2$

$X_{L2} = j(377)(30\times 10^{-3})$

$X_{L2} = j11.31\Omega$

$X_{C2} = \dfrac{1}{j\omega C_2}$

$X_{C2} = \dfrac{1}{j(377)(100\times 10^{-6})}$

$X_{C2} = -j26.52\Omega$

Step 4 of 7

Therefore the circuit in the frequency domain is,

Step 5 of 7

The impedance seen by the source is,

$Z = 20 - j13.26 + \left[(10 + j7.54) \parallel (15 + j11.31 - j26.52)\right]$

$Z = 20 - j13.26 + \left[(10 + j7.54) \parallel (15 - j15.21)\right]$

$Z = 20 - j13.26 + \left[\dfrac{(10 + j7.54)(15 - j15.21)}{10 + j7.54 + 15 - j15.21}\right]$

$Z = 20 - j13.26 + \left[\dfrac{(12.524\angle 37.016^\circ)(21.36\angle -45.398^\circ)}{25 - j7.67}\right]$

$Z = 20 - j13.26 + \left[\dfrac{267.51\angle -8.382}{26.15\angle -17.056}\right]$

$Z = 20 - j13.26 + 10.23\angle 8.674^\circ$

$Z = 20 - j13.26 + 10.11 + j1.543$

$Z = 30.11 - j11.72$

$Z = 32.31\angle -21.27^\circ \Omega$

Step 6 of 7

Therefore the current through the source is,

$I_1 = \dfrac{170\angle 0^\circ}{Z}$

$I_1 = \dfrac{170\angle 0^\circ}{32.31\angle -21.27^\circ}$

$I_1 = 5.26\angle 21.27^\circ \text{A}$

Hence, by current division,

$I_2 = I_1 \dfrac{10 + j7.54}{(10 + j7.54) + (j11.31 - j26.52 + 15)}$

$I_2 = 5.26\angle 21.27^\circ \left(\dfrac{10 + j7.54}{25 - j7.67}\right)$

$I_2 = 5.26\angle 21.27^\circ \left(\dfrac{12.524\angle 37.016^\circ}{26.15\angle -17.056^\circ}\right)$

$I_2 = 2.52\angle 75.34^\circ \text{A}$

Step 7 of 7

Hence the output voltage is,

$V_0 = 15 I_2$

$V_0 = 15(2.52\angle 75.34^\circ)$

$V_0 = 37.8\angle 75.34^\circ \text{V}$

Therefore in the time domain,

Step 1 of 7

The given circuit is,

Step 2 of 7

The current of the current source is,

$i_s(t) = 5\cos 10t \text{ A}$

$\therefore I_s = 5\angle 0^\circ \text{A}$

$\omega = 10 \text{rad/s}$

Therefore the impedances in the frequency domain,

$X_L = j\omega L$

$X_L = j(10)(0.4)$

$X_L = j4\Omega$

Step 3 of 7

$$X_{C1} = \frac{1}{j\omega C_1}$$

$$X_{C1} = \frac{1}{j(10)(0.02)}$$

$$X_{C1} = -j5\Omega$$

$$X_{C2} = \frac{1}{j\omega C_2}$$

$$X_{C2} = \frac{1}{j(10)(0.1)}$$

$$X_{C2} = -j1\Omega$$

Step 4 of 7

Therefore the circuit in the frequency domain is,

Step 5 of 7

The network shown above can be represented as shown below.

Step 6 of 7

Therefore the equivalent impedance 'Z' is given by,

$$\therefore Z = \frac{1}{\frac{1}{5} + \frac{1}{j4} + \frac{1}{-j5} + \frac{1}{5-j1}}$$

$$Z = \frac{1}{0.2 - j0.25 + j0.2 + \frac{5+j1}{5^2+1^2}}$$

$$Z = \frac{1}{0.39 - j0.01}$$

$$Z = \frac{0.39 + j0.01}{0.39^2 + 0.01^2}$$

$$Z = 2.56 + j0.07$$

$$Z = 2.56\angle 1.57^\circ \Omega$$

Step 7 of 7

Therefore the voltage across 'Z' is,

$V = (5\angle 0^\circ)Z$

$V = (5\angle 0^\circ)(2.56\angle 1.57^\circ)$

$V = 12.8\angle 1.57^\circ \text{V}$

Hence by voltage division the voltage across the 5Ω resistor is,

$$V_0 = V\left(\frac{5}{5-j1}\right)$$

$$V_0 = \left(\frac{5}{5.099\angle -11.31^\circ}\right)12.8\angle 1.57^\circ$$

$V_0 = 12.55\angle 12.88^\circ \text{V}$

Therefore in the time domain,

$$\boxed{v_0(t) = 12.55\cos(10t + 12.88^\circ)\text{V}}$$

Step 1 of 5

Calculate the impedance of inductor with $20\times10^{-3}\ \text{H}$.

$$Z_L = j\omega L$$

Substitute 100 rad/sec for ω, $20\times10^{-3}\ \text{H}$ for *L*.

$$\begin{aligned} Z_L &= j(100)\left(20\times10^{-3}\right) \\ &= j2\Omega \end{aligned}$$

Calculate the impedance of inductor with $50\times10^{-3}\ \text{H}$.

$$Z_L = j\omega L$$

Substitute 100 rad/sec for ω, $50\times10^{-3}\ \text{H}$ for *L*.

$$\begin{aligned} Z_L &= j(100)\left(50\times10^{-3}\right) \\ &= j5\Omega \end{aligned}$$

Calculate the impedance of capacitor with $2000\times10^{-6}\ \text{F}$.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 100 rad/sec for ω, $2000\times10^{-6}\ \text{F}$ for *C*.

$$\begin{aligned} Z_C &= \frac{1}{j(100)\left(2000\times10^{-6}\right)} \\ &= -j5\Omega \end{aligned}$$

Calculate the impedance of capacitor with $1000\times10^{-6}\ \text{F}$.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 100 rad/sec for ω, $1000\times10^{-6}\ \text{F}$ for *C*.

$$\begin{aligned} Z_C &= \frac{1}{j(100)\left(1000\times10^{-6}\right)} \\ &= -j10\Omega \end{aligned}$$

Step 2 of 5

The equivalent circuit of Figure P8.29 in the textbook is represented by Figure 1.

Figure 1

Step 3 of 5

The impedances $(6-j10)\Omega$ and $(5+j5)\Omega$ are in parallel.

$$\begin{aligned} Z_{eq} &= \frac{(6-j10)(5+j5)}{(6-j10)+(5+j5)} \\ &= \frac{80-j20}{11-j5} \\ &= (6.712+j1.233)\Omega \end{aligned}$$

The impedances $(3-j5)\Omega$ and $(6.712+j1.233)\Omega$ are in parallel.

$$\begin{aligned} Z_{eq} &= \frac{(3-j5)(6.712+j1.233)}{(3-j5)+(6.712+j1.233)} \\ &= \frac{26.301-j29.861}{9.712-j3.767} \\ &= (3.39-j1.759)\Omega \end{aligned}$$

The equivalent circuit in Figure 1 is represented by Figure 2.

Figure 2

Step 4 of 5

Determine the value of V_0.

$$\begin{aligned} V_0 &= 50\angle0^\circ\left(\frac{3.39-j1.76}{4+j2+3.39-j1.76}\right) \\ &= 50\angle0^\circ\left(\frac{3.39-j1.76}{7.39+j0.24}\right) \\ &= 50\angle0^\circ\left(0.45-j0.253\right) \\ &= \left(50\angle0^\circ\right)\left(0.516\angle-29.3^\circ\right) \end{aligned}$$

$$V_0 = 25.83\angle-29.3^\circ\ \text{V}.$$

Step 5 of 5

Determine the value of current I_0.

$$I_0 = \frac{V_0}{Z}$$

Substitute $25.83\angle-29.3^\circ\ \text{V}$ for V_0, $(3-j5)\Omega$ for *Z*.

$$\begin{aligned} I_0 &= \frac{25.83\angle-29.3^\circ\ \text{V}}{(3-j5)\Omega} \\ &= \frac{25.83\angle-29.3^\circ\ \text{V}}{5.83\angle-59.04^\circ\ \Omega} \\ &= 4.43\angle29.74^\circ\ \text{A} \end{aligned}$$

$$i_0(t) = 4.43\cos\left(100t+29.74^\circ\right)\text{A}.$$

Therefore, the value of $i_0(t)$ is $\boxed{4.43\cos\left(100t+29.74^\circ\right)\text{A}}$.

Step 1 of 6

The given circuit is,

Step 2 of 6

The voltage of the voltage source is,

$v_s(t) = 25\cos 20t$ V

$\therefore V_s = 25\angle 0^\circ$V

$\omega = 20$rad/s

Therefore the impedances in the frequency domain,

$X_L = j\omega L$

$X_L = j(20)(0.4)$

$X_L = j8\Omega$

Step 3 of 6

$X_{C1} = \dfrac{1}{j\omega C_1}$

$X_{C1} = \dfrac{1}{j(20)(0.02)}$

$X_{C1} = -j2.5\Omega$

$X_{C2} = \dfrac{1}{j\omega C_2}$

$X_{C2} = \dfrac{1}{j(20)(0.01)}$

$X_{C2} = -j5\Omega$

Step 4 of 6

Therefore the circuit in the frequency domain is,

Step 5 of 6

Now since all the elements are in parallel, the same voltage appears across all the elements,

$I_1 = \dfrac{25\angle 0^\circ}{j8}$

$I_1 = -j3.125$A

$I_2 = \dfrac{25\angle 0^\circ}{-j2.5}$

$I_2 = j10$A

$I_3 = \dfrac{25\angle 0^\circ}{5-j5}$

$I_3 = \dfrac{25(5+j5)}{5^2+5^2}$

$I_3 = (2.5+j2.5)$A

Step 6 of 6

Now writing KCL equation at the top node,

$I_0 = I_1 + I_2 + I_3$

$I_0 = -j3.125 + j10 + 2.5 + j2.5$

$I_0 = (2.5 + j9.375)$A

$I_0 = 9.7\angle 75.07^\circ$A

Hence the voltage across the 5Ω resistor is,

$V_0 = 5I_3$

$V_0 = 5(2.5 + j2.5)$

$V_0 = (12.5 + j12.5)$V

$V_0 = 17.68\angle 45^\circ$V

Therefore in the time domain,

$\boxed{i_0(t) = 9.7\cos(20t + 75.07^\circ)\text{A}}$

$\boxed{v_0(t) = 17.68\cos(20t + 45^\circ)\text{V}}$

Step 1 of 5

Calculate the impedance of inductor with 2 H.

$$Z_L = j\omega L$$

Substitute 5 rad/sec for ω, 2 H for L.

$$\begin{aligned} Z_L &= j(5)(2) \\ &= j10\Omega \end{aligned}$$

Calculate the impedance of inductor with 1 H.

$$Z_L = j\omega L$$

Substitute 5 rad/sec for ω, 1 H for L.

$$\begin{aligned} Z_L &= j(5)(1) \\ &= j5\Omega \end{aligned}$$

Calculate the impedance of capacitor with 0.05 F.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 5 rad/sec for ω, 0.05 F for C.

$$\begin{aligned} Z_C &= \frac{1}{j(5)(0.05)} \\ &= -j4\Omega \end{aligned}$$

Calculate the impedance of capacitor with 0.2 F.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 5 rad/sec for ω, 0.2 F for C.

$$\begin{aligned} Z_C &= \frac{1}{j(5)(0.2)} \\ &= -j1\Omega \end{aligned}$$

Step 2 of 5

The equivalent circuit of Figure P8.32 in the textbook is represented by Figure 1.

Figure 1

Step 3 of 5

The impedances $(5+j5)\Omega$ and $(3-j1)\Omega$ are in parallel.

$$\begin{aligned} Z_{eq} &= \frac{(5+j5)(3-j1)}{(5+j5)+(3-j1)} \\ &= \frac{20+j10}{8+j4} \\ &= 2.5\Omega \end{aligned}$$

The circuit in Figure 1 is represented by Figure 2.

Figure 2

Step 4 of 5

The impedances $(6+j6)\Omega$ and 4.5Ω are in parallel.

$$\begin{aligned} \frac{(6+j6)(4.5)}{(6+j6)+(4.5)} &= \frac{27+j27}{10.5+j6} \\ &= (3.046+j0.83)\Omega \end{aligned}$$

The circuit in Figure 2 is represented by Figure 3.

Figure 3

Step 5 of 5

From Ohm's law,

$$V_0 = IZ$$

$$\bar{I} = \frac{V_0}{Z}$$

Substitute $50\angle 0^\circ$ V for V_0, $(4+3.046+j0.83)\Omega$ for Z.

$$\begin{aligned} \bar{I} &= \frac{50\angle 0^\circ \text{ V}}{(4+3.046+j0.83)\Omega} \\ &= \frac{50\text{ V}}{(7.046+j0.83)\Omega} \\ &= (6.99-j0.82)\text{ A} \\ &= 7.04\angle -6.7^\circ \text{ A} \end{aligned}$$

Determine the value of $\overline{V_0}$.

$$\begin{aligned} \overline{V_0} &= -4\bar{I} \\ &= -4(6.99-j0.82) \\ &= -27.96+j3.28 \\ &= -28.15\angle 173.3^\circ \end{aligned}$$

$v_o(t) = 28.15\cos(5t+173.3^\circ)$ V.

Therefore, the value of $v_o(t)$ is $\boxed{28.15\cos(5t+173.3^\circ)\text{ V}}$.

Step 1 of 8

The given circuit is,

Step 2 of 8

The current of the current source is,

$i_s(t) = 2\cos 400t$ A

$\therefore I_s = 2\angle 0^\circ$ A

$\omega = 400$ rad/s

Therefore the impedances in the frequency domain,

$$X_C = \frac{1}{j\omega C}$$

$$X_C = \frac{1}{j(400)(625\times 10^{-6})}$$

$$X_C = -j4\Omega$$

Step 3 of 8

$$X_{L1} = j\omega L_1$$

$$X_{L1} = j(400)(10\times 10^{-3})$$

$$X_{L1} = j4\Omega$$

$$X_{L2} = j\omega L_2$$

$$X_{L2} = j(400)(25\times 10^{-3})$$

$$X_{L2} = j10\Omega$$

Step 4 of 8

Therefore the circuit in frequency domain,

Step 5 of 8

The network shown above can be represented as shown below.

Step 6 of 8

The equivalent impedance on the right side of the source is,

$$Z_1 = 2 + (4 \| j4) + 6$$

$$Z_1 = 8 + \frac{4(j4)}{4+j4}$$

$$Z_1 = 8 + \frac{(j16)}{4+j4}\times\frac{4-j4}{4-j4}$$

$$Z_1 = 8 + \frac{64+j64}{4^2+4^2}$$

$$Z_1 = 8 + \frac{64+j64}{32}$$

$$Z_1 = 8+2+j2$$

$$Z_1 = (10+j2)\Omega$$

Step 7 of 8

The equivalent impedance on the left side of the source is,

$$Z_2 = 5 + (8 \| -j4) + j10$$

$$Z_2 = 5 + j10 + \frac{8(-j4)}{8-j4}$$

$$Z_2 = 5 + j10 + \frac{(-j32)}{8-j4}\times\frac{8+j4}{8+j4}$$

$$Z_2 = 5 + j10 + \frac{128-j256}{8^2+4^2}$$

$$Z_2 = 5 + j10 + \frac{128-j256}{80}$$

$$Z_2 = 5 + j10 + 1.6 - j3.2$$

$$Z_2 = (6.6 + j6.8)\Omega$$

Step 8 of 8

Therefore, using current division,

$$I_2 = 2\angle 0^\circ\left(\frac{Z_1}{Z_1+Z_2}\right)$$

$$I_2 = 2\angle 0^\circ \times \frac{10+j2}{(6.6+j6.8)+(10+j2)}$$

$$I_2 = 2\angle 0^\circ \times \frac{10+j2}{16.6+j8.8}$$

$$I_2 = 2\angle 0^\circ \times \frac{10.198\angle 11.31^\circ}{18.788\angle 27.93^\circ}$$

$$I_2 = 1.086\angle -16.62^\circ \text{A}$$

Hence in the time domain,

$$\boxed{i_2(t) = 1.086\cos(400t - 16.62^\circ)\text{ A}}$$

Step 1 of 2

The given circuit is,

Step 2 of 2

By current division,

$$I = \left(\frac{-j60}{80 - j60}\right)\left(10\angle 0^\circ\right)$$

$$I = \left(\frac{60\angle -90^\circ}{100\angle -36.87^\circ}\right)\left(10\angle 0^\circ\right)$$

$$\boxed{I = 6\angle -53.13^\circ \text{A}}$$

Step 1 of 4

The given circuit is,

Step 2 of 4

The given network is represented as shown below.

Step 3 of 4

The equivalent impedance seen by the source is,

$$Z = \frac{1}{\frac{1}{j2} + \frac{1}{-j5} + \frac{1}{10}}$$

$$Z = \frac{1}{-j0.5 + j0.2 + 0.1}$$

$$Z = \frac{10}{1 - j3}$$

$$Z = \frac{10}{1 - j3} \times \frac{1 + j3}{1 + j3}$$

$$Z = \frac{10(1 + j3)}{1^2 + 3^2}$$

$$Z = \frac{10(1 + j3)}{10}$$

$$Z = (1 + j3)\,\Omega$$

$$Z = 3.16\angle 71.57^\circ\,\Omega$$

Step 4 of 4

Therefore the output voltage is given by,

$$V_0 = IZ$$

$$V_0 = (0.5\angle 25^\circ)(3.16\angle 71.57^\circ)$$

$$\boxed{V_0 = 1.58\angle 96.57^\circ\,\text{V}}$$

Step 1 of 3

The given circuit is,

Step 2 of 3

The equivalent impedance seen by the source is,

$$Z = \frac{1}{\frac{1}{j1} + \frac{1}{-j2} + \frac{1}{1}}$$

$$Z = \frac{1}{-j1 + j0.5 + 1}$$

$$Z = \frac{1}{1 - j0.5}$$

$$Z = \frac{1}{1.118\angle -26.57^\circ}$$

$$Z = 0.894\angle 26.57^\circ\,\Omega$$

Step 3 of 3

Therefore the output voltage is given by,

$$V = IZ$$

$$V = \left(1\angle 30^\circ\right)\left(0.894\angle 26.57^\circ\right)$$

$$\boxed{V = 0.894\angle 56.57^\circ \text{V}}$$

Step 1 of 4

The given circuit is,

Step 2 of 4

The impedance that is seen by the source is,

$$Z = 5 + j6 + (-j4 \| 10)$$

$$Z = 5 + j6 + \frac{10(-j4)}{10 - j4}$$

$$Z = 5 + j6 + \frac{-j40}{10 - j4}$$

$$Z = 5 + j6 + \frac{40\angle -90^\circ}{10.77\angle -21.8^\circ}$$

$$Z = 5 + j6 + 1.38 - j3.45$$

$$Z = (6.38 + j2.55)\,\Omega$$

$$Z = 6.87\angle 21.79^\circ\,\Omega$$

Step 3 of 4

Therefore the current through the source is given by,

$$I_0 = \frac{V}{Z}$$

$$I_0 = \frac{37\angle -145^\circ}{6.87\angle 21.79^\circ}$$

$$I_0 = 5.39\angle -166.79^\circ\,\text{A}$$

Step 4 of 4

Therefore by current division,

$$I = I_0\left(\frac{-j4}{10 - j4}\right)$$

$$I = \left(5.39\angle -166.79^\circ\right)\left(\frac{4\angle -90^\circ}{10.77\angle -21.8^\circ}\right)$$

$$I = 2\angle -235^\circ\,\text{A}$$

$$I = 2\angle 360 - 235^\circ\,\text{A}$$

$$\boxed{I = 2\angle 125^\circ\,\text{A}}$$

Step 1 of 7

Calculate the impedance of inductor with 0.1 H.

$$Z_L = j\omega L$$

Substitute 40 rad/sec for ω , 0.1 H for L.

$$\begin{aligned} Z_L &= j(40)(0.1) \\ &= j4\,\Omega \end{aligned}$$

Calculate the impedance of inductor with 0.2 H.

$$Z_L = j\omega L$$

Substitute 40 rad/sec for ω , 0.2 H for L.

$$\begin{aligned} Z_L &= j(40)(0.2) \\ &= j8\,\Omega \end{aligned}$$

Calculate the impedance of capacitor with 0.005 F.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 40 rad/sec for ω , 0.005 F for C.

$$\begin{aligned} Z_C &= \frac{1}{j(40)(0.005)} \\ &= -j5\,\Omega \end{aligned}$$

Step 2 of 7

The equivalent circuit of Figure P8.36 in the textbook is represented by Figure 1.

Figure 1

Step 3 of 7

With the supply of $100\angle 0^\circ$ V in active mode, the voltage $40\angle -30^\circ$ V is short circuited.

The equivalent circuit of Figure 1 is represented by Figure 2.

Figure 2

Step 4 of 7

Determine the value of $\overline{V_x}'$.

Apply voltage law to the circuit in Figure 2.

$$\begin{aligned} \overline{V_x}' &= \left(\frac{j8 - j5}{j8 - j5 + 10 + j4 + 5}\right)(100\angle 0^\circ\text{ V}) \\ &= \left(\frac{j3}{15 + j7}\right)(100\angle 0^\circ) \\ &= (0.076 + j0.164)(100) \\ &= 7.6 + j16.4 \\ &= 18.07\angle 65.13^\circ\text{ V} \end{aligned}$$

Step 5 of 7

With the supply of $40\angle -30^\circ$ V in active mode, the voltage $100\angle 0^\circ$ V is short circuited.

The equivalent circuit of Figure 1 is represented by Figure 3.

Figure 3

Step 6 of 7

Determine the value of $\overline{V_x}''$.

Apply voltage law to the circuit in Figure 3.

$$\begin{aligned} \overline{V_x}'' &= \left(\frac{5 + 10 + j4}{j8 - j5 + 10 + j4 + 5}\right)(40\angle -30^\circ\text{ V}) \\ &= \left(\frac{15 + j4}{15 + j7}\right)(40\angle -30^\circ) \\ &= (0.923 - j0.164)(40\angle -30^\circ) \\ &= (0.937\angle -10.07^\circ)(40\angle -30^\circ) \\ &= 37.48\angle -40.1^\circ\text{ V} \end{aligned}$$

Step 7 of 7

Determine the value of $\overline{V_x}$.

$$\overline{V_x} = \overline{V_x}' + \overline{V_x}''$$

Substitute $18.07\angle 65.13^\circ$ V for $\overline{V_x}'$, and $37.48\angle -40.1^\circ$ V for $\overline{V_x}''$.

$$\begin{aligned} \overline{V_x} &= 18.07\angle 65.13^\circ\text{ V} + 37.48\angle -40.1^\circ\text{ V} \\ &= 7.59 + j16.39 + 28.67 - j24.14 \\ &= 36.26 - j7.75 \\ &= 37.17\angle -12.06^\circ\text{ V} \end{aligned}$$

$v_x(t) = 37.17\cos(40t - 12.06^\circ)$ V .

Therefore, the value of $v_x(t)$ is $\boxed{37.17\cos(40t - 12.06^\circ)\text{ V}}$.

Step 1 of 5

Calculate the impedance of inductor with 0.2 H.

$$Z_L = j\omega L$$

Substitute 10 rad/sec for ω , 0.2 H for *L*.

$$\begin{aligned} Z_L &= j(10)(0.2) \\ &= j2\Omega \end{aligned}$$

Calculate the impedance of capacitor with 0.02 F.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 10 rad/sec for ω , 0.02 F for *C*.

$$\begin{aligned} Z_C &= \frac{1}{j(10)(0.02)} \\ &= -j5\Omega \end{aligned}$$

Step 2 of 5

The equivalent circuit of Figure P8.38 in the textbook is represented by Figure 1.

Figure 1

Step 3 of 5

Determine the value of $\overline{I_1}$.

Apply Kirchhoff's current law to the circuit in Figure 1.

$$\begin{aligned} \overline{I_1} &= 4\angle 0^\circ + 2\angle 15^\circ \\ &= 5.95\angle 5^\circ \text{ A} \end{aligned}$$

Step 4 of 5

Determine the value of $\overline{V_1}$.

$$\overline{V_1} = (-j5\Omega)\overline{I_1}$$

Substitute $5.95\angle 5^\circ$ A for $\overline{I_1}$.

$$\begin{aligned} \overline{V_1} &= (-j5\Omega)(5.95\angle 5^\circ \text{ A}) \\ &= (5\angle -90^\circ)(5.95\angle 5^\circ) \\ &= 29.75\angle -85^\circ \text{ V} \end{aligned}$$

$$v_1(t) = 29.75\cos(10t - 85^\circ)\text{V}$$

Therefore, the value of $v_1(t)$ is $\boxed{29.75\cos(10t - 85^\circ)\text{V}}$.

Step 5 of 5

Determine the value of $\overline{V_2}$.

Apply Kirchhoff's voltage law to the circuit in Figure 1.

$$12\angle -25^\circ \text{ V} + j2\Omega(4\angle 0^\circ) + 29.75\angle -85^\circ + \overline{V_2} = 0$$

$$\begin{aligned} \overline{V_2} &= -(12\angle -25^\circ + j2\Omega(4\angle 0^\circ) + 29.75\angle -85^\circ) \\ &= -(10.87 - j5.07 + j8 + 2.59 - j29.64) \\ &= -(13.46 - j26.71) \\ &= -13.46 + j26.71 \\ &= 29.91\angle 116.74^\circ \text{ V} \end{aligned}$$

$$v_2(t) = 29.91\cos(10t + 116.74^\circ)\text{V}.$$

Therefore, the value of $v_2(t)$ is $\boxed{29.91\cos(10t + 116.74^\circ)\text{V}}$.

Step 1 of 1

Refer the circuit in Figure P8.39 in the text book.

Determine the value of $\overline{V}$.

Apply voltage division rule to find the voltage $\overline{V}$.

$$\begin{aligned}\overline{V} &= \left(\frac{-j1}{1-j1}\right)\left(100\angle 0^\circ\right)\\ &= (-j1)(0.5+j0.5)\left(100\angle 0^\circ\right)\\ &= (0.5-j0.5)(100)\\ &= 50-j50\\ &= 70.71\angle -45^\circ \text{ V}.\end{aligned}$$

Therefore, the value of $\overline{V}$ is $\boxed{70.71\angle -45^\circ \text{ V}}$.

Step 1 of 1

Refer the circuit in Figure P8.40 in the textbook.

Determine the value of V_0 .

Apply Voltage division rule to the circuit in Figure 1.

$$\begin{aligned} V_0 &= \left(\frac{-j12}{2+j10-j12}\right)\left(10\angle 30^\circ\right) \\ &= \left(\frac{-j12}{2-j2}\right)\left(10\angle 30^\circ\right) \\ &= (3-j3)\left(10\angle 30^\circ\right) \\ &= \left(4.24\angle -45^\circ\right)\left(10\angle 30^\circ\right) \\ &= 42.4\angle -15^\circ \text{ V}. \end{aligned}$$

Therefore, the value of V_0 is $\boxed{42.4\angle -15^\circ \text{ V}}$.

Step 1 of 2

Refer the circuit in Figure P8.41 in the textbook.

Determine the value of I_0.

Apply Kirchhoff's law to the circuit.

$$\begin{aligned} I_0 &= \left(\frac{15}{15+1-j12}\right)\left(50\angle 30^\circ\right) \\ &= \left(\frac{15}{16-j12}\right)\left(50\angle 30^\circ\right) \\ &= \left(0.6+j0.45\right)\left(50\angle 30^\circ\right) \\ &= \left(0.75\angle 36.87\right)\left(50\angle 30^\circ\right) \\ &= 37.5\angle 66.87^\circ \text{ A}. \end{aligned}$$

Step 2 of 2

Determine the value of V_0.

Apply Kirchhoff's voltage law to the circuit.

$$V_0 = \left(-j12\right)I_0$$

Substitute $37.5\angle 66.87^\circ$ A for I_0.

$$\begin{aligned} V_0 &= \left(-j12\right)\left(37.5\angle 66.87^\circ\right) \\ &= \left(-j12\right)\left(1.473+j3.448\right) \\ &= 41.376-j17.676 \\ &= 45\angle -23.13^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{45\angle -23.13^\circ \text{ V}}$.

Step 1 of 4

Refer the circuit in Figure P8.42 in the textbook.

Determine the open circuit voltage of the circuit. The circuit is represented by Figure-1.

Figure-1

Determine the open circuit voltage.

$$V_{oc} = -12\angle 0^\circ$$
$$= 12\angle 180^\circ \text{ V}$$

Step 2 of 4

Now, the voltage source is short-circuited and the circuit in Figure-1 is represented by Figure-2.

Figure-2

Determine the impedance of the circuit.

As the terminals are short circuited, the impedance is zero.

$$Z_{TH} = 0\Omega$$

Step 3 of 4

Now, the circuit is represented by Figure-3.

Figure-3

Step 4 of 4

Determine the value of V_0 .

Apply voltage division rule.

$$V_0 = \left(\frac{2}{2-j1}\right)\left(12\angle 180^\circ\right)$$
$$= \left(0.8 + j0.4\right)\left(12\angle 180^\circ\right)$$
$$= -9.6 - j4.8$$
$$= 10.73\angle -153.43^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{10.73\angle -153.43^\circ \text{ V}}$.

Step 1 of 6

The given circuit is,

Step 2 of 6

The impedance that is seen across the capacitor is,

$$Z_1 = -j2 \| \left[2 + (j2 \| 2)\right]$$

$$Z_1 = -j2 \| \left[2 + \frac{(j2)(2)}{2+j2}\right]$$

$$Z_1 = -j2 \| \left[\frac{4+j4+j4}{2+j2}\right]$$

$$Z_1 = -j2 \| \left(\frac{4+j8}{2+j2}\right)$$

$$Z_1 = \frac{-j2\left(\frac{4+j8}{2+j2}\right)}{-j2+\frac{4+j8}{2+j2}}$$

Step 3 of 6

$$Z_1 = \frac{-j2(4+j8)}{-j2(2+j2)+4+j8}$$

$$Z_1 = \frac{16-j8}{4-j4+4+j8}$$

$$Z_1 = \frac{16-j8}{8+j4}$$

$$Z_1 = \frac{17.89\angle -26.565^\circ}{8.94\angle 26.565^\circ}$$

$$Z_1 = 2\angle -53.13^\circ \Omega$$

$$Z_1 = (1.2 - j1.6)\Omega$$

Step 4 of 6

Therefore the voltage across the capacitor is,

$$V_1 = V_S\left(\frac{Z_1}{2+Z_1}\right)$$

$$V_1 = (12\angle 0^\circ)\left(\frac{1.2-j1.6}{2+1.2-j1.6}\right) \qquad (\because V_S = 12\angle 0^\circ \text{V})$$

$$V_1 = (12\angle 0^\circ)\left(\frac{1.2-j1.6}{3.2-j1.6}\right)$$

$$V_1 = (12\angle 0^\circ)\left(\frac{2\angle -53.13^\circ}{3.58\angle -26.565}\right)$$

$$V_1 = 6.7\angle -26.565^\circ \text{V}$$

Step 5 of 6

The impedance that is seen across the inductor is,

$$Z_2 = 2 \| j2$$

$$Z_2 = \frac{2(j2)}{2+j2}$$

$$Z_2 = \frac{j4}{2+j2}$$

$$Z_2 = \frac{4\angle 90^\circ}{2.828\angle 45^\circ}$$

$$Z_2 = 1.414\angle 45^\circ \Omega$$

$$Z_2 = (1+j1)\Omega$$

Step 6 of 6

Therefore the voltage across the inductor is,

$$V_2 = V_1\left(\frac{Z_2}{2+Z_2}\right)$$

$$V_2 = (6.7\angle -26.565^\circ)\left(\frac{1+j1}{2+1+j1}\right)$$

$$V_2 = (6.7\angle -26.565^\circ)\left(\frac{1+j1}{3+j1}\right)$$

$$V_2 = (6.7\angle -26.565^\circ)\left(\frac{1.414\angle 45^\circ}{3.16\angle 18.43^\circ}\right)$$

$$V_2 = 3\angle 0^\circ \text{V}$$

Therefore the current I_0 is,

$$I_0 = \frac{V_2}{2}$$

$$I_0 = \frac{3\angle 0^\circ}{2}$$

$$\boxed{I_0 = 1.5\angle 0^\circ \text{A}}$$

Step 1 of 6

Refer the circuit in Figure P8.46 in the text book.

The circuit in Figure P8.46 is represented by Figure 1.

Figure 1

Step 2 of 6

Determine the value of I_1.

$$I_1 = \frac{V_1}{R}$$

Substitute $4\angle 0^\circ \text{ V}$ for V_1, and 2Ω for *R*.

$$\begin{aligned} I_1 &= \frac{4\angle 0^\circ \text{ V}}{2\Omega} \\ &= 2\angle 0^\circ \text{ A} \end{aligned}$$

Step 3 of 6

Determine the value of I_2.

$$I_2 = \frac{V_1}{R + X_C}$$

Substitute $4\angle 0^\circ \text{ V}$ for V_1, 1Ω for *R*, and $-j1\Omega$ for X_C.

$$\begin{aligned} I_2 &= \frac{4\angle 0^\circ \text{ V}}{(1 - j1)\Omega} \\ &= 2 + j2 \\ &= 2.83\angle 45^\circ \text{ A} \end{aligned}$$

Step 4 of 6

Determine the value of current I_s.

$$I_s = -I_1 - I_2$$

Substitute $2\angle 0^\circ \text{ A}$ for I_1, and $2.83\angle 45^\circ \text{ A}$ for I_2.

$$\begin{aligned} I_s &= -2\angle 0^\circ \text{ A} - 2.83\angle 45^\circ \text{ A} \\ &= -2 - 2 - j2 \\ &= -4 - j2 \\ &= 4.47\angle -153.43^\circ \text{ A} \end{aligned}$$

Step 5 of 6

Determine the value of current I.

Apply current division rule.

$$\begin{aligned} I &= \left(\frac{2 + j1}{2 + j1 - j1}\right)\left(4.47\angle -153.43^\circ\right) \\ &= (1 + j0.5)\left(4.47\angle -153.43^\circ\right) \\ &= -2.99 - j3.99 \\ &= 5\angle -126.86^\circ \text{ A} \end{aligned}$$

Step 6 of 6

Determine the value of V_S.

Apply Kirchhoff's voltage law to the circuit in Figure 1.

$$\begin{aligned} -j1I &= 2I_1 + V_S \\ V_S &= -j1I - 2I_1 \end{aligned}$$

Substitute $5\angle -126.86^\circ \text{ A}$ for I, and $2\angle 0^\circ \text{ A}$ for I_1.

$$\begin{aligned} V_S &= -j1\left(5\angle -126.86^\circ \text{ A}\right) - 2\left(2\angle 0^\circ \text{ A}\right) \\ &= \left(1\angle -90^\circ\right)\left(5\angle -126.86^\circ\right) - \left(4\angle 0^\circ\right) \\ &= -4 + j3 - 4 \\ &= -8 + j3 \\ &= 8.54\angle 159.45^\circ \text{ V}. \end{aligned}$$

Therefore, the value of V_S is $\boxed{8.54\angle 159.45^\circ \text{ V}}$.

Step 1 of 3

Refer the circuit in Figure P8.45 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Here, A and B represents the nodes of the circuit.

Apply Kirchhoff's current law at node A.

$$\overline{I_1} = \overline{I_2} + \overline{I_3}$$

$$\frac{\overline{V_A}}{j1} = \frac{\overline{V_B} - \overline{V_A}}{2} + \frac{\overline{V_B} - \overline{V_A}}{-j2}$$

$$\frac{\overline{V_A}}{j1} = \frac{1}{2}\left[\frac{-j\left(\overline{V_B} - \overline{V_A}\right) + \left(\overline{V_B} - \overline{V_A}\right)}{-j}\right]$$

$$-2\overline{V_A} = \left(\overline{V_B} - \overline{V_A}\right) - j1\left(\overline{V_B} - \overline{V_A}\right)$$

$$-2\overline{V_A} = \overline{V_B} - \overline{V_A} - j\overline{V_B} + j\overline{V_A}$$

$$(1 + j1)\overline{V_A} + (1 - j1)\overline{V_B} = 0 \text{ ..... (1)}$$

Step 2 of 3

From the circuit in Figure 1,

$$\overline{V_B} - \overline{V_A} = 4\angle 0^\circ$$

$$\overline{V_B} = \overline{V_A} + 4\angle 0^\circ \text{ ..... (2)}$$

Substitute equation (2) in equation (1).

$$(1 + j1)\overline{V_A} + (1 - j1)\left(\overline{V_A} + 4\angle 0^\circ\right) = 0$$

$$2\overline{V_A} = -(1 - j1)4\angle 0^\circ$$

$$\overline{V_A} = \frac{1}{2}\left(1.414\angle 135^\circ\right)\left(4\angle 0^\circ\right)$$

$$\overline{V_A} = 2.83\angle 135^\circ \text{ V ..... (3)}$$

Substitute equation (3) in equation (2).

$$\begin{aligned}\overline{V_B} &= 2.83\angle 135^\circ + 4\angle 0^\circ \\ &= 1.99 + j2 \\ &= 2.82\angle 45^\circ \text{ V}\end{aligned}$$

Step 3 of 3

Determine the value of $\overline{I_0}$.

$$\overline{I_0} = \frac{\overline{V_B}}{1}$$

Substitute $2.82\angle 45^\circ$ V for $\overline{V_B}$.

$$\begin{aligned}\overline{I_0} &= \frac{2.82\angle 45^\circ}{1} \\ &= 2.82\angle 45^\circ \text{ A}\end{aligned}$$

Therefore, the value of $\overline{I_0}$ is $\boxed{2.82\angle 45^\circ \text{ A}}$.

Step 1 of 8

Refer the circuit in Figure P8.48 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 8

Apply Kirchhoff's current law at node-1.

$$I_1 = I_2 + I_3$$
$$\frac{V_2 - V_1}{1} = \frac{V_1 - V_3}{j1} + \frac{V_1 - V_4}{-j1}$$
$$j1(V_2 - V_1) = V_1 - V_3 - V_1 + V_4$$
$$-j1V_1 + j1V_2 + V_3 - V_4 = 0 \text{ ..... (1)}$$

Step 3 of 8

Apply Kirchhoff's current law at node-2.

$$I_1 + 2\angle 0^\circ = I_x$$
$$\frac{V_2 - V_1}{1} + 2\angle 0^\circ = \frac{-V_2}{1}$$
$$V_2 - V_1 + 2\angle 0^\circ = -V_2$$
$$V_1 - 2V_2 = 2\angle 0^\circ \text{ ..... (2)}$$

Step 4 of 8

Apply Kirchhoff's current law at node-4.

$$I_3 + I_4 = I_0$$
$$\frac{V_1 - V_4}{-j1} + \frac{V_3 - V_4}{1} = \frac{V_4}{1}$$
$$V_1 - V_4 - (j1)(V_3 - V_4) = (-j1)(V_4)$$
$$V_1 - V_4 - (j1)V_3 + (j1)V_4 + (j1)(V_4) = 0$$
$$V_1 - (j1)(V_3) + (-1 + j2)(V_4) = 0 \text{ ..... (3)}$$

Step 5 of 8

From Figure 1,

$$\begin{aligned} V_4 &= (1)(I_0) \\ &= (1)(4\angle 0^\circ) \\ &= 4\angle 0^\circ \text{ V} \end{aligned}$$

Step 6 of 8

Determine the value of V_1.

Substitute $12\angle 0^\circ$ V for V_3, and $4\angle 0^\circ$ V for V_4 in equation (3).

$$V_1 - (j1)(12\angle 0^\circ \text{ V}) + (-1 + j2)(4\angle 0^\circ \text{ V}) = 0$$
$$\begin{aligned} V_1 &= j12 - (-4 + j8) \\ &= 4 = j4 \\ &= 5.65\angle 45^\circ \text{ V} \end{aligned}$$

Step 7 of 8

Determine the value of V_2.

From equation (2),

$$V_1 - 2V_2 = 2\angle 0^\circ$$

Substitute $5.65\angle 45^\circ$ V for V_1.

$$(5.65\angle 45^\circ \text{ V}) - 2V_2 = 2\angle 0^\circ$$
$$\begin{aligned} V_2 &= \frac{5.65\angle 45^\circ - 2\angle 0^\circ}{2} \\ &= \frac{1.99 + j3.99}{2} \\ &= 1 + j2 \\ &= 2.24\angle 63.43^\circ \text{ V} \end{aligned}$$

Step 8 of 8

Determine the value of I_x.

$$I_x = (-1)(V_2)$$

Substitute $2.24\angle 63.43^\circ$ V for V_2.

$$\begin{aligned} I_x &= (-1)(2.24\angle 63.43^\circ \text{ V}) \\ &= 2.24\angle(-180^\circ + 63.43^\circ) \\ &= 2.24\angle -116.57^\circ \text{ A} \end{aligned}$$

Therefore, the value of I_x is $\boxed{2.24\angle -116.57^\circ \text{ A}}$.

Step 1 of 8

Refer the circuit in Figure P8.49 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 8

Determine the value of V_o.

$$V_o = \mathbf{I}_o Z$$

Substitute $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_o$, 1Ω for Z.

$$\begin{aligned} V_o &= (4\angle 0°\ \mathrm{A})(1\Omega) \\ &= 4\angle 0°\ \mathrm{V} \end{aligned}$$

Step 3 of 8

Determine the value of I_1.

Apply Kirchhoff's current law to the circuit in Figure 1.

$$\begin{aligned} \mathbf{I}_o &= 2\angle 0° + I_1 \\ I_1 &= \mathbf{I}_o - 2\angle 0° \end{aligned}$$

Substitute $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_o$.

$$\begin{aligned} I_1 &= 4\angle 0° - 2\angle 0° \\ &= 2\angle 0°\ \mathrm{A} \end{aligned}$$

Step 4 of 8

Determine the value of V_C.

Apply Kirchhoff's voltage law to the circuit in Figure 1.

$$V_C = V_o + I_1(1\Omega)$$

Substitute $4\angle 0°\ \mathrm{V}$ for V_o, and $2\angle 0°\ \mathrm{A}$ for I_1.

$$\begin{aligned} V_C &= 4\angle 0°\ \mathrm{V} + (2\angle 0°\ \mathrm{A})(1\Omega) \\ &= 6\angle 0°\ \mathrm{V} \end{aligned}$$

Step 5 of 8

Determine the value of I_C.

From Ohms law,

$$V = IZ$$

$$I_C = \frac{V_C}{-j1}$$

Substitute $6\angle 0°\ \mathrm{V}$ for V_C.

$$\begin{aligned} I_C &= \frac{6\angle 0°\ \mathrm{V}}{-j1} \\ &= 6\angle 90°\ \mathrm{A} \end{aligned}$$

Step 6 of 8

Determine the value of I_2.

Apply Kirchhoff's voltage law to the circuit in figure 1.

$$V_C + 12\angle 0° = 1(I_2) + 4\angle 0°$$

Substitute $6\angle 0°\ \mathrm{V}$ for V_C.

$$\begin{aligned} 6\angle 0°\ \mathrm{V} + 12\angle 0° &= 1(I_2) + 4\angle 0° \\ I_2 &= 14\angle 0°\ \mathrm{A} \end{aligned}$$

Step 7 of 8

Determine the value of I_L.

Apply Kirchhoff's current law to the circuit in Figure 1.

$$I_2 + I_1 + I_C = I_L$$

Substitute $2\angle 0°\ \mathrm{A}$ for I_1, $14\angle 0°\ \mathrm{A}$ for I_2, and $6\angle 90°\ \mathrm{A}$ for I_C.

Step 8 of 8

Determine the value of .
Apply Kirchhoff's voltage law to the circuit in figure 1.

Substitute for , for I_L.

$$\begin{aligned} \mathbf{I}_x &= -6\angle 0°\ \mathrm{V} - (j1)((16 + j6)\mathrm{A}) \\ &= -6\angle 0° - (-6 + j16) \\ &= -6 + 6 + j16 \\ &= 16\angle -90°\ \mathrm{A} \end{aligned}$$

Therefore, the value of $\mathbf{I}_x$ is $\boxed{16\angle -90°\ \mathrm{A}}$.

Step 1 of 13

Refer the circuit in Figure P8.50 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 13

Determine the value of V_0.

From Ohms law,

$$V = IZ$$
$$V_0 = I_0(1\Omega)$$

Substitute $4\angle 0°$ A for I_0.

$$V_0 = (4\angle 0° \text{ A})(1\Omega)$$
$$= 4\angle 0° \text{ V}$$

Step 3 of 13

Determine the value of I_1.

Apply Kirchhoff's voltage law at node A.

$$I_1 = 2\angle 0° + I_0$$

Substitute $4\angle 0°$ A for I_0.

$$I_1 = 2\angle 0° + 4\angle 0°$$
$$= 6\angle 0° \text{ A}$$

Step 4 of 13

Determine the value of V_1.

$$V_1 = I_1(1\Omega)$$

Substitute $6\angle 0°$ A for I_1.

$$V_1 = (6\angle 0° \text{ A})(1\Omega)$$
$$= 6\angle 0° \text{ V}$$

Step 5 of 13

Determine the value of V_2.

Apply Kirchhoff's voltage law to loop-1.

$$V_2 = V_1 + V_0$$

Substitute $6\angle 0°$ V for V_1, $4\angle 0°$ V for V_0.

$$V_2 = 6\angle 0° \text{ V} + 4\angle 0° \text{ V}$$
$$= 10\angle 0° \text{ V}$$

Step 6 of 13

Determine the value of I_2.

$$I_2 = \frac{V_2}{-j1\Omega}$$

Substitute $10\angle 0°$ V for V_2.

$$I_2 = \frac{10\angle 0° \text{ V}}{-j1\Omega}$$
$$= 10\angle 90° \text{ A}$$

Step 7 of 13

Determine the value of V_3.

Apply Kirchhoff's voltage law to loop-2.

$$12\angle 0° \text{ V} = V_3 + V_2$$
$$V_3 = 12\angle 0° - V_2$$

Substitute $10\angle 0°$ V for V_2.

$$V_3 = 12\angle 0° - 10\angle 0°$$
$$= 2\angle 0° \text{ V}$$

Step 8 of 13

Determine the value of I_3.

$$I_3 = \frac{V_3}{1\Omega}$$

Substitute $2\angle 0°$ V for V_3.

$$I_3 = \frac{2\angle 0° \text{ V}}{1\Omega}$$
$$= 2\angle 0° \text{ A}$$

Step 8 of 13

Determine the value of I_4.

Apply Kirchhoff's current law at node B.

$$I_3 + I_4 = I_1 + I_2$$
$$I_4 = I_1 + I_2 - I_3$$

Substitute $6\angle 0°$ A for I_1, $10\angle 90°$ A for I_2, and $2\angle 0°$ A for I_3.

$$I_4 = 6\angle 0° \text{ A} + 10\angle 90° \text{ A} - 2\angle 0° \text{ A}$$
$$= 4\angle 0° + 10\angle 90°$$
$$= 4 + j10$$
$$= 10.77\angle 68.2° \text{ A}$$

Step 10 of 13

Determine the value of V_4.

$$V_4 = I_4(1\Omega)$$

Substitute $10.77\angle 68.2°$ A for I_4.

$$V_4 = (10.77\angle 68.2° \text{ A})(1\Omega)$$
$$= 10.77\angle 68.2° \text{ V}$$

Step 11 of 13

Determine the value of V_5.

Apply Kirchhoff's voltage law to loop-3.

$$V_3 + V_5 = V_4$$
$$V_5 = V_4 - V_3$$

Substitute $10.77\angle 68.2°$ V for V_4, and $2\angle 0°$ V for V_3.

$$V_5 = 10.77\angle 68.2° \text{ V} - 2\angle 0° \text{ V}$$
$$= 4 + j10 - 2$$
$$= 2 + j10$$
$$= 10.2\angle 78.69° \text{ V}$$

Step 12 of 13

Determine the value of I_5.

$$I_5 = \frac{V_5}{1\Omega}$$

Substitute $10.2\angle 78.69°$ V for V_5.

$$I_5 = \frac{10.2\angle 78.69° \text{ V}}{1\Omega}$$
$$= 10.2\angle 78.69° \text{ A}$$

Step 13 of 13

Determine the value of I_x.

Apply Kirchhoff's current law at node-C.

$$I_x + I_5 + I_4 = 2\angle 0°$$
$$I_x = 2\angle 0° - I_5 - I_4$$

Substitute $10.2\angle 78.69°$ A for I_5, $10.77\angle 68.2°$ A for I_4.

$$I_x = 2\angle 0° - 10.2\angle 78.69° - 10.77\angle 68.2°$$
$$= 2 - 2 - j10 - 4 - j10$$
$$= -4 - j20$$
$$= 20.39\angle -101.3° \text{ A}$$

Therefore, the value of I_x is $\boxed{20.39\angle -101.3° \text{ A}}$.

Step 1 of 5

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 5

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 5

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 5

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 5 of 5

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 7

The given circuit is,

Step 2 of 7

Given $V_1 = 5\angle -120^\circ \text{V}$

The current through the $j1\Omega$ is,

$$I_1 = \frac{V_1}{j1}$$

$$I_1 = \frac{5\angle -120^\circ}{1\angle 90^\circ}$$

$$I_1 = 5\angle -210^\circ \text{A}$$

Step 3 of 7

Writing KCL at node '1'

$$-I_1 + I_2 - 6\angle 0^\circ = 0$$

$$I_2 = I_1 + 6$$

$$I_2 = 5\angle -210^\circ + 6$$

$$I_2 = -4.33 + j2.5 + 6$$

$$I_2 = 1.67 + j2.5$$

$$I_2 = 3.01\angle 56.26^\circ \text{A}$$

Step 4 of 7

The voltage across the 0.25Ω resistor is,

$$V_{0.25\Omega} = 0.25 I_2$$

$$V_{0.25\Omega} = 0.25\left(3.01\angle 56.26^\circ\right)$$

$$V_{0.25\Omega} = 0.7525\angle 56.26^\circ \text{V}$$

Hence the voltage across the 2Ω resistor is,

$$V_{2\Omega} + V_1 + V_{0.25\Omega} = 0$$

$$V_{2\Omega} = -V_1 - V_{0.25\Omega}$$

$$V_{2\Omega} = -5\angle -120^\circ - 0.7525\angle 56.26^\circ$$

$$V_{2\Omega} = 2.5 + j4.33 - 0.418 - j0.626$$

$$V_{2\Omega} = 2.082 + j3.704$$

$$V_{2\Omega} = 4.25\angle 60.66^\circ \text{V}$$

Step 5 of 7

The current through the 2Ω resistor is,

$$I_3 = \frac{V_{2\Omega}}{2}$$

$$I_3 = \frac{4.25\angle 60.66^\circ}{2}$$

$$I_3 = 2.125\angle 60.66^\circ \text{A}$$

Writing KCL at node '2'

$$I_2 = I_3 + I_Z$$

$$I_Z = I_2 - I_3$$

$$I_Z = \left(3.01\angle 56.26^\circ\right) - \left(2.125\angle 60.66^\circ\right)$$

$$I_Z = 1.672 + j2.5 - 1.041 - j1.852$$

$$I_Z = 0.631 + j0.648$$

$$I_Z = 0.904\angle 45.76^\circ \text{A}$$

Step 6 of 7

Writing KCL at node '3'

$$I_3 = I_1 + I_4$$

$$I_4 = I_3 - I_1$$

$$I_4 = \left(2.125\angle 60.66^\circ\right) - \left(5\angle -210^\circ\right)$$

$$I_4 = 1.041 + j1.852 + 4.33 - j2.5$$

$$I_4 = 5.371 - j0.648$$

$$I_4 = 5.41\angle -6.88^\circ \text{A}$$

Therefore the voltage across the Z is,

$$V_Z = V_{2\Omega} + \left(-j0.25\right) I_4$$

$$V_Z = 4.25\angle 60.66^\circ + \left(-j0.25\right)\left(5.41\angle -6.88^\circ\right)$$

$$V_Z = 4.25\angle 60.66^\circ + \left(0.25\angle -90^\circ\right)\left(5.41\angle -6.88^\circ\right)$$

$$V_Z = 4.25\angle 60.66^\circ + 1.3525\angle -96.88^\circ$$

$$V_Z = 2.082 + j3.705 - 0.162 - j1.343$$

$$V_Z = 1.92 + j2.362$$

$$V_Z = 3.04\angle 50.89^\circ \text{V}$$

Step 7 of 7

Therefore the impedance Z is obtained by,

$$Z = \frac{V_Z}{I_Z}$$

$$Z = \frac{3.04\angle 50.89^\circ}{0.904\angle 45.76^\circ}$$

$$Z = 3.363\angle 5.13^\circ \Omega$$

$$\boxed{Z = \left(3.35 + j0.3\right)\Omega}$$

Step 1 of 4

The given circuit is,

Step 2 of 4

From the above circuit,

$I_2 - I_1 = 2\angle 90^\circ$

$I_2 - I_1 = j2$ .....(1)

Writing KVL equation across the outer loop,

$-24\angle 0^\circ + 2I_1 - j2I_2 + 2I_2 = 0$

$2I_1 + (2 - j2)I_2 = 24$ .....(2)

Step 3 of 4

From (1) we have

$I_1 = I_2 - j2$

Substituting I_1 in (2) we get,

$2(I_2 - j2) + (2 - j2)I_2 = 24$

$I_2(4 - j2) = 24 + j4$

$$I_2 = \frac{24 + j4}{4 - j2}$$

$$I_2 = \frac{24.33\angle 9.46^\circ}{4.472\angle -26.565^\circ}$$

$I_2 = 5.44\angle 36.025^\circ \text{A}$

Step 4 of 4

Therefore the output voltage is given by,

$V_0 = 2I_2$

$V_0 = 2(5.44\angle 36.025^\circ)$

$\boxed{V_0 = 10.88\angle 36.025^\circ \text{V}}$

Step 1 of 1

Refer to Figure P8.61 in the textbook.

Apply nodal analysis at the node $\mathbf{V}_o$.

$$\frac{\mathbf{V}_o}{30}+\frac{\mathbf{V}_o}{j10}+\frac{\mathbf{V}_o-10\angle 30^\circ}{10}=2\angle 60^\circ$$

$$\mathbf{V}_o\left(\frac{1}{30}+\frac{1}{j10}+\frac{1}{10}\right)=2\angle 60^\circ+1\angle 30^\circ$$

$$\mathbf{V}_o(0.1333-j0.1)=1.866+j2.23$$

$$\begin{aligned}\mathbf{V}_o&=\frac{2\angle 60^\circ+1\angle 30^\circ}{0.1333-j0.1}\\&=0.92+j17.3\\&=17.456\angle 86.97^\circ\ \text{V}\end{aligned}$$

Thus, the output voltage, $\mathbf{V}_o$ is $\boxed{17.456\angle 86.97^\circ\ \text{V}}$.

Step 1 of 4

Refer to the circuit in Figure P8.51 in the textbook.

The circuit with current directions and node notations is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node-1.

$$I_1 = I_0 + I_2 + 2\angle 0^\circ$$

$$\frac{12\angle 0^\circ - V_1}{1} = \frac{V_1}{1} + \frac{V_1 - V_2}{1} + 2\angle 0^\circ$$

$$12\angle 0^\circ - V_1 - 2\angle 0^\circ = V_1 + V_1 - V_2$$

$$3V_1 - V_2 = 10\angle 0^\circ$$

$$V_2 = 3V_1 - 10 \text{ ..... (1)}$$

Step 3 of 4

Apply Kirchhoff's current law at node-2.

$$I_2 + 4\angle 0^\circ = I_3$$

$$\frac{V_1 - V_2}{1} + 4\angle 0^\circ = \frac{V_2}{-j1}$$

$$(-j1)(V_1 - V_2 + 4\angle 0^\circ) = V_2$$

$$-j1V_1 + j1V_2 - j1(4\angle 0^\circ) = V_2$$

$$(-j1)V_1 + (-1 + j1)V_2 = 4\angle 90^\circ \text{ ..... (2)}$$

Step 4 of 4

Substitute $3V_1 - 10$ for V_2 in the equation.

$$(-j1)V_1 + (-1 + j1)(3V_1 - 10) = 4\angle 90^\circ$$

$$(-3 + j2)V_1 = -10 + j14$$

$$V_1 = \frac{-10 + j14}{-3 + j2}$$

$$= 4.46 - j1.69$$

$$= 4.77\angle -20.77^\circ \text{ V}$$

Determine the value of I_0.

$$I_0 = \frac{V_1}{1\Omega}$$

Substitute $4.77\angle -20.77^\circ$ V for V_1 in the equation.

$$I_0 = \frac{4.77\angle -20.77^\circ \text{ V}}{1\ \Omega}$$

$$= 4.77\angle -20.77^\circ \text{ A}$$

Therefore, the value of I_0 is $\boxed{3.23\angle -177.34^\circ \text{ A}}$.

Step 1 of 4

Refer the circuit in Figure P8.52 in the textbook.

The circuit with current directions and node notations is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node-2 (reference node).

$$I_2 + 4\angle 0^\circ + I_3 + I_1 + I_0 = 0$$

$$\frac{V_2 - V_1}{2} + 4\angle 0^\circ + \frac{V_2 - V_3}{-j1} + \frac{V_2}{j2} + \frac{V_2}{2} = 0$$

$$(j1)(V_2) - (j1)(V_1) + (j2)(4\angle 0^\circ) - 2V_2 + 2V_3 + V_2 + (j1)V_2 = 0$$

$$(-j1)(V_1) + (-1 + j2)(V_2) + 2V_3 = (-j2)(4\angle 0^\circ)$$

$$(-j1)(V_1) + (-1 + j2)(V_2) + 2V_3 = 8\angle -90^\circ \quad \text{..... (1)}$$

Step 3 of 4

From the circuit,

$$V_1 = 12\angle 0^\circ \text{ V}$$

$$V_3 = 6\angle 0^\circ \text{ V}$$

Determine the value of V_2.

Substitute $12\angle 0^\circ$ V for V_1, and $6\angle 0^\circ$ V for V_3 in equation (1).

$$(-j1)(12\angle 0^\circ) + (-1 + j2)(V_2) + 2(6\angle 0^\circ) = 8\angle -90^\circ$$

$$\begin{aligned}(-1 + j2)V_2 &= 8\angle -90^\circ - 12\angle 0^\circ + j1(12\angle 0^\circ) \\ &= -12 + j4\end{aligned}$$

$$\begin{aligned}V_2 &= \frac{(-12 + j4)}{(-1 + j2)} \\ &= -4 - j4 \\ &= 5.65\angle -135^\circ \text{ V} \\ &= 5.65\angle 45^\circ \text{ V}\end{aligned}$$

Step 4 of 4

Determine the value of V_0.

$$\begin{aligned}V_0 &= V_2 \\ &= 5.65\angle 45^\circ \text{ V}\end{aligned}$$

Determine the value of I_0.

$$I_0 = \frac{V_0}{2}$$

Substitute $5.65\angle 45^\circ$ V for V_0 in the equation.

$$\begin{aligned}I_0 &= \frac{5.65\angle 45^\circ \text{ V}}{2} \\ &= 2.83\angle 45^\circ \text{ A}\end{aligned}$$

Therefore, the value of I_0 is $\boxed{2.83\angle 45^\circ \text{ A}}$.

Step 1 of 4

Refer the circuit in Figure P8.53 in the textbook.

The circuit with current directions and node notations is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node A.

$$I_1 + I_3 = I_2 + 2\angle 0^\circ$$

$$\frac{12\angle 0^\circ - V_1}{(2-j1)\Omega} + \frac{4\angle 0^\circ - V_1}{1\Omega} = \frac{V_1}{(2+j2)\Omega} + 2\angle 0^\circ$$

$$\frac{12\angle 0^\circ}{(2-j1)\Omega} + \frac{4\angle 0^\circ}{1\Omega} - 2\angle 0^\circ = \frac{V_1}{(2+j2)\Omega} + \frac{V_1}{(2-j1)\Omega} + \frac{V_1}{1\Omega}$$

$$V_1\left[\frac{1}{2+j2} + \frac{1}{2-j1} + 1\right] = \frac{12\angle 0^\circ + 4\angle 0^\circ(2-j1) - 2\angle 0^\circ(2-j1)}{(2-j1)}$$

$$V_1\left[\frac{2-j1+2+j2+(2+j2)(2-j1)}{(2+j2)(2-j1)}\right] = \frac{12\angle 0^\circ + 4\angle 0^\circ(2-j1) - 2\angle 0^\circ(2-j1)}{(2-j1)}$$

$$\begin{aligned} V_1 &= \frac{(2+j2)(12+4(2-j1)-2(2-j1))}{4+j1+4-j2+j4+2} \\ &= \frac{(2+j2)(12+8-j4-4+j2)}{10+j3} \\ &= \frac{(2+j2)(16-j2)}{10+j3} \\ &= \frac{36+j28}{10+j3} \\ &= 4.07 + j1.57 \\ &= 4.36\angle 21.09^\circ \text{ V} \end{aligned}$$

Step 3 of 4

Determine the value of I_2.

$$I_2 = \frac{V_1}{(2+j2)\Omega}$$

Substitute $4.36\angle 21.09^\circ$ V for V_1 in the equation.

$$\begin{aligned} I_2 &= \frac{4.36\angle 21.09^\circ \text{ V}}{(2+j2)\Omega} \\ &= \frac{4.06+j1.57}{2+j2} \\ &= 1.41 - j0.625 \\ &= 1.54\angle -23.9^\circ \text{ A} \end{aligned}$$

Step 4 of 4

Determine the value of V_0.

$$V_0 = 2I_2$$

Substitute $1.54\angle -23.9^\circ$ A for I_2.

$$\begin{aligned} V_0 &= 2(1.54\angle -23.9^\circ \text{ A}) \\ &= 3.1\angle -23.9^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{3.1\angle -23.9^\circ \text{ V}}$.

Step 1 of 4

The given circuit is,

Step 2 of 4

Since the voltage source $12\angle 45^\circ$ is in parallel with the inductor $j4\Omega$, the voltage across the inductor is $12\angle 45^\circ$V, therefore the current through the inductor is,

$$I_1 = \frac{12\angle 45^\circ}{j4}$$

$$I_1 = \frac{12\angle 45^\circ}{4\angle 90^\circ}$$

$$\boxed{I_1 = 3\angle -45^\circ \text{A}}$$

Step 3 of 4

Since on the left side of the circuit the voltage source is in parallel with all the elements, the circuit can be represented as,

Step 4 of 4

By KVL across the loop,

$$-12\angle 45^\circ + 6\angle 0^\circ + V_0 = 0$$

$$V_0 = 12\angle 45^\circ - 6\angle 0^\circ$$

$$V_0 = 8.485 + j8.485 - 6$$

$$V_0 = 2.485 + j8.485$$

$$\boxed{V_0 = 8.842\angle 73.68^\circ \text{V}}$$

Refer to Figure P8.67 in the textbook.

Draw the following circuit diagram.

Apply nodal analysis at the supernode.

$$\frac{\mathbf{V}_o}{2}+\frac{\mathbf{V}_1}{-j2+j4}=2\angle 0^\circ$$

$$0.5\mathbf{V}_o-j0.5\mathbf{V}_1=2$$

Substitute $\mathbf{V}_o-12$ for $\mathbf{V}_1$.

$$0.5\mathbf{V}_o-j0.5\left[\mathbf{V}_o-12\right]=2$$

$$(0.5-j0.5)\mathbf{V}_o=2-j6$$

$$\begin{aligned}\mathbf{V}_o&=\frac{2-j6}{0.5-j0.5}\\&=8-j4\\&=8.944\angle-26.565^\circ\text{ V}\end{aligned}$$

Thus, the output voltage, $\mathbf{V}_o$ is $\boxed{8.944\angle-26.565^\circ\text{ V}}$.

Step 1 of 3

Refer to Figure P8.678 in the textbook.

Draw the circuit diagram with notations.

Figure 1

Step 2 of 3

Apply nodal analysis at the node, $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_1-\mathbf{V}_2}{-j1}=2\angle 0°$$
$$\mathbf{V}_1(1+j)-j\mathbf{V}_2=2$$
$$j\mathbf{V}_2=(1+j)\mathbf{V}_1-2$$
$$\mathbf{V}_2=\left(\frac{1+j}{j}\right)\mathbf{V}_1-\frac{2}{j}$$
$$\mathbf{V}_2=(1-j)\mathbf{V}_1+j2$$

Apply nodal analysis at the node, $\mathbf{V}_2$.

$$\frac{\mathbf{V}_2-12\angle 0°}{1}+\frac{\mathbf{V}_2-\mathbf{V}_1}{-j1}+\frac{\mathbf{V}_2}{j1}=0$$
$$-j\mathbf{V}_1+\mathbf{V}_2(1+j-j)=12$$
$$-j\mathbf{V}_1+\mathbf{V}_2=12$$

Step 3 of 3

Substitute $(1-j)\mathbf{V}_1+j2$ for $\mathbf{V}_2$.

$$-j\mathbf{V}_1+(1-j)\mathbf{V}_1+j2=12$$
$$(1-j-j)\mathbf{V}_1=12-j2$$
$$\mathbf{V}_1=\frac{12-j2}{1-2j}$$
$$=3.2+j4.4$$
$$=5.44\angle 53.97°\ \text{V}$$

Calculate the value of the output current, $\mathbf{I}_o$.

$$\mathbf{I}_o=\frac{\mathbf{V}_1}{1}$$
$$=5.44\angle 53.97°\ \text{A}$$

Thus, the output current, $\mathbf{I}_o$ is $\boxed{5.44\angle 53.97°\ \text{A}}$.

Step 1 of 3

8.069P

Refer to Figure P8.69 in the textbook.

Draw the circuit diagram with notations.

Figure 1

Step 2 of 3

Apply nodal analysis at the node, $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1 - 6\angle 0°}{1} + \frac{\mathbf{V}_1 - \mathbf{V}_o}{j1} = 2\angle 0°$$

$$\mathbf{V}_1(1-j) + j\mathbf{V}_o = 2+6$$

$$\mathbf{V}_1(1-j) = 8 - j\mathbf{V}_o$$

$$\mathbf{V}_1 = \frac{8}{1-j} - \left(\frac{j}{1-j}\right)\mathbf{V}_o$$

$$\mathbf{V}_1 = (4+j4) + (0.5-j0.5)\mathbf{V}_o$$

Apply nodal analysis at the node, $\mathbf{V}_2$.

$$\frac{\mathbf{V}_o - 6\angle 0°}{-j1} + \frac{\mathbf{V}_o - \mathbf{V}_1}{j1} + \frac{\mathbf{V}_o}{1} = 0$$

$$j\mathbf{V}_1 + \mathbf{V}_o(1+j-j) = j6$$

$$j\mathbf{V}_1 + \mathbf{V}_o = j6$$

Step 3 of 3

Substitute $(4+j4)+(0.5-j0.5)\mathbf{V}_o$ for $\mathbf{V}_1$.

$$j\left[(4+j4)+(0.5-j0.5)\mathbf{V}_o\right] + \mathbf{V}_o = j6$$

$$(1+j0.5+0.5)\mathbf{V}_o = j6+4-j4$$

$$(1.5+j0.5)\mathbf{V}_o = 4+j2$$

$$\begin{aligned}\mathbf{V}_o &= \frac{4+j2}{1.5+j0.5} \\ &= 2.8+j0.4 \\ &= 2.828\angle 8.13°\text{ V}\end{aligned}$$

Thus, the output voltage, $\mathbf{V}_o$ is $\boxed{2.828\angle 8.13°\text{ V}}$.

Step 1 of 3

Refer to Figure P8.70 in the textbook.

Draw the circuit diagram with notations.

Figure 1

Step 2 of 3

From the supernode,

$$\mathbf{V}_o - \mathbf{V}_1 = 12\angle 0^\circ$$
$$\mathbf{V}_1 = \mathbf{V}_o - 12$$

Apply nodal analysis at the supernode.

$$\frac{\mathbf{V}_o - \mathbf{V}_2}{1} + \frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{1} = 2\angle 0^\circ$$
$$\mathbf{V}_1 + 2\mathbf{V}_o - 2\mathbf{V}_2 = 2$$

Substitute $\mathbf{V}_o - 12$ for $\mathbf{V}_1$.

$$\mathbf{V}_o - 12 + 2\mathbf{V}_o - 2\mathbf{V}_2 = 2$$
$$3\mathbf{V}_o - 2\mathbf{V}_2 = 14$$
$$\mathbf{V}_2 = 1.5\mathbf{V}_o - 7$$

Step 3 of 3

Apply nodal analysis at the node, $\mathbf{V}_2$.

$$\frac{\mathbf{V}_2 - \mathbf{V}_o}{1} + \frac{\mathbf{V}_2 - \mathbf{V}_1}{1} + \frac{\mathbf{V}_2}{-j1} = 0$$
$$\mathbf{V}_2(2 + j) - \mathbf{V}_1 - \mathbf{V}_o = 0$$

Substitute $\mathbf{V}_o - 12$ for $\mathbf{V}_1$ and $1.5\mathbf{V}_o - 7$ for $\mathbf{V}_2$.

$$(1.5\mathbf{V}_o - 7)(2 + j) - \mathbf{V}_o + 12 - \mathbf{V}_o = 0$$
$$(3 + j1.5 - 2)\mathbf{V}_o = 14 + j7 - 12$$

$$\begin{aligned}\mathbf{V}_o &= \frac{2 + j7}{1 + j1.5} \\ &= 3.846 + j1.23 \\ &= 4.04\angle 17.75^\circ \text{ V}\end{aligned}$$

Thus, the output voltage, $\mathbf{V}_o$ is $\boxed{4.04\angle 17.75^\circ \text{ V}}$.

Step 1 of 2

Refer to circuit diagram in Figure P8.71 in the textbook.

Redraw the circuit with node notation.

Figure 1

Step 2 of 2

Apply Kirchhoff's current law at node v_1 .

$$\frac{v_1 - 4\angle 0^\circ}{1\ \Omega} + \frac{v_1 - 6\angle 0^\circ}{1\ \Omega} + \frac{v_1 - 12\angle 0^\circ}{-j1\ \Omega} = 0$$

$$(2 + j)v_1 = 4 + 6 + j12$$

$$v_1 = \frac{10 + j12}{2 + j}$$

$$= 6.4 + j2.8 \text{ V}$$

Calculate the output voltage.

$$\begin{aligned} \mathbf{V}_o &= v_1 - 6 \text{ V} \\ &= 6.4 + j2.8 - 6 \text{ V} \\ &= 0.4 + 2.8 \text{ V} \\ &= 2.828\angle 81.87^\circ \text{ V} \end{aligned}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{2.828\angle 81.87^\circ \text{ V}}$.

Step 1 of 4

Refer to circuit diagram in Figure P8.72 in the textbook.

Redraw the circuit with node notations.

Figure 1

Step 2 of 4

From the circuit shown in Figure 1, $12\ \text{V}$ source is between nodes 1 and 2, and it forms supernode. Write the voltage expression.

$$V_2 - V_1 = 12\ \text{V}$$

$$V_2 = V_1 + 12\ \text{V} \quad \text{.....} \ (1)$$

Apply Kirchhoff's current law at supernode.

$$\frac{V_1}{1\ \Omega} + \frac{V_1 - V_3}{1\ \Omega} + \frac{V_2}{-j1\ \Omega} = -2\ \text{A}$$

$$V_1 + V_1 - V_3 + jV_2 = -2\ \text{V}$$

Substitute $V_1 + 12\ \text{V}$ for V_2 in the equation.

$$V_1 + V_1 - V_3 + j(V_1 + 12\ \text{V}) = -2\ \text{V}$$

$$(2+j)V_1 - V_3 + j12\ \text{V} = -2\ \text{V}$$

$$(2+j)V_1 = V_3 - j12 - 2\ \text{V}$$

$$V_1 = \frac{V_3 - j12 - 2\ \text{V}}{2+j}$$

$$V_1 = (0.4 - j0.2)V_3 - 3.2 - j4.4\ \text{V} \quad \text{.....} \ (2)$$

Step 3 of 4

Apply Kirchhoff's current law at node 3.

$$\frac{V_3 - V_1}{1\ \Omega} + \frac{V_3}{1\ \Omega} = 2\ \text{A}$$

$$2V_3 - V_1 = 2\ \text{V}$$

Substitute $(0.4 - j0.2)V_3 - 3.2 - j4.4\ \text{V}$ for V_1 in the equation.

$$\frac{V_3 - V_1}{1\ \Omega} + \frac{V_3}{1\ \Omega} = 2\ \text{A}$$

$$2V_3 - (0.4 - j0.2)V_3 + 3.2 + j4.4\ \text{V} = 2\ \text{V}$$

$$(1.6 + j0.2)V_3 = -1.2 - j4.4\ \text{V}$$

$$V_3 = \frac{-1.2 - j4.4}{1.6 + j0.2}\ \text{V}$$

$$= -1.077 - j2.615\ \text{V}$$

Step 4 of 4

Calculate the output current.

$$\mathbf{I}_o = \frac{V_3}{1\ \Omega}$$

Substitute $-1.077 - j2.615\ \text{V}$ for V_3 in the equation.

$$\mathbf{I}_o = \frac{-1.077 - j2.615\ \text{V}}{1\ \Omega}$$

$$= \frac{2.818\angle -112.46°\ \text{V}}{1\ \Omega}$$

$$= 2.818\angle -112.46°\ \text{A}$$

Therefore, the current, $\mathbf{I}_o$ in the network is $\boxed{2.818\angle -112.46°\ \text{A}}$.

Step 1 of 5

Refer the circuit in Figure P8.55 in the textbook.

The circuit with current directions and node notations is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law at node-2 (reference node).

$$I_1 + I_2 + I_3 + I_0 = 2\angle 0^\circ$$

$$\frac{V_1}{1\Omega} + \frac{V_2}{(-j1\Omega)} + \frac{V_3}{(j2\Omega)} + \frac{V_3}{(1\Omega + 1\Omega)} = 2\angle 0^\circ$$

$$(j2)V_1 - 2V_2 + V_3 + (j1)V_3 = 2\angle 0^\circ (j2)$$

$$(j2)V_1 - 2V_2 + (1 + j1)V_3 = 4\angle 90^\circ \text{ ..... (1)}$$

From the Figure 1,

$$V_1 - V_2 = 6\angle 0^\circ$$

$$V_1 = 6\angle 0^\circ + V_2 \text{ ..... (2)}$$

And,

$$-V_2 + V_3 = 12\angle 0^\circ$$

$$V_3 = 12\angle 0^\circ + V_2 \text{ ..... (3)}$$

Step 3 of 5

Substitute $6\angle 0^\circ + V_2$ for V_1 and $12\angle 0^\circ + V_2$ for V_3 in equation (1).

$$(j2)(6\angle 0^\circ + V_2) - 2V_2 + (1 + j1)(12\angle 0^\circ + V_2) = 4\angle 90^\circ$$

$$j12 + (j2)V_2 - 2V_2 + 12 + V_2 + j12 + (j1)V_2 = 4\angle 90^\circ$$

$$(-1 + j3)V_2 = 4\angle 90^\circ - j24 - 12$$

$$= j4 - j24 - 12$$

$$V_2 = \frac{-12 - j20}{-1 + j3}$$

$$= -4.8 + j5.6$$

$$= 7.37\angle 130.6^\circ \text{ V}$$

Step 4 of 5

Determine the value of V_3.

Substitute $7.37\angle 130.6^\circ$ V for V_2 in equation (3).

$$V_3 = 12\angle 0^\circ + 7.37\angle 130.6^\circ$$

$$= 7.2 + j5.6$$

$$= 9.12\angle 37.87^\circ \text{ V}$$

Determine the value of I_0.

$$I_0 = \frac{V_3}{2\Omega}$$

Substitute $9.12\angle 37.87^\circ$ V for V_3 in the equation.

$$I_0 = \frac{9.12\angle 37.87^\circ \text{ V}}{2\Omega}$$

$$= 4.56\angle 37.87^\circ \text{ A}$$

Step 5 of 5

Determine the value of V_0.

$$V_0 = I_0(1\Omega)$$

Substitute $4.56\angle 37.87^\circ$ A for I_0 in the equation.

$$V_0 = (4.56\angle 37.87^\circ \text{ A})(1\ \Omega)$$

$$= 4.56\angle 37.87^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{4.56\angle 37.87^\circ \text{ V}}$.

Step 1 of 6

Refer the circuit in Figure P8.56 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law at node-3.

$$I_2 + I_0 = I_3 + 2\angle 0°$$

$$\frac{V_2 - V_3}{(-j2\Omega)} + \frac{V_1 - V_3}{2\Omega} = \frac{V_3}{(j1\Omega)} + 2\angle 0° \text{ ..... (1)}$$

From figure,

$$V_2 = 12\angle 0° \text{ V}$$
$$V_4 = 6\angle 0° \text{ V}$$

Substitute $12\angle 0°$ V for V_2 in equation (1).

$$\frac{12\angle 0° \text{ V} - V_3}{(-j2\Omega)} + \frac{V_1 - V_3}{2\Omega} = \frac{V_3}{(j1\Omega)} + 2\angle 0°$$
$$\frac{12\angle 0°}{-j2} - \frac{V_3}{j2} + \frac{V_1}{2} - \frac{V_3}{2} = \frac{V_3}{j1} + 2\angle 0°$$
$$-12\angle 0° + V_3 - (j1)V_3 = 2V_3 + (j1)4\angle 0°$$
$$(j1)V_1 - (1 + j1)V_3 = (j1)4\angle 0° + 12\angle 0°$$
$$(j1)V_1 - (1 + j1)V_3 = 12 + j4 \text{ ..... (2)}$$

Step 3 of 6

Apply Kirchhoff's current law at node-1.

$$I_1 + I_4 = I_0$$
$$\frac{V_2 - V_1}{2} + \frac{V_4 - V_1}{1} = \frac{V_1 - V_3}{2}$$
$$V_2 - V_1 + 2V_4 - 2V_1 = V_1 - V_3$$
$$-4V_1 + V_2 + V_3 + 2V_4 = 0$$
$$4V_1 - V_3 = V_2 + 2V_4$$

Substitute $12\angle 0°$ V for V_2, $6\angle 0°$ V for V_4.

$$\begin{aligned} 4V_1 - V_3 &= 12\angle 0° + 2(6\angle 0°) \\ &= 12\angle 0° + 12\angle 0° \\ &= 24\angle 0° \end{aligned}$$

$$V_1 = \frac{V_3 + 24\angle 0°}{4} \text{ ..... (3)}$$

Step 4 of 6

Determine the value of V_3.

Substitute equation (3) in equation (2).

$$(j1)\left(\frac{V_3 + 24\angle 0°}{4}\right) - (1 + j1)V_3 = 12 + j4$$
$$(j1)V_3 + (j1)(24\angle 0°) - 4V_3 - (j4)V_3 = 48 + j16$$

$$\begin{aligned} (-4 - j3)V_3 &= (48 + j16) - (j1)(24\angle 0°) \\ &= 48 + j16 - j24 \\ &= 48 - j8 \end{aligned}$$

$$\begin{aligned} V_3 &= \frac{48 - j8}{-4 - j3} \\ &= -6.72 + j7.04 \\ &= 9.73\angle 133.66° \text{ V} \end{aligned}$$

Step 5 of 6

Determine the value of V_1.

Substitute $9.73\angle 133.66°$ V for V_1 in equation (3).

$$\begin{aligned} V_1 &= \frac{9.73\angle 133.66° + 24\angle 0°}{4} \\ &= \frac{17.28 + j7.04}{4} \\ &= 4.32 + j1.76 \\ &= 4.66\angle 22.16° \text{ V} \end{aligned}$$

Step 6 of 6

Determine the value of I_0.

From figure-1,

$$I_0 = \frac{V_1 - V_3}{2}$$

Substitute $4.32 + j1.76$ V for V_1, $-6.72 + j7.04$ V for V_3.

$$\begin{aligned} I_0 &= \frac{4.32 + j1.76 + 6.72 - j7.04}{2} \\ &= \frac{11.04 - j5.28}{2} \\ &= 5.52 - j2.64 \\ &= 6.12\angle -25.56° \text{ A} \end{aligned}$$

Therefore, the value of I_0 is $\boxed{6.12\angle -25.56° \text{ A}}$.

Step 1 of 7

Refer to Figure P8.57 in the textbook.

Re-draw the circuit diagram by assigning with node voltages V_1, V_2, V_3, V_4 and V_5 :

Step 2 of 7

From the Figure, it is clear that, between the nodes 1 and 3, there is voltage source, hence it forms a super node, and similar case exists with the nodes 4 and 5.

Write the super node equation for nodes 1 and 3.

$\mathbf{V_1 - V_3 = 6\angle 0° V}$ ..... (1)

Apply Kirchhoff's current law at the nodes 1 and 3 which forms super node.

$$\frac{\mathbf{V_1 - V_2}}{\mathbf{1}} + \frac{\mathbf{V_1 - V_4}}{j\mathbf{1}} - 4 + \frac{\mathbf{V_3}}{\mathbf{1}} + 2 = 0$$

$$\mathbf{V_1 - V_2 - j1(V_1 - V_4) + V_3 - 2 = 0}$$

$$\mathbf{V_1(1 - j1) - V_2 + V_3 + (j1)V_4 = 2} \text{ ..... (2)}$$

Step 3 of 7

Write the super node equation for nodes 4 and 5.

$\mathbf{V_4 - V_5 = 12\angle 0°}$ ..... (3)

Apply Kirchhoff's current law at the nodes 4 and 5 which forms super node.

$$\frac{\mathbf{V_4}}{\mathbf{1}} + \frac{\mathbf{V_4 - V_1}}{j\mathbf{1}} + 4 + \frac{\mathbf{V_5}}{\mathbf{1}} = 0$$

$$\mathbf{V_4 - j1(V_4 - V_1) + 4 + V_5 = 0}$$

$$\mathbf{(j1)V_1 + V_4(1 - j1) + V_5 = -4} \text{ ..... (4)}$$

Step 4 of 7

Apply Kirchhoff's current law at the node 2.

$$\frac{\mathbf{V_2}}{-j\mathbf{1}} + \frac{\mathbf{V_2 - V_1}}{\mathbf{1}} - 2 = 0$$

$$\mathbf{-V_1 + V_2(1 + j1) = 2} \text{ ..... (5)}$$

From the equation (1), $\mathbf{V_3 = V_1 - 6}$

From the equation (5),

$$\mathbf{V_2 = \frac{2 + V_1}{(1 + j1)}}$$

Step 5 of 7

Substitute $\mathbf{V_1 - 6}$ for $\mathbf{V_3}$ and $\frac{\mathbf{2 + V_1}}{\mathbf{1 + j1}}$ for $\mathbf{V_2}$ in equation (2).

$$\mathbf{V_1(1 - j1) - \frac{(2 + V_1)}{1 + j1} + (V_1 - 6) + (j1)V_4 = 2}$$

$$\mathbf{V_1(1 - j1)(1 + j1) - (2 + V_1) + (V_1 - 6)(1 + j1) + (1 + j1)(j1)V_4 = 2(1 + j1)}$$

$$\mathbf{V_1(1 + 1) - 2 - V_1 + V_1(1 + j1) - 6(1 + j1) + (-1 + j1)V_4 = 2 + j2}$$

$$\mathbf{V_1(2 - 1 + 1 + j1) + (-1 + j1)V_4 = 2 + j2 + 2 + 6 + j6}$$

$$\mathbf{V_1(2 + j1) + (-1 + j1)V_4 = 10 + j8} \text{ ..... (6)}$$

Re-write the equation (3) as follows:

$$\mathbf{V_5 = V_4 - 12}$$

Step 6 of 7

Substitute $\mathbf{V_4 - 12}$ for $\mathbf{V_5}$ in equation (4).

$$\mathbf{(j1)V_1 + V_4(1 - j1) + (V_4 - 12) = -4}$$

$$\mathbf{(j1)V_1 + V_4(2 - j1) = 8}$$

$$\begin{aligned}\mathbf{V_1} &= \mathbf{\frac{8 - V_4(2 - j1)}{j1}} \\ &= \mathbf{-j[8 - V_4(2 - j1)]} \\ &= \mathbf{-j8 + V_4(2j + 1)} \\ &= \mathbf{V_4(2j + 1) - j8}\end{aligned}$$

Substitute $\mathbf{V_4(2j + 1) - j8}$ for V_1 in equation (6).

$$\mathbf{[V_4(1 + j2) - j8](2 + j1) + (-1 + j1)V_4 = 10 + j8}$$

$$\mathbf{V_4(1 + j2)(2 + j1) - (j8)(2 + j1) + (-1 + j1)V_4 = 10 + j8}$$

$$\mathbf{V_4(2 + j1 + j4 - 2) - (j16 - 8) + (-1 + j1)V_4 = 10 + j8}$$

$$\mathbf{V_4(j5) + V_4(-1 + j1) = 10 + j8 + j16 - 8}$$

Step 7 of 7

Further simplification yields,

$$\mathbf{V_4(-1 + j6) = 2 + j24}$$

$$\begin{aligned}\mathbf{V_4} &= \mathbf{\frac{2 + j24}{-1 + j6}} \\ &= \mathbf{\frac{24.08\angle 85.236°}{6.08\angle 99.46°}} \\ &= \mathbf{3.96\angle -14.224° \ V}\end{aligned}$$

Determine the current, $\mathbf{I_o}$:

$$\begin{aligned}\mathbf{I_o} &= \mathbf{\frac{V_4}{1}} \\ &= \mathbf{\frac{3.96\angle -14.224°}{1}} \\ &= \mathbf{3.96\angle -14.224° \ A}\end{aligned}$$

Therefore, the value of current $\mathbf{I_o}$ is $\boxed{\mathbf{3.96\angle -14.224° \ A}}$.

Step 1 of 3

Refer to circuit diagram in Figure P8.76 in the textbook.

Redraw the circuit with node notations.

ıit, write the expression for $\mathbf{V}_x$.

..... (1)

n the textbook.

ıit shown in Figure 1, dependent voltage source is between nodes $\mathbf{V}_1$ and $\mathbf{V}_o$, and it forms
Vrite the voltage expression.

$-\mathbf{V}_1$ for $\mathbf{V}_x$ in the equation.

$12-\mathbf{V}_1)$

$-2\mathbf{V}_1$

$$\mathbf{V}_1 = \frac{24+\mathbf{V}_o}{3} \quad \text{..... (2)}$$

Step 3 of 3

Apply Kirchhoff's current law at super node.

$$\frac{\mathbf{V}_1 - 12\text{ V}}{1\ \Omega} + \frac{\mathbf{V}_1}{-j1\ \Omega} + \frac{\mathbf{V}_o}{1\ \Omega} = 0$$

$$\mathbf{V}_1 + j\mathbf{V}_1 + \mathbf{V}_o = 12\text{ V}$$

$$(1+j)\mathbf{V}_1 + \mathbf{V}_o = 12\text{ V}$$

Substitute $\frac{24+\mathbf{V}_o}{3}$ for $\mathbf{V}_1$ in the equation.

$$(1+j)\left(\frac{24+\mathbf{V}_o}{3}\right) + \mathbf{V}_o = 12\text{ V}$$

$$(0.33+j0.33+1)\mathbf{V}_o = 12-8-j8\text{ V}$$

$$(1.33+j0.33)\mathbf{V}_o = 4-j8\text{ V}$$

$$\begin{aligned}\mathbf{V}_o &= \frac{4-j8\text{ V}}{1.33+j0.33}\\ &= 1.4117-j6.353\text{ V}\\ &= 6.508\angle -77.47^\circ\text{ V}\end{aligned}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{6.508\angle -77.47^\circ\text{ V}}$.

Step 1 of 2

Refer to circuit diagram in Figure P8.77P in the textbook.

Redraw the circuit with node notations.

Figure 1

Step 2 of 2

From the circuit, the expression for voltage $\mathbf{V}_x$ is,

$$\mathbf{V}_x = 6\text{ V} - 2\mathbf{V}_x$$
$$3\mathbf{V}_x = 6\text{ V}$$
$$\mathbf{V}_x = 2\text{ V}$$

Apply Kirchhoff's current law at node $\mathbf{V}_o$.

$$\frac{\mathbf{V}_o - 2\mathbf{V}_x}{-j\,\Omega} + \frac{\mathbf{V}_o}{1\,\Omega} = 2\text{ A}$$
$$\frac{\mathbf{V}_o - 2(2\text{ V})}{-j\,\Omega} + \frac{\mathbf{V}_o}{1\,\Omega} = 2\text{ A}$$
$$j\mathbf{V}_o - j4\text{ V} + \mathbf{V}_o = 2\text{ V}$$
$$(1+j)\mathbf{V}_o = 2 + j4\text{ V}$$

$$\begin{aligned}\mathbf{V}_o &= \frac{2+j4\text{ V}}{1+j}\\ &= 3 + j\text{ V}\\ &= 3.162\angle 18.43^\circ\text{ V}\end{aligned}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{3.162\angle 18.43^\circ\text{ V}}$.

Step 1 of 3

8.078P

Refer to circuit diagram in Figure P8.78P in the textbook.

Redraw the circuit with node notations.

Figure 1

Step 2 of 3

From the circuit, the expression for voltage V_x is,

$$V_x = 12\ V - V_1$$

Apply Kirchhoff's current law at node V_1.

$$\frac{V_1 - 2V_x}{1\ \Omega} + \frac{V_1}{1\ \Omega} + \frac{V_1 - 12\ V}{1\ \Omega} = 0$$
$$3V_1 - 2V_x = 12\ V$$

Substitute $12\ V - V_1$ for V_x in the equation.

$$3V_1 - (2)(12\ V - V_1) = 12\ V$$
$$3V_1 - 24\ V + 2V_1 = 12\ V$$
$$5V_1 = 36\ V$$
$$V_1 = 7.2\angle 0°\ V$$

Step 3 of 3

Calculate the current I_o.

$$I_o = \frac{V_1}{1\ \Omega}$$
$$= \frac{7.2\angle 0°\ V}{1\ \Omega}$$
$$= 7.2\angle 0°\ A$$

Therefore, the current, I_o is $\boxed{7.2\angle 0°\ A}$.

Step 1 of 2

8.079P

Refer to Figure P8.79 in the text book for the circuit. Mark the nodes on the circuit as shown in Figure 1.

Figure 1

Step 2 of 2

Nodes V_1 and V_o form a super node.

So,

$$V_o - V_1 = 4\angle 0°$$
$$V_1 = V_o - 4$$

Apply Kirchhoff's current law to the top node, V_o .

$$\frac{V_o}{1} + \frac{V_o - 4V_o}{j1} + \frac{V_1}{1} + \frac{V_1 - 4V_o}{1} = 0$$
$$(1 + j3 - 4)V_o + 2V_1 = 0$$
$$(-3 + j3)V_o + 2V_1 = 0$$

Substitute $V_o - 4$ for V_1 .

$$(-3 + j3)V_o + 2(V_o - 4) = 0$$
$$(-1 + j3)V_o = 8$$
$$V_o = \frac{8}{-1 + j3}$$
$$= 2.53\angle -108°\ \text{V}$$

Thus, the output voltage V_o is $\boxed{2.53\angle -108°\ \text{V}}$.

Step 1 of 2

8.080P

Refer to Figure P8.80 in the text book for the circuit.

Mark the nodes as shown in Figure 1.

Figure 1

Step 2 of 2

Observe from Figure 1 that the voltage $\mathbf{V}_x$ is,

$$\mathbf{V}_x = \mathbf{V}_2 - 12$$

Apply Kirchhoff's current law to the node, $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1 + 2\mathbf{V}_x}{-j1} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{1} + \frac{\mathbf{V}_1}{1} = 0$$

$$(2 + j1)\mathbf{V}_1 - \mathbf{V}_2 + j2\mathbf{V}_x = 0$$

Substitute $\mathbf{V}_2 - 12$ for $\mathbf{V}_x$.

$$(2 + j1)\mathbf{V}_1 - \mathbf{V}_2 + j2(\mathbf{V}_2 - 12) = 0$$

$$(2 + j1)\mathbf{V}_1 + (-1 + j2)\mathbf{V}_2 = j24 \quad \text{..... (1)}$$

Apply Kirchhoff's current law to the node, $\mathbf{V}_2$. $\frac{\mathbf{V}_2 - \mathbf{V}_1}{1} + \frac{\mathbf{V}_2}{1} + \frac{\mathbf{V}_2 - 12}{1} = 0$

$$-\mathbf{V}_1 + 3\mathbf{V}_2 = 12 \quad \text{..... (2)}$$

Arrange equations (1) and (2) in matrix form.

$$\begin{bmatrix} 2 + j1 & -1 + j2 \\ -1 & 3 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} j24 \\ 12 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} 2 + j1 & -1 + j2 \\ -1 & 3 \end{bmatrix}^{-1} \begin{bmatrix} j24 \\ 12 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} 0.3 - j0.3 & -0.1 - j0.3 \\ 0.1 - j0.1 & 0.3 - j0.1 \end{bmatrix} \begin{bmatrix} j24 \\ 12 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} 6 + j3.6 \\ 6 + j1.2 \end{bmatrix}$$

The voltage $\mathbf{V}_2$ is,

$$\begin{aligned} \mathbf{V}_2 &= 6 + j1.2 \\ &= 6.12\angle 11.3^\circ \ \ \mathbf{V} \end{aligned}$$

The current $\mathbf{I}_o$ is,

$$\begin{aligned} \mathbf{I}_o &= \frac{\mathbf{V}_2}{1} \\ &= 6.12\angle 11.3^\circ \ \ \mathbf{A} \end{aligned}$$

Thus, the current $\mathbf{I}_o$ is $\boxed{6.12\angle 11.3^\circ \ \ \mathbf{A}}$.

Step 1 of 2

Refer to Figure P8.81 in the text book for the circuit.

Mark the nodes on the circuit as shown in Figure 1.

Figure 1

Step 2 of 2

Observe from Figure 1 that the node voltage,

$$\mathbf{V}_1 = 4\angle 0° - 2\mathbf{V}_o$$

Apply Kirchhoff's current law at the node $\mathbf{V}_o$.

$$\frac{\mathbf{V}_o}{-j1} + \frac{\mathbf{V}_o - \mathbf{V}_1}{1} + \frac{\mathbf{V}_o - 4}{1} = 0$$

$$(2 + j1)\mathbf{V}_o - \mathbf{V}_1 = 4$$

Substitute $4\angle 0° - 2\mathbf{V}_o$ for $\mathbf{V}_1$.

$$(2 + j1)\mathbf{V}_o - (4\angle 0° - 2\mathbf{V}_o) = 4$$

$$(4 + j1)\mathbf{V}_o = 8$$

$$\mathbf{V}_o = \frac{8}{4 + j1}$$

$$= 1.94\angle -14° \text{ V}$$

Thus, the voltage $\mathbf{V}_o$ is $\boxed{1.94\angle -14° \text{ V}}$.

Step 1 of 7

Refer the circuit in Figure P8.66 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 7

Apply Kirchhoff's current law at reference node.

$$2V_x + I_1 + I_x + I_0 = 0$$

$$2V_x + \frac{V_1}{1} + \frac{V_x}{-j1} + \frac{V_x}{1+j1} = 0$$

$$2V_x + V_1 + (j1)V_x + \frac{V_x}{1+j1} = 0$$

$$V_1 + \left(2 + j1 + \frac{1}{1+j1}\right)V_x = 0$$

$$V_1 + (2 + j1 + 0.5 - j0.5)V_x = 0$$

$$V_1 + (2.5 + j0.5)V_x = 0 \text{ ..... (1)}$$

Step 3 of 7

From the figure,

$$V_1 - V_x = 12\angle 0^\circ$$

$$V_1 = 12 + V_x \text{ ..... (2)}$$

Step 4 of 7

Determine the value of V_x.

Substitute equation (2) in equation (1).

$$12 + V_x + (2.5 + j0.5)V_x = 0$$

$$(3.5 + j0.5)V_x = -12$$

$$\begin{aligned} V_x &= \frac{-12}{(3.5 + j0.5)} \\ &= -3.36 + j0.48 \\ &= 3.39\angle 171.87^\circ \text{ V} \end{aligned}$$

Step 5 of 7

Determine the value of V_1.

Substitute $-3.36 + j0.48$ for V_x in equation (2).

$$\begin{aligned} V_1 &= 12 - 3.36 + j0.48 \\ &= 8.64 + j0.48 \\ &= 8.65\angle 3.18^\circ \text{ V} \end{aligned}$$

Step 6 of 7

Determine the value of I_0.

From the circuit,

$$I_0 = \frac{V_x}{1+j1}$$

Substitute $-3.36 + j0.48$ for V_x.

$$\begin{aligned} I_0 &= \frac{V_x}{1+j1} \\ &= \frac{-3.36 + j0.48}{1+j1} \\ &= -1.44 + j1.92 \\ &= 2.4\angle 126.87^\circ \text{ A} \end{aligned}$$

Step 7 of 7

Determine the value of V_0.

$$V_0 = I_0(1\Omega)$$

Substitute $2.4\angle 126.87^\circ$ A for I_0.

$$\begin{aligned} V_0 &= (2.4\angle 126.87^\circ \text{ A})(1\Omega) \\ &= 2.4\angle 126.87^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{2.4\angle 126.87^\circ \text{ V}}$.

Step 1 of 3

Refer the circuit in Figure P8.67 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 3

From the circuit,

$$I_x = \frac{10\angle 30^\circ \text{ V}}{4\Omega}$$
$$= 2.5\angle 30^\circ \text{ A}$$

Step 3 of 3

Apply Kirchhoff's current law at node-2.

$$I_1 = I_2 + 2I_x$$
$$\frac{10\angle 30^\circ - V_2}{-j2} = \frac{V_2}{j1} + 2\left(2.5\angle 30^\circ\right)$$
$$10\angle 30^\circ - V_2 = -2V_2 + 2(-j2)\left(2.5\angle 30^\circ\right)$$

$$V_2 = -j4\left(2.5\angle 30^\circ\right) - 10\angle 30^\circ$$
$$= -j4(2.16 + j1.25) - (8.66 + j5)$$
$$= -j8.64 + 5 - 8.66 - j5$$
$$= -3.66 - j13.64$$

$$= 14.12\angle -105.02^\circ \text{ V}$$

Therefore, the voltage across the inductor is $\boxed{14.12\angle -105.02^\circ \text{ V}}$.

Step 1 of 2

Refer to Figure P8.84 in the text book for the circuit.

Mark the nodes on the circuit as shown in Figure 1.

Figure 1

Step 2 of 2

Observe from Figure 1 that the node voltage $\mathbf{V}_x$ is,

$$\mathbf{V}_x = \mathbf{V}_o + 4$$

Nodes $\mathbf{V}_x$ and $\mathbf{V}_o$ form a super node.

Apply Kirchhoff's current law to the node $\mathbf{V}_o$.

$$\frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o - 4\mathbf{V}_x}{1} + \frac{\mathbf{V}_x}{1} + \frac{\mathbf{V}_x - 4\mathbf{V}_x}{-j1} = 0$$

$$2\mathbf{V}_o + (-3 - j3)\mathbf{V}_x = 0$$

Substitute $\mathbf{V}_o + 4$ for $\mathbf{V}_x$.

$$2\mathbf{V}_o + (-3 - j3)(\mathbf{V}_o + 4) = 0$$

$$(-1 - j3)\mathbf{V}_o = 4(3 + j3)$$

$$\mathbf{V}_o = \frac{4(3 + j3)}{-1 - j3}$$

$$= 5.37\angle 153^\circ \text{ V}$$

Thus, the voltage $\mathbf{V}_o$ is $\boxed{5.37\angle 153^\circ \text{ V}}$.

Step 1 of 2

Refer to circuit diagram in Figure P8.77P in the textbook.

Redraw the circuit with node notations.

Figure 1

Step 2 of 2

From the circuit, the expression for voltage $\mathbf{V}_x$ is,

$$\mathbf{V}_x = 6\text{ V} - 2\mathbf{V}_x$$
$$3\mathbf{V}_x = 6\text{ V}$$
$$\mathbf{V}_x = 2\text{ V}$$

Apply Kirchhoff's current law at node $\mathbf{V}_o$.

$$\frac{\mathbf{V}_o - 2\mathbf{V}_x}{-j\,\Omega} + \frac{\mathbf{V}_o}{1\,\Omega} = 2\text{ A}$$
$$\frac{\mathbf{V}_o - 2(2\text{ V})}{-j\,\Omega} + \frac{\mathbf{V}_o}{1\,\Omega} = 2\text{ A}$$
$$j\mathbf{V}_o - j4\text{ V} + \mathbf{V}_o = 2\text{ V}$$
$$(1+j)\mathbf{V}_o = 2 + j4\text{ V}$$

$$\begin{aligned}\mathbf{V}_o &= \frac{2+j4\text{ V}}{1+j}\\ &= 3 + j\text{ V}\\ &= 3.162\angle 18.43^\circ\text{ V}\end{aligned}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{3.162\angle 18.43^\circ\text{ V}}$.

Step 1 of 7

Refer to Figure P8.64 in the textbook.

Let us assign the unknown node voltages as $\mathbf{V_1}, \mathbf{V_2}, \mathbf{V_3}$ and $\mathbf{V_4}$.

Now the circuit is modified as,

Step 2 of 7

From the circuit,

$$\mathbf{V_1} - \mathbf{V_3} = 6\angle 0° \text{ V}$$

$$\mathbf{V_3} = \mathbf{V_1} - 6 \text{ ..... (1)}$$

$$\mathbf{V_x} = \mathbf{V_1} - \mathbf{V_2} \text{ ..... (2)}$$

$$\mathbf{V_4} = 4\mathbf{V_x}$$

$$\mathbf{V_4} = 4(\mathbf{V_1} - \mathbf{V_2}) \text{ ..... (3)}$$

Step 3 of 7

Apply Kirchhoff's current law at the super node (1-3).

$$\frac{\mathbf{V_1} - \mathbf{V_2}}{1} - 2\angle 0° + \frac{\mathbf{V_3}}{1} + \frac{\mathbf{V_3} - \mathbf{V_2}}{-j1} + \frac{\mathbf{V_3} - \mathbf{V_4}}{1} = 0$$

$$\mathbf{V_1}(1) - \mathbf{V_2}(1 + j1) - 2\angle 0° + \mathbf{V_3}(1 + j1 + 1) - \mathbf{V_4} = 0$$

Substitute $\mathbf{V_1} - 6$ for $\mathbf{V_3}$, $4(\mathbf{V_1} - \mathbf{V_2})$ for $\mathbf{V_4}$ in the equation.

$$\mathbf{V_1} - \mathbf{V_2}(1 + j1) + (\mathbf{V_1} - 6)(2 + j1) - 4(\mathbf{V_1} - \mathbf{V_2}) = 2$$

$$\mathbf{V_1} - \mathbf{V_2}(1 + j1) + 2\mathbf{V_1} + j\mathbf{V_1} - 12 - j6 - 4\mathbf{V_1} + 4\mathbf{V_2} = 2$$

$$\mathbf{V_1}(1 + 2 + j1 - 4) - \mathbf{V_2}(1 + j1 - 4) - 12 - j6 = 2$$

$$\mathbf{V_1}(-1 + j1) - \mathbf{V_2}(-3 + j1) = 2 + 12 + j6$$

$$\mathbf{V_1}(-1 + j1) - \mathbf{V_2}(-3 + j1) = 14 + j6 \text{ ..... (4)}$$

Step 4 of 7

Apply Kirchhoff's current law at node 2.

$$-4\angle 0° + \frac{\mathbf{V_2} - \mathbf{V_1}}{1} + \frac{\mathbf{V_2} - \mathbf{V_3}}{-j1} = 0$$

$$-\mathbf{V_1}(1) + \mathbf{V_2}(1 + j1) - \mathbf{V_3}(j1) = 4$$

Substitute $\mathbf{V_1} - 6$ for $\mathbf{V_3}$ in the equation.

$$-\mathbf{V_1} + \mathbf{V_2}(1 + j1) - (\mathbf{V_1} - 6)(j1) = 4$$

$$-\mathbf{V_1} + \mathbf{V_2}(1 + j1) - j\mathbf{V_1} + j6 = 4$$

$$-\mathbf{V_1}(1 + j1) + \mathbf{V_2}(1 + j1) = 4 - j6 \text{ ..... (5)}$$

Step 5 of 7

Add equations (4) and (5).

$$\mathbf{V_1}(-1 + j1) - \mathbf{V_2}(-3 + j1) - \mathbf{V_1}(1 + j1) + \mathbf{V_2}(1 + j1) = 14 + j6 + 4 - j6$$

$$\mathbf{V_1}(-1 + j1 - 1 - j1) + \mathbf{V_2}(3 - j1 + 1 + j1) = 18$$

$$\mathbf{V_1}(-2) + \mathbf{V_2}(4) = 18$$

$$-2\mathbf{V_1} + 4\mathbf{V_2} = 18$$

$$\mathbf{V_2} = \frac{2\mathbf{V_1} + 18}{4} \text{ ..... (6)}$$

Step 6 of 7

Recall equation (4).

$$\mathbf{V_1}(-1 + j1) - \mathbf{V_2}(-3 + j1) = 14 + j6$$

Substitute $\frac{2\mathbf{V_1} + 18}{4}$ for $\mathbf{V_2}$ in the equation.

$$\mathbf{V_1}(-1 + j1) - \left(\frac{2\mathbf{V_1} + 18}{4}\right)(-3 + j1) = 14 + j6$$

$$\mathbf{V_1}(-4 + j4) - (2\mathbf{V_1} + 18)(-3 + j1) = 4(14 + j6)$$

$$-4\mathbf{V_1} + j4\mathbf{V_1} - (-6\mathbf{V_1} + j2\mathbf{V_1} - 54 + j18) = 56 + j24$$

$$\mathbf{V_1}(-4 + j4 + 6 - j2 + 54 - j18) = 56 + j24$$

$$\mathbf{V_1}(56 - j16) = 56 + j24$$

$$\begin{aligned}\mathbf{V_1} &= \frac{56 + j24}{56 - j16} \\ &= 0.81 + j0.66 \\ &= 1.05\angle 39.1° \text{ V}\end{aligned}$$

Calculate the voltage at node 2.

$$\begin{aligned}\mathbf{V_2} &= \frac{2(0.81 + j0.66) + 18}{4} \\ &= \frac{1.62 + j1.32 + 18}{4} \\ &= 4.9 + j0.33 \\ &= 4.92\angle 3.85° \text{ V}\end{aligned}$$

Step 7 of 7

Now, calculate the output voltage.
From the given circuit, we have

$$\mathbf{V_o} = \mathbf{V_4}$$

$$\begin{aligned}\mathbf{V_o} &= 4(\mathbf{V_1} - \mathbf{V_2}) \\ &= 4(0.81 + j0.66 - (4.9 + j0.33)) \\ &= -16.36 + j1.32 \text{ V} \\ &= 16.4\angle 175.38° \text{ V}\end{aligned}$$

Therefore, the output voltage, $\mathbf{V_o}$ is $\boxed{16.4\angle 175.38° \text{ V}}$.

Step 1 of 9

Refer the circuit in Figure P8.63 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 9

Apply nodal analysis to the circuit at node-1.

$$\frac{V_1-6}{-j1}+\frac{V_1-2V_x}{1}=4I_x$$

$$(j1)V_1-j6+V_1-2V_x=4I_x$$

$$(1+j1)V_1-2V_x-j6=4I_x \text{ ..... (1)}$$

Step 3 of 9

Apply nodal analysis to the circuit at node-2.

$$\frac{V_x}{1}+\frac{V_x-6}{1}+4I_x=0$$

$$2V_x+4I_x-6=0 \text{ ..... (2)}$$

Step 4 of 9

From the circuit,

$$I_x=\frac{V_1-2V_x}{1}$$

$$I_x=V_1-2V_x \text{ ..... (3)}$$

Step 5 of 9

Substitute equation (3) in equation (1).

$$(1+j1)V_1-2V_x-j6=4(V_1-2V_x)$$

$$V_1+(j1)V_1-2V_x-j6=4V_1-8V_x$$

$$V_1+(j1)V_1-2V_x-j6-4V_1+8V_x=0$$

$$(-3+j1)V_1+6V_x-j6=0$$

$$V_1(-3+j1)+6V_x=j6 \text{ ..... (4)}$$

Step 6 of 9

Substitute equation (3) in equation (2).

$$2V_x+4(V_1-2V_x)-6=0$$

$$2V_x+4V_1-8V_x=6$$

$$4V_1-6V_x=6$$

$$2V_1-3V_x=3$$

$$V_1=\frac{3+3V_x}{2} \text{ ..... (5)}$$

Step 7 of 9

Determine the value of V_x.

Substitute equation (5) in equation (4).

$$\left(\frac{3+3V_x}{2}\right)(-3+j1)+6V_x=j6$$

$$(-3+j1)(3+3V_x)+12V_x=j12$$

$$-9-9V_x+j3+j3V_x+12V_x=j12$$

$$(3+j3)V_x=j12+9-j3$$

$$3(1+j1)V_x=9+j9$$

$$V_x=\frac{3+j3}{1+j1}$$

$$=3$$

Step 8 of 9

Determine the value of V_1.

Substitute 3 for V_x in equation (5).

$$V_1=\frac{3+3(3)}{2}$$

$$=\frac{12}{2}$$

$$=6$$

Step 9 of 9

Determine the value of V_0.

From the figure,

$$V_0=\frac{V_x-6}{1}$$

Substitute 3 for V_x.

$$V_0=\frac{3-6}{1}$$

$$=-3$$

$$=-3\angle 0° \text{ V}$$

Therefore, the value of V_0 is $\boxed{-3\angle 0° \text{ V}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.65 in the textbook.

Let us assign the unknown node voltages as $\mathbf{V_1}, \mathbf{V_2}, \mathbf{V_3}$ and $\mathbf{V_4}$.

Now the circuit is modified as,

Step 2 of 6

From the circuit,

$$\mathbf{V}_x = \mathbf{V}_1 - \mathbf{V}_2 \text{ ..... (1)}$$

$$\mathbf{V}_4 = 2\mathbf{V}_x$$

$$\mathbf{V}_4 = 2(\mathbf{V}_1 - \mathbf{V}_2) \text{ ..... (2)}$$

$$\begin{aligned}\mathbf{I}_x &= \frac{\mathbf{V}_1 - \mathbf{V}_4}{1} \\ &= \mathbf{V}_1 - \mathbf{V}_4 \\ &= \mathbf{V}_1 - 2(\mathbf{V}_1 - \mathbf{V}_2)\end{aligned}$$

$$= 2\mathbf{V}_2 - \mathbf{V}_1 \text{ ..... (3)}$$

$$\mathbf{I}_o = \frac{\mathbf{V}_3 - \mathbf{V}_4}{1}$$

$$= \mathbf{V}_3 - \mathbf{V}_4 \text{ ..... (4)}$$

Step 3 of 6

Apply Kirchhoff's current law at node '1'.

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{1} + \frac{\mathbf{V}_1 - \mathbf{V}_3}{-j1} + \frac{\mathbf{V}_1 - \mathbf{V}_4}{1} = 0$$

$$\mathbf{V}_1(1 + j1 + 1) - \mathbf{V}_2(1) - \mathbf{V}_3(j1) - \mathbf{V}_4 = 0$$

Substitute $2(\mathbf{V}_1 - \mathbf{V}_2)$ for $\mathbf{V}_4$ in the equation.

$$\mathbf{V}_1(2 + j1) - \mathbf{V}_2(1) - (4\angle 0°)(j1) - 2(\mathbf{V}_1 - \mathbf{V}_2) = 0$$

$$\mathbf{V}_1(2 + j1) - \mathbf{V}_2(1) - j4 - 2\mathbf{V}_1 + 2\mathbf{V}_2 = 0$$

$$\mathbf{V}_1(2 + j1 - 2) - \mathbf{V}_2(1 - 2) = j4$$

$$\mathbf{V}_1(j1) + \mathbf{V}_2 = j4$$

$$\mathbf{V}_2 = j4 - j\mathbf{V}_1 \text{ ..... (5)}$$

Step 4 of 6

Apply Kirchhoff's current law at node '2'.

$$-4\mathbf{I}_x + \frac{\mathbf{V}_2 - \mathbf{V}_1}{1} + \frac{\mathbf{V}_2 - \mathbf{V}_3}{1} = 0$$

$$-4(2\mathbf{V}_2 - \mathbf{V}_1) + \mathbf{V}_2(1 + 1) - \mathbf{V}_1 - \mathbf{V}_3 = 0$$

$$-8\mathbf{V}_2 + 4\mathbf{V}_1 + 2\mathbf{V}_2 - \mathbf{V}_1 - \mathbf{V}_3 = 0$$

$$\mathbf{V}_2(-8 + 2) + \mathbf{V}_1(4 - 1) - 4\angle 0° = 0$$

$$\mathbf{V}_1(3) - \mathbf{V}_2(6) = 4$$

Substitute $j4 - j\mathbf{V}_1$ for $\mathbf{V}_2$ in the equation.

$$\mathbf{V}_1(3) - [j4 - j\mathbf{V}_1](6) = 4$$

$$\mathbf{V}_1(3 + j6) - j24 = 4$$

$$\mathbf{V}_1(3 + j6) = 4 + j24$$

$$\begin{aligned}\mathbf{V}_1 &= \frac{4 + j24}{3 + j6} \\ &= 3.63\angle 17.1° \text{ V} \\ &= 3.46 + j1.06 \text{ V}\end{aligned}$$

Step 5 of 6

Recall equation (5).

$$\mathbf{V}_2 = j4 - j\mathbf{V}_1$$

Substitute $3.46 + j1.06$ V for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{V}_2 &= j4 - \mathbf{V}_1(j1) \\ &= j4 - (3.46 + j1.06)(j1) \\ &= j4 - j3.46 + 1.06 \\ &= 1.06 + j0.54 \text{ V}\end{aligned}$$

Step 6 of 6

Recall equation (2).

$$\mathbf{V}_4 = 2(\mathbf{V}_1 - \mathbf{V}_2)$$

Substitute $3.46 + j1.06$ V for $\mathbf{V}_1$ and $1.06 + j0.54$ V for $\mathbf{V}_2$ in the equation.

$$\begin{aligned}\mathbf{V}_4 &= 2(\mathbf{V}_1 - \mathbf{V}_2) \\ &= 2[(3.46 + j1.06) - (1.06 + j0.54)] \\ &= 2(2.4 + j0.52) \\ &= 4.8 + j1.04 \text{ V}\end{aligned}$$

Calculate the current $\mathbf{I}_o$.

$$\begin{aligned}\mathbf{I}_o &= \mathbf{V}_3 - \mathbf{V}_4 \\ &= 4\angle 0° - (4.8 + j1.04) \\ &= -0.8 - j1.04 \text{ A} \\ &= 1.31\angle -127.57° \text{ A}\end{aligned}$$

Therefore, the current, $\mathbf{I}_o$ is $\boxed{1.31\angle -127.57° \text{ A}}$.

Step 1 of 7

Refer the circuit in Figure P8.68 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 7

Apply mesh analysis to the circuit in loop-1.

$$I_1 = I + I_2$$
$$I = I_1 - I_2$$

Apply Kirchhoff's voltage law to the circuit in loop-1.

$$6\angle 0^\circ - (j1)I_1 + (j2)I = 0$$
$$(j1)I_1 - (j2)(I_1 - I_2) = 6\angle 0^\circ$$
$$(j1)I_1 - (j2)I_1 + (j2)I_2 = 6\angle 0^\circ$$
$$(-j1)I_1 + (j2)I_2 = 6\angle 0^\circ \quad \text{..... (1)}$$

Step 3 of 7

Apply Kirchhoff's voltage law to the circuit in loop-2.

$$2I_2 - (j2)I = 12\angle 45^\circ$$
$$2I_2 - (j2)(I_1 - I_2) = 12\angle 45^\circ$$
$$2I_2 - (j2)I_1 + (j2)I_2 = 12\angle 45^\circ$$
$$(-j2)I_1 + (2 + j2)I_2 = 12\angle 45^\circ \quad \text{..... (2)}$$

Step 4 of 7

Solve equations (1) and (2).

From equation (1),

$$(-j1)I_1 + (j2)I_2 = 6\angle 0^\circ$$
$$I_1 + \left(\frac{j2}{-j1}\right)I_2 = \frac{6}{-j1}$$
$$I_1 - 2I_2 = j6$$
$$I_1 = 2I_2 + j6$$

Step 5 of 7

Determine the value of I_2.

Substitute $2I_2 + j6$ for I_1 in equation (2).

$$(-j2)(2I_2 + j6) + (2 + j2)I_2 = 12\angle 45^\circ$$
$$-j4I_2 + 12 + 2I_2 + (j2)I_2 = 8.48 + j8.48$$
$$(2 - j2)I_2 = -12 + 8.48 + j8.48$$
$$= -3.52 + j8.48$$
$$I_2 = \frac{-3.52 + j8.48}{2 - j2}$$
$$= -3 + j1.24$$

Step 6 of 7

Determine the value of I_1.

$$I_1 = 2I_2 + j6$$

Substitute $-3 + j1.24$ for I_2.

$$I_1 = 2(-3 + j1.24) + j6$$
$$= -6 + j2.48 + j6$$
$$= -6 + j8.48$$

Step 7 of 7

Determine the value of V_0.

$$V_0 = (I_2)(2\Omega)$$

Substitute $-3 + j1.24$ for I_2.

$$V_0 = (-3 + j1.24)(2)$$
$$= -6 + j2.48$$
$$= 6.49\angle 157.54^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{6.49\angle 157.54^\circ \text{ V}}$.

Step 1 of 2

Refer to Figure P8.67 in the text book for the circuit.

Mark loop currents in the circuit as shown in Figure 1.

Figure 1

Step 2 of 2

Observe from Figure 1 that the loop current, $\mathbf{I}_1 = 2\angle 0°\ \mathrm{A}$

Apply Kirchhoff's voltage law to the second loop.

$$(j4 - j2)(\mathbf{I}_2 - \mathbf{I}_1) - 12\angle 0° + 2\mathbf{I}_2 = 0$$
$$(j2 + 2)\mathbf{I}_2 - (j2)\mathbf{I}_1 = 12\angle 0°$$

Substitute $2\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$(j2 + 2)\mathbf{I}_2 - (j2)2 = 12\angle 0°$$
$$\mathbf{I}_2 = \frac{12 + 4j}{j2 + 2}$$
$$= 4.472\angle -26.6°\ \mathrm{A}$$

Determine the output voltage $\mathbf{V}_o$.

$$\mathbf{V}_o = 2\mathbf{I}_2$$
$$= 8.944\angle -26.6°\ \mathrm{V}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{8.944\angle -26.6°\ \mathrm{V}}$.

Step 1 of 3

Refer to Figure P8.68 in the textbook.

Draw the circuit diagram with loop currents.

Figure 1

Step 2 of 3

From Figure 1, the loop current $\mathbf{I}_1$ is,

$$\mathbf{I}_1 = 2\angle 0° \text{ A}$$

Apply Kirchhoff's voltage law for loop $\mathbf{I}_2$.

$$1(\mathbf{I}_2 - \mathbf{I}_1) - j1\mathbf{I}_2 + j1(\mathbf{I}_2 - \mathbf{I}_3) = 0$$
$$-\mathbf{I}_1 + \mathbf{I}_2 - j1\mathbf{I}_3 = 0$$

Substitute $2\angle 0°$ A for $\mathbf{I}_1$.

$$-2\angle 0° + \mathbf{I}_2 - j1\mathbf{I}_3 = 0$$
$$\mathbf{I}_2 - j1\mathbf{I}_3 = 2\angle 0°$$

$$\mathbf{I}_2 = 2 + (j1)\mathbf{I}_3 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law for loop $\mathbf{I}_3$.

$$j1(\mathbf{I}_3 - \mathbf{I}_2) + 1\mathbf{I}_3 + 12\angle 0° = 0$$

$$-j\mathbf{I}_2 + (1+j)\mathbf{I}_3 = -12 \text{ ..... (2)}$$

Step 3 of 3

Substitute $2 + (j1)\mathbf{I}_3$ for $\mathbf{I}_2$ in equation (2).

$$-j(2 + (j1)\mathbf{I}_3) + (1+j)\mathbf{I}_3 = -12$$
$$-j2 + \mathbf{I}_3 + (1+j)\mathbf{I}_3 = -12$$
$$(2+j)\mathbf{I}_3 = -12 + j2$$

$$\mathbf{I}_3 = \frac{-12 + j2}{2 + j}$$
$$= -4.4 + j3.2 \text{ A}$$

Substitute $-4.4 + j3.2$ A for $\mathbf{I}_3$ in equation (1).

$$\mathbf{I}_2 = 2 + (j1)(-4.4 + j3.2)$$
$$= 2 - 3.2 - j4.4$$
$$= -1.2 - j4.4 \text{ A}$$

Calculate the current, $\mathbf{I}_o$ in the circuit.

$$\mathbf{I}_o = \mathbf{I}_1 - \mathbf{I}_2$$

Substitute 2 A for $\mathbf{I}_1$ and $-1.2 - j4.4$ for $\mathbf{I}_2$.

$$\mathbf{I}_o = 2 - (-1.2 - j4.4)$$
$$= 3.2 + j4.4$$
$$= 5.44\angle 53.97 \text{ A}$$

Therefore, the current flowing through $1\ \Omega$ resistor, $\mathbf{I}_o$ is $\boxed{5.44\angle 53.97 \text{ A}}$.

Step 1 of 4

Refer to Figure P8.69 in the textbook.

Draw the circuit diagram with loop currents.

Figure 1

Step 2 of 4

The constraint equation for the super mesh is,

$$\mathbf{I}_2 - \mathbf{I}_1 = 2\angle 0°$$

$$\mathbf{I}_1 = \mathbf{I}_2 - 2\angle 0° \quad \text{..... (1)}$$

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_1$.

$$-6\angle 0° + 1(\mathbf{I}_1 - \mathbf{I}_3) + j1(\mathbf{I}_2 - \mathbf{I}_3) + 1\mathbf{I}_2 = 0$$
$$\mathbf{I}_1 + (1+j)\mathbf{I}_2 - (1+j)\mathbf{I}_3 = 6$$

Substitute $\mathbf{I}_2 - 2\angle 0°$ for $\mathbf{I}_1$.

$$-6\angle 0° + 1(\mathbf{I}_1 - \mathbf{I}_3) + j1(\mathbf{I}_2 - \mathbf{I}_3) + 1\mathbf{I}_2 = 0$$
$$\mathbf{I}_2 - 2\angle 0° + (1+j)\mathbf{I}_2 - (1+j)\mathbf{I}_3 = 6$$

$$(2+j)\mathbf{I}_2 - (1+j)\mathbf{I}_3 = 8 \quad \text{..... (2)}$$

Step 3 of 4

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_3$.

$$-j1\mathbf{I}_3 + 1(\mathbf{I}_3 - \mathbf{I}_1) + j1(\mathbf{I}_3 - \mathbf{I}_2) = 0$$
$$-\mathbf{I}_1 - j\mathbf{I}_2 + \mathbf{I}_3 = 0$$

Substitute $\mathbf{I}_2 - 2\angle 0°$ for $\mathbf{I}_1$.

$$-(\mathbf{I}_2 - 2) - j\mathbf{I}_2 + \mathbf{I}_3 = 0$$
$$-(1+j)\mathbf{I}_2 + \mathbf{I}_3 = -2$$

$$\mathbf{I}_3 = (1+j)\mathbf{I}_2 - 2 \quad \text{..... (3)}$$

Substitute $(1+j)\mathbf{I}_2 - 2$ for $\mathbf{I}_3$ in equation (2).

$$(2+j)\mathbf{I}_2 - (1+j)\big((1+j)\mathbf{I}_2 - 2\big) = 8$$
$$(2+j)\mathbf{I}_2 - j2\mathbf{I}_2 + (2+j2) = 8$$
$$(2-j)\mathbf{I}_2 = 6 - j2$$

$$\mathbf{I}_2 = \frac{6-j2}{2-j}$$
$$= 2.828\angle 8.13°\ \text{A}$$

Step 4 of 4

Calculate the voltage, $\mathbf{V}_o$ in the circuit shown in Figure 1.

$$\mathbf{V}_o = 1(\mathbf{I}_2)$$

Substitute $2.828\angle 8.13°\ \text{A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_o = 1(2.828\angle 8.13°)$$
$$= 2.828\angle 8.13°\ \text{V}$$

Therefore, the voltage across $1\,\Omega$ resistor, $\mathbf{V}_o$ is $\boxed{2.828\angle 8.13°\ \text{V}}$.

Step 1 of 3

Refer to Figure P8.93 in the textbook.

Draw the circuit diagram with loop currents.

Figure 1

Step 2 of 3

From Figure 1, the loop current $\mathbf{I}_1$ is,

$$\mathbf{I}_1 = 2\angle 0°\ \mathrm{A}$$

Apply Kirchhoff's voltage law for loop $\mathbf{I}_2$.

$$-12\angle 0° + 1\mathbf{I}_2 - j1\mathbf{I}_2 + (1+j2)(\mathbf{I}_2 - \mathbf{I}_1) = 0$$
$$(2+j1)\mathbf{I}_2 - (1+j2)\mathbf{I}_1 = 12\angle 0°$$

Substitute $2\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$(2+j1)\mathbf{I}_2 - (1+j2)(2\angle 0°) = 12\angle 0°$$
$$(2+j1)\mathbf{I}_2 - (2+j4) = 12$$
$$(2+j1)\mathbf{I}_2 = 12+2+j4$$

$$\mathbf{I}_2 = \frac{14+j4}{2+j1}$$
$$= (6.4 - j1.2)\ \Omega$$

Step 3 of 3

Calculate the voltage across $1\ \Omega$ resistor.

$$\mathbf{V}_o = 1(\mathbf{I}_2 - \mathbf{I}_1)$$

Substitute $2\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$ and $(6.4 - j1.2)\ \Omega$ for $\mathbf{I}_2$.

$$\mathbf{V}_o = 1(6.4 - j1.2 - 2)$$
$$= 4.4 - j1.2$$
$$= 4.56\angle -15.26°\ \mathrm{V}$$

Therefore, the voltage across the $1\ \Omega$ resistor, $\mathbf{V}_o$ is $\boxed{4.56\angle -15.26°\ \mathrm{V}}$.

Step 1 of 4

Refer to Figure P8.94 in the textbook.

Draw the circuit diagram with loop currents.

Figure 1

Step 2 of 4

The constraint equation for the super mesh is,

$$\mathbf{I}_2 - \mathbf{I}_1 = 2\angle 0°$$

$$\mathbf{I}_1 = \mathbf{I}_2 - 2\angle 0° \quad \text{..... (1)}$$

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_1$.

$$-12\angle 0° + 1(\mathbf{I}_1 - \mathbf{I}_3) - j1(\mathbf{I}_2 - \mathbf{I}_3) + 1\mathbf{I}_2 = 0$$
$$\mathbf{I}_1 + (1-j)\mathbf{I}_2 - (1-j)\mathbf{I}_3 = 12$$

Substitute $\mathbf{I}_2 - 2\angle 0°$ for $\mathbf{I}_1$.

$$\mathbf{I}_2 - 2\angle 0° + (1-j)\mathbf{I}_2 - (1-j)\mathbf{I}_3 = 12$$

$$(2-j)\mathbf{I}_2 - (1-j)\mathbf{I}_3 = 14 \quad \text{..... (2)}$$

Step 3 of 4

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_3$.

$$1\mathbf{I}_3 + 1(\mathbf{I}_3 - \mathbf{I}_1) - j1(\mathbf{I}_3 - \mathbf{I}_2) = 0$$
$$-\mathbf{I}_1 + j\mathbf{I}_2 + (2-j)\mathbf{I}_3 = 0$$

Substitute $\mathbf{I}_2 - 2\angle 0°$ for $\mathbf{I}_1$.

$$-(\mathbf{I}_2 - 2\angle 0°) + j\mathbf{I}_2 + (2-j)\mathbf{I}_3 = 0$$
$$-(1-j)\mathbf{I}_2 + (2-j)\mathbf{I}_3 = -2$$
$$(1-j)\mathbf{I}_2 = (2-j)\mathbf{I}_3 + 2$$

$$\mathbf{I}_2 = \frac{(2-j)\mathbf{I}_3 + 2}{(1-j)} \quad \text{..... (3)}$$

Substitute $\frac{(2-j)\mathbf{I}_3 + 2}{(1-j)}$ for $\mathbf{I}_2$ in equation (2).

$$(2-j)\left(\frac{(2-j)\mathbf{I}_3 + 2}{(1-j)}\right) - (1-j)\mathbf{I}_3 = 14$$
$$(3.5 - j0.5)\mathbf{I}_3 + (3+j) - (1-j)\mathbf{I}_3 = 14$$
$$(3.5 - j0.5)\mathbf{I}_3 - (1-j)\mathbf{I}_3 = 11 - j$$
$$(2.5 + j0.5)\mathbf{I}_3 = 11 - j$$

$$\mathbf{I}_3 = \frac{11-j}{2.5+j0.5}$$
$$= 4.33\angle -16.5° \text{ A}$$

Step 4 of 4

Calculate the voltage, $\mathbf{V}_o$ in the circuit shown in Figure 1.

$$\mathbf{V}_o = 1(\mathbf{I}_3)$$

Substitute $4.33\angle -16.5°$ A for $\mathbf{I}_3$.

$$\mathbf{V}_o = 1(4.33\angle -16.5°)$$
$$= 4.33\angle -16.5° \text{ V}$$

Therefore, the voltage across $1\,\Omega$ resistor, $\mathbf{V}_o$ is $\boxed{4.33\angle -16.5° \text{ V}}$.

Step 1 of 3

Refer to Figure P8.95 in the textbook.

Draw the circuit diagram with loop currents.

Figure 1

Step 2 of 3

From Figure 1, the current, $\mathbf{I}_3$ is,

$$\mathbf{I}_3 = -4\angle 0^\circ \text{ A}$$

The constraint equation for the super mesh is,

$$\mathbf{I}_1 - \mathbf{I}_2 = 2\angle 0^\circ$$

$$\mathbf{I}_1 = \mathbf{I}_2 + 2\angle 0^\circ \text{ ..... (1)}$$

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_1$.

$$1\mathbf{I}_1 + 12\angle 0^\circ + 1(\mathbf{I}_2 - \mathbf{I}_4) - j1(\mathbf{I}_2) = 0$$
$$\mathbf{I}_1 + (1-j)\mathbf{I}_2 - \mathbf{I}_4 = -12$$

Substitute $\mathbf{I}_2 + 2\angle 0^\circ$ for $\mathbf{I}_1$.

$$\mathbf{I}_2 + 2\angle 0^\circ + (1-j)\mathbf{I}_2 - \mathbf{I}_4 = -12$$

$$(2-j)\mathbf{I}_2 - \mathbf{I}_4 = -14 \text{ ..... (2)}$$

Write the Kirchhoff's voltage law equation for loop $\mathbf{I}_4$.

$$1(\mathbf{I}_4 - \mathbf{I}_2) + 1(\mathbf{I}_4 - \mathbf{I}_3) + j1\mathbf{I}_4 = 0$$
$$-\mathbf{I}_2 - \mathbf{I}_3 + (2+j)\mathbf{I}_4 = 0$$

Substitute -4 for $\mathbf{I}_3$.

$$-\mathbf{I}_2 - (-4) + (2+j)\mathbf{I}_4 = 0$$
$$-\mathbf{I}_2 + (2+j)\mathbf{I}_4 = -4$$

$$\mathbf{I}_2 = (2+j)\mathbf{I}_4 + 4 \text{ ..... (3)}$$

Step 3 of 3

Substitute $(2+j)\mathbf{I}_4 + 4$ for $\mathbf{I}_2$ in equation (2).

$$(2-j)((2+j)\mathbf{I}_4 + 4) - \mathbf{I}_4 = -14$$
$$5\mathbf{I}_4 + 8 - j4 - \mathbf{I}_4 = -14$$
$$4\mathbf{I}_4 = -22 + j4$$
$$\mathbf{I}_4 = (-5.5 + j) \text{ A}$$

Substitute $(-5.5+j)$ A for $\mathbf{I}_4$ in equation (3).

$$\begin{aligned}\mathbf{I}_2 &= (2+j)(-5.5+j) + 4 \\ &= -12 - j3.5 + 4 \\ &= (-8 - j3.5) \text{ A}\end{aligned}$$

Calculate the current $\mathbf{I}_o$ in the circuit shown in Figure 1.

$$\mathbf{I}_o = \mathbf{I}_2 - \mathbf{I}_4$$

Substitute $(-5.5+j)$ A for $\mathbf{I}_4$ and $(-8-j3.5)$ A for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_o &= -8 - j3.5 - (-5.5 + j) \\ &= -2.5 - j4.5 \\ &= 5.147\angle -119^\circ \text{ A}\end{aligned}$$

Therefore, the current flowing through $1\ \Omega$ resistor, $\mathbf{I}_o$ is $\boxed{5.147\angle -119^\circ \text{ A}}$.

Step 1 of 6

Refer the circuit in Figure P8.73 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law to the circuit.

$$I_1 = I + I_2$$
$$I = I_1 - I_2$$

Step 3 of 6

Apply Kirchhoff's voltage law to the circuit in loop-2.

$$(j2)I_2 + 2I_2 - (j1)(-I) = 6\angle 0^\circ$$
$$(2 + j2)I_2 + (j1)I = 6\angle 0^\circ$$

Substitute $I_1 - I_2$ for I.

$$(2 + j2)I_2 + (j1)(I_1 - I_2) = 6\angle 0^\circ$$
$$(2 + j1)I_2 + (j1)I_1 = 6\angle 0^\circ \quad \text{..... (1)}$$

Step 4 of 6

From the circuit,

$$I_1 = -2\angle 0^\circ \text{ A}$$
$$= 2\angle 180^\circ \text{ A}$$

Step 5 of 6

Determine the value of I_2.

Substitute $2\angle 180^\circ$ A for I_1 in equation (1).

$$(2 + j1)I_2 + (j1)(2\angle 180^\circ) = 6\angle 0^\circ$$
$$(2 + j1)I_2 = 6\angle 0^\circ - (j1)(2\angle 180^\circ)$$
$$= 6 + j2$$
$$I_2 = \frac{6 + j2}{2 + j1}$$
$$= 2.8 - j0.4$$
$$= 2.83\angle -8.13^\circ \text{ A}$$

Step 6 of 6

Determine the value of V_0.

$$V_0 = 2I_2$$

Substitute $2.83\angle -8.13^\circ$ A for I_2.

$$V_0 = 2(2.83\angle -8.13^\circ)$$
$$= 5.66\angle -8.13^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{5.66\angle -8.13^\circ \text{ V}}$.

Step 1 of 5

Refer the circuit in Figure P8.76 in the textbook.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law to the circuit at node-1.

$$I_2 = I + I_1$$
$$I = I_2 - I_1$$

Apply Kirchhoff's current law to the circuit at node-2

$$I_1 = I' + I_3$$
$$I' = I_1 - I_3$$

Apply Kirchhoff's current law to the circuit at node-3.

$$I_3 + 2\angle 0^\circ = I_2$$
$$I_2 - I_3 = 2\angle 0^\circ$$

Step 3 of 5

Apply Kirchhoff's voltage law to the circuit in loop-1.

$$2I' - (j1)(-I) = 12\angle 0^\circ$$

Substitute $I_1 - I_3$ for I', $I_2 - I_1$ for I.

$$2(I_1 - I_3) - (j1)(-(I_2 - I_1)) = 12\angle 0^\circ$$
$$2(I_1 - I_3) + (j1)(I_2 - I_1) = 12\angle 0^\circ$$
$$2I_1 - 2I_3 + (j1)I_2 - (j1)I_1 = 12\angle 0^\circ$$
$$(2 - j1)I_1 + (j1)I_2 - 2I_3 = 12$$

Step 4 of 5

Apply Kirchhoff's voltage law to the outer loop in Figure 1.

$$(j1)I_3 + 2I_3 + 16\angle 0^\circ = 12\angle 0^\circ$$
$$(2 + j1)I_3 = 12 - 16$$

$$\begin{aligned} I_3 &= \frac{-4}{2 + j1} \\ &= -1.6 + j0.8 \\ &= 1.79\angle 153.43^\circ \text{ A} \end{aligned}$$

Step 5 of 5

Determine the value of V_0.

$$V_0 = 2I_3$$

Substitute $1.79\angle 153.43^\circ$ A for I_3.

$$\begin{aligned} V_0 &= 2(1.79\angle 153.43^\circ) \\ &= 3.58\angle 153.43^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{3.58\angle 153.43^\circ \text{ V}}$.

Step 1 of 4

Refer the circuit in Figure P8.77 in the textbook.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law to the circuit at node-2.

$$I_1 = I_2 + I_0$$

$$\frac{V_1 - V_2}{-j1} = \frac{V_2}{j2} + \frac{V_2}{3} \quad \text{..... (1)}$$

From Figure 1,

$$V_1 = 12\angle 0^\circ \text{ V}$$

Substitute $12\angle 0^\circ$ V for V_1 in equation (1).

$$\frac{12\angle 0^\circ - V_2}{-j1} = \frac{V_2}{j2} + \frac{V_2}{3}$$

$$\frac{12\angle 0^\circ}{-j1} + \frac{V_2}{j1} = V_2\left(\frac{1}{j2} + \frac{1}{3}\right)$$

$$V_2\left(\frac{1}{j2} + \frac{1}{3} - \frac{1}{j1}\right) = -\frac{12\angle 0^\circ}{j1}$$

$$V_2\left(\frac{3 + j2 - 6}{j6}\right) = -\frac{12\angle 0^\circ}{j1}$$

$$V_2(0.33 + j0.5) = j12$$

$$\begin{aligned} V_2 &= \frac{j12}{0.33 + j0.5} \\ &= 16.7 + j11.03 \\ &= 20\angle 33.4^\circ \text{ V} \end{aligned}$$

Step 3 of 4

Determine the value of I_0.

$$I_0 = \frac{V_2}{3}$$

Substitute $20\angle 33.4^\circ$ V for V_2.

$$\begin{aligned} I_0 &= \frac{20\angle 33.4^\circ}{3} \\ &= 6.67\angle 33.4^\circ \text{ A} \end{aligned}$$

Step 4 of 4

Determine the value of V_0.

$$V_0 = 1(I_0)$$

Substitute $6.67\angle 33.4^\circ$ A for I_0.

$$\begin{aligned} V_0 &= 1(6.67\angle 33.4^\circ) \\ &= 6.67\angle 33.4^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{6.67\angle 33.4^\circ \text{ V}}$.

Step 1 of 4

Refer the circuit in Figure P8.69 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law to the circuit.

$$I_1 = I + I_2$$
$$I = I_1 - I_2$$

Apply Kirchhoff's voltage law to the circuit in loop-1.

$$4I_1 - j4(I_1 - I_2) + 2(I_1 - I_2) = 12\angle 0^\circ \text{ V}$$
$$4I_1 - (j4)I_1 + (j4)I_2 + 2I_1 - 2I_2 = 12\angle 0^\circ$$
$$(6 - j4)I_1 + (-2 + j4)I_2 = 12\angle 0^\circ \quad \text{..... (1)}$$

Step 3 of 4

From the circuit,

$$I_2 = -4\angle 90^\circ \text{ A}$$

Substitute $-4\angle 90^\circ$ A for I_2 in equation (1).

$$(6 - j4)I_1 + (-2 + j4)(-4\angle 90^\circ \text{ A}) = 12\angle 0^\circ$$
$$(6 - j4)I_1 - (-16 - j8) = 12$$

$$(6 - j4)I_1 = 12 - 16 - j8$$
$$= -4 - j8$$

$$I_1 = \frac{-4 - j8}{6 - j4}$$
$$= 0.154 - j1.23$$
$$= 1.24\angle -82.86^\circ \text{ A}$$

Step 4 of 4

Determine the value of V_0.

$$V_0 = 2(I_1 - I_2)$$

Substitute $1.24\angle -82.86^\circ$ A for I_1, $-4\angle 90^\circ$ A for I_2.

$$V_0 = 2(1.24\angle -82.86^\circ - 4\angle 90^\circ)$$
$$= 2(0.154 + j2.77)$$
$$= 0.308 + j5.54$$
$$= 5.55\angle 86.8^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{5.55\angle 86.8^\circ \text{ V}}$.

Step 1 of 6

Refer the circuit in Figure P8.72 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law to the circuit.

$$I_2 = I_0 + I_3$$
$$I_0 = I_2 - I_3$$

Apply Kirchhoff's current law to the circuit.

$$I + I_0 = 2\angle 0^\circ \text{ A}$$
$$I = 2\angle 0^\circ - I_0$$

Apply Kirchhoff's voltage law to the circuit for superloop.

$$2I_1 + (j1)(-I) + 2I_0 - (j2)I_2 = 12\angle 0^\circ \quad \text{..... (1)}$$

Substitute $2\angle 0^\circ - I_0$ for I , $I_2 - I_3$ for I_0 in equation (1).

$$2I_1 + (j1)\left(-\left(2\angle 0^\circ - I_0\right)\right) + 2(I_2 - I_3) - (j2)I_2 = 12\angle 0^\circ$$
$$2I_1 - (j1)2\angle 0^\circ + (j1)I_0 + 2I_2 - 2I_3 - (j2)I_2 = 12\angle 0^\circ$$
$$2I_1 - j2 + j1I_0 + 2I_2 - 2I_3 - j2I_2 = 12$$
$$2I_1 + (2 - j2)I_2 - 2I_3 + (j1)I_0 = 12 + j2$$

Substitute $I_2 - I_3$ for I_0 .

$$2I_1 + (2 - j2)I_2 - 2I_3 + (j1)(I_2 - I_3) = 12 + j2$$
$$2I_1 + 2I_2 - j2I_2 - 2I_3 + j1I_2 - j1I_3 = 12 + j2$$

$$2I_1 + (2 - j1)I_2 + (-2 - j1)I_3 = 12 + j2 \quad \text{..... (2)}$$

Step 3 of 6

From the circuit,

$$I_3 = -4\angle 0^\circ \text{ A}$$
$$= 4\angle 180^\circ \text{ A}$$

Substitute $4\angle 180^\circ$ A for I_3 in equation (2).

$$2I_1 + (2 - j1)I_2 + (-2 - j1)\left(4\angle 180^\circ\right) = 12 + j2$$
$$2I_1 + (2 - j1)I_2 + 8 + j4 = 12 + j2$$

$$2I_1 + (2 - j1)I_2 = 4 - j2 \quad \text{..... (3)}$$

Step 4 of 6

Apply Kirchhoff's current law to the circuit.

$$I_1 + 2\angle 0^\circ = I_2$$
$$I_1 - I_2 = -2\angle 0^\circ$$
$$I_1 - I_2 = 2\angle 180^\circ$$

Substitute $I_1 + 2$ for I_2 in equation (3).

$$2I_1 + (2 - j1)(I_1 + 2) = 4 - j2$$
$$2I_1 + 2I_1 + 4 - j1I_1 - j2 = 4 - j2$$
$$(4 - j1)I_1 = 0$$
$$I_1 = 0 \text{ A}$$

Step 5 of 6

Determine the value of I_2 .

$$2I_1 + (2 - j1)I_2 = 4 - j2$$

Substitute 0 A for I_1 .

$$2(0) + (2 - j1)I_2 = 4 - j2$$
$$(2 - j1)I_2 = 4 - j2$$

$$I_2 = \frac{4 - j2}{2 - j1}$$
$$= 2$$

Step 6 of 6

Determine the value of I_0 .

$$I_0 = I_2 - I_3$$

Substitute 2 A for I_2 , $4\angle 180^\circ$ A for I_3 .

$$I_0 = 2 - \left(4\angle 180^\circ\right)$$
$$= 6 + j0$$
$$= 6\angle 0^\circ \text{ A}$$

Therefore, the value of I_0 is $\boxed{6\angle 0^\circ \text{ A}}$.

Step 1 of 6

Refer the circuit in Figure P8.74 in the textbook.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law to the circuit.

$$I_3 = I + I_1$$
$$I = I_3 - I_1$$

Apply Kirchhoff's current law to the circuit.

$$I_0 + I_4 = I_3$$
$$I_0 = I_3 - I_4$$

Step 3 of 6

Apply Kirchhoff's voltage law to the circuit at loop-3.

$$(-j2)I + 2I_0 + 2I_3 = 0$$

Substitute $I_3 - I_1$ for I, $I_3 - I_4$ for I_0.

$$(-j2)(I_3 - I_1) + 2(I_3 - I_4) + 2I_3 = 0$$
$$(-j2)I_3 - (-j2)I_1 + 2I_3 - 2I_4 + 2I_3 = 0$$
$$(-j2)I_3 + (j2)I_1 + 2I_3 - 2I_4 + 2I_3 = 0$$

$$(j2)I_1 + (4 - j2)I_3 - 2I_4 = 0 \text{ ..... (1)}$$

Step 4 of 6

From Figure 1,

$$I_1 = 6\angle 0^\circ \text{ A}$$

$$I_2 = -4\angle 0^\circ \text{ A}$$
$$= 4\angle 180^\circ \text{ A}$$

$$I_4 = 2\angle 0^\circ \text{ A}$$

Step 5 of 6

Determine the value of I_3.

Substitute $6\angle 0^\circ$ A for I_1, $2\angle 0^\circ$ A for I_4 in equation (1).

$$(j2)(6\angle 0^\circ) + (4 - j2)I_3 - 2(2\angle 0^\circ) = 0$$
$$j12 + (4 - j2)I_3 - 4 = 0$$
$$(4 - j2)I_3 = 4 - j12$$

$$I_3 = \frac{4 - j12}{4 - j2}$$
$$= 2 - j2$$
$$= 2.83\angle -45^\circ \text{ A}$$

Step 6 of 6

Determine the value of V_0.

$$V_0 = 2I_0$$

Substitute $I_3 - I_4$ for I_0.

$$V_0 = 2(I_3 - I_4)$$

Substitute $2.83\angle -45^\circ$ A for I_3, and $2\angle 0^\circ$ A for I_4.

$$V_0 = 2(2.83\angle -45^\circ - 2\angle 0^\circ)$$
$$= 2(1.11\times 10^{-3} - j2)$$
$$= 2(2\angle -89.97^\circ \text{ V})$$
$$= 4\angle -90^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{4\angle -90^\circ \text{ V}}$.

Step 1 of 7

Refer the circuit in Figure P8.75 in the textbook.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 7

Apply Kirchhoff's current law to the circuit.

$$I_1 = I_0 + I_2$$
$$I_0 = I_1 - I_2$$

Apply Kirchhoff's current law to the circuit.

$$I_3 = I' + I_1$$
$$I' = I_3 - I_1$$

Apply Kirchhoff's current law to the circuit.

$$I + I_2 = I_4$$
$$I = I_4 - I_2$$

Step 3 of 7

Apply Kirchhoff's voltage law to the circuit at loop-1.

$$1(I_1) - (j1)I_0 + 1(-I') = 0$$

Substitute $I_1 - I_2$ for I_0, $I_3 - I_1$ for I'.

$$1(I_1) - (j1)(I_1 - I_2) - 1(I_3 - I_1) = 0$$
$$I_1 - (j1)I_1 + (j1)I_2 - I_3 + I_1 = 0$$

$$(2 - j1)I_1 + (j1)I_2 - I_3 = 0 \text{ ..... (1)}$$

Step 4 of 7

From Figure 1,

$$I_2 = 4\angle 30^\circ \text{ A}$$

Substitute $4\angle 30^\circ$ A for I_2 in equation (1)

$$(2 - j1)I_1 + (j1)(4\angle 30^\circ) - I_3 = 0$$
$$(2 - j1)I_1 - 2 + j3.46 - I_3 = 0$$
$$(2 - j1)I_1 - I_3 = 2 - j3.46$$

$$(2 - j1)I_1 - I_3 = 4\angle -60^\circ \text{ ..... (2)}$$

Step 5 of 7

Apply Kirchhoff's voltage law to the circuit at super mesh.

$$1(I_1) - (j1)(I_0) + (1)(I) + 1(I_4) = 2V_x \text{ ..... (3)}$$

From the circuit,

$$V_x = (1)I_4$$
$$= I_4$$

Step 6 of 7

Determine the value of I_1.

Substitute I_4 for V_x, $I_1 - I_2$ for I_0, and $I_4 - I_2$ for I in equation (3).

$$1(I_1) - (j1)(I_1 - I_2) + (1)(I_4 - I_2) + 1(I_4) = 2I_4$$
$$I_1 - (j1)I_1 + (j1)I_2 + I_4 - I_2 + I_4 = 2I_4$$
$$(1 - j1)I_1 + (-1 + j1)I_2 = 0$$

Substitute $4\angle 30^\circ$ A for I_2.

$$(1 - j1)I_1 + (-1 + j1)(4\angle 30^\circ) = 0$$
$$(1 - j1)I_1 - 5.46 - j1.46 = 0$$

$$I_1 = \frac{5.46 - j1.46}{1 - j1}$$
$$= 3.46 + j2$$
$$= 4\angle 30^\circ \text{ A}$$

Step 7 of 7

Determine the value of I_0.

$$I_0 = I_1 - I_2$$

Substitute $4\angle 30^\circ$ A for I_1, $4\angle 30^\circ$ A for I_2.

$$I_0 = 4\angle 30^\circ - 4\angle 30^\circ$$
$$= 0 \text{ A}$$

Therefore, the value of I_0 is $\boxed{0 \text{ A}}$.

Step 1 of 6

Refer the circuit in Figure P8.78 in the textbook.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law to the circuit at node-1.

$$2I_x = 4\angle 0^\circ + I_1$$
$$2\left(\frac{V_2 - V_3}{1}\right) = 4\angle 0^\circ + \frac{V_1 - V_2}{-j1}$$
$$(-j2)(V_2 - V_3) = (-j1)(4\angle 0^\circ) + V_1 - V_2$$
$$-j2V_2 + j2V_3 = -j4 + V_1 - V_2$$
$$V_1 + (-1 + j2)V_2 - j2V_3 = j4 \text{ ..... (1)}$$

Step 3 of 6

Apply Kirchhoff's current law to the circuit at node-2.

$$I_1 = I_2 + I_x$$
$$\frac{V_1 - V_2}{-j1} = \frac{V_2}{j1} + \frac{V_2 - V_3}{1}$$
$$V_1 - V_2 = -V_2 - (j1)(V_2 - V_3)$$
$$V_1 - V_2 = -V_2 - j1V_2 + j1V_3$$
$$V_1 + (j1)V_2 - (j1)V_3 = 0 \text{ ..... (2)}$$

Step 4 of 6

Apply Kirchhoff's current law to the circuit at node-3.

$$I_x + 4\angle 0^\circ = I_0$$
$$\frac{V_2 - V_3}{1} + 4\angle 0^\circ = \frac{V_3}{1}$$
$$V_2 - V_3 + 4\angle 0^\circ = V_3$$
$$V_2 - 2V_3 = -4\angle 0^\circ$$
$$V_2 - 2V_3 = 4\angle 180^\circ$$
$$V_2 = 4\angle 180^\circ + 2V_3 \text{ ..... (3)}$$

Step 5 of 6

Subtract equation (2) from equation (1).

$$V_1 + (-1 + j2)V_2 - j2V_3 - (V_1 + (j1)V_2 - (j1)V_3) = j4$$
$$V_1 - V_2 + j2V_2 - j2V_3 - V_1 - (j1)V_2 + (j1)V_3 = j4$$
$$(-1 + j1)V_2 - j1V_3 = j4$$

Substitute $4\angle 180^\circ + 2V_3$ for V_2.

$$(-1 + j1)(4\angle 180^\circ + 2V_3) - j1V_3 = j4$$
$$-4\angle 180^\circ - 2V_3 + (j1)(4\angle 180^\circ) + j2V_3 - j1V_3 = j4$$
$$-(-4) - 2V_3 - j4 + j2V_3 - j1V_3 = j4$$
$$4 - j4 - (2 - j1)V_3 = j4$$
$$(2 - j1)V_3 = 4 - j4 - j4$$
$$(2 - j1)V_3 = 4 - j8$$
$$V_3 = \frac{4 - j8}{2 - j1}$$
$$= 3.2 - j2.4$$
$$= 4\angle -36.87^\circ \text{ V}$$

Step 6 of 6

Determine the value of V_0.

From the figure,

$$V_0 = V_3$$

Substitute $4\angle -36.87^\circ$ V for V_3.

$$V_0 = 4\angle -36.87^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{4\angle -36.87^\circ \text{ V}}$.

Step 1 of 3

8.104P

Refer to Figure P8.104 in the text book for the circuit.

Mark loop currents as shown in Figure 1.

Figure 1

Step 2 of 3

Observe from Figure 1 that the loop current, $\mathbf{I}_1$ is,

$$\mathbf{I}_1 = 4\mathbf{I}_x$$

Also,

$$\mathbf{I}_x = \mathbf{I}_2$$

So,

$$\mathbf{I}_1 = 4\mathbf{I}_2$$

Apply Kirchhoff's voltage law to the second loop.

$$\mathbf{I}_2 + 1(\mathbf{I}_2 - \mathbf{I}_1) + 4 = 0$$
$$2\mathbf{I}_2 - \mathbf{I}_1 = -4$$

Substitute $4\mathbf{I}_2$ for $\mathbf{I}_1$.

$$2\mathbf{I}_2 - 4\mathbf{I}_2 = -4$$
$$-2\mathbf{I}_2 = -4$$
$$\mathbf{I}_2 = 2\angle 0^\circ \text{ A}$$

Step 3 of 3

Apply Kirchhoff's voltage law to the third loop.

$$-4 - (j1)(\mathbf{I}_3 - \mathbf{I}_1) + \mathbf{I}_3 = 0$$
$$(1 - j1)\mathbf{I}_3 + j1\mathbf{I}_1 = 4$$

Substitute $4\mathbf{I}_2$ for $\mathbf{I}_1$.

$$(1 - j1)\mathbf{I}_3 + (j1)(4\mathbf{I}_2) = 4$$

Substitute $2\angle 0^\circ$ A for $\mathbf{I}_2$.

$$(1 - j1)\mathbf{I}_3 + (j4)(2\angle 0^\circ) = 4$$
$$\mathbf{I}_3 = \frac{4 - j8}{1 - j1}$$
$$= 6.32\angle -18.4^\circ \text{ A}$$

The output voltage $\mathbf{V}_o$ is,

$$\mathbf{V}_o = (1)\mathbf{I}_3$$
$$= 6.32\angle -18.4^\circ \text{ V}$$

Thus, the voltage $\mathbf{V}_o$ is $\boxed{6.32\angle -18.4^\circ \text{ V}}$.

Step 1 of 4

Refer the circuit in Figure P8.79 in the textbook.

The circuit is represented by Figure 1.

Figure 1

Step 2 of 4

From Figure 1, the value of $I_3 = 4\angle 0^\circ$ A .

Apply Kirchhoff's voltage law to the circuit in loop-1.

$$(1)(I_1)+6-(j1)(I_1-4)=0$$
$$I_1-(j1)I_1+j4=-6$$
$$(1-j1)I_1=-6-j4$$

$$I_1=\frac{-6-j4}{1-j1}$$
$$=-1-j5$$

Step 3 of 4

Determine the value of V_x .

From the circuit,

$$V_x=-I_1$$

Substitute $-1-j5$ for I_1 .

$$V_x=-(-1-j5)$$
$$=1+j5$$

Step 4 of 4

Determine the value of V_0 .

From the circuit,

$$V_0=V_x$$

Substitute $1+j5$ for V_x .

$$V_0=1+j5\text{ V}$$
$$=5\angle 78.69^\circ\text{ V}$$

Therefore, the value of V_0 is $\boxed{5\angle 78.69^\circ\text{ V}}$.

Step 1 of 6

Refer the circuit in Figure P8.85 in the textbook.

In order to apply super position theorem, the current source in the circuit is open circuited and draw the modified circuit diagram as shown in Figure 1.

Figure 1

Step 2 of 6

Apply voltage division rule to determine the value of voltage, V_0'.

$$\begin{aligned} V_0' &= \left(\frac{-j1}{1+1-j1}\right)12\angle 0^\circ \\ &= \left(\frac{-j1}{2-j1}\right)12\angle 0^\circ \\ &= (0.2-j0.4)12 \\ &= (2.4-j4.8)\,\text{V} \end{aligned}$$

Step 3 of 6

Now, the voltage source is short circuited and draw the modified circuit diagram is shown in Figure-2.

Figure-2

Step 4 of 6

Determine the value of current, I_0''.

$$\begin{aligned} I_0'' &= \left(\frac{1}{1+1-j1}\right)(-4\angle 0^\circ) \\ &= \left(\frac{1}{2-j1}\right)(-4\angle 0^\circ) \\ &= (0.4+j0.2)(-4) \\ &= (-1.6-j0.8)\,\text{A} \end{aligned}$$

Step 5 of 6

Determine the value of voltage, V_0''.

$$V_0'' = (-j1)(I_0'').$$

Substitute $(-1.6-j0.8)\,\text{A}$ for I_0''.

$$\begin{aligned} V_0'' &= (-j1)(-1.6-j0.8) \\ &= -0.8+j1.6 \\ &= 1.79\angle 116.56^\circ\ \text{V} \end{aligned}$$

Step 6 of 6

Determine the value of V_0.

$$V_0 = V_0' + V_0''$$

Substitute $(2.4-j4.8)\,\text{V}$ for V_0', and $(-0.8+j1.6)\,\text{V}$ for V_0''.

$$\begin{aligned} V_0 &= (2.4-j4.8)+(-0.8+j1.6) \\ &= 1.6-j3.2 \\ &= 3.58\angle -63.43^\circ\ \text{V} \end{aligned}$$

Therefore, the value of voltage, V_0 is $\boxed{3.58\angle -63.43^\circ\ \text{V}}$.

Step 1 of 4

Refer to Figure P8.67 in the text book for the circuit.

Apply superposition theorem to find the output voltage.

Consider the current source and replace the voltage source with a short circuit.

Redraw the circuit by marking loop currents.

Figure 1

Step 2 of 4

Observe from Figure 1 that the loop current, $\mathbf{I}_1 = 2\angle 0°\ \text{A}$

Apply Kirchhoff's voltage law to the second loop.

$$(j4 - j2)(\mathbf{I}_2 - \mathbf{I}_1) + 2\mathbf{I}_2 = 0$$
$$(j2 + 2)\mathbf{I}_2 - (j2)\mathbf{I}_1 = 0$$

Substitute $2\angle 0°\ \text{A}$ for $\mathbf{I}_1$.

$$(j2 + 2)\mathbf{I}_2 - (j2)2 = 0$$
$$\mathbf{I}_2 = \frac{4j}{j2 + 2}$$
$$= 1 + j1\ \text{A}$$

Step 3 of 4

Consider the voltage source and replace the current source with an open circuit.

Redraw the circuit by marking loop current.

Figure 2

Step 4 of 4

Apply Kirchhoff's voltage law to the loop.

$$(j4 - j2)\mathbf{I}'_2 - 12 + 2\mathbf{I}'_2 = 0$$
$$(j2 + 2)\mathbf{I}'_2 = 12$$
$$\mathbf{I}'_2 = \frac{12}{2 + j2}$$
$$= 3 - j3$$

Determine the output voltage $\mathbf{V}_o$.

$$\mathbf{V}_o = 2(\mathbf{I}_2 + \mathbf{I}'_2)$$
$$= 2(1 + j1 + 3 - j3)$$
$$= 2(4 - j2)$$
$$= 8.944\angle -26.6°\ \text{V}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{8.944\angle -26.6°\ \text{V}}$.

Step 1 of 4

Refer to Figure P8.68 in the text book for the circuit.

Apply superposition theorem to find the current, $\mathbf{I}_o$.

Consider the current source and replace the voltage source with a short circuit. Redraw the circuit by marking node voltages.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law at node $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_1-\mathbf{V}_2}{-j1}-2=0$$

$$(1+j1)\mathbf{V}_1-j1\mathbf{V}_2=2 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law at node $\mathbf{V}_2$.

$$\frac{\mathbf{V}_2}{j1}+\frac{\mathbf{V}_2-\mathbf{V}_1}{-j1}+\frac{\mathbf{V}_2}{1}=0$$

$$-j1\mathbf{V}_1+\mathbf{V}_2=0$$

$$\mathbf{V}_1=-j\mathbf{V}_2$$

Substitute $-j\mathbf{V}_2$ for $\mathbf{V}_1$ in equation (1).

$$(1+j1)(-j\mathbf{V}_2)-j1\mathbf{V}_2=2$$

$$(1-j2)\mathbf{V}_2=2$$

$$\mathbf{V}_2=\frac{2}{1-j2}$$

$$=0.4+j0.8 \text{ V}$$

The voltage $\mathbf{V}_1$ is,

$$\mathbf{V}_1=-j(0.4+j0.8)$$

$$=0.8-j0.4 \text{ V}$$

The current $\mathbf{I}'_o$ is,

$$\mathbf{I}'_o=\frac{\mathbf{V}_1}{1}$$

$$=0.8-j0.4 \text{ A}$$

Step 3 of 4

Consider the voltage source and replace the current source with an open circuit.

Redraw the circuit by marking node voltages.

Figure 2

Step 4 of 4

Apply Kirchhoff's voltage law at node $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1}{j1}+\frac{\mathbf{V}_1}{1-j1}+\frac{\mathbf{V}_1-12}{1}=0$$

$$(1.5-j0.5)\mathbf{V}_1=12$$

$$\mathbf{V}_1=\frac{12}{1.5-j0.5}$$

$$=7.2+j2.4 \text{ V}$$

The current $\mathbf{I}''_o$ is,

$$\mathbf{I}''_o=\frac{\mathbf{V}_1}{1-j1}$$

$$=\frac{7.2+j2.4}{1-j1}$$

$$=2.4+j4.8 \text{ A}$$

The current $\mathbf{I}_o$ is,

$$\mathbf{I}_o=\mathbf{I}'_o+\mathbf{I}''_o$$

$$=0.8-j0.4+2.4+j4.8$$

$$=3.2+j4.4$$

$$=5.44\angle 53.97^\circ \text{ A}$$

Thus, the current $\mathbf{I}_o$ is $\boxed{5.44\angle 53.97^\circ \text{ A}}$.

Step 1 of 4

Refer to Figure P8.69 in the text book for the circuit.

Apply superposition theorem to find the voltage, $\mathbf{V}_o$.

Consider the voltage source and replace the current source with an open circuit.

Redraw the circuit by marking loop currents.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to the first loop.

$$-6+(1+j1)(\mathbf{I}_1-\mathbf{I}_2)+1\mathbf{I}_1=0$$

$$(2+j1)\mathbf{I}_1-(1+j1)\mathbf{I}_2=6 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law to the second loop.

$$(1+j1)(\mathbf{I}_2-\mathbf{I}_1)-j1\mathbf{I}_2=0$$
$$\mathbf{I}_2=(1+j1)\mathbf{I}_1$$

Substitute $(1+j1)\mathbf{I}_1$ for $\mathbf{I}_2$ in equation (1).

$$(2+j1)\mathbf{I}_1-(1+j1)(1+j1)\mathbf{I}_1=6$$
$$\mathbf{I}_1=\frac{6}{2-j1}$$
$$=2.4+j1.2 \text{ A}$$

Step 3 of 4

Consider the current source and replace the voltage source with a short circuit.

Redraw the circuit by marking node voltages.

Figure 2

Step 4 of 4

Apply Kirchhoff's current law to the node 1.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_1-\mathbf{V}_2}{j1}=2\angle 0^\circ$$

$$\mathbf{V}_1(1-j)+j\mathbf{V}_2=2 \text{ ..... (2)}$$

Apply Kirchhoff's current law to the node 2.

$$\frac{\mathbf{V}_2}{1}+\frac{\mathbf{V}_2}{-j1}+\frac{\mathbf{V}_2-\mathbf{V}_1}{j1}=0$$
$$j\mathbf{V}_1=-\mathbf{V}_2$$
$$\mathbf{V}_1=j\mathbf{V}_2$$

Substitute $j\mathbf{V}_2$ for $\mathbf{V}_1$ in equation (2).

$$j\mathbf{V}_2(1-j)+j\mathbf{V}_2=2$$
$$\mathbf{V}_2=\frac{2}{1+2j}$$
$$=0.4-j0.8 \text{ V}$$

The current $\mathbf{I}_2$ through $1\ \Omega$ resistor is,

$$\mathbf{I}_2=\frac{\mathbf{V}_2}{1}$$
$$=0.4-j0.8 \text{ A}$$

Determine the output voltage. $\mathbf{V}_o$.

$$\mathbf{V}_o=(\mathbf{I}_1+\mathbf{I}_2)(1)$$
$$=(2.4+j1.2+0.4-j0.8)$$
$$=2.8+j0.4$$
$$=2.828\angle 8.13^\circ \text{ V}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{2.828\angle 8.13^\circ \text{ V}}$.

Step 1 of 7

Refer the circuit in Figure P8.86 in the textbook.

In order to apply super position theorem, the current source in the circuit is open circuited and draw the modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 7

Determine the equivalent impedance of the circuit.

$$\begin{aligned} Z &= (1\Omega)\|(-j1+j1) \\ &= 1\|0 \\ &= 0\Omega \end{aligned}$$

The simplified circuit diagram is shown in Figure-2.

Figure-2

Step 3 of 7

Apply voltage division rule to determine voltage, V_0'.

$$\begin{aligned} V_0' &= \left(\frac{1}{1+0}\right)(-6\angle 0^\circ) \\ &= 6\angle 180^\circ \text{ V} \end{aligned}$$

Step 4 of 7

Now, the voltage source is short circuited and draw the modified circuit diagram is shown in Figure-3.

Figure-3

Step 5 of 7

The modified circuit diagram is shown in Figure 4.

Figure-4

Apply current-division rule to determine the value of current, I_1.

$$\begin{aligned} I_1 &= \left(\frac{-j1}{(-j1)+(j1+(1\|1))}\right)(6\angle 0^\circ \text{ A}) \\ &= \left(\frac{-j1}{(-j1)+\left(j1+\left(\frac{(1)(1)}{1+1}\right)\right)}\right)(6\angle 0^\circ \text{ A}) \\ &= \left(\frac{-j1}{(-j1)+(j1+0.5)}\right)(6\angle 0^\circ \text{ A}) \\ &= \left(\frac{-j1}{0.5}\right)6 \\ &= -j12 \text{ A} \end{aligned}$$

Step 6 of 7

Determine the value of voltage, V_0''.

$$\begin{aligned} V_0'' &= (I_1)(1\|1) \\ &= I_1\left(\frac{(1)(1)}{1+1}\right) \\ &= I_1\left(\frac{1}{2}\right) \\ &= 0.5I_1 \end{aligned}$$

Substitute $-j12\text{ A}$ for I_1.

$$\begin{aligned} V_0'' &= (0.5)(-j12) \\ &= -j6 \text{ V} \end{aligned}$$

Step 7 of 7

Determine the value of V_0.

$$V_0 = V_0' + V_0''$$

Substitute $6\angle 180^\circ \text{ V}$ for V_0', and $-j6\text{ V}$ for V_0''.

$$\begin{aligned} V_0 &= 6\angle 180^\circ - j6 \\ &= -6 - j6 \\ &= 8.48\angle -135^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{8.48\angle -135^\circ \text{ V}}$.

Step 1 of 6

Refer the circuit in Figure P8.87 in the textbook.

In order to apply superposition theorem, the current source is open circuited and draw the modified circuit diagram is shown in Figure-1.

Figure-1

Step 2 of 6

Determine the value of V_0' .

Apply voltage division rule to the circuit in Figure-1.

$$\begin{aligned} V_0' &= \left(\frac{2}{2+j2+1-j1}\right)6\angle 0^\circ \\ &= \left(\frac{2}{3+j1}\right)6\angle 0^\circ \\ &= (0.6-j0.2)6 \\ &= (3.6-j1.2)\text{ V} \end{aligned}$$

Step 3 of 6

Now, the voltage source is short circuited and the draw the modified circuit diagram is shown in Figure 2.

Figure-2

Step 4 of 6

Determine the value of current, I_0'' .

$$\begin{aligned} I_0'' &= \left(\frac{1-j1}{1-j1+2+j2}\right)(-2\angle 0^\circ) \\ &= \left(\frac{1-j1}{3+j1}\right)(-2\angle 0^\circ) \\ &= (0.2-j0.4)(-2) \\ &= (-0.4+j0.8)\text{ A} \end{aligned}$$

Step 5 of 6

Determine the value of voltage, V_0'' .

$$V_0'' = (2)I_0''$$

Substitute $(-0.4+j0.8)\text{ A}$ for I_0'' .

$$\begin{aligned} V_0'' &= (2)(-0.4+j0.8) \\ &= (-0.8+j1.6)\text{ V} \end{aligned}$$

Step 6 of 6

Determine the value of V_0 .

$$V_0 = V_0' + V_0''$$

Substitute $(3.6-j1.2)\text{ V}$ for V_0' , $(-0.8+j1.6)\text{ V}$ for V_0'' .

$$\begin{aligned} V_0 &= (3.6-j1.2)+(-0.8+j1.6) \\ &= 2.8+j0.4 \\ &= 2.83\angle 8.13^\circ\text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{2.83\angle 8.13^\circ\text{ V}}$.

Step 1 of 11

Refer the circuit in Figure P8.89 in the textbook.

In order to apply superposition theorem, the voltage source is short circuited and the circuit is represented by Figure 1.

Figure-1

Step 2 of 11

Determine the equivalent impedance of the circuit in Figure-1.

$$\begin{aligned} Z &= (-j2 \| 2) + j3 \\ &= \frac{(-j2)(2)}{-j2+2} + j3 \\ &= \frac{-j2}{1-j1} + j3 \\ &= 1 - j1 + j3 \\ &= (1 + j2) \\ &= 2.24\angle 63.43^\circ\ \Omega \end{aligned}$$

Step 3 of 11

The circuit in Figure-1 is represented by Figure-2.

Figure-2

Step 4 of 11

Determine the value of I_0'.

Apply current-division rule.

$$\begin{aligned} I_0' &= \left[\frac{(1+j2)}{(1+j2)+1+2}\right](-4\angle 0^\circ) \\ &= \left(\frac{1+j2}{4+j2}\right)(-4\angle 0^\circ) \\ &= (0.4 + j0.3)(-4) \\ &= -1.6 - j1.2 \\ &= 2\angle -143.13^\circ\ \text{A} \end{aligned}$$

Step 5 of 11

Determine the value of V_0'.

$$V_0' = 2I_0'$$

Substitute $2\angle -143.13^\circ\ \text{A}$ for I_0'.

$$\begin{aligned} V_0' &= 2(2\angle -143.13^\circ\ \text{A}) \\ &= 4\angle -143.13^\circ\ \text{V} \end{aligned}$$

Step 6 of 11

Now, the current source is open-circuited and the circuit is represented by Figure-3.

Figure-3

Step 7 of 11

The circuit in Figure-3 is represented by Figure-4.

Figure-4

Step 8 of 11

Determine the equivalent impedance of the circuit in Figure-4.

$$\begin{aligned} Z_1 &= (-j2 \| 2) \\ &= \frac{(-j2)(2)}{-j2+2} \\ &= \frac{-j2}{1-j1} \\ &= 1 - j1 \end{aligned}$$

Step 9 of 11

Determine the value of I_0''.

$$\begin{aligned} I_0'' &= \left[\frac{1-j1}{1-j1+1+2+j3}\right](8\angle 90^\circ) \\ &= \left[\frac{1-j1}{4+j2}\right](8\angle 90^\circ) \\ &= (0.1 - j0.3)(8\angle 90^\circ) \\ &= 2.4 + j0.8 \\ &= 2.53\angle 18.43^\circ\ \text{A} \end{aligned}$$

Step 10 of 11

Determine the value of V_0''.

$$V_0'' = 2I_0''$$

Substitute $2.53\angle 18.43^\circ\ \text{A}$ for I_0''.

$$\begin{aligned} V_0'' &= 2(2.53\angle 18.43^\circ\ \text{A}) \\ &= 5.06\angle 18.43^\circ\ \text{V} \end{aligned}$$

Step 11 of 11

Determine the value of V_0.

$$V_0 = V_0' + V_0''$$

Substitute $4\angle -143.13^\circ\ \text{V}$ for V_0', and $5.06\angle 18.43^\circ\ \text{V}$ for V_0''.

$$\begin{aligned} V_0 &= (4\angle -143.13^\circ\ \text{V}) + (5.06\angle 18.43^\circ\ \text{V}) \\ &= 1.6 - j0.8 \\ &= 1.79\angle -26.56^\circ\ \text{V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{1.79\angle -26.56^\circ\ \text{V}}$.

Step 1 of 9

Refer the circuit in Figure P8.88 in the textbook.

In order to apply superposition theorem, the voltage source is short circuited and draw the modified circuit diagram is shown in Figure-1.

Figure-1

Step 2 of 9

Apply Kirchhoff's Current Law to the circuit at node-2.

$$I_1 + I_3 + I_0' = 0$$

$$\frac{V_1}{-j2} + \frac{V_2}{j4} + \frac{V_3}{2} = 0$$

$$-2V_1 + V_2 + j2V_3 = 0 \text{ ..... (1)}$$

Step 3 of 9

Apply Kirchhoff's Current Law to the circuit at node-1.

$$I_1 + I_2 = 2\angle 0°$$

$$\frac{V_1}{-j2} + \frac{V_1 - V_3}{2} = 2\angle 0°$$

$$V_1 - j1(V_1 - V_3) = -j2(2\angle 0°)$$

$$(1 - j1)V_1 + j1V_3 = 4\angle -90° \text{ ..... (2)}$$

Step 4 of 9

From Figure 1,

$$V_2 - V_3 = 0$$

$$V_2 = V_3$$

Substitute V_3 for V_2 in equation (1).

$$-2V_1 + V_3 + j2V_3 = 0$$

$$-2V_1 + (1 + j2)V_3 = 0$$

$$2V_1 = (1 + j2)V_3$$

$$V_1 = \left(\frac{1 + j2}{2}\right)V_3$$

$$V_1 = (0.5 + j1)V_3 \text{ ..... (3)}$$

Step 5 of 9

Determine the value of voltage, V_3 .

Substitute equation (3) in equation (2).

$$(1 - j1)(0.5 + j1)V_3 + j1V_3 = 4\angle -90°$$

$$V_3\left[(1 - j1)(0.5 + j1) + j1\right] = 4\angle -90°$$

$$V_3\left[1.5 + j0.5 + j1\right] = -j4$$

$$V_3(1.5 + j1.5) = -j4$$

$$V_3 = \frac{-j4}{1.5 + j1.5}$$

$$= -1.33 - j1.33$$

$$= 1.88\angle -135° \text{ V}$$

Step 6 of 9

Determine the value of V_0' .

$$V_0' = V_3$$

Substitute $1.88\angle -135° \text{ V}$ for V_3 .

$$V_0' = 1.88\angle -135° \text{ V}$$

Step 7 of 9

Now, the current source is open-circuited and draw the modified circuit diagram is shown in Figure-2.

Figure-2

Step 8 of 9

Apply voltage-division rule to determine the value of voltage, V_0'' .

$$V_0'' = \left[\frac{2 \| (2 - j2)}{(2 \| (2 - j2)) + j4}\right](12\angle 0°)$$

$$= \left[\frac{\frac{(2)(2 - j2)}{2 + 2 - j2}}{\frac{(2)(2 - j2)}{2 + 2 - j2} + j4}\right](12)$$

$$= \left[\frac{4 - j4}{4 - j4 + j4(4 - j2)}\right](12)$$

$$= \left[\frac{4 - j4}{4 - j4 + j16 + 8}\right](12)$$

$$= \left(\frac{4 - j4}{12 + j12}\right)(12)$$

$$= \left(\frac{1 - j1}{3 + j3}\right)(12)$$

$$= -j4$$

$$= 4\angle -90° \text{ V}$$

Step 9 of 9

Determine the value of voltage, V_0 .

$$V_0 = V_0' + V_0''$$

Substitute $1.88\angle -135° \text{ V}$ for V_0' , $4\angle -90° \text{ V}$ for V_0'' .

$$V_0 = (1.88\angle -135°) + (4\angle -90°)$$

$$= -1.33 - j5.33$$

$$= 5.5\angle -104° \text{ V}$$

Thus, the value of voltage, V_0 is $\boxed{5.5\angle -104° \text{ V}}$.

Step 1 of 7

Consider only voltage source $6\angle 0^\circ$ is acting in the circuit other sources are absent that means voltage sources are short circuited current sources are open circuited.

Figure 1

Step 2 of 7

Apply voltage-division rule to Figure 1.

$$\begin{aligned}\mathbf{V}_o' &= 6\angle 0^\circ\left(\frac{1}{1+1}\right)\\ &= 6\angle 0^\circ\left(\frac{1}{2}\right)\\ &= 3\angle 0^\circ\,\mathrm{V}\end{aligned}$$

Voltage drop across the 1Ω resistor is $\boxed{3\angle 0^\circ\,\mathrm{V}}$.

Step 3 of 7

Consider only current source $4\angle 0^\circ\,\mathrm{A}$ is acting in the circuit other sources are absent that means voltage sources are short circuited current sources are open circuited.

Figure 2

Step 4 of 7

In Figure 2, the $(1-j1)\Omega$ impedance is parallel to a short circuit. Hence, its equivalent impedance will be zero. Therefore the circuit reduces to Figure 3.

Figure 3

Step 5 of 7

From Figure 3, current flowing through 1Ω resistor is,

$$\begin{aligned}\mathbf{I}_1 &= 4\angle 0^\circ\left(\frac{1}{1+1}\right)\\ &= 4\angle 0^\circ\left(\frac{1}{2}\right)\\ &= 2\angle 0^\circ\,\mathrm{A}\end{aligned}$$

Current flowing through 1Ω resistor is $2\angle 0^\circ\,\mathrm{A}$

The voltage drop across the 1Ω resistor is,

$$\begin{aligned}\mathbf{V}_o'' &= 1(\mathbf{I}_1)\\ &= (1)(2\angle 0^\circ)\\ &= 2\angle 0^\circ\,\mathrm{V}\end{aligned}$$

The voltage drop across the 1Ω resistor is $\boxed{2\angle 0^\circ\,\mathrm{V}}$

Step 6 of 7

Consider only current source $2\angle 0^\circ\,\mathrm{A}$ is acting in the circuit other sources are absent that means voltage sources are short circuited current sources are open circuited

Figure 4

Step 7 of 7

From Figure 4, current flowing through $1\,\Omega$ resistor is zero because of short circuit across the series combination of two $1\,\Omega$ resistors.

Thus, the voltage drop across the 1Ω resistor is,

$$\mathbf{V}_o''' = 0\,\mathrm{V}$$

Now output voltage $\mathbf{V}_o$ is,

$$\begin{aligned}\mathbf{V}_o &= \mathbf{V}_o' + \mathbf{V}_o'' + \mathbf{V}_o'''\\ &= 3\angle 0^\circ + 0 + 2\angle 0^\circ\\ &= 5\angle 0^\circ\,\mathrm{V}\end{aligned}$$

Thus, the output voltage $\mathbf{V}_o$ is $\boxed{5\angle 0^\circ\,\mathrm{V}}$.

Step 1 of 10

8.115P

Refer the circuit in Figure P8.91 in the textbook.

In order to apply superposition theorem, the voltage source is short circuited and the circuit source is active as shown in Figure 1.

Figure 1

Step 2 of 10

Determine the equivalent impedance of the circuit in Figure-1.

$$\begin{aligned} Z &= (1 \| 1) \\ &= \frac{(1)(1)}{1+1} \\ &= \frac{1}{2} \\ &= 0.5\Omega \end{aligned}$$

Step 3 of 10

The modified circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 10

Determine the value of voltage, V_0'.

$$\begin{aligned} V_0' &= \left[\frac{1(0.5-j1)}{1+0.5-j1}\right](4\angle 0^\circ) \\ &= \left(\frac{0.5-j1}{1.5-j1}\right)4 \\ &= 2.154 - j1.23 \\ &= 2.48\angle -29.73^\circ \text{ V} \end{aligned}$$

Step 5 of 10

In order to apply superposition theorem, the current source is open-circuited and the voltage source is active as shown in Figure 3.

Figure 3

Step 6 of 10

The modified circuit diagram is shown in Figure 4.

Figure 4

Step 7 of 10

Apply Kirchhoff's voltage law for loop-1 in Figure 4.

$$1(I_1) + 6 + 1(I_1 - I_2) = 0$$

$$I_1(1+1) - I_2 = -6$$

$$2I_1 - I_2 = -6$$

Apply Kirchhoff's voltage law for loop-2 in Figure 4.

$$1(I_2 - I_1) - 6 + 1(I_2) - j1(I_2) = 0$$

$$I_2(1+1-j1) - I_1 = 6$$

$$-I_1 + I_2(2-j1) = 6 \quad \text{..... (1)}$$

Step 8 of 10

Substitute $\frac{I_2 - 6}{2}$ for I_1 in equation (2).

$$-\left(\frac{I_2-6}{2}\right) + I_2(2-j1) = 6$$

$$(-0.5+2-1j)I_2 + 3 = 6$$

$$I_2 = \frac{3}{1.5-1j}$$

$$I_2 = 1.66\angle 33.69^\circ \text{ A}$$

Step 9 of 10

Determine the value of V_0''.

$$\begin{aligned} V_0'' &= (1)(I_2) \\ &= (1)(1.66\angle 33.69^\circ) \\ &= 1.66\angle 33.69^\circ \text{ V} \end{aligned}$$

Step 10 of 10

Determine the value of voltage, V_0.

$$V_0 = V_0' + V_0''$$

Substitute $2.48\angle -29.73^\circ$ V for V_0', and $1.66\angle 33.69^\circ$ V for V_0''.

$$\begin{aligned} V_0 &= 2.48\angle -29.73^\circ + 1.66\angle 33.69^\circ \\ &= 3.535 - j0.309 \\ &= 3.55\angle -4.99^\circ \text{ V} \end{aligned}$$

Thus, the value of voltage, V_0 is $\boxed{3.55\angle -4.99^\circ \text{ V}}$.

Step 1 of 3

8.116P

Refer to Figure P8.68 in the text book for the circuit.

Redraw the circuit by exchanging the voltage source and parallel resistance with a current of $12\angle 0^\circ$ A and a parallel resistance of $1\ \Omega$. Mark node voltages.

Figure 1

Step 2 of 3

Apply Kirchhoff's voltage law to node $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_1-\mathbf{V}_2}{-j1}=2$$

$$(1+j)\mathbf{V}_1-j\mathbf{V}_2=2 \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to node $\mathbf{V}_2$.

$$\frac{\mathbf{V}_2-\mathbf{V}_1}{-j1}+\frac{\mathbf{V}_2}{j1}+\frac{\mathbf{V}_2}{1}=12$$

$$-j\mathbf{V}_1+\mathbf{V}_2=12$$

$$\mathbf{V}_2=12+j\mathbf{V}_1$$

Substitute $12+j\mathbf{V}_1$ for $\mathbf{V}_2$ in equation (1).

$$(1+j)\mathbf{V}_1-j(12+j\mathbf{V}_1)=2$$

$$(2+j)\mathbf{V}_1=2+12j$$

$$\mathbf{V}_1=3.2+j4.4$$

$$=5.44\angle 53.97^\circ \text{ V}$$

Step 3 of 3

Determine the current $\mathbf{I}_o$.

$$\mathbf{I}_o=\frac{\mathbf{V}_1}{1}$$

$$=5.44\angle 53.97^\circ \text{ A}$$

Thus, the current $\mathbf{I}_o$ is $\boxed{5.44\angle 53.97^\circ \text{ A}}$.

Step 1 of 7

Refer the circuit in Figure P8.93 in the textbook.

Apply source transformation to convert the voltage source with series resistance to current sources with a parallel resistance.

Determine the value of current.

$$I = \frac{V}{Z}$$

Substitute $12\angle 0^\circ\ \text{V}$ for *V*, and 2Ω for *Z*.

$$\begin{aligned} I &= \frac{12\angle 0^\circ\ \text{V}}{2\Omega} \\ &= 6\angle 0^\circ\ \text{A} \end{aligned}$$

Step 2 of 7

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 3 of 7

In Figure 1, there are two current sources. The equivalent current source value is,

$$\begin{aligned} I &= 6\angle 0^\circ - 2\angle 0^\circ \\ &= 4\angle 0^\circ\ \text{A} \end{aligned}$$

In Figure 1, the voltage source $4\angle -90^\circ\ \text{V}$ with series impedance of $(1 - j1)\Omega$ is exchanged with current source with parallel impedance.

Determine the value of current.

$$I = \frac{V}{Z}$$

Substitute $4\angle -90^\circ\ \text{V}$ for *V*, and $(1 - j1)\Omega$ for *Z*.

$$\begin{aligned} I &= \frac{4\angle -90^\circ\ \text{V}}{(1 - j1)\Omega} \\ &= 2 - j2 \\ &= 2.83\angle -45^\circ\ \text{A} \end{aligned}$$

Step 4 of 7

The simplified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 7

Calculate the equivalent impedance of the circuit.

$$\begin{aligned} Z_{eq} &= 2 \| (1 - j1) \\ &= \frac{2(1 - j1)}{2 + (1 - j1)} \\ &= \frac{2 - j2}{3 - j1} \\ &= (0.8 - j0.4)\Omega \end{aligned}$$

In Figure 2, there are two current sources. The equivalent current source value is,

$$\begin{aligned} I &= 4\angle 0^\circ + 2.83\angle -45^\circ \\ &= 6.326\angle -18.44^\circ\ \text{A} \end{aligned}$$

Step 6 of 7

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 7

Apply current-division rule to determine the value of I_0.

$$\begin{aligned} I_0 &= \left[\frac{0.8 - j0.4}{0.8 - j0.4 + 2}\right](6.326\angle -18.44^\circ) \\ &= \left[\frac{0.8 - j0.4}{2.8 - j0.4}\right](6.326\angle -18.44^\circ) \\ &= 1.6 - j1.2 \\ &= 2\angle -36.87^\circ\ \text{A} \end{aligned}$$

Thus, the value of current, I_0 is $\boxed{2\angle -36.87^\circ\ \text{A}}$.

Step 1 of 7

Refer the circuit in Figure P8.95 in the textbook.

Apply source transformation to convert the voltage source with series resistance to current sources with a parallel resistance.

Determine the value of current.

$$I = \frac{V}{Z}$$

Substitute $12\angle 0^\circ \text{ V}$ for *V*, and $-j1\Omega$ for *Z*.

$$\begin{aligned} I &= \frac{12\angle 0^\circ \text{ V}}{-j1\Omega} \\ &= 12\angle 90^\circ \text{ A} \end{aligned}$$

Step 2 of 7

The source transformed circuit is shown in Figure 1.

Figure 1

Step 3 of 7

Calculate the equivalent impedance of the circuit.

$$\begin{aligned} Z_{eq} &= 1 \| -j1 \\ &= \frac{1(-j1)}{1-j1} \\ &= \frac{-j1}{1-j1} \\ &= (0.5 - j0.5)\Omega \end{aligned}$$

In Figure 1, two current sources are there. The equivalent current source value is,

$$\begin{aligned} I &= 12\angle 90^\circ - 2\angle 0^\circ \\ &= -2 + j12 \\ &= 12.16\angle 99.46^\circ \text{ A} \end{aligned}$$

Step 4 of 7

The modified circuit diagram is shown in Figure 2

Figure 2

Step 5 of 7

In Figure 2, the current source $12.16\angle 99.46^\circ \text{ A}$ with parallel impedance of $(0.5 - j0.5)\Omega$ is exchanged with voltage source with series impedance.

Determine the value of voltage.

$$V = IZ$$

Substitute $12.16\angle 99.46^\circ \text{ A}$ for *I*, and $(0.5 - j0.5)\Omega$ for *Z*.

$$\begin{aligned} V &= (12.16\angle 99.46^\circ \text{ A})(0.5 - j0.5)\Omega \\ &= 8.6\angle 54.56^\circ \text{ V} \end{aligned}$$

Step 6 of 7

The simplified circuit diagram is shown in Figure 3.

Figure 3

Step 7 of 7

Apply voltage-division rule to determine the value of V_0.

$$\begin{aligned} V_0 &= \left(\frac{2}{2 + 0.5 - j0.5}\right)(6\angle 0^\circ + 8.6\angle 54.56^\circ) \\ &= \left(\frac{2}{2.5 - j0.5}\right)(6\angle 0^\circ + 8.6\angle 54.56^\circ) \\ &= 7.3734 + j7.0799 \\ &= 10.22\angle 43.84^\circ \text{ V} \end{aligned}$$

Thus, the value of voltage, V_0 is $\boxed{10.22\angle 43.84^\circ \text{ V}}$.

Step 1 of 9

Refer to circuit diagram in Figure P8.119 in the textbook. $1\ \Omega$ resistor and current source are connected in parallel. Convert parallel combination of current source and resistor into series combination of voltage source and resistor using source transformation.

Calculate the value of voltage source.

$$\begin{aligned}\mathbf{V}_{S1} &= (2\angle 0^\circ\ \text{A})(1\ \Omega)\\ &= 2\angle 0^\circ\ \text{V}\end{aligned}$$

In the circuit, $1\ \Omega$ and $12\ \Omega$ resistors are connected in parallel. Calculate the equivalent resistance.

$$\begin{aligned}R_{eq1} &= (1\ \Omega)\|(12\ \Omega)\\ &= \frac{(1\ \Omega)(12\ \Omega)}{1\ \Omega + 12\ \Omega}\\ &= \frac{12\ \Omega}{13}\\ &= 0.923\ \Omega\end{aligned}$$

Step 2 of 9

The simplified circuit is shown in Figure 1.

Figure 1

Step 3 of 9

In the circuit shown in Figure 1, $12\angle 0^\circ\ \text{V}$ voltage source is in series with resistor. Convert this series combination into parallel combination of current source and resistor using source transformation.

Calculate the value of current source.

$$\begin{aligned}\mathbf{I}_{S1} &= \frac{12\angle 0^\circ\ \text{V}}{0.923\ \Omega}\\ &= 13\angle 0^\circ\ \text{A}\end{aligned}$$

Step 4 of 9

The modified circuit is shown in Figure 2.

Figure 2

Step 5 of 9

In the circuit shown in Figure 2, $13\angle 0^\circ\ \text{A}$ current source, $0.923\ \Omega$ resistor and $-2\ \Omega$ capacitor are connected in parallel. Convert this parallel combination into series combination of voltage series source series with impedance using source transformation.

Calculate the equivalent source.

$$\begin{aligned}R_{eq2} &= (0.923\ \Omega)\|(-j2\ \Omega)\\ &= \left(\frac{(0.923\ \Omega)(-j2\ \Omega)}{0.923 - j2\ \Omega}\right)\\ &= 0.76 - j0.35\ \Omega\end{aligned}$$

Calculate the value of voltage source.

$$\begin{aligned}\mathbf{V}_{S2} &= (13\angle 0^\circ\ \text{V})(0.76 - j0.35\ \Omega)\\ &= 9.89 - j4.56\ \Omega\\ &= 10.89\angle -24.77^\circ\ \text{V}\end{aligned}$$

Step 6 of 9

The simplified circuit is shown in Figure 3.

Figure 3

Step 7 of 9

In the circuit, two voltage sources are connected in series. Calculate the total voltage.

$$\begin{aligned}\mathbf{V}_S &= 10.89\angle -24.77^\circ\ \text{V} + 2\angle 0^\circ\ \text{V}\\ &= 9.89 - j4.56 + 2\ \text{V}\\ &= 11.89 - j4.56\ \text{V}\\ &= 12.738\angle -21^\circ\ \text{V}\end{aligned}$$

In the circuit, two resistors are connected in series. Calculate the equivalent resistance.

$$\begin{aligned}R_{eq} &= 0.76\ \Omega + 1\ \Omega\\ &= 1.76\ \Omega\end{aligned}$$

Step 8 of 9

The modified circuit is shown in Figure 4.

Figure 4

Step 9 of 9

Calculate the output voltage.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{1\ \Omega}{1.76 - j0.35 + 1\ \Omega}\right)(12.738\angle -21^\circ\ \text{V})\\ &= \left(\frac{1\ \Omega}{2.76 - j0.35\ \Omega}\right)(11.89 - j4.56\ \text{V})\\ &= (0.3565 + j0.045)(11.89 - j4.56\ \text{V})\\ &= 4.446 - j1.09\ \text{V}\end{aligned}$$

$$= 4.578\angle -13.77^\circ\ \text{V}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{4.578\angle -13.77^\circ\ \text{V}}$.

Step 1 of 12

Refer the circuit in Figure P8.98 in the textbook.

Voltage source with series impedance is exchanged with current source with parallel impedance and vice versa.

Determine the value of voltage.

From ohms law,

$$V = IZ$$

Substitute $2\angle 0^\circ\ \text{A}$ for I, and 5Ω for Z.

$$\begin{aligned} V &= (2\angle 0^\circ\ \text{A})(5\Omega) \\ &= 10\angle 0^\circ\ \text{V} \end{aligned}$$

Determine the value of current.

From ohms law,

$$V = IZ$$

$$I = \frac{V}{Z}$$

Substitute $4\angle 0^\circ\ \text{V}$ for V, and 2Ω for Z.

$$\begin{aligned} I &= \frac{4\angle 0^\circ\ \text{V}}{2\Omega} \\ &= 2\angle 0^\circ\ \text{A} \end{aligned}$$

Step 2 of 12

The circuit is represented by Figure-1.

Figure 1

Step 3 of 12

Determine the value of equivalent impedance.

$$\begin{aligned} Z_{eq} &= 2 \| 2 \\ &= \frac{2(2)}{2+2} \\ &= \frac{4}{4} \\ &= 1\Omega \end{aligned}$$

Step 4 of 12

The circuit in Figure-1 is represented by Figure-2.

Figure-2

Step 5 of 12

Current source with parallel impedance is transformed to a voltage source with series impedance.

Determine the value of voltage.

From ohms law,

$$V = IZ$$

Substitute $2\angle 0^\circ\ \text{A}$ for I, and 1Ω for Z.

$$\begin{aligned} V &= (2\angle 0^\circ\ \text{A})(1\Omega) \\ &= 2\angle 0^\circ\ \text{V} \end{aligned}$$

Step 6 of 12

The circuit in Figure-2 is represented by Figure-3.

Figure-3

Step 7 of 12

Determine the value of equivalent voltage.

$$\begin{aligned} V &= (6\angle 0^\circ\ \text{V}) - (2\angle 0^\circ\ \text{V}) \\ &= 4\angle 0^\circ\ \text{V} \end{aligned}$$

Voltage source with series impedance is transformed to current source with parallel impedance.

Determine the value of current.

From ohms law,

$$V = IZ$$

$$I = \frac{V}{Z}$$

Substitute $4\angle 0^\circ\ \text{V}$ for V, and 1Ω for Z.

$$\begin{aligned} I &= \frac{4\angle 0^\circ\ \text{V}}{1\Omega} \\ &= 4\angle 0^\circ\ \text{A} \end{aligned}$$

Step 8 of 12

The circuit in Figure-3 is represented by Figure-4.

Figure-4

Step 9 of 12

Determine the value of equivalent impedance.

$$\begin{aligned} Z_{eq} &= 1 \| 1 \\ &= \frac{1(1)}{1+1} \\ &= \frac{1}{2} \\ &= 0.5\Omega \end{aligned}$$

Current source with parallel impedance is transformed to a voltage source with series impedance.

Determine the value of voltage.

From ohms law,

$$V = IZ$$

Substitute $4\angle 0^\circ\ \text{A}$ for I, and 0.5Ω for Z.

$$\begin{aligned} V &= (2\angle 0^\circ\ \text{A})(1\Omega) \\ &= 2\angle 0^\circ\ \text{V} \end{aligned}$$

Step 10 of 12

The circuit in Figure-4 is represented by Figure-5.

Figure-5

Step 11 of 12

Determine the value of equivalent voltage.

$$\begin{aligned} V &= (10\angle 0^\circ\ \text{V}) - (2\angle 0^\circ\ \text{V}) \\ &= 8\angle 0^\circ\ \text{V} \end{aligned}$$

The circuit in Figure-5 is represented by Figure-6.

Figure-6

Step 12 of 12

Determine the value of V_0.

$$\begin{aligned} V_0 &= \left(\frac{1}{5+0.5-j2+1}\right)8 \\ &= \left(\frac{2}{13-j4}\right)8 \\ &= \frac{16}{13-j4} \\ &= 1.124 + j0.345 \\ &= 1.175\angle 17.06^\circ\ \text{V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{1.175\angle 17.06^\circ\ \text{V}}$.

Step 1 of 9

Refer the circuit in Figure P8.99 in the textbook.

The circuit in Figure P8.99 is represented by Figure-1.

Figure-1

Step 2 of 9

Voltage source with series impedance is exchanged with current source with parallel impedance.

Determine the value of current (left).

From ohms law,

$$V = IZ$$

$$I = \frac{V}{Z}$$

Substitute $6\angle 0^\circ\ \text{V}$ for *V*, and 3Ω for *Z*.

$$I = \frac{6\angle 0^\circ\ \text{V}}{3\Omega}$$
$$= 2\angle 0^\circ\ \text{A}$$

Step 3 of 9

Determine the value of current (right).

From ohms law,

$$V = IZ$$

$$I = \frac{V}{Z}$$

Substitute $8\angle 0^\circ\ \text{V}$ for *V*, and 4Ω for *Z*.

$$I = \frac{8\angle 0^\circ\ \text{V}}{4\Omega}$$
$$= 2\angle 0^\circ\ \text{A}$$

Step 4 of 9

The circuit in Figure-1 is represented by Figure-2.

Figure 2

Step 5 of 9

Calculate the value of equivalent impedance.

$$Z_1 = 3 \| 6$$
$$= \frac{(3)(6)}{3+6}$$
$$= \frac{18}{9}$$
$$= 2\Omega$$

$$Z_2 = 12 \| 4$$
$$= \frac{(12)(4)}{12+4}$$
$$= \frac{48}{16}$$
$$= 3\Omega$$

Determine the equivalent current (left).

$$I = 2\angle 0^\circ\ \text{V} + 2\angle 0^\circ\ \text{V}$$
$$= 4\angle 0^\circ\ \text{V}$$

Determine the equivalent current (right).

$$I = 2\angle 0^\circ\ \text{V} + \left(-4\angle 0^\circ\ \text{V}\right)$$
$$= -2\angle 0^\circ\ \text{V}$$

Step 6 of 9

The circuit in Figure-2 is represented by Figure-3.

Figure-3

Current source with parallel impedance is transformed to voltage source with series impedance.

Determine the value of voltage (left).

From ohms law,

$$V = IZ$$

Substitute $4\angle 0^\circ\ \text{A}$ for *I*, and 2Ω for *Z*.

$$V = \left(4\angle 0^\circ\ \text{A}\right)\left(2\Omega\right)$$
$$= 8\angle 0^\circ\ \text{V}$$

Step 7 of 9

Determine the value of voltage (right).

From ohms law,

$$V = IZ$$

Substitute $2\angle 0^\circ\ \text{A}$ for *I*, and 3Ω for *Z*.

$$V = \left(2\angle 0^\circ\ \text{A}\right)\left(3\Omega\right)$$
$$= 6\angle 0^\circ\ \text{V}$$

Step 8 of 9

The circuit in Figure-3 is represented by Figure-4.

Figure-4

Step 9 of 9

Determine the value of I_0.

Apply current-division rule.

$$I_0 = \left(\frac{1}{1+2+3-j3}\right)\left(8\angle 0^\circ + 6\angle 0^\circ\right)$$
$$= \left(\frac{1}{6-j3}\right)(14)$$
$$= 1.86 + j0.93$$
$$= 2.08\angle 26.56^\circ\ \text{A}$$

Therefore, the value of I_0 is $\boxed{2.08\angle 26.56^\circ\ \text{A}}$.

Step 1 of 6

Refer to Figure P8.67 in the textbook.

Draw the following circuit diagram to determine the Thevenin voltage.

Figure 1

Step 2 of 6

Apply nodal analysis at node $\mathbf{V_1}$.

$$\frac{\mathbf{V_1}}{-j2+j4}=2\angle 0°$$

$$\begin{aligned}\mathbf{V_1}&=(2\angle 0°)(-j2+j4)\\&=j4\\&=4\angle 90°\end{aligned}$$

Use Kirchhoff's voltage law to determine the Thevenin voltage.

$$-4\angle 90°+12\angle 0°+\mathbf{V_{Th}}=0$$

$$\begin{aligned}\mathbf{V_{Th}}&=(4\angle 90°+12\angle 0°)\\&=4j+12\\&=12.64\angle 18.434°\,\mathrm{V}\end{aligned}$$

Step 3 of 6

Draw the following circuit diagram to determine the value of Thevenin resistance.

Figure 2

Step 4 of 6

Determine the value of Thevenin impedance using Figure 2.

$$\begin{aligned}\mathbf{Z_{TH}}&=(-j2)+4j\\&=2j\end{aligned}$$

Step 5 of 6

Draw the following Thevenin equivalent circuit diagram.

Figure 3

Step 6 of 6

Determine the value of output voltage using Figure 3.

$$\begin{aligned}\mathbf{V_o}&=(12.64\angle 18.434°\,\mathrm{V})\left(\frac{2}{2+j2}\right)\\&=(12.64\angle 18.434°\,\mathrm{V})(0.707\angle -45°)\\&=8.937\angle -26.56°\,\mathrm{V}\end{aligned}$$

Thus, the output voltage, $\mathbf{V_o}$ is $\boxed{8.937\angle -26.56°\ \mathrm{V}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.68 in the textbook.

To calculate the Thevenin's voltage across the load, open the terminals and calculate the open circuit or Thevenin's voltage. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law at the node, $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1-\mathbf{V}_2}{-j1}=2\angle 0°$$
$$\mathbf{V}_1-\mathbf{V}_2=-j2$$
$$\mathbf{V}_2=\mathbf{V}_1+j2 \quad \text{..... (1)}$$

Apply Kirchhoff's current law at the node, $\mathbf{V}_2$.

$$\frac{\mathbf{V}_2-12\angle 0°}{1}+\frac{\mathbf{V}_2-\mathbf{V}_1}{-j1}+\frac{\mathbf{V}_2}{j1}=0$$
$$-j\mathbf{V}_1+\mathbf{V}_2(1+j-j)=12$$
$$-j\mathbf{V}_1+\mathbf{V}_2=12$$

Substitute $\mathbf{V}_1+j2$ for $\mathbf{V}_2$.

$$-j\mathbf{V}_1+\mathbf{V}_1+j2=12$$
$$(1-j)\mathbf{V}_1=12-j2$$
$$\begin{aligned}\mathbf{V}_1&=\frac{12-j2}{1-j}\\&=7+j5\\&=8.6\angle 35.53°\ \text{V}\end{aligned}$$

Calculate the Thevenin's voltage.

$$\begin{aligned}\mathbf{V}_{Th}&=\mathbf{V}_1\\&=8.6\angle 35.53°\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance, short circuit the voltage source and open circuit the current source. The modified circuit is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th}&=(1\ \Omega)\|(j\ \Omega)-j\ \Omega\\&=\frac{(1\ \Omega)(j\ \Omega)}{1+j\ \Omega}-j\ \Omega\\&=0.5+j0.5-j\ \Omega\\&=0.5-j0.5\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the output current.

$$\begin{aligned}\mathbf{I}_o&=\frac{8.6\angle 35.53°\ \text{V}}{0.5+j0.5-1\ \Omega}\\&=\frac{8.6\angle 35.53°\ \text{V}}{1.5-j0.5\ \Omega}\\&=\frac{8.6\angle 35.53°\ \text{V}}{1.581\angle -18.43°\ \Omega}\\&=5.44\angle 53.96°\ \text{A}\end{aligned}$$

Therefore, the output current, $\mathbf{I}_o$ is $\boxed{5.44\angle 53.96°\ \text{A}}$.

8.124P

Refer to circuit diagram in Figure P8.69 in the textbook.

To calculate the Thevenin's voltage across the load, open the terminals and calculate the open circuit or Thevenin's voltage. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 6

Apply nodal analysis at the node, V_{Th} .

$$\frac{V_{Th}-6\angle 0°}{-j1}+\frac{V_{Th}-V_1}{j1}=0$$
$$-V_{Th}+6\angle 0°+V_{Th}-V_1=0$$
$$6\angle 0°-V_1=0$$
$$V_1=6\angle 0°\ \text{V}$$

Apply nodal analysis at the node, V_1 .

$$\frac{V_1-6\angle 0°}{1}+\frac{V_1-V_{Th}}{j1}=2\angle 0°$$
$$V_1-6\angle 0°-jV_1+jV_{Th}=2\angle 0°$$
$$V_1(1-j)+jV_{Th}=2+6$$
$$V_{Th}=\frac{8-V_1(1-j)}{j}$$

Substitute $6\ \text{V}$ for V_1 in the equation.

$$\begin{aligned}V_{Th}&=\frac{8-(6\ \text{V})(1-j)}{j}\\&=\frac{8-6+j6}{j}\\&=6-j2\ \text{V}\\&=6.324\angle -18.44°\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance, short circuit the voltage source and open circuit the current source. The modified circuit is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}Z_{Th}&=(1\ \Omega+j\ \Omega)\|(-j\ \Omega)\\&=\frac{(1+j\ \Omega)(-j\ \Omega)}{1+j-j\ \Omega}\\&=-j+1\ \Omega\\&=1-j\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the output current.

$$\begin{aligned}V_o&=\left(\frac{1\ \Omega}{1-j+1\ \Omega}\right)(6.324\angle -18.44°\ \text{V})\\&=(0.4+j0.2)(6.324\angle -18.44°\ \text{V})\\&=(0.447\angle 26.56°)(6.324\angle -18.44°\ \text{V})\\&=2.827\angle 8.12°\ \text{V}\end{aligned}$$

Therefore, the output voltage, V_o is $\boxed{2.827\angle 8.12°\ \text{V}}$.

Step 1 of 4

Refer to Figure P8.101 in the textbook.

Open circuit the $2\ \Omega$ resistor, and find the voltage across this open circuited terminals.

Draw the modified circuit to find the open-circuit voltage.

Figure 1

The only current available in the circuit is $\mathbf{I}_2 = 4\angle 90°\ \mathrm{A}$, and it does not flow through the capacitor due to open terminals below the capacitor.

Determine the open-circuit voltage, $\mathbf{V}_{OC}$.

$$\begin{aligned}\mathbf{V}_{OC} &= 4(4\angle 90°) + 12\angle 0° \\ &= 16\angle 90° + 12\angle 0° \\ &= 12 + j16 \\ &= 20\angle 53.13°\ \mathrm{V}\end{aligned}$$

Step 2 of 4

Determine the value of Thevenin's equivalent impedance.

Short circuit the voltage sources and open circuit the current sources in the circuit to calculate the Thevenin's equivalent impedance.

Draw the modified circuit to find the Thevenin's equivalent impedance.

Figure 2

Determine the Thevenin's equivalent impedance.

$$Z_{Th} = 4 - j4\ \Omega$$

Step 3 of 4

Connect the $2\ \Omega$ load resistance to the Thevenin's equivalent circuit.

Draw the simplified circuit.

Figure 3

Step 4 of 4

Apply voltage division rule to determine the value of $\mathbf{V}_O$ in the circuit.

$$\begin{aligned}\mathbf{V}_O &= \left(\frac{2}{2 - j2 + 4}\right)(20\angle 53.13°) \\ &= \left(\frac{2}{6 - j4}\right)(20\angle 53.13°) \\ &= (0.23 + j0.15)(20\angle 53.13°) \\ &= 0.36 + j5.47\end{aligned}$$

$$\mathbf{V}_O = 5.5\angle 86.23°\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{5.5\angle 86.23°\ \mathrm{V}}$.

Step 1 of 9

Refer the circuit in Figure P8.102 in the textbook.

In order to apply Thevenin theorem twice, the circuit is open circuited at $j1\Omega$ terminal and the circuit is represented by Figure-1.

Figure-1

Step 2 of 9

Determine the value of V_{OC_1}.

Apply voltage-division rule.

$$\begin{aligned} V_{OC_1} &= \left(\frac{-j1}{1-j1}\right)\left(6\angle 0^\circ\right) \\ &= (0.5-j0.5)6 \\ &= (3-j3) \\ &= 4.24\angle -45^\circ \text{ V} \end{aligned}$$

Step 3 of 9

Determine the value of Thevenin impedance, Z_{TH_1}.

The circuit for Thevenin impedance is represented by Figure-2.

Figure-2

Impedace of the circuit is,

$$\begin{aligned} Z_{TH_1} &= (1 \| -j1)+2 \\ &= \frac{(1)(-j1)}{1-j1}+2 \\ &= 0.5-j0.5+2 \\ &= 2.5-j0.5 \\ &= 2.55\angle -11.3^\circ\ \Omega \end{aligned}$$

Step 4 of 9

Now, the circuit is represented by Figure-3.

Figure-3

Step 5 of 9

Now, the output terminal is short circuited at 1Ω and the circuit is represented by Figure-4.

Figure-4

Step 6 of 9

Determine the value of V_{OC_2}.

Apply voltage-division rule.

$$\begin{aligned} V_{OC_2} &= \left(\frac{j1}{j1+2.5-j0.5}\right)(3-j3) \\ &= \left(\frac{j1}{2.5+j0.5}\right)(3-j3) \\ &= (0.077+j0.38)(3-j3) \\ &= 1.37+j0.91 \\ &= 1.64\angle 33.59^\circ \text{ V} \end{aligned}$$

Step 7 of 9

Determine the value of Thevenin impedance.
The circuit for Thevenin impedance is represented by Figure-5.

Figure-5

$$\begin{aligned} Z_{TH_2} &= 1+\left[(2.5-j0.5) \| j1\right] \\ &= 1+\left[\frac{(2.5-j0.5)(j1)}{(2.5-j0.5)+(j1)}\right] \\ &= 1+\frac{0.5+j2.5}{2.5+j0.5} \\ &= 1+0.38+j0.92 \\ &= 1.38+j0.92 \\ &= 1.66\angle 33.69^\circ\ \Omega \end{aligned}$$

Step 8 of 9

The equivalent circuit of the network is represented by Figure-6.

Figure-6

Step 9 of 9

Determine the value of V_0.

Apply voltage-division rule.

$$\begin{aligned} V_0 &= \left(\frac{1}{1+1.66\angle 33.69^\circ}\right)\left(1.64\angle 33.59^\circ\right) \\ &= \left(\frac{1}{1+1.38+j0.92}\right)(1.37+j0.91) \\ &= \left(\frac{1}{2.38+j0.92}\right)(1.37+j0.91) \\ &= (0.36-j0.14)(1.37+j0.91) \\ &= 0.62+j0.13 \\ &= 0.63\angle 11.84^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{0.63\angle 11.84^\circ \text{ V}}$.

Step 1 of 6

Refer to the Figure P8.127 in the text book.

Draw the following circuit diagram to determine the thevenins voltage.

Figure 1

Step 2 of 6

Use Kirchhoff's current law in Figure 1 to determine the voltage $\mathbf{V}_{TH}$.

$$\frac{\mathbf{V}_{\mathrm{Th}} - 6\angle 0^\circ}{1} - 2\angle 0^\circ = 0$$

$$\mathbf{V}_{\mathrm{Th}} = 6\angle 0^\circ + 2\angle 0^\circ$$

$$\mathbf{V}_{\mathrm{Th}} = 8\angle 0^\circ$$

Step 3 of 6

Draw the following circuit diagram to determine the thevenins impedance.

Figure 2

Step 4 of 6

Determine the voltage $\mathbf{Z}_{\mathrm{Th}}$ using Figure 2.

$$\begin{aligned}\mathbf{Z}_{\mathrm{Th}} &= -j2 + 1 \\ &= 1 - j2\end{aligned}$$

Step 5 of 6

Draw the following circuit thevenins equivalent diagram:

Figure 3

Step 6 of 6

Determine the value of output voltage using Figure 3.

Use voltage divider rule.

$$\begin{aligned}\mathbf{V}_o &= (8\angle 0^\circ)\left(\frac{1}{1+(-j2+1)}\right) \\ &= (8\angle 0^\circ)\left(\frac{1}{2-2j}\right) \\ &= (8\angle 0^\circ)(0.3535\angle 45^\circ) \\ &= 2.828\angle 45^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of output voltage is $\boxed{\mathbf{V}_o = 2.828\angle 45^\circ\ \mathrm{V}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.128 in the textbook.

To calculate the Thevenin's voltage, open the load resistor $(1\ \Omega)$ and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the open circuit voltage.

$$\begin{aligned}\mathbf{V}_{oc} &= 12\angle 0^\circ\ \text{V} + (j1\ \Omega)(2\angle 0^\circ\ \text{A})\\ &= 12\angle 0^\circ\ \text{V} + 2\angle 90^\circ\ \text{V}\\ &= 12 + j2\ \text{V}\\ &= 12.265\angle 9.46^\circ\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance from the load terminals, short circuit the voltage source and open circuit the current source to zero impedance. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th} &= (1 - j\ \Omega) \| (0\ \Omega) + j1\ \Omega\\ &= 0 + j1\ \Omega\\ &= j1\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the output current.

$$\begin{aligned}\mathbf{I}_o &= \frac{12.265\angle 9.46^\circ\ \text{V}}{1 + j\ \Omega}\\ &= \frac{12.265\angle 9.46^\circ\ \text{V}}{1.414\angle 45^\circ\ \Omega}\\ &= 0.894\angle -35.54^\circ\ \text{A}\\ &= 894\angle -35.54^\circ\ \text{mA}\end{aligned}$$

Therefore, the output current, $\mathbf{I}_o$ is $\boxed{894\angle -35.54^\circ\ \text{mA}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.129 in the textbook.

To calculate the Thevenin's voltage, open the load resistor $(2\ \Omega)$ and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the open circuit voltage.

$$\begin{aligned}\mathbf{V}_{oc} &= (-j1\ \Omega)(2\angle 0°\ \text{A}) - 12\angle 0°\ \text{V}\\ &= 2\angle -90°\ \text{V} - 12\angle 0°\ \text{V}\\ &= -12 - j2\ \text{V}\\ &= 12.265\angle -170.54°\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance from the load terminals, short circuit the voltage source and open circuit the current source to zero impedance. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th} &= -j1\ \Omega + (1 + j\ \Omega) \| (0\ \Omega)\\ &= -j1\ \Omega + 0\\ &= -j1\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the voltage across the $2\ \Omega$ resistor.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{2\ \Omega}{2 - j\ \Omega}\right)(12.265\angle -170.54°\ \text{V})\\ &= (0.8 + j0.4)(12.265\angle -170.54°\ \text{V})\\ &= (0.894\angle 26.56°)(12.265\angle -170.54°\ \text{V})\\ &= 10.88\angle -143.98°\ \text{V}\end{aligned}$$

Therefore, the voltage across the $2\ \Omega$ resistor, $\mathbf{V}_o$ is $\boxed{10.88\angle -143.98°\ \text{V}}$.

Step 1 of 7

Refer to circuit diagram in Figure P8.129 in the textbook.

To calculate the Thevenin's voltage, open the load resistor $(2\ \Omega)$ and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 7

From the circuit shown in Figure 1, a current source is between loops 1 and 2, and it forms supermesh. Write the current expression.

$$\mathbf{I}_2 - \mathbf{I}_1 = 2\ \text{A}$$

$$\mathbf{I}_2 = \mathbf{I}_1 + 2\ \text{A} \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to supermesh.

$$\mathbf{I}_1 + (1 - j1)\mathbf{I}_2 = 12\ \text{V}$$

Substitute $\mathbf{I}_1 + 2\ \text{A}$ for $\mathbf{I}_2$ in the equation.

$$\mathbf{I}_1 + (1 - j1)(\mathbf{I}_1 + 2\ \text{A}) = 12\ \text{V}$$
$$(2 - j1)\mathbf{I}_1 = 12 - 2 + j2\ \text{A}$$

$$\mathbf{I}_1 = \frac{10 + j2\ \text{A}}{2 - j1}$$
$$= 3.6 + j2.8\ \text{A}$$

Step 3 of 7

Calculate the current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \mathbf{I}_1 + 2\ \text{A}$$
$$= 3.6 + j2.8 + 2\ \text{A}$$
$$= 5.6 + j2.8\ \text{A}$$

Calculate the open circuit voltage.

$$\mathbf{V}_{oc} = (1\ \Omega)\mathbf{I}_1 + (-j\ \Omega)\mathbf{I}_2$$
$$= (1\ \Omega)(3.6 + j2.8\ \text{A}) + (-j\ \Omega)(5.6 + j2.8\ \text{A})$$
$$= 6.4 - j2.8\ \text{V}$$
$$= 6.985\angle -23.63°\ \text{V}$$

Step 4 of 7

To calculate the Thevenin's impedance from the load terminals, short circuit the voltage source and open circuit the current source to zero impedance. The modified impedance network is shown in Figure 2.

Figure 2

Step 5 of 7

Calculate the Thevenin's impedance.

$$\mathbf{Z}_{Th} = (1\ \Omega) \| (1 - j\ \Omega)$$
$$= \frac{(1\ \Omega)(1 - j\ \Omega)}{1 + 1 - j\ \Omega}$$
$$= \frac{1 - j\ \Omega}{2 - j}$$
$$= 0.6 - j0.2\ \Omega$$

Step 6 of 7

Draw the Thevenin's equivalent circuit.

Figure 3

Step 7 of 7

Calculate the current through $1\ \Omega$ resistor.

$$\mathbf{I}_o = \frac{6.985\angle -23.63°\ \text{V}}{0.6 - j0.2 + 1\ \Omega}$$
$$= \frac{6.985\angle -23.63°\ \text{V}}{1.6 - j0.2\ \Omega}$$
$$= \frac{6.985\angle -23.63°\ \text{V}}{1.612\angle -7.125°\ \Omega}$$
$$= 4.33\angle -16.5°\ \text{A}$$

Therefore, the current through $1\ \Omega$ resistor, $\mathbf{I}_o$ is $\boxed{4.33\angle -16.5°\ \text{A}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.131 in the textbook.

To calculate the Thevenin's voltage, open the load resistor $(1\ \Omega)$ and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law to mesh 1.

$$(1\ \Omega)(\mathbf{I}_1 - 2\ \text{A}) + (1\ \Omega)\mathbf{I}_1 = 12\ \text{V}$$
$$2\mathbf{I}_1 = 12 + 2\ \text{A}$$
$$\mathbf{I}_1 = 7\ \text{A}$$

Calculate the open circuit voltage.

$$\begin{aligned}\mathbf{V}_{oc} &= (1\ \Omega)\mathbf{I}_1 + (-j\ \Omega)(2\ \text{A})\\ &= (1\ \Omega)(7\ \text{A}) + (-j\ \Omega)(2\ \text{A})\\ &= 7 - j2\ \text{V}\\ &= 7.28\angle -15.945^\circ\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance from the load terminals, short circuit the voltage source and open circuit the current source to zero impedance. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th} &= (1\ \Omega)\|(1\ \Omega) - j\ \Omega\\ &= \frac{(1\ \Omega)(1\ \Omega)}{1 + 1\ \Omega} - j\ \Omega\\ &= \frac{1\ \Omega}{2} - j\ \Omega\\ &= 0.5\ \Omega - j\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the voltage across $1\ \Omega$ resistor.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{1\ \Omega}{0.5 - j + 1\ \Omega}\right)(7.28\angle -15.945^\circ\ \text{V})\\ &= \left(\frac{1\ \Omega}{1.5 - j\ \Omega}\right)(7.28\angle -15.945^\circ\ \text{V})\\ &= (0.461 + j0.307)(7.28\angle -15.945^\circ\ \text{V})\\ &= (0.554\angle 33.69^\circ)(7.28\angle -15.945^\circ\ \text{V})\\ &= 4.033\angle 17.745^\circ\ \text{V}\end{aligned}$$

Therefore, the voltage across $1\ \Omega$ resistor, $\mathbf{V}_o$ is $\boxed{4.033\angle 17.745^\circ\ \text{V}}$.

Step 1 of 6

Refer to circuit diagram in Figure P8.132 in the textbook.

To calculate the Thevenin's voltage, open the load resistor $(1\ \Omega)$ and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the open circuit voltage.

$$\begin{aligned}\mathbf{V}_{oc} &= (-j\ \Omega)(4\ \text{A}) + 12\ \text{V}\\ &= -j4 + 12\ \text{V}\\ &= 12 - j4\ \text{V}\\ &= 12.649\angle -18.434°\ \text{V}\end{aligned}$$

Step 3 of 6

To calculate the Thevenin's impedance from the load terminals, short circuit the voltage source and open circuit the current source to zero impedance. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 6

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th} &= -j\ \Omega + (1 + j\ \Omega) \| (0\ \Omega)\\ &= -j\ \Omega + (1 + j\ \Omega) \| (0\ \Omega)\\ &= -j\ \Omega\end{aligned}$$

Step 5 of 6

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 6

Calculate the current through $1\ \Omega$ resistor.

$$\begin{aligned}\mathbf{I}_o &= \frac{12.649\angle -18.434°\ \text{V}}{1 - j\ \Omega}\\ &= \frac{12.649\angle -18.434°\ \text{V}}{1.414\angle -45°\ \Omega}\\ &= 8.945\angle 26.56°\ \text{A}\end{aligned}$$

Therefore, the current through $1\ \Omega$ resistor, $\mathbf{I}_o$ is $\boxed{8.945\angle 26.56°\ \text{A}}$.

Step 1 of 7

Refer the circuit in Figure P8.109 in the textbook.

In order to apply Thevenin theorem, open circuit the 2Ω load resistor, then the circuit is as shown in figure 1.

Figure-1

Step 2 of 7

From the circuit,

$$I_2 = -4\angle 0^\circ \text{ A}$$
$$I_3 = -6\angle 0^\circ \text{ A}$$

Apply KCL at node A,

$$4\angle 0^\circ = I' + I_3$$
$$I' = 4\angle 0^\circ - I_3$$
$$I' = 4\angle 0^\circ + 6\angle 0^\circ$$
$$I' = 10\angle 0^\circ \text{ A}$$

Step 3 of 7

Measure the open circuit voltage (V_{OC}) which is the Thevenin voltage (V_{TH}).

Apply KVL to the super loop,

$$j2(-I_2) + 1(-I') + 1(I_3) + V_{OC} = 0$$
$$V_{OC} = j2I_2 + I' - I_3$$

From the circuit,

$$I_2 = -4\angle 0^\circ \text{ A}$$
$$I_3 = -6\angle 0^\circ \text{ A}$$
$$I' = 10\angle 0^\circ \text{ A}$$

$$\begin{aligned} V_{OC} &= j2(-4\angle 0^\circ) + 10\angle 0^\circ - (-6\angle 0^\circ) \\ &= -j8\angle 0^\circ + 10\angle 0^\circ + 6\angle 0^\circ \\ &= 16\angle 0^\circ - j8\angle 0^\circ \\ &= 17.9\angle -26.57^\circ \text{ V} \end{aligned}$$

Step 4 of 7

Now find the Thevinin equivalent impedance (Z_{TH}). To find Z_{TH}, open circuit the current sources and short circuit the voltage source and the circuit is represented by Figure 2.

Figure-2

Step 5 of 7

From the circuit, two 1Ω resistors are in series with $j2\Omega$ impedance. So,

$$\begin{aligned} Z_{TH} &= 1 + 1 + (j2) \\ &= (2 + j2)\Omega \end{aligned}$$

Step 6 of 7

Now as per the Thevenin theorem, connect Z_{TH} in series with voltage source (V_{TH}) and re-connect the load resistor. Then the Thevinin equivalent circuit is as shown in Figure 3.

Figure-3

Step 7 of 7

Determine the value of V_0.
Apply voltage division rule,

$$\begin{aligned} V_0 &= \frac{2}{2+2+j2}(17.9\angle -26.57^\circ) \\ &= (0.4 - j0.2)(17.9\angle -26.57^\circ) \\ &= 4.8 - j6.4 \\ &= 8\angle -53.13^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_0 is $\boxed{8\angle -53.13^\circ \text{ V}}$.

Step 1 of 8

Refer the circuit in Figure P8.104 in the textbook.

Resistor in which the current is to be determined is known as load resistor and is denoted by R_L. In order to apply Thevinin's theorem, open circuit the 1Ω load resistor, then the circuit is as shown in Figure 1.

Figure-1

Step 2 of 8

Measure the open circuit voltage (V_{OC}) which is the thevinin voltage (V_{TH}). To determine the thevinin voltage, calculate the current flowing in that loop.

Apply KVL in the loop 2,

$$I_2(1)-6-j2(I_2-2)+(I_2-4)=0$$
$$I_2-6-j2I_2+4j+I_2-4=0$$
$$I_2(1-j2+1)=10-j4$$

$$I_2=\frac{10-j4}{2-j2}\times\frac{2+j2}{2+j2}$$
$$=\frac{20+j20-j8+8}{4+j4-j4+4}$$
$$=\frac{28+j12}{8}\text{A}$$

Step 3 of 8

From the circuit 1,

$$V_{OC}=6-1(I_2)$$
$$=6-\frac{28+j12}{8}$$
$$=\frac{48-28-j12}{8}$$
$$=\frac{20-j12}{8}$$
$$=\frac{5-j3}{2}\text{V}$$

Step 4 of 8

Now find the Thevinin equivalent impedance (Z_{TH}). To find Z_{TH}, open circuit the current sources and short circuit the voltage source as shown in Figure 2.

Figure-2

Step 5 of 8

The circuit in Figure 3 is represented by Figure 3.

Figure-3

Step 6 of 8

From the circuit, $(1-j2)\Omega$ impedance is in parallel with 1Ω resistor. So,

$$Z_{TH}=\frac{(1-j2)\times 1}{(1-j2)+1}$$
$$=\frac{1-j2}{2-j2}\times\frac{2+j2}{2+j2}$$
$$=\frac{2-j4+j2+4}{4-j4+j4+4}$$
$$=\frac{6-j2}{8}$$
$$=\frac{3-j1}{4}\Omega$$

Step 7 of 8

Now as per the Thevinin's theorem, connect the Z_{TH} in series with voltage source (V_{TH}) and re-connect the load resistor. Then the Thevinin equivalent circuit is as shown in Figure 4.

Figure-4

Step 8 of 8

Apply Ohm's law to the circuit.

$$I_o=\frac{V_{TH}}{Z_{TH}+R_L}$$
$$=\frac{\frac{5-j3}{2}}{\frac{3-j}{4}+1}$$
$$=\frac{5-j3}{2}\times\frac{4}{3-j+4}$$
$$=\frac{10-j6}{7-j}$$

$$=\frac{10-j6}{7-j}\times\frac{7+j}{7+j}$$
$$=\frac{70-j42+j10+6}{49-j7+j7+1}$$
$$=\frac{76-j32}{50}$$
$$=\frac{38-j16}{25}\text{A}$$

Therefore, the value of I_0 is, $\boxed{\frac{34-j16}{25}\text{A}}$.

Step 1 of 6

Refer to Figure P8.135 in the textbook.

To calculate the open circuit voltage, remove the load resistor from the circuit and calculate the open circuit voltage.

Figure 1

Step 2 of 6

From Figure 1,

$$\mathbf{V}_x = 6\angle 0° - 2\mathbf{V}_x$$
$$\mathbf{V}_x + 2\mathbf{V}_x = 6\angle 0°$$
$$3\mathbf{V}_x = 6\angle 0°$$
$$\mathbf{V}_x = 2\angle 0° \text{ V}$$

Apply Kirchhoff's current law at node $\mathbf{V}_{oc}$.

$$\frac{\mathbf{V}_{oc} - 2\mathbf{V}_x}{-j1} - 2\angle 0° = 0$$
$$\mathbf{V}_{oc} - 2\mathbf{V}_x + j2 = 0$$

Substitute $2\angle 0°$ V for $\mathbf{V}_x$.

$$\mathbf{V}_{oc} - 2(2\angle 0°) + j2 = 0$$
$$\mathbf{V}_{oc} - 4 + j2 = 0$$
$$\mathbf{V}_{oc} = 4 - j2$$
$$\mathbf{V}_{oc} = 4.47\angle -26.56° \text{ V}$$

Therefore, the Thevenin voltage is, $\mathbf{V}_{oc} = 4.47\angle -26.56°$ V.

Step 3 of 6

Short circuit the load resistor and calculate the short circuit current.

Figure 2

Step 4 of 6

From Figure 2, the voltage at node 1 is, $V_1 = 0$ V.

From Figure 2,

$$\mathbf{V}_x = 6\angle 0° - 2\mathbf{V}_x$$
$$\mathbf{V}_x + 2\mathbf{V}_x = 6\angle 0°$$
$$3\mathbf{V}_x = 6\angle 0°$$
$$\mathbf{V}_x = 2\angle 0° \text{ V}$$

Apply Kirchhoff's current law at node 1.

$$\frac{0 - 2\mathbf{V}_x}{-j1} - 2\angle 0° + \mathbf{I}_{sc} = 0$$
$$-2j\mathbf{V}_x - 2 + \mathbf{I}_{sc} = 0$$
$$-2j(2) - 2 + \mathbf{I}_{sc} = 0$$

$$\mathbf{I}_{sc} = 2 + j4$$
$$\mathbf{I}_{sc} = 4.47\angle 63.43° \text{ A}$$

Calculate the Thevenin impedance.

$$Z_{Th} = \frac{\mathbf{V}_{oc}}{\mathbf{I}_{sc}}$$
$$= \frac{4.47\angle -26.56°}{4.47\angle 63.43}$$
$$= 1\angle -90°$$
$$= -j1\ \Omega$$

Therefore, the Thevenin impedance is, $Z_{Th} = -j1\ \Omega$.

Step 5 of 6

Draw the Thevenin equivalent circuit with load.

Figure 3

Step 6 of 6

Calculate the load voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{oc}\left(\frac{1}{1 + Z_{Th}}\right)$$
$$= (4.47\angle -26.56)\left(\frac{1}{1 - j1}\right)$$
$$= (4.47\angle -26.56)(0.707\angle 45°)$$
$$= 3.16\angle 18.44° \text{ V}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{3.16\angle 18.44° \text{ V}}$.

Step 1 of 6

Refer to Figure P8.136 in the textbook.

To calculate the open circuit voltage, remove the load resistor from the circuit and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 6

From Figure 1,

$$\mathbf{V}_x = 12 - \mathbf{V}_{oc}$$

Apply Kirchhoff's voltage law for loop 1.

$$\frac{\mathbf{V}_{oc} - 2\mathbf{V}_x}{1} + \frac{\mathbf{V}_{oc} - 12}{1} = 0$$
$$\mathbf{V}_{oc} - 2\mathbf{V}_x + \mathbf{V}_{oc} - 12 = 0$$
$$2\mathbf{V}_{oc} - 2\mathbf{V}_x - 12 = 0$$

Substitute $12 - \mathbf{V}_{oc}$ for $\mathbf{V}_x$.

$$2\mathbf{V}_{oc} - 2(12 - \mathbf{V}_{oc}) - 12 = 0$$
$$4\mathbf{V}_{oc} - 36 = 0$$
$$4\mathbf{V}_{oc} = 36$$
$$\mathbf{V}_{oc} = 9\angle 0°\ \text{V}$$

Therefore, the Thevenin voltage is, $\mathbf{V}_{oc} = 9\angle 0°\ \text{V}$.

Step 3 of 6

Short circuit the load resistor and calculate the short circuit current.

The modified circuit diagram is shown in Figure 1.

Figure 2

Step 4 of 6

The voltage at node 1 is, $V_1 = 0\ \text{V}$.

From Figure 1,

$$\begin{aligned}\mathbf{V}_x &= 12 - \mathbf{V}_{oc}\\ &= 12 - 0\\ &= 12\ \text{V}\end{aligned}$$

Apply Kirchhoff's current law at node 1.

$$\frac{V_1 - 2\mathbf{V}_x}{1} + \frac{V_1 - 12}{1} + \mathbf{I}_{sc} = 0$$
$$0 - 2(12) + 0 - 12 + \mathbf{I}_{sc} = 0$$
$$\mathbf{I}_{sc} = 36\ \text{A}$$

Calculate the Thevenin impedance.

$$\begin{aligned}Z_{Th} &= \frac{\mathbf{V}_{oc}}{\mathbf{I}_{sc}}\\ &= \frac{9\angle 0°}{36}\\ &= 0.25\ \Omega\end{aligned}$$

Therefore, the Thevenin impedance is, $Z_{Th} = 0.25\ \Omega$.

Step 5 of 6

Draw the Thevenin equivalent circuit with load resistor.

Figure 3

Step 6 of 6

Calculate the current flowing in the circuit.

$$\begin{aligned}\mathbf{I}_o &= \frac{\mathbf{V}_{oc}}{Z_{Th} + 1}\\ &= \frac{9\angle 0°}{0.25 + 1}\\ &= \frac{9\angle 0°}{1.25}\\ &= 7.2\angle 0°\ \text{A}\end{aligned}$$

Therefore, the output current, $\mathbf{I}_o$ is $\boxed{7.2\angle 0°\ \text{A}}$.

Step 1 of 8

8.137P

Refer the circuit in Figure P8.111 in the textbook.

In order to apply Thevinin theorem, the output terminal is open circuited and the circuit is represented by Figure-1.

Figure-1

Step 2 of 8

From the circuit,

$$V_x = V_2$$

Apply Kirchhoff's current law at the super node formed by nodes 1 and 2.

$$2V_x + I_1 + I_x = 0$$
$$2V_x + \frac{V_1}{1} + \frac{V_2}{-j1} = 0$$

Substitute V_2 for V_x.

$$2V_2 + V_1 + j1V_2 = 0$$

$$V_1 + (2 + j1)V_2 = 0 \text{ ..... (1)}$$

From the circuit,

$$V_1 - V_2 = 12\angle 0^\circ \text{ V}$$

$$V_1 = V_2 + 12 \text{ ..... (2)}$$

Step 3 of 8

Determine the value of V_2.

Substitute equation (2) in equation (1).

$$(V_2 + 12) + (2 + j1)V_2 = 0$$
$$V_2 + 12 + 2V_2 + j1V_2 = 0$$
$$(3 + j1)V_2 = -12$$

$$V_2 = \frac{-12}{3 + j1}$$
$$= (-3.6 + j1.2)\text{V}$$

Determine the value of V_1.

$$V_1 = V_2 + 12$$

Substitute $(-3.6 + j1.2)\text{V}$ for V_2.

$$V_1 = (-3.6 + j1.2) + 12$$
$$= (8.4 + j1.2)\text{V}$$

Step 4 of 8

Determine the value of open circuit voltage.

$$V_{OC} = V_2$$

Substitute $(-3.6 + j1.2)\text{V}$ for V_2.

$$V_{OC} = (-3.6 + j1.2)\text{V}$$
$$= 3.8\angle 161.57^\circ \text{ V}$$

Now, the output terminal is short circuited and the circuit is represented by Figure-2.

Figure-2

Step 5 of 8

From the circuit,

$$V_x = 0\text{V}$$

Determine the value of I_{SC}.

$$I_{SC} = \frac{-12\angle 0^\circ \text{ V}}{1\Omega}$$
$$= -12\angle 0^\circ \text{ A}$$
$$= 12\angle 180^\circ \text{ A}$$

Step 6 of 8

Determine the value of Thevinin impedance.

$$Z_{TH} = \frac{V_{OC}}{I_{SC}}$$

Substitute $3.8\angle 161.57^\circ \text{ V}$ for V_{OC}, and $12\angle 180^\circ \text{ A}$ for I_{SC}.

$$Z_{TH} = \frac{3.8\angle 161.57^\circ \text{ V}}{12\angle 180^\circ \text{ A}}$$
$$= 0.3 - j0.1$$
$$= 0.32\angle -18.43^\circ \Omega$$

Step 7 of 8

Thevinin equivalent circuit is represented by Figure-3.

Figure-3

Step 8 of 8

Determine the value of V_0.

Apply voltage division rule.

$$V_0 = \left(\frac{1}{1 + j1 + 0.3 - j0.1}\right)(-3.6 + j1.2)$$
$$= \left(\frac{1}{1.3 + j0.9}\right)(-3.6 + j1.2)$$
$$= (-1.44 + j1.92)\text{V}$$
$$= 2.4\angle 127^\circ \text{ V}$$

Therefore, the value of V_0 is $\boxed{2.4\angle 127^\circ \text{ V}}$.

Step 1 of 12

Refer to the circuit in Figure P8.112 in the textbook.

The circuit is represented by Figure-1.

Figure-1

Step 2 of 12

Apply Kirchhoff's current law at node 1.

$$4\angle 0° + I_1 + I_2 = 0$$
$$\frac{V_1 - V_2}{1} + \frac{V_1}{j1} = -4\angle 0°$$
$$V_1 - V_2 - j1V_1 = -4\angle 0°$$
$$(1 - j1)V_1 - V_2 = -4$$

$$V_2 = (1 - j1)V_1 + 4 \text{ ..... (1)}$$

Step 3 of 12

From the circuit,

$$V_x = V_{oc} - V_2$$

Apply Kirchhoff's current law at node-2.

$$I_3 + I_1 = 2V_x$$
$$\frac{V_{oc} - V_2}{-j1} + \frac{V_1 - V_2}{1} = 2V_x$$

Substitute $V_{oc} - V_2$ for V_x in the equation.

$$\frac{V_{oc} - V_2}{-j1} + \frac{V_1 - V_2}{1} = 2(V_{oc} - V_2)$$
$$j1V_{oc} - j1V_2 + V_1 - V_2 = 2V_{oc} - 2V_2$$
$$V_1 + (1 - j1)V_2 + (-2 + j1)V_{oc} = 0$$

Substitute $(1 - j1)V_1 + 4$ for V_2 in the equation.

$$V_1 + (1 - j1)\left[(1 - j1)V_1 + 4\right] + (-2 + j1)V_{oc} = 0$$
$$V_1 - j2V_1 + 4 - j4 + (-2 + j1)V_{oc} = 0$$

$$(1 - j2)V_1 + (-2 + j1)V_{oc} = -4 + j4 \text{ ..... (2)}$$

Step 4 of 12

Apply Kirchhoff's current law at node-3.

$$I_3 = 4\angle 0° \text{ A}$$
$$\frac{V_{oc} - V_2}{-j1} = 4\angle 0°$$
$$j1V_{oc} - j1V_2 = 4\angle 0°$$

Substitute $(1 - j1)V_1 + 4$ for V_2 in the equation.

$$j1V_{oc} - j1\left[(1 - j1)V_1 + 4\right] = 4\angle 0°$$
$$j1V_{oc} - j1V_1 - V_1 - j4 = 4$$
$$j1V_{oc} - (1 + j1)V_1 = (4 + j4)$$
$$V_{oc} = \frac{1}{j1}\left[(1 + j1)V_1 + (4 + j4)\right]$$

$$V_{oc} = 4 - j4 + (1 - j1)V_1 \text{ ..... (3)}$$

Step 5 of 12

Determine the value of V_1.

Substitute equation (3) in equation (2).

$$(1 - j2)V_1 + (-2 + j1)\left[4 - j4 + (1 - j1)V_1\right] = -4 + j4$$
$$(1 - j2)V_1 - 8 + j4 + j8 + 4 + (-1 + j3)V_1 = -4 + j4$$
$$(1 - j2 - 1 + j3)V_1 = -j8$$
$$j1V_1 = -j8$$
$$V_1 = -8$$
$$= 8\angle 180° \text{ V}$$

Step 6 of 12

Determine the value of V_{oc}.

Substitute -8 V for V_1 in equation (3).

$$V_{oc} = 4 - j4 + (1 - j1)(-8)$$
$$= 4 - j4 - 8 + j8$$
$$= -4 + j4$$
$$= 5.65\angle 135° \text{ V}$$

Step 7 of 12

Now, the output terminal is short circuited and the circuit is represented by Figure-2.

Figure-2

Step 8 of 12

From the circuit,

$$I_2 = I + I_1$$
$$I = I_2 - I_1$$

$$4\angle 0° = I_x + I_{SC}$$
$$I_x = 4 - I_{SC}$$

Apply Kirchhoff's voltage law in super loop.

$$(j1)I_2 + 1(I) - j1(-I_x) = 0$$
$$j1I_2 + I + j1(I_x) = 0$$

Substitute $I_2 - I_1$ for I, $4 - I_{SC}$ for I_x in the equation.

$$j1I_2 + I_2 - I_1 + j1(4 - I_{SC}) = 0$$
$$j1I_2 + I_2 - I_1 + j4 - j1I_{SC} = 0$$
$$-I_1 + (1 + j1)I_2 - j1I_{SC} = -j4$$

From the circuit,

$$I_1 = 4\angle 0° \text{ A}$$

Substitute $4\angle 0°$ A for I_1 in the equation.

$$-4\angle 0° + (1 + j1)I_2 - j1I_{SC} = -j4$$

$$(1 + j1)I_2 - j1I_{SC} = 4 - j4 \text{ ..... (4)}$$

Step 9 of 12

Apply Kirchhoff's current law at node-3.

$$I_x + I = 2V_x$$

Substitute $I_2 - I_1$ for I, $4 - I_{SC}$ for I_x, and $-j1I_x$ for V_x in the equation.

$$4 - I_{SC} + I_2 - I_1 = 2(-j1I_x)$$
$$4 - I_{SC} + I_2 - I_1 = 2\left[(-j1)(4 - I_{SC})\right]$$
$$4 - I_{SC} + I_2 - I_1 = -j8 + j2I_{SC}$$

Substitute $4\angle 0°$ A for I_1 in the equation.

$$4 - I_{SC} + I_2 - 4 = -j8 + j2I_{SC}$$

$$I_2 = (1 + j2)I_{SC} - j8 \text{ ..... (5)}$$

Step 10 of 12

Determine the value of I_{SC}.

Substitute equation (5) in equation (4).

$$(1 + j1)\left[(1 + j2)I_{SC} - j8\right] - j1I_{SC} = 4 - j4$$
$$(-1 + j3)I_{SC} - j8 + 8 - j1I_{SC} = 4 - j4$$
$$(-1 + j2)I_{SC} = -4 + j4$$

$$I_{SC} = \frac{-4 + j4}{-1 + j2}$$
$$= 2.4 + j0.8$$
$$= 2.53\angle 18.43° \text{ A}$$

Step 11 of 12

Determine the value of Thevenin impedance.

$$Z_{TH} = \frac{V_{OC}}{I_{SC}}$$

Substitute $5.65\angle 135°$ V for V_{OC}, $2.53\angle 18.43°$ A for I_{SC} in the equation.

$$Z_{TH} = \frac{5.65\angle 135° \text{ V}}{2.53\angle 18.43° \text{ A}}$$
$$= 2.24\angle 116.57° \ \Omega$$

Step 12 of 12

The Thevenin equivalent network is represented by Figure-3.

Figure-3

Therefore, the Thevenin equivalent is shown in Figure 3.

Step 1 of 11

Refer to Figure P8.110 in the textbook.

Thevenin's theorem can be applied to find Thevenin's equivalent across terminals A and B in two cases as given below

Internal impedance of a voltage source is zero. Hence replace voltage source by short circuit. Thevenin's impedance Z_{Th} is measured by looking into the circuit as seen from the terminals A and B by replacing voltage source with their internal resistance as shown in Figure 1.

Figure 1

Step 2 of 11

Redraw the Figure 1 as a simple circuit diagram to calculate the Thevenin's impedance as shown in Figure 2.

Figure 2

Step 3 of 11

Equivalent resistance for Parallel combination of two $1\ \Omega$ resistors is,

$$R_{eq} = \frac{(1)(1)}{1+1}$$
$$= 0.5\ \Omega$$

Redraw the figure 2 by placing equivalent resistance for Parallel combination of two $1\ \Omega$ resistors as shown in Figure 3.

Figure 3

Step 4 of 11

Parallel equivalent impedance of inductor and capacitor is,

$$Z_{eq} = \frac{(j1)(-j1)}{j1 - j1}$$
$$= \infty\ \Omega$$

Step 5 of 11

Replace Parallel combination inductor and capacitor with an open circuit as shown in Figure 4.

Figure 4

Step 6 of 11

The Thevenin's impedance Z_{Th} is,

$$Z_{Th} = 0.5\ \Omega$$

Therefore, the Thevenin's impedance, Z_{Th} is $\boxed{0.5\ \Omega}$.

Step 7 of 11

Thevenin's Voltage V_{Th} is found from the Figure 5.

Figure 5

Step 8 of 11

Apply Nodal analysis at node 1.

$$\frac{V_1}{j1} + \frac{V_1 - 4\angle 0^\circ}{1} + \frac{V_2 - 4\angle 0^\circ}{-j1} + \frac{V_2 - (-6\angle 0^\circ) - 4\angle 0^\circ}{1} = 0$$

$$V_1(1 - j1) + V_2(1 + j1) = 2 + j4 \quad \text{..... (1)}$$

Constraint equation is,

$$V_2 - V_1 = 12\angle 0^\circ$$

$$V_2 = V_1 + 12 \quad \text{..... (2)}$$

Substitute equation (2) in equation (1) to find V_1.

$$V_1(1 - j1) + (V_1 + 12)(1 + j1) = 2 + j4$$
$$V_1(1 - 1j + 1 + 1j) + 12 + 12j = 2 + j4$$
$$2V_1 = 2 + j4 - 12 - 12j$$
$$V_1 = -5 - 4j$$

$$V_1 = 6.403\angle -141.34^\circ \quad \text{..... (3)}$$

Recall equation (2).

$V_2 = V_1 + 12$ Substitute $6.403\angle -141.34^\circ$ for V_1 in the equation.

$$V_2 = 6.403\angle -141.34^\circ + 12$$
$$= 8.062\angle -29.74^\circ\ \text{V}$$

Step 9 of 11

Current I_1 flowing through $1\ \Omega$ connected between node voltages V_2 and V_3.

The current I_1 flowing through $1\ \Omega$ resistor is,

$$I_1 = \frac{V_2 - (-6) - V_3}{1}$$
$$= \frac{8.062\angle -29.74^\circ + 6 - 4}{1}$$
$$= 9.84\angle -23.95^\circ\ \text{A}$$

Step 10 of 11

Apply Kirchhoff's voltage law in loop 1 in Figure 5 to find Thevenin's voltage V_{Th}.

$$-4\angle 0^\circ - (I_1)(1) + V_{Th} = 0$$

$$V_{Th} = 4 + I_1$$
$$= 4 + 9.84\angle -23.95^\circ$$
$$= 13.60\angle -17.09^\circ\ \text{V}$$

Thus, Thevenin's voltage V_{Th} is $\boxed{13.60\angle -17.09^\circ\ \text{V}}$.

Step 11 of 11

Thus, Thevenin's equivalent of the network across the terminals A and B is,

Figure 6

Step 1 of 6

Step 2 of 6

By Nodal analysis

$V_1 = 6\text{V}$ ..... (i)

$V_3 = 12\text{V}$ ..... (ii)

At node V_0,

$$\frac{V_0 - V_1}{1\Omega} + \frac{V_0}{j1} + \frac{V_0 - V_4}{1} + \frac{V_0 - V_2}{1} = 0$$

$$V_0 - V_1 - jV_0 + V_0 - V_4 + V_0 - V_2 = 0$$

$$-V_1 - V_2 - V_4 + V_0(3 - j) = 0 \quad \text{..... (iii)}$$

Step 3 of 6

At node V_2,

$$\frac{V_2 - V_3}{-j1} + \frac{V_2 - V_0}{1} + \frac{V_2}{1} + \frac{V_2 - V_4}{1} = 0$$

$$jV_2 - jV_3 + V_2 - V_0 + V_2 + V_2 - V_4 = 0$$

$$V_2(3 + j) - jV_3 - V_4 - V_0 = 0 \text{ ..... (iv)}$$

At node V_4,

$$\frac{V_4 - V_2}{1} + \frac{V_4 - V_0}{1} + 4 - 2 = 0$$

$$-V_2 + 2V_4 - V_0 = -2 \text{ ..... (v)}$$

Step 4 of 6

Expressing the equations in matrix form

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ -1 & -1 & 0 & -1 & 3-j \\ 0 & 3+j & -j & -1 & -1 \\ 0 & -1 & 0 & 2 & -1 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix} = \begin{bmatrix} 6 \\ 12 \\ 0 \\ 0 \\ -2 \end{bmatrix}$$

It is in the form

$YV = I$

Hence $V = \text{inv}(Y)\, I$

Step 5 of 6

In MATLAB

```
>> Y = [1 0 0 0 0; 0 0 1 0 0; -1 -1 0 -1 3-j; 0 3+j -j -1 -1; 0 -1 0 2 -1]
Y =
Columns 1 through 4
```

1.0000	0	0	0
0	0	1.0000	0
-1.0000	-1.0000	0	-1.0000
0	3.0000 + 1.0000i	0 − 1.0000i	-1.0000
0	-1.0000	0	2.0000

```
Column 5
     0
     0
3.0000 - 1.0000i
-1.0000
-1.0000
>> I = [6; 12; 0; 0; -2]
   I =  6
       12
        0
        0
       -2
>> V = inv(Y)*I
V=
6.0000
3.4000+6.2000i
12.0000
1.8000+5.4000i
2.2000+4.6000i
```

Step 6 of 6

From the figure

$$I_0 = \frac{V_2 - V_0}{1}$$

$$I_0 = \frac{3.4000 + 6.2000i - 2.2000 - 4.6000i}{1}$$

$$I_0 = 1.2000 + j1.6000$$

$$\boxed{I_0 = 2\angle 53.13^\circ \text{ A}}$$

Step 1 of 8

8.141P

Refer to Figure P8.141 in the textbook.

To calculate the open circuit voltage, remove the load resistor from the circuit and calculate the open circuit voltage.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 8

From Figure 1,

$$V_x = V_{oc} - 12$$

Apply Kirchhoff's current law at node 1.

$$\frac{V_1 + 2V_x}{-j1} + \frac{V_1}{1} + \frac{V_1 - V_{oc}}{1} = 0$$
$$j(V_1 + 2V_x) + V_1 + V_1 - V_{oc} = 0$$
$$j(V_1 + 2(V_{oc} - 12)) + V_1 + V_1 - V_{oc} = 0$$
$$(2 + j)V_1 - (1 - 2j)V_{oc} = j24 \quad \text{..... (1)}$$

Apply Kirchhoff's current law at node V_{oc}.

$$\frac{V_{oc} - V_1}{1} + \frac{V_{oc} - 12}{1} = 0$$
$$V_{oc} - V_1 + V_{oc} - 12 = 0$$
$$2V_{oc} - V_1 - 12 = 0$$
$$V_1 = 2V_{oc} - 12 \quad \text{..... (2)}$$

Step 3 of 8

Substitute $2V_{oc} - 12$ for V_1 in equation (1).

$$(2 + j)(2V_{oc} - 12) - (1 - 2j)V_{oc} = j24$$
$$(4 + 2j)V_{oc} - 12(2 + j) - (1 - 2j)V_{oc} = j24$$
$$(3 + 4j)V_{oc} = j24 + 12(2 + j)$$
$$V_{oc} = \frac{24 + j36}{3 + 4j}$$
$$= 8.653\angle 3.18° \text{ V}$$

Therefore, the Thevenin voltage is, $V_{oc} = 8.653\angle 3.18°$ V.

Step 4 of 8

Short circuit the load resistor and calculate the short circuit current.

The modified circuit diagram is shown in Figure 2.

Figure 2

Step 5 of 8

In Figure 2, the voltage at node 2 is zero.

That is, $V_2 = 0$ V

From Figure 2,

$$V_x = V_2 - 12$$
$$= -12$$

Apply Kirchhoff's current law at node 1.

$$\frac{V_1 + 2V_x}{-j1} + \frac{V_1}{1} + \frac{V_1 - 0}{1} = 0$$
$$j(V_1 + 2V_x) + V_1 + V_1 = 0$$
$$j(V_1 + 2(-12)) + 2V_1 = 0$$
$$(2 + j)V_1 = j24$$
$$V_1 = \frac{j24}{(2 + j)}$$
$$= 4.8 + j9.6 \text{ V}$$

Step 6 of 8

Apply Kirchhoff's current law at node 2.

$$\frac{0 - V_1}{1} + \frac{0 - 12}{1} + I_{sc} = 0$$
$$-(4.8 + j9.6) - 12 + I_{sc} = 0$$
$$I_{sc} = 16.8 + j9.6$$
$$I_{sc} = 19.35\angle 29.74° \text{ A}$$

Therefore, the short circuit current is, $I_{sc} = 19.35\angle 29.74°$ A.

Calculate the Thevenin impedance.

$$Z_{Th} = \frac{V_{oc}}{I_{sc}}$$
$$= \frac{8.653\angle 3.18°}{19.35\angle 29.74°}$$
$$= 0.45\angle -26.56°$$
$$= 0.4 - j0.2 \ \Omega$$

Therefore, the Thevenin impedance is, $Z_{Th} = 0.4 - j0.2 \ \Omega$.

Step 7 of 8

Draw the Thevenin equivalent circuit with load resistor.

Figure 3

Step 8 of 8

Calculate the current flowing in the circuit.

$$I_o = \frac{V_{oc}}{Z_{Th} + 1}$$
$$= \frac{8.653\angle 3.18°}{0.4 - j0.2 + 1}$$
$$= \frac{8.653\angle 3.18°}{1.414\angle -8.13°}$$
$$= 6.12\angle 11.31° \text{ A}$$

Therefore, the output current, I_o is $\boxed{6.12\angle 11.31° \text{ A}}$.

Step 1 of 5

Refer to Figure P8.68 in the textbook.

To calculate the Norton current, short circuit the load resistor and calculate short circuit current.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

In Figure 1, the voltage at node 1 is, $V_1 = 0$.

Apply Kirchhoff's current law at node 2.

$$\frac{V_2 - 0}{-j1} + \frac{V_2}{j1} + \frac{V_2 - 12}{1} = 0$$

$$\frac{V_2 - 12}{1} = 0$$

$$V_2 = 12 \text{ V}$$

Apply Kirchhoff's current law at node 1.

$$-2\angle 0° + \mathbf{I}_{sc} + \frac{0 - V_2}{-j1} = 0$$

$$\mathbf{I}_{sc} + \frac{V_2}{j1} = 2$$

$$\mathbf{I}_{sc} + \frac{12}{j1} = 2$$

$$\mathbf{I}_{sc} - j12 = 2$$

$$\mathbf{I}_{sc} = 2 + j12$$

$$\mathbf{I}_{sc} = 12.17\angle 80.54° \text{ A}$$

Step 3 of 5

To calculate the Norton impedance from the load terminals, short circuit the voltage source and open circuit the current source. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the Norton impedance.

$$\begin{aligned} Z_N &= (1 \| j1) - j1 \\ &= \frac{(1)(j1)}{1 + j1} - j1 \\ &= 0.5 + j0.5 - j1 \\ &= 0.5 - j0.5\ \Omega \end{aligned}$$

Draw the Norton equivalent circuit with load resistor.

Figure 3

Step 5 of 5

Calculate the current, $\mathbf{I}_o$ using current division rule.

$$\begin{aligned} \mathbf{I}_o &= \mathbf{I}_{sc}\left(\frac{Z_N}{1 + Z_N}\right) \\ &= (12.17\angle 80.54°)\left(\frac{0.5 - j0.5}{1 + 0.5 - j0.5}\right) \\ &= (12.17\angle 80.54°)\left(\frac{0.5 - j0.5}{1.5 - j0.5}\right) \\ &= (12.17\angle 80.54°)(0.45\angle -26.56°) \end{aligned}$$

$$\mathbf{I}_o = 5.44\angle 53.97° \text{ A}$$

Therefore, the current flowing through $1\,\Omega$ resistor, $\mathbf{I}_o$ is $\boxed{5.44\angle 53.97 \text{ A}}$.

Step 1 of 5

Refer to Figure P8.69 in the textbook.

To calculate the Norton current, short circuit the load resistor and calculate short circuit current.

The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

In Figure 1, the voltage at node 2 is, $V_2 = 0$.

Apply Kirchhoff's current law at node 1.

$$\frac{V_1 - 0}{j1} + \frac{V_1 - 6}{1} - 2 = 0$$
$$-jV_1 + V_1 - 6 - 2 = 0$$
$$(1 - j)V_1 = 8$$

Apply Kirchhoff's current law at node 2.

$$\frac{0 - V_1}{j1} + \frac{0 - 6}{-j1} + \mathbf{I}_{sc} = 0$$
$$jV_1 - j6 + \mathbf{I}_{sc} = 0$$
$$j(V_1 - 6) + \mathbf{I}_{sc} = 0$$
$$j(4 + j4 - 6) + \mathbf{I}_{sc} = 0$$
$$j(-2 + j4) + \mathbf{I}_{sc} = 0$$
$$-4 - j2 + \mathbf{I}_{sc} = 0$$
$$\mathbf{I}_{sc} = 4 + j2$$
$$\mathbf{I}_{sc} = 4.47\angle 26.56°\ \text{A}$$

Therefore, the short circuit current is, $\mathbf{I}_{sc} = 4.47\angle 26.56°\ \text{A}$.

Step 3 of 5

To calculate the Norton impedance from the load terminals, short circuit the voltage source and open circuit the current source. The modified impedance network is shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the Norton impedance.

$$\begin{aligned} Z_N &= (1 + j1) \| (-j1) \\ &= \frac{(1 + j1)(-j1)}{1 + j1 - j1} \\ &= \frac{(1 + j1)(-j1)}{1} \\ &= (1 - j)\ \Omega \end{aligned}$$

Therefore, the Norton impedance is, $Z_N = (1 - j)\ \Omega$.

Draw the Norton equivalent circuit with load resistor.

Figure 3

Step 5 of 5

Calculate the current flowing through $1\ \Omega$ resistor, using current division rule.

$$\begin{aligned} \mathbf{I}_{1\,\Omega} &= \mathbf{I}_{sc}\left(\frac{Z_N}{1 + Z_N}\right) \\ &= (4.47\angle 26.56°)\left(\frac{1 - j}{1 + 1 - j}\right) \\ &= (4.47\angle 26.56°)\left(\frac{1 - j}{2 - j}\right) \\ &= (4.47\angle 26.56°)(0.63\angle -18.43°) \end{aligned}$$

$$= 2.82\angle 8.13°\ \text{A}$$

Calculate the output voltage, using Ohm's law.

$$\begin{aligned} \mathbf{V}_o &= (1)I_{1\,\Omega} \\ &= (1)(2.82\angle 8.13°) \\ &= 2.82\angle 8.13°\ \text{V} \end{aligned}$$

Therefore, the output voltage, $\mathbf{V}_o$ is $\boxed{2.82\angle 8.13°\ \text{V}}$.

Step 1 of 6

Refer the circuit in Figure P8.113 in the textbook.

In order to calculate the Norton's current, apply super position theorem to calculate the Norton's current. First, short circuit the voltage source and the circuit is shown in Figure 1.

Figure-1

Determine the value of I_{sc}' due to current source.

$$I_{sc}' = -2\angle 0^\circ \text{ A}$$

Step 2 of 6

Now, the open circuit current source and the circuit is shown in Figure-2.

Figure-2

Determine the value of I_{sc}'' due to voltage source.

$$\begin{aligned} I_{sc}'' &= \frac{11.3\angle 45^\circ \text{ V}}{j4\Omega} \\ &= 2 - j2 \\ &= 2.83\angle -45^\circ \text{ A} \end{aligned}$$

Step 3 of 6

Determine the value of I_{sc} due to both sources.

$$I_{sc} = I_{sc}' + I_{sc}''$$

Substitute $-2\angle 0^\circ$ A for I_{sc}', and $2.83\angle -45^\circ$ A for I_{sc}'' in the equaiton.

$$\begin{aligned} I_{sc} &= \left(-2\angle 0^\circ\right) + \left(2.83\angle -45^\circ\right) \\ &= -2 + 2 - j2 \\ &= -j2 \\ &= 2\angle -90^\circ \text{ A} \end{aligned}$$

Step 4 of 6

Thevinin equivalent circuit is represented by Figure-3.

Figure-3

Determine the equivalent Thevinin impedance.

$$\begin{aligned} Z_{TH} &= 10 \,||\, j4 \\ &= \frac{(10)(j4)}{10 + j4} \\ &= 1.38 + j3.45 \\ &= 3.7\angle 68.2^\circ\ \Omega \end{aligned}$$

Step 5 of 6

Determine the value of I_x.

Apply current-division rule.

$$I_x = \left(\frac{Z_{TH}}{Z_{TH} - j3}\right) I_{sc}$$

Substitute $3.7\angle 68.2^\circ\ \Omega$ for Z_{TH}, and $2\angle -90^\circ$ A for I_{sc} in the equation.

$$\begin{aligned} I_x &= \left(\frac{3.7\angle 68.2^\circ}{3.7\angle 68.2^\circ - j3}\right)\left(2\angle -90^\circ\right) \\ &= \left(\frac{1.37 + j3.45}{1.37 + j3.45 - j3}\right)(-j2) \\ &= \left(\frac{1.37 + j3.45}{1.37 + j0.45}\right)(-j2) \\ &= (1.65 + j2)(-j2) \\ &= 4 - j3.3 \\ &= 5.2\angle -39.5^\circ \text{ A} \end{aligned}$$

Step 6 of 6

Determine the value of V_x.

$$V_x = (-j3) I_x$$

Substitute $5.2\angle -39.5^\circ$ A for I_x in the equation.

$$\begin{aligned} V_x &= (-j3)\left(5.2\angle -39.5^\circ\right) \\ &= -9.9 - j12 \\ &= 15.5\angle -129.5^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_x is $\boxed{15.5\angle -129.5^\circ \text{ V}}$.

Step 1 of 8

8.145P

Refer the circuit in Figure P8.114 in the textbook.

In order to apply Norton's theorem, resistor is short-circuited to determine short circuit current and the circuit is represented by Figure-1.

Figure-1

Step 2 of 8

Now, the source with $2\angle 0^\circ$ A is open circuited and the circuit in Figure-1 is represented by Figure-2.

Figure-2

Step 3 of 8

Apply current-division rule to determine the value of I'_{sc}.

$$\begin{aligned} I'_{sc} &= \left(\frac{j1}{j1-j2}\right)(6\angle 45^\circ) \\ &= -1(6\angle 45^\circ) \\ &= 6\angle -135^\circ \text{ A} \end{aligned}$$

Step 4 of 8

Now, the source with $6\angle 45^\circ$ A is open circuited and the circuit in Figure-1 is represented by Figure-3.

Figure-3

Step 5 of 8

From Figure-3,

$$I''_{sc} = -2\angle 0^\circ \text{ A}$$

Determine the value of I_{sc}.

$$I_{sc} = I'_{sc} + I''_{sc}$$

Substitute $6\angle -135^\circ$ A for I'_{sc}, and $-2\angle 0^\circ$ A for I''_{sc}.

$$\begin{aligned} I_{sc} &= 6\angle -135^\circ - 2\angle 0^\circ \\ &= -6.24 - j4.24 \\ &= 7.55\angle -145.8^\circ \text{ A} \end{aligned}$$

Step 6 of 8

Short circuit all the dc voltage sources and open circuit all the dc current sources to find the Norton's equivalent resistance.

Draw the modified circuit diagram.

Figure-4

Step 7 of 8

Calculate the Norton equivalent resistance Z_N.

$$\begin{aligned} Z_N &= j1 - j2 \\ &= -j1\Omega \end{aligned}$$

Draw the Norton's equivalent circuit.

Figure-5

Step 8 of 8

Apply current-division rule to determine the value of I_0.

$$I_0 = \left(\frac{Z_N}{Z_N + 2}\right) I_{sc}$$

Substitute $-j1\Omega$ for Z_N, and $7.55\angle -145.8^\circ$ A for I_{sc}.

$$\begin{aligned} I_0 &= \left(\frac{-j1}{-j1+2}\right)(7.55\angle -145.8^\circ) \\ &= (0.2 - j0.4)(7.55\angle -145.8^\circ) \\ &= -2.95 + j1.65 \\ &= 3.38\angle 150.8^\circ \text{ A} \end{aligned}$$

Therefore, the value of I_0 is $\boxed{3.38\angle 150.8^\circ \text{ A}}$.

Step 1 of 12

Refer the circuit in Figure P8.120 in the textbook.

In order to apply Norton's theorem, the resistor with I_o is short circuited and the circuit is represented by Figure-1.

Figure-1

Step 2 of 12

Apply Kirchhoff's current law to the circuit in loop-1.

$$4\angle 0° = I_x + I_{SC}$$
$$I_x = 4\angle 0° - I_{SC}$$

Apply Kirchhoff's current law to the circuit in loop-2.

$$I_2 = I + I_1$$
$$I = I_2 - I_1$$

From the circuit,

$$I_1 = 4\angle 0° \text{ A}$$

Step 3 of 12

Apply Kirchhoff's voltage law to the circuit in super loop.

$$(1)I - (j1)(-I_x) + 1(I_{SC}) + (j1)I_2 = 0$$

Substitute $4\angle 0° - I_{SC}$ for I_x , $I_2 - I_1$ for I , $4\angle 0°$ A for I_1 in the equation.

$$(1)(I_2 - 4\angle 0°) + (j1)(4\angle 0° - I_{SC}) + 1(I_{SC}) + (j1)I_2 = 0$$
$$I_2 - 4 + j1(4\angle 0°) - j1I_{SC} + I_{SC} + (j1)I_2 = 0$$
$$(1+j1)I_2 + (1-j1)I_{SC} = 4 + 4\angle -90°$$
$$= 4 - j4$$
$$= 5.66\angle -45°$$
$$(1+j1)I_2 + (1-j1)I_{SC} = 5.66\angle -45° \quad \text{..... (1)}$$

Step 4 of 12

From the circuit,

$$V_x = (-j1)I_x$$

Substitute $4\angle 0° - I_{SC}$ for I_x in the equation.

$$V_x = (-j1)(4\angle 0° - I_{SC})$$

Apply Kirchhoff's current law at node-1.

$$2V_x + I_{SC} = I_2$$

Substitute $(-j1)(4\angle 0° - I_{SC})$ for V_x in the equation.

$$2(-j1)(4\angle 0° - I_{SC}) + I_{SC} = I_2$$
$$-j8 + j2I_{SC} + I_{SC} = I_2$$
$$I_2 = (1+j2)I_{SC} - j8 \quad \text{..... (2)}$$

Step 5 of 12

Determine the value of I_{SC} .

Substitute equation (2) in equation (1).

$$(1+j1)((1+j2)I_{SC} - j8) + (1-j1)I_{SC} = 5.66\angle -45°$$
$$(-1+j3)I_{SC} - (-8+j8) + (1-j1)I_{SC} = 5.66\angle -45°$$
$$(-1+j3+1-j1)I_{SC} = 4 - j4 - 8 + j8$$
$$(j2)I_{SC} = -4 + j4$$
$$I_{SC} = \frac{-4+j4}{j2}$$
$$= (2+j2)\text{ A}$$
$$= 2.83\angle 45° \text{ A}$$

Step 6 of 12

Now, the output terminal is open circuited and the circuit is represented by Figure-2.

Figure-2

Step 7 of 12

Apply Kirchhoff's current law in loop-2.

$$I_2 = I + I_1$$
$$I = I_2 - I_1$$

From loop-1 in the circuit,

$$I_1 = 4\angle 0° \text{ A}$$

Apply Kirchhoff's voltage law in loop-2.

$$(j1)I_2 + (1)I - j1(-I_1) + V_{OC} = 0$$
$$j1I_2 + I + j1I_1 + V_{OC} = 0$$

Substitute $I_2 - I_1$ for I in the equation.

$$j1I_2 + I_2 - I_1 + j1I_1 + V_{OC} = 0$$
$$(-1+j1)I_1 + (1+j1)I_2 + V_{OC} = 0$$

Substitute $4\angle 0°$ A for I_1 in the equation.

$$(-1+j1)4\angle 0° \text{ A} + (1+j1)I_2 + V_{OC} = 0$$
$$V_{OC} = 4 - j4 + (-1-j1)I_2 \quad \text{..... (3)}$$

Step 8 of 12

Apply Kirchhoff's current law in loop-1.

$$V_x = -j1I_1$$

Apply Kirchhoff's current law in loop-2.

$$2V_x = I_2$$

Substitute $-j1I_1$ for V_x in the equation.

$$2(-j1I_1) = I_2$$
$$-j2I_1 = I_2$$

Substitute $4\angle 0°$ A for I_1 in the equation.

$$I_2 = -j2(4\angle 0°)$$
$$= -j8\angle 0°$$
$$= 8\angle -90° \text{ A}$$

Step 9 of 12

Determine the value of V_{OC} .

Substitute $8\angle -90°$ A for I_2 in equation (3).

$$V_{OC} = 4 - j4 + (-1-j1)8\angle -90°$$
$$= 4 - j4 + j8 - 8$$
$$= -4 + j4$$
$$= 5.65\angle 135° \text{ V}$$

Step 10 of 12

Thevenin equivalent circuit is represented by Figure-3.

Figure-3

Step 11 of 12

Determine the value of Thevenin impedance.

$$Z_{TH} = \frac{V_{OC}}{I_{SC}}$$

Substitute $5.65\angle 135°$ V for V_{OC} , $2.83\angle 45°$ A for I_{SC} in the equation.

$$Z_{TH} = \frac{5.65\angle 135° \text{ V}}{2.83\angle 45° \text{ A}}$$
$$= 2\angle 90° \ \Omega$$

Step 12 of 12

Determine the value of I_o .

Apply current-division rule.

$$I_o = \left(\frac{2\angle 90°}{2\angle 90° + 1}\right)(2.83\angle 45°)$$
$$= (0.8 + j0.4)(2.83\angle 45°)$$
$$= 0.8 + j2.4$$
$$= 2.53\angle 71.6° \text{ A}$$

Determine the value of V_o .

$$V_o = (1\Omega)I_o$$

Substitute $2.53\angle 71.6°$ A for I_o in the equation.

$$V_o = (1\Omega)(2.53\angle 71.6° \text{ A})$$
$$= 2.53\angle 71.6° \text{ V}$$

Therefore, the value of V_o is $\boxed{2.53\angle 71.6° \text{ V}}$.

Step 1 of 22

The given circuit is,

Step 2 of 22

Calculating Norton's short circuit current:
Removing the 1Ω resistor and short the terminals the circuit will be,

Step 3 of 22

From the circuit,

$\mathbf{I}_{sc} = \mathbf{I}_4$

$\mathbf{V}_x = 1(\mathbf{I}_4 - \mathbf{I}_2)$

$\mathbf{V}_x = \mathbf{I}_4 - \mathbf{I}_2$

Step 4 of 22

Applying Mesh analysis to loop '1' we have

$$-4\angle 0° - j1(\mathbf{I}_1 - \mathbf{I}_2) + 1(\mathbf{I}_1 - \mathbf{I}_3) = 0$$

$$\mathbf{I}_1(1 - j1) + \mathbf{I}_2(j1) - \mathbf{I}_3 = 4 \qquad \text{..... (1)}$$

Step 5 of 22

Applying Mesh analysis to loop '2' we have

$$-j1(\mathbf{I}_2 - \mathbf{I}_1) + 8\angle 0° + 1(\mathbf{I}_2 - \mathbf{I}_4) = 0$$

$$\mathbf{I}_1(j1) + \mathbf{I}_2(1 - j1) - \mathbf{I}_4 = -8 \qquad \text{..... (2)}$$

Step 6 of 22

Applying Mesh analysis to loop '3' we have

$$j1(\mathbf{I}_3) + 1(\mathbf{I}_3 - \mathbf{I}_1) + 2\mathbf{V}_x = 0$$

$$-\mathbf{I}_1(1) + \mathbf{I}_3(1 + j1) + 2(\mathbf{I}_3 - \mathbf{I}_2) = 0$$

$$-\mathbf{I}_1 - 2\mathbf{I}_2 + \mathbf{I}_3(1 + j1) + 2\mathbf{I}_4 = 0 \qquad \text{..... (3)}$$

Step 7 of 22

Applying Mesh analysis to loop '4' we have

$$-2\mathbf{V}_x + 1(\mathbf{I}_4 - \mathbf{I}_2) = 0$$

$$-2(\mathbf{I}_4 - \mathbf{I}_2) + 1(\mathbf{I}_4 - \mathbf{I}_2) = 0$$

$$\mathbf{I}_2(2-1) + \mathbf{I}_4(-2+1) = 0$$

$$\mathbf{I}_4 = \mathbf{I}_2 \qquad \text{..... (4)}$$

Step 8 of 22

Substituting equation (4) in equation (2) we get,

$$\mathbf{I}_1(j1) + \mathbf{I}_2(1 - j1) - (\mathbf{I}_2) = -8$$

$$\mathbf{I}_1(j1) + \mathbf{I}_2(1 - j1 - 1) = -8$$

$$\mathbf{I}_1(j1) + \mathbf{I}_2(-j1) = -8$$

$$\mathbf{I}_1 = \frac{\mathbf{I}_2(j1) - 8}{j1}$$

$$\mathbf{I}_1 = \mathbf{I}_2 + j8 \qquad \text{..... (5)}$$

Step 9 of 22

Substituting equations (4) & (5) in equation (3) we get

$$-(\mathbf{I}_2 + j8) - 2\mathbf{I}_2 + \mathbf{I}_3(1 + j1) + 2(\mathbf{I}_2) = 0$$

$$-\mathbf{I}_2 - j8 + \mathbf{I}_3(1 + j1) = 0$$

$$-\mathbf{I}_2 + \mathbf{I}_3(1 + j1) = j8$$

$$\mathbf{I}_3(1 + j1) = \mathbf{I}_2 + j8$$

$$\mathbf{I}_3 = \frac{\mathbf{I}_2 + j8}{1 + j1}$$

$$\mathbf{I}_3 = \mathbf{I}_2(0.5 - j0.5) + 4 + j4 \qquad \text{..... (6)}$$

Step 10 of 22

Substituting equations (5) & (6) in equation (1), we get

$$(\mathbf{I}_2 + j8)(1 - j1) + \mathbf{I}_2(j1) - \left[\mathbf{I}_2(0.5 - j0.5) + 4 + j4\right] = 4$$

$$\mathbf{I}_2(1 - j1 + j1 - 0.5 + j0.5) + j8 + 8 - 4 - j4 = 4$$

$$\mathbf{I}_2(0.5 + j0.5) + 4 + j4 = 4$$

$$\mathbf{I}_2(0.5 + j0.5) = -j4$$

$$\mathbf{I}_2 = \frac{-j4}{0.5 + j0.5}$$

$$= \frac{4\angle -90°}{0.707\angle 45°}$$

$$= 5.66\angle -135°$$

Since from equation (4), we know that $(\mathbf{I}_4 = \mathbf{I}_2)$

$\mathbf{I}_2 = (-4 - j4)$ A

Step 11 of 22

From the circuit, we get

$\mathbf{I}_{sc} = \mathbf{I}_4$

$= -4 - j4$

$\mathbf{I}_{sc} = 5.657\angle -135°$ A

Step 12 of 22

Calculating the Norton's impedance:

Since there is a dependent voltage source the Thevenin's impedance or Norton's impedance is found by calculating the open circuit voltage and dividing it with short circuit current, $\mathbf{I}_{sc}$. Removing the 1Ω resistor and calculating for open circuit voltage circuit the circuit will be

Step 13 of 22

From the circuit,

$\mathbf{V}_x = 1(-\mathbf{I}_2)$

$\mathbf{V}_x = -\mathbf{I}_2$

$\mathbf{V}_{oc} = -\mathbf{V}_x + 2\mathbf{V}_x$

$\mathbf{V}_{oc} = \mathbf{V}_x$

$\mathbf{V}_{oc} = -\mathbf{I}_2$

Step 14 of 22

Applying Mesh analysis to loop '1' we have

$$-4\angle 0° - j1(\mathbf{I}_1 - \mathbf{I}_2) + 1(\mathbf{I}_1 - \mathbf{I}_3) = 0$$

$$\mathbf{I}_1(1 - j1) + \mathbf{I}_2(j1) - \mathbf{I}_3 = 4 \qquad \text{..... (7)}$$

Step 15 of 22

Applying Mesh analysis to loop '2' we have

$$-j1(\mathbf{I}_2 - \mathbf{I}_1) + 8\angle 0° + 1(\mathbf{I}_2) = 0$$

$$\mathbf{I}_1(j1) + \mathbf{I}_2(1 - j1) = -8$$

$$\mathbf{I}_1(j1) = -8 - \mathbf{I}_2(1 - j1)$$

$$\mathbf{I}_1 = \frac{-8 - \mathbf{I}_2(1 - j1)}{j1}$$

$$\mathbf{I}_1 = \mathbf{I}_2(1 + j1) + j8 \qquad \text{..... (8)}$$

Step 16 of 22

Applying Mesh analysis to loop '3' we have

$$j1(\mathbf{I}_3) + 1(\mathbf{I}_3 - \mathbf{I}_1) + 2\mathbf{V}_x = 0$$

$$-\mathbf{I}_1 + \mathbf{I}_3(1 + j1) + 2(-\mathbf{I}_2) = 0$$

$$-\mathbf{I}_1 - 2\mathbf{I}_2 + \mathbf{I}_3(1 + j1) = 0 \qquad \text{..... (9)}$$

Step 17 of 22

Substituting equation (8) in equation (9) we get,

$$-\left[\mathbf{I}_2(1 + j1) + j8\right] - 2\mathbf{I}_2 + \mathbf{I}_3(1 + j1) = 0$$

$$\mathbf{I}_2(-1 - j1 - 2) + \mathbf{I}_3(1 + j1) - j8 = 0$$

$$\mathbf{I}_2(-3 - j1) + \mathbf{I}_3(1 + j1) = j8$$

$$\mathbf{I}_3 = \frac{j8 - \mathbf{I}_2(-3 - j1)}{1 + j1}$$

$$\mathbf{I}_3 = 4 + j4 - \mathbf{I}_2(-2 + j1) \qquad \text{..... (10)}$$

Step 18 of 22

Substituting equations (8) and (10) in equation (7) we get

$$\left[\mathbf{I}_2(1 + j1) + j8\right](1 - j1) + \mathbf{I}_2(j1) - \left[4 + j4 - \mathbf{I}_2(-2 + j1)\right] = 4$$

$$\mathbf{I}_2(2) + (8 + j8) + \mathbf{I}_2(j1) - 4 - j4 + \mathbf{I}_2(-2 + j1) = 4$$

$$\mathbf{I}_2(2 + j1 - 2 + j1) + 8 + j8 - 4 - j4 = 4$$

$$\mathbf{I}_2(j2) + 4 + j4 = 4$$

$$\mathbf{I}_2(j2) = -j4$$

$$\mathbf{I}_2 = -2 \text{ A}$$

Step 19 of 22

From the circuit,

$\mathbf{V}_{oc} = -\mathbf{I}_2$

$= -(-2)$

$\mathbf{V}_{oc} = 2$ V

Now Thevenin's impedance is given by

$$Z_{Th} = \frac{\mathbf{V}_{oc}}{\mathbf{I}_{sc}}$$

$$Z_{Th} = \frac{2}{5.657\angle -135°}$$

$$Z_{Th} = 0.3535\angle 135° \Omega$$

$$Z_{Th} = (-0.25 + j0.25)\ \Omega$$

Step 20 of 22

Now the Norton's equivalent circuit is

Step 21 of 22

Equivalent impedance of the circuit is

$$Z_{eq} = \frac{Z_{Th} \times 1}{Z_{Th} + 1}$$

$$Z_{eq} = \frac{(-0.25 + j0.25) \times 1}{-0.25 + j0.25 + 1}$$

$$Z_{eq} = \frac{-0.25 + j0.25}{0.75 + j0.25}$$

$$Z_{eq} = (-0.2 + j0.4)\ \Omega$$

Step 22 of 22

Output voltage is

$\mathbf{V}_o = \mathbf{I}_{sc} \times Z_{eq}$

$\mathbf{V}_o = (5.657\angle -135°) \times (-0.2 + j0.4)$

$\mathbf{V}_o = 2.4 - j0.8$

$\boxed{\mathbf{V}_o = 2.53\angle -18.43° \text{ V}}$

Step 1 of 7

Consider Figure P8.122 from the text book.

Disconnect the $2\ \Omega$ resistor. Identify the currents in the circuit diagram in Figure 1.

Figure 1

Step 2 of 7

Calculate the value of the open circuit voltage $\mathbf{V_{oc}}$.

$$\begin{aligned}\mathbf{V_{oc}} &= (2)(1)+(4)(1)\\ &= 6\ \mathrm{V}\end{aligned}$$

Therefore, the value of the open circuit voltage of the circuit is $6\ \mathrm{V}$.

Step 3 of 7

Disconnect the $2\ \Omega$ resistor and short the terminals. Identify the currents in the circuit diagram in Figure 2.

Figure 2

Step 4 of 7

Apply Kirchhoff's Voltage Law in loop-4.

$$\begin{aligned}&\mathbf{I_{sc}} - 4 + \mathbf{I_{sc}} - 2 = 0\\ &2\mathbf{I_{sc}} - 6 = 0\\ &\mathbf{I_{sc}} - 3 = 0\\ &\mathbf{I_{sc}} = 3\ \mathrm{A}\end{aligned}$$

Therefore, the value of the short circuit current is $\boxed{3\ \mathrm{A}}$.

This value of the short circuit current is the Norton's current.

Step 5 of 7

Calculate the value of the Norton's impedance.

$$\mathbf{Z_N} = \frac{\mathbf{V_{oc}}}{\mathbf{I_{sc}}}$$

Substitute $3\ \mathrm{A}$ for $\mathbf{I_{sc}}$ and $6\ \mathrm{V}$ for $\mathbf{V_{oc}}$.

$$\begin{aligned}\mathbf{Z_N} &= \frac{6}{3}\\ &= 2\ \Omega\end{aligned}$$

Therefore, the value of the Norton's impedance is $\boxed{2\ \Omega}$.

Step 6 of 7

Draw the Norton's equivalent circuit diagram with a resistor of $2\ \Omega$ as the load.

Figure 3

Step 7 of 7

Calculate the value of the voltage $\mathbf{V_o}$ using current division rule.

$$\begin{aligned}\mathbf{V_o} &= (3)\left(\frac{2}{2+2}\right)(2)\\ &= 3\ \mathrm{V}\end{aligned}$$

Therefore, the value of the output voltage $\mathbf{V_o}$ is $\boxed{3\ \mathrm{V}}$.

Step 1 of 10

8.149P

Consider Figure P8.128 from the text book.

Disconnect the $1\ \Omega$ resistor across the output terminals. Short the terminals to Find out the short circuit current.

Figure 3

Step 2 of 10

Apply Kirchhoff's Voltage Law in Loop-1.

$$I_1(-j1)+(I_1-I_3)(1)+(I_1-I_2)(j1)-6=0$$
$$I_1(-j1+1+j1)+I_2(-j1)+I_3(-1)=6$$
$$I_1(1)+I_2(-j1)+I_3(-1)=6 \text{ ..... (1)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-1 is $I_1(1)+I_2(-j1)+I_3(-1)=6$.

Step 3 of 10

Apply Kirchhoff's Voltage Law in Loop-3.

$$I_3(1)+(I_3-I_2)(1)+(I_3-I_2)(1)=0$$
$$I_1(-1)+I_2(-1)+I_3(3)=0 \text{ ..... (2)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-3 is $I_1(-1)+I_2(-1)+I_3(3)=0$.

Step 4 of 10

Consider the value of the current I_2 .

$$I_2=4\text{ A} \text{ ..... (3)}$$

Therefore, the value of the current I_2 is 4 A .

Step 5 of 10

Recall the equations (1), (2) and (3).

$$I_1(1)+I_2(-j1)+I_3(-1)=6$$
$$I_1(-1)+I_2(-1)+I_3(3)=0$$
$$I_2=2\text{ A}$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix}1 & -j1 & -1\\ -1 & -1 & 3\\ 0 & 1 & 0\end{bmatrix}}_{Z}\cdot\underbrace{\begin{bmatrix}I_1\\ I_2\\ I_3\end{bmatrix}}_{I}=\underbrace{\begin{bmatrix}6\\ 0\\ 4\end{bmatrix}}_{V}$$

Here, Z represents the impedance matrix.

V represents the voltage vector.

I represents the current vector.

Step 6 of 10

Use the following MATLAB code to solve for output voltage.

```
>> Z=[1,-j1,-1; -1,-1,3;0,1,0]; % IMPEDANCE MATRIX
>> V=[6;0;4]; % VOLTAGE VECTOR
>> I=inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR
IN = I(3) % EQUATION FOR SHORT CIRCUIT CURRENT
```

Output:

```
IN =
5.0000 + 2.0000i
```

Therefore, the value of the Norton's current is $5+j2\text{ A}$.

Step 7 of 10

Open the current source and short the voltage source in the circuit diagram.

Figure 2

Step 8 of 10

Calculate the value of Norton's impedance Z_N .

$$\begin{aligned}Z_N&=\left[(-j1+j1)\|1\right]+1+1\\&=\left[(0)\|1\right]+1+1\\&=\frac{(0)(1)}{0+1}+1+1\\&=2\ \Omega\end{aligned}$$

Therefore, the value of Norton's impedance Z_N is $2\ \Omega$.

Step 9 of 10

Draw the Norton's equivalent circuit diagram with a resistor of $1\ \Omega$ as the load.

Figure 3

Step 10 of 10

Calculate the value of the voltage V_o using current division rule.

$$\begin{aligned}V_o&=(5+j2)\left(\frac{2}{2+1}\right)(1)\\&=3.33+j1.33\\&=3.59\angle 21.8^\circ\text{ V}\end{aligned}$$

Therefore, the value of the output voltage V_o is $\boxed{3.59\angle 21.8^\circ\text{ V}}$.

Step 1 of 8

Refer Figure P8.129 from the text book.

Identify the currents in the circuit diagram.

Figure 1

Step 2 of 8

Consider the super mesh equation in loop-1 and 3.

$$(I_1 - I_2)(-j1) + (I_3 - I_4)(1) + (I_3 - I_5)(1) + (I_3 - I_2)(1) - 6 = 0$$
$$I_1(-j1) + I_2(-1 + j1) + I_3(1 + 1 + 1) + I_4(-1) + I_5(-1) = 6$$

$$I_1(-j1) + I_2(-1 + j1) + I_3(3) + I_4(-1) + I_5(-1) = 6 \text{ ..... (1)}$$

Therefore, the super mesh equation is $I_1(-j1) + I_2(-1 + j1) + I_3(3) + I_4(-1) + I_5(-1) = 6$.

Step 3 of 8

Consider Kirchhoff's Voltage equation in loop 2.

$$I_2(1) + (I_2 - I_1)(-j1) + (I_2 - I_3)(1) = 0$$
$$I_1(j1) + I_2(1 - j1 + 1) + I_3(-1) = 0$$

$$I_1(j1) + I_2(2 - j1) + I_3(-1) = 0 \text{ ..... (2)}$$

Therefore, the Kirchhoff's Voltage equation in loop 2 is $I_1(j1) + I_2(2 - j1) + I_3(-1) = 0$.

Step 4 of 8

Consider Kirchhoff's Voltage equation in loop 4.

$$I_4(1) + (I_4 - I_3)(1) - 12 = 0$$
$$I_4(1 + 1) + I_3(-1) = 12$$

$$I_3(-1) + I_4(2) = 12 \text{ ..... (3)}$$

Therefore, the Kirchhoff's Voltage equation in loop 4 is $I_3(-1) + I_4(2) = 12$.

Step 5 of 8

Consider Kirchhoff's Voltage equation in loop 5.

$$I_5(j1) + (I_5 - I_3)(1) + 12 = 0$$
$$I_5(1 + j1) + I_3(-1) = -12$$

$$I_3(-1) + I_5(1 + j1) = -12 \text{ ..... (4)}$$

Therefore, the Kirchhoff's Voltage equation in loop 5 is $I_3(-1) + I_5(1 + j1) = -12$.

Step 6 of 8

Consider the relation between the currents I_3 and I_1 .

$$I_1 - I_3 = 2 \text{ ..... (5)}$$

Therefore, the relation between the currents I_3 and I_1 is $I_1 - I_3 = 2$.

Step 7 of 8

Recall the equations (1), (2), (3), (4) and (5).

$$I_1(-j1) + I_2(-1 + j1) + I_3(3) + I_4(-1) + I_5(-1) = 6$$

$$I_1(j1) + I_2(2 - j1) + I_3(-1) = 0$$

$$I_3(-1) + I_4(2) = 12$$

$$I_3(-1) + I_5(1 + j1) = -12$$

$$I_1 - I_3 = 2$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} j1 & -1+j1 & 3 & -1 & -1 \\ j1 & 2-j1 & -1 & 0 & 0 \\ 0 & 0 & -1 & 2 & 0 \\ 0 & 0 & -1 & 0 & 1+j1 \\ 1 & 0 & -1 & 0 & 0 \end{bmatrix}}_{Z} \cdot \underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix}}_{I} = \underbrace{\begin{bmatrix} 6 \\ 0 \\ 12 \\ -12 \\ 2 \end{bmatrix}}_{V}$$

Here, Z represents the impedance matrix.

V represents the voltage vector.

I represents the current vector.

Step 8 of 8

Use the following MATLAB code to solve for output voltage.

```
>>Z = [-1j,-1+1j,3,-1,-1;1j,2-1j,-1,0,0;0,0,-1,2,0;0,0,-1,0,1+1j;1,0,-1,0,0];% IMPEDANCE MATRIX

>> V = [6;0;12;-12;2]; % VOLTAGE VECTOR

>> I = inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR

>> I0 = I(2)-I(3) % EQUATION FOR OUTPUT CURRENT
```

Output:

```
I0 =

-0.5660 - 3.0189i

>> V0 = I0*1 % EQUATION FOR OUTPUT VOLTAGE
```

Output:

```
V0 =

-0.5660 - 3.0189i
```

Therefore, the value of the output voltage is $-0.5660 - j3.0189$, that is

$\boxed{3.072\angle -100.62^\circ \text{ V}}$.

Step 1 of 7

Refer Figure P8.130 from the text book.

Identify the voltages in the circuit diagram.

Figure 1

Step 2 of 7

Consider the nodal equation at node-1.

$$\frac{V_1-12}{2}+\frac{V_1-V_3}{-j1}+\frac{V_1-V_2}{1}=0$$

$$V_1\left(\frac{1}{2}+\frac{1}{-j1}+1\right)+V_2(-1)+V_3\left(\frac{-1}{-j1}\right)-\frac{12}{2}=0$$

$$V_1(0.5+j1+1)+V_2(-1)+V_3(-j1)-6=0$$

$$V_1(1.5+j1)+V_2(-1)+V_3(-j1)=6 \text{ ..... (1)}$$

Therefore, the nodal equation node-1 is $V_1(1.5+j1)+V_2(-1)+V_3(-j1)=6$.

Step 3 of 7

Consider the nodal equation at node-2.

$$\frac{V_2-V_1}{1}+\frac{V_2}{1}-2=0$$

$$V_2(1+1)+V_1(-1)=2$$

$$V_1(-1)+V_2(2)=2 \text{ ..... (2)}$$

Therefore, the nodal equation node-2 is $V_1(-1)+V_2(2)=2$.

Step 4 of 7

Consider the nodal equation at node-3.

$$\frac{V_3-V_1}{-j1}+\frac{V_3-12}{1}+\frac{V_3-V_4}{j1}+\frac{V_3}{2}=0$$

$$V_3\left(\frac{1}{-j1}+1+\frac{1}{j1}+\frac{1}{2}\right)+V_1\left(\frac{-1}{-j1}\right)+V_4\left(\frac{-1}{j1}\right)-\frac{12}{1}=0$$

$$V_1(-j1)+V_3(1.5)+V_4(j1)=12 \text{ ..... (3)}$$

Therefore, the nodal equation node-3 is $V_1(-j1)+V_3(2)+V_4(j1)=12$.

Step 5 of 7

Consider the nodal equation at node-4.

$$\frac{V_4-V_3}{j1}+\frac{V_4}{-j2}+2=0$$

$$V_3\left(\frac{-1}{j1}\right)+V_1\left(\frac{1}{j1}+\frac{1}{-j2}\right)=-2$$

$$V_3(j1)+V_4(-j1+0.5j)=-2$$

$$V_3(j1)+V_4(-0.5j)=-2 \text{ ..... (4)}$$

Therefore, the nodal equation node-4 is $V_3(j1)+V_4(-0.5j)=-2$.

Step 6 of 7

Recall the equations (1), (2), (3) and (4).

$$V_1(1.5+j1)+V_2(-1)+V_3(-j1)=6$$

$$V_1(-1)+V_2(2)=2$$

$$V_1(-j1)+V_3(2)+V_4(j1)=12$$

$$V_3(j1)+V_4(-0.5j)=-2$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 1.5+j1 & -1 & -j1 & 0 \\ -1 & 2 & 0 & 0 \\ -j1 & 0 & 1.5 & j1 \\ 0 & 0 & j1 & -j0.5 \end{bmatrix}}_{Y}\cdot\underbrace{\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}}_{V}=\underbrace{\begin{bmatrix} 6 \\ 2 \\ 12 \\ -2 \end{bmatrix}}_{I}$$

Here, Y represents the admittance matrix.

V represents the voltage vector.

I represents the current vector.

Step 7 of 7

Use the following MATLAB code to solve for output voltage.

```
>>Y=[1.5+1j,-1,-1j,0;-1,2,0,0;-1j,0,1.5,1j;0,0,1j,-0.5j];% ADMITTANCE MATRIX

>> I = [6;2;12;-2]; % CURRENT VECTOR

>> V = inv(Y)*I % FORMULA TO FIND VOLTAGE VECTOR
```

Output:

```
>> V =

6.5800 - 2.0600i

4.2900 - 1.0300i

4.5200 - 1.6400i

9.0400 - 7.2800i
```

Therefore, the values of the nodal voltages are $\boxed{V_1 = 6.5800 - j2.0600 \text{ V}}$,

$\boxed{V_2 = 4.2900 - j1.0300 \text{ V}}$, $\boxed{V_3 = 4.5200 - 1.6400 \text{ V}}$ and

$\boxed{V_4 = 9.0400 - 7.2800 \text{ V}}$.

Step 1 of 8

8.152P

Refer Figure P8.131 from the text book.

Identify the voltages in the circuit diagram. Use complex number notation for source voltage.

Figure 1

Step 2 of 8

Identify the super node between the nodes 1 and 2.

Consider the nodal equation at nodes-1 and 2.

$$\frac{V_1-V_4}{1}+\frac{V_1}{-j1}+\frac{V_2}{1}+2=0$$

$$V_1\left(1+\frac{1}{-j1}\right)+V_2(1)+V_4(-1)=-2$$

$$V_1(1+j1)+V_2(1)+V_4(-1)=-2 \text{ ..... (1)}$$

Therefore, the nodal equation at nodes 1 and 2 is $V_1(1+j1)+V_2(1)+V_4(-1)=-2$.

Step 3 of 8

Consider the relation between the voltages V_1 and V_2 .

$$V_2-V_1=6$$

$$V_1(-1)+V_2(1)=6 \text{ ..... (2)}$$

Therefore, the relation between the voltages V_1 and V_2 is $V_1(-1)+V_2(1)=6$.

Step 4 of 8

Consider the nodal equation at node-3.

$$\frac{V_3-V_4}{1}+\frac{V_3}{j1}+\frac{V_3-V_o}{1}=0$$

$$V_3\left(1+\frac{1}{j1}+1\right)+V_4(-1)+V_o(-1)=0$$

$$V_3(2-j1)+V_4(-1)+V_o(-1)=0 \text{ ..... (3)}$$

Therefore, the nodal equation at node-3 is $V_3(2-j1)+V_4(-1)+V_o(-1)=0$.

Step 5 of 8

Identify the super node between the nodes 4 and 5.

Consider the nodal equation at nodes-4 and 5.

$$\frac{V_o-V_3}{1}+\frac{V_o}{1}+\frac{V_4-V_1}{1}+\frac{V_4-V_3}{1}-2=0$$

$$V_1(-1)+V_3(-1-1)+V_4(1+1)+V_o(1+1)=2$$

$$V_1(-1)+V_3(-2)+V_4(2)+V_o(2)=2 \text{ ..... (4)}$$

Therefore, the nodal equation at nodes 4 and 5 is $V_1(-1)+V_3(-2)+V_4(2)+V_o(2)=2$.

Step 6 of 8

Consider the relation between the voltages V_4 and V_5 .

$$V_4-V_o=10.39+j6\ \Omega$$

$$V_4(1)+V_o(-1)=10.39+j6\ \Omega \text{ ..... (5)}$$

Therefore, the relation between the voltages V_4 and V_5 is $V_4(1)+V_o(-1)=10.39+j6\ \Omega$.

Step 7 of 8

Recall the equations (1), (2), (3), (4) and (5).

$$V_1(1+j1)+V_2(1)+V_4(-1)=-2$$

$$V_1(-1)+V_2(1)=6$$

$$V_3(2-j1)+V_4(-1)+V_o(-1)=0$$

$$V_1(-1)+V_3(-2)+V_4(2)+V_o(2)=2$$

$$V_4(1)+V_o(-1)=10.39+j6\ \Omega$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 1+j1 & 1 & 0 & -1 & 0 \\ -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 2-j1 & -1 & -1 \\ -1 & 0 & -2 & 2 & 2 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}}_{Y} \cdot \underbrace{\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix}}_{V} = \underbrace{\begin{bmatrix} -2 \\ 6 \\ 0 \\ 2 \\ 10.39+j6 \end{bmatrix}}_{I}$$

Here, Y represents the admittance matrix.

V represents the voltage vector.

I represents the current vector.

Step 8 of 8

Use the following MATLAB code to solve for output voltage.

```
>>Y=[1+1j,1,0,-1,0;-1,1,0,0,00;0,0,2-1j,-1,-1;-1,0,-2,2,2;0,0,0,1,-1]; % ADMITTANCE MATRIX

>> I=[-2;6;0;2;10.39+6jj]; % CURRENT VECTOR

>> V = inv(Y)*I % FORMULA TO FIND VOLTAGE VECTOR
```

Output:

```
V =

-0.1455 + 2.0783i

5.8545 + 2.0783i

-0.0560 + 0.9832i

5.6306 + 4.0112i

-4.7594 - 1.9888i

>> V0=V(5) % COMMAND FOR OUTPUT VOLTAGE
```

Output:

```
V0 = -4.7594 - 1.9888i
```

Therefore, the value of the output voltage is $-4.7594 - j1.9888$, that is

$$\boxed{5.158\angle -157.32^\circ\ \text{V}}$$.

Step 1 of 7

Refer Figure P8.133 from the text book.

Identify the circuit diagram shown in the Figure 1.

Figure 1

Step 2 of 7

Consider the Kirchhoff's Voltage Law in Loop-2.

$$(I_2 - I_1)(1) + (I_2 - I_3)(1) + (I_2 - I_5)(1) = 0$$
$$I_1(-1) + I_2(1+1+1) + I_3(-1) + I_5(-1) = 0$$
$$I_1(-1) + I_2(3) + I_3(-1) + I_5(-1) = 0$$

Substitute 2 A for I_1 and 4 A for I_3.

$$2(-1) + I_2(3) + (4)(-1) + I_5(-1) = 0$$
$$I_2(3) + I_5(-1) - 2 - 4 = 0$$
$$I_2(3) + I_5(-1) - 6 = 0$$

$I_2(3) + I_5(-1) = 6$ ..... (1)

Therefore, the Kirchhoff's Voltage Law in Loop-1 is $I_2(3) + I_5(-1) = 6$.

Step 3 of 7

Consider the Kirchhoff's Voltage Law in Loop-4.

$$(I_4 - I_1)(-j1) + (I_4 - I_5)(1) - 12 = 0$$
$$I_1(j1) + I_4(1 - j1) + I_5(-1) - 12 = 0$$

Substitute 2 A for I_1.

$$2(j1) + I_4(1 - j1) + I_5(-1) - 12 = 0$$

$I_4(1 - j1) + I_5(-1) = 12 - j2$ ..... (2)

Therefore, the Kirchhoff's Voltage Law in Loop-2 is $I_4(1 - j1) + I_5(-1) = 12 - j2$.

Step 4 of 7

Consider the Kirchhoff's Voltage Law in loops 5.

$$(I_5 - I_4)(1) + (I_5 - I_2)(1) + (I_5 - I_6)(j1) = 0$$
$$I_2(-1) + I_4(-1) + I_5(1 + 1 + j1) + I_6(j1) = 0$$

$I_2(-1) + I_4(-1) + I_5(2 + j1) + I_6(j1) = 0$ ..... (3)

Therefore, the Kirchhoff's Voltage Law in Loop-5

$$I_2(-1) + I_4(-1) + I_5(2 + j1) + I_6(j1) = 0.$$

Step 5 of 7

Consider the Kirchhoff's Voltage Law in loops 6.

$$(I_6 - I_3)(1) + (I_6 - I_5)(j1) + 6 = 0$$
$$I_3(-1) + I_5(-j1) + I_6(1 + j1) + 6 = 0$$

Substitute 4 A for I_3.

$$(4)(-1) + I_5(-j1) + I_6(1 + j1) + 6 = 0$$

$I_5(-j1) + I_6(1 + j1) = -2$ ..... (4)

Therefore, the Kirchhoff's Voltage Law in Loop-6 $I_5(-j1) + I_6(1 + j1) = -2$.

Step 6 of 7

Recall the equations (1), (2), (3) and (4).

$$I_2(3) + I_5(-1) = 6$$
$$I_4(1 - j1) + I_5(-1) = 12 - j2$$
$$I_2(-1) + I_4(-1) + I_5(2 + j1) + I_6(-j1) = 0$$
$$I_5(-j1) + I_6(1 + j1) = -2$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 3 & 0 & -1 & 0 \\ 0 & 1 - j1 & -1 & 0 \\ -1 & -1 & 2 + j1 & -j1 \\ 0 & 0 & -j1 & 1 + j1 \end{bmatrix}}_{Z} \cdot \underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}}_{I} = \underbrace{\begin{bmatrix} 2 \\ 12 - j2 \\ 0 \\ -2 \end{bmatrix}}_{V}$$

Here, Z represents the impedance matrix.

V represents the voltage vector.

I represents the current vector.

Step 7 of 7

Use the following MATLAB code to solve for output voltage.

```
>> Z=[3,0,-1,0; 0,1-1j,-1,0;-1,-1,2+j1,-j1;0,0,-j1,1+j1]; % IMPEDANCE MATRIX

>> V=[6;12-j2;0;-2]; % VOLTAGE VECTOR

>> I=inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR

I0 = I(5)-I(1) % EQUATION FOR OUTPUT CURRENT
```

Output:

I0 = 1.2000 + 1.6000i

Therefore, the value of the output current is $1.2 + j1.6$, that is $\boxed{2\angle 53.13^\circ\text{ V}}$.

Step 1 of 14

Given circuit is

Step 2 of 14

Let us assign the loop currents as I_1, I_2, I_3, I_4, I_5 and I_6 and unknown node voltages as V_1, V_2, V_3, V_4 and V_5. Now the given circuit is modified as below

Step 3 of 14

From the above circuit, we have

$$I_2 - I_1 = 2\angle 0° \text{ A}$$
$$V_x = (1)(I_4 - I_5)$$
$$V_x = (I_4 - I_5) \text{ V}$$
$$I_x = I_5 - I_6$$
$$I_o = I_4 - I_1$$
$$V_1 = -1(I_1) + 2V_x$$
$$V_4 = 1(I_5 - I_6)$$
$$V_4 = (I_5 - I_6)$$
$$V_5 = j1(I_6)$$
$$V_5 = jI_6$$

Step 4 of 14

By applying Mesh Analysis to the loop 4, we get

$$-2V_x + 1(I_4 - I_1) + V_x = 0$$
$$-V_x + I_4 - I_1 = 0$$
$$-(I_4 - I_5) + I_4 - I_1 = 0$$
$$-I_4 + I_5 + I_4 - I_1 = 0$$
$$I_1 = I_5 \qquad \text{..... (1)}$$

Step 5 of 14

By applying Mesh Analysis to the loop 5, we get

$$-12\angle 0° + 1(I_5 - I_6) + 1(I_5 - I_4) = 0$$
$$-I_4 + 2I_5 - I_6 = 12 \qquad \text{..... (2)}$$

Step 6 of 14

By applying Mesh Analysis to the loop 6, we get

$$1(I_6 - I_3) + j1(I_6) + 1(I_6 - I_5) = 0$$
$$I_6(1 + 1 + j1) - I_3(1) - I_5(1) = 0$$
$$-I_3 - I_5 + I_6(2 + j1) = 0 \qquad \text{..... (3)}$$

Step 7 of 14

By applying Mesh Analysis to the super-mesh, we get

$$1(I_1) - j1(I_2 - I_3) + 12\angle 0° + 1(I_1 - I_4) = 0$$
$$I_1(1+1) - I_2(j1) + I_3(j1) - I_4 = -12$$
$$I_1(2) - (2 + I_1)(j1) + I_3(j1) - I_4 = -12$$
$$I_1(2) - j2 - I_1(j1) + I_3(j1) - I_4 = -12$$
$$I_1(2 - j1) + I_3(j1) - I_4 = -12 + j2 \qquad \text{..... (4)}$$

Step 8 of 14

By applying Nodal Analysis at node '1', we get

$$\frac{V_1 - V_2}{1} - 2\angle 0° + \frac{V_1 - V_4}{-j1} + 2I_x = 0$$
$$V_1(1 + j1) - V_2 - V_4(j1) + 2(I_5 - I_6) = 2\angle 0°$$
$$\left[-1(I_1) + 2V_x\right](1 + j1) - 2V_x - \left[1(I_x)\right](j1) + 2(I_5 - I_6) = 2\angle 0°$$
$$\left[-I_1 + 2(I_4 - I_5)\right](1 + j1) - 2(I_4 - I_5) - (I_5 - I_6)(j1) + 2(I_5 - I_6) = 2\angle 0°$$
$$-I_1(1 + j1) + I_4(2 + j2 - 2) + I_5(-2 - j2 + 2 - j1 + 2) - I_6(-j1 + 2) = 2$$

Step 9 of 14

$$-I_1(1 + j1) + I_4(j2) + I_5(2 - j3) - I_6(2 - j1) = 2$$
$$-I_5(1 + j1) + I_4(j2) + I_5(2 - j3) - I_6(2 - j1) = 2 \qquad \because (I_1 = I_5)$$
$$I_4(j2) + I_5(2 - j3 - 1 - j1) - I_6(2 - j1) = 2$$
$$I_4(j2) + I_5(1 - j4) - I_6(2 - j1) = 2 \qquad \text{..... (5)}$$

Step 10 of 14

By applying Nodal Analysis at node '5', we get

$$-2I_x + \frac{V_5}{j1} + \frac{V_5 - V_4}{1} = 0$$
$$-2(I_5 - I_6) + V_5(-j1 + 1) - V_4 = 0$$
$$-2(I_5 - I_6) + (jI_6)(-j1 + 1) - (I_5 - I_6) = 0$$
$$-3(I_5 - I_6) + (I_6)(1 + j1) = 0$$
$$-3I_5 + I_6(4 + j1) = 0$$
$$I_6(4 + j1) = 3I_5$$
$$I_6 = \left[\frac{3}{4 + j1}\right] I_5 \qquad \text{..... (6)}$$

Step 11 of 14

By substituting equation (6) in equation (5), we get

$$I_4(j2) + I_5(1 - j4) - \left[\left(\frac{3}{4 + j1}\right) I_5\right](2 - j1) = 2$$
$$I_4(j2) + I_5(1 - j4) - I_5(1.235 - j1.059) = 2$$
$$I_4(j2) + I_5(1 - j4 - 1.235 + j1.059) = 2$$
$$I_4(j2) + I_5(-0.235 - j2.941) = 2$$
$$I_4 = \frac{2 - I_5(-0.235 - j2.941)}{j2} \qquad \text{..... (7)}$$

Step 12 of 14

By substituting equations (6) and (7) in equation (2), we get

$$-\left[\frac{2 - I_5(-0.235 - j2.941)}{j2}\right] + 2I_5 - \left[\frac{3}{4 + j1}\right] I_5 = 12$$
$$I_5\left(\frac{-0.235 - j2.941}{j2} + 2 - \frac{3}{4 + j1}\right) - \frac{2}{j2} = 12$$
$$I_5(-1.4705 + j0.1175 + 2 - 0.7059 + j0.1765) + j1 = 12$$
$$I_5(-0.1764 + j0.294) = 12 - j1$$
$$I_5 = \frac{12 - j1}{-0.1764 + j0.294}$$
$$= \frac{12.042\angle -4.76°}{0.34\angle 120.96°}$$
$$= 35.12\angle -125.73°$$
$$I_5 = (-20.5 - j28.5) \text{ A}$$

Step 13 of 14

From equation (7)

$$I_4 = \frac{2 - I_5(-0.235 - j2.941)}{j2}$$
$$= \frac{2 - (-20.5 - j28.5)(-0.235 - j2.941)}{j2}$$
$$= \frac{2 - (-79 + j66.98)}{j2}$$
$$= \frac{81 - j66.98}{j2}$$
$$= 52.55\angle -129.58°$$
$$I_4 = (-33.49 - j40.5) \text{ A}$$

Step 14 of 14

From the circuit I_o is given by

$$I_o = I_4 - I_1$$
$$= I_4 - I_5$$
$$= (-33.49 - j40.5) - (-20.5 - j28.5)$$
$$= -13 - j12$$
$$\boxed{I_o = 17.68\angle -137.26° \text{ A}}$$

Step 1 of 10

Consider Figure P8.139 from the text book.

Identify the circuit diagram shown in the Figure 1.

Figure 1

Step 2 of 10

Consider the expression for $\mathbf{I}_x$.

$$\mathbf{I}_x = \mathbf{I}_1 - \mathbf{I}_2$$

Therefore, the expression for V_x is $I_1 - I_2$.

Step 3 of 10

Consider the Kirchhoff's Voltage Law in Loop-1.

$$\mathbf{I}_1(1)+(\mathbf{I}_1-\mathbf{I}_2)(1)+(\mathbf{I}_1-\mathbf{I}_4)(j1)=0$$
$$\mathbf{I}_1(1+1+j1)+\mathbf{I}_2(-1)+\mathbf{I}_4(-j1)=0$$

$$\mathbf{I}_1(2+j1)+\mathbf{I}_2(-1)+\mathbf{I}_4(-j1)=0 \text{ ..... (1)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-1 is $\mathbf{I}_1(2+j1)+\mathbf{I}_2(-1)+\mathbf{I}_4(-j1)=0$.

Step 4 of 10

Consider the super mesh voltage equation in Loops 2 and 3.

$$(\mathbf{I}_2-\mathbf{I}_1)(1)+\mathbf{I}_3(1)+(\mathbf{I}_3-\mathbf{I}_6)(-j1)+(\mathbf{I}_2-\mathbf{I}_5)(1)+\mathbf{I}_6(-1)=0$$
$$\mathbf{I}_1(-1)+\mathbf{I}_2(1+1)+\mathbf{I}_3(1+1)+\mathbf{I}_5(-1)+\mathbf{I}_6(-1)=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_2(2)+\mathbf{I}_3(2)+\mathbf{I}_5(-1)+\mathbf{I}_6(-1)=0 \text{ ..... (2)}$$

Therefore, the super mesh voltage equation in Loops 2 and 3 is

$$\mathbf{I}_1(-1)+\mathbf{I}_2(2)+\mathbf{I}_3(2)+\mathbf{I}_5(-1)+\mathbf{I}_4(-1)=0.$$

Step 5 of 10

Consider the Kirchhoff's Voltage Law in Loop-4.

$$\mathbf{I}_4(1)+(\mathbf{I}_4-\mathbf{I}_1)(j1)+6=0$$

$$\mathbf{I}_1(-j1)+\mathbf{I}_4(1+j1)=-6 \text{ ..... (3)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-3 is $\mathbf{I}_1(-j1)+\mathbf{I}_4(1+j1)=-6$.

Step 6 of 10

Consider the Kirchhoff's Voltage Law in Loop-5.

$$(\mathbf{I}_5-\mathbf{I}_2)(1)+(\mathbf{I}_5-\mathbf{I}_6)(-j1)-6=0$$

$$\mathbf{I}_2(-1)+\mathbf{I}_5(1-j1)+\mathbf{I}_6(j1)=6 \text{ ..... (4)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-5 $\mathbf{I}_2(-1)+\mathbf{I}_5(1-j1)+\mathbf{I}_6(j1)=6$.

Step 7 of 10

Consider the Kirchhoff's Voltage Law in Loop-6.

$$(\mathbf{I}_6-\mathbf{I}_3)(1)+(\mathbf{I}_6-\mathbf{I}_5)(-j1)-4=0$$

$$\mathbf{I}_3(-1)+\mathbf{I}_5(j1)+\mathbf{I}_6(1-j1)=4 \text{ ..... (5)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-6 is $\mathbf{I}_3(-1)+\mathbf{I}_5(j1)+\mathbf{I}_6(1-j1)=4$.

Step 8 of 10

Consider the relation between the currents $\mathbf{I}_2$ and $\mathbf{I}_3$.

$$\mathbf{I}_2-\mathbf{I}_3=2\mathbf{I}_x$$

Substitute $\mathbf{I}_1-\mathbf{I}_2$ for $\mathbf{I}_x$.

$$\mathbf{I}_2-\mathbf{I}_3=2(\mathbf{I}_1-\mathbf{I}_2)$$

$$\mathbf{I}_1(2)+\mathbf{I}_2(-3)+\mathbf{I}_3(1)=0 \text{ ..... (6)}$$

Therefore, the relation between the currents $\mathbf{I}_2$ and $\mathbf{I}_3$ is $\mathbf{I}_1(2)+\mathbf{I}_2(-3)+\mathbf{I}_3(1)=0$.

Step 9 of 10

Recall the equations (1), (2), (3), (4), (5) and (6).

$$\mathbf{I}_1(2+j1)+\mathbf{I}_2(-1)+\mathbf{I}_4(-j1)=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_2(2)+\mathbf{I}_3(2)+\mathbf{I}_5(-1)+\mathbf{I}_6(-1)=0$$

$$\mathbf{I}_1(-j1)+\mathbf{I}_4(1+j1)=-6$$

$$\mathbf{I}_2(-1)+\mathbf{I}_5(1-j1)+\mathbf{I}_6(j1)=6$$

$$\mathbf{I}_3(-1)+\mathbf{I}_5(j1)+\mathbf{I}_6(1-j1)=4$$

$$\mathbf{I}_1(2)+\mathbf{I}_2(-3)+\mathbf{I}_3(1)=0$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 2+j1 & -1 & 0 & -j1 & 0 & 0 \\ -1 & 2 & 2 & 0 & -1 & -1 \\ -j1 & 0 & 0 & 1+j1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1-j1 & j1 \\ 0 & 0 & -1 & 0 & j1 & 1-j1 \\ 2 & -3 & 1 & 0 & 0 & 0 \end{bmatrix}}_{\mathbf{Z}} \cdot \underbrace{\begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \\ \mathbf{I}_3 \\ \mathbf{I}_4 \\ \mathbf{I}_5 \\ \mathbf{I}_6 \end{bmatrix}}_{\mathbf{I}} = \underbrace{\begin{bmatrix} 0 \\ 0 \\ -6 \\ 6 \\ 4 \\ 0 \end{bmatrix}}_{\mathbf{V}}$$

Here, $\mathbf{Z}$ represents the impedance matrix.

$\mathbf{V}$ represents the voltage vector.

$\mathbf{I}$ represents the current vector.

Step 10 of 10

Use the following MATLAB code to solve for output voltage.

```
>> Z=[2+1j,-1,0,-1j,0,0; -1,2,2,0,-1,-1;-1j,0,0,1+1j,0,0;0,-1,0,0,1-1j,1j;0,0,-1,0,1j,1-1j;2,-3,1,0,0,0]; %
IMPEDANCE MATRIX

>> V=[0;0;-6;6;4;0]; % VOLTAGE VECTOR

>> I=inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR

>>I0 = I(6)-I(3) % EQUATION FOR OUTPUT CURRENT
```

MATLAB Output:

I0 =

2.5057 + 0.3698i

Therefore, the value of the output current is $\mathbf{2.5057 + j0.3698}$, that is $\boxed{2.533\angle 8.4^\circ \text{ V}}$.

Step 1 of 10

8.157P

Consider Figure P8.140 from the text book.

Identify the circuit diagram shown in the Figure 1.

Figure 1

Step 2 of 10

Consider the expression for $\mathbf{V}_x$.

$$\mathbf{V}_x = \mathbf{I}_6(1)$$

Therefore, the expression for $\mathbf{V}_x$ is $\mathbf{I}_6(1)$.

Step 3 of 10

Consider the Kirchhoff's Voltage Law in Loop-1.

$$\mathbf{I}_1(1)+(\mathbf{I}_1-\mathbf{I}_2)(1)+(\mathbf{I}_1-\mathbf{I}_4)(1)=0$$

$$\mathbf{I}_1(1+1+1)+\mathbf{I}_2(-1)+\mathbf{I}_4(-1)=0$$

$$\mathbf{I}_1(3)+\mathbf{I}_2(-1)+\mathbf{I}_4(-1)=0 \text{ ..... (1)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-1 is $\mathbf{I}_1(3)+\mathbf{I}_2(-1)+\mathbf{I}_4(-1)=0$.

Step 4 of 10

Consider the Kirchhoff's Voltage Law in Loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(1)+(\mathbf{I}_2-\mathbf{I}_3)(-j1)+2\mathbf{V}_x=0$$

Substitute $\mathbf{I}_6(1)$ for $\mathbf{V}_x$.

$$(\mathbf{I}_2-\mathbf{I}_1)(1)+(\mathbf{I}_2-\mathbf{I}_3)(-j1)+2\mathbf{I}_6(1)=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_2(1-j1)+\mathbf{I}_3(j1)+\mathbf{I}_6(2)=0 \text{ ..... (2)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-2 is

$$\mathbf{I}_1(-1)+\mathbf{I}_2(1-j1)+\mathbf{I}_3(j1)+\mathbf{I}_6(2)=0.$$

Step 5 of 10

Consider the Kirchhoff's Voltage Law in Loop-3.

$$\mathbf{I}_3(1)+(\mathbf{I}_3-\mathbf{I}_2)(-j1)+12=0$$

$$\mathbf{I}_2(j1)+\mathbf{I}_3(1-j1)=-12 \text{ ..... (3)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-3 is $\mathbf{I}_2(j1)+\mathbf{I}_3(1-j1)=-12$.

Step 6 of 10

Consider the super mesh voltage equation in Loops 4 and 5.

$$(\mathbf{I}_4-\mathbf{I}_1)(1)+(\mathbf{I}_5-\mathbf{I}_6)(1)-2\mathbf{V}_x+\mathbf{I}_4(-j1)-2\mathbf{I}_6=0$$

Substitute $\mathbf{I}_6(1)$ for V_x .

$$(\mathbf{I}_4-\mathbf{I}_1)(1)+(\mathbf{I}_5-\mathbf{I}_6)(1)-2\mathbf{I}_6(1)+\mathbf{I}_4(j1)-2\mathbf{I}_6=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_4(1+j1)+\mathbf{I}_5(1)+\mathbf{I}_6(-1-2)=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_4(1+j1)+\mathbf{I}_5(1)+\mathbf{I}_6(-3)=0 \text{ ..... (4)}$$

Therefore, the super mesh voltage equation in Loops 4 and 5

$$\mathbf{I}_1(-1)+\mathbf{I}_4(1+j1)+\mathbf{I}_5(1)+\mathbf{I}_6(-3)=0.$$

Step 7 of 10

Consider the relation between the currents $\mathbf{I}_5$ and $\mathbf{I}_4$.

$$\mathbf{I}_5-\mathbf{I}_4=2 \text{ ..... (5)}$$

Therefore, the relation between the currents $\mathbf{I}_5$ and $\mathbf{I}_4$ is $\mathbf{I}_5-\mathbf{I}_4=2$.

Step 8 of 10

Consider the Kirchhoff's Voltage Law in Loop-6.

$$\mathbf{I}_6(1)+(\mathbf{I}_6-\mathbf{I}_5)(1)-12=0$$

$$\mathbf{I}_5(-1)+\mathbf{I}_6(2)=12 \text{ ..... (6)}$$

Therefore, the Kirchhoff's Voltage Law in Loop-6 is $\mathbf{I}_5(-1)+\mathbf{I}_6(2)=12$.

Step 9 of 10

Recall the equations (1), (2), (3), (4), (5) and (6).

$$\mathbf{I}_1(3)+\mathbf{I}_2(-1)+\mathbf{I}_4(-1)=0$$

$$\mathbf{I}_1(-1)+\mathbf{I}_2(1-j1)+\mathbf{I}_3(j1)+\mathbf{I}_6(2)=0$$

$$\mathbf{I}_2(j1)+\mathbf{I}_3(1-j1)=-12$$

$$\mathbf{I}_1(-1)+\mathbf{I}_4(1+j1)+\mathbf{I}_5(1)+\mathbf{I}_6(-3)=0$$

$$\mathbf{I}_5-\mathbf{I}_4=2$$

$$\mathbf{I}_5(-1)+\mathbf{I}_6(2)=12$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 3 & -1 & 0 & -1 & 0 & 0 \\ -1 & 1-j1 & j1 & 0 & 0 & 2 \\ 0 & j1 & 1-j1 & 0 & 0 & 0 \\ -1 & 0 & 0 & 1+j1 & 1 & -3 \\ 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & 0 & 0 & -1 & 2 \end{bmatrix}}_{\mathbf{Z}} \cdot \underbrace{\begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \\ \mathbf{I}_3 \\ \mathbf{I}_4 \\ \mathbf{I}_5 \\ \mathbf{I}_6 \end{bmatrix}}_{\mathbf{I}} = \underbrace{\begin{bmatrix} 0 \\ 0 \\ -12 \\ 0 \\ 2 \\ 12 \end{bmatrix}}_{\mathbf{V}}$$

Here, $\mathbf{Z}$ represents the impedance matrix.

$\mathbf{V}$ represents the voltage vector.

$\mathbf{I}$ represents the current vector.

Step 10 of 10

Use the following MATLAB code to solve for output voltage.

```
>> Z = [3,-1,0,-1,0,0;-1,1-1j,1j,0,0,2;0,1j,1-1j,0,0,0;-1,0,0,1+1j,1,-3;0,0,0,-1,1,0;0,0,0,0,-1,2];% IMPEDANCE MATRIX

V = [0;0;-12;0;2;12]; % VOLTAGE VECTOR

I = inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR

I0 = I(5)-I(6) % EQUATION FOR OUTPUT CURRENT

I0 =

-3.4897 - 5.8759i
```

Therefore, the value of the output current is $-3.4897-j5.8759$, that is

$$\boxed{6.834\angle -120.71^\circ \text{ V}}.$$

Step 1 of 8

Consider Figure P8.141 from the text book.

Figure 1

Step 2 of 8

Apply Kirchhoff's Voltage Law in Loop-1.

$$(I_1 - I_2)(-j1) + (I_1 - I_4)(1) - 12 = 0$$

$$I_1(1 - j1) + I_2(j1) + I_4(-1) = 12 \text{ ..... (1)}$$

Therefore, Kirchhoff's Voltage Law in Loop-1 is $I_1(1 - j1) + I_2(j1) + I_4(-1) = 12$.

Step 3 of 8

Apply Kirchhoff's Voltage Law in Loop-2.

$$(I_2 - I_1)(-j1) + (I_2 - I_5)(1) + (I_2 - I_3)(1) = 0$$
$$I_1(j1) + I_2(1 + 1 - j1) + I_3(-1) + I_5(-1) = 0$$
$$I_1(j1) + I_2(2 - j1) + I_3(-1) + I_5(-1) = 0$$

Substitute -2 A for I_3.

$$I_1(j1) + I_2(2 - j1) + (-2)(-1) + I_5(-1) = 0$$
$$I_1(j1) + I_2(2 - j1) + 2 + I_5(-1) = 0$$

$$I_1(j1) + I_2(2 - j1) + I_5(-1) = -2 \text{ ..... (2)}$$

Therefore, Kirchhoff's Voltage Law in Loop-2 is $I_1(j1) + I_2(2 - j1) + I_5(-1) = -2$.

Step 4 of 8

Apply super mesh equation in Loops 4 and 5.

$$(I_4 - I_1)(1) + (I_5 - I_2)(1) + I_4(1) + 6 = 0$$
$$I_1(-1) + I_2(-1) + I_4(1 + 1) + I_5(1) + 6 = 0$$

$$I_1(-1) + I_2(-1) + I_4(2) + I_5(1) = -6 \text{ ..... (3)}$$

Therefore, super mesh equation in Loops 4 and 5 is $I_1(-1) + I_2(-1) + I_4(2) + I_5(1) = -6$.

Step 5 of 8

Apply Kirchhoff's Voltage Law in Loop-6.

$$(I_6 - I_3)(1) + I_6(j1) - 6 = 0$$
$$I_6(1 + j1) - I_3 = 6$$

Substitute -2 A for I_3.

$$I_6(1 + j1) + 2 = 6$$
$$I_6(1 + j1) = 6 - 2$$
$$I_6(1 + j1) = 4$$
$$I_6 = \frac{4}{1 + j1}$$

$$I_6 = 2 - j2 \text{ A}$$

Therefore, the value of the current I_6 is $2 - j2$ A.

Step 6 of 8

Consider the relation between the currents I_5 and I_4.

$$I_5 - I_4 = 2I_x$$

Substitute $I_6 - I_3$ for I_x.

$$I_5 - I_4 = 2(I_6 - I_3)$$

Substitute $2 - j2$ A for I_6 and -2 A for I_3.

$$I_5 - I_4 = 2(2 - j2 - (-2))$$
$$I_4(-1) + I_5 = 2(2 - j2 + 2)$$
$$I_4(-1) + I_5 = 2(4 - j2)$$

$$I_4(-1) + I_5 = 8 - j4 \text{ ..... (4)}$$

Therefore, the relation between the currents I_5 and I_4 is $I_4(-1) + I_5 = 8 - j4$.

Step 7 of 8

Recall the equations (1), (2), (3) and (4).

$$I_1(1 - j1) + I_2(j1) + I_4(-1) = 12$$

$$I_1(j1) + I_2(2 - j1) + I_5(-1) = 2$$

$$I_1(-1) + I_2(-1) + I_4(2) + I_5(1) = -6$$

$$I_4(-1) + I_5 = 8 - j4$$

Rewrite the equations in matrix notation.

$$\underbrace{\begin{bmatrix} 1 - j1 & j1 & -1 & 0 \\ j1 & 2 - j1 & 0 & -1 \\ -1 & -1 & 2 & 1 \\ 0 & 0 & -1 & 1 \end{bmatrix}}_{Z} \cdot \underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_4 \\ I_5 \end{bmatrix}}_{I} = \underbrace{\begin{bmatrix} 12 \\ -2 \\ -6 \\ 8 - j4 \end{bmatrix}}_{V}$$

Here, Z represents the impedance matrix.

V represents the voltage vector.

I represents the current vector.

Step 8 of 8

Use the following MATLAB code to solve for output voltage.

```
>> Z = [1-1j,1j,-1,0;1j,2-1j,0,-1;-1,-1,2,1;0,0,-1,-1];% IMPEDANCE MATRIX

V = [12;-2;-6;8-4j]; % VOLTAGE VECTOR

I = inv(Z)*V; % FORMULA TO FIND CURRENT VECTOR

I0 = I(4)-I(2) % EQUATION FOR OUTPUT CURRENT

I0 = -12.0000 + 4.0000i
```

Therefore, the value of the output current is $-12 + j4$, that is $\boxed{12.65\angle 161.56^\circ \text{ A}}$.

Consider the expression for voltage.

$$v(t) = 170\cos(\omega t + 30°)\,\text{V}$$

Compare with $v(t) = V_M \cos(\omega t + \theta_v)\,\text{V}$.

$V_M = 170\ \text{V}$ and $\theta_v = 30°$

Therefore, the values of V_M and θ_v are $170\ \text{V}$ and $30°$ respectively.

Consider the expression for the current.

$$i(t) = 5\cos(\omega t + 45°)\,\text{A}$$

Compare with $i(t) = I_M \cos(\omega t + \theta_i)\,\text{A}$.

$I_M = 5\ \text{V}$ and $\theta_i = 45°$

Therefore, the values of I_M and θ_i are $5\ \text{A}$ and $45°$ respectively.

Consider the expression for average power.

$$P = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute $170\ \text{V}$ for V_M , $5\ \text{A}$ for I_M , $30°$ for θ_v and $45°$ for θ_i in the equation.

$$\begin{aligned} P &= \frac{(170)(5)}{2}\cos(30° - 45°) \\ &= 425\cos(-15°) \\ &= (425)(0.966) \\ &= 410.52\ \text{W} \end{aligned}$$

Therefore, the value of the average power absorbed by the network is $\boxed{410.52\ \text{W}}$.

Step 1 of 4

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.707)\\ &= 45°\end{aligned}$$

Therefore, the value of θ_{old} is $45°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $120\,\text{kW}$ for P_{old} and $45°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (120\,\text{k})\ \tan 45°\\ &= (120\,\text{k})(1)\\ &= 120\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $120\,\text{kvar}$.

Step 2 of 4

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.95)\\ &= 18.2°\end{aligned}$$

Therefore, the value of θ_{new} is $18.2°$.

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $120\,\text{kW}$ for P_{old} and $18.2°$ for θ_{new} in the equation.

$$\begin{aligned}Q_{new} &= (120\,\text{k})\ \tan 18.2°\\ &= (120\,\text{k})(0.329)\\ &= 39.48\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $39.48\,\text{kvar}$.

Step 3 of 4

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $39.48\,\text{kvar}$ for Q_{new} and $120\,\text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{cap} &= 39.48\ \text{k} - 120\ \text{k}\\ &= -80.52\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-80.52\,\text{kvar}$.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$\begin{aligned}Q_{cap} &= -(2\pi f)V_L^2 C\\ C &= \frac{-Q_{cap}}{f(2\pi f)V_L^2}\end{aligned}$$

Substitute $-80.52\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $480\,\text{V rms}$ for V_L in the equation.

$$\begin{aligned}C &= \frac{-(-80.52\ \text{k})}{(2\pi(60))(480)^2}\\ &= \frac{80.52\ \text{k}}{(376.99)(480)^2}\\ &= 927.02\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $927.02\,\mu\text{F}$ which is approximately equal to the value of $928\,\mu\text{F}$.

Hence, the correct option is $\boxed{c}$.

Step 1 of 8

Consider Figure E9.2 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 8

Calculate the value of the current $\mathbf{I}_1$ using current division rule.

$$\begin{aligned}\mathbf{I}_1 &= (10\angle 30°)\left(\frac{4+j2}{3+4+j2}\right)\\ &= (10\angle 30°)\left(\frac{4+j2}{7+j2}\right)\\ &= (10\angle 30°)(0.614\angle 10.62°)\\ &= 6.14\angle 40.62°\ \text{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}_1$ is $6.14\angle 40.62°\ \text{A}$.

Step 3 of 8

Calculate the value of the power absorbed by 3Ω resistor.

$$P_{3\Omega} = \frac{|\mathbf{I}_1|^2(2)}{2}$$

Substitute $6.14\ \text{A}$ for $|\mathbf{I}_1|$.

$$\begin{aligned}P_{3\Omega} &= \frac{(6.14)^2(3)}{2}\\ &= (6.14)^2(1.5)\\ &= (37.7)(1.5)\\ &= 56.6\ \text{W}\end{aligned}$$

Therefore, the value of the power absorbed by 3Ω resistor is $\boxed{56.6\ \text{W}}$.

Step 4 of 8

Calculate the value of the current $\mathbf{I}_2$ using current division rule.

$$\begin{aligned}\mathbf{I}_2 &= (10\angle 30°)\left(\frac{3}{3+4+j2}\right)\\ &= (10\angle 30°)\left(\frac{3}{7+j2}\right)\\ &= (10\angle 30°)(0.412\angle -15.95°)\\ &= 4.12\angle 14.05°\ \text{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}_2$ is $4.12\angle 14.05°\ \text{A}$.

Step 5 of 8

Calculate the value of the power absorbed by 4Ω resistor.

$$P_{4\Omega} = \frac{|\mathbf{I}_2|^2(4)}{2}$$

Substitute $4.12\ \text{A}$ for $|\mathbf{I}_2|$.

$$\begin{aligned}P_{4\Omega} &= \frac{(4.12)^2(4)}{2}\\ &= (4.12)^2(2)\\ &= (16.97)(2)\\ &= 33.95\ \text{W}\end{aligned}$$

Therefore, the value of the power absorbed by 4Ω resistor is $\boxed{33.95\ \text{W}}$.

Reactive element impedances does not absorb any average power, hence the average power absorbed by the inductor is $\boxed{0\ \text{W}}$.

Step 6 of 8

Calculate the value of voltage $\mathbf{V}$.

$$\mathbf{V} = \mathbf{I}_1(3)$$

Substitute $6.14\angle 40.62°\ \text{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V} &= (6.14\angle 40.62°)(3)\\ &= 18.42\angle 40.62°\ \text{V}\end{aligned}$$

Therefore, the value of the voltage $\mathbf{V}$ is $18.42\angle 40.62°\ \text{V}$.

Compare with $\mathbf{V} = V_M\angle\theta_v\ \text{V}$.

$V_M = 18.42\ \text{V}$ and $\theta_v = 40.62°$

Therefore, the values of V_M and θ_v are $18.42\ \text{V}$ and $40.62°$ respectively.

Step 7 of 8

Consider the value of the current source.

$$\mathbf{I} = 10\angle 30°\ \text{A}$$

Compare with $\mathbf{I} = I_M\angle\theta_i\ \text{A}$.

$I_M = 10\ \text{A}$ and $\theta_i = 30°$

Therefore, the values of I_M and θ_i are $10\ \text{A}$ and $30°$ respectively.

Step 8 of 8

Calculate the average power delivered by the current source.

$$P_{CS} = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute $18.42\ \text{V}$ for V_M, $10\ \text{A}$ for I_M, $40.62°$ for θ_v and $30°$ for θ_i.

$$\begin{aligned}P_{CS} &= \frac{(18.42)(10)}{2}\cos(40.62° - 30°)\\ &= 92.1\cos(10.62°)\\ &= (92.1)(0.983)\\ &= 90.53\ \text{W}\end{aligned}$$

Therefore, the value of average power delivered by the current source is $\boxed{90.53\ \text{W}}$.

Consider the expression for voltage.

$$v(t) = 6\cos\omega t \text{ V}$$

Compare with $v(t) = V_M \cos(\omega t + \theta_v)\text{V}$.

$V_M = 6 \text{ V}$ and $\theta_v = 0°$

Therefore, the values of V_M and θ_v are 6 V and $0°$ respectively.

Consider the expression for the current.

$$i(t) = 4\sin\omega t \text{ A}$$

Convert into cosine terms.

$$i(t) = 4\cos(\omega t - 90°)\text{A}$$

Compare with $i(t) = I_M \cos(\omega t + \theta_i)\text{A}$.

$I_M = 6 \text{ V}$ and $\theta_i = -90°$

Therefore, the values of I_M and θ_i are 4 A and $-90°$ respectively.

Consider the expression for average power.

$$P = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 6 V for V_M , 4 A for I_M , $0°$ for θ_v and $-90°$ for θ_i in the equation.

$$\begin{aligned} P &= \frac{(6)(4)}{2}\cos(0° - (-90°)) \\ &= 12\cos(90°) \\ &= (12)(0) \\ &= 0 \text{ W} \end{aligned}$$

Therefore, the value of the average power absorbed by the network is $\boxed{0 \text{ W}}$.

9.02FE

Refer to Figure 9PFE-2 in the text book.

Define the function for the voltage $v(t)$.

$$v(t)=\begin{cases}1\,\text{V} & 0<t<1\\ 2\,\text{V} & 1<t<2\\ 1\,\text{V} & 2<t<3\\ 0\,\text{V} & 3<t<4\end{cases}$$

Consider the expression for the root mean square voltage.

$$V_{\text{rms}}=\sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Substitute $\begin{cases}1\,\text{V} & 0<t<1\\ 2\,\text{V} & 1<t<2\\ 1\,\text{V} & 2<t<3\\ 0\,\text{V} & 3<t<4\end{cases}$ for $v(t)$ and $4\,\text{sec}$ for T in the equation.

$$\begin{aligned}V_{\text{rms}}&=\sqrt{\frac{1}{4}\left\{\int_0^1 1^2dt+\int_1^2 2^2dt+\int_2^3 1^2dt+\int_3^4 0^2dt\right\}}\\ &=\sqrt{\frac{1}{4}\left\{\int_0^1 dt+4\int_1^2 dt+\int_2^3 dt+0\right\}}\\ &=\sqrt{\frac{1}{4}\left\{[t]_0^1+4[t]_1^2+[t]_2^3\right\}}\\ &=\sqrt{\frac{1}{4}\left\{[1-0]+4[2-1]+[3-2]\right\}}\end{aligned}$$

$$\begin{aligned}&=\sqrt{\frac{1}{4}(1+4+1)}\\ &=\sqrt{\frac{6}{4}}\\ &=1.2247\ \text{V}\end{aligned}$$

Therefore, the root mean square value of the voltage is $1.2247\ \text{V}$ which is approximately equal to the value of $1.22\ \text{V}$.

Hence the correct option is $\boxed{d}$.

Step 1 of 8

Consider Figure E9.3 from the text book.

Identify the voltages sin the circuit.

Figure I

Step 2 of 8

Consider Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}}{4-j2}+\frac{\mathbf{V}}{j2}+\frac{\mathbf{V}}{2-j2}+2\angle 0^\circ=0$$

$$\mathbf{V}\left(\frac{1}{4-j2}+\frac{1}{j2}+\frac{1}{2-j2}\right)=-2\angle 0^\circ$$

$$\mathbf{V}(0.2+j0.1-j0.5+0.25+j0.25)=2\angle 180^\circ$$

$$\mathbf{V}(0.45-j0.15)=2\angle 180^\circ$$

$$\mathbf{V}(0.474\angle -18.44^\circ)=2\angle 180^\circ$$

$$\mathbf{V}=\frac{2\angle 180^\circ}{0.474\angle -18.44^\circ}$$

$$\mathbf{V}=4.219\angle -161.56^\circ\ \mathrm{V}$$

Therefore, the value of the voltage at node-1 is $4.219\angle -161.56^\circ\ \mathbf{V}$.

Compare with $\mathbf{V}=V_M\angle\theta_v\ \mathrm{V}$.

$V_M=4.219\ \mathrm{V}$ and $\theta_v=-161.56^\circ$

Therefore, the values of V_M and θ_v are $4.219\ \mathrm{V}$ and -161.56° respectively.

Step 3 of 8

Calculate the voltage across $4\,\Omega$ resistor using voltage division rule.

$$\mathbf{V}_4=\mathbf{V}\left(\frac{4}{4-j2}\right)$$

Substitute $4.219\angle -161.56^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\begin{aligned}\mathbf{V}_4&=(4.219\angle -161.56^\circ)\left(\frac{4}{4-j2}\right)\\&=(4.219\angle -161.56^\circ)(0.894\angle 26.57^\circ)\\&=3.77\angle -134.99^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage across $4\,\Omega$ resistor is $3.77\angle -134.99^\circ\ \mathbf{V}$.

Step 4 of 8

Calculate the value of the power absorbed by $4\,\Omega$ resistor.

$$P_{4\Omega}=\frac{|\mathbf{V}_4|^2}{2(4)}$$

Substitute $3.77\ \mathrm{V}$ for $|\mathbf{V}_4|$.

$$\begin{aligned}P_{4\Omega}&=\frac{(3.77)^2}{2(4)}\\&=\frac{14.21}{8}\\&=1.78\ \mathrm{W}\end{aligned}$$

Therefore, the value of the power absorbed by $4\,\Omega$ resistor is $\boxed{1.78\ \mathrm{W}}$.

Step 5 of 8

Calculate the voltage across $2\,\Omega$ resistor using voltage division rule.

$$\mathbf{V}_2=\mathbf{V}\left(\frac{2}{2-j2}\right)$$

Substitute $4.219\angle -161.56^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\begin{aligned}\mathbf{V}_2&=(4.219\angle -161.56^\circ)\left(\frac{2}{2-j2}\right)\\&=(4.219\angle -161.56^\circ)(0.707\angle 45^\circ)\\&=2.98\angle -16.59^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage across $2\,\Omega$ resistor is $2.98\angle -16.59^\circ\ \mathbf{V}$.

Step 6 of 8

Calculate the value of the power absorbed by $2\,\Omega$ resistor.

$$P_{2\Omega}=\frac{|\mathbf{V}_2|^2}{2(2)}$$

Substitute $2.98\ \mathrm{V}$ for $|\mathbf{V}_2|$.

$$\begin{aligned}P_{2\Omega}&=\frac{(2.98)^2}{2(2)}\\&=\frac{8.88}{4}\\&=2.22\ \mathrm{W}\end{aligned}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor is $\boxed{2.22\ \mathrm{W}}$.

Step 7 of 8

Consider the value of the current source.

$$\mathbf{I}=2\angle 0^\circ\ \mathrm{A}$$

Compare with $\mathbf{I}=I_M\angle\theta_i\ \mathrm{A}$.

$I_M=2\ \mathrm{A}$ and $\theta_i=0^\circ$

Therefore, the values of I_M and θ_i are $2\ \mathrm{A}$ and 0° respectively.

Step 8 of 8

Calculate the average power delivered by the current source.

$$P_{CS}=\frac{V_M I_M}{2}\cos(\theta_v-\theta_i)$$

Substitute $4.219\ \mathbf{V}$ for V_M, $2\ \mathrm{A}$ for I_M, -161.56° for θ_v and 0° for θ_i.

$$\begin{aligned}P_{CS}&=\frac{(4.219)(2)}{2}\cos(-161.56^\circ-0^\circ)\\&=4.219\cos(-161.56^\circ)\\&=-(4.219)(0.949)\\&=-4\ \mathrm{W}\end{aligned}$$

Therefore, the value of average power delivered by the current source is $\boxed{-4\ \mathrm{W}}$.

Reactive element impedances does not absorb any average power, hence the average power absorbed by the inductor and the capacitors in the circuit is $\boxed{0\ \mathrm{W}}$.

Step 1 of 3

Step 2 of 3

The current source is given as,

$I = 2\angle 25^\circ \text{A}$

$Z = 4 + j4\Omega$

$Z = 5.66\angle 45^\circ \Omega$

Hence the voltage is given by,

$\therefore V = IZ$

$V = \left(2\angle 25^\circ\right)\left(5.66\angle 45^\circ\right)$

$V = 11.32\angle 70^\circ \text{V}$

Therefore, the equation for voltage is:

$$\boxed{v(t) = 11.32\cos(\omega t + 70^\circ)\text{V}}$$

Step 3 of 3

Therefore, the equation for instantaneous power is:

$$p(t) = \frac{V_M I_M}{2}[\cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v + \theta_i)]$$

we have obtained, $V_M = 11.32\text{V}$

$I_M = 2\text{A}$

$\theta_v = 70^\circ$

$\theta_i = 25^\circ$

$$p(t) = \frac{11.32 \times 2}{2}[\cos(70^\circ - 25^\circ) + \cos(2\omega t + 70^\circ + 25^\circ)]$$

$$p(t) = 11.32[\cos(45^\circ) + \cos(2\omega t + 95^\circ)]$$

$$\boxed{p(t) = 8 + 11.32\cos(2\omega t + 95^\circ)\text{W}}$$

Step 1 of 2

Refer to Figure 9PFE-3 in the text book.

Deactivate the active sources in the in the circuit to find the value of $\mathbf{Z}_{TH}$.

Figure 1

Step 2 of 2

Calculate the value of the Thevenin's impedance $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_{TH} &= [2 \| (-j1)] + j2 \\ &= \frac{2(-j1)}{2-j1} + j2 \\ &= 0.4 - j0.8 + j2 \\ &= 0.4 + j1.2\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin's impedance is $0.4 + j1.2\,\Omega$.

Calculate the value of the load impedance.

$$\mathbf{Z}_L = (\mathbf{Z}_{TH})^*$$

Substitute $0.4 + j1.2\,\Omega$ for $\mathbf{Z}_{TH}$ in the equation.

$$\begin{aligned}\mathbf{Z}_L &= (0.4 + j1.2\,\Omega)^* \\ &= 0.4 - j1.2\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $0.4 - j1.2\,\Omega$.

Hence, the correct option is $\boxed{b}$.

Step 1 of 2

The given circuit is,

Step 2 of 2

By voltage division rule,

$$V_0 = \left(\frac{-j12}{2+j10-j12}\right)(10\angle 120^\circ)$$

$$V_0 = \left(\frac{-j12}{2-j2}\right)(10\angle 120^\circ)$$

$$V_0 = \left(\frac{12\angle -90^\circ}{2.828\angle -45^\circ}\right)(10\angle 120^\circ)$$

$$\boxed{V_0 = 42.43\angle 75^\circ \text{V}}$$

Step 1 of 2

9.004P

Refer to circuit diagram in Figure P9.3 in the textbook.

Consider the value of voltage.

$$V = 12\angle 75^\circ \text{ V}$$

Rewrite the value of voltage in instantaneous form.

$$v(t) = 12\cos(2\omega t + 75^\circ)\text{ V}$$

Compare with $v(t) = V_M \cos(\omega t + \theta_v)\text{ V}$.

$V_M = 12\text{ V}$ and $\theta_v = 75^\circ$

Therefore, the values of V_M and θ_v are 12 V and 75° respectively.

Consider the expression for current in the circuit.

$$\begin{aligned} I &= \frac{12\angle 75^\circ}{4 + j3} \\ &= \frac{12\angle 75^\circ}{5\angle 36.87^\circ} \\ &= 2.4\angle 38.13^\circ \text{ A} \end{aligned}$$

Rewrite the value of the current in instantaneous form.

$$i(t) = 2.4\cos(2\omega t + 38.13^\circ)\text{ A}$$

Therefore, the value of the current (I) in the circuit is $\boxed{2.4\cos(2\omega t + 38.13^\circ)\text{ A}}$.

Step 2 of 2

Compare with $i(t) = I_M \cos(\omega t + \theta_i)\text{ A}$.

$I_M = 2.4\text{ V}$ and $\theta_i = 38.13^\circ$

Therefore, the values of I_M and θ_i are 2.4 A and 38.13° respectively.

Consider the expression for the instantaneous power absorbed by the network.

$$p(t) = \frac{V_M I_M}{2}\left[\cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v + \theta_i)\right]$$

Substitute 2.4 for I_M , 38.13° for θ_i , 12 for V_M and 75° for θ_v in the equation.

$$\begin{aligned} p(t) &= \frac{(12)(2.4)}{2}\left[\cos(75^\circ - 38.13^\circ) + \cos(2\omega t + 75^\circ + 38.13^\circ)\right] \\ &= (14.4)\left[\cos(36.87^\circ) + \cos(2\omega t + 113.13^\circ)\right] \\ &= (14.4)\left[0.8 + \cos(2\omega t + 113.13^\circ)\right] \\ &= (14.4)(0.8) + 14.4\cos(2\omega t + 113.13^\circ) \end{aligned}$$

$$p(t) = 11.52 + 14.4\cos(2\omega t + 113.13^\circ)\text{ W}$$

Therefore, the instantaneous value of the power absorbed by the network is

$\boxed{11.52 + 14.4\cos(2\omega t + 113.13^\circ)\text{ W}}$.

Step 1 of 2

Refer to Figure 9PFE-4 in the text book.

Consider the value of the source voltage.

$$v_S(t) = 1.414\cos\omega t \text{ V}$$

Convert to phasor form.

$$\mathbf{V_S} = 1.414\angle 0° \text{ V}$$

Therefore, the value of the source voltage in phasor notation is $1.414\angle 0° \text{ V}$.

The value of voltage $\mathbf{V_I}$ at inverting terminal of the op-amp is 0 V due to the virtual ground available at the non-inverting terminal of the amplifier. Hence,

$$\mathbf{V_I} = 0 \text{ V}$$

Therefore, the value of $\mathbf{V_I}$ is 0 V .

Step 2 of 2

Consider the Kirchhoff's Current Law at inverting terminal of the amplifier.

$$\frac{\mathbf{V_I} - \mathbf{V}_O}{36 \text{ k}} + \frac{\mathbf{V_I} - \mathbf{V_S}}{12 \text{ k}} = 0$$

Substitute 0 V for $\mathbf{V_I}$ and $1.414\angle 0° \text{ V}$ for $\mathbf{V_S}$ in the equation.

$$\frac{0 - \mathbf{V}_O}{36 \text{ k}} + \frac{0 - 1.414\angle 0°}{12 \text{ k}} = 0$$

$$\frac{-\mathbf{V}_O}{3} - \frac{1.414\angle 0°}{1} = 0$$

$$-\mathbf{V}_O - 3(1.414)\angle 0° = 0$$

$$\mathbf{V}_O = 4.24\angle 180° \text{ V}$$

Therefore, the reading of the voltmeter is 4.24 V .

Hence, the correct option is $\boxed{c}$.

Step 1 of 6

Refer to circuit diagram in Figure P9.5 in the textbook.

Calculate the impedance value for the series combination of the capacitor and the resistor.

$$\begin{aligned} Z_1 &= 2+(-j2) \\ &= 2-j2\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $2-j2\,\Omega$.

Step 2 of 6

Draw the simplified circuit diagram as shown in Figure 1.

Figure 1

Step 3 of 6

Calculate the impedance due to parallel combination of the inductor and Z_1.

$$Z = j2 \,||\, Z_1$$

Substitute $2-j2\,\Omega$ for Z_1.

$$\begin{aligned} Z &= j2 \,||\, 2-j2 \\ &= \frac{(j2)(2-j2)}{j2+2-j2} \\ &= \frac{4+j4}{2} \\ &= 2+j2\,\Omega \end{aligned}$$

Therefore, the value of Z is $2+j2\,\Omega$.

Step 4 of 6

Redraw the circuit diagram as shown in Figure 2.

Figure 2

Step 5 of 6

Consider the

$$I_1 = \frac{V_S}{4+2+}$$

Step 5 of 6

Consider the expression for I_1.

$$I_1 = \frac{V_S}{4+2+j2}$$

Substitute $12\angle 60°$ volts for V_S.

$$\begin{aligned} I_1 &= \frac{12\angle 60°}{6+j2} \\ &= \frac{12\angle 60°}{6.33\angle 18.44°} \\ &= 1.89\angle 41.56°\ \text{A} \end{aligned}$$

Therefore, the value of I_1 is $1.89\angle 41.56°$ A.

Compare with $I = I_M\angle\theta_i$ A.

$I_M = 1.89$ A and $\theta_i = 41.56°$

Therefore, the values of I_M and θ_i are 1.89 A and $41.56°$ respectively.

Consider the value of the source voltage.

$V_S = 12\angle 60°$ V

Compare with $V = V_M\angle\theta_v$ A.

$V_M = 12$ V and $\theta_v = 60°$

Therefore, the values of V_M and θ_v are 12 A and $60°$ respectively.

Step 6 of 6

Consider the expression for the instantaneous power absorbed by the network.

$$p(t) = \frac{V_M I_M}{2}\left[\cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v + \theta_i)\right]$$

Substitute 1.89 for I_M, $41.56°$ for θ_i, 12 for V_M and $60°$ for θ_v.

$$\begin{aligned} p(t) &= \frac{(12)(1.89)}{2}\left[\cos(60°-41.56°) + \cos(2\omega t + 60° + 41.56°)\right] \\ &= (11.34)\left[\cos(18.44°) + \cos(2\omega t + 101.56°)\right] \\ &= (11.34)\left[0.95 + \cos(2\omega t + 101.56°)\right] \\ &= 11.11 + 11.34\cos(2\omega t + 101.56°)\ \text{W} \end{aligned}$$

Therefore, the instantaneous value of the power supplied by the source is $\boxed{10.75 + 11.34\cos(2\omega t + 101.56°)\ \text{W}}$.

Step 1 of 10

Consider Figure E9.5 from the text book.

Identify the voltages sin the circuit.

Figure 1

Step 2 of 10

Consider Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}-24\angle 0^\circ}{2}+\frac{\mathbf{V}-12\angle 0^\circ}{j2}+\frac{\mathbf{V}}{4}=0$$

$$\mathbf{V}\left(\frac{1}{2}+\frac{1}{j2}+\frac{1}{4}\right)-\frac{24\angle 0^\circ}{2}-\frac{12\angle 0^\circ}{2\angle 90^\circ}=0$$

$$\mathbf{V}(0.5-j0.5+0.25)=12\angle 0^\circ+6\angle -90^\circ$$

$$\mathbf{V}(0.75-j0.5)=13.416\angle -26.57^\circ$$

$$\mathbf{V}(0.901\angle -33.69^\circ)=13.416\angle -26.57^\circ$$

$$\mathbf{V}=\frac{13.416\angle -26.57^\circ}{0.901\angle -33.69^\circ}$$

$$\mathbf{V}=14.89\angle 7.12^\circ\ \mathrm{V}$$

Therefore, the value of the voltage at node-1 is $14.89\angle 7.12^\circ\ \mathrm{V}$.

Step 3 of 10

Calculate the value of the power absorbed by $4\,\Omega$ resistor.

$$P_{4\Omega}=\frac{|\mathbf{V}|^2}{2(4)}$$

Substitute $14.89\ \mathrm{V}$ for $|\mathbf{V}|$.

$$P_{4\Omega}=\frac{(14.89)^2}{2(4)}$$
$$=\frac{221.71}{8}$$
$$=27.7\ \mathrm{W}$$

Therefore, the value of the power absorbed by $4\,\Omega$ resistor is $\boxed{27.7\ \mathrm{W}}$.

Step 4 of 10

Calculate the value of the current $\mathbf{I}_1$.

$$\mathbf{I}_1=\frac{\mathbf{V}-24\angle 0^\circ}{2}$$

Substitute $14.89\angle 7.12^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\mathbf{I}_1=\frac{14.89\angle 7.12^\circ-24\angle 0^\circ}{2}$$
$$=\frac{9.408\angle 168.69^\circ}{2}$$
$$=4.704\angle 168.69^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_1$ is $4.704\angle 168.69^\circ\ \mathrm{A}$.

Compare with $\mathbf{I}_1=I_{1M}\angle\theta_{1i}\ \mathrm{A}$.

$I_{1M}=4.704\ \mathrm{A}$ and $\theta_{1i}=168.69^\circ$

Therefore, the values of I_{1M} and θ_{1i} are $4.704\ \mathrm{A}$ and 168.69° respectively.

Step 5 of 10

Calculate the value of the power absorbed by $2\,\Omega$ resistor.

$$P_{2\Omega}=\frac{|\mathbf{I}_1|^2(2)}{2}$$

Substitute $4.704\ \mathrm{V}$ for $|\mathbf{I}_1|$.

$$P_{2\Omega}=\frac{(4.704)^2(2)}{2}$$
$$=22.13\ \mathrm{W}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor is $\boxed{22.13\ \mathrm{W}}$.

Step 6 of 10

Consider the value of the $24\angle 0^\circ\ \mathrm{V}$ voltage source.

$$\mathbf{V}_{24\angle 0^\circ}=24\angle 0^\circ\ \mathrm{V}$$

Compare with $\mathbf{V}_{24\angle 0^\circ}=V_{24\angle 0^\circ M}\angle\theta_{24\angle 0^\circ v}\ \mathrm{V}$.

$V_{24\angle 0^\circ M}=24\ \mathrm{V}$ and $\theta_{24\angle 0^\circ v}=0^\circ$

Therefore, the values of $V_{24\angle 0^\circ M}$ and $\theta_{24\angle 0^\circ v}$ are $24\ \mathrm{V}$ and 0° respectively.

Step 7 of 10

Calculate the average power delivered by $24\angle 0^\circ\ \mathrm{V}$ voltage source.

$$P_{24\angle 0^\circ}=\frac{V_{24\angle 0^\circ M}I_{1M}}{2}\cos(\theta_{24\angle 0^\circ v}-\theta_{1i})$$

Substitute $24\ \mathrm{V}$ for $V_{24\angle 0^\circ M}$, $4.704\ \mathrm{A}$ for I_{1M}, 0° for $\theta_{24\angle 0^\circ v}$ and 168.69° for θ_{1i}.

$$P_{24\angle 0^\circ}=\frac{(24)(4.704)}{2}\cos(0^\circ-168.69^\circ)$$
$$=56.448\cos(-168.69^\circ)$$
$$=(56.448)(-0.981)$$
$$=-55.38\ \mathrm{W}$$

Therefore, the value of average power delivered by $24\angle 0^\circ\ \mathrm{V}$ voltage source is

$\boxed{-55.38\ \mathrm{W}}$.

Step 8 of 10

Calculate the value of the current $\mathbf{I}_2$.

$$\mathbf{I}_2=\frac{\mathbf{V}-12\angle 0^\circ}{j2}$$

Substitute $14.89\angle 7.12^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\mathbf{I}_2=\frac{14.89\angle 7.12^\circ-12\angle 0^\circ}{2\angle 90^\circ}$$
$$=\frac{3.33\angle 33.63^\circ}{22\angle 90^\circ}$$
$$=1.67-56.37^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_2$ is $1.67\angle -56.37^\circ\ \mathrm{A}$.

Compare with $\mathbf{I}_2=I_{2M}\angle\theta_{2i}\ \mathrm{A}$.

$I_{2M}=1.67\ \mathrm{A}$ and $\theta_{2i}=-56.37^\circ$

Therefore, the values of I_{2M} and θ_{2i} are $1.67\ \mathrm{A}$ and $\angle -56.37^\circ$ respectively.

Step 9 of 10

Consider the value of the $12\angle 0^\circ\ \mathrm{V}$ voltage source.

$$\mathbf{V}_{12\angle 0^\circ}=12\angle 0^\circ\ \mathrm{V}$$

Compare with $\mathbf{V}_{12\angle 0^\circ}=V_{12\angle 0^\circ M}\angle\theta_{12\angle 0^\circ v}\ \mathrm{V}$.

$V_{12\angle 0^\circ M}=12\ \mathrm{V}$ and $\theta_{12\angle 0^\circ v}=0^\circ$

Therefore, the values of $V_{12\angle 0^\circ M}$ and $\theta_{12\angle 0^\circ v}$ are $12\ \mathrm{V}$ and 0° respectively.

Step 10 of 10

Calculate the average power delivered by $12\angle 0^\circ\ \mathrm{V}$ voltage source.

$$P_{12\angle 0^\circ}=\frac{V_{12\angle 0^\circ M}I_{2M}}{2}\cos(\theta_{12\angle 0^\circ v}-\theta_{2i})$$

Substitute $12\ \mathrm{V}$ for $V_{12\angle 0^\circ M}$, $1.67\ \mathrm{A}$ for I_{2M}, 0° for $\theta_{12\angle 0^\circ v}$ and -56.37° for θ_{1i}.

$$P_{12\angle 0^\circ}=\frac{(12)(1.67)}{2}\cos(0^\circ-(-56.37^\circ))$$
$$=10.02\cos(56.37^\circ)$$
$$=(10.02)(0.554)$$
$$=-5.55\ \mathrm{W}$$

Therefore, the value of average power delivered by the $12\angle 0^\circ\ \mathrm{V}$ voltage source is $\boxed{-5.55\ \mathrm{W}}$.

Reactive element impedances does not absorb any average power, hence the average power absorbed by the inductor is $\boxed{0\ \mathrm{W}}$.

Step 1 of 6

Consider Figure E9.6 from the text book.

Convert the current source to voltage source using source transformation technique as shown in Figure 1.

Figure 1

Step 2 of 6

Consider Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}-12\angle 0^\circ}{3+j2}+\frac{\mathbf{V}-6\angle 0^\circ}{j3}+\frac{\mathbf{V}-6\angle -80^\circ}{4-j2}=0$$

$$\mathbf{V}\left(\frac{1}{3+j2}+\frac{1}{j3}+\frac{1}{4-j2}\right)-\frac{12\angle 0^\circ}{3+j2}-\frac{6\angle 0^\circ}{j3}-\frac{6\angle -80^\circ}{4-j2}=0$$

$$\mathbf{V}(0.231-j0.154-j0.333+0.2+j0.1)=\frac{12\angle 0^\circ}{3+j2}+\frac{6\angle 0^\circ}{j3}+\frac{6\angle -80^\circ}{4-j2}$$

$$\mathbf{V}(0.431-j0.387)=\frac{12\angle 0^\circ}{3.61\angle 33.69^\circ}+\frac{6\angle 0^\circ}{3\angle 90^\circ}+\frac{6\angle -80^\circ}{4.472\angle -26.57^\circ}$$

$$\mathbf{V}(0.579\angle -41.42^\circ)=3.324\angle -33.69^\circ+2\angle -90+1.342\angle -53.43^\circ$$

$$\mathbf{V}(0.579\angle -41.42^\circ)=6.08\angle -5.08^\circ$$

$$\mathbf{V}=\frac{6.08\angle -5.08^\circ}{0.579\angle -41.42^\circ}$$

$$\mathbf{V}=10.5\angle -12.16^\circ\ \mathrm{V}$$

Therefore, the value of the voltage at node-1 is $10.5\angle -12.16^\circ\ \mathrm{V}$.

Step 3 of 6

Calculate the value of the current $\mathbf{I}_3$.

$$\mathbf{I}_3=\frac{\mathbf{V}-12\angle 0^\circ}{3+j2}$$

Substitute $10.5\angle -12.16^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\mathbf{I}_3=\frac{10.5\angle -12.16^\circ\ \mathrm{V}-12\angle 0^\circ}{3+j2}$$

$$=\frac{2.811\angle -128.12^\circ}{3.61\angle 33.69}$$

$$=0.779\angle -161.81^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_3$ is $0.779\angle -161.81^\circ\ \mathrm{A}$.

Step 4 of 6

Calculate the value of the power absorbed by $3\,\Omega$ resistor.

$$P_{3\Omega}=\frac{|\mathbf{I}_3|^2(3)}{2}$$

Substitute $0.779\ \mathrm{V}$ for $|\mathbf{I}_3|$.

$$P_{3\Omega}=\frac{(0.779)^2(3)}{2}$$

$$=0.91\ \mathrm{W}$$

Therefore, the value of the power absorbed by $3\,\Omega$ resistor is $\boxed{0.91\ \mathrm{W}}$.

Step 5 of 6

Calculate the value of the current $\mathbf{I}_4$.

$$\mathbf{I}_4=\frac{\mathbf{V}-6\angle -80^\circ}{4-j2}$$

Substitute $10.5\angle -12.16^\circ\ \mathrm{V}$ for $\mathbf{V}$.

$$\mathbf{I}_4=\frac{10.5\angle -12.16^\circ\ \mathrm{V}-6\angle -80^\circ}{4-j2}$$

$$=\frac{9.936\angle 21.85^\circ}{4.472\angle -26.57^\circ}$$

$$=2.22\angle 48.42^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_4$ is $2.22\angle 48.42^\circ\ \mathrm{A}$.

Step 6 of 6

Calculate the value of the power absorbed by $4\,\Omega$ resistor.

$$P_{4\Omega}=\frac{|\mathbf{I}_4|^2(4)}{2}$$

Substitute $2.22\ \mathrm{V}$ for $|\mathbf{I}_4|$.

$$P_{4\Omega}=\frac{(2.22)^2(4)}{2}$$

$$=9.86\ \mathrm{W}$$

Therefore, the value of the power absorbed by $3\,\Omega$ resistor is $\boxed{9.86\ \mathrm{W}}$.

Step 1 of 6

Refer to circuit diagram in Figure P9.8 in the textbook.

Calculate the impedance value for the series combination of the capacitor and the resistor.

$$\begin{aligned} Z_1 &= 2+(-j2) \\ &= 2-j2\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $2-j2\,\Omega$.

Step 2 of 6

Draw the simplified circuit diagram as shown in Figure 1.

Figure 1

Step 3 of 6

Calculate the equivalent impedance of the parallel combination of passive elements in the circuit.

$$\begin{aligned} \frac{1}{Z} &= \frac{1}{2-j2}+\frac{1}{4}+\frac{1}{-j2}+\frac{1}{j1} \\ &= 0.25+j0.25+0.25+j0.5-j1 \\ &= 0.5-j0.25 \\ Z &= 1.6+j0.8\,\Omega \end{aligned}$$

Therefore, the value of the equivalent impedance is $1.6+j0.8\,\Omega$.

Step 4 of 6

Draw the simplified circuit diagram as shown in Figure 2.

Figure 2

Step 5 of 6

Consider the expression for the voltage across the impedance Z.

$$\mathrm{V} = \mathrm{I}_S Z$$

Substitute $6\angle 45°\ \mathrm{A}$ for I_S and $1.6+j0.8\,\Omega$ for Z.

$$\begin{aligned} \mathrm{V} &= (6\angle 45°)(1.6+j0.8) \\ &= (6\angle 45°)(1.79\angle 26.57°) \\ &= 10.733\angle 71.56°\ \mathrm{V} \end{aligned}$$

Therefore, the value of the voltage across Z is $10.733\angle 71.56°\ \mathrm{V}$.

Compare with $\mathrm{V} = V_M\angle\theta_v\ \mathrm{V}$.

$V_M = 10.733\ \mathrm{V}$ and $\theta_v = 71.56°$

Therefore, the values of V_M and θ_v are $10.733\ \mathrm{V}$ and $71.56°$ respectively.

Consider the value of the source current

$$\mathrm{I}_S = 6\angle 45°\ \mathrm{A}$$

Compare with $\mathrm{I} = I_M\angle\theta_i\ \mathrm{A}$.

$I_M = 6\ \mathrm{A}$ and $\theta_i = 45°$

Therefore, the values of I_M and θ_i are $6\ \mathrm{A}$ and $45°$ respectively.

Step 6 of 6

Consider the expression for the instantaneous power absorbed by the network.

$$p(t) = \frac{V_M I_M}{2}\left[\cos(\theta_v-\theta_i)+\cos(2\omega t+\theta_v+\theta_i)\right]$$

Substitute $6\ \mathrm{A}$ for I_M. $45°$ for θ_i. 10.733 for V_M and $71.56°$ for θ_v in the equation.

$$\begin{aligned} p(t) &= \frac{(6)(10.733)}{2}\left[\cos(71.56°-45°)+\cos(2\omega t+71.56°+45°)\right] \\ &= (32.2)\left[\cos(26.56°)+\cos(2\omega t+116.56°)\right] \\ &= (32.2)\left[0.89+\cos(2\omega t+116.56°)\right] \\ &= 28.8+32.2\cos(2\omega t+116.56°)\ \mathrm{W} \end{aligned}$$

Therefore, the instantaneous value of the power supplied by the source is

$\boxed{28.8+32.2\cos(2\omega t+116.56°)\ \mathrm{W}}$.

Step 1 of 9

Consider Figure E9.7 from the text book.

Apply Thevenin theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 9

Consider Kirchhoff's Voltage Law in loop-1.

$$2\mathbf{I}_1 - 24\angle 0° - 12\angle 0° + \mathbf{I}_1(j2) = 0$$
$$(2 + j2)\mathbf{I}_1 = 36\angle 0°$$
$$\mathbf{I}_1 = \frac{36\angle 0°}{2.828\angle 45°}$$
$$\mathbf{I}_1 = 12.73\angle -45°$$

Therefore, the value of $\mathbf{I}_1$ is $12.73\angle -45°$.

Step 3 of 9

Calculate the value of $\mathbf{V}_{oc}$.

$$\mathbf{V}_{oc} = -12\angle 0° + \mathbf{I}_1(j2)$$

Substitute $12.73\angle -45°$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_{oc} &= -12\angle 0° + (12.73\angle -45°)(2\angle 90°)\\ &= -12\angle 0° + 25.76\angle 45°\\ &= 18.98\angle 71.56° \text{ V}\end{aligned}$$

Therefore, the expression for $\mathbf{V}_{oc}$ is $18.98\angle 71.56° \text{ V}$.

Step 4 of 9

Deactivate the sources to calculate the value of the Thevenin impedance at the output terminals.

Figure 2

Step 5 of 9

Calculate the value of Thevenin impedance.

$$\begin{aligned}\mathbf{Z}_{TH} &= (2 \parallel j2) - j2\\ &= \frac{(j4)}{2 + j2} - j2\\ &= 1 + j1 - j2\\ &= 1 - j1\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin impedance is $1 - j1\,\Omega$.

Step 6 of 9

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{TH}^*$$

Substitute $1 - j1\,\Omega$ for $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_L &= (1 - j1\,\Omega)^*\\ &= 1 + j1\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{1 + j1\,\Omega}$.

Step 7 of 9

Draw the Thevenin equivalent circuit.

Figure 3

Step 8 of 9

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I} &= \frac{18.98\angle 71.56°}{1 - j1 + 1 + j1}\\ &= \frac{18.98\angle 71.56°}{2}\\ &= 9.49\angle 71.56° \text{ A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $9.49\angle 71.56° \text{ A}$.

Step 9 of 9

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute 9.49 A for I_M and $1\,\Omega$ for R_L .

$$\begin{aligned}P_L &= \frac{1}{2}(9.49)^2(1)\\ &= 45 \text{ W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{45 \text{ W}}$.

Step 1 of 3

Refer to Figure 9PFE-5 in the text book.

Find the equation for the current between the interval $0 < t < 1$ having end points $(0,0)$ and $(1,1)$.

$$i(t) - 0 = \left(\frac{1-0}{1-0}\right)(t-0) \qquad \left(\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right)$$

$$i(t) = t$$

Therefore, the equation for the current between the interval $0 < t < 1$ is $i(t) = t$.

Define the function for the current $i(t)$.

$$i(t) = \begin{cases} t & 0 < t < 1 \\ -2 & 1 < t < 2 \end{cases}$$

Step 2 of 3

Consider the expression for the root mean square current.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases} t & 0 < t < 1 \\ -2 & 1 < t < 2 \end{cases}$ for $i(t)$ and 2sec for T in the equation.

$$I_{rms} = \sqrt{\frac{1}{2}\left\{\int_0^1 (t)^2 dt + \int_1^2 (-2)^2 dt\right\}}$$

$$= \sqrt{\frac{1}{2}\left\{\int_0^1 t^2 dt + 4\int_1^2 dt\right\}}$$

$$= \sqrt{\frac{1}{2}\left\{\left[\frac{t^3}{3}\right]_0^1 + 4[t]_1^2\right\}}$$

$$= \sqrt{\frac{1}{2}\left\{\left[\frac{1^3 - 0}{3}\right] + 4[2-1]\right\}}$$

$$= \sqrt{\frac{1}{2}\left\{\frac{1}{3} + 4\right\}}$$

$$= \sqrt{\frac{1}{2}\left\{\frac{1+12}{3}\right\}}$$

$$= \sqrt{\frac{13}{6}}$$

$$= 1.47 \text{ A}$$

Therefore, the root mean square value of the current is 1.47 A.

Step 3 of 3

Consider the expression for the power dissipated in $4\,\Omega$ resistor.

$$P_{4\Omega} = I^2_{rms}(4)$$

Substitute 1.47 A for I_{rms} in the equation.

$$P_{4\Omega} = (1.47)^2(4)$$
$$= 8.64 \text{ W}$$

Therefore, the value of the power dissipated in the resistor is 8.64 W.

Hence, the correct option is $\boxed{b}$.

Step 1 of 9

Consider Figure E9.8 from the text book.

Apply Thevenin theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 9

Consider Kirchhoff's Voltage Law in loop-1.

$$2\mathbf{I}_1 - 24\angle 0° + \mathbf{I}_1(-j2) + \mathbf{I}_1(j2) = 0$$
$$2\mathbf{I}_1 = 24\angle 0°$$
$$\mathbf{I}_1 = 12\angle 0°$$

Therefore, the value of $\mathbf{I}_1$ is $12\angle 0°\ \mathrm{A}$.

Step 3 of 9

Calculate the value of $\mathbf{V}_{oc}$.

$$\mathbf{V}_{oc} = 12\angle 0° + \mathbf{I}_1(j2)$$

Substitute $6\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_{oc} &= 12\angle 0° + (12\angle 0°)(2\angle 90°)\\ &= 12\angle 0° + 24\angle 90°\\ &= 26.83\angle 63.44°\ \mathrm{V}\end{aligned}$$

Therefore, the expression for $\mathbf{V}_{oc}$ is $26.83\angle 63.44°\ \mathrm{V}$.

Step 4 of 9

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 5 of 9

Calculate the value of Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{TH} &= (2 - j2) \| j2\\ &= \frac{(2 - j2)(j2)}{2 - j2 + j2}\\ &= 2 + j2\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin impedance is $2 + j2\,\Omega$.

Step 6 of 9

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{TH}^*$$

Substitute $2 + j2\,\Omega$ for $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_L &= (2 + j2)^*\\ &= 2 - j2\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{2 - j2\,\Omega}$.

Step 7 of 9

Draw the Thevenin's equivalent circuit.

Figure 3

Step 8 of 9

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I} &= \frac{26.83\angle 64.44°}{2 + j2 + 2 - j2}\\ &= \frac{26.83\angle 64.44°}{4}\\ &= 6.71\angle 64.44°\ \mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $6.71\angle 64.44°\ \mathrm{A}$.

Step 9 of 9

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute $6.71\ \mathrm{A}$ for I_M and $2\,\Omega$ for R_L.

$$\begin{aligned}P_L &= \frac{1}{2}(6.71)^2(2)\\ &= 45\ \mathrm{W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{45\ \mathrm{W}}$.

Step 1 of 2

Refer Figure P9.16 from the text book.

Calculate the value of current flowing in the circuit.

$$\begin{aligned}\mathbf{I} &= \frac{10\angle 0}{1 + j1 - j1} \\ &= 10\angle 0^\circ \ \mathbf{A}\end{aligned}$$

Therefore, the value of the current flowing in the circuit is $10\angle 0^\circ \ \mathbf{A}$.

Step 2 of 2

Consider the expression for the power absorbed by $1\,\Omega$ resistor.

$$P_{1\Omega} = \frac{|\mathbf{I}|^2 (1)}{2}$$

Substitute $10\ \mathbf{A}$ for $|\mathbf{I}|$.

$$\begin{aligned}P_{1\Omega} &= \frac{(10)^2 \cdot (1)}{2} \\ &= 50\ \mathbf{W}\end{aligned}$$

Therefore, the value of the power absorbed by $1\,\Omega$ resistor is $\boxed{50\ \mathbf{W}}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $\boxed{0\ \mathbf{W}}$.

Step 1 of 6

Consider the Figure P7.73 from the text book.

Step-1:

Let the value of the output current $i_O(t)$ be $K_1 + K_2 e^{-t/\tau}$ ..... (1)

Step-2:

Consider the circuit diagram at $t = 0^-$.

Figure 1

Step 2 of 6

Calculate the value of the current $i_L(0^-)$ using current division rule.

$$\begin{aligned} i_L(0^-) &= (10\text{ m})\left(\frac{2\text{ k}}{2\text{ k}+2\text{ k}}\right) \\ &= (10\text{ m})\left(\frac{2\text{ k}}{4\text{ k}}\right) \\ &= (10\text{ m})\left(\frac{1}{2}\right) \\ &= 5\text{ mA} \end{aligned}$$

Therefore, the value of the current $i_L(0^-)$ is 5 mA .

The value of the current $i_O(0^-)$ is equal to 5 mA since $i_O(0^-) = i_L(0^-)$.

The value of the constant K_1 is equal to 5 mA .

Step 3 of 6

Step-3:

The value of the current $i_L(0^+)$ is equal to the value of $i_L(0^-)$. Therefore, the value of the current $i_O(0^+)$ is 5 mA .

Step 4 of 6

Step-4:

Consider the circuit diagram at $t = \infty$.

Figure 2

The part of the circuit shown in dotted lines will be shorted and does not effect the value of the current through the inductor at $t = \infty$.

Therefore, the value of the current is $i_O(\infty)$ is 5 mA .

Step 5 of 6

Calculate the value of the constant K_2 .

$$K_2 = i_O(0^+) - i_O(\infty)$$

Substitute 5 mA for $i_O(\infty)$ and 2 A for $i_O(0^+)$.

$$\begin{aligned} K_2 &= 5\text{ m} - 5\text{ m} \\ &= 0\text{ A} \end{aligned}$$

Therefore, the value of the constant K_2 is 0 A .

As the value of the constant K_2 is 0 A , there is no need to find the value of the time constant.

Step 6 of 6

Step-5:

Recall equation (1).

$$i_O(t) = K_1 + K_2 e^{-t/\tau}$$

Substitute 0 A for K_2 and 5 mA for K_1 .

$$\begin{aligned} i_O(t) &= 5\text{ mA} + (0)\, e^{-t/\tau} \\ &= 5\text{ mA} \end{aligned}$$

Therefore, the value of the output current $i_O(t)$ is $\boxed{5\text{ mA}}$.

Step 1 of 6

The given circuit diagram is,

Step 2 of 6

Given $I = 6\angle 0^\circ A$

By current division,

$$I_1 = \frac{6\angle 0^\circ}{2+j2+2-j1} \times (2-j1)$$

$$I_1 = \frac{(6\angle 0^\circ)(2-j1)}{(4+j1)}$$

$$I_1 = \frac{(6\angle 0^\circ)(2.236\angle -26.565^\circ)}{(4.123\angle 14.04^\circ)}$$

$$I_1 = 3.254\angle -40.6^\circ \text{A}$$

Step 3 of 6

Similarly,

$$I_2 = \frac{6\angle 0^\circ}{2+j2+2-j1} \times (2+j2)$$

$$I_2 = \frac{(6\angle 0^\circ)(2+j2)}{(4+j1)}$$

$$I_2 = \frac{(6\angle 0^\circ)(2.828\angle 45^\circ)}{(4.123\angle 14.04^\circ)}$$

$$I_2 = 4.116\angle 30.96^\circ \text{A}$$

Step 4 of 6

Hence the voltage across the source terminals is given by,

$$V_T = I_1(2+j2)$$

$$V_T = (3.254\angle -40.6^\circ)(2.828\angle 45^\circ)$$

$$V_T = 9.2\angle 4.4^\circ \text{V}$$

Step 5 of 6

Therefore, average power absorbed by the resistor R_1 is:

$$P_{R1} = \frac{1}{2} I_M^2 R_1$$

$$P_{R1} = \frac{1}{2} \times (3.252)^2 \times 2$$

$$\boxed{P_{R1} = 10.588\text{W}}$$

Similarly, average power absorbed by the resistor R_2 is:

$$P_{R2} = \frac{1}{2} I_M^2 R_2$$

$$P_{R2} = \frac{1}{2} \times (4.116)^2 \times 2$$

$$\boxed{P_{R2} = 16.941\text{W}}$$

Step 6 of 6

Since, the inductor and the capacitor in the circuit are purely reactive, they do not absorb any real power.

Therefore, $\boxed{P_L = P_C = 0\text{W}}$

The total average power supplied by the source is:

$$P_S = \frac{1}{2} V_M I_M \cos(\theta_v - \theta_i)$$

$$P_S = \frac{1}{2} \times 9.2 \times 6 \cos(4.4^\circ - 0^\circ)$$

$$\boxed{P_S = 27.52\text{W}}$$

Step 1 of 12

Consider Figure E9.10 from the text book.

Disconnect the load impedance and the current source.

Apply Nortons's theorem for the remaining circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 12

Apply Kirchhoff's Voltage Law in the loop.

$$2\mathbf{I}_x + \mathbf{I}_1(3 + j2 + j3) - 6\angle 0^\circ = 0$$

Substitute $0\ \mathrm{A}$ for $\mathbf{I}_x$.

$$2(0) + \mathbf{I}_1(3 + j2 + j3) - 6\angle 0^\circ = 0$$
$$\mathbf{I}_1(3 + j5) = 6\angle 0^\circ$$
$$\mathbf{I}_1(5.83\angle 59.04^\circ) = 6\angle 0^\circ$$
$$\mathbf{I}_1 = \frac{6\angle 0^\circ}{5.83\angle 59.04^\circ}$$
$$\mathbf{I}_1 = \frac{6\angle 0^\circ}{5.83\angle 59.04^\circ}$$
$$= 1.03\angle -59.04^\circ\ \mathrm{A}$$

Therefore, the value of $\mathbf{I}_1$ is $1.03\angle -59.04^\circ\ \mathrm{A}$.

Step 3 of 12

Calculate the value of open circuit voltage $\mathbf{V}_{OC}$.

$$\mathbf{V}_{OC} = -\mathbf{I}_1(j3) + 6\angle 0^\circ$$

Substitute $1.03\angle -59.04^\circ\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\mathbf{V}_{OC} = -(1.03\angle -59.04^\circ)(j3) + 6\angle 0^\circ$$
$$= -3.09\angle 30.96^\circ + 6\angle 0^\circ$$
$$= 3.71\angle -25.38^\circ\ \mathrm{V}$$

Therefore, the value of the open circuit voltage $\mathbf{V}_{OC}$ is $3.71\angle -25.38^\circ\ \mathbf{V}$.

Step 4 of 12

Open the output terminals to calculate the short circuit current.

Figure 2

Step 5 of 12

Consider the expression for current $\mathbf{I}_x$.

$$\mathbf{I}_x = -\frac{\mathbf{V}}{4}$$

Therefore, the expression for current $\mathbf{I}_x$ is $-\frac{\mathbf{V}}{4}$.

Step 6 of 12

Apply Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V} - 2\mathbf{I}_x}{3 + j2} + \frac{\mathbf{V} - 6}{j3} + \frac{\mathbf{V}}{4} = 0$$

Substitute $-\frac{\mathbf{V}}{4}$ for $\mathbf{I}_x$.

$$\frac{\mathbf{V} - 2\left(-\frac{\mathbf{V}}{4}\right)}{3 + j2} + \frac{\mathbf{V} - 6}{j3} + \frac{\mathbf{V}}{4} = 0$$
$$\frac{\mathbf{V} + \frac{\mathbf{V}}{2}}{3 + j2} + \frac{\mathbf{V} - 6}{j3} + \frac{\mathbf{V}}{4} = 0$$
$$\frac{3\mathbf{V}}{6 + j4} + \frac{\mathbf{V} - 6}{j3} + \frac{\mathbf{V}}{4} = 0$$
$$\mathbf{V}\left(\frac{3}{6 + j4} + \frac{1}{j3} + \frac{1}{4}\right) = \frac{6}{j3}$$
$$\mathbf{V}(0.82\angle -43.42^\circ) = 2\angle -90^\circ$$
$$\mathbf{V} = \frac{2\angle -90^\circ}{0.82\angle -43.42^\circ}$$
$$\mathbf{V} = 2.44\angle -46.58^\circ\ \mathbf{V}$$

Therefore, the value of the voltage $\mathbf{V}$ is $2.44\angle -46.58^\circ\ \mathbf{V}$.

Step 7 of 12

Calculate the value of short circuit current $\mathbf{I}_{SC}$.

$$\mathbf{I}_{SC} = \frac{\mathbf{V}}{4}$$

Substitute $2.44\angle -46.58^\circ\ \mathbf{V}$ for $\mathbf{V}$.

$$\mathbf{I}_{SC} = \frac{2.44\angle -46.58^\circ}{4}$$
$$= 0.61\angle -46.58^\circ\ \mathrm{A}$$

Therefore, the value of the short circuit current $\mathbf{I}_{SC}$ is $0.61\angle -46.58^\circ\ \mathrm{A}$.

Step 8 of 12

Calculate the value of the Norton's impedance $\mathbf{Z}_{TH}$.

$$\mathbf{Z}_N = \frac{\mathbf{V}_{OC}}{\mathbf{I}_{SC}}$$

Substitute $3.71\angle -25.38^\circ\ \mathbf{V}$ for $\mathbf{V}_{OC}$ and $0.61\angle -46.58^\circ\ \mathrm{A}$ for $\mathbf{I}_{SC}$.

$$\mathbf{Z}_N = \frac{3.71\angle -25.38^\circ}{0.61\angle -46.58^\circ}$$
$$= \frac{3.71\angle -25.38^\circ}{0.61\angle -46.58^\circ}$$
$$= 6.08\angle 21.2$$
$$= 5.67 + j2.2\ \Omega$$

Therefore, the value of the Norton's Impedance $\mathbf{Z}_N$ is $5.67 + j2.2\ \Omega$.

Step 9 of 12

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_N^*$$

Substitute $5.67 + j2.2\ \Omega$ for $\mathbf{Z}_N$.

$$\mathbf{Z}_L = (5.67 + j2.2)^*$$
$$= 5.67 - j2.2\ \Omega$$

Therefore, the value of the load impedance is $\boxed{5.67 - j2.2\ \Omega}$.

Step 10 of 12

Draw the Norton's equivalent circuit diagram.

Figure 3

Step 11 of 12

Calculate the value of current $\mathbf{I}$ using current Division rule.

$$\mathbf{I} = (0.61\angle -46.58^\circ + 3\angle 10^\circ)\left(\frac{5.67 + j2.2}{5.67 + j2.2 + 5.67 - j2.2}\right)$$
$$= (3.3746\angle 1.32^\circ)(0.536\angle 21.21^\circ)$$
$$= 1.81\angle 22.53^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}$ is $1.81\angle 22.53^\circ\ \mathrm{A}$.

Step 12 of 12

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute $1.81\ \mathrm{A}$ for I_M and $5.67\ \Omega$ for R_L.

$$P_L = \frac{1}{2}(1.81)^2(5.67)$$
$$= 9.29\ \mathrm{W}$$

Therefore, the value of the maximum power transferred to load is $\boxed{9.29\ \mathrm{W}}$.

Step 1 of 8

The given circuit is,

Step 2 of 8

Given

$v_s = 25\cos 20t \text{ V}$

$\therefore V_s = 25\angle 0^\circ \text{V}$

$\omega = 20\text{rad/s}$

Therefore the impedances in frequency domain,

$X_L = j\omega L$

$X_L = j(20)(0.4)$

$X_L = j8\Omega$

Step 3 of 8

$X_{C1} = \dfrac{1}{j\omega C_1}$

$X_{C1} = \dfrac{1}{j(20)(0.02)}$

$X_{C1} = -j2.5\Omega$

$X_{C2} = \dfrac{1}{j\omega C_2}$

$X_{C2} = \dfrac{1}{j(20)(0.01)}$

$X_{C2} = -j5\Omega$

Step 4 of 8

The current through the resistor 5Ω is,

$I_1 = \dfrac{25\angle 0^\circ}{5}$

$I_1 = 5\angle 0^\circ \text{A}$

The current through the inductor $j8\Omega$ is,

$I_L = \dfrac{25\angle 0^\circ}{j8}$

$I_L = \dfrac{25\angle 0^\circ}{8\angle 90^\circ}$

$I_L = 3.125\angle -90^\circ \text{A}$

Step 5 of 8

The current through the capacitor $-j2.5\Omega$ is,

$I_C = \dfrac{25\angle 0^\circ}{-j2.5}$

$I_C = \dfrac{25\angle 0^\circ}{2.5\angle -90^\circ}$

$I_C = 10\angle 90^\circ \text{A}$

The current through the series combination of resistor and capacitor $5-j5\Omega$ is,

$I_2 = \dfrac{25\angle 0^\circ}{5-j5}$

$I_2 = \dfrac{25\angle 0^\circ}{7.071\angle -45^\circ}$

$I_2 = 3.535\angle 45^\circ \text{A}$

Step 6 of 8

Therefore, power absorbed by R_1:

$P_{R1} = \dfrac{1}{2} I_M{}^2 R$

$P_{R1} = \dfrac{1}{2} \times 25 \times 5$

$\boxed{P_{R1} = 62.5\text{W}}$

Therefore, power absorbed by R_2:

$P_{R2} = \dfrac{1}{2} I_2{}^2 R_2$

$P_{R2} = \dfrac{1}{2} \times 3.535^2 \times 5$

$P_{R2} = \dfrac{1}{2} \times 12.5 \times 5$

$\boxed{P_{R2} = 31.25\text{W}}$

Since, the inductors and the capacitors in the circuit are purely reactive, they do not absorb any power.

Therefore, $\boxed{P_{0.04\text{H}} = P_{0.02\text{F}} = P_{0.01\text{F}} = 0\text{W}}$

Step 7 of 8

Check:

The current through the voltage source is given by,

$I = I_1 + I_L + I_{C1} + I_2$

$I = 5\angle 0^\circ + 3.125\angle -90^\circ + 5\angle 90^\circ + 3.535\angle 45^\circ$

$I = 5 - j3.125 + j5 + 2.5 + j2.5$

$I = 7.5 - j4.375$

$I = 8.683\angle -30.256^\circ \text{A}$

Step 8 of 8

Hence the Average Power supplied by the source is,

$P_s = \dfrac{1}{2} V_M I_M \cos(\theta_V - \theta_I)$

$P_s = \dfrac{1}{2}(25)(8.683)\cos(30.256^\circ)$

$P_s = 93.75\text{W}$

The total power absorbed is given by,

$P_{abs} = P_{R1} + P_{R2}$

$P_{abs} = 62.5 + 31.25$

$P_{abs} = 93.75\text{W}$

$\therefore P_s = P_{abs} = 93.75\text{W}$

Step 1 of 3

9.011E

Consider Figure E9.11 from the text book.

Define the function for the current $i(t)$.

$$i(t)=\begin{cases}2\text{ A} & 0<t<2\\ 4\text{ A} & 2<t<4\\ 2\text{ A} & 4<t<6\end{cases}$$

Step 2 of 3

Consider the expression for the root mean square current.

$$I_{\text{rms}}=\sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases}2\text{ A} & 0<t<2\\ 4\text{ A} & 2<t<4\\ 2\text{ A} & 4<t<6\end{cases}$ for $i(t)$ and $6\,\text{sec}$ for T.

$$\begin{aligned}I_{\text{rms}}&=\sqrt{\frac{1}{6}\left\{\int_0^2 2^2dt+\int_2^4 4^2dt+\int_4^6 2^2dt\right\}}\\&=\sqrt{\frac{1}{6}\left\{4\int_0^2 dt+16\int_2^4 dt+4\int_4^6 dt\right\}}\\&=\sqrt{\frac{1}{6}\left\{4[t]_0^2+16[t]_2^4+4[t]_4^6\right\}}\\&=\sqrt{\frac{1}{6}\{4[2-0]+16[4-2]+4[6-4]\}}\end{aligned}$$

$$\begin{aligned}I_{\text{rms}}&=\sqrt{\frac{1}{6}(4(2)+16(2)+4(2))}\\&=\sqrt{\frac{1}{6}(8+32+8)}\\&=\sqrt{\frac{48}{6}}\\&=2.828\text{ A}\end{aligned}$$

Therefore, the root mean square value of the current is 2.828 A.

Step 3 of 3

Consider the expression for the power dissipated in $4\,\Omega$ resistor.

$$P_{4\Omega}=I^2{}_{\text{rms}}(4)$$

Substitute 2.828 A for I_{rms}.

$$\begin{aligned}P_{4\Omega}&=(2.828)^2(4)\\&=32\text{ W}\end{aligned}$$

Therefore, the value of the power delivered to the resistor is $\boxed{32\text{ W}}$.

Step 1 of 9

Consider Figure E9.9 from the text book.

Apply Thevenin theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 9

Consider Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}-6\angle 0^\circ}{j3}+\frac{\mathbf{V}-12\angle 0^\circ}{3+j2}-3\angle 10^\circ=0$$

$$\frac{\mathbf{V}}{j3}+\frac{\mathbf{V}}{3+j2}-\frac{6\angle 0^\circ}{j3}-\frac{12\angle 0^\circ}{3+j2}-3\angle 10^\circ=0$$

$$\mathbf{V}\left(\frac{1}{j3}+\frac{1}{3+j2}\right)=\frac{6\angle 0^\circ}{j3}+\frac{12\angle 0^\circ}{3+j2}+3\angle 10^\circ$$

$$\mathbf{V}(-j0.333+0.231-j0.154)=\frac{6\angle 0^\circ}{3\angle 90^\circ}+\frac{12\angle 0^\circ}{3.61\angle 33.69}+3\angle 10^\circ$$

$$\mathbf{V}(0.231-j0.487)=2\angle -90^\circ+3.324\angle -33.69^\circ+3\angle 10^\circ$$

$$\mathbf{V}(0.539\angle -64.62^\circ)=6.615\angle -30.15^\circ$$

$$\mathbf{V}=\frac{6.615\angle -30.15^\circ}{0.539\angle -64.62^\circ}$$

$$\mathbf{V}=12.27\angle -34.47^\circ\ \mathrm{V}$$

Therefore, the value of the voltage at node-1 is $12.27\angle -34.47^\circ\ \mathrm{V}$.

Step 3 of 9

Calculate the value of $\mathbf{V}_{oc}$.

$$\mathbf{V}_{oc}=\mathbf{V}+4(3\angle 10^\circ)$$

Substitute $12.27\angle -34.47^\circ\ \mathrm{V}$ for $\mathbf{V}_3$.

$$\begin{aligned}\mathbf{V}_{oc}&=12.27\angle -34.47^\circ+4(3\angle 10^\circ)\\&=12.27\angle -34.47^\circ+12\angle 10^\circ\\&=23.18\angle 17.43^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the expression for $\mathbf{V}_{oc}$ is $23.18\angle 17.43^\circ\ \mathrm{V}$.

Step 4 of 9

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 5 of 9

Calculate the value of Thevenin impedance.

$$\begin{aligned}\mathbf{Z}_{\mathrm{TH}}&=[(3+j2)\|j3]+4\\&=\left(\frac{(3+j2)(j3)}{3+j2+j3}\right)+4\\&=0.79+j1.68+4\\&=4.79+j1.68\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin impedance is $4.79+j1.68\,\Omega$.

Step 6 of 9

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L=\mathbf{Z}_{\mathrm{TH}}^*$$

Substitute $4.79+j1.68\,\Omega$ for $\mathbf{Z}_{\mathrm{TH}}$.

$$\begin{aligned}\mathbf{Z}_L&=(4.79+j1.68)^*\\&=4.79-j1.68\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{4.79-j1.68\,\Omega}$.

Step 7 of 9

Draw the Thevenin equivalent circuit.

Figure 3

Step 8 of 9

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I}&=\frac{23.18\angle 17.43^\circ}{4.79+j1.68+4.79-j1.68}\\&=\frac{23.18\angle 17.43^\circ}{9.58}\\&=2.42\angle 17.43^\circ\ \mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $2.42\angle 17.43^\circ\ \mathrm{A}$.

Step 9 of 9

Consider the expression for the maximum power transferred to load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Substitute $2.42\ \mathrm{A}$ for I_M and $4.79\,\Omega$ for R_L.

$$\begin{aligned}P_L&=\frac{1}{2}(2.42)^2(4.79)\\&=14.026\ \mathrm{W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{14.026\ \mathrm{W}}$.

Step 1 of 3

Consider Figure E9.12 from the text book.

Define the function for the current $i(t)$.

$$i(t)=\begin{cases}4\text{ A} & 0<t<2\\ 0\text{ A} & 2<t<4\\ -4\text{ A} & 4<t<6\\ 0\text{ A} & 6<t<8\end{cases}$$

Step 2 of 3

Consider the expression for the root mean square current.

$$I_{\text{rms}}=\sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases}4\text{ A} & 0<t<2\\ 0\text{ A} & 2<t<4\\ -4\text{ A} & 4<t<6\\ 0\text{ A} & 6<t<8\end{cases}$ for $i(t)$ and 8sec for T .

$$\begin{aligned}I_{\text{rms}}&=\sqrt{\frac{1}{8}\left\{\int_0^2 4^2dt+\int_2^4 0^2dt+\int_4^6(-4)^2dt+\int_6^8 0^2dt\right\}}\\&=\sqrt{\frac{1}{8}\left\{16\int_0^2 dt+16\int_4^6 dt+0\right\}}\\&=\sqrt{\frac{1}{8}\left\{16[t]_0^2+16[t]_4^6\right\}}\\&=\sqrt{\frac{1}{8}\{16[2-0]+16[6-4]\}}\end{aligned}$$

$$\begin{aligned}I_{\text{rms}}&=\sqrt{\frac{1}{8}(32+32)}\\&=\sqrt{\frac{1}{8}(64)}\\&=\sqrt{8}\\&=2.828\text{ A}\end{aligned}$$

Therefore, the root mean square value of the current is 2.828 A .

Step 3 of 3

Consider the expression for the power dissipated in $10\,\Omega$ resistor.

$$P_{10\,\Omega}=I^2{}_{\text{rms}}(10)$$

Substitute 2.828 A for I_{rms} .

$$\begin{aligned}P_{10\Omega}&=(2.828)^2(10)\\&=80\text{ W}\end{aligned}$$

Therefore, the value of the power dissipated in the resistor is $\boxed{80\text{ W}}$.

Step 1 of 4

Refer to Figure P9.12 in the text book.

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law in the first loop to calculate the loop current.

$$-10\angle 0° + (I_1)(1j) + (I_1)(-1j) + 1(I_1 + 2\angle 30°) = 0$$
$$-10\angle 0° + I_1 + 2\angle 30° = 0$$
$$I_1 = 10 - 2\angle 30°$$
$$I_1 = 8.33\angle -6.9°\ \text{A}$$

Calculate the value of voltage across the current source.

$$V_1 = 1(I_1 + 2\angle 30°)$$
$$V_1 = I_1 + 2\angle 30°$$

Substitute $10 - 2\angle 30°$ for I_1 in the equation.

$$V_1 = 10 - 2\angle 30° + 2\angle 30°$$
$$= 10\angle 0°\ \text{V}$$

Step 3 of 4

Calculate the average power supplied by the voltage source in the network.

$$P_{10\angle 0°} = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute $10\ \text{V}$ for V_M, $8.33\ \text{A}$ for I_M, $0°$ for θ_v and $-6.9°$ for θ_i in the equation.

$$P_{10\angle 0°} = \frac{(10)(8.33)}{2}\cos(0° - (-6.9°))$$
$$= 41.65\cos(6.9°)$$
$$= 41.35\ \text{W}$$

Thus, the average power supplied by the voltage source, $P_{10\angle 0°}$ is $\boxed{41.35\ \text{W}}$.

Step 4 of 4

Calculate the average power supplied by the current source in the network.

$$P_{2\angle 30°} = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute $10\ \text{V}$ for V_M, $2\ \text{A}$ for I_M, $0°$ for θ_v and $30°$ for θ_i in the equation.

$$P_{2\angle 30°} = \frac{(10)(2)}{2}\cos(0° - 30°)$$
$$= 10\cos(-30°)$$
$$= 8.66\ \text{W}$$

Thus, the average power supplied by the current source, $P_{2\angle 30°}$ is $\boxed{8.66\ \text{W}}$.

Step 1 of 3

Consider Figure E9.13 from the text book.

Find the equation for the voltage between the interval $0 < t < 2$ having end points $(0,0)$ and $(2,-10)$.

$$v(t) - 0 = \left(\frac{-10-0}{2-0}\right)(t-0) \quad \text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)$$

$$v(t) = -5t$$

Therefore, the equation for the voltage between the interval $0 < t < 2$ is $i(t) = -5t$.

Step 2 of 3

Define the function for the voltage $v(t)$.

$$v(t) = \begin{cases} -5t & 0 < t < 2 \\ -10 & 2 < t < 4 \\ 0 & 4 < t < 5 \\ 10 & 5 < t < 10 \end{cases}$$

Consider the expression for the root mean square voltage.

$$V_{\text{rms}} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Substitute $\begin{cases} -5t & 0 < t < 2 \\ -10 & 2 < t < 4 \\ 0 & 4 < t < 5 \\ 10 & 5 < t < 10 \end{cases}$ for $v(t)$ and $10\,\text{sec}$ for T.

$$\begin{aligned} V_{\text{rms}} &= \sqrt{\frac{1}{10}\left\{\int_0^2 (-5t)^2 dt + \int_2^4 (-10)^2 dt + \int_4^5 (0)^2 dt + \int_5^{10} (10)^2 dt\right\}} \\ &= \sqrt{\frac{1}{10}\left\{25\int_0^2 (t)^2 dt + 100\int_2^4 dt + 100\int_5^{10} dt\right\}} \\ &= \sqrt{\frac{1}{10}\left\{25\left[\frac{t^3}{3}\right]_0^2 + 100[t]_2^4 + 100[t]_5^{10}\right\}} \\ &= \sqrt{\frac{1}{10}\left\{25\left[\frac{2^3-0}{3}\right] + 100[4-2] + 100[10-5]\right\}} \end{aligned}$$

$$\begin{aligned} V_{\text{rms}} &= \sqrt{\frac{1}{10}\left\{25\left[\frac{8}{3}\right] + 100[2] + 100[5]\right\}} \\ &= \sqrt{\frac{1}{10}\left\{\frac{200}{3} + 200 + 500\right\}} \\ &= \sqrt{\frac{2300}{30}} \\ &= 8.756\text{ V} \end{aligned}$$

Therefore, the root mean square value of the voltage is 8.756 V.

Step 3 of 3

Consider the expression for the power dissipated in 2Ω resistor.

$$P_{2\Omega} = \frac{V_{\text{rms}}^2}{2}$$

Substitute 8.756 V for I_{rms}.

$$\begin{aligned} P_{2\Omega} &= \frac{(8.756)^2}{2} \\ &= \frac{76.67}{2} \\ &= 38.34\text{ W} \end{aligned}$$

Therefore, the value of the power dissipated in the resistor is $\boxed{38.34\text{ W}}$.

Step 1 of 6

Refer to Figure P9.13 in the text book.

Redraw the network by representing node voltages in Figure P9.13 as shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's current law at super node in Figure 1.

$$-4\angle 0° + \frac{V_1}{2} + \frac{V_2}{j1} + \frac{V_2}{4} = 0$$

$$\frac{V_1}{2} + V_2\left(\frac{1}{j1} + \frac{1}{4}\right) = 4\angle 0° \text{ ..... (1)}$$

From Figure 1, the expression for voltage source is,

$$V_1 - V_2 = 12\angle 0°$$
$$V_1 = 12\angle 0° + V_2$$

Calculate the value of voltage, V_2.

Substitute $(12\angle 0° + V_2)$ for V_1 in equation (1).

$$\frac{12\angle 0° + V_2}{2} + V_2\left(\frac{1}{j1} + \frac{1}{4}\right) = 4\angle 0°$$
$$6\angle 0° + V_2\left(\frac{1}{2} + \frac{1}{j1} + \frac{1}{4}\right) = 4\angle 0°$$

$$V_2 = \frac{-2\angle 0°}{\left(\frac{1}{2} + \frac{1}{j1} + \frac{1}{4}\right)}$$
$$= -0.96 - 1.28j$$
$$= 1.6\angle -126.87° \text{ V}$$

Step 3 of 6

Calculate the value of voltage, V_1.

$$V_1 = 12\angle 0° + V_2$$

Substitute $1.6\angle -126.87°$ V for V_2 in the equation.

$$V_1 = 12\angle 0° + 1.6\angle -126.87°$$
$$= 11.11\angle -6.6° \text{ V}$$

Calculate the value of current, I in Figure 1.

$$I = 4\angle 0° + \frac{V_1}{2}$$

Substitute $11.11\angle -6.6°$ V for V_1 in the equation.

$$I = 4\angle 0° + \frac{11.11\angle -6.6° \text{ V}}{2}$$
$$= 9.54\angle -3.84° \text{ A}$$

Step 4 of 6

Calculate the average power supplied by the current source in the network.

$$P_{4\angle 0°} = \frac{V_{1M} I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 11.11 V for V_{1M}, 4 A for I_M, $-6.6°$ for θ_v and $0°$ for θ_i in the equation.

$$P_{4\angle 0°} = \frac{(11.11)(4)}{2}\cos(-6.6° - 0°)$$
$$= 22.22\cos(-6.6°)$$
$$= 22.07 \text{ W}$$

Thus, the average power supplied by the current source, $P_{4\angle 0°}$ is $\boxed{22.07 \text{ W}}$.

Step 5 of 6

Calculate the average power supplied by the voltage source in the network.

$$P_{12\angle 0°} = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 12 V for V_M, 9.54 A for I_M, $0°$ for θ_v and $-3.84°$ for θ_i in the equation.

$$P_{12\angle 0°} = \frac{(12)(9.54)}{2}\cos(0° - (-3.84°))$$
$$= 57.24\cos(3.84°)$$
$$= 57.11 \text{ W}$$

Thus, the average power supplied by the voltage source, $P_{12\angle 0°}$ is $\boxed{57.11 \text{ W}}$.

Step 6 of 6

Determine the amount of average power supplied to the network.

$$P = P_{4\angle 0°} + P_{12\angle 0°}$$

Substitute 22.07 W for $P_{4\angle 0°}$ and 57.11 W for $P_{12\angle 0°}$ in the equation.

$$P = 22.07 + 57.11$$
$$= 79.18 \text{ W}$$

Thus, the amount of average power supplied to the network, P is $\boxed{79.18 \text{ W}}$.

Step 1 of 2

Consider Figure E9.14 from the text book.

Find the equation for the voltage between the interval $0 < t < 2$ having end points $(0,0)$ and $(2,4)$.

$$v(t) - 0 = \left(\frac{4-0}{2-0}\right)(t-0) \quad \text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)$$

$$v(t) = 2t$$

Therefore, the equation for the voltage between the interval $0 < t < 2$ is $i(t) = 2t$.

Step 2 of 2

Define the function for the voltage $v(t)$.

$$v(t) = \begin{cases} 2t & 0 < t < 2 \\ 0 & 2 < t < 4 \end{cases}$$

Consider the expression for the root mean square voltage.

$$V_{\text{rms}} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Substitute $\begin{cases} 2t & 0 < t < 2 \\ 0 & 2 < t < 4 \end{cases}$ for $v(t)$ and $4\,\text{sec}$ for T.

$$\begin{aligned} V_{\text{rms}} &= \sqrt{\frac{1}{4}\left\{\int_0^2 (2t)^2 dt + \int_2^4 (0)^2 dt\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4\int_0^2 t^2 dt\right\}} \\ &= \sqrt{\left[\frac{t^3}{3}\right]_0^2} \\ &= \sqrt{\frac{2^3 - 0}{3}} \end{aligned}$$

$$\begin{aligned} V_{\text{rms}} &= \sqrt{\frac{8}{3}} \\ &= 1.633\,\text{V} \end{aligned}$$

Therefore, the root mean square value of the voltage is $\boxed{1.633\,\text{V}}$.

Step 1 of 3

Refer to Figure P9.14 in the text book.

Redraw the network by representing node V_1 in Figure P9.14 as shown in Figure 1.

Figure 1

Step 2 of 3

Apply Kirchhoff's current law at top node V_1 in Figure 1.

$$\frac{V_1}{4}+\frac{V_1}{-j4}-4\angle 0°+\frac{V_1-12\angle 90°}{2}=0$$

$$V_1\left(\frac{1}{4}+\frac{1}{-j4}+\frac{1}{2}\right)-6\angle 90°=4\angle 0°$$

$$V_1(0.75+0.25j)=4\angle 0°+6\angle 90°$$

$$V_1=\frac{4+6j}{0.75+0.25j}$$

$$V_1=9.12\angle 37.87°\ \text{V}$$

Step 3 of 3

Calculate the average power absorbed by the $4\ \Omega$ resistor in the network.

$$P_{4\Omega}=\frac{1}{2}\frac{V_M^2}{R}$$

Substitute $9.12\ \text{V}$ for V_M and $4\ \Omega$ for R in the equation.

$$\begin{aligned}P_{4\Omega}&=\frac{1}{2}\frac{(9.12)^2}{4}\\&=10.397\\&\approx 10.4\ \text{W}\end{aligned}$$

Thus, the average power absorbed by the $4\ \Omega$ resistor, $P_{4\Omega}$ is $\boxed{10.4\ \text{W}}$.

Step 1 of 5

Consider the expression for line current when the load power factor is 0.707 lagging.

$$\mathbf{I}_{\text{old}} = \frac{P_L}{\mathbf{V}_L(\text{pf})}$$

Substitute 100 kW for P_L, 0.707 for pf and 480 V rms for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_{\text{old}} &= \frac{100\text{ k}}{(480)(0.707)}\\ &= \frac{100\text{ k}}{339.36}\\ &= 294.67\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the line current is 294.67 A rms.

Step 2 of 5

Calculate the value of the real power loss in the line.

$$P_{\text{line,old}} = \mathbf{I}_{\text{old}}^2(0.1)$$

Substitute 294.67 A rms for $\mathbf{I}_{\text{old}}$.

$$\begin{aligned}P_{\text{line,old}} &= (294.67)^2(0.1)\\ &= 8683.04\text{ W}\end{aligned}$$

Therefore, the value of the real power loss in the line when the load power factor is 0.707 lagging is 8683.04 W.

Step 3 of 5

Consider the expression for line current when the load power factor is 0.94 lagging.

$$\mathbf{I}_{\text{new}} = \frac{P_L}{\mathbf{V}_L(\text{pf})}$$

Substitute 100 kW for P_L, 0.94 for pf and 480 V rms for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_{\text{new}} &= \frac{100\text{ k}}{(480)(0.94)}\\ &= \frac{100\text{ k}}{451.2}\\ &= 221.63\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the line current is 221.63 A rms.

Step 4 of 5

Calculate the value of the real power loss in the line.

$$P_{\text{line,new}} = \mathbf{I}_{\text{old}}^2(0.1)$$

Substitute 221.63 A rms for $\mathbf{I}_{\text{new}}$.

$$\begin{aligned}P_{\text{line,new}} &= (221.63)^2(0.1)\\ &= 4911.99\text{ W}\end{aligned}$$

Therefore, the value of the real power loss in the line when the load power factor is 0.94 lagging is 4911.99 W.

Step 5 of 5

Calculate the power saved when the power factor is changed from 0.707 lagging to 0.94 lagging.

$$P_{\text{saved}} = P_{\text{line,lod}} - P_{\text{line,new}}$$

Substitute 4911.99 W for $P_{\text{line,new}}$ and 8683.04 W for $P_{\text{line,old}}$.

$$\begin{aligned}P_{\text{saved}} &= 8683.04 - 4911.99\\ &= 3771.05\text{ W}\\ &= 3.771\text{ kW}\end{aligned}$$

Therefore, the value of the power saved is $\boxed{3.771\text{ kW}}$.

Step 1 of 7

Refer Figure P9.11 from the text book.

Identify the currents in the circuit shown in Figure 1.

Figure 1

Step 2 of 7

Consider Kirchhoff's voltage law in loop 2.

$$(\mathbf{I}_2-\mathbf{I}_3)(-j2)+(\mathbf{I}_2-\mathbf{I}_1)(j2)=0$$
$$\mathbf{I}_2(-j2)-\mathbf{I}_3(-j2)+\mathbf{I}_2(j2)-\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_3(j2)-\mathbf{I}_1(j2)=0$$

$\mathbf{I}_3=\mathbf{I}_1$ ..... (1)

Step 3 of 7

Consider Kirchhoff's voltage law in loop 1.

$$\mathbf{I}_1(1)+(\mathbf{I}_1-\mathbf{I}_3)(2)+(\mathbf{I}_1-\mathbf{I}_2)(j2)=12\angle 0°$$
$$\mathbf{I}_1(1+2+j2)-\mathbf{I}_3(2)-\mathbf{I}_2(j2)=12\angle 0°$$
$$\mathbf{I}_1(3+j2)-\mathbf{I}_3(2)-\mathbf{I}_2(j2)=12\angle 0°$$

Substitute $\mathbf{I}_1$ for $\mathbf{I}_3$.

$$\mathbf{I}_1(3+j2)-\mathbf{I}_1(2)-\mathbf{I}_2(j2)=12\angle 0°$$
$$\mathbf{I}_1(3+j2-2)-\mathbf{I}_2(j2)=12\angle 0°$$

$\mathbf{I}_1(1+j2)-\mathbf{I}_2(j2)=12\angle 0°$ ..... (2)

Step 4 of 7

Consider Kirchhoff's voltage law in loop 3.

$$\mathbf{I}_3(1-j1)+(\mathbf{I}_3-\mathbf{I}_1)(2)+(\mathbf{I}_3-\mathbf{I}_2)(-j2)=0$$
$$\mathbf{I}_1(-2)+\mathbf{I}_3(1-j1+2-j2)-\mathbf{I}_2(-j2)=0$$
$$\mathbf{I}_1(-2)+\mathbf{I}_3(3-j3)-\mathbf{I}_2(-j2)=0$$

Substitute $\mathbf{I}_1$ for $\mathbf{I}_3$.

$$\mathbf{I}_1(-2)+\mathbf{I}_1(3-j3)-\mathbf{I}_2(-j2)=0$$
$$\mathbf{I}_1(-2+3-j3)-\mathbf{I}_2(-j2)=0$$
$$\mathbf{I}_1(1-j3)+\mathbf{I}_2(j2)=0$$

$\mathbf{I}_2(j2)=-\mathbf{I}_1(1-j3)$ ..... (3)

Step 5 of 7

Consider equation (2).

$$\mathbf{I}_1(1+j2)-\mathbf{I}_2(j2)=12\angle 0°$$

Substitute $-\mathbf{I}_1(1-j3)$ for $\mathbf{I}_2(j2)$.

$$\mathbf{I}_1(1+j2)+\mathbf{I}_1(1-j3)=12\angle 0°$$
$$\mathbf{I}_1(1+j2+1-j3)=12\angle 0°$$
$$\mathbf{I}_1(2-j1)=12\angle 0°$$
$$\mathbf{I}_1=\frac{12\angle 0°}{2-j1}$$
$$\mathbf{I}_1=\frac{12\angle 0°}{2.24\angle -26.58°}$$
$$=5.36\angle 26.58°\ \mathbf{A}$$

Therefore, the value of the current $\mathbf{I}_1$ is $5.36\angle 26.58°\ \mathbf{A}$.

Compare with $\mathbf{I}=I_M\angle\theta_i\ \mathrm{A}$.

$I_M=5.36\ \mathbf{A}$ and $\theta_i=26.58°$

Therefore, the values of I_M and θ_i are $5.36\ \mathbf{A}$ and $26.58°$ respectively.

Step 6 of 7

Consider the value of the voltage source.

$$\mathbf{V}_S=12\angle 0°\ \mathbf{V}$$

Compare with $\mathbf{V}=V_M\angle\theta_v\ \mathbf{V}$.

$V_M=12\ \mathbf{V}$ and $\theta_v=0°$

Therefore, the values of V_M and θ_v are $12\ \mathbf{V}$ and $0°$ respectively.

Step 7 of 7

Consider the expression for average power delivered by the source.

$$P=\frac{V_M I_M}{2}\cos(\theta_v-\theta_i)$$

Substitute $12\ \mathbf{V}$ for V_M, $5.36\ \mathrm{A}$ for I_M, $0°$ for θ_v and $26.58°$ for θ_i.

$$P=\frac{(12)(5.36)}{2}\cos(0°-26.56°)$$
$$=32.16\cos(-26.56°)$$
$$=(32.16)(0.9)$$
$$=28.94\ \mathbf{W}$$

Therefore, the value of the average power absorbed by the network is $\boxed{28.94\ \mathbf{W}}$.

Step 1 of 7

Consider Figure 1.

Figure 1

Step 2 of 7

Consider the expression for line current $\mathbf{I}$.

$$\mathbf{I} = \frac{P_L}{\mathbf{V}_L(\text{pf})}$$

Substitute $40\,\text{kW}$ for P_L, 0.84 for pf and 220 V rms for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I} &= \frac{40\text{ k}}{(220)(0.84)}\\ &= \frac{40\text{ k}}{184.8}\\ &= 216.45\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the line current is 216.45 A rms.

Step 3 of 7

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.84 for pf.

$$\begin{aligned}\theta &= \cos^{-1}(0.84)\\ &= 32.86°\end{aligned}$$

Therefore, the power factor angle at the load is $32.86°$.

Step 4 of 7

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_L - \angle\mathbf{I}$$

Substitute $32.86°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$\begin{aligned}32.86° &= 0° - \angle\mathbf{I}\\ \angle\mathbf{I} &= 0° - 32.86°\\ \angle\mathbf{I} &= -32.86°\end{aligned}$$

Therefore, the phase angle of the line current is $-32.86°$.

Hence, the phasor value of the line current is $216.45\angle -32.86°\text{ A rms}$.

Step 5 of 7

Consider the expression for the load voltage $\mathbf{V}_L$.

$$\mathbf{V}_S = \mathbf{I}(0.1 + j0.25) + \mathbf{V}_L$$

Substitute $216.45\angle -32.86°\text{ A rms}$ for $\mathbf{I}$, $220\angle 0°\text{ V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{V}_S &= (216.45\angle -32.86°)(0.1 + j0.25) + 220\angle 0°\\ &= (216.45\angle -32.86°)(0.269\angle 68.2°) + 220\angle 0°\\ &= 58.23\angle 35.34° + 220\angle 0°\\ &= 269.61\angle 7.18°\text{ V rms}\end{aligned}$$

Therefore, the value of the source voltage is $269.61\angle 7.18°\text{ V rms}$.

Step 6 of 7

Calculate the value of the complex power delivered by the source.

$$S_S = \mathbf{V}_S\mathbf{I}^*$$

Substitute $269.61\angle 7.18°\text{ V rms}$ for $\mathbf{V}_S$ and $216.45\angle -32.86°\text{ A rms}$ for $\mathbf{I}$.

$$\begin{aligned}S_S &= (269.61\angle 7.18°)(216.45\angle -32.86°)^*\\ &= (269.61\angle 7.18°)(216.45\angle 32.86°)\\ &= 58.38\angle 40.04°\text{ k}\\ &= 44.68 + j37.54\text{ kVA}\end{aligned}$$

Therefore, the value of the real power delivered by the source is $\boxed{44.68\text{ kW}}$ and the value of the reactive power delivered by the source is $\boxed{37.54\text{ kvar}}$.

Step 7 of 7

Calculate the value of the complex power loss in the line.

$$S_{\text{line}} = (\mathbf{V}_S - \mathbf{V}_L)\mathbf{I}^*$$

Substitute $220\angle 0°\text{ V rms}$ for $\mathbf{V}_L$, $269.61\angle 7.18°\text{ V rms}$ for $\mathbf{V}_S$ and $216.45\angle -32.86°\text{ A rms}$ for $\mathbf{I}$.

$$\begin{aligned}S_{\text{line}} &= (269.61\angle 7.18° - 220\angle 0°)(216.45\angle -32.86°)^*\\ &= (58.24\angle 35.36°)(216.45\angle 32.86°)\\ &= 12.61\angle 68.22°\text{ k}\\ &= 4.68 + j11.71\text{ kVA}\end{aligned}$$

Therefore, the value of the real power loss in the line is $\boxed{4.68\text{ kW}}$ and the value of the reactive power loss in the line is $\boxed{11.71\text{ kvar}}$.

Step 1 of 2

Refer to circuit diagram in Figure P9.9 in the textbook.

Consider the expression for the voltage across the resistor.

$$V_R = V_1 - V_2$$

Substitute $10\angle 60^\circ\ \text{V}$ for V_1 and $20\angle 120^\circ\ \text{V}$ for V_2.

$$\begin{aligned} V_R &= 10\angle 60^\circ - 20\angle 120^\circ \\ &= 17.32\angle -30^\circ\ \text{V} \end{aligned}$$

Therefore, the value of the voltage across the resistor is $17.32\angle -30^\circ\ \text{V}$.

Compare with $V = V_M\angle\theta_v\ \text{V}$.

$V_M = 17.32\ \text{V}$ and $\theta_v = -30^\circ$

Therefore, the values of V_M and θ_v are $17.32\ \text{V}$ and -30° respectively.

Consider the expression for the current through the resistor.

$$I_R = \frac{V_R}{1}$$

Substitute $17.32\angle -30^\circ\ \text{V}$ for V_R.

$$\begin{aligned} I_R &= \frac{17.32\angle -30^\circ}{1} \\ &= 17.32\angle -30^\circ\ \text{A} \end{aligned}$$

Therefore, the value of the current through the resistor is $17.32\angle -30^\circ\ \text{A}$.

Compare with $I = I_M\angle\theta_i\ \text{A}$.

$I_M = 17.32\ \text{A}$ and $\theta_i = -30^\circ$

Therefore, the values of I_M and θ_i are $17.32\ \text{A}$ and -30° respectively.

Step 2 of 2

Consider the expression for average power absorbed by the resistor.

$$P = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute $17.32\ \text{V}$ for V_M, $17.32\ \text{A}$ for I_M, -30° for θ_v and -30° for θ_i.

$$\begin{aligned} P &= \frac{(17.32)(17.32)}{2}\cos(-30^\circ - (-30^\circ)) \\ &= 150\cos(0^\circ) \\ &= (150)(1) \\ &= 150\ \text{W} \end{aligned}$$

Therefore, the value of the average power absorbed by the resistor is $\boxed{150\ \text{W}}$.

Step 1 of 6

Consider Figure 1.

Figure 1

Step 2 of 6

Consider the expression for line current $\mathbf{I}$.

$$\mathbf{I} = \frac{P_L}{\mathbf{V}_L(\text{pf})}$$

Substitute 60 kW for P_L, 0.85 for pf and 220 V rms for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I} &= \frac{60\text{ k}}{(220)(0.85)}\\ &= \frac{60\text{ k}}{187}\\ &= 320.86\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the line current is 320.86 A rms.

Step 3 of 6

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.85 for pf.

$$\begin{aligned}\theta &= \cos^{-1}(0.85)\\ &= 31.79°\end{aligned}$$

Therefore, the power factor angle at the source is $31.79°$.

Step 4 of 6

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_S - \angle\mathbf{I}$$

Substitute $31.79°$ for θ and $0°$ for $\angle\mathbf{V}$.

$$\begin{aligned}31.79° &= 0° - \angle\mathbf{I}\\ \angle\mathbf{I} &= 0° - 31.79°\\ \angle\mathbf{I} &= -31.79°\end{aligned}$$

Therefore, the phase angle of the line current is $-31.79°$.

Hence, the phasor value of the line current is $320.86\angle -31.79°\text{ A rms}$.

Step 5 of 6

Consider the expression for the load voltage $\mathbf{V}_L$.

$$\mathbf{V}_S = \mathbf{I}(0.12 + j0.18) + \mathbf{V}_L$$

Substitute $320.86\angle -31.79°\text{ A rms}$ for $\mathbf{I}$, $220\angle 0°\text{ V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{V}_S &= (320.86\angle -31.79°)(0.12 + j0.18) + 220\angle 0°\\ &= (320.86\angle -31.79°)(0.216\angle 56.31°) + 220\angle 0°\\ &= 69.31\angle 24.52° + 220\angle 0°\\ &= 284.52\angle 5.8°\text{ V rms}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{284.52\angle 5.8°\text{ V rms}}$.

Step 6 of 6

Calculate the power factor at the source.

$$\text{pf} = \cos(\angle\mathbf{V}_S - \angle\mathbf{I})$$

Substitute $5.8°$ for $\angle\mathbf{V}_S$ and $-31.79°$ for $\angle\mathbf{I}$.

$$\begin{aligned}\text{pf} &= \cos(5.8° + 31.79°)\\ &= \cos(37.59°)\\ &= 0.792\end{aligned}$$

Therefore, the value fo the power factor at the source is $\boxed{0.792}$.

Step 1 of 10

Consider the value of current $i_g(t)$.

$$i_g(t) = 0.5\cos 2000t \text{ A}$$

Convert to phasor form.

$$\mathbf{I}_g = 0.5\angle 0° \text{ A}$$

Therefore, the value of $\mathbf{I}_g$ is $0.5\angle 0° \text{ A}$.

Compare with $\mathbf{I} = I_M\angle\theta_i \text{ A}$.

$I_M = 0.5 \text{ A}$ and $\theta_i = 0°$

Therefore, the values of I_M and θ_i are 0.5 A and $0°$ respectively.

Step 2 of 10

Convert the inductance value to impedance value.

$$Z_L = j\omega L$$

Substitute 2000 for ω and 60 mH for L.

$$\begin{aligned} Z_L &= j(2000)(60 \text{ m}) \\ &= j120\ \Omega \end{aligned}$$

Therefore, the value of Z_L is $j120\ \Omega$.

Step 3 of 10

Convert the capacitance value to impedance value.

$$Z_C = \frac{1}{j\omega C}$$

Substitute 2000 for ω and $12.6\ \mu\text{F}$ for C.

$$\begin{aligned} Z_C &= \frac{1}{j(2000)(12.5\ \mu)} \\ &= \frac{1}{j0.025} \\ &= -j40\ \Omega \end{aligned}$$

Therefore, the value of Z_C is $-j40\ \Omega$.

Step 4 of 10

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 5 of 10

Calculate the expression for $\mathbf{I}_1$ using current division rule.

$$\begin{aligned} \mathbf{I}_1 &= \mathbf{I}_g\left(\frac{40 + j120}{40 + j120 + 120 - j40}\right) \\ &= \mathbf{I}_g\left(\frac{40 + j120}{160 + j80}\right) \\ &= \mathbf{I}_g(0.5 + j0.5) \end{aligned}$$

Substitute $0.5\angle 0° \text{ A}$ for $\mathbf{I}_g$.

$$\begin{aligned} \mathbf{I}_1 &= (0.5\angle 0°)(0.5 + j0.5) \\ &= 0.25 + j0.25 \\ &= 0.353\angle 45° \text{ A} \end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $0.353\angle 45° \text{ A}$.

Step 6 of 10

Calculate the expression for $\mathbf{I}_2$ using current division rule.

$$\begin{aligned} \mathbf{I}_2 &= \mathbf{I}_g\left(\frac{120 - j40}{40 + j120 + 120 - j40}\right) \\ &= \mathbf{I}_g\left(\frac{120 - j40}{160 + j80}\right) \\ &= \mathbf{I}_g(0.5 - j0.5) \end{aligned}$$

Substitute $0.5\angle 0° \text{ A}$ for $\mathbf{I}_g$.

$$\begin{aligned} \mathbf{I}_2 &= (0.5\angle 0°)(0.5 - j0.5) \\ &= 0.25 - j0.25 \\ &= 0.353\angle -45° \text{ A} \end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $0.353\angle -45° \text{ A}$.

Step 7 of 10

Calculate the voltage across the current source.

$$\mathbf{V}_g = \mathbf{I}_1(120 - j40)$$

Substitute $0.353\angle 45° \text{ A}$ for $\mathbf{I}_1$.

$$\begin{aligned} \mathbf{V}_g &= (0.353\angle 45°)(120 - j40) \\ &= (0.353\angle 45°)(126.491\angle -18.44°) \\ &= 44.65\angle 26.56° \text{ V} \end{aligned}$$

Therefore, the value of voltage across the current source is $44.65\angle 26.56° \text{ V}$.

Compare with $\mathbf{V} = V_M\angle\theta_v \text{ V}$.

$V_M = 44.65 \text{ V}$ and $\theta_v = 26.56°$

Therefore, the values of V_M and θ_v are 44.65 V and $26.56°$ respectively.

Step 8 of 10

Consider the expression for average power delivered by the source.

$$P_g = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 44.65 V for V_M, 0.5 A for I_M, $26.56°$ for θ_v and $0°$ for θ_i.

$$\begin{aligned} P_g &= \frac{(44.65)(0.5)}{2}\cos(26.56° - 0°) \\ &= 11.16\cos(26.56°) \\ &= (11.16)(0.9) \\ &= 10.04 \text{ W} \end{aligned}$$

Therefore, the value of the average power delivered by the source is $\boxed{10.04 \text{ W}}$.

Step 9 of 10

Consider the expression for the power absorbed by $120\ \Omega$ resistor.

$$P_{120} = \frac{|\mathbf{I}_1|^2(120)}{2}$$

Substitute 0.353 A for $|\mathbf{I}_1|$.

$$\begin{aligned} P_{120} &= \frac{(0.353)^2 \cdot (120)}{2} \\ &= \frac{14.953}{2} \\ &= 7.477 \text{ W} \end{aligned}$$

Therefore, the value of the power absorbed by $120\ \Omega$ resistor is $\boxed{7.477 \text{ W}}$.

Step 10 of 10

Consider the expression for the power absorbed by the resistor $40\ \Omega$.

$$P_{40} = \frac{|\mathbf{I}_2|^2(40)}{2}$$

Substitute 0.353 A for $|\mathbf{I}_2|$.

$$\begin{aligned} P_{40} &= \frac{(0.353)^2 \cdot (40)}{2} \\ &= \frac{4.984}{2} \\ &= 2.492 \text{ W} \end{aligned}$$

Therefore, the value of the power absorbed by $40\ \Omega$ resistor is $\boxed{2.492 \text{ W}}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $\boxed{0 \text{ W}}$.

Step 1 of 8

Consider Figure 1.

Figure 1

Step 2 of 8

Consider the expression for line current $\mathbf{I}$.

$$\mathbf{I} = \frac{P_S}{\mathbf{V_S}(\mathrm{pf})}$$

Substitute $40\,\mathrm{kW}$ for P_S, 0.9 for pf and $440\,\mathrm{V\ rms}$ for $\mathbf{V_S}$.

$$\begin{aligned}\mathbf{I} &= \frac{40\,\mathrm{k}}{(440)(0.9)}\\ &= \frac{40\,\mathrm{k}}{396}\\ &= 101.01\,\mathrm{A\ rms}\end{aligned}$$

Therefore, the magnitude value of the line current is $101.01\,\mathrm{A\ rms}$.

Step 3 of 8

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\mathrm{pf})$$

Substitute 0.9 for pf.

$$\begin{aligned}\theta &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the power factor angle at the source is $25.84°$.

Step 4 of 8

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V_S} - \angle\mathbf{I}$$

Substitute $25.84°$ for θ and $0°$ for $\angle\mathbf{V}$.

$$\begin{aligned}25.84° &= 0° - \angle\mathbf{I}\\ \angle\mathbf{I} &= 0° - 25.84°\\ \angle\mathbf{I} &= -25.84°\end{aligned}$$

Therefore, the phase angle of the line current is $-25.84°$.

Hence, the phasor value of the line current is $101.01\angle -25.84°\,\mathrm{A\ rms}$.

Step 5 of 8

Consider the expression for the real power loss in the lines.

$$P_{\mathrm{Line}} = \mathbf{I}^2 R$$

Substitute $1.6\,\mathrm{kW}$ for P_{Line} and $101.01\,\mathrm{A\ rms}$ for $\mathbf{I}$.

$$\begin{aligned}1.6\,\mathrm{k} &= (101.01)^2 R\\ R &= \frac{1.6\,\mathrm{k}}{(101.01)^2}\\ R &= \frac{1.6\,\mathrm{k}}{102.03\,\mathrm{k}}\\ R &= 0.157\,\Omega\end{aligned}$$

Therefore, the real value of the impedance of the lines is $0.157\,\Omega$.

Step 6 of 8

Consider the expression for the reactive power loss in the lines.

$$Q_{\mathrm{Line}} = \mathbf{I}^2 R_{\mathrm{Line}}$$

Substitute $2.1\,\mathrm{kvar}$ for Q_{Line} and $101.01\,\mathrm{A\ rms}$ for $\mathbf{I}$.

$$\begin{aligned}2.1\,\mathrm{k} &= (92.59)^2 X\\ X &= \frac{2.1\,\mathrm{k}}{(101.01)^2}\\ X &= \frac{2.1\,\mathrm{k}}{102.03\,\mathrm{k}}\\ X &= 0.206\,\Omega\end{aligned}$$

Therefore, the reactive value of the impedance of the lines is $0.206\,\Omega$.

Step 7 of 8

Consider the expression for the load voltage $\mathbf{V_L}$.

$$\mathbf{V_L} = \mathbf{V_S} - \mathbf{I}(R + jX)$$

Substitute $101.01\angle -25.84°\,\mathrm{A\ rms}$ for $\mathbf{I}$, $440\angle 0°\,\mathrm{V\ rms}$ for $\mathbf{V_S}$, $0.157\,\Omega$ for R and $0.206\,\Omega$ for X.

$$\begin{aligned}\mathbf{V_L} &= 440\angle 0° - (101.01\angle -25.84°)(0.157 + j0.206)\\ &= 440\angle 0° - (101.01\angle -25.84°)(0.259\angle 52.69°)\\ &= 440\angle 0° - 26.16\angle 26.85°\\ &= 416.83\angle -1.62°\,\mathrm{V\ rms}\end{aligned}$$

Therefore, the value of the load voltage is $\boxed{416.83\angle -1.62°\,\mathrm{V\ rms}}$.

Step 8 of 8

Calculate the value of the complex power absorbed by the load.

$$S_L = \mathbf{V_L}\mathbf{I}^*$$

Substitute $416.83\angle -1.62°\,\mathrm{V\ rms}$ for $\mathbf{V_L}$ and $101.01\,\mathrm{A\ rms}\angle -25.84°\,\mathrm{A\ rms}$ for $\mathbf{I}$.

$$\begin{aligned}S_L &= (416.83\angle -1.62°)(101.01\angle -25.84°)^*\\ &= (416.83\angle -1.62°)(101.01\angle 25.84°)\\ &= 42.103\angle 24.22°\\ &= 38.4 + j17.27\,\mathrm{kVA}\end{aligned}$$

Therefore, the value of the real power absorbed by the load is $\boxed{38.4\,\mathrm{kW}}$ and the value of the reactive power absorbed by the load is $\boxed{17.27\,\mathrm{kvar}}$.

Step 1 of 2

Refer Figure P9.17 from the text book.

Calculate the current passing through the resistor using current division rule.

$$\begin{aligned}\mathbf{I}_R &= 4\angle 60^\circ\left(\frac{j2-j4}{j2-j4+2}\right)\\ &= 4\angle 60^\circ\left(\frac{-j2}{-j2+2}\right)\\ &= (4\angle 60^\circ)(0.5-j0.5)\\ &= (4\angle 60^\circ)(0.707\angle -45^\circ)\end{aligned}$$

$$\mathbf{I}_R = 2.83\angle 15^\circ$$

Therefore, the value of the current passing through the resistor is $\mathbf{I}_R = 2.83\angle 15^\circ$.

Step 2 of 2

Consider the expression for the power absorbed by $2\,\Omega$ resistor.

$$P_{2\Omega} = \frac{|\mathbf{I}_R|^2(2)}{2}$$

Substitute $2.83\,\mathbf{A}$ for $|\mathbf{I}_R|$.

$$\begin{aligned}P_{2\Omega} &= \frac{(2.83)^2\cdot(2)}{2}\\ &= 8.01\,\mathbf{W}\end{aligned}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor is $8.01\,\mathbf{W}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $0\,\mathbf{W}$.

Hence, the total average power absorbed by the network is equal to the power absorbed by the resistor.

Therefore, the power absorbed by the network is $\boxed{8.01\,\mathbf{W}}$.

Step 1 of 10

Consider Figure 1.

Figure 1

Step 2 of 10

Consider the expression for the power absorbed by the load 2.

$$\mathbf{S}_2 = \mathbf{V}_L \mathbf{I}_2^*$$

Substitute $50\angle -\cos^{-1}(0.95)\,\text{kVA}$ for $\mathbf{S}_2$ and $480\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$.

$$50\angle -\cos^{-1}(0.95)\,\text{k} = (480\angle 0°)\mathbf{I}_2^*$$

Solve for $\mathbf{I}_2^*$.

$$50\angle -18.2°\ \text{k} = (480\angle 0°)\mathbf{I}_2^*$$

$$\mathbf{I}_2^* = \frac{50\angle -18.2°\ \text{k}}{480\angle 0°}$$

$$\mathbf{I}_2^* = 104.167\angle -18.2°$$

$$\begin{aligned}\mathbf{I}_2 &= (104.167\angle -18.2°)^* \\ &= 104.167\angle 18.2°\ \text{A rms}\end{aligned}$$

Therefore, the value of the load current $\mathbf{I}_2$ is $104.167\angle 18.2°\ \text{A rms}$.

Step 3 of 10

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\text{pf})_1}$$

Substitute $50\,\text{kW}$ for P_1, 0.82 for $(\text{pf})_1$ and $480\ \text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{50\,\text{k}}{(480)(0.82)} \\ &= \frac{50\,\text{k}}{393.6} \\ &= 127.03\ \text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $127.03\ \text{A rms}$.

Step 4 of 10

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.82 for pf.

$$\begin{aligned}\theta &= \cos^{-1}(0.82) \\ &= 34.92°\end{aligned}$$

Therefore, the power factor angle at the load-1 is $34.92°$.

Step 5 of 10

Consider the expression for power factor angle.

$$\theta = \angle \mathbf{V}_L - \angle \mathbf{I}_1$$

Substitute $34.92°$ for θ and $0°$ for $\angle \mathbf{V}_L$.

$$34.92° = 0° - \angle \mathbf{I}_1$$

$$\angle \mathbf{I}_1 = 0° - 34.92°$$

$$\angle \mathbf{I}_1 = -34.92°$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $-34.92°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $127.03\angle -34.92°\ \text{A rms}$.

Step 6 of 10

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $127.03\angle -34.92°\ \text{A rms}$ for $\mathbf{I}_1$ and $104.167\angle 18.2°\ \text{A rms}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I} &= 127.03\angle -34.92° + 104.167\angle 18.2° \\ &= 207.05\angle -11.19°\ \text{A rms}\end{aligned}$$

Therefore, the value of the line current is $207.05\angle -11.19°\ \text{A rms}$.

Step 7 of 10

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $207.05\angle -11.19°\ \text{A rms}$ for $\mathbf{I}$, $480\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$, $0.2\,\Omega$ for R and $j0.4\,\Omega$ for X.

$$\begin{aligned}\mathbf{V}_S &= (207.05\angle -11.19°)(0.2 + j0.4) + 480\angle 0° \\ &= (207.05\angle -11.19°)(0.447\angle 63.44°) + 480\angle 0° \\ &= 92.55\angle 52.25° + 480\angle 0° \\ &= 541.63\angle 7.77°\ \text{V rms}\end{aligned}$$

Therefore, the value of the source voltage is $541.63\angle 7.77°\ \text{V rms}$.

Step 8 of 10

Consider the expression for the power supplied by the source.

$$\mathbf{S}_S = \mathbf{V}_S \mathbf{I}^*$$

Substitute $541.63\angle 7.77°\ \text{V rms}$ for $\mathbf{V}_S$ and $207.05\angle -11.19°\ \text{A rms}$ for $\mathbf{I}$.

$$\begin{aligned}\mathbf{S}_S &= (541.63\angle 7.77°)(207.05\angle -11.19°)^* \\ &= (541.63\angle 7.77°)(207.05\angle 11.19°) \\ &= 112.15\angle 18.96°\ \text{kVA}\end{aligned}$$

Therefore, the value of the power supplied by the source is $\boxed{112.15\angle 18.96°\ \text{kVA}}$.

Step 9 of 10

Consider the expression for power factor at the source.

$$(\text{pf})_S = \cos(\theta_S)$$

Substitute $18.96°$ for θ_S.

$$\begin{aligned}(\text{pf})_S &= \cos(18.96°) \\ &= 0.9457\ \text{lagging}\end{aligned}$$

Therefore, the value of the power factor at the source is $\boxed{0.9457\ \text{lagging}}$.

Step 10 of 10

Consider the value of the source voltage.

$$\mathbf{V}_S = 541.63\angle 7.77°\ \text{V rms}$$

Convert to time domain.

$$v_S(t) = \sqrt{2}(V_{\text{rms}})\cos(2\pi f t + \theta_v)$$

Substitute $541.63\ \text{V rms}$ for V_{rms}, $60\ \text{Hz}$ for f and $7.77°$ for θ_v.

$$\begin{aligned}v_S(t) &= \sqrt{2}(541.63)\cos(2\pi(60)t + 5.1°) \\ &= 765.94\cos(376.99t + 7.77°)\ \text{V}\end{aligned}$$

Therefore, the value of $v_S(t)$ is $\boxed{765.94\cos(376.99t + 7.77°)\ \text{V}}$.

Step 1 of 8

Refer Figure P9.19 from the text book.

Identify the currents in the circuit shown in Figure 1.

Figure 1

Step 2 of 8

Calculate the value of current $\mathbf{I}_1$ using current division rule.

$$\begin{aligned}\mathbf{I}_1 &= (4\angle 30°)\left(\frac{2-j1}{4+j3+2-j1}\right)\\ &= (4\angle 30°)\left(\frac{2-j1}{6+j2}\right)\\ &= (4\angle 30°)(0.25-j0.25)\\ &= (4\angle 30°)(0.354\angle -45°)\end{aligned}$$

$$\mathbf{I}_1 = 1.416\angle -15° \text{ A}$$

Therefore, the value of $\mathbf{I}_1$ is $1.416\angle -15°$ A.

Step 3 of 8

Calculate the value of current $\mathbf{I}_2$ using current division rule.

$$\begin{aligned}\mathbf{I}_2 &= (4\angle 30°)\left(\frac{4+j3}{4+j3+2-j1}\right)\\ &= (4\angle 30°)\left(\frac{4+j3}{6+j2}\right)\\ &= (4\angle 30°)(0.75+j0.25)\\ &= (4\angle 30°)(0.79\angle 18.44°)\end{aligned}$$

$$\mathbf{I}_2 = 3.16\angle 48.44° \text{ A}$$

Therefore, the value of $\mathbf{I}_2$ is $3.16\angle 48.44°$ A.

Step 4 of 8

Calculate the value of voltage $\mathbf{V}_T$.

$$\mathbf{V}_T = \mathbf{I}_1(4+j3)$$

Substitute $1.416\angle -15°$ A for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_T &= (1.416\angle -15°)(4+j3)\\ &= (1.416\angle -15°)(5\angle 36.87°)\\ &= 7.08\angle 21.87° \text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_T$ is $7.08\angle 21.87°$ V.

Compare with $\mathbf{V}_T = V_M\angle\theta_v$ V.

$V_M = 7.08$ V and $\theta_v = 21.87°$

Therefore, the values of V_M and θ_v are 7.08 V and $21.87°$ respectively.

Step 5 of 8

Consider the value of the current source.

$$\mathbf{I} = 4\angle 30° \text{ A}$$

Compare with $\mathbf{I} = I_M\angle\theta_i$ A.

$I_M = 4$ A and $\theta_i = 30°$

Therefore, the values of I_M and θ_i are 4 A and $30°$ respectively.

Step 6 of 8

Calculate the value of the average power supplied by the current source.

$$P = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 7.08 V for V_M, 4 A for I_M, $21.87°$ for θ_v and $30°$ for θ_i.

$$\begin{aligned}P &= \frac{(7.08)(4)}{2}\cos(21.87° - 30°)\\ &= 14.16\cos(-8.13°)\\ &= (14.16)(0.99)\\ &= 14.02 \text{ W}\end{aligned}$$

Therefore, the value of the average power delivered by the current source is $\boxed{14.02 \text{ W}}$.

Step 7 of 8

Calculate the value of power absorbed by 4Ω resistor.

$$P_{4\Omega} = \frac{|\mathbf{I}_1|^2(4)}{2}$$

Substitute 1.416 A for $|\mathbf{I}_1|$.

$$\begin{aligned}P_{4\Omega} &= \frac{(1.416)^2(4)}{2}\\ &= (1.416)^2(2)\\ &= 4.01 \text{ W}\end{aligned}$$

Therefore, the value of the power absorbed by 4Ω resistor is $\boxed{4.01 \text{ W}}$.

Step 8 of 8

Calculate the value of power absorbed by 2Ω resistor.

$$P_{2\Omega} = \frac{|\mathbf{I}_2|^2(2)}{2}$$

Substitute 3.16 A for $|\mathbf{I}_2|$.

$$\begin{aligned}P_{2\Omega} &= \frac{(3.16)^2(2)}{2}\\ &= (3.16)^2\\ &= 9.99 \text{ W}\end{aligned}$$

Therefore, the value of the power absorbed by 2Ω resistor is $\boxed{9.99 \text{ W}}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $\boxed{0 \text{ W}}$.

Step 1 of 6

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.84)\\ &= 32.86^\circ\end{aligned}$$

Therefore, the value of θ_{old} is 32.86°.

Step 2 of 6

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{\text{old}} = P_{\text{old}} \tan\theta_{\text{old}}$$

Substitute $40\,\text{kW}$ for P_{old} and 32.86° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (40\text{k})\ \tan(32.86^\circ)\\ &= (40\text{k})(0.646)\\ &= 25.84\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $25.84\ \text{kvar}$.

Step 3 of 6

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{\text{new}} &= \cos^{-1}(0.95)\\ &= 18.2^\circ\end{aligned}$$

Therefore, the value of θ_{new} is 18.2°.

Step 4 of 6

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{\text{new}} = P_{\text{old}} \tan\theta_{\text{new}}$$

Substitute $40\,\text{kW}$ for P_{old} and 18.2° for θ_{new}.

$$\begin{aligned}Q_{\text{new}} &= (40\text{k})\ \tan(18.2^\circ)\\ &= (40\text{k})(0.329)\\ &= 13.16\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $13.16\,\text{kvar}$.

Step 5 of 6

Calculate the value of the reactive power offered by the capacitor.

$$Q_{\text{cap}} = Q_{\text{new}} - Q_{\text{old}}$$

Substitute $13.16\,\text{kvar}$ for Q_{new} and $25.84\ \text{kvar}$ for Q_{old}.

$$\begin{aligned}Q_{\text{cap}} &= 13.16\ \text{kvar} - 25.84\ \text{kvar}\\ &= -12.68\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-12.68\,\text{kvar}$.

Step 6 of 6

Consider the expression for the reactive power due to capacitor.

$$Q_{\text{cap}} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$Q_{\text{cap}} = -(2\pi f)V_L^2 C$$

$$C = \frac{-Q_{\text{cap}}}{j(2\pi f)V_L^2}$$

Substitute $-12.68\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $220\ \text{V rms}$ for V_L.

$$\begin{aligned}C &= \frac{-(-12.68\,\text{k})}{(2\pi(60))(220)^2}\\ &= \frac{12.68\,\text{k}}{(376.99)(48.4\,\text{k})}\\ &= 694.94\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.95 is $\boxed{694.94\ \mu\text{F}}$.

Step 1 of 10

Refer Figure P9.20 from the text book.

Identify the currents and voltages in the circuit.

Figure 1

Step 2 of 10

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1}{4}+\frac{\mathbf{V}_1-6\angle 45°}{-j2+j3}-2\angle 0°=0$$

$$\frac{\mathbf{V}_1}{4}+\frac{\mathbf{V}_1-6\angle 45°}{j1}-2\angle 0°=0$$

$$0.25\mathbf{V}_1-j1\mathbf{V}_1+6\angle 135°-2\angle 0°=0$$

$$(0.25-j1)\mathbf{V}_1=-6\angle 135°+2\angle 0°$$

$$(1.03\angle -75.96°)\mathbf{V}_1=7.55\angle -34.2°$$

$$\mathbf{V}_1=\frac{7.55\angle -34.2°}{1.03\angle -75.96°}$$

$$\mathbf{V}_1=7.33\angle 41.76°\ \mathbf{V}$$

Therefore, the value of voltage at node-1 is $7.33\angle 41.76°\ \mathbf{V}$.

Compare with $\mathbf{V}_1=V_M\angle\theta_v\ \mathbf{V}$.

$V_M=7.33\ \mathbf{V}$ and $\theta_v=41.76°$

Therefore, the values of V_M and θ_v are $7.33\ \mathbf{V}$ and $41.76°$ respectively.

Step 3 of 10

Consider the value of the current source.

$$\mathbf{I}_S=2\angle 0°\ \mathbf{A}$$

Compare with $\mathbf{I}_S=I_{SM}\angle\theta_{SI}\ \mathbf{A}$.

$I_{SM}=2\ \mathbf{A}$ and $\theta_{SI}=0°$

Therefore, the values of I_{SM} and θ_{SI} are $2\ \mathbf{A}$ and $0°$ respectively.

Step 4 of 10

Calculate the value of the average power supplied by the current source.

$$P_{IS}=\frac{V_M I_{SM}}{2}\cos(\theta_v-\theta_{SI})$$

Substitute $7.33\ \mathbf{V}$ for V_M, $2\ \mathbf{A}$ for I_M, $41.76°$ for θ_v and $0°$ for θ_I in the equation.

$$\begin{aligned}P_{IS}&=\frac{(7.33)(2)}{2}\cos(41.76°-0°)\\&=7.33\cos(41.76°)\\&=(7.33)(0.7459)\\&=5.467\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the current source is $5.467\ \mathbf{W}$.

Step 5 of 10

Consider the value of the voltage source.

$$\mathbf{V}_S=6\angle 45°\ \mathbf{V}$$

Compare with $\mathbf{V}_S=V_{SM}\angle\theta_{Sv}\ \mathbf{V}$.

$V_{SM}=6\ \mathbf{V}$ and $\theta_{Sv}=45°$

Therefore, the values of V_{SM} and θ_{Sv} are $6\ \mathbf{V}$ and $45°$ respectively.

Step 6 of 10

Calculate the value of current $\mathbf{I}_2$.

$$\mathbf{I}_2=\frac{6\angle 45°-\mathbf{V}_1}{-j2+j3}$$

Substitute $7.33\angle 41.76°\ \mathbf{V}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{I}_2&=\frac{6\angle 45°-7.33\angle 41.76°}{-j2+j3}\\&=\frac{6\angle 45°-7.33\angle 41.76°}{j1}\\&=\frac{1.38\angle -152.45°}{1\angle 90°}\\&=1.38\angle 117.55°\end{aligned}$$

Therefore, the value of current $\mathbf{I}_2$ is $1.38\angle 117.55°\ \mathbf{A}$.

Compare with $\mathbf{I}_2=I_{2M}\angle\theta_{2I}\ \mathbf{A}$.

$I_{2M}=1.38\ \mathbf{A}$ and $\theta_{2I}=117.55°$

Therefore, the values of I_{2M} and θ_{2I} are $1.38\ \mathbf{A}$ and $117.55°$ respectively.

Step 7 of 10

Calculate the value of the average power supplied by the voltage source.

$$P_{VS}=\frac{V_{SM}I_{2M}}{2}\cos(\theta_{Sv}-\theta_{2I})$$

Substitute $6\ \mathbf{V}$ for V_{SM}, $1.38\ \mathbf{A}$ for I_{2M}, $45°$ for θ_{Sv} and $117.55°$ for θ_{2I} in the equation.

$$\begin{aligned}P_{VS}&=\frac{(6)(1.38)}{2}\cos(45°-117.55°)\\&=4.14\cos(-72.55°)\\&=(4.14)(0.3)\\&=1.24\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the voltage source is $1.24\ \mathbf{W}$.

Step 8 of 10

Calculate the value of total power supplied.

$$P_T=P_{IS}+P_{VS}$$

Substitute $1.24\ \mathbf{W}$ for P_{VS} and $5.467\ \mathbf{W}$ for P_{IS} in the equation.

$$\begin{aligned}P_T&=5.467+1.24\\&=6.71\ \mathbf{W}\end{aligned}$$

Therefore, the value of the total power supplied by the sources is $\boxed{6.71\ \mathbf{W}}$.

Step 9 of 10

Calculate the value of current $\mathbf{I}_1$.

$$\mathbf{I}_1=\frac{\mathbf{V}_1}{4}$$

Substitute $7.33\angle 41.76°\ \mathbf{V}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{I}_1&=\frac{7.33\angle 41.76°}{4}\\&=1.833\angle 41.76°\ \mathbf{A}\end{aligned}$$

Therefore, the value of current $\mathbf{I}_1$ is $1.833\angle 41.76°\ \mathbf{A}$.

Step 10 of 10

Calculate the value of power absorbed by 4Ω resistor.

$$P_{4\Omega}=\frac{|\mathbf{I}_1|^2(4)}{2}$$

Substitute $1.833\ \mathbf{A}$ for $|\mathbf{I}_1|$ in the equation.

$$\begin{aligned}P_{4\Omega}&=\frac{(1.833)^2(4)}{2}\\&=(1.833)^2(2)\\&=6.71\ \mathbf{W}\end{aligned}$$

Therefore, the value of the power absorbed by 4Ω resistor is $\boxed{6.71\ \mathbf{W}}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $\boxed{0\ \mathbf{W}}$.

Refer to the values of the power supplied by the sources and the power absorbed by the passive elements. Hence, the power supplied by the sources is equal to the power absorbed by the passive elements.

Step 1 of 6

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.82)\\ &= 34.92°\end{aligned}$$

Therefore, the value of θ_{old} is $34.92°$.

Step 2 of 6

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $50\,\text{kW}$ for P_{old} and $34.92°$ for θ_{old}.

$$\begin{aligned}Q_{old} &= (50\,\text{k})\tan 34.92°\\ &= (50\,\text{k})(0.698)\\ &= 34.9\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $34.9\ \text{kvar}$.

Step 3 of 6

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= -\cos^{-1}(0.95)\\ &= -18.2°\end{aligned}$$

Therefore, the value of θ_{new} is $-18.2°$.

Step 4 of 6

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $50\,\text{kW}$ for P_{old} and $-18.2°$ for θ_{new}.

$$\begin{aligned}Q_{new} &= (50\,\text{k})\tan(-18.2°)\\ &= (50\,\text{k})(-0.329)\\ &= -16.45\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $-16.45\ \text{kvar}$.

Step 5 of 6

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $-16.45\ \text{kvar}$ for Q_{new} and $34.9\ \text{kvar}$ for Q_{old}.

$$\begin{aligned}Q_{cap} &= -16.45\,\text{k} - 34.9\ \text{kvar}\\ &= -51.35\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-51.35\ \text{kvar}$.

Step 6 of 6

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$Q_{cap} = -(2\pi f)V_L^2 C$$

$$C = \frac{-Q_{cap}}{j(2\pi f)V_L^2}$$

Substitute $-51.35\ \text{kvar}$ for Q_{cap}, $60\ \text{Hz}$ for f and $480\ \text{V rms}$ for V_L.

$$\begin{aligned}C &= \frac{-(-51.35\,\text{k})}{(2\pi(60))(480)^2}\\ &= \frac{51.35\,\text{k}}{(376.99)(230.4\,\text{k})}\\ &= 591.06\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.95 is $\boxed{591.06\ \mu\text{F}}$.

Step 1 of 4

Refer to circuit diagram in Figure P9.22 in the text book.

Identify the currents and voltages in the circuit.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1}{2}+\frac{\mathbf{V}_1}{1-j1}+\frac{\mathbf{V}_1-6\angle 0^\circ}{j2}=0$$

$$\mathbf{V}_1\left(\frac{1}{2}+\frac{1}{1-j1}+\frac{1}{j2}\right)-\frac{6\angle 0^\circ}{j2}=0$$

$$\mathbf{V}_1(0.5+0.5+j0.5-j0.5)-j3=0$$

$$\mathbf{V}_1=3\angle -90^\circ\ \mathbf{V}$$

Therefore, the value of voltage at node-1 is $3\angle -90^\circ\ \mathbf{V}$.

Step 3 of 4

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1=\frac{\mathbf{V}_1}{1-j1}$$

Substitute $3\angle -90^\circ\ \mathbf{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_1&=\frac{3\angle -90^\circ}{1-j1}\\&=\frac{3\angle -90^\circ}{1.41\angle -45^\circ}\\&=2.127\angle -45^\circ\ \mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}_1$ is $2.127\angle -45^\circ\ \mathrm{A}$.

Step 4 of 4

Calculate the value of power absorbed by $1\,\Omega$ resistor.

$$P_{1\Omega}=\frac{|\mathbf{I}_1|^2(1)}{2}$$

Substitute $2.127\ \mathrm{A}$ for $|\mathbf{I}_1|$.

$$\begin{aligned}P_{1\Omega}&=\frac{(2.127)^2(1)}{2}\\&=\frac{4.524}{2}\\&=2.26\ \mathrm{W}\end{aligned}$$

Therefore, the value of the power absorbed by $1\,\Omega$ resistor is $\boxed{2.26\ \mathrm{W}}$.

Step 1 of 2

(a)

The power line voltage, $V = 7200\ \text{V}$

Resistance of dry skin, $R_{\text{skin}}(dry) = 15\ \text{k}\Omega$

Resistance of body, $R_{\text{body}} = 400\Omega$

Assume surface contact resistance, R_{sc} to be 150Ω

Determine the current through her body.

$$I = \frac{V}{R_{skin}(dry) + R_{body} + R_{sc}}$$

Substitute 7200 for V, $15{,}000\ \Omega$ for $R_{\text{skin}}(dry)$, 400Ω for R_{body} and 150Ω for R_{sc}.

$$\begin{aligned} I &= \frac{7200}{15000 + 400 + 150} \\ &= 0.463\ \text{A} \\ &= 463\ \text{mA} \end{aligned}$$

Thus, the potential current through her body is $\boxed{463\ \text{mA}}$.

This current is extremely dangerous.

Step 2 of 2

(b)

Wet ground acts as a good conductor of electricity and hence provides return path to the current to the body of the woman. As there is no return path to the current in the car, she would be safe.

Thus, if she remained in the car she would be safe, as there is no return path to the current.

Step 1 of 2

Refer to Figure P9.22 in the text book.

Calculate the total impedance seen by the current source.

$$\begin{aligned} Z &= (2+2j)\|(1-1j) \\ &= \frac{(2+2j)(1-1j)}{(2+2j)+(1-1j)} \\ &= 1.2-0.4j \end{aligned}$$

Calculate the voltage across the current source.

$$V = IZ$$

Substitute $(1.2-0.4j)$ for Z and $4\angle 30°$ A for I in the equation.

$$\begin{aligned} V &= (4\angle 30°)(1.2-0.4j) \\ &= (4\angle 30°)(1.2-0.4j) \\ &= 4.957+1.014j \\ &= 5.06\angle 11.56° \text{ V} \end{aligned}$$

Step 2 of 2

Calculate the average power supplied by the current source in the network.

$$P = \frac{V_M I_M}{2}\cos(\theta_v - \theta_i)$$

Substitute 5.06 V for V_M, 4 A for I_M, $11.56°$ for θ_v and $30°$ for θ_i in the equation.

$$\begin{aligned} P &= \frac{(5.06)(4)}{2}\cos(11.56° - 30°) \\ &= 10.12\cos(-18.44) \\ &= 9.6 \text{ W} \end{aligned}$$

Thus, the average power supplied by the current source in the network, P is $\boxed{9.6 \text{ W}}$.

Step 1 of 14

Refer Figure P9.14 from the text book.

Identify the voltages in the circuit shown in Figure 1.

Figure 1

Step 2 of 14

Consider nodal equation at node-2.

$$\frac{\mathbf{V}_2 - 12\angle 0°}{2} + \frac{\mathbf{V}_2}{j2} + \frac{\mathbf{V}_2 - \mathbf{V}_1}{-j2} = 0$$

$$\mathbf{V}_2\left(\frac{1}{2} + \frac{1}{j2} + \frac{1}{-j2}\right) - \frac{\mathbf{V}_1}{-j2} = \frac{12\angle 0°}{2}$$

$$\mathbf{V}_2(0.5) - (j0.5)\mathbf{V}_1 = 6\angle 0°$$

$$\mathbf{V}_2(0.5\angle 0°) - (0.5\angle 90°)\mathbf{V}_1 = 6\angle 0°$$

Solve for $\mathbf{V}_2$.

$$\mathbf{V}_2(0.5\angle 0°) = 6\angle 0° + (0.5\angle 90°)\mathbf{V}_1$$

$$\mathbf{V}_2 = \frac{6\angle 0°}{(0.5\angle 0°)} + \left(\frac{0.5\angle 90°}{(0.5\angle 0°)}\right)\mathbf{V}_1$$

$$\mathbf{V}_2 = 12\angle 0° + (1\angle 90°)\mathbf{V}_1 \quad \text{..... (1)}$$

Therefore, the value of $\mathbf{V}_2$ is $12\angle 0° + (1\angle 90°)\mathbf{V}_1$.

Step 3 of 14

Consider nodal equation at node-1.

$$\frac{\mathbf{V}_1}{2} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j2} - 4\angle 0° = 0$$

$$\mathbf{V}_1\left(\frac{1}{2} + \frac{1}{-j2}\right) - \frac{\mathbf{V}_2}{-j2} = 4\angle 0°$$

$$\mathbf{V}_1(0.5 + j0.5) - (j0.5)\mathbf{V}_2 = 4\angle 0°$$

$$\mathbf{V}_1(0.71\angle 45°) - (0.5\angle 90°)\mathbf{V}_2 = 4\angle 0°$$

Substitute $12\angle 0° + (1\angle 90°)\mathbf{V}_1$ for $\mathbf{V}_2$.

$$\mathbf{V}_1(0.71\angle 45°) - (0.5\angle 90°)[12\angle 0° + (1\angle 90°)]\mathbf{V}_1 = 4\angle 0°$$

$$\mathbf{V}_1(0.71\angle 45°) - 6\angle 0° - (0.5\angle 180°)\mathbf{V}_1 = 4\angle 0°$$

$$\mathbf{V}_1(0.71\angle 45° - 0.5\angle 180°) = 4\angle 0° + 6\angle 0°$$

$$\mathbf{V}_1(1.12\angle 26.61°) = 7.21\angle 56.31°$$

$$\mathbf{V}_1 = \frac{7.21\angle 56.31°}{1.12\angle 26.61°}$$
$$= 6.44\angle 29.7°\ \mathbf{V}$$

Therefore, the value of the voltage at node-1 is $6.44\angle 29.7°\ \mathbf{V}$.

Step 4 of 14

Consider equation (1).

$$\mathbf{V}_2 = 12\angle 0° + (1\angle 90°)\mathbf{V}_1$$

Substitute $6.44\angle 29.7°\ \mathbf{V}$ for $\mathbf{V}_1$.

$$\mathbf{V}_2 = 12\angle 0° + (1\angle 90°)(6.44\angle 29.7°)$$
$$= 12\angle 0° + 6.44\angle 119.7°$$
$$= 10.44\angle 32.42°\ \mathbf{V}$$

Therefore, the value of $\mathbf{V}_2$ is $10.44\angle 32.42°\ \mathbf{V}$.

Step 5 of 14

Consider the value of current source.

$$\mathbf{I}_S = 4\angle 0°\ \mathbf{A}$$

Compare with $\mathbf{I}_S = I_{SM}\angle\theta_{Si}\ \mathbf{A}$.

$I_{SM} = 4\ \mathbf{A}$ and $\theta_{Si} = 0°$

Therefore, the values of I_{SM} and θ_{Si} are $4\ \mathbf{A}$ and $0°$ respectively.

Step 6 of 14

Consider the value of voltage across the current source.

$$\mathbf{V}_1 = 6.44\angle 29.7°\ \mathbf{V}$$

Compare with $\mathbf{V}_1 = V_{1M}\angle\theta_{1v}\ \mathbf{V}$.

$V_{1M} = 6.44\ \mathbf{V}$ and $\theta_{1v} = 29.7°$

Therefore, the values of V_{1M} and θ_{1v} are $6.44\ \mathbf{V}$ and $29.7°$ respectively.

Step 7 of 14

Calculate the average power delivered by the current source.

$$P_{IS} = \frac{V_{1M} I_{SM}}{2}\cos(\theta_{1v} - \theta_{Si})$$

Substitute $6.44\ \mathbf{V}$ for V_{1M}, $4\ \mathbf{A}$ for I_{SM}, $29.7°$ for θ_{1v} and $0°$ for θ_{Si}.

$$P_{IS} = \frac{(6.44)(4)}{2}\cos(29.7° - 0°)$$
$$= 12.88\cos(29.7°)$$
$$= (12.88)(0.87)$$
$$= 11.21\ \mathbf{W}$$

Therefore, the value of average power delivered by the current source is $11.21\ \mathbf{W}$.

Step 8 of 14

Consider the value of voltage source.

$$\mathbf{V}_S = 12\angle 0°\ \mathbf{V}$$

Compare with $\mathbf{V}_S = V_{SM}\angle\theta_{Sv}\ \mathbf{V}$.

$V_{SM} = 12\ \mathbf{V}$ and $\theta_{Sv} = 0°$

Therefore, the values of V_{SM} and θ_{Sv} are $12\ \mathbf{V}$ and $0°$ respectively.

Step 9 of 14

Calculate the value of current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{12\angle 0° - \mathbf{V}_2}{2}$$

Substitute $10.44\angle 32.42°\ \mathbf{V}$ for $\mathbf{V}_2$.

$$\mathbf{I}_2 = \frac{12\angle 0° - 10.44\angle 32.42°}{2}$$
$$= \frac{6.44\angle -60.34°}{2}$$
$$= 3.22\angle -60.34°\ \mathbf{A}$$

Therefore, the value of $\mathbf{I}_2$ is $3.22\angle -60.34°\ \mathbf{A}$.

Compare with $\mathbf{I}_2 = I_{2M}\angle\theta_{2i}\ \mathbf{A}$.

$I_{2M} = 3.22\ \mathbf{A}$ and $\theta_{2i} = -60.34°$

Therefore, the values of I_{2M} and θ_{2i} are $3.22\ \mathbf{A}$ and $-60.34°$ respectively.

Step 10 of 14

Consider the value of the voltage source.

$$\mathbf{V}_S = 12\angle 0°\ \mathbf{V}$$

Compare with $\mathbf{V}_S = V_{SM}\angle\theta_{Sv}\ \mathbf{V}$.

$V_{SM} = 12\ \mathbf{V}$ and $\theta_{Sv} = 0°$

Therefore, the values of V_{SM} and θ_{Sv} are $12\ \mathbf{V}$ and $0°$ respectively.

Step 11 of 14

Calculate the average power delivered by the voltage source.

$$P_{VS} = \frac{V_{SM} I_{2M}}{2}\cos(\theta_{Sv} - \theta_{2i})$$

Substitute $12\ \mathbf{V}$ for V_{SM}, $3.22\ \mathbf{A}$ for I_{2M}, $0°$ for θ_{Sv} and $-60.34°$ for θ_{2i}.

$$P_{VS} = \frac{(12)(3.22)}{2}\cos(0° + 60.34°)$$
$$= 19.32\cos(60.34°)$$
$$= (19.32)(0.5)$$
$$= 9.66\ \mathbf{W}$$

Therefore, the value of average power delivered by the voltage source is $9.66\ \mathbf{W}$.

Step 12 of 14

Calculate the total average power supplied.

$$P_T = P_{VS} + P_{IS}$$

Substitute $9.66\ \mathbf{W}$ for P_{VS} and $11.21\ \mathbf{W}$ for P_{IS}.

$$P_T = 11.21 + 9.66$$
$$= 20.87\ \mathbf{W}$$

Therefore, the total average power supplied is $\boxed{20.87\ \mathbf{W}}$.

Step 13 of 14

Consider the expression for the power absorbed by $2\,\Omega$ resistor in series with the voltage source.

$$P_{2\Omega,V} = \frac{|\mathbf{I}_2|^2(2)}{2}$$

Substitute $3.22\ \mathbf{A}$ for $|\mathbf{I}_2|$.

$$P_{2\Omega,V} = \frac{(3.22)^2 \cdot (2)}{2}$$
$$= 10.37\ \mathbf{W}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor in series with the voltage source is $\boxed{10.37\ \mathbf{W}}$.

Step 14 of 14

Consider the expression for the power absorbed by $2\,\Omega$ resistor in parallel with the current source.

$$P_{2\Omega,I} = \frac{|\mathbf{V}_1|^2}{2(2)}$$

Substitute $6.44\ \mathbf{A}$ for $|\mathbf{V}_1|$.

$$P_{2\Omega,V} = \frac{(6.44)^2}{4}$$
$$= 10.37\ \mathbf{W}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor in parallel with the current source is $\boxed{10.37\ \mathbf{W}}$.

Reactive element impedances does not absorb any average power, hence the average powers absorbed by the inductor and the capacitor are $\boxed{0\ \mathbf{W}}$.

Step 1 of 3

Refer Figure P9.18 from the text book.

Calculate the value of $\mathbf{V}$ using nodal analysis.

$$\frac{\mathbf{V}}{2}+\frac{\mathbf{V}}{j1}+\frac{\mathbf{V}}{4-j2}-4\angle 0^\circ=0$$

$$\mathbf{V}\left(\frac{1}{2}+\frac{1}{j1}+\frac{1}{4-j2}\right)=4\angle 0^\circ$$

$$\mathbf{V}(0.5-j1+0.2+j0.1)=4\angle 0^\circ$$

$$\mathbf{V}(0.7-j0.9)=4\angle 0^\circ$$

$$\mathbf{V}(1.14\angle -52.13^\circ)=4\angle 0^\circ$$

$$\mathbf{V}=\frac{4\angle 0^\circ}{1.14\angle -52.13^\circ}$$

$$\mathbf{V}=3.51\angle 52.13^\circ\,\mathbf{V}$$

Therefore, the value of the voltage $\mathbf{V}$ is $3.51\angle 52.13^\circ\,\mathbf{V}$.

Compare with $\mathbf{V}=V_M\angle\theta_v\,\mathbf{V}$.

$V_M=3.51\,\mathbf{V}$ and $\theta_v=52.13^\circ$

Therefore, the values of V_M and θ_v are $3.51\,\mathbf{V}$ and 52.13° respectively.

Step 2 of 3

Consider the value of the source current.

$$\mathbf{I}=4\angle 0^\circ\,\mathbf{A}$$

Compare with $\mathbf{I}=I_M\angle\theta_i\,\mathbf{A}$.

$I_M=4\,\mathbf{A}$ and $\theta_i=0^\circ$

Therefore, the values of I_M and θ_i are $4\,\mathbf{A}$ and 0° respectively.

Step 3 of 3

Consider the expression for average power delivered by the source.

$$P=\frac{V_M I_M}{2}\cos(\theta_v-\theta_i)$$

Substitute $3.51\,\mathbf{V}$ for V_M, $4\,\mathbf{A}$ for I_M, 52.13° for θ_v and 0° for θ_i.

$$\begin{aligned}P&=\frac{(3.51)(4)}{2}\cos(52.13^\circ-0^\circ)\\&=7.02\cos(52.13^\circ)\\&=(7.02)(0.61)\\&=4.28\,\mathbf{W}\end{aligned}$$

Therefore, the value of the total average power delivered by the source is $\boxed{4.28\,\mathbf{W}}$.

Step 1 of 7

Refer to circuit diagram in Figure P9.21 in the text book.

Identify the currents and voltages in the circuit.

Figure 1

Step 2 of 7

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1}{1-j2}+\frac{\mathbf{V}_1-4\angle 0^\circ}{2+j1}-12\angle 0^\circ=0$$

$$\frac{\mathbf{V}_1}{1-j2}+\frac{\mathbf{V}_1}{2+j1}-\frac{4\angle 0^\circ}{2+j1}-12\angle 0^\circ=0$$

$$\mathbf{V}_1(0.45\angle 63.44^\circ)+\mathbf{V}_1(0.45\angle -26.57^\circ)-1.79\angle -26.57^\circ-12\angle 0^\circ=0$$

$$\mathbf{V}_1(0.45\angle 63.44^\circ+0.45\angle -26.57^\circ)=1.79\angle -26.57^\circ+12\angle 0^\circ$$

$$\mathbf{V}_1(0.64\angle 18.44^\circ)=13.63\angle -3.37^\circ$$

$$\mathbf{V}_1=\frac{13.63\angle -3.37^\circ}{0.64\angle 18.44^\circ}$$

$$\mathbf{V}_1=21.3\angle -21.81^\circ\ \mathbf{V}$$

Therefore, the value of voltage at node-1 is $21.3\angle -21.81^\circ\ \mathbf{V}$.

Compare with $\mathbf{V}_1=V_M\angle\theta_v\ \mathbf{V}$.

$V_M=21.3\ \mathbf{V}$ and $\theta_v=-21.81^\circ$

Therefore, the values of V_M and θ_v are $21.3\ \mathbf{V}$ and -21.81° respectively.

Step 3 of 7

Consider the value of the current source.

$$\mathbf{I}_S=12\angle 0^\circ\ \mathbf{A}$$

Compare with $\mathbf{I}_S=I_{SM}\angle\theta_{Si}\ \mathbf{A}$.

$I_{SM}=12\ \mathbf{A}$ and $\theta_{Si}=0^\circ$

Therefore, the values of I_{SM} and θ_{Si} are $12\ \mathbf{A}$ and 0° respectively.

Step 4 of 7

Calculate the value of the average power supplied by the current source.

$$P_{IS}=\frac{V_M I_{SM}}{2}\cos(\theta_v-\theta_{Si})$$

Substitute $21.3\ \mathbf{V}$ for V_M , $12\ \mathbf{A}$ for I_M , -21.81° for θ_v and 0° for θ_i .

$$\begin{aligned}P_{IS}&=\frac{(21.3)(12)}{2}\cos(-21.81^\circ-0^\circ)\\&=127.8\cos(-21.81^\circ)\\&=(127.8)(0.93)\\&=118.85\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the current source is $118.85\ \mathbf{W}$.

Step 5 of 7

Consider the value of the voltage source.

$$\mathbf{V}_S=4\angle 0^\circ\ \mathbf{V}$$

Compare with $\mathbf{V}_S=V_{SM}\angle\theta_{Sv}\ \mathbf{V}$.

$V_{SM}=4\ \mathbf{V}$ and $\theta_{Sv}=0^\circ$

Therefore, the values of V_{SM} and θ_{Sv} are $4\ \mathbf{V}$ and 0° respectively.

Step 6 of 7

Calculate the value of current $\mathbf{I}_2$.

$$\mathbf{I}_2=\frac{4\angle 0^\circ-\mathbf{V}_1}{2+j1}$$

Substitute $21.3\angle -21.81^\circ\ \mathbf{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_2&=\frac{4\angle 0^\circ-21.3\angle -21.81^\circ}{2+j1}\\&=\frac{4\angle 0^\circ-21.3\angle -21.81^\circ}{2.24\angle 26.57^\circ}\\&=\frac{17.65\angle 153.36^\circ}{2.24\angle 26.57^\circ}\\&=7.88\angle 126.79^\circ\end{aligned}$$

Therefore, the value of current $\mathbf{I}_2$ is $7.88\angle 126.79^\circ\ \mathbf{A}$.

Compare with $\mathbf{I}_2=I_{2M}\angle\theta_{2i}\ \mathbf{A}$.

$I_{2M}=7.88\ \mathbf{A}$ and $\theta_{2i}=126.79^\circ$

Therefore, the values of I_{2M} and θ_{2i} are $7.88\ \mathbf{A}$ and 126.79° respectively.

Step 7 of 7

Calculate the value of the average power supplied by the voltage source.

$$P_{VS}=\frac{V_{SM}I_{2M}}{2}\cos(\theta_{Sv}-\theta_{2i})$$

Substitute $4\ \mathbf{V}$ for V_{SM} , $7.88\ \mathbf{A}$ for I_{2M} , 0° for θ_{Sv} and 126.79° for θ_{2i} .

$$\begin{aligned}P_{VS}&=\frac{(4)(7.88)}{2}\cos(0^\circ-126.79^\circ)\\&=17.6\cos(-126.79^\circ)\\&=(17.6)(-0.598)\\&=-10.54\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the voltage source is $-10.54\ \mathbf{W}$.

Negative sign indicates that the power is absorbed by the voltage source.

Hence the total power supplied to the circuit is the power supplied by the current source only. Therefore, the power supplied to the circuit is $\boxed{118.85\ \mathbf{W}}$.

Step 1 of 7

Refer to circuit diagram in Figure P9.21 in the text book.

Identify the currents and voltages in the circuit.

Figure 1

Step 2 of 7

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1}{1-j2}+\frac{\mathbf{V}_1-4\angle 0°}{2+j1}-12\angle 0°=0$$

$$\frac{\mathbf{V}_1}{1-j2}+\frac{\mathbf{V}_1}{2+j1}-\frac{4\angle 0°}{2+j1}-12\angle 0°=0$$

$$\mathbf{V}_1(0.45\angle 63.44°)+\mathbf{V}_1(0.45\angle -26.57°)-1.79\angle -26.57°-12\angle 0°=0$$

$$\mathbf{V}_1(0.45\angle 63.44°+0.45\angle -26.57°)=1.79\angle -26.57°+12\angle 0°$$

$$\mathbf{V}_1(0.64\angle 18.44°)=13.63\angle -3.37°$$

$$\mathbf{V}_1=\frac{13.63\angle -3.37°}{0.64\angle 18.44°}$$

$$\mathbf{V}_1=21.3\angle -21.81°\ \mathbf{V}$$

Therefore, the value of voltage at node-1 is $21.3\angle -21.81°\ \mathbf{V}$.

Compare with $\mathbf{V}_1=V_M\angle\theta_v\ \mathbf{V}$.

$V_M=21.3\ \mathbf{V}$ and $\theta_v=-21.81°$

Therefore, the values of V_M and θ_v are $21.3\ \mathbf{V}$ and $-21.81°$ respectively.

Step 3 of 7

Consider the value of the current source.

$$\mathbf{I}_S=12\angle 0°\ \mathbf{A}$$

Compare with $\mathbf{I}_S=I_{SM}\angle\theta_{Si}\ \mathbf{A}$.

$I_{SM}=12\ \mathbf{A}$ and $\theta_{Si}=0°$

Therefore, the values of I_{SM} and θ_{Si} are $12\ \mathbf{A}$ and $0°$ respectively.

Step 4 of 7

Calculate the value of the average power supplied by the current source.

$$P_{IS}=\frac{V_M I_{SM}}{2}\cos(\theta_v-\theta_{Si})$$

Substitute $21.3\ \mathbf{V}$ for V_M , $12\ \mathbf{A}$ for I_M , $-21.81°$ for θ_v and $0°$ for θ_i .

$$\begin{aligned}P_{IS}&=\frac{(21.3)(12)}{2}\cos(-21.81°-0°)\\&=127.8\cos(-21.81°)\\&=(127.8)(0.93)\\&=118.85\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the current source is $118.85\ \mathbf{W}$.

Step 5 of 7

Consider the value of the voltage source.

$$\mathbf{V}_S=4\angle 0°\ \mathbf{V}$$

Compare with $\mathbf{V}_S=V_{SM}\angle\theta_{Sv}\ \mathbf{V}$.

$V_{SM}=4\ \mathbf{V}$ and $\theta_{Sv}=0°$

Therefore, the values of V_{SM} and θ_{Sv} are $4\ \mathbf{V}$ and $0°$ respectively.

Step 6 of 7

Calculate the value of current $\mathbf{I}_2$.

$$\mathbf{I}_2=\frac{4\angle 0°-\mathbf{V}_1}{2+j1}$$

Substitute $21.3\angle -21.81°\ \mathbf{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_2&=\frac{4\angle 0°-21.3\angle -21.81°}{2+j1}\\&=\frac{4\angle 0°-21.3\angle -21.81°}{2.24\angle 26.57°}\\&=\frac{17.65\angle 153.36°}{2.24\angle 26.57°}\\&=7.88\angle 126.79°\end{aligned}$$

Therefore, the value of current $\mathbf{I}_2$ is $7.88\angle 126.79°\ \mathbf{A}$.

Compare with $\mathbf{I}_2=I_{2M}\angle\theta_{2i}\ \mathbf{A}$.

$I_{2M}=7.88\ \mathbf{A}$ and $\theta_{2i}=126.79°$

Therefore, the values of I_{2M} and θ_{2i} are $7.88\ \mathbf{A}$ and $126.79°$ respectively.

Step 7 of 7

Calculate the value of the average power supplied by the voltage source.

$$P_{VS}=\frac{V_{SM}I_{2M}}{2}\cos(\theta_{Sv}-\theta_{2i})$$

Substitute $4\ \mathbf{V}$ for V_{SM} , $7.88\ \mathbf{A}$ for I_{2M} , $0°$ for θ_{Sv} and $126.79°$ for θ_{2i} .

$$\begin{aligned}P_{VS}&=\frac{(4)(7.88)}{2}\cos(0°-126.79°)\\&=17.6\cos(-126.79°)\\&=(17.6)(-0.598)\\&=-10.54\ \mathbf{W}\end{aligned}$$

Therefore, the value of the average power delivered by the voltage source is $-10.54\ \mathbf{W}$.

Negative sign indicates that the power is absorbed by the voltage source.

Hence the total power supplied to the circuit is the power supplied by the current source only. Therefore, the power supplied to the circuit is $\boxed{118.85\ \mathbf{W}}$.

Step 1 of 4

Refer to circuit diagram in Figure P9.23 in the text book.

Identify the voltages in the circuit diagram.

Figure 1

Step 2 of 4

Consider the expression for the Kirchhoff's current Law at node 2.

$$2\angle 0^\circ + \frac{\mathbf{V}_2}{4} + \frac{\mathbf{V}_2 - \mathbf{V}_1}{-j4} = 0$$

$$\mathbf{V}_2\left(\frac{1}{4} + \frac{1}{-j4}\right) - \frac{\mathbf{V}_1}{-j4} = -2\angle 0^\circ$$

$$\mathbf{V}_2(0.25 + j0.25) - (j0.25)\mathbf{V}_1 = 2\angle 180^\circ$$

$$\mathbf{V}_2(0.35\angle 45^\circ) + (0.25\angle -90^\circ)\mathbf{V}_1 = 2\angle 180^\circ$$

Solve for $\mathbf{V}_1$.

$$(0.25\angle -90^\circ)\mathbf{V}_1 = 2\angle 180^\circ - \mathbf{V}_2(0.35\angle 45^\circ)$$

$$\mathbf{V}_1 = \frac{2\angle 180^\circ - \mathbf{V}_2(0.35\angle 45^\circ)}{0.25\angle -90^\circ}$$

$$\mathbf{V}_1 = \frac{2\angle 180^\circ}{0.25\angle -90^\circ} - \frac{\mathbf{V}_2(0.35\angle 45^\circ)}{0.25\angle -90^\circ}$$

$$\mathbf{V}_1 = 8\angle 90^\circ - (1.4\angle 135^\circ)\mathbf{V}_2$$

Therefore, the expression for $\mathbf{V}_1$ is $8\angle 90^\circ - (1.4\angle 135^\circ)\mathbf{V}_2$.

Step 3 of 4

Consider the expression for the Kirchhoff's current Law at node 1.

$$\frac{\mathbf{V}_1 - 12\angle 0^\circ}{2} + \frac{\mathbf{V}_1}{j2} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j4} = 0$$

$$\mathbf{V}_1\left(\frac{1}{2} + \frac{1}{j2} + \frac{1}{-j4}\right) - \frac{\mathbf{V}_2}{-j4} - \frac{12\angle 0^\circ}{2} = 0$$

$$\mathbf{V}_1(0.5 - j0.5 + j0.25) - (j0.25)\mathbf{V}_2 = 6\angle 0^\circ$$

$$\mathbf{V}_1(0.5 - j0.25) - (j0.25)\mathbf{V}_2 = 6\angle 0^\circ$$

$$\mathbf{V}_1(0.56\angle -26.57^\circ) + (0.25\angle -90^\circ)\mathbf{V}_2 = 6\angle 0^\circ$$

Substitute $8\angle 90^\circ - (1.4\angle 135^\circ)\mathbf{V}_2$ for $\mathbf{V}_1$.

$$(0.56\angle -26.57^\circ)[8\angle 90^\circ - (1.4\angle 135^\circ)\mathbf{V}_2] + (0.25\angle -90^\circ)\mathbf{V}_2 = 6\angle 0^\circ$$

$$(8\angle 90^\circ)(0.56\angle -26.57^\circ) - (0.56\angle -26.57^\circ)(1.4\angle 135^\circ)\mathbf{V}_2 + (0.25\angle -90^\circ)\mathbf{V}_2 = 6\angle 0^\circ$$

$$4.48\angle -116.57^\circ - (0.78\angle 108.43^\circ)\mathbf{V}_2 + (0.25\angle -90^\circ)\mathbf{V}_2 = 6\angle 0^\circ$$

$$4.48\angle -116.57^\circ + (1.02\angle -76.01^\circ)\mathbf{V}_2 = 6\angle 0^\circ$$

$$(1.02\angle -76.01^\circ)\mathbf{V}_2 = 6\angle 0^\circ - 4.48\angle -116.57^\circ$$

$$(1.02\angle -76.01^\circ)\mathbf{V}_2 = 8.95\angle 26.59^\circ$$

$$\mathbf{V}_2 = \frac{8.95\angle 26.59^\circ}{1.02\angle -76.01^\circ}$$

$$\mathbf{V}_2 = 8.78\angle 102.6^\circ\ \mathbf{V}$$

Therefore, the value of $\mathbf{V}_2$ is $8.78\angle 102.6^\circ\ \mathbf{V}$.

Step 4 of 4

Calculate the value of power absorbed by $4\,\Omega$ resistor.

$$P_{4\Omega} = \frac{|\mathbf{V}_2|^2}{2(4)}$$

Substitute $8.78\ \mathrm{V}$ for $|\mathbf{V}_2|$.

$$P_{4\Omega} = \frac{(8.78)^2}{8}$$

$$= \frac{77.088}{8}$$

$$= 9.64\ \mathrm{W}$$

Therefore, the value of the power absorbed by $4\,\Omega$ resistor is $\boxed{9.64\ \mathrm{W}}$.

Refer to circuit diagram in Figure P9.24 in the text book.

Identify the voltages in Figure 1.

Figure 1

Step 2 of 6

Let node-0 is the reference node.

Apply Kirchhoff's Current Law at node-0.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_3}{j1}=1\angle 0^\circ$$
$$\mathbf{V}_1+\mathbf{V}_3(-j1)=1\angle 0^\circ$$
$$\mathbf{V}_1+\mathbf{V}_3(1\angle -90^\circ)=1\angle 0^\circ$$
$$\mathbf{V}_1=1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ)$$

Therefore, the expression for $\mathbf{V}_1$ is $1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ)$.

Step 3 of 6

Apply Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}_1}{1}+\frac{\mathbf{V}_1-\mathbf{V}_2}{-j1}+\frac{\mathbf{V}_1-\mathbf{V}_3}{1+j1}=0$$
$$\mathbf{V}_1+(\mathbf{V}_1-\mathbf{V}_2)(j1)+(\mathbf{V}_1-\mathbf{V}_3)(0.5-j0.5)=0$$
$$\mathbf{V}_1(1+j1+0.5-j0.5)-\mathbf{V}_2(j1)-\mathbf{V}_3(0.5-j0.5)=0$$
$$\mathbf{V}_1(1.5+j0.5)-\mathbf{V}_2(j1)-\mathbf{V}_3(0.5-j0.5)=0$$
$$\mathbf{V}_1(1.58\angle 18.44^\circ)-\mathbf{V}_2(1\angle 90^\circ)-\mathbf{V}_3(0.71\angle -45^\circ)=0$$

Substitute $1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ)$ for $\mathbf{V}_1$.

$$[1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ)](1.58\angle 18.44^\circ)-\mathbf{V}_2(1\angle 90^\circ)-\mathbf{V}_3(0.71\angle -45^\circ)=0$$
$$(1\angle 0^\circ)(1.58\angle 18.44^\circ)-\mathbf{V}_3(1\angle -90^\circ)(1.58\angle 18.44^\circ)-\mathbf{V}_2(1\angle 90^\circ)-\mathbf{V}_3(0.71\angle -45^\circ)=0$$
$$1.58\angle 18.44^\circ-\mathbf{V}_3(1.58\angle -71.56^\circ)-\mathbf{V}_2(1\angle 90^\circ)-\mathbf{V}_3(0.71\angle -45^\circ)=0$$
$$\mathbf{V}_3[(1.58\angle -71.56^\circ)+(0.71\angle -45^\circ)]=1.58\angle 18.44^\circ-\mathbf{V}_2(1\angle 90^\circ)$$

$$\mathbf{V}_3(2.24\angle -63.40^\circ)=1.58\angle 18.44^\circ-\mathbf{V}_2(1\angle 90^\circ)$$

$$\begin{aligned}\mathbf{V}_3&=\frac{1.58\angle 18.44^\circ-\mathbf{V}_2(1\angle 90^\circ)}{2.24\angle -63.40^\circ}\\&=\frac{1.58\angle 18.44^\circ}{2.24\angle -63.40^\circ}-\frac{\mathbf{V}_2(1\angle 90^\circ)}{2.24\angle -63.40^\circ}\\&=0.71\angle 81.84^\circ-\mathbf{V}_2(0.45\angle 153.4^\circ)\end{aligned}$$

Therefore, the expression for $\mathbf{V}_3$ is $0.71\angle 81.84^\circ-\mathbf{V}_2(0.45\angle 153.4^\circ)$.

Step 4 of 6

Apply Kirchhoff's Current Law at node-2.

$$\frac{\mathbf{V}_2-\mathbf{V}_1}{-j1}+\frac{\mathbf{V}_2-\mathbf{V}_3}{2}=1\angle 0^\circ$$
$$(\mathbf{V}_2-\mathbf{V}_1)(j1)+(\mathbf{V}_2-\mathbf{V}_3)(0.5)=0$$
$$\mathbf{V}_2(0.5+j1)-\mathbf{V}_1(j1)-\mathbf{V}_3(0.5)=0$$
$$\mathbf{V}_2(1.12\angle 63.44^\circ)-\mathbf{V}_1(1\angle 90^\circ)-\mathbf{V}_3(0.5\angle 0^\circ)=0$$

Substitute $1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ)$ for $\mathbf{V}_1$.

$$\mathbf{V}_2(1.12\angle 63.44^\circ)-(1\angle 0^\circ-\mathbf{V}_3(1\angle -90^\circ))(1\angle 90^\circ)-\mathbf{V}_3(0.5\angle 0^\circ)=0$$
$$\mathbf{V}_2(1.12\angle 63.44^\circ)-(1\angle 90^\circ)+\mathbf{V}_3(1\angle 0^\circ)-\mathbf{V}_3(0.5\angle 0^\circ)=0$$
$$\mathbf{V}_2(1.12\angle 63.44^\circ)-(1\angle 90^\circ)+\mathbf{V}_3(1\angle 0^\circ-0.5\angle 0^\circ)=0$$
$$\mathbf{V}_2(1.12\angle 63.44^\circ)-(1\angle 90^\circ)+\mathbf{V}_3(0.5\angle 0^\circ)=0$$

Solve for $\mathbf{V}_2$.

$$\mathbf{V}_2(1.12\angle 63.44^\circ)=(1\angle 90^\circ)-\mathbf{V}_3(0.5\angle 0^\circ)$$
$$\mathbf{V}_2=\frac{(1\angle 90^\circ)-\mathbf{V}_3(0.5\angle 0^\circ)}{1.12\angle 63.44^\circ}$$
$$\mathbf{V}_2=\frac{1\angle 90^\circ}{1.12\angle 63.44^\circ}-\frac{\mathbf{V}_3(0.5\angle 0^\circ)}{1.12\angle 63.44^\circ}$$
$$\mathbf{V}_2=0.89\angle 26.56^\circ-\mathbf{V}_3(0.45\angle -63.44^\circ)$$

Substitute $0.71\angle 81.84^\circ-\mathbf{V}_2(0.45\angle 153.4^\circ)$ for $\mathbf{V}_3$.

$$\mathbf{V}_2=0.89\angle 26.56^\circ-[0.71\angle 81.84^\circ-\mathbf{V}_2(0.45\angle 153.4^\circ)](0.45\angle -63.44^\circ)$$
$$\mathbf{V}_2=0.89\angle 26.56^\circ-(0.71\angle 81.84^\circ)(0.45\angle -63.44^\circ)+\mathbf{V}_2(0.45\angle 153.4^\circ)(0.45\angle -63.44^\circ)$$
$$\mathbf{V}_2=0.89\angle 26.56^\circ-0.32\angle 18.4^\circ+\mathbf{V}_2(0.20\angle 89.96^\circ)$$
$$\mathbf{V}_2(1-0.20\angle 89.96^\circ)=0.58\angle 31.1^\circ$$

$$\mathbf{V}_2(1.02\angle -11.31^\circ)=0.58\angle 31.1^\circ$$
$$\mathbf{V}_2=0.57\angle 42.41^\circ\ \mathbf{V}$$

Therefore, the value of $\mathbf{V}_2$ is $0.57\angle 42.41^\circ\ \mathbf{V}$.

Step 5 of 6

Compare with $\mathbf{V}_2=V_{2M}\angle\theta_{2v}\ \mathrm{V}$.

$V_{2M}=0.57\ \mathrm{V}$ and $\theta_{2v}=42.41^\circ$

Therefore, the values of V_{2M} and θ_{2v} are $0.57\ \mathrm{V}$ and 42.41° respectively.

Consider the value of the current source.

$$\mathbf{I}_S=1\angle 0^\circ\ \mathrm{A}$$

Compare with $\mathbf{I}_S=I_{SM}\angle\theta_{Si}\ \mathrm{A}$.

$I_{SM}=1\ \mathrm{A}$ and $\theta_{Si}=0^\circ$

Therefore, the values of I_{SM} and θ_{Si} are $1\ \mathrm{V}$ and 0° respectively.

Step 6 of 6

Calculate the value of the average power supplied by the current source.

$$P_{IS}=\frac{V_{2M}I_{SM}}{2}\cos(\theta_{2v}-\theta_{Si})$$

Substitute $0.57\ \mathrm{V}$ for V_{2M}, $1\ \mathrm{A}$ for I_{2M}, 42.41° for θ_{2v} and 0° for θ_{Si}.

$$\begin{aligned}P_{IS}&=\frac{(0.57)(1)}{2}\cos(42.41^\circ-0^\circ)\\&=0.29\cos(42.41^\circ)\\&=(0.29)(0.79)\\&=0.23\ \mathrm{W}\end{aligned}$$

Therefore, the value of the average power delivered by the current source is $\boxed{0.23\ \mathrm{W}}$.

Step 1 of 5

Refer to circuit diagram in Figure P9.25 in the text book.

Connect $2\,\Omega$ resistor across the open terminals, the modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for the current $\mathbf{I}_x$.

$$\mathbf{I}_x = \frac{12\angle 0° - \mathbf{V}_1}{2}$$

Therefore, the expression for the current $\mathbf{I}_x$ is $\frac{12\angle 0° - \mathbf{V}_1}{2}$.

Step 3 of 5

Consider the Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}_1 - 12\angle 0°}{2} + \frac{\mathbf{V}_1 - 2\mathbf{I}_x}{-j2} + \frac{\mathbf{V}_1}{2+j1} = 0$$

$$\mathbf{V}_1\left(\frac{1}{2} + \frac{1}{-j2} + \frac{1}{2+j1}\right) - \frac{2\mathbf{I}_x}{-j2} - \frac{12\angle 0°}{2} = 0$$

$$\mathbf{V}_1(0.5 + j0.5 + 0.4 - j0.2) - (j1)\mathbf{I}_x = 6\angle 0°$$

$$\mathbf{V}_1(0.9 + j0.3) - (j1)\mathbf{I}_x = 6\angle 0°$$

Substitute $\frac{12\angle 0° - \mathbf{V}_1}{2}$ for $\mathbf{I}_x$ in the equation.

$$\mathbf{V}_1(0.9 + j0.3) - (j1)\left(\frac{12\angle 0° - \mathbf{V}_1}{2}\right) = 6\angle 0°$$

$$\mathbf{V}_1(0.9 + j0.3) - (1\angle 90°)(6\angle 0° - 0.5\mathbf{V}_1) = 6\angle 0°$$

$$\mathbf{V}_1(0.95\angle 18.44°) - 6\angle 90° + 0.5\angle 90°\mathbf{V}_1 = 6\angle 0°$$

$$\mathbf{V}_1(0.95\angle 18.44° + 0.5\angle 90°) = 6\angle 0° + 6\angle 90°$$

$$\mathbf{V}_1(1.2\angle 41.63°) = 8.485\angle 45°$$

$$\begin{aligned}\mathbf{V}_1 &= \frac{8.485\angle 45°}{1.2\angle 41.63°} \\ &= 7.07\angle 3.37°\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $7.07\angle 3.37°$ V .

Step 4 of 5

Calculate the value of voltage across $2\,\Omega$ resistor connected at the output terminals using voltage division rule.

$$\mathbf{V}_R = \mathbf{V}_1\left(\frac{2}{2+j1}\right)$$

Substitute $7.07\angle 3.37°$ V for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_R &= (7.07\angle 3.37°)\left(\frac{2}{2.24\angle 26.57°}\right) \\ &= (7.07\angle 3.37°)(0.89\angle -26.57°) \\ &= 6.3125\angle -23.2°\ \text{V}\end{aligned}$$

Therefore, the value of the voltage across the $2\,\Omega$ resistor is $6.3125\angle -23.2°$ V .

Step 5 of 5

Calculate the value of power absorbed by $2\,\Omega$ resistor.

$$P_{2\Omega} = \frac{|\mathbf{V}_R|^2}{2(2)}$$

Substitute 6.3125 V for $|\mathbf{V}_R|$.

$$\begin{aligned}P_{2\Omega} &= \frac{(6.3125)^2}{4} \\ &= \frac{39.85}{4} \\ &= 9.96\ \text{W}\end{aligned}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor is $\boxed{9.96\ \text{W}}$.

Step 1 of 3

9.030P

Refer to circuit diagram in Figure P9.26 in the text book.

Draw the circuit with node notations.

Figure 1

Step 2 of 3

Consider the expression for the current $\mathbf{I}_x$.

$$\mathbf{I}_x = \frac{12\angle 0° - \mathbf{V}_1}{j2}$$

Therefore, the expression for the current $\mathbf{I}_x$ is $\frac{12\angle 0° - \mathbf{V}_1}{j2}$.

Consider the Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}_1 - 12\angle 0°}{j2} + \frac{\mathbf{V}_1}{2} - 2\mathbf{I}_x = 0$$

Substitute $\frac{12\angle 0° - \mathbf{V}_1}{j2}$ for $\mathbf{I}_x$.

$$\frac{\mathbf{V}_1 - 12\angle 0°}{j2} + \frac{\mathbf{V}_1}{2} - 2\left(\frac{12\angle 0° - \mathbf{V}_1}{j2}\right) = 0$$

$$\frac{\mathbf{V}_1 - 12\angle 0°}{j2} + \frac{\mathbf{V}_1}{2} - \frac{24\angle 0°}{j2} + \frac{\mathbf{V}_1}{j1} = 0$$

$$\mathbf{V}_1\left(\frac{1}{j2} + \frac{1}{2} + \frac{1}{j1}\right) = \frac{12\angle 0°}{j2} + \frac{24\angle 0°}{j2}$$

$$\mathbf{V}_1(-j0.5 + 0.5 - j1) = -j6 - j12$$

$$\mathbf{V}_1(0.5 - j1.5) = -j18$$

$$\mathbf{V}_1 = \frac{-j18}{0.5 - j1.5}$$

$$\mathbf{V}_1 = 10.8 - j3.6$$

$$\mathbf{V}_1 = 11.38\angle -18.44° \text{ V}$$

Therefore, the value of $\mathbf{V}_1$ is $11.38\angle -18.44°$ V.

Step 3 of 3

Calculate the value of power absorbed by $2\,\Omega$ resistor.

$$P_{2\Omega} = \frac{|\mathbf{V}_1|^2}{2(2)}$$

Substitute 11.38 V for $|\mathbf{V}_1|$ in the equation.

$$P_{2\Omega} = \frac{(11.38)^2}{4}$$
$$= 32.38 \text{ W}$$

Therefore, the value of the power absorbed by $2\,\Omega$ resistor is $\boxed{32.38 \text{ W}}$.

Step 1 of 7

Refer to Figure P9.29 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 7

No current flow through the inductor since one of its terminal is opened.

Calculate the value of $\mathbf{V}_{oc}$.

$$\begin{aligned}\mathbf{V}_{oc} &= (6\angle 0°)(1)\\ &= 6\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{oc}$ is $6\angle 0°\ \mathrm{V}$.

Step 3 of 7

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 4 of 7

Calculate the value of Thevenin's impedance.

$$\mathbf{Z}_{TH} = 1 + j1\,\Omega$$

Therefore, the value of the Thevenin's impedance is $1 + j1\,\Omega$.

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{TH}^*$$

Substitute $1 + j1\,\Omega$ for $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_L &= (1 + j1)^*\\ &= 1 - j1\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{1 - j1\,\Omega}$.

Step 5 of 7

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 7

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I} &= \frac{6\angle 0°}{1 + j1 + 1 - j1}\\ &= \frac{6\angle 0°}{2}\\ &= 3\angle 0°\ \mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $3\angle 0°\ \mathrm{A}$.

Step 7 of 7

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute $3\ \mathrm{A}$ for I_M and $1\,\Omega$ for R_L .

$$\begin{aligned}P_L &= \frac{1}{2}(3)^2(1)\\ &= \frac{9}{2}\\ &= 4.5\ \mathrm{W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{4.5\ \mathrm{W}}$.

Step 1 of 7

Refer Figure P9.30 from the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 7

No current flow through series combination of the resistor and the inductor since one of its terminal is opened.

Calculate the value of V_{oc} .

$$\begin{aligned} V_{oc} &= (4\angle 0°)(1 - j1) + 12\angle 30° \\ &= (4\angle 0°)(1.41\angle -45°) + 12\angle 30° \\ &= 5.64\angle -45° + 12\angle 30° \\ &= 14.52\angle 7.96° \text{ V} \end{aligned}$$

Therefore, the value of V_{oc} is $14.52\angle 7.96°$ V .

Step 3 of 7

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 4 of 7

Calculate the value of Thevenin's impedance.

$$\begin{aligned} Z_{TH} &= 1 - j1 + 4 + j1\,\Omega \\ &= 5\,\Omega \end{aligned}$$

Therefore, the value of the Thevenin's impedance is $5\,\Omega$.

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L = Z_{TH}^*$$

Substitute $5\,\Omega$ for Z_{TH} .

$$\begin{aligned} Z_L &= (5)^* \\ &= 5\,\Omega \end{aligned}$$

Therefore, the value of the load impedance is $\boxed{5\,\Omega}$.

Step 5 of 7

Draw the Thevenin's equivalent circuit.

Figure 3

Step 6 of 7

Calculate the value of current I .

$$\begin{aligned} I &= \frac{14.53\angle 7.91°}{5+5} \\ &= \frac{14.53\angle 7.91°}{10} \\ &= 1.45\angle 7.91° \text{ A} \end{aligned}$$

Therefore, the value of the current I is $1.45\angle 7.91°$ A .

Step 7 of 7

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute 1.45 A for I_M and $5\,\Omega$ for R_L .

$$\begin{aligned} P_L &= \frac{1}{2}(1.45)^2(5) \\ &= \frac{10.51}{2} \\ &= 5.26 \text{ W} \end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{5.26 \text{ W}}$.

Step 1 of 7

Refer to Figure P3.33 in the textbook.

From figure P3.33 in the textbook, remove the load impedance $\mathbf{Z}_L$ and calculate the Thevenin's voltage across it.

Re-draw the circuit diagram.

Figure 1

Step 2 of 7

From Figure 1, write the expression for $\mathbf{V}_{OC}$.

$$\frac{\mathbf{V}_{OC}-12\angle 0^\circ}{4}=4\angle 90^\circ$$

$$\mathbf{V}_{OC}-12\angle 0^\circ=16\angle 90^\circ$$

$$\begin{aligned}\mathbf{V}_{OC}&=16\angle 90^\circ+12\angle 0^\circ\\&=20\angle 53.13^\circ\ \text{V}\end{aligned}$$

Step 3 of 7

Determine the Thevenin's impedance $\mathbf{Z}_{TH}$.

Re-draw the circuit diagram.

Figure 2

Step 4 of 7

From Figure 2, determine the value of Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{TH}&=4-j4\ \Omega\\&=5.66\angle -45^\circ\ \Omega\end{aligned}$$

Re-draw the Thevenin's equivalent circuit diagram.

Figure 3

Step 5 of 7

According to maximum power transfer theorem, for maximum average power transfer to the load, the load impedance must be equal to Thevenin's impedance.

Determine the load impedance.

$$\begin{aligned}\mathbf{Z}_L&=\mathbf{Z}_{TH}^*\\&=(4-j4)^*\\&=4+j4\ \Omega\end{aligned}$$

Therefore, the load impedance is $\boxed{4+j4\ \Omega}$.

Step 6 of 7

Determine the maximum average power transfer to the load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Determine the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I}&=\frac{\mathbf{V}_{OC}}{\mathbf{Z}_{TH}+\mathbf{Z}_{OC}}\\&=\frac{20\angle 53.13^\circ\ \text{V}}{(4-j4\ \Omega)+(4+j4\ \Omega)}\\&=\frac{20\angle 53.13^\circ\ \text{V}}{8}\\&=2.5\angle 53.13^\circ\ \text{A}\end{aligned}$$

Step 7 of 7

Calculate the maximum average power transfer to the load.

$$\begin{aligned}P_L&=\frac{1}{2}I_M^2R_L\\&=\frac{1}{2}(2.5)^2(4)\\&=12.5\ \text{W}\end{aligned}$$

Therefore, the maximum average power transfer to the load is $\boxed{12.5\ \text{W}}$.

Step 1 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 5 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 6 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 7 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 8 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 9 of 9

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 10

Refer to circuit diagram in Figure P9.37 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 10

Consider the Kirchhoff's current's Law at node-1.

$$\frac{V_1}{j1}+\frac{V_1-4\angle 0°}{1}+\frac{V_1-4\angle 0°}{1-j1}=0$$

$$V_1\left(\frac{1}{j1}+1+\frac{1}{1-j1}\right)-4\angle 0°-\frac{4\angle 0°}{1-j1}=0$$

$$V_1\left(\frac{1}{j1}+1+\frac{1}{1-j1}\right)=4\angle 0°\left(1+\frac{1}{1-j1}\right)$$

$$V_1(-j1+1+0.5+j0.5)=4\angle 0°(1+0.5+j0.5)$$

$$V_1(1.5-j0.5)=4\angle 0°(1.5+j0.5)$$

$$V_1=(4\angle 0°)\left(\frac{1.5+j0.5}{1.5-j0.5}\right)$$

$$V_1=(4\angle 0°)(1\angle 36.86°)$$

$$V_1=4\angle 36.86°\text{ V}$$

Therefore, the value of V_1 is $1\angle 36.86°\text{ V}$.

Step 3 of 10

Calculate the value of the current I

$$I=\frac{V_1-4\angle 0°}{1-j1}$$

Substitute $1\angle 36.86°\text{ V}$ for V_1 in the equation.

$$I=\frac{4\angle 36.86°-4\angle 0°}{1.41\angle -45°}$$
$$=\frac{2.53\angle 108.44°}{1.41\angle -45°}$$
$$=1.79\angle 153.44°\text{ A}$$

Therefore, the value of the current I is $1.79\angle 153.44°\text{ A}$.

Step 4 of 10

Calculate the value of V_{oc}.

$$V_{oc}=(I)(1)+4\angle 0°$$

Substitute $1.79\angle 153.44°\text{ A}$ for I in the equation.

$$V_{oc}=(1.79\angle 153.44°)(1)+4\angle 0°$$
$$=1.79\angle 153.44°+4\angle 0°$$
$$=2.53\angle 18.45°\text{ V}$$

Therefore, the value of V_{oc} is $2.53\angle 18.45°\text{ V}$.

Step 5 of 10

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 6 of 10

Consider the simplified circuit diagram to calculate the value of Thevenin's impedance.

Figure 3

Step 7 of 10

Calculate the Thevenin's impedance of the circuit.

$$Z_{Th}=\left[(1\|j1)-j1\right]\|1$$
$$=\left(\frac{j1}{1+j1}-j1\right)\|1$$
$$=(0.5+j0.5-j1)\|1$$
$$=(0.5-j0.5)\|1$$

$$=\frac{0.5-j0.5}{0.5-j0.5+1}$$
$$=\frac{0.5-j0.5}{1.5-j0.5}$$
$$=0.4-j0.2\,\Omega$$

Therefore, the value of the Thevenin's impedance is $0.4-j0.2\,\Omega$.

Step 8 of 10

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L=Z_{Th}^*$$

Substitute $0.4-j0.2\,\Omega$ for Z_{Th} in the equation.

$$Z_L=(0.4-j0.2)^*$$
$$=0.4+j0.2\,\Omega$$

Therefore, the value of the load impedance is $\boxed{0.4+j0.2\,\Omega}$.

Step 9 of 10

Draw the Thevenin's equivalent circuit.

Figure 4

Step 10 of 10

Calculate the value of current I.

$$I=\frac{2.53\angle 18.45°}{0.4-j0.2+0.4+j0.2}$$
$$=\frac{2.53\angle 18.45°}{0.8}$$
$$=3.16\angle 18.45°\text{ A}$$

Therefore, the value of the current I is $3.16\angle 18.45°\text{ A}$.

Consider the expression for the maximum power transferred to load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Substitute 3.16 A for I_M and $0.4\,\Omega$ for R_L.

$$P_L=\frac{1}{2}(3.16)^2(0.4)$$
$$=2\text{ W}$$

Therefore, the value of the maximum power transferred to load is $\boxed{2\text{ W}}$.

Step 1 of 10

Refer to circuit diagram in Figure P9.37 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 10

Consider the Kirchhoff's current's Law at node-1.

$$\frac{V_1}{j1}+\frac{V_1-4\angle 0°}{1}+\frac{V_1-4\angle 0°}{1-j1}=0$$

$$V_1\left(\frac{1}{j1}+1+\frac{1}{1-j1}\right)-4\angle 0°-\frac{4\angle 0°}{1-j1}=0$$

$$V_1\left(\frac{1}{j1}+1+\frac{1}{1-j1}\right)=4\angle 0°\left(1+\frac{1}{1-j1}\right)$$

$$V_1(-j1+1+0.5+j0.5)=4\angle 0°(1+0.5+j0.5)$$

$$V_1(1.5-j0.5)=4\angle 0°(1.5+j0.5)$$

$$V_1=(4\angle 0°)\left(\frac{1.5+j0.5}{1.5-j0.5}\right)$$

$$V_1=(4\angle 0°)(1\angle 36.86°)$$

$$V_1=4\angle 36.86°\text{ V}$$

Therefore, the value of V_1 is $1\angle 36.86°$ V .

Step 3 of 10

Calculate the value of the current I

$$I=\frac{V_1-4\angle 0°}{1-j1}$$

Substitute $1\angle 36.86°$ V for V_1 in the equation.

$$I=\frac{4\angle 36.86°-4\angle 0°}{1.41\angle -45°}$$
$$=\frac{2.53\angle 108.44°}{1.41\angle -45°}$$
$$=1.79\angle 153.44°\text{ A}$$

Therefore, the value of the current I is $1.79\angle 153.44°$ A.

Step 4 of 10

Calculate the value of V_{oc} .

$$V_{oc}=(I)(1)+4\angle 0°$$

Substitute $1.79\angle 153.44°$ A for I in the equation.

$$V_{oc}=(1.79\angle 153.44°)(1)+4\angle 0°$$
$$=1.79\angle 153.44°+4\angle 0°$$
$$=2.53\angle 18.45°\text{ V}$$

Therefore, the value of V_{oc} is $2.53\angle 18.45°$ V .

Step 5 of 10

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 6 of 10

Consider the simplified circuit diagram to calculate the value of Thevenin's impedance.

Figure 3

Step 7 of 10

Calculate the Thevenin's impedance of the circuit.

$$Z_{Th}=\left[(1\,\|\,j1)-j1\right]\|1$$
$$=\left(\frac{j1}{1+j1}-j1\right)\|1$$
$$=(0.5+j0.5-j1)\|1$$
$$=(0.5-j0.5)\|1$$

$$=\frac{0.5-j0.5}{0.5-j0.5+1}$$
$$=\frac{0.5-j0.5}{1.5-j0.5}$$
$$=0.4-j0.2\,\Omega$$

Therefore, the value of the Thevenin's impedance is $0.4-j0.2\,\Omega$.

Step 8 of 10

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L=Z_{Th}^*$$

Substitute $0.4-j0.2\,\Omega$ for Z_{Th} in the equation.

$$Z_L=(0.4-j0.2)^*$$
$$=0.4+j0.2\,\Omega$$

Therefore, the value of the load impedance is $\boxed{0.4+j0.2\,\Omega}$.

Step 9 of 10

Draw the Thevenin's equivalent circuit.

Figure 4

Step 10 of 10

Calculate the value of current I .

$$I=\frac{2.53\angle 18.45°}{0.4-j0.2+0.4+j0.2}$$
$$=\frac{2.53\angle 18.45°}{0.8}$$
$$=3.16\angle 18.45°\text{ A}$$

Therefore, the value of the current I is $3.16\angle 18.45°$ A .

Consider the expression for the maximum power transferred to load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Substitute 3.16 A for I_M and $0.4\,\Omega$ for R_L .

$$P_L=\frac{1}{2}(3.16)^2(0.4)$$
$$=2\text{ W}$$

Therefore, the value of the maximum power transferred to load is $\boxed{2\text{ W}}$.

Step 1 of 7

Refer to circuit diagram in Figure P9.39 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 7

Calculate the value of $\mathbf{V}_{oc}$.

$$\begin{aligned}\mathbf{V}_{oc} &= 12\angle 0^\circ - 4\angle 0^\circ(1+j1)\\ &= 12\angle 0^\circ - 4\angle 0^\circ(1.41\angle 45^\circ)\\ &= 12\angle 0^\circ - 5.64\angle 45^\circ\\ &= 8.95\angle -26.46^\circ \text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{oc}$ is $8.95\angle -26.46^\circ \text{ V}$.

Step 3 of 7

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 4 of 7

Calculate the Thevenin's impedance of the circuit.

$$\begin{aligned}\mathbf{Z}_{Th} &= 1 + j1 - j1\\ &= 1\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin's impedance is $1\,\Omega$.

Step 5 of 7

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^*$$

Substitute $1\,\Omega$ for $\mathbf{Z}_{Th}$ in the equation.

$$\begin{aligned}\mathbf{Z}_L &= (1)^*\\ &= 1\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{1\,\Omega}$.

Step 6 of 7

Draw the Thevenin's equivalent circuit.

Figure 3

Step 7 of 7

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I} &= \frac{8.95\angle -26.46^\circ}{2+2}\\ &= \frac{8.95\angle -26.46^\circ}{4}\\ &= 4.48\angle 35.99^\circ \text{ A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $4.48\angle 35.99^\circ \text{ A}$.

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute 4.48 A for I_M and $1\,\Omega$ for R_L .

$$\begin{aligned}P_L &= \frac{1}{2}(4.48)^2(1)\\ &= 10.04 \text{ W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{10 \text{ W}}$.

Step 1 of 11

Refer Figure P9.41 from the text book.

Apply Thevenin theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 11

Consider the Kirchhoff's current's Law at node-1.

$$\mathbf{I}+2\mathbf{I}=\mathbf{I}$$
$$3\mathbf{I}=\mathbf{I}_1$$
$$3\left(\frac{-\mathbf{V}_1}{1-j1}\right)=\frac{\mathbf{V}_1}{1+j1}$$
$$\mathbf{V}_1=0\,\mathrm{V}$$

Therefore, the value of $\mathbf{V}_1$ is $0\,\mathrm{V}$.

Step 3 of 11

Calculate the value of $\mathbf{V}_{oc}$.

$$\mathbf{V}_{oc}=\mathbf{V}_1+12\angle 0^\circ$$

Substitute $0\,\mathrm{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_{oc}&=0+12\angle 0^\circ\\&=12\angle 0^\circ\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{oc}$ is $12\angle 0^\circ\,\mathrm{V}$.

Step 4 of 11

Short the output terminals to calculate the short circuit current.

Figure 2

Step 5 of 11

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1=-12\angle 0^\circ\,\mathrm{V}$$

Therefore, the value of $\mathbf{V}_1$ is $-12\angle 0^\circ\,\mathrm{V}$.

Step 6 of 11

Consider the Kirchhoff's current's Law at node-0.

$$\mathbf{I}_{sc}+\mathbf{I}_1=\mathbf{I}+2\mathbf{I}$$
$$\mathbf{I}_{sc}=3\mathbf{I}-\mathbf{I}_1$$
$$\mathbf{I}_{sc}=3\left(\frac{-\mathbf{V}_1}{1-j1}\right)-\frac{\mathbf{V}_1}{1+j1}$$
$$\mathbf{I}_{sc}=-3\mathbf{V}_1\left(\frac{1}{1-j1}+\frac{1}{1+j1}\right)$$
$$\begin{aligned}\mathbf{I}_{sc}&=-3\mathbf{V}_1(0.5+j0.5+0.5-j0.5)\\&=-3\mathbf{V}_1\end{aligned}$$

Substitute $-12\angle 0^\circ\,\mathrm{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_{sc}&=-3(-12\angle 0^\circ)\\&=36\angle 0^\circ\,\mathrm{A}\end{aligned}$$

Therefore, the value of the short circuit current is $36\angle 0^\circ\,\mathrm{A}$.

Step 7 of 11

Calculate the value of the Thevenin's impedance.

$$\mathbf{Z}_{TH}=\frac{\mathbf{V}_{oc}}{\mathbf{I}_{sc}}$$

Substitute $36\angle 0^\circ\,\mathrm{A}$ for $\mathbf{I}_{sc}$ and $12\angle 0^\circ\,\mathrm{V}$ for $\mathbf{V}_{oc}$.

$$\begin{aligned}\mathbf{Z}_{TH}&=\frac{12\angle 0^\circ}{36\angle 0^\circ}\\&=\frac{1}{3}\Omega\end{aligned}$$

Therefore, the value of the Thevenin impedance is $\frac{1}{3}\Omega$.

Step 8 of 11

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L=\mathbf{Z}_{TH}^*$$

Substitute $\frac{1}{3}\Omega$ for $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_L&=\left(\frac{1}{3}\right)^*\\&=\frac{1}{3}\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{\frac{1}{3}\Omega}$.

Step 9 of 11

Draw the Thevenin's equivalent circuit.

Figure 3

Step 10 of 11

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I}&=\frac{12\angle 0^\circ}{\frac{1}{3}+\frac{1}{3}}\\&=\frac{12\angle 0^\circ}{\frac{2}{3}}\\&=18\angle 0^\circ\,\mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $18\angle 0^\circ\,\mathrm{A}$.

Step 11 of 11

Consider the expression for the maximum power transferred to load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Substitute $18\angle 0^\circ\,\mathrm{A}$ for I_M and $\frac{1}{3}\Omega$ for R_L .

$$\begin{aligned}P_L&=\frac{1}{2}(18)^2\left(\frac{1}{3}\right)\\&=54\,\mathrm{W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{54\,\mathrm{W}}$.

Step 1 of 10

Refer Figure P9.42 from the text book.

Apply Thevenin theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 10

Calculate the value of $\mathbf{V}_x$.

$$\mathbf{V}_x = (1)\mathbf{I}_1$$

Substitute $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_x &= (1)(4\angle 0°)\\ &= 4\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_x$ is $4\angle 0°\ \mathrm{V}$.

Step 3 of 10

Calculate the value of $\mathbf{V}_{oc}$.

$$\mathbf{V}_{oc} = 2\mathbf{V}_x + \mathbf{I}_1(1 - j1)$$

Substitute $4\angle 0°\ \mathrm{V}$ for $\mathbf{V}_x$ and $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_{oc} &= 2(4\angle 0°) + (4\angle 0°)(1.414\angle -45°)\\ &= 8\angle 0° + 5.66\angle -45°\\ &= 12.65\angle -18.43°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{oc}$ is $12.65\angle -18.43°\ \mathrm{V}$.

Step 4 of 10

Short the output terminals to calculate the short circuit current.

Figure 2

Step 5 of 10

Equate the voltages in the parallel branches.

$$\mathbf{I}_1(1 - j1) = \mathbf{I}_{sc}(1) - 2\mathbf{V}_x$$

Substitute $\mathbf{I}_1(1)$ for $\mathbf{V}_x$.

$$\begin{aligned}\mathbf{I}_1(1 - j1) &= \mathbf{I}_{sc}(1) - 2\mathbf{I}_1(1)\\ \mathbf{I}_1(3 - j1) &= \mathbf{I}_{sc}(1)\end{aligned}$$

Substitute $4\angle 0° - \mathbf{I}_{sc}$ for $\mathbf{I}_1$.

$$\begin{aligned}(4\angle 0° - \mathbf{I}_{sc})(3 - j1) &= \mathbf{I}_{sc}\\ (4\angle 0° - \mathbf{I}_{sc})(3.16\angle -18.44°) &= \mathbf{I}_{sc}\\ 12.64\angle -18.44° - \mathbf{I}_{sc}(3.16\angle -18.44°) &= \mathbf{I}_{sc}\\ \mathbf{I}_{sc} + \mathbf{I}_{sc}(3.16\angle -18.44°) &= 12.64\angle -18.44°\\ \mathbf{I}_{sc}(4.12\angle -14.04°) &= 12.64\angle -18.44°\\ \mathbf{I}_{sc} &= \frac{12.64\angle -18.44°}{4.12\angle -14.04°}\\ \mathbf{I}_{sc} &= 3.07\angle -4.4°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{sc}$ is $3.07\angle -4.4°\ \mathrm{A}$.

Step 6 of 10

Calculate the value of the Thevenin impedance.

$$\mathbf{Z}_{TH} = \frac{\mathbf{V}_{oc}}{\mathbf{I}_{sc}}$$

Substitute $\mathbf{I}_{sc} = 3.07\angle -4.4°\ \mathrm{A}$ for $\mathbf{I}_{sc}$ and $12.65\angle -18.43°\ \mathrm{V}$ for $\mathbf{V}_{oc}$.

$$\begin{aligned}\mathbf{Z}_{TH} &= \frac{12.65\angle -18.43°}{3.07\angle -4.4°}\\ &= 4.12\angle -14.04\\ &= 4 - j1\,\Omega\end{aligned}$$

Therefore, the value of the Thevenin impedance is $4 - j1\,\Omega$.

Step 7 of 10

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{TH}^*$$

Substitute $4 - j1\,\Omega$ for $\mathbf{Z}_{TH}$.

$$\begin{aligned}\mathbf{Z}_L &= (4 - j1)^*\\ &= 4 + j1\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{4 + j1\,\Omega}$.

Step 8 of 10

Draw the Thevenin equivalent circuit.

Figure 3

Step 9 of 10

Calculate the value of current $\mathbf{I}$.

$$\begin{aligned}\mathbf{I} &= \frac{12.65\angle -18.43°}{4 + j1 + 4 - j1}\\ &= \frac{12.65\angle -18.43°}{8}\\ &= 1.58\angle -18.43°\ \mathrm{A}\end{aligned}$$

Therefore, the value of the current $\mathbf{I}$ is $1.58\angle -18.43°\ \mathrm{A}$.

Step 10 of 10

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute $1.58\ \mathrm{A}$ for I_M and $4\,\Omega$ for R_L.

$$\begin{aligned}P_L &= \frac{1}{2}(1.58)^2(4)\\ &= 5\ \mathrm{W}\end{aligned}$$

Therefore, the value of the maximum power transferred to load is $\boxed{5\ \mathrm{W}}$.

Step 1 of 9

Refer to circuit diagram in Figure P9.32 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 9

Consider Kirchhoff's Current at law at reference node.

$$\frac{V_1}{-j1}+\frac{V_3}{1}=0$$
$$V_1-(j1)V_3=0$$
$$V_1=(j1)V_3$$

Therefore, the expression for V_1 is $(j1)V_3$.

Consider the expression for the voltage source.

$$V_3-V_1=6\angle 0°$$

Substitute $(j1)V_3$ for V_1 in the equation.

$$V_3-(j1)V_3=6\angle 0°$$
$$V_3(1-j1)=6\angle 0°$$
$$V_3(1.41\angle -45°)=6\angle 0°$$
$$V_3=\frac{6\angle 0°}{1.41\angle -45°}$$

$V_3=4.26\angle 45°\ \text{V}$ Therefore, the value of V_3 is $4.26\angle 45°\ \text{V}$.

Step 3 of 9

Consider Kirchhoff's Current at law at node-2.

$$\frac{V_{oc}-V_1}{2}+\frac{V_{oc}-V_3}{j1}=0$$
$$(V_{oc}-V_1)(j1)+2(V_{oc}-V_3)=0$$
$$V_{oc}(2+j1)-(j1)V_1-2V_3=0$$
$$V_{oc}(2+j1)=(j1)V_1+2V_3$$

Substitute $(j1)V_3$ for V_1 in the equation.

$$V_{oc}(2+j1)=(j1)(j1)V_3+2V_3$$
$$V_{oc}(2+j1)=-V_3+2V_3$$
$$V_{oc}(2.24\angle 26.57°)=V_3$$
$$V_{oc}=\frac{V_3}{2.24\angle 26.57°}$$

Substitute $4.26\angle 45°\ \text{V}$ for V_3 in the equation.

$$V_{oc}=\frac{4.26\angle 45°}{2.24\angle 26.57°}$$
$$=1.9\angle 18.43°\ \text{V}$$

Therefore, the expression for V_{oc} is $1.9\angle 18.43°\ \text{V}$.

Step 4 of 9

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 5 of 9

Consider the simplified circuit diagram to calculate the value of Thevenin's impedance.

Figure 3

Step 6 of 9

Calculate the value of Thevenin's impedance.

$$Z_{Th}=(2\,||\,j1)+(1\,||-j1)$$
$$=\left(\frac{j2}{2+j1}\right)+\left(\frac{-j1}{1-j1}\right)$$
$$=0.4+j0.8+0.5-j0.5$$
$$=0.9+j0.3\ \Omega$$

Therefore, the value of the Thevenin's impedance is $0.9+j0.3\,\Omega$.

Step 7 of 9

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L=Z_{Th}^*$$

Substitute $0.9+j0.3\,\Omega$ for Z_{TH} in the equation.

$$Z_L=(0.9+j0.3)^*$$
$$=0.9-j0.3\,\Omega$$

Therefore, the value of the load impedance is $\boxed{0.9-j0.3\,\Omega}$.

Step 8 of 9

Draw the Thevenin's equivalent circuit.

Figure 4

Step 9 of 9

Calculate the value of current I.

$$I=\frac{1.9\angle 18.43°}{0.9+j0.3+0.9-j0.3}$$
$$=\frac{1.9\angle 18.43°}{1.8}$$
$$=1.06\angle 18.43°\ \text{A}$$

Therefore, the value of the current I is $1.06\angle 18.43°\ \text{A}$.

Consider the expression for the maximum power transferred to load.

$$P_L=\frac{1}{2}I_M^2R_L$$

Substitute $1.06\ \text{A}$ for I_M and $0.9\,\Omega$ for R_L.

$$P_L=\frac{1}{2}(1.06)^2(0.9)$$
$$=505.62\ \text{mW}$$

Therefore, the value of the maximum power transferred to load is $\boxed{505.62\ \text{mW}}$.

Step 1 of 5

Refer to circuit diagram in Figure P9.34 in the text book.

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 1

Step 2 of 5

Now convert the delta connected impedances $4\ \Omega, j2\ \Omega,$ and $-j2\ \Omega$ to star impedance.

Calculate the impedances $\mathbf{Z}_1, \mathbf{Z}_2$ and $\mathbf{Z}_3$ of star connected network.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{(4)(-j2)}{(4)+(-j2)+(j2)}\\ &= \frac{(4)(-j2)}{(4)}\\ &= -j2\ \Omega\end{aligned}$$

$$\begin{aligned}\mathbf{Z}_2 &= \frac{(4)(j2)}{(4)+(-j2)+(j2)}\\ &= \frac{(4)(j2)}{(4)}\\ &= j2\ \Omega\end{aligned}$$

And,

$$\begin{aligned}\mathbf{Z}_3 &= \frac{(-j2)(j2)}{(4)+(-j2)+(j2)}\\ &= \frac{(-j2)(j2)}{(4)}\\ &= 1\ \Omega\end{aligned}$$

Step 3 of 5

Convert the delta connected impedances to wye connection as shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the value of the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{Th} &= \left[(2-j2)\,\|\,(2+j2)\right]+1\\ &= \frac{(2-j2)(2+j2)}{(2-j2)+(2+j2)}+1\\ &= 2+1\\ &= 3\ \Omega\end{aligned}$$

Therefore, the value of the Thevenin's impedance is $3\ \Omega$.

Step 5 of 5

Calculate the value of load impedance so that maximum power is transferred to load.

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^*$$

Substitute $3\ \Omega$ for $\mathbf{Z}_{Th}$ in the equation.

$$\begin{aligned}\mathbf{Z}_L &= (3)^*\\ &= 3\ \Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{3\ \Omega}$.

Step 1 of 10

Refer to circuit diagram in Figure P9.42 in the textbook.

To calculate the Thevenin's impedance across the terminals of the load, short circuit the voltage source to zero impedance. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 10

In the circuit shown in Figure 1, $j2\ \Omega$ inductor, $2\ \Omega$ resistor and $-j4\ \Omega$ capacitor are connected in delta. Now convert it into equivalent star. The delta-wye network is shown below.

Figure 2

Step 3 of 10

Calculate the equivalent wye impedances.

$$\mathbf{Z}_1 = \frac{(j2)(-j4)}{j2-j4+2} = \frac{8}{2-j2} = 2+j2\ \Omega$$

$$\mathbf{Z}_2 = \frac{(2)(-j4)}{j2-j4+2} = \frac{-j8}{2-j2} = 1.6-j3.2\ \Omega$$

$$\mathbf{Z}_3 = \frac{(2)(j2)}{j2-j4+2} = \frac{j4}{2-j2} = -1+j\ \Omega$$

Step 4 of 10

The modified network of Figure 1 is shown in Figure 3.

Figure 3

Step 5 of 10

In the circuit shown in Figure 3, impedances $-1+j\ \Omega$ and $1.6-j3.2\ \Omega$ are connected in parallel. Calculate the equivalent impedance.

$$\mathbf{Z}_{eq1} = (-1+j\ \Omega)\|(1.6-j3.2\ \Omega) = \frac{(-1+j\ \Omega)(1.6-j3.2\ \Omega)}{-1+j+1.6-j3.2\ \Omega} = \frac{1.6+j4.8\ \Omega}{0.6-j2.2} = -1.846+j1.23\ \Omega$$

Step 6 of 10

The modified network of Figure 3 is shown in Figure 4.

Figure 4

Step 7 of 10

From the circuit, shown in Figure 4, $4\ \Omega$ resistor and $-j4\ \Omega$ capacitor are connected in series. Calculate the equivalent resistance.

$$\mathbf{Z}_{eq2} = 4-j4\ \Omega$$

Similarly, $4\ \Omega$ resistor, impedances $2+j2\ \Omega$ and $-1.846-j1.23\ \Omega$ are connected in series. Calculate the equivalent resistance.

$$\mathbf{Z}_{eq3} = 4+2+j2-1.846-j1.23\ \Omega = 4.154+j0.77\ \Omega$$

Step 8 of 10

The simplified impedance network is shown in Figure 5.

Figure 5

Step 9 of 10

Calculate the Thevenin's impedance.

$$\mathbf{Z}_{Th} = (4-j4\ \Omega)\|(4.154+j0.77\ \Omega)-j2\ \Omega = \frac{(4-j4\ \Omega)(4.154+j0.77\ \Omega)}{4-j4+4.154+j0.77\ \Omega}-j2\ \Omega = \frac{19.69-j13.536\ \Omega}{8.154-j3.23\ \Omega}-j2\ \Omega = 2.655-j0.6-j2\ \Omega$$

$$= 2.655-j2.6\ \Omega$$

Step 10 of 10

When maximum power is transferred from source to load, load impedance is the complex conjugate of the source impedance or Thevenin's impedance.

$$\mathbf{Z}_L = \mathbf{Z}_{Th}^* = (2.655-j2.6\ \Omega)^* = 2.655+j2.6\ \Omega$$

Therefore, the load impedance, $\mathbf{Z}_L$ is $\boxed{2.655+j2.6\ \Omega}$.

Step 1 of 8

Refer to circuit diagram in Figure P9.38 in the text book.

Apply Thevenin's theorem for the circuit.

Open the output terminals to calculate the open circuit voltage.

Figure 1

Step 2 of 8

Apply Kirchhoff's voltage Law in loop 2.

$$(I_2 - I_1)(-j2) + I_2(1) + 6\angle 0° = 0$$
$$I_1(-j2) + I_2(1 + j2) = -6\angle 0°$$
$$I_1(2\angle -90°) + I_2(2.24\angle 63.44°) = 6\angle 180°$$

Substitute $2\angle 0°\ \text{A}$ for I_1 in the equation.

$$(2\angle 0°)(2\angle -90°) + I_2(2.24\angle 63.44°) = 6\angle 180°$$
$$I_2(2.24\angle 63.44°) = 6\angle 180° - 4\angle -90°$$
$$I_2(2.24\angle 63.44°) = 7.21\angle 146.31°$$
$$I_2 = \frac{7.21\angle 146.31°}{2.24\angle 63.44°}$$
$$I_2 = 3.22\angle 82.87°\ \text{A}$$

Therefore, the value of I_2 is $3.22\angle 82.87°\ \text{A}$.

Step 3 of 8

Calculate the value of V_{oc}.

$$V_{oc} = (I_1)(2) + (I_2)(1)$$

Substitute $3.22\angle 82.87°\ \text{A}$ for I_2 and $2\angle 0°\ \text{A}$ for I_1 in the equation.

$$V_{oc} = (2\angle 0°)(2) + (\ )(1)$$
$$= 4\angle 0° + 3.22\angle 82.87°$$
$$= 5.44\angle 35.99°\ \text{V}$$

Therefore, the value of V_{oc} is $5.44\angle 35.99°\ \text{V}$.

Step 4 of 8

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 2

Step 5 of 8

Calculate the Thevenin's impedance of the circuit.

$$Z_{Th} = 2 + (1 \| -j2)$$
$$= 2 + \left(\frac{-j2}{1 - -j2}\right)$$
$$= 2 + 0.8 - j0.4$$
$$= 2.8 - j0.4\ \Omega$$

Therefore, the value of the Thevenin's impedance is $2.8 - j0.4\,\Omega$.

Step 6 of 8

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L = Z_{Th}^*$$

Substitute $2.8 - j0.4\,\Omega$ for Z_{Th} in the equation.

$$Z_L = (2.8 - j0.4)^*$$
$$= 2.8 + j0.4\,\Omega$$

Therefore, the value of the load impedance is $\boxed{2.8 + j0.4\ \Omega}$.

Step 7 of 8

Draw the Thevenin's equivalent circuit.

Figure 3

Step 8 of 8

Calculate the value of current I.

$$I = \frac{5.44\angle 35.99°}{2.8 - j0.4 + 2.8 + j0.4}$$
$$= \frac{5.44\angle 35.99°}{5.6}$$
$$= 0.97\angle 35.99°\ \text{A}$$

Therefore, the value of the current I is $0.97\angle 35.99°\ \text{A}$.

Consider the expression for the maximum power transferred to load.

$$P_L = \frac{1}{2} I_M^2 R_L$$

Substitute $0.97\ \text{A}$ for I_M and $2.8\,\Omega$ for R_L in the equation.

$$P_L = \frac{1}{2}(0.97)^2(2.8)$$
$$= 1.32\ \text{W}$$

Therefore, the value of the maximum power transferred to load is $\boxed{1.32\ \text{W}}$.

Step 1 of 5

Refer to circuit diagram in Figure P9.33 in the text book.

Deactivate the sources to calculate the value of the Thevenin's impedance at the output terminals.

Figure 1

Step 2 of 5

Now convert the delta connected impedances $2\ \Omega, j4\ \Omega,$ and $-j4\ \Omega$ to star impedance.

The

$$\begin{aligned} Z_{12} &= \frac{2(-j4)}{2-j4+j4} \\ &= -j4\ \Omega \end{aligned}$$

$$\begin{aligned} Z_{13} &= \frac{2(j4)}{2-j4+j4} \\ &= j4\ \Omega \end{aligned}$$

And,

$$\begin{aligned} Z_{23} &= \frac{(j4)(-j4)}{2-j4+j4} \\ &= 8\ \Omega \end{aligned}$$

Step 3 of 5

Convert the delta connected impedances to wye connection as shown in Figure 2.

Figure 2

Step 4 of 5

Calculate the value of the Thevenin's impedance.

$$\begin{aligned} Z_{Th} &= 6+\left[(4-j4)\|10\right]+j4 \\ &= 6+\frac{(4-j4)(10)}{(4-j4)+10}+j4 \\ &= 6+3.4-j1.89+j4 \\ &= 9.4+j2.11\ \Omega \end{aligned}$$

Therefore, the value of the Thevenin's impedance is $9.4+j2.11\ \Omega$.

Step 5 of 5

Calculate the value of load impedance so that maximum power is transferred to load.

$$Z_L = Z_{Th}^*$$

Substitute $9.4+j2.11\ \Omega$ for Z_{Th} .

$$\begin{aligned} Z_L &= (9.4+j2.11)^* \\ &= 9.4-j2.11\ \Omega \end{aligned}$$

Therefore, the value of the load impedance is $\boxed{9.4-j2.11\ \Omega}$.

The following is the given circuit diagram:

Figure 1

First, remove the load impedance and find the open circuit voltage, V_{oc} across the open circuited terminals of the circuit in Figure 2.

Figure 2

From Figure 2, the left loop has a current,

$$I_1 = -2V_x$$

Where $V_x = (-j1)I_2$

$$I_1 = j2I_2 \qquad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the second loop.

$$2(I_2 - I_1) + 12 + (-j1)I_2 = 0$$

$$2I_1 + (-2 + j1)I_2 = 12 \qquad \text{..... (2)}$$

Substitute equation (1) in equation (2).

$$(j4)I_2 + (-2 + j1)I_2 = 12$$

$$I_2(-2 + j5) = 12$$

$$I_2 = \frac{12}{-2 + j5}$$

$$I_2 = 2.228\angle -111.8°\text{A}$$

Calculate the current I_1 in the circuit.

$$I_1 = (j2)I_2$$

$$= 4.457\angle -21.8°\text{A}$$

Calculate the Open circuit voltage,

$$V_{oc} = (-j1)I_2$$

$$= (1\angle -90°)(2.228\angle -111.8°)$$

$$= 2.228\angle -201.8°\text{ V}$$

Since, there is a dependent source, to find the thevenin impedance, we find the short circuit current, I_{sc}.

Figure 3

From Figure 3, the current I_1.

$$I_1 = -2V_x$$

Where $V_x = (-j1)(I_2 - I_{sc})$

$$I_1 = j2I_2 - j2I_{sc} \qquad \text{..... (3)}$$

Apply Kirchhoff's voltage law to the second loop.

$$2(I_2 - I_1) + 12 + (-j1)(I_2 - I_{sc}) = 0$$

$$2I_1 + (-2 + j1)I_2 - (j1)I_{sc} = 12 \qquad \text{..... (4)}$$

Apply Kirchhoff's voltage law to the third loop.

$$-j1(I_{sc} - I_2) + (1)I_{sc} = 0$$

$$I_{sc}(1 - j1) = (-j1)I_2$$

$$I_{sc}(1 + j1) = I_2 \qquad \text{..... (5)}$$

Substitute equation (5) and (3) in equation (4)

$$2[j2I_2 - j2I_{sc}] + (-2 + j1)I_2 - (j1)I_{sc} = 12$$

$$(-2 + j5)I_2 - (j5)I_{sc} = 12$$

$$(-2 + j5)(1 + j1)I_{sc} - (j5)I_{sc} = 12$$

$$I_{sc}[(-2 + j5)(1 + j1) - j5] = 12$$

Calculate the short circuit current.

$$I_{sc}[-2 - j2 + j5 - 5 - j5] = 12$$

$$I_{sc} = \frac{12}{-7 - j2}$$

$$I_{sc} = 1.648\angle 164.05°\text{A}$$

Calculate the Thevenin impedance of the circuit.

$$Z_{th} = \frac{V_{oc}}{I_{sc}}$$

$$= \frac{2.228\angle -201.8°}{1.648\angle 164.05°}$$

$$= 1.352\angle -365.85°\ \Omega$$

$$= (1.345 - j0.138)\ \Omega$$

For maximum power transfer load impedance is complex conjugate of Thevenin's impedance,

$$Z_L = Z_{Th}^*$$

Therefore, the Thevenin impedance of the circuit is, $\boxed{1.345 + j0.138\ \Omega}$.

Now, the thevenin equivalent circuit is shown in Figure 4.

Figure 4

Calculate the load current in the circuit:

$$I_L = \frac{2.228\angle -201.8°}{1.345 - j0.138 + 1.345 + j0.138}$$

$$= \frac{2.228\angle -201.8°}{2.69}$$

$$= 0.8283\angle -201.8°\text{A}$$

Calculate the maximum average power delivered to load.

$$P_{max} = \frac{1}{2}|I_{L,M}|^2 R_L$$

$$= \frac{1}{2} \times (0.8283)^2 \times 1.345$$

Thus, the maximum power transferred to the load is, $\boxed{0.46\text{ W}}$.

Step 1 of 6

Now we remove Z_L and find the thevenin equivalent voltage across it.

Step 2 of 6

By nodal analysis,

$$-2\angle 45° + \frac{V}{5} + \frac{V - 2I_x}{j4} = 0$$

and $I_x = \frac{V}{5}$

$$\frac{V}{5} + \frac{V - 2\left(\frac{V}{5}\right)}{j4} = 2\angle 45°$$

$$\frac{V}{5} + \frac{5V - 2V}{j20} = 2\angle 45°$$

$$4V - j3V = 40\angle 45°$$

$$V(4 - j3) = 40\angle 45°$$

$$V = \frac{40\angle 45°}{4 - j3}$$

$$V = \frac{40\angle 45°}{5\angle -36.86°}$$

$$V = 8\angle 81.86° \text{V}$$

Therefore,

$V_{th} = 8\angle 81.86° \text{V}$

Step 3 of 6

Now we find the short circuit current,

Step 4 of 6

Due to the short circuit no current flows through the 5Ω. Hence, $I_x = 0\text{A}$, therefore the dependent voltage source is $2I_x = 0\text{V}$. Hence no current flows through the $j4\Omega$ branch also.

Therefore $I_{sc} = 2\angle 45° \text{A}$

Therefore the thevenin equivalent impedance is,

$$Z_{th} = \frac{V_{th}}{I_{sc}}$$

$$= \frac{8\angle 81.86°}{2\angle 45°}$$

$$= 4\angle 36.86°$$

$$Z_{th} = 3.2 + j2.4\Omega$$

Therefore Z_L for maximum average power transfer is,

$$Z_L = Z_{th}^*$$

$$\boxed{Z_L = 3.2 - j2.4\Omega}$$

Step 5 of 6

Now the thevenin equivalent circuit is,

Step 6 of 6

$$I_L = \frac{8\angle 81.86°}{3.2 + 3.2}$$

$$I_L = \frac{8\angle 81.86°}{6.4}$$

$$I_L = 1.25\angle 81.86° \text{A}$$

Therefore maximum average power transfer is,

$$P_L = \frac{1}{2}(I_L)^2 R_L$$

$$= \frac{1}{2}(1.25)^2(3.2)$$

$$\boxed{P_L = 2.5\text{W}}$$

Step 1 of 13

Given circuit,

Step 2 of 13

First we remove the load Z_L and find the open circuit voltage, V_{oc} across the open circuited terminals.
The circuit is redrawn as

Step 3 of 13

From the circuit

$I_x = I_1 - I_2$ ..... (1)

Applying KVL to the first loop we have

$I_1 + 2(I_1 - I_2) = 12\angle 0°$

$3I_1 - 2I_2 = 12\angle 0°$

$I_1 = \dfrac{2I_2 + 12\angle 0°}{3}$ ..... (2)

Applying KVL to the second loop we have

$2(I_2 - I_1) - jI_2 = 2I_x$

$2(I_2 - I_1) - jI_2 = 2I_x$ ..... (3)

Step 4 of 13

Substituting I_x value in equation (3), we get

$2(I_2 - I_1) - jI_2 = 2(I_1 - I_2)$

$-4I_1 + (4 - j)I_2 = 0$ ..... (4)

Substituting equation (2) in (4) we get

$-4\left(\dfrac{2I_2 + 12\angle 0°}{3}\right) + (4 - j)I_2 = 0$

$-8I_2 - 48\angle 0° + (12 - j3)I_2 = 0$

$(4 - j3)I_2 = 48\angle 0°$

$I_2 = \dfrac{48\angle 0°}{4 - 3j}$

$= 9.6\angle 36.86°$ A

Step 5 of 13

Therefore the Open circuit voltage,

$V_{oc} = (-j1)I_2$

$= (1\angle -90°)(9.6\angle 36.86°)$

$= 9.6\angle -53.14°$ V

Step 6 of 13

Since there is a dependent source, to find the thevenin's impedance, we find the short circuit current, I_{sc} as shown in the figure.

Step 7 of 13

Applying KVL to the first loop we have

$I_1 + 2(I_1 - I_2) = 12\angle 0°$

$3I_1 - 2I_2 = 12\angle 0°$

$I_1 = \dfrac{2I_2 + 12\angle 0°}{3}$ ..... (5)

Applying KVL to the second loop we have

$2(I_2 - I_1) - j(I_2 - I_{sc}) = 2I_x$ ..... (6)

Step 8 of 13

Substituting I_x from equation (1) in equation (6) we get

$2(I_2 - I_1) - j(I_2 - I_{sc}) = 2(I_1 - I_2)$

$-4I_1 + (4 - j)I_2 + jI_{sc} = 0$ ..... (7)

Substituting equation (5) in equation (7) we get,

$-4\left(\dfrac{2I_2 + 12\angle 0°}{3}\right) + (4 - j)I_2 + jI_{sc} = 0$

$-8I_2 - 48\angle 0° + (12 - 3j)I_2 + j3I_{sc} = 0$

$(4 - 3j)I_2 + j3I_{sc} = 48\angle 0°$ ..... (8)

Step 9 of 13

Applying KVL to the third loop we have

$j2I_{sc} - j(I_{sc} - I_2) = 0$

$jI_{sc} + jI_2 = 0$

$I_2 = -I_{sc}$ ..... (9)

Substituting equation (9) in (8),

$(4 - 3j)(-I_{sc}) + j3I_{sc} = 48\angle 0°$

$-4I_{sc} + j3I_{sc} + j3I_{sc} = 48\angle 0°$

$(-4 + j6)I_{sc} = 48\angle 0°$

$I_{sc} = \dfrac{48\angle 0°}{(-4 + j6)}$

$= -3.692 - j5.538$ A

Step 10 of 13

Thevenin's impedance is given by,

$Z_{Th} = \dfrac{V_{oc}}{I_{sc}}$

$= \dfrac{9.6\angle -53.14°}{-3.692 - j5.538}$

$= (0.4802 + j1.36)\ \Omega$

For maximum power transfer, the load impedance should be equal to the complex conjugate of the Thevenin's impedance.
That is,

$Z_L = Z_{Th}^*$

$\boxed{Z_L = 0.4802 - j1.36\ \Omega}$

Step 11 of 13

Now the thevenin's equivalent circuit will be,

Step 12 of 13

The load current is given by,

$I_L = \dfrac{9.6\angle -53.14}{0.4802 + j1.36 + 0.4802 - j1.36}$

$= \dfrac{9.6\angle -53.14}{0.9604}$

$= 9.9958\angle -53.14°$ A

Step 13 of 13

Therefore, the maximum average power absorbed by the load is

$P_L = \dfrac{1}{2}(I_M)^2 R$

$= \dfrac{1}{2}(9.9958)^2(0.4802)$

$\boxed{P_L = 23.98\ \text{W}}$

Step 1 of 4

Consider Figure P9.50 from the text book.

Find the equation for the current between the interval $0 < t < 2$ having end points $(0,0)$ and $(2,10)$.

$$i(t)-10=\left(\frac{10-0}{2-0}\right)(t-2) \quad \text{since } y-y_1=\left(\frac{y_2-y_1}{x_2-x_1}\right)(x-y)$$

$$i(t)-10=5t-10$$
$$i(t)=5t$$

Therefore, the equation for the current between the interval $0 < t < 2$ is $i(t)=5t$.

Step 2 of 4

Find the equation for the current between the interval $4 < t < 6$ having end points $(4,10)$ and $(6,0)$.

$$i(t)-10=\left(\frac{0-10}{6-4}\right)(t-4) \quad \text{since } y-y_1=\left(\frac{y_2-y_1}{x_2-x_1}\right)(x-y)$$

$$i(t)-10=-5t+20$$
$$i(t)=-5t+30$$

Therefore, the equation for the current between the interval $4 < t < 6$ is $i(t)=-5t+30$.

Step 3 of 4

Define the function for the current $i(t)$.

$$i(t)=\begin{cases} 5t\text{ A} & 0<t<2 \\ 10\text{ A} & 2<t<4 \\ 30-5t\text{ A} & 4<t<6 \\ 10\text{ A} & 6<t<8 \end{cases}$$

Step 4 of 4

Consider the expression for the root mean square current.

$$I_{rms}=\sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases} 5t\text{ A} & 0<t<2 \\ 10\text{ A} & 2<t<4 \\ 6-2t\text{ A} & 4<t<6 \\ 10\text{ A} & 6<t<8 \end{cases}$ for $i(t)$ and 8 sec for T.

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{8}\left\{\int_0^2 (5t)^2dt+\int_2^4 10^2dt+\int_4^6 (30-5t)^2dt+\int_6^8 0^2dt\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\int_0^2 25t^2dt+\int_2^4 100dt+\int_4^6 (900+25t^2-300t)dt+0\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\int_0^2 25t^2dt+\int_2^4 100dt+\int_4^6 900dt+\int_4^6 25t^2dt-\int_4^6 300tdt\right\}} \\ &= \sqrt{\frac{1}{8}\left\{25\int_0^2 t^2dt+100\int_2^4 dt+900\int_4^6 dt+25\int_4^6 t^2dt-300\int_4^6 tdt\right\}} \end{aligned}$$

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{8}\left\{25\left[\frac{t^3}{3}\right]_0^2+100[t]_2^4+900[t]_4^6+25\left[\frac{t^3}{3}\right]_4^6-300\left[\frac{t^2}{2}\right]_4^6\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\frac{25}{3}[8-0]+100[4-2]+900[6-4]+\frac{25}{3}[216-64]-\frac{300}{2}[36-16]\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\frac{25}{3}[8]+100[2]+900[2]+\frac{25}{3}[152]-\frac{300}{2}[20]\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\frac{200}{3}+200+1800+\frac{3800}{3}-3000\right\}} \end{aligned}$$

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{8}\left\{\frac{4000}{3}-1000\right\}} \\ &= \sqrt{\frac{1}{8}\left\{\frac{4000-3000}{3}\right\}} \\ &= \sqrt{\frac{1000}{24}} \\ &= 6.46\text{ A} \end{aligned}$$

Therefore, the root mean square value of the current is $\boxed{6.46\text{ A}}$.

Step 1 of 2

Consider Figure P9.47 from the text book.

Define the function for the voltage $v(t)$.

$$v(t)=\begin{cases}1\,\text{V} & 0<t<2\\ 2\,\text{V} & 2<t<4\\ 3\,\text{V} & 4<t<6\\ 0\,\text{V} & 6<t<8\end{cases}$$

Step 2 of 2

Consider the expression for the root mean square voltage.

$$V_{\text{rms}}=\sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Substitute $\begin{cases}1\,\text{V} & 0<t<2\\ 2\,\text{V} & 2<t<4\\ 3\,\text{V} & 4<t<6\\ 0\,\text{V} & 6<t<8\end{cases}$ for $v(t)$ and $8\,\text{sec}$ for T.

$$\begin{aligned}V_{\text{rms}}&=\sqrt{\frac{1}{8}\left\{\int_0^2 1^2dt+\int_2^4 2^2dt+\int_4^6 3^2dt+\int_6^8 0^2dt\right\}}\\&=\sqrt{\frac{1}{8}\left\{\int_0^2 dt+4\int_2^4 dt+9\int_4^6 dt+0\right\}}\\&=\sqrt{\frac{1}{8}\left\{[t]_0^2+4[t]_2^4+9[t]_4^6\right\}}\\&=\sqrt{\frac{1}{8}\left\{[2-0]+4[4-2]+9[6-4]\right\}}\end{aligned}$$

$$\begin{aligned}V_{\text{rms}}&=\sqrt{\frac{1}{8}(2+4(2)+9(2))}\\&=\sqrt{\frac{1}{8}(2+8+18)}\\&=\sqrt{\frac{28}{8}}\\&=1.87\,\text{V}\end{aligned}$$

Therefore, the root mean square value of the voltage is $\boxed{1.87\,\text{V}}$.

Step 1 of 2

9.050P

Consider Figure P9.48 from the text book.

Find the equation for the current between the interval $2 < t < 3$ having end points $(2,2)$ and $(3,0)$.

$$i(t) - 2 = \left(\frac{0-2}{3-2}\right)(t-2) \quad \text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)$$

$$i(t) - 2 = -2t + 4$$
$$i(t) = -2t + 6$$

Therefore, the equation for the current between the interval $2 < t < 3$ is $i(t) = -2t + 6$.

Define the function for the current $i(t)$.

$$i(t) = \begin{cases} 2\text{ A} & 0 < t < 2 \\ 6 - 2t\text{ A} & 2 < t < 3 \\ 0\text{ A} & 3 < t < 4 \end{cases}$$

Step 2 of 2

Consider the expression for the root mean square current.

$$I_{\text{rms}} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases} 2\text{ A} & 0 < t < 2 \\ 6 - 2t\text{ A} & 2 < t < 3 \\ 0\text{ A} & 3 < t < 4 \end{cases}$ for $i(t)$ and 4sec for T.

$$\begin{aligned} I_{\text{rms}} &= \sqrt{\frac{1}{4}\left\{\int_0^2 2^2 dt + \int_2^3 (6-2t)^2 dt + \int_3^4 0^2 dt\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4\int_0^2 dt + \int_2^3 (36 + 4t^2 - 24t)dt + 0\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4\int_0^2 dt + \int_2^3 36dt + \int_2^3 4t^2 dt - \int_2^3 24t dt\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4\int_0^2 dt + 36\int_2^3 dt + 4\int_2^3 t^2 dt - 24\int_2^3 t dt\right\}} \end{aligned}$$

$$\begin{aligned} I_{\text{rms}} &= \sqrt{\frac{1}{4}\left\{4[t]_0^2 + 36[t]_2^3 + 4\left[\frac{t^3}{3}\right]_2^3 - 24\left[\frac{t^2}{2}\right]_2^3\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4[2-0] + 36[3-2] + \frac{4}{3}[27-8] - \frac{24}{2}[9-4]\right\}} \\ &= \sqrt{\frac{1}{4}\left\{4[2] + 36[1] + \frac{4}{3}[19] - 12[5]\right\}} \\ &= \sqrt{\frac{1}{4}\left\{8 + 36 + \frac{76}{3} - 60\right\}} \end{aligned}$$

$$\begin{aligned} I_{\text{rms}} &= \sqrt{\frac{1}{4}\left\{\frac{76-48}{3}\right\}} \\ &= \sqrt{\frac{28}{12}} \\ &= 1.53\text{ A} \end{aligned}$$

Therefore, the root mean square value of the current is $\boxed{1.53\text{ A}}$.

Step 1 of 3

Refer to circuit diagram in Figure P9.56 in the text book.

Find the equation for the voltage between the interval $0 < t < 1$ having end points $(0,0)$ and $(1,4)$.

$$v(t) - 0 = \left(\frac{4-0}{1-0}\right)(t-0) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$v(t) = 4t$$

Therefore, the equation for the voltage between the interval $0 < t < 1$ is $v(t) = 4t$.

Find the equation for the voltage between the interval $1 < t < 2$ having end points $(1,4)$ and $(2,0)$.

$$v(t) - 0 = \left(\frac{4-0}{1-2}\right)(t-2) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$v(t) = -4t + 8$$

Therefore, the equation for the voltage between the interval $1 < t < 2$ is $v(t) = -4t + 8$.

Step 2 of 3

Define the function for the voltage $v(t)$.

$$v(t) = \begin{cases} 4t & 0 < t < 1 \\ -4t + 8 & 1 < t < 2 \\ 0 & 2 < t < 4 \end{cases}$$

Write the expression for the root mean square voltage.

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Substitute $\begin{cases} 4t & 0 < t < 1 \\ -4t + 8 & 1 < t < 2 \\ 0 & 2 < t < 4 \end{cases}$ for $v(t)$ and $4\,\text{sec}$ for T in the equation.

$$\begin{aligned} V_{rms} &= \sqrt{\frac{1}{4}\left\{\int_0^1 (4t)^2 dt + \int_1^2 (-4t+8)^2 dt + \int_2^4 (0)^2 dt\right\}} \\ &= \sqrt{\frac{1}{4}\left\{\int_0^1 16t^2 dt + \int_1^2 (16t^2 + 64 - 64t)dt + 0\right\}} \\ &= \sqrt{\frac{1}{4}\left\{16\int_0^1 t^2 dt + 16\int_1^2 t^2 dt + 64\int_1^2 dt - 64\int_1^2 t dt\right\}} \\ &= \sqrt{\frac{1}{4}\left\{16\left[\frac{t^3}{3}\right]_0^1 + 16\left[\frac{t^3}{3}\right]_1^2 + 64[t]_1^2 - 64\left[\frac{t^2}{2}\right]_1^2\right\}} \end{aligned}$$

Step 3 of 3

On Further simplification:

$$\begin{aligned} V_{rms} &= \sqrt{\frac{1}{4}\left\{\frac{16}{3}[1^3 - 0] + 16\left[\frac{2^3 - 1^3}{3}\right] + 64[2-1] - 64\left[\frac{2^2 - 1^2}{2}\right]\right\}} \\ &= \sqrt{\frac{1}{4}\left\{\frac{16}{3}[1] + 16\left[\frac{8-1}{3}\right] + 64[2-1] - 64\left[\frac{4-1}{2}\right]\right\}} \\ &= \sqrt{\frac{1}{4}\left\{\frac{16}{3} + \frac{112}{3} + 64 - 96\right\}} \\ &= \sqrt{\frac{1}{4}\left\{\frac{128}{3} - 32\right\}} \end{aligned}$$

$$= \sqrt{\frac{1}{4}\left\{\frac{128-96}{3}\right\}}$$

$$= \sqrt{\frac{32}{12}}$$

$$= 1.63\text{ V}$$

Therefore, the root mean square value of the voltage is $\boxed{1.63\text{ V}}$.

Step 1 of 3

Refer to circuit diagram in Figure P9.57 in the text book.

Find the equation for the current between the interval $0 < t < 2$ having end points $(0,0)$ and $(2,4)$.

$$i(t) - 0 = \left(\frac{4-0}{2-0}\right)(t-0) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$i(t) = 2t$$

Therefore, the equation for the current between the interval $0 < t < 2$ is $i(t) = 2t$.

Define the function for the current $i(t)$.

$$i(t) = \begin{cases} 2t & 0 < t < 2 \\ -4 & 2 < t < 4 \end{cases}$$

Step 2 of 3

Write the expression for the root mean square current.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases} 2t & 0 < t < 2 \\ -4 & 2 < t < 4 \end{cases}$ for $i(t)$ and $4\,\text{sec}$ for T in the equation.

$$I_{rms} = \sqrt{\frac{1}{4}\left\{\int_0^2 (2t)^2 dt + \int_2^4 (-4)^2 dt\right\}}$$

$$= \sqrt{\frac{1}{4}\left\{4\int_0^2 t^2 dt + 16\int_2^4 dt\right\}}$$

$$= \sqrt{\frac{1}{4}\left\{4\left[\frac{t^3}{3}\right]_0^2 + 16[t]_2^4\right\}}$$

$$= \sqrt{\frac{1}{4}\left\{4\left[\frac{2^3 - 0}{3}\right] + 16[4-2]\right\}}$$

$$= \sqrt{\frac{1}{4}\left\{\frac{32}{3} + 32\right\}}$$

$$= \sqrt{\frac{1}{4}\left\{\frac{32+96}{3}\right\}}$$

$$= \sqrt{\frac{128}{12}}$$

$$= 3.27\text{ A}$$

Therefore, the root mean square value of the current is 3.27 A.

Step 3 of 3

Consider the expression for the power dissipated in $5\,\Omega$ resistor.

$$P_{5\Omega} = I^2_{rms}(5)$$

Substitute 3.27 A for I_{rms} in the equation.

$$P_{5\Omega} = (3.27)^2(5)$$

$$= 53.47\text{ W}$$

Therefore, the value of the power dissipated in the resistor is $\boxed{53.47\text{ W}}$.

Step 1 of 3

9.053P

Refer to circuit diagram in Figure P9.58 in the text book.

Find the equation for the current between the interval $0 < t < 1$ having end points $(0,-2)$ and $(1,0)$.

$$i(t) - 0 = \left(\frac{-2-0}{0-1}\right)(t-1) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$i(t) = 2t - 2$$

Therefore, the equation for the current between the interval $0 < t < 1$ is $i(t) = 2t - 2$.

Define the function for the current $i(t)$.

$$i(t) = \begin{cases} 2t-2 & 0 < t < 1 \\ 1 & 1 < t < 2 \\ 0 & 2 < t < 3 \end{cases}$$

Step 2 of 3

Write the expression for the root mean square current.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

Substitute $\begin{cases} 2t-2 & 0 < t < 1 \\ 1 & 1 < t < 2 \\ 0 & 2 < t < 3 \end{cases}$ for $i(t)$ and $3\,\text{sec}$ for T in the equation.

$$I_{rms} = \sqrt{\frac{1}{3}\left\{\int_0^1 (2t-2)^2 dt + \int_1^2 (1)^2 dt + \int_2^3 (0)^2 dt + \right\}}$$

$$= \sqrt{\frac{1}{3}\left\{\int_0^1 (4t^2 + 4 - 8t)dt + \int_1^2 dt + 0\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{4\int_0^1 t^2 dt + 4\int_0^1 dt - 8\int_0^1 t dt + \int_1^2 dt\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{4\left[\frac{t^3}{3}\right]_0^1 + 4[t]_0^1 - 8\left[\frac{t^2}{2}\right]_0^1 + 1[t]_1^2\right\}}$$

Step 3 of 3

On further simplification:

$$I_{rms} = \sqrt{\frac{1}{3}\left\{\frac{4}{3}[1-0] + 4[1-0] - 8\left[\frac{1-0}{2}\right] + [2-1]\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{\frac{4}{3}[1] + 4[1] - 4[1] + 1\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{\frac{4}{3} + 1\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{\frac{4+3}{3}\right\}}$$

$$= \sqrt{\frac{1}{3}\left\{\frac{7}{3}\right\}}$$

$$= \sqrt{\frac{7}{9}}$$

$$= 0.88\text{ A}$$

Therefore, the root mean square value of the current is $\boxed{0.88\text{ A}}$.

Step 1 of 3

9.054P

Refer to circuit diagram in Figure P9.55 in the text book.

Find the equation for the current between the interval $0 < t < 1$ having end points $(0,0)$ and $(1,2)$.

$$i(t) - 0 = \left(\frac{2-0}{1-0}\right)(t-0) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$i(t) = 2t$$

Therefore, the equation for the current between the interval $0 < t < 1$ is $i(t) = 2t$.

Find the equation for the current between the interval $1 < t < 2$ having end points $(1,-2)$ and $(2,0)$.

$$i(t) - 0 = \left(\frac{-2-0}{1-2}\right)(t-2) \qquad \left[\text{since } y - y_1 = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - y)\right]$$

$$i(t) = 2t - 4$$

Therefore, the equation for the current between the interval $3 < t < 4$ is $i(t) = 2t - 4$.

Step 2 of 3

Define the function for the current $i(t)$.

$$i(t) = \begin{cases} 2t & 0 < t < 1 \\ 2t - 4 & 1 < t < 2 \\ 0 & 2 < t < 3 \end{cases}$$

Write the expression for the root mean square current.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$$

Substitute $\begin{cases} 2t & 0 < t < 1 \\ 2t - 4 & 1 < t < 2 \\ 0 & 2 < t < 3 \end{cases}$ for $i(t)$ and $3\,\text{sec}$ for T in the equation.

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{3}\left\{\int_0^1 (2t)^2\,dt + \int_1^2 (2t-4)^2\,dt + \int_2^3 (0)^2\,dt + \right\}} \\ &= \sqrt{\frac{1}{3}\left\{\int_0^1 4t^2\,dt + \int_1^2 \left(4t^2 + 16 - 16t\right)dt + 0\right\}} \\ &= \sqrt{\frac{1}{3}\left\{4\int_0^1 t^2\,dt + 4\int_1^2 t^2\,dt + 16\int_1^2 dt - 16\int_1^2 t\,dt\right\}} \\ &= \sqrt{\frac{1}{3}\left\{4\left[\frac{t^3}{3}\right]_0^1 + 4\left[\frac{t^3}{3}\right]_1^2 + 16[t]_1^2 - 16\left[\frac{t^2}{2}\right]_1^2\right\}} \end{aligned}$$

Step 3 of 3

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{3}\left\{\frac{4}{3}\left[1^3 - 0\right] + 4\left[\frac{2^3 - 1^3}{3}\right] + 16[2-1] - 8\left[2^2 - 1^2\right]\right\}} \\ &= \sqrt{\frac{1}{3}\left\{\frac{4}{3}[1] + 4\left[\frac{8-1}{3}\right] + 16[1] - 8[4-1]\right\}} \\ &= \sqrt{\frac{1}{3}\left\{\frac{4}{3} + \frac{28}{3} + 16 - 24\right\}} \\ &= \sqrt{\frac{1}{3}\left\{\frac{32}{3} - 8\right\}} \end{aligned}$$

$$= \sqrt{\frac{1}{3}\left\{\frac{32-24}{3}\right\}}$$

$$= \sqrt{\frac{8}{9}}$$

$$= 0.942\ \text{A}$$

Therefore, the root mean square value of the current is $\boxed{0.942\ \text{A}}$.

The formula to calculate the rms value of voltage is,

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

Here,

T is the time period that is 1 sec.

Calculate the rms value for the voltage expression.

$$\begin{aligned}
V_{rms} &= \left[\int_0^1 \left(\cos t + \cos(t+120°)\right)^2 dt\right]^{\frac{1}{2}} \\
&= \left[\int_0^1 \left(\cos^2 t + \cos^2(t+120°) + 2\cos t\cos(t+120°)\right)dt\right]^{\frac{1}{2}} \\
&= \left[\int_0^1 \left(\frac{1+\cos 2t}{2}\right)dt + \int_0^1 \left(\frac{1+\cos 2(t+120°)}{2}\right)dt + \int_0^1 \left(\cos(2t+120°) + \cos(120°)\right)dt\right]^{\frac{1}{2}}
\end{aligned}$$

The average value of cosine wave is zero.

The value of rms voltage, V_{rms} is,

$$\begin{aligned}
V_{rms} &= \left[\int_0^1 \frac{1}{2}dt + \int_0^1 \frac{1}{2}dt\right]^{\frac{1}{2}} \\
&= \left[\frac{1}{2}(1+1)\right]^{\frac{1}{2}} \\
&= 1\text{ V}
\end{aligned}$$

Therefore, the rms value of the voltage is, $\boxed{1\text{ V}}$.

Step 1 of 2

9.056P

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 2

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 3

Step 2 of 3

The waveform is periodic with period $T = 8s$.
The equation for current in the time frame $0 \le t \le 8s$ is:

$$i(t) = \begin{cases} 4A \ldots\ldots\ldots\ldots\ldots 0 < t \le 2s \\ -2A \ldots\ldots\ldots\ldots 2 < t \le 3s \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots 3 < t \le 5s \\ 2A \ldots\ldots\ldots\ldots\ldots 5 < t \le 7s \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots 7 < t \le 8s \end{cases}$$

Step 3 of 3

The rms value is:

$$I_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} i^2(t)dt}$$

$$I_{rms} = \left\{\frac{1}{8}\left[\int_0^2 (4)^2 dt + \int_2^3 (-2)^2 dt + \int_3^5 (0)^2 dt + \int_5^7 (2)^2 dt + \int_7^8 (0)^2 dt\right]\right\}^{\frac{1}{2}}$$

$$I_{rms} = \left\{\frac{1}{8}\left[16|t|_0^2 + 4|t|_2^3 + 0 + 4|t|_5^7 + 0\right]\right\}^{\frac{1}{2}}$$

$$I_{rms} = \left\{\frac{1}{8}\left[16(2-0) + 4(3-2) + 4(7-5)\right]\right\}^{\frac{1}{2}}$$

$$I_{rms} = \sqrt{\frac{44}{8}}$$

$$\boxed{I_{rms} = 2.345A}$$

Step 1 of 3

Refer to Figure P9.49 in the text book.

The waveform is periodic with period $T = 4\text{ s}$.

Consider the formula for straight line equation for two points (x_1, y_1) and (x_2, y_2).

$$(y - y_1) = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

Where,

$$y = v(t)$$
$$x = t$$

Step 2 of 3

For $0 \le t < 2\text{ s}$, calculate the straight line equation of points $(0,0)$ and $(2,6)$.

$$(y - 0) = \frac{6-0}{2-0}(x - 0)$$
$$y = \frac{6}{2}x$$
$$y = 3x$$
$$v(t) = 3t \qquad \text{for } 0 \le t < 2\text{ s}$$

Therefore, the equation for the voltage during the time $0 \le t \le 4\text{s}$ is,

$$v(t) = \begin{cases} 3t\text{ V} & 0 < t \le 2\text{ s} \\ 6\text{ V} & 2\text{ s} < t \le 3\text{ s} \\ 0\text{ V} & 3\text{ s} < t \le 4\text{ s} \end{cases}$$

Step 3 of 3

Calculate the rms value of voltage waveform.

$$v_{rms} = \left\{\frac{1}{4}\left[\int_0^2 (3t)^2\,dt + \int_2^3 (6)^2\,dt + \int_3^4 (0)^2\,dt\right]\right\}^{1/2}$$
$$= \left\{\frac{1}{4}\left[9\int_0^2 t^2\,dt + 36\int_2^3 (1)\,dt + 0\right]\right\}^{1/2}$$
$$= \left\{\frac{1}{4}\left[9\left[\frac{t^3}{3}\right]_0^2 + 36\,[t]_2^3\right]\right\}^{1/2}$$
$$= \left\{\frac{1}{4}\left[9\left[\frac{8}{3} - 0\right] + 36[3-2]\right]\right\}^{1/2}$$
$$= \left\{\frac{1}{4}[24 + 36]\right\}^{1/2}$$
$$= [15]^{1/2}$$
$$= 3.87\text{ V}$$

Therefore, the rms value of voltage waveform, v_{rms} is $\boxed{3.87\text{ V}}$.

Step 1 of 3

Step 2 of 3

The waveform is periodic with period $T = 4s$.
The equation for voltage in the time frame $0 \le t \le 4s$ is:

$$v(t) = \begin{cases} 3t & \text{.....} 0 < t \le 1s \\ -t+4 & \text{.....} 1 < t \le 4s \end{cases}$$

Step 3 of 3

The rms value is:

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2(t)\,dt}$$

$$V_{rms} = \left\{\frac{1}{4}\left[\int_0^1 (3t)^2\,dt + \int_1^4 (-t+4)^2\,dt\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{4}\left[9\int_0^1 t^2 dt + \int_1^4 \left(t^2+16-8t\right)dt\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{4}\left[9\frac{t^3}{3}\Big|_0^1 + \frac{t^3}{3}\Big|_1^4 + 16t\Big|_1^4 - 8\frac{t^2}{2}\Big|_1^4\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{4}\left[3(1-0)+\frac{1}{3}(64-1)+16(4-1)-4(16-1)\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{4}\left[3+\frac{63}{3}+48-60\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{4}\left[\frac{63}{3}-9\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \sqrt{3}$$

$$\boxed{V_{rms} = 1.73V}$$

Step 1 of 2

Refer to Figure P9.60 in the textbook.

The current waveform has a period of 4sec.

The current expressions, $i(t)$ for the current waveform in Figure P9.60 is,

$$i(t)=\begin{cases}2t, & 0<t<1\\ 2, & 1<t<2\\ 4, & 2<t<3\\ 0, & 3<t<4\end{cases}$$

Calculate the rms value of the current.

$$\begin{aligned}I_{rms}&=\left[\frac{1}{4}\left(\int_0^4\left(i(t)^2\right)dt\right)\right]^{\frac{1}{2}}\\&=\left[\frac{1}{4}\left(\int_0^1 4t^2dt+\int_1^2 4dt+\int_2^3 16dt+\int_3^4 0dt\right)\right]^{\frac{1}{2}}\\&=\left[\frac{1}{4}\left(\frac{4t^3}{3}\right)\Big|_0^1+\frac{1}{4}(4t)\Big|_1^2+\frac{1}{4}(16t)\Big|_2^3\right]^{\frac{1}{2}}\\&=\left[\left(\frac{1-0}{3}\right)+(2-1)+4(3-2)\right]^{\frac{1}{2}}\\&=\left[\frac{1}{3}+1+4\right]^{\frac{1}{2}}\\&=2.31\text{ A}\end{aligned}$$

Step 2 of 2

Calculate the average power absorbed by a $4-\Omega$ resistor.

$$\begin{aligned}P&=I_{rms}^2R\\&=(2.31)^2(4)\\&=(5.333)(4)\\&=21.33\text{ W}\end{aligned}$$

Therefore, the average power absorbed by a $4-\Omega$ resistor for the current, $i(t)$, passing through it is $\boxed{21.33\text{ W}}$.

Step 1 of 2

Refer to the Figure P9.61 in the text book.

Write the expression of current.

$$i(t)=\begin{cases} t & 0\le t<2 \\ 1 & 2\le t<4 \\ 2 & 4\le t<6 \end{cases}$$

The time period of the current wave form is, $T=6s$

Determine the RMS value of current.

$$\begin{aligned} I_{\text{eff}} &= \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \\ &= \sqrt{\frac{1}{6}\left(\int_0^2 (t)^2\,dt+\int_2^4 (1)^2\,dt+\int_4^6 (2)^2\,dt\right)} \\ &= \sqrt{\frac{1}{6}\left[\frac{t^3}{3}\right]_0^2+\frac{1}{6}[t]_2^4+\frac{4}{6}[t]_4^6} \\ &= \sqrt{\frac{1}{18}[8-0]+\frac{1}{6}[4-2]+\frac{4}{6}[6-4]} \end{aligned}$$

$$\begin{aligned} &= \sqrt{\frac{8}{18}+\frac{2}{6}+\frac{8}{6}} \\ &= 1.45\,\text{A} \end{aligned}$$

Step 2 of 2

Determine the average power delivered to 12Ω resistor.

$$P=(I_{\text{eff}})^2 R$$

Substitute 1.45 A for I_{eff} and 12Ω for *R*.

$$\begin{aligned} P &= (1.45\,\text{A})^2(12\Omega) \\ &= 25.23\,\text{W} \end{aligned}$$

Therefore, the average power delivered to 12Ω resistor is $\boxed{25.23\,\text{W}}$.

Step 1 of 2

Refer to the Figure P9.62 (a) in the text book.

Determine the equation of current wave form in the interval $0 < t < 1$:

Determine the equation of line between $(0,0)$ and $(1,4)$.

$$i(t) - 0 = \left(\frac{4-0}{1-0}\right)(t-0)$$
$$i(t) = 4t$$

Write the expression of current.

$$i(t) = \begin{cases} 4t & 0 \le t < 1 \\ 4 & 1 \le t < 2 \\ 2 & 2 \le t < 3 \\ 0 & 3 \le t < 4 \end{cases}$$

The time period of the current wave form is, $T = 4\,s$

Determine the RMS value of current.

$$\begin{aligned} I_{\text{eff}} &= \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \\ &= \sqrt{\frac{1}{4}\left(\int_0^1 (4t)^2\,dt + \int_1^2 (4)^2\,dt + \int_2^3 (2)^2\,dt + \int_3^4 (0)^2\,dt\right)} \\ &= \sqrt{\frac{16}{4}\left[\frac{t^3}{3}\right]_0^1 + \frac{16}{4}[t]_1^2 + \frac{4}{4}[t]_2^3} \\ &= \sqrt{\frac{16}{12}[1-0] + \frac{16}{4}[2-1] + \frac{4}{4}[3-2]} \end{aligned}$$

$$= \sqrt{\frac{16}{12} + \frac{16}{4} + 1}$$
$$= 2.51\,\text{A}$$

Step 2 of 2

Refer to the Figure P9.62 (b) in the text book.

The resistors 2Ω and 4Ω are in series.

Determine the equivalent resistance.

$$\begin{aligned} R &= 2\Omega + 4\Omega \\ &= 6\Omega \end{aligned}$$

Determine the average power delivered to 6Ω resistor.

$$P = (I_{\text{eff}})^2 R$$

Substitute 2.51 A for I_{eff} and 6Ω for *R*.

$$\begin{aligned} P &= (2.51\,\text{A})^2 (6\Omega) \\ &= 37.8\,\text{W} \end{aligned}$$

Therefore, the average power observed by the network is $\boxed{37.8\,\text{W}}$.

Step 1 of 2

9.063P

Refer to the Figure P9.62 (a) in the text book.

Determine the equation of current wave form in the interval $1 < t < 2$:

Determine the equation of line between $(1,1)$ and $(2,2)$.

$$i(t) - 1 = \left(\frac{2-1}{2-1}\right)(t-1)$$
$$i(t) = t$$

Write the expression of current.

$$i(t) = \begin{cases} 1 & 0 \le t < 1 \\ t & 1 \le t < 2 \\ 2 & 2 \le t < 3 \\ 1 & 3 \le t < 4 \\ 0 & 4 \le t < 5 \end{cases}$$

The time period of the current wave form is, $T = 5s$

Determine the RMS value of current.

$$\begin{aligned} I_{\text{eff}} &= \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \\ &= \sqrt{\frac{1}{5}\left(\int_0^1 (1)^2\,dt + \int_1^2 (t)^2\,dt + \int_2^3 (2)^2\,dt + \int_3^4 (1)^2\,dt + + \int_4^5 (0)^2\,dt\right)} \\ &= \sqrt{\frac{1}{5}[t]_0^1 + \frac{1}{5}\left[\frac{t^3}{3}\right]_1^2 + \frac{4}{5}[t]_2^3 + \frac{1}{5}[t]_3^4 + 0} \\ &= \sqrt{\frac{1}{5}[1-0] + \frac{1}{15}[8-1] + \frac{4}{5}[3-2] + \frac{1}{5}[4-3] + 0} \\ &= \sqrt{\frac{1}{5} + \frac{7}{15} + \frac{4}{5} + \frac{1}{5}} \\ &= 1.29\,\text{A} \end{aligned}$$

Step 2 of 2

Refer to the Figure P9.62 (a) in the text book.

The resistors 3Ω and 6Ω are in series.

Determine the equivalent resistance.

$$\begin{aligned} R &= 3\Omega + 6\Omega \\ &= 9\Omega \end{aligned}$$

Determine the average power delivered to 9Ω resistor.

$$P = (I_{\text{eff}})^2 R$$

Substitute 1.29 A for I_{eff} and 9Ω for *R*.

$$\begin{aligned} P &= (1.29\,\text{A})^2 (9\Omega) \\ &= 14.97\,\text{W} \end{aligned}$$

Therefore, the average power observed by the network is $\boxed{14.97\,\text{W}}$.

Step 1 of 4

Refer to the Figure P9.64 (b) in the text book.

Determine the equation of current wave form in the interval $0 < t < 1$:

Determine the equation of line between $(0,0)$ and $(1,2)$.

$$i(t) - 0 = \left(\frac{2-0}{1-0}\right)(t-0)$$
$$i(t) = 2t$$

Write the expression of current.

$$i(t) = \begin{cases} 2t & 0 \le t < 1 \\ 2 & 1 \le t < 2 \end{cases}$$

The time period of the current wave form is, $T = 2s$

Determine the RMS value of current.

$$\begin{aligned} I_{\text{eff}} &= \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \\ &= \sqrt{\frac{1}{2}\left(\int_0^1 (2t)^2\,dt + \int_1^2 (2)^2\,dt\right)} \\ &= \sqrt{\frac{1}{2}\left(4\left[\frac{t^3}{3}\right]_0^1 + 4[t]_1^2\right)} \\ &= \sqrt{\frac{4}{2}\left(\frac{1}{3}[1-0] + [2-1]\right)} \\ &= \sqrt{\frac{4}{2}\left(\frac{4}{3}\right)} \\ &= 1.63\,\text{A} \end{aligned}$$

Step 2 of 4

Refer to the Figure P9.64 (a) in the text book.

Draw the following modified circuit diagram.

Figure 1

Step 3 of 4

The resistors 3Ω and 6Ω are in parallel.

$$\begin{aligned} 3\Omega \| 6\Omega &= \frac{(3\Omega)(6\Omega)}{3\Omega + 6\Omega} \\ &= \frac{18\Omega}{9} \\ &= 2\Omega \end{aligned}$$

The resistors 9Ω and 18Ω are in parallel.

$$\begin{aligned} 9\Omega \| 18\Omega &= \frac{(9\Omega)(18\Omega)}{9\Omega + 18\Omega} \\ &= \frac{162\Omega}{27} \\ &= 6\Omega \end{aligned}$$

Determine the equivalent resistance.

$$\begin{aligned} R &= 2\Omega + 6\Omega \\ &= 8\Omega \end{aligned}$$

Step 4 of 4

Determine the average power delivered to 9Ω resistor.

$$P = (I_{\text{eff}})^2 R$$

Substitute 1.63 A for I_{eff} and 9Ω for *R*.

$$\begin{aligned} P &= (1.63\,\text{A})^2 (9\Omega) \\ &= 23.91\,\text{W} \end{aligned}$$

Therefore, the average power observed by the network is $\boxed{23.91\,\text{W}}$.

Consider the expression for load voltage V_{rms}.

$$V_{rms} = \frac{P}{I_{rms}(\text{pf})}$$

Substitute $100\,\text{kW}$ for P, 0.9 for pf and $200\,\text{A rms}$ for I_{rms}.

$$\begin{aligned} V_{rms} &= \frac{100\,\text{k}}{(200)(0.9)} \\ &= \frac{100\,\text{k}}{180} \\ &= 555.56\,\text{V rms} \end{aligned}$$

Therefore, the value of the load voltage is $\boxed{555.56\,\text{V rms}}$.

Step 1 of 1

Consider the expression for the power factor.

$$\text{pf} = \frac{P}{V_{\text{rms}} I_{\text{rms}}}$$

Substitute $50\,\text{kW}$ for P, $240\,\text{V rms}$ for V_{rms} and $250\,\text{A rms}$ for I_{rms}.

$$\begin{aligned}\text{pf} &= \frac{50\,\text{k}}{(240)(250)} \\ &= \frac{50\,\text{k}}{60\,\text{k}} \\ &= 0.833\end{aligned}$$

Therefore, the value of the load power factor is $\boxed{0.833}$.

Step 1 of 2

Consider the expression for the power loss in the lines in terms of current and the line impedance.

$$P_{\text{Line}} = I_{rms}^2 R_{\text{Line}}$$

Substitute $560\ \text{W}$ for P_{Line} and $0.08\ \Omega$ for R_{Line}.

$$560 = I_{rms}^2 (0.08)$$

$$I_{rms}^2 = \frac{560}{0.08}$$

$$I_{rms}^2 = 7\ \text{k}$$

$$I_{rms} = \sqrt{7\ \text{k}}$$

$$I_{rms} = 83.67\ \text{A rms}$$

Therefore, the value of the ammeter reading is $83.67\ \text{A rms}$.

Step 2 of 2

Consider the expression for the power factor.

$$\text{pf} = \frac{P}{V_{\text{rms}} I_{\text{rms}}}$$

Substitute $12\ \text{kW}$ for P, $220\ \text{V rms}$ for V_{rms} and $83.67\ \text{A rms}$ for I_{rms}.

$$\begin{aligned}\text{pf} &= \frac{12\ \text{k}}{(220)(83.67)} \\ &= \frac{12\ \text{k}}{18.41\ \text{k}} \\ &= 0.652\end{aligned}$$

Therefore, the value of the load power factor is $\boxed{0.652}$.

Step 1 of 2

Consider the expression for power absorbed by the load voltage.

$$P_L = V_{rms} I_{rms} (\text{pf})$$

Substitute 440 V rms for V_{rms}, 0.8 for pf and 220 A rms for I_{rms}.

$$\begin{aligned} P_L &= (440)(220)(0.8) \\ &= 77.44\text{ kW} \end{aligned}$$

Therefore, the value of the power absorbed by the load is 77.44 kW.

Step 2 of 2

Consider the expression for the power loss in the lines.

$$P_{Line} = P_S - P_L$$

Substitute 80 kW for P_S and 77.44 kW for P_L.

$$\begin{aligned} P_{Line} &= 80\text{ k} - 77.44\text{ kW} \\ &= 2.56\text{ kW} \end{aligned}$$

Therefore, the value of the power loss in the lines $\boxed{2.56\text{ kW}}$.

Step 1 of 3

Consider the expression for the power loss in the lines.

$$P_{\text{Line}} = P_{\text{S}} - P_{\text{L}}$$

Substitute $44\,\text{kW}$ for P_{S} and $40\,\text{kW}$ for P_{L}.

$$\begin{aligned} P_{\text{Line}} &= 44\,\text{k} - 40\,\text{k} \\ &= 4\,\text{kW} \end{aligned}$$

Therefore, the value of the power loss in the lines $4\,\text{kW}$.

Step 2 of 3

Consider the expression for the power loss in the lines in terms of current and the line impedance.

$$P_{\text{Line}} = I_{rms}^2 R_{\text{Line}}$$

Substitute $4\,\text{kW}$ for P_{Line} and $0.1\,\Omega$ for R_{Line}.

$$\begin{aligned} 4\,\text{k} &= I_{rms}^2 (0.1) \\ I_{rms}^2 &= \frac{4\,\text{k}}{0.1} \\ I_{rms}^2 &= 40\,\text{k} \\ I_{rms} &= \sqrt{40\,\text{k}} \\ I_{rms} &= 200\,\text{A rms} \end{aligned}$$

Therefore, the value of the ammeter reading is $200\,\text{A rms}$.

Step 3 of 3

Consider the expression for the power factor at the load.

$$\text{pf} = \frac{P_{\text{L}}}{V_{\text{rms}} I_{\text{rms}}}$$

Substitute $40\,\text{kW}$ for P_{L}, $240\,\text{V rms}$ for V_{rms} and $200\,\text{A rms}$ for I_{rms}.

$$\begin{aligned} \text{pf} &= \frac{40\,\text{k}}{(240)(200)} \\ &= \frac{40\,\text{k}}{48\,\text{k}} \\ &= 0.83 \end{aligned}$$

Therefore, the value of the load power factor at the load is $\boxed{0.83}$.

Step 1 of 7

Consider Figure 1.

Figure 1

Step 2 of 7

Consider the expression for load current I_{rms}.

$$I_{rms} = \frac{P}{V_{rms}(\text{pf})}$$

Substitute $30\,\text{kW}$ for P, 0.8 for pf and 240 V rms for V_{rms}.

$$\begin{aligned} I_{rms} &= \frac{30\,\text{k}}{(240)(0.8)} \\ &= \frac{30\,\text{k}}{192} \\ &= 156.25\text{ A rms} \end{aligned}$$

Therefore, the magnitude value of the load current is 156.25 A rms.

Step 3 of 7

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.8 for pf.

$$\begin{aligned} \theta &= \cos^{-1}(0.8) \\ &= 36.87° \end{aligned}$$

Therefore, the power factor angle at the load is $36.87°$.

Step 4 of 7

Consider the expression for power factor angle.

$$\theta = \angle V_{rms} - \angle I_{rms}$$

Substitute $36.87°$ for θ and $0°$ for $\angle V_{rms}$.

$$\begin{aligned} 35.87° &= 0° - \angle I_{rms} \\ \angle I_{rms} &= 0° - 36.87° \\ \angle I_{rms} &= -36.87° \end{aligned}$$

Therefore, the phase angle of the load current is $-36.87°$.

Hence, the phasor value of the load current is $156.25\angle -36.87°\text{ A rms}$.

Step 5 of 7

Consider the expression for the real power loss in the lines.

$$P_{Linc} = I_{rms}^2 R_{Linc}$$

Substitute $1.8\,\text{kW}$ for P_{Linc} and 156.25 A rms for I_{rms}.

$$\begin{aligned} 1.8\,\text{k} &= (156.25)^2 R_{Linc} \\ R_{Linc} &= \frac{1.8\,\text{k}}{(156.25)^2} \\ R_{Linc} &= \frac{1.8\,\text{k}}{24.41\,\text{k}} \\ R_{Linc} &= 0.074\,\Omega \end{aligned}$$

Therefore, the real value of the impedance of the lines is $0.074\,\Omega$.

Step 6 of 7

Consider the expression for the real power loss in the lines.

$$Q_{Linc} = I_{rms}^2 X_{Linc}$$

Substitute $2.4\,\text{kVA}$ for Q_{Linc} and 156.25 A rms for I_{rms}.

$$\begin{aligned} 2.4\,\text{k} &= (156.25)^2 X_{Linc} \\ X_{Linc} &= \frac{2.4\,\text{k}}{(156.25)^2} \\ X_{Linc} &= \frac{2.4\,\text{k}}{24.41\,\text{k}} \\ X_{Linc} &= 0.098\,\Omega \end{aligned}$$

Therefore, the complex value of the impedance of the lines is $0.098\,\Omega$.

Hence, the overall impedance value of the transmission lines is $\boxed{0.074 + j0.098\,\Omega}$.

Step 7 of 7

Consider the expression for the source voltage.

$$\mathbf{V}_S = I_{rms} Z_{Linc} + \mathbf{V}_L$$

Substitute $156.25\angle -36.87°\text{ A rms}$ for I_{rms}, $0.074 + j0.098\,\Omega$ for Z_{Linc} and $240\angle 0°\text{ V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned} \mathbf{V}_S &= (156.25\angle -36.87°)(0.074 + j0.098) + 240\angle 0° \\ &= (156.25\angle -36.87°)(0.123\angle 52.94°) + 240\angle 0° \\ &= 19.22\angle 16.07° + 240\angle 0° \\ &= 258.52\angle 1.18°\text{ V rms} \end{aligned}$$

Therefore, the value of the source voltage is $\boxed{258.52\angle 1.18°\text{ V rms}}$.

Step 1 of 3

Step 2 of 3

The waveform is periodic with period $T = 6s$.
The equation for voltage in the time frame $0 \le t \le 6s$ is:

$$v(t) = \begin{cases} -4 & \text{.....} 0 < t \le 2s \\ -2t+8 & \text{.....} 2 < t \le 4s \\ 0 & \text{.....} 4 < t \le 6s \end{cases}$$

Step 3 of 3

The rms value is:

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2(t)dt}$$

$$V_{rms} = \left\{\frac{1}{6}\left[\int_0^2 (-4)^2\,dt + \int_2^4 (-2t+8)^2\,dt + \int_4^6 (0)^2\,dt\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{6}\left[16\int_0^2 (1)\,dt + \int_2^4 \left(4t^2+64-32t\right)dt + \int_4^6 (0)^2\,dt\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{6}\left[16\left|t\right|_0^2 + 4\left|\frac{t^3}{3}\right|_2^4 + 64\left|t\right|_2^4 - 32\left|\frac{t^2}{2}\right|_2^4 + 0\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{6}\left[16(2-0) + \frac{4}{3}(64-8) + 64(4-2) - 16(16-4)\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{6}\left[32 + \frac{224}{3} + 128 - 192\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \left\{\frac{1}{6}\left[\frac{224}{3} - 32\right]\right\}^{\frac{1}{2}}$$

$$V_{rms} = \sqrt{\frac{128}{18}}$$

$$\boxed{V_{rms} = 2.67\text{V}}$$

Step 1 of 2

Step 2 of 2

Power consumed at the load, $P_L = 100\text{kW}$

Load power factor, $pf = 0.8$

Load current, $I_{rms} = 200\text{A rms}$

Therefore, load voltage, $V_L = \dfrac{P_L}{(pf)I_{rms}}$

$$V_L = \frac{100\times10^3}{0.8\times200}$$

$$\boxed{V_L = 625\,\text{V rms}}$$

9.073P

Refer to circuit diagram in Figure P9.59 in the text book.

Consider the expression for the power factor.

$$\text{pf} = \frac{P}{V_{\text{rms}} I_{\text{rms}}}$$

Substitute $90\,\text{kW}$ for P , $480\,\text{V rms}$ for V_{rms} and $260\,\text{A rms}$ for I_{rms} in the equation.

$$\begin{aligned}\text{pf} &= \frac{90\text{ k}}{(480)(260)} \\ &= \frac{90\text{ k}}{124.8\text{ k}} \\ &= 0.7211\end{aligned}$$

Therefore, the value of the total power factor is $\boxed{0.7211}$.

9.074P

Refer to circuit diagram in Figure P9.59 in the text book.

Consider the expression for V_{rms} .

$$V_{rms} = \frac{P}{I_{rms}(\text{pf})}$$

Substitute $110\,\text{kW}$ for P , 0.88 for pf and 252 A rms for I_{rms} in the equation.

$$\begin{aligned} V_{rms} &= \frac{110\,\text{k}}{(252)(0.88)} \\ &= \frac{110\,\text{k}}{221.76} \\ &= 496.03\text{ V} \end{aligned}$$

Therefore, the value of the voltmeter reading is $\boxed{496.03\text{ V rms}}$.

Step 1 of 3

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.9 for pf.

$$\begin{aligned}\theta &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the angle by which the load voltage leads the load current is $\boxed{25.84°}$.

Step 2 of 3

Consider the expression for load current I_{rms}.

$$I_{\text{rms}} = \frac{P}{V_{\text{rms}}(\text{pf})}$$

Substitute $20\,\text{kW}$ for P, 0.9 for pf and $240\,\text{V rms}$ for V_{rms}.

$$\begin{aligned}I_{\text{rms}} &= \frac{20\,\text{k}}{(240)(0.9)}\\ &= \frac{20\,\text{k}}{216}\\ &= 92.59\,\text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current is $92.59\,\text{A rms}$.

Step 3 of 3

Consider the expression for power factor angle.

$$\theta = \angle V_{\text{rms}} - \angle I_{\text{rms}}$$

Substitute $25.84°$ for θ and $0°$ for $\angle V_{\text{rms}}$.

$$\begin{aligned}25.84° &= 0° - \angle I_{\text{rms}}\\ \angle I_{\text{rms}} &= 0° - 25.84°\\ \angle I_{\text{rms}} &= -25.84°\end{aligned}$$

Therefore, the phase angle of the load current is $-25.84°$.

Hence, the phasor value of the load current is $\boxed{92.59\angle -25.84°\,\text{A rms}}$.

Step 1 of 3

Consider the expression for the power loss in the lines.

$$P_{\text{Line}} = P_{\text{S}} - P_{\text{L}}$$

Substitute $100\,\text{kW}$ for P_{S} and $94\,\text{kW}$ for P_{L}.

$$\begin{aligned} P_{\text{Line}} &= 100\,\text{k} - 94\,\text{k} \\ &= 6\,\text{kW} \end{aligned}$$

Therefore, the value of the power loss in the lines $6\,\text{kW}$.

Step 2 of 3

Consider the expression for the power loss in the lines in terms of current and the line impedance.

$$P_{\text{Line}} = I_{rms}^2 R_{\text{Line}}$$

Substitute $6\,\text{kW}$ for P_{Line} and $0.09\,\Omega$ for R_{Line}.

$$\begin{aligned} 6\,\text{k} &= I_{rms}^2 (0.09) \\ I_{rms}^2 &= \frac{6\,\text{k}}{0.09} \\ I_{rms}^2 &= 66.67\,\text{k} \\ I_{rms} &= \sqrt{66.67\,\text{k}} \\ I_{rms} &= 258.21\,\text{A rms} \end{aligned}$$

Therefore, the value of the ammeter reading is $258.21\,\text{A rms}$.

Step 3 of 3

Consider the expression for load voltage V_{rms}.

$$V_{\text{rms}} = \frac{P}{I_{\text{rms}}(\text{pf})}$$

Substitute $94\,\text{kW}$ for P, 0.83 for pf and $258.21\,\text{A rms}$ for I_{rms}.

$$\begin{aligned} V_{\text{rms}} &= \frac{94\,\text{k}}{(258.21)(0.83)} \\ &= \frac{94\,\text{k}}{214.31} \\ &= 438.61\,\text{V rms} \end{aligned}$$

Therefore, the value of the voltmeter reading is $\boxed{438.61\,\text{V rms}}$.

Step 1 of 2

Consider the expression for power absorbed by the load voltage.

$$P_L = V_{rms} I_{rms} (\text{pf})$$

Substitute 240 V rms for V_{rms}, 0.8 for pf and 200 A rms for I_{rms}.

$$\begin{aligned} P_L &= (240)(200)(0.8) \\ &= 38.4\text{ kW} \end{aligned}$$

Therefore, the value of the power absorbed by the load is 38.4 kW.

Step 2 of 2

Consider the expression for the power loss in the lines.

$$P_{Line} = P_S - P_L$$

Substitute 40 kW for P_S and 38.4 kW for P_L.

$$\begin{aligned} P_{Line} &= 40\text{ k} - 38.4\text{ k} \\ &= 1.6\text{ kW} \end{aligned}$$

Therefore, the value of the power loss in the lines $\boxed{1.6\text{ kW}}$.

Step 1 of 6

Consider Figure 1.

Figure 1

Step 2 of 6

Consider the expression for the power loss in the lines in terms of current and the line impedance.

$$P_{Line} = I_{rms}^2 R_{Line}$$

Substitute $660\ \text{W}$ for P_{Line} and $0.1\ \Omega$ for R_{Line}.

$$\begin{aligned} 660 &= I_{rms}^2 (0.1) \\ I_{rms}^2 &= \frac{660}{0.1} \\ I_{rms}^2 &= 6.6\ \text{k} \\ I_{rms} &= \sqrt{6.6\ \text{k}} \\ I_{rms} &= 81.24\ \text{A rms} \end{aligned}$$

Therefore, the value of the line current is $81.24\ \text{A rms}$.

Step 3 of 6

Consider the expression for the power factor at the load.

$$\text{pf} = \frac{P_L}{V_{rms} I_{rms}}$$

Substitute $15\ \text{kW}$ for P, $240\ \text{V rms}$ for V_{rms} and $81.24\ \text{A rms}$ for I_{rms}.

$$\begin{aligned} \text{pf} &= \frac{15\ \text{k}}{(240)(81.24)} \\ &= \frac{15\ \text{k}}{19.5\ \text{k}} \\ &= 0.769 \end{aligned}$$

Therefore, the value of the load power factor is 0.769.

Step 4 of 6

Consider the expression for the power factor angle.

$$\theta = -\cos^{-1}(\text{pf})$$

Substitute 0.769 for pf.

$$\begin{aligned} \theta &= -\cos^{-1}(0.769) \\ &= -39.74° \end{aligned}$$

Therefore, the power factor angle at the load is $-39.74°$.

Step 5 of 6

Consider the expression for power factor angle.

$$\theta = \angle V_{rms} - \angle I_{rms}$$

Substitute $-39.74°$ for θ and $0°$ for $\angle V_{rms}$.

$$\begin{aligned} -39.74° &= 0° - \angle I_{rms} \\ \angle I_{rms} &= 0° - (-39.74°) \\ \angle I_{rms} &= 39.74° \end{aligned}$$

Therefore, the phase angle of the load current is $39.74°$.

Hence, the phasor value of the load current is $81.24\angle 39.74°\ \text{A rms}$.

Step 6 of 6

Consider the expression for the source voltage.

$$\mathbf{V}_S = I_{rms} R_{Line} + \mathbf{V}_L$$

Substitute $81.24\angle 39.74°\ \text{A rms}$ for I_{rms}, $0.1 + j0.2\ \Omega$ for R_{Line} and $240\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned} \mathbf{V}_S &= (81.24\angle 39.74°)(0.1 + j0.2) + 240\angle 0° \\ &= (81.24\angle 39.74°)(0.224\angle 63.44°) + 240\angle 0° \\ &= 18.2\angle 103.18° + 240\angle 0° \\ &= 236.52\angle 4.3°\ \text{V rms} \end{aligned}$$

Therefore, the value of the source voltage is $\boxed{236.52\angle 4.3°\ \text{V rms}}$.

Step 1 of 5

a) Consider the following data:

Current, $I = 2\angle 40^\circ \text{ A rms}$

Voltage, $V = 450\angle 70^\circ \text{ V rms}$

Write the formula for complex power.

$$\begin{aligned} S &= V_{rms} I_{rms}^* \\ &= (450\angle 70^\circ)(2\angle 40^\circ)^* \\ &= (450\angle 70^\circ)(2\angle -40^\circ) \\ &= 900\angle 30^\circ \end{aligned}$$

$S = 779.422 + j450 \text{ VA}$ ..... (1)

Thus the complex power S is $\boxed{779.422 + j450 \text{ VA}}$

Step 2 of 5

Write the formula for complex power.

$S = P + jQ$ ..... (2)

Where, S is the complex power,

P is the real power,

Q is the reactive power.

Compare equation (1) with equation (2).

$P = 779.422 \text{ W}$ and $Q = 450 \text{ VAR}$.

Thus the real power P is $\boxed{779.422 \text{ W}}$ and reactive power Q is $\boxed{450 \text{ VAR}}$.

Write the formula for power factor.

$$\begin{aligned} \text{pf} &= \cos\theta \\ &= \cos(30) \\ &= 0.866 \end{aligned}$$

Thus the power factor is $\boxed{0.866 \text{ lagging}}$

Step 3 of 5

b) Consider the following data:

Current, $I = 1.5\angle -20^\circ \text{ A rms}$

Impedance, $Z = 5000\angle 15^\circ\ \Omega$

Write the formula for complex power.

$$\begin{aligned} S &= V_{rms} I_{rms}^* \\ &= (I_{rms} Z) I_{rms}^* \\ &= |I_{rms}|^2 Z \qquad \left(\text{Since } (I_{rms})(I_{rms}^*) = |I_{rms}|^2\right) \\ &= (1.5)^2\, 5000\angle 15^\circ \end{aligned}$$

$$\begin{aligned} &= (2.25)5000\angle 15^\circ \\ &= 11250\angle 15^\circ \end{aligned}$$

$S = 10.867 + j2.912 \text{ kVA}$ ..... (3)

Thus the complex power S is $\boxed{10.867 + j2.912 \text{ kVA}}$

Step 4 of 5

Write the formula for complex power.

$S = P + jQ$ ..... (4)

Where, S is the complex power,

P is the real power,

Q is the reactive power.

Compare equation (3) with equation (4).

$P = 10.867 \text{ kW}$ and $Q = 2.912 \text{ kVAR}$.

Thus the real power P is $\boxed{10.867 \text{ kW}}$ and reactive power Q is $\boxed{2.912 \text{ kVAR}}$.

Write the formula for power factor.

$$\begin{aligned} \text{pf} &= \cos\theta \\ &= \cos(15) \\ &= 0.9659 \end{aligned}$$

Thus the power factor is $\boxed{0.9659 \text{ lagging}}$

Step 5 of 5

c) Consider the following data:

Voltage, $V = 200\angle +35^\circ$

Impedance, $Z = 1500\angle -15^\circ\ \Omega$

Write the formula for complex power.

$$\begin{aligned} S &= V_{rms} I_{rms}^* \\ &= V_{rms}\left(\frac{V_{rms}}{Z}\right)^* \\ &= \frac{|V_{rms}|^2}{Z^*} \qquad \left(\text{Since } (V_{rms})(V_{rms}^*) = |V_{rms}|^2\right) \\ &= \frac{200^2}{(1500\angle -15^\circ)^*} \end{aligned}$$

$$\begin{aligned} &= \frac{200^2}{(1500\angle 15^\circ)} \\ &= 26.667\angle -15^\circ \end{aligned}$$

$S = 25.76 - j6.9 \text{ VA}$ ..... (5)

Thus the complex power S is $\boxed{25.76 - j6.9 \text{ VA}}$

Write the formula for complex power.

$S = P + jQ$ ..... (6)

Where, S is the complex power,

P is the real power,

Q is the reactive power.

Compare equation (5) with equation (6).

$P = 25.76 \text{ W}$ and $Q = -6.9 \text{ VAR}$.

Thus the real power P is $\boxed{25.76 \text{ W}}$ and reactive power Q is $\boxed{-6.9 \text{ VAR}}$.

Write the formula for power factor.

$$\begin{aligned} \text{pf} &= \cos\theta \\ &= \cos(-15) \\ &= 0.9659 \end{aligned}$$

Thus the power factor is $\boxed{0.9659 \text{ leading}}$.

Step 1 of 9

Refer to the Figure P6.80 in the text book.

Determine the current flowing through the circuit.

$$\begin{aligned} I &= \frac{(240\angle 0^\circ)-(220\angle -30^\circ)}{4-j5} \\ &= \frac{32.15+j120}{4-j5} \\ &= -11.49+j15.62 \\ &= 19.4\angle 126.34^\circ \text{ A} \end{aligned}$$

Step 2 of 9

Determine the real power delivered by $240\angle 0^\circ \text{ V}$ voltage source.

$$\begin{aligned} P &= V_{rms} I_{rms} \cos(\theta_v - \theta_v) \\ &= (240)(19.4)\cos(0^\circ - 126.34^\circ) \\ &= -2.76 \text{ kW} \end{aligned}$$

Therefore, the real power delivered by $240\angle 0^\circ \text{ V}$ voltage source is $\boxed{-2.76 \text{ kW}}$.

Step 3 of 9

Determine the reactive power delivered by $240\angle 0^\circ \text{ V}$ voltage source.

$$\begin{aligned} Q &= V_{rms} I_{rms} \sin(\theta_v - \theta_v) \\ &= (240)(19.4)\sin(0^\circ - 126.34^\circ) \\ &= -3.75 \text{ kVAR} \end{aligned}$$

Therefore, the reactive power delivered by $240\angle 0^\circ \text{ V}$ voltage source is $\boxed{-3.75 \text{ kVAR}}$.

Step 4 of 9

Determine the real power delivered by $220\angle -30^\circ \text{ V}$ voltage source.

$$\begin{aligned} P &= V_{rms} I_{rms} \cos(\theta_v - \theta_i) \\ &= (220)(19.4)\cos(-30^\circ - 126.34^\circ) \\ &= (220)(19.4)\cos(-156.34^\circ) \\ &= -3.9 \text{ kW} \end{aligned}$$

Therefore, the real power delivered by $220\angle -30^\circ \text{ V}$ voltage source is $\boxed{-3.9 \text{ kW}}$.

Step 5 of 9

Determine the reactive power delivered by $220\angle -30^\circ \text{ V}$ voltage source.

$$\begin{aligned} Q &= V_{rms} I_{rms} \sin(\theta_v - \theta_v) \\ &= (240)(19.4)\sin(-30^\circ - 126.34^\circ) \\ &= (240)(19.4)\sin(-156.34^\circ) \\ &= -3.75 \text{ kVA} \end{aligned}$$

Therefore, the reactive power delivered by $220\angle -30^\circ \text{ V}$ voltage source is $\boxed{-3.75 \text{ kVA}}$.

Step 6 of 9

Determine the real power delivered to 4Ω resistor.

$$\begin{aligned} P &= (I_{rms})^2 R \\ &= (19.4)^2 (4) \\ &= 1.505 \text{ W} \end{aligned}$$

Therefore, the real power delivered to 4Ω resistor is $\boxed{1.505 \text{ W}}$.

Step 7 of 9

The reactive power in a resistor is zero due to zero phase shift between voltage and current.

Therefore, the reactive power delivered to 4Ω resistor is $\boxed{0 \text{ kVAR}}$.

Step 8 of 9

The real power in the capacitor is zero due to 90° phase shift between voltage and current.

Therefore, the real power delivered to capacitor is $\boxed{0 \text{ W}}$.

Step 9 of 9

Determine the reactive power to the capacitor.

$$\begin{aligned} Q &= (I_{rms})^2 (5\Omega) \\ &= (19.4)^2 (5\Omega) \\ &= 1.88 \text{ kVAR} \end{aligned}$$

Therefore, the reactive power delivered to capacitor is $\boxed{1.88 \text{ kVAR}}$.

Step 1 of 3

Step 2 of 3

Given

$S_1 = 2000\angle -30°$

$V_1 I^* = 2000\angle -30°$

$I^* = \dfrac{2000\angle -30°}{200\angle 10°}$

$I^* = 10\angle -40°$

Hence,

$I = 10\angle 40°\,\text{A rms}$

Step 3 of 3

Hence voltage across the impedance,

$V_Z = I(Z)$

$= 10\angle 40°(5 + j10)$

$= (10\angle 40°)(11.18\angle 63.43°)$

$V_Z = 111.8\angle 103.43°\ \text{V}$

Hence,

$V_2 = V_1 - V_Z$

$= 200\angle 10° - 111.8\angle 103.43°$

$= 196.96 + j34.73 + 25.96° - j108.74°$

$= 221.92 - j74.01$

$\boxed{V_2 = 233.93\angle -18.44°\ \text{V rms}}$

Step 1 of 3

Refer to the Figure P9.82 in the text book.

Determine the current delivered by the source.

$$P = VI\cos\theta$$

Substitute $240\,\text{V}$ for V, 12 kW for P and 0.8 for $\cos\theta$.

$$P = VI\cos\theta$$
$$12\,\text{kW} = (240)I(0.8)$$
$$I = \frac{12\,\text{kW}}{(240)(0.8)}$$
$$I = 62.5\,\text{A}$$

Step 2 of 3

Assume the impedance of the load is, Z

Apply Kirchhoff's voltage law in the loop.

$$-240\angle 0^\circ + (0.5 + j1)I + ZI = 0$$
$$-240\angle 0^\circ + (0.5 + j)(62.5) + Z(62.5) = 0$$
$$Z = \frac{(240\angle 0^\circ) - (0.5 + j)(62.5)}{62.5}$$
$$Z = \frac{(240\angle 0^\circ) - (0.5 + j)(62.5)}{62.5}$$
$$Z = 3.34 - j$$

Determine the value of admittance.

$$Y = \frac{1}{Z}$$
$$= \frac{1}{3.34 - j}$$
$$Y = 0.274 + j0.082$$

The admittance in parallel combination is sum of admittances of parallel elements.

$$Y = 0.274 + j0.082$$
$$= Y_1 + Y_2$$

Determine the value of resistor.

$$R = \frac{1}{Y_1}$$
$$= \frac{1}{0.274}$$
$$= 3.64\,\Omega$$

Therefore, the value of resistor is $\boxed{3.64\,\Omega}$.

Step 3 of 3

Determine the value of capacitor.

$$Z_C = \frac{1}{Y_2}$$
$$= \frac{1}{j0.082}$$
$$= -j12.19$$

$$-j\frac{1}{\omega C} = -j12.19$$
$$\frac{1}{\omega C} = 12.19$$
$$C = \frac{1}{2\pi(60)(12.19)}$$
$$C = 2.41\,\text{mF}$$

Therefore, the value of capacitor is $\boxed{2.41\,\text{mF}}$.

Step 1 of 4

Refer to Figure P9.75 in the textbook.

Draw the modified circuit of Figure P9.75 with current notations.

Figure 1

Step 2 of 4

Consider the power absorbed the source $\mathbf{V}_{S_2}$.

$$\mathbf{S}_{V_{S2}} = \mathbf{V}_{S_2}\mathbf{I}^*$$

Substitute $0 + j1582.5$ for $\mathbf{S}_{V_{S2}}$ and $150\angle 0°\ \text{V rms}$ for $\mathbf{V}_{S_2}$.

$$0 + j1582.5 = (150\angle 0°)\mathbf{I}^*$$

Solve for $\mathbf{I}$.

$$0 + j1582.5 = (150\angle 0°)\mathbf{I}^*$$
$$1582.5\angle 90° = (150\angle 0°)\mathbf{I}^*$$
$$\mathbf{I}^* = \frac{1582.5\angle 90°}{150\angle 0°}$$
$$\mathbf{I}^* = 10.55\angle 90°$$
$$\mathbf{I} = (10.55\angle 90°)^*$$
$$= 10.55\angle -90°\ \text{A rms}$$

Therefore, the value of the line current is $10.55\angle -90°\ \text{A rms}$.

Step 3 of 4

Consider the expression for the source voltage $\mathbf{V}_{S_1}$.

$$\mathbf{V}_{S_1} = \mathbf{I}(R + jX) + \mathbf{V}_{S_2}$$

Substitute $10.55\angle -90°\ \text{A rms}$ for I_{rms}, $120\angle -10°\ \text{V rms}$ for $\mathbf{V}_{S_1}$ and $150\angle 0°\ \text{V rms}$ for $\mathbf{V}_{S_2}$.

$$120\angle -10° = (10.55\angle -90°)(R + jX) + 150\angle 0°$$
$$(10.55\angle -90°)(R + jX) = 120\angle -10° - 150\angle 0°$$
$$R + jX = \frac{38.04\angle -146.78°}{10.55\angle -90°}$$
$$R + jX = 3.61\angle -56.78°$$
$$R + jX = 1.98 - j3.02$$

Compare the terms.

$R = 1.98\,\Omega$ and $jX = -j3.02\,\Omega$

Therefore, the value of the line resistance is $\boxed{1.98\,\Omega}$.

Step 4 of 4

The value of the reactance is negative. Hence, the element is capacitor.

Calculate the value of the capacitor.

$$X = \frac{1}{2\pi fC}$$

Substitute $3.02\,\Omega$ for X and $60\ \text{Hz}$ for f.

$$3.02 = \frac{1}{2\pi(60)C}$$
$$C = \frac{1}{2\pi(60)(3.02)}$$
$$C = \frac{1}{1138.51}$$
$$C = 878.34\ \mu\text{F}$$

Therefore, the value of the capacitor is $\boxed{878.34\ \mu\text{F}}$.

Step 1 of 4

Consider Figure 1.

Figure 1

Step 2 of 4

Calculate the current flowing in the circuit.

$$\begin{aligned}\mathbf{I} &= \frac{125\angle 0° - 95\angle -10°}{2 + j3 - j5} \\ &= \frac{35.51\angle 27.68°}{2 - j2} \\ &= \frac{35.51\angle 27.68°}{2.83\angle -45°} \\ &= 12.55\angle 72.68° \text{ A rms}\end{aligned}$$

Therefore, the value of the current flowing in the circuit is $12.55\angle 72.68°$ A rms .

Consider the expression for the power supplied by the source $\mathbf{V}_{S1}$.

$$S_{V_{S1}} = -\mathbf{V}_{S1}\mathbf{I}^*$$

Substitute $12.55\angle 72.68°$ A rms for $\mathbf{I}$ and $125\angle 0°$ V rms for $\mathbf{V}_{S1}$.

$$\begin{aligned}S_{V_{S1}} &= -(125\angle 0°)(12.55\angle 72.68°)^* \\ &= -(125\angle 0°)(12.55\angle -72.68°) \\ &= -(1568.75\angle -72.68°) \\ &= -(467.03 - j1497.62)\end{aligned}$$

$$S_{V_{S1}} = -467.03 + j1497.62 \text{ VA}$$

Therefore, the value of the real power absorbed by the source $\mathbf{V}_{S1}$ is $\boxed{-467.03 \text{ W}}$ and the value of the reactive power delivered is $\boxed{1497.62 \text{ Vars}}$.

Step 3 of 4

Consider the expression for the power supplied by the source $\mathbf{V}_{S2}$.

$$S_{V_{S2}} = \mathbf{V}_{S2}\mathbf{I}^*$$

Substitute $12.55\angle 72.68°$ A rms for $\mathbf{I}$ and $95\angle -10°$ V rms for $\mathbf{V}_{S2}$.

$$\begin{aligned}S_{V_{S2}} &= (95\angle -10°)(12.55\angle 72.68°)^* \\ &= (95\angle -10°)(12.55\angle -72.68°) \\ &= (1192.25\angle -82.68°) \\ &= 151.91 - j1182.53 \text{ VA}\end{aligned}$$

Therefore, the value of the real power delivered by the source $\mathbf{V}_{S2}$ is $\boxed{151.91 \text{ W}}$ and the value of the reactive power absorbed is $\boxed{1182.53 \text{ Vars}}$.

Step 4 of 4

The reactive power absorbed by the resistor is $\boxed{0 \text{ Vars}}$ since the complex term is zero.

Consider the expression for the real power absorbed by the resistor.

$$P_R = |\mathbf{I}|^2 R$$

Substitute 12.55 A rms for $|\mathbf{I}|$ and $2\,\Omega$ for R .

$$\begin{aligned}P_R &= (12.55)^2(2) \\ &= (157.5)(2) \\ &= 315 \text{ W}\end{aligned}$$

Therefore, the value of the real power absorbed by the resistor is $\boxed{315 \text{ W}}$.

The value of the real power absorbed by the inductor is $\boxed{0 \text{ W}}$ since the real term of the impedance is zero.

Consider the expression for the reactive power absorbed by the inductor.

$$Q_L = |\mathbf{I}|^2 X_L$$

Substitute 12.55 A rms for $|\mathbf{I}|$ and $j3\,\Omega$ for X_L .

$$\begin{aligned}Q_L &= (12.55)^2(3) \\ &= (157.5)(3) \\ &= 472.5 \text{ Vars}\end{aligned}$$

Therefore, and the complex power absorbed by the inductor is $\boxed{472.5 \text{ Vars}}$.

The value of the real power absorbed by the capacitor is $\boxed{0 \text{ W}}$ since the real term of the impedance is zero.

Consider the expression for the reactive power absorbed by the capacitor.

$$Q_C = |\mathbf{I}|^2 X_C$$

Substitute 12.55 A rms for $|\mathbf{I}|$ and $-j5\,\Omega$ for X_C .

$$\begin{aligned}Q_C &= (12.55)^2(-5) \\ &= (157.5)(-5) \\ &= -787.5 \text{ Vars}\end{aligned}$$

Therefore, and the complex power absorbed by the capacitor is $\boxed{-787.5 \text{ Vars}}$.

Step 1 of 9

Given circuit is

Step 2 of 9

Now at load 1,

$V_1 = 240\angle 0°$ V rms

$P_1 = 10$ kW

$p.f = 0.8$ leading

Hence,

$$I_1 = \frac{P_1}{V_1 \times p.f}$$

$$= \frac{10\times 10^3}{240\times 0.8}$$

$I_1 = 52.08$ A rms

Step 3 of 9

Since,

$p.f = 0.8$

$\theta = \cos^{-1}(0.8)$

$= 36.869°$

So, we have

$\theta_v + \theta_1 = 36.869°$

Since, $\theta_v = 0$

We have,

$\theta_1 = 36.869°$

Hence

$I_1 = 52.08\angle 36.869°$ A rms

Step 4 of 9

Now at load 2,

$V_2 = 240\angle 0°$ V rms

$P_2 = 12$ kW

$p.f = 1$

Hence

$$I_2 = \frac{P_2}{V_2 \times p.f}$$

$$= \frac{12\times 10^3}{240\times 1}$$

$= 50$ A rms

Step 5 of 9

Since,

$p.f = 1$

$\cos\theta = 1$

$\theta = \cos^{-1}(1)$

$= 0°$

So,

$\theta_v - \theta_1 = 0°$

Since,

$\theta_v = 0$

We have,

$\theta_1 = 0°$

Hence,

$I_2 = 50\angle 0°$ A rms

Step 6 of 9

Applying KCL at the load,

$I = I_1 + I_2$

$= 52.08\angle 36.869° + 50\angle 0°$

$= 41.66 + j31.247 + 50 + j0$

$= 91.66 + j31.247$

$I = 96.837\angle 18.82°$ A

Therefore,

$V_Z = (I)(Z)$

$= (96.837\angle 18.82°)(0.2 + j0.4)$

$= 43.306\angle 82.25°$ V

Step 7 of 9

Hence,

$V_s = V_Z + V_L$

$= 43.306\angle 82.25° + 240\angle 0°$

$= 249.55\angle 9.9°$ V

$= 249.55\angle 9.9°$ V rms

Step 8 of 9

Therefore,

$v_s(t) = 249.55\cos(\omega t + 9.9°)$

Given,

$f = 60$ Hz

So, we have

$\omega = 2\pi f$

$= 2\pi \times 60$

$= 376.99$ rad/sec

Step 9 of 9

Therefore,

$\boxed{v_s(t) = 249.55\cos(376.99t + 9.9°)\text{ Vrms}}$

Power factor at the source

$p.f = \cos(\theta)$

$= \cos(\theta_v - \theta_1)$

$= \cos[9.9° - (18.82°)]$

$= \cos(-8.92°)$

$\boxed{p.f = 0.988 \text{ lagging}}$

9.086P

Step 2 of 5

$V_S = 240\angle 0^\circ \text{V}$

Power factor, $pf = 0.8$

Power supplied by the source, $P_S = 12\text{kW}$

Clarification s

Now, $P_S = |V_S||I|(pf)$

$$|I| = \frac{P_S}{|V_S|(pf)}$$

$$|I| = \frac{12\times 10^3}{240\times 0.8}$$

$$|I| = 62.5\text{A}$$

Step 3 of 5

Also, $pf = 0.8$

$$\cos(\theta_{V_S} - \theta_I) = 0.8$$

$$(0^\circ - \theta_I) = 36.87^\circ$$

$$\theta_I = -36.87^\circ$$

$$\therefore I = 62.5\angle -36.87^\circ$$

Step 4 of 5

Now, $I = \dfrac{V_S - V_L}{0.5 + j1}$

$$V_L = V_S - I(0.5 + j1)$$

$$V_L = \left(240\angle 0^\circ\right) - \left(62.5\angle -36.87^\circ\right)(0.5 + j1)$$

$$V_L = \left(240\angle 0^\circ\right) - \left(62.5\angle -36.87^\circ\right)\left(1.118\angle 63.43^\circ\right)$$

$$V_L = \left(240\angle 0^\circ\right) - \left(69.88\angle 26.56^\circ\right)$$

$$V_L = 180.23\angle -10^\circ \text{V}$$

Step 5 of 5

Therefore, complex power absorbed by the load is:

$$S_L = |V_L||I|\cos(\theta_{V_L} - \theta_I) + j|V_L||I|\sin(\theta_{V_L} - \theta_I)$$

$$S_L = (180.23)(62.5)\cos(-10^\circ + 36.87^\circ) + j(180.23)(62.5)\sin(-10^\circ + 36.87^\circ)$$

$$S_L = 10048.21 + j5091.13 \text{ VA}$$

$$\boxed{S_L = 11.26\angle 26.87^\circ \text{kVA}}$$

Step 1 of 7

Determine the value of complex power of the load 1.

$$\begin{aligned} S_1 &= \frac{P_1}{\cos\theta_1} \\ &= \frac{P_1}{pf_1} \\ &= \frac{44\,kW}{0.82} \\ &= \frac{44,000}{0.82} \end{aligned}$$

$$S_1 = 53.65\,kVA$$

Step 2 of 7

The power factor of the first load is,

$$\cos\theta_1 = pf_1$$

$$\theta_1 = \cos^{-1}(0.82)$$

$$\theta_1 = 34.91°$$

The complex power of the load 1 is,

$$S_1 = 53.65\angle 34.91°\,kVA$$

$$S_1 = (43.99 + j30.70)\,kVA$$

Step 3 of 7

Determine the value of complex power of the load 2.

$$\begin{aligned} S_2 &= \frac{P_2}{\cos\theta_2} \\ &= \frac{P_2}{pf_2} \\ &= \frac{64\,kW}{0.92} \\ &= 69.56\,kVA \end{aligned}$$

Step 4 of 7

The power factor of the second load is,

$$\cos\theta_2 = pf_2$$

$$\begin{aligned} \theta_2 &= \cos^{-1}(0.92) \\ &= 23.07° \end{aligned}$$

The complex power of the load 2 is,

$$\begin{aligned} S_2 &= 69.56\angle 23.07°\,kVA \\ &= (63.99 + j27.25)\,kVA \end{aligned}$$

Step 5 of 7

Therefore the total load complex power is

$$\begin{aligned} S_L &= S_1 + S_2 \\ &= (43.99 + j30.70 + 63.99 + j27.25)\,kVA \\ &= 107.98 + j57.95\ kVA \\ S_L &= 122.54\angle 28.22°\,kVA \end{aligned}$$

The current drawn by the load is

$$S_L = V_L I^*$$

$$\begin{aligned} I^* &= \frac{S_L}{V_L} \\ &= \frac{122.54\times 10^3\angle 28.22°}{240\angle 0°\ V} \\ &= 51.05\angle 28.22°\ A\ rms \end{aligned}$$

Step 6 of 7

The complex power of the transmission line is,

$$\begin{aligned} S_{line} &= I^2 Z_{line} \\ &= (51.05)^2(0.1 + j0.2) \\ &= 260.61 + j521.22\,VA \end{aligned}$$

Hence the complex power supplied by the source is

$$\begin{aligned} S_S &= S_L + S_{line} \\ &= (107.98 + j57.95) + (260.61 + j521.22)\ kVA \\ &= 889.79 + j57.9 \\ &= 891.67\angle 3.72°\,kVA \end{aligned}$$

Step 7 of 7

Determine the power factor at the source.

$$\begin{aligned} pf_{tn} &= \cos(\theta_S) \\ &= \cos(3.72°) \\ &= 0.99 \end{aligned}$$

Therefore, the power factor of the source is $\boxed{0.99(\text{lagging})}$.

Step 1 of 9

Refer to Figure P9.81 in the textbook.

Draw the modified circuit of Figure P9.81 with current notations.

Figure 1

Step 2 of 9

Consider the expression for load current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{P_2}{\mathbf{V}_L(\text{pf})_2}$$

Substitute $36\,\text{kW}$ for P_2, 0.78 for $(\text{pf})_2$ and $220\,\text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{36\,\text{k}}{(220)(0.78)}\\ &= \frac{36\,\text{k}}{171.6}\\ &= 209.79\,\text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_2$ is $209.79\,\text{A rms}$.

Step 3 of 9

Consider the expression for the power factor angle.

$$\theta_2 = \cos^{-1}(\text{pf})$$

Substitute 0.78 for pf.

$$\begin{aligned}\theta_2 &= \cos^{-1}(0.78)\\ &= 38.74°\end{aligned}$$

Therefore, the power factor angle at the load-2 is $38.74°$.

Step 4 of 9

Consider the expression for power factor angle.

$$\theta_2 = \angle\mathbf{V}_L - \angle\mathbf{I}_2$$

Substitute $38.74°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$\begin{aligned}38.74° &= 0° - \angle\mathbf{I}_2\\ \angle\mathbf{I}_2 &= 0° - 38.74°\\ \angle\mathbf{I}_2 &= -38.74°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_2$ is $-38.74°$.

Hence, the phasor value of the load current $\mathbf{I}_2$ is $209.79\angle -38.74°\,\text{A rms}$.

Step 5 of 9

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\text{pf})_1}$$

Substitute $24\,\text{kW}$ for P_1, 0.85 for $(\text{pf})_1$ and $220\,\text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{24\,\text{k}}{(220)(0.85)}\\ &= \frac{20\,\text{k}}{187}\\ &= 128.34\,\text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $128.34\,\text{A rms}$.

Step 6 of 9

Consider the expression for the power factor angle.

$$\theta_1 = \cos^{-1}(\text{pf})$$

Substitute 0.85 for pf.

$$\begin{aligned}\theta_1 &= \cos^{-1}(0.85)\\ &= 31.79°\end{aligned}$$

Therefore, the power factor angle at the load-1 is $31.79°$.

Step 7 of 9

Consider the expression for power factor angle.

$$\theta_1 = \angle\mathbf{V}_L - \angle\mathbf{I}_1$$

Substitute $31.79°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$\begin{aligned}31.79° &= 0° - \angle\mathbf{I}_1\\ \angle\mathbf{I}_1 &= 0° - 31.79°\\ \angle\mathbf{I}_1 &= -31.79°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $-31.79°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $128.34\angle -31.79°\,\text{A rms}$.

Step 8 of 9

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $128.34\angle -31.79°\,\text{A rms}$ for $\mathbf{I}_1$ and $209.79\angle -38.74°\,\text{A rms}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I} &= 128.34\angle -31.79° + 209.79\angle -38.74°\\ &= 337.54\angle -36.10°\,\text{A rms}\end{aligned}$$

Step 9 of 9

Therefore, the value of the line current is $337.54\angle -36.10°\,\text{A rms}$.

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $337.54\angle -36.10°\,\text{A rms}$ for $\mathbf{I}$, $220\angle 0°\,\text{V rms}$ for $\mathbf{V}_L$, $0.09\,\Omega$ for R and $j0.25\,\Omega$ for X.

$$\begin{aligned}\mathbf{V}_S &= (337.54\angle -36.10°)(0.09 + j0.25) + 220\angle 0°\\ &= (337.54\angle -36.10°)(0.27\angle 70.2°) + 220\angle 0°\\ &= 91.14\angle 34.1° + 220\angle 0°\\ &= 299.86\angle 9.81°\,\text{V rms}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{299.86\angle 9.81°\,\text{V rms}}$.

Step 1 of 6

Refer to circuit diagram in Figure P9.82 in the textbook.

Draw the circuit with node notations and current directions.

Figure 1

Step 2 of 6

Consider the expression for load current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{P_2}{\mathbf{V}_L(\text{pf})_2}$$

Substitute $48\,\text{kW}$ for P_2, 0.88 for $(\text{pf})_2$ and $240\,\text{V rms}$ for $\mathbf{V}_L$ in the equation.

$$\begin{aligned}\mathbf{I}_2 &= \frac{48\,\text{k}}{(240)(0.88)}\\ &= \frac{48\,\text{k}}{211.6}\\ &= 227.27\,\text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_2$ is $227.27\,\text{A rms}$.

Consider the expression for the power factor angle.

$$\theta_2 = \cos^{-1}(\text{pf})$$

Substitute 0.88 for pf in the equation.

$$\begin{aligned}\theta_2 &= \cos^{-1}(0.88)\\ &= 28.36°\end{aligned}$$

Therefore, the power factor angle at the load-2 is $28.36°$.

Step 3 of 6

Consider the expression for power factor angle.

$$\theta_2 = \angle\mathbf{V}_L - \angle\mathbf{I}_2$$

Substitute $28.36°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$\begin{aligned}28.36° &= 0° - \angle\mathbf{I}_2\\ \angle\mathbf{I}_2 &= 0° - 28.36°\\ \angle\mathbf{I}_2 &= -28.36°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_2$ is $-28.36°$.

Hence, the phasor value of the load current $\mathbf{I}_2$ is $227.27\angle -28.36°\,\text{A rms}$.

Step 4 of 6

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\text{pf})_1}$$

Substitute $36\,\text{kW}$ for P_1, 0.82 for $(\text{pf})_1$ and $240\,\text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{36\,\text{k}}{(240)(0.82)}\\ &= \frac{36\,\text{k}}{196.8}\\ &= 182.93\,\text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $182.93\,\text{A rms}$.

Consider the expression for the power factor angle.

$$\theta_1 = \cos^{-1}(\text{pf})$$

Substitute 0.82 for pf.

$$\begin{aligned}\theta_1 &= \cos^{-1}(0.82)\\ &= 34.92°\end{aligned}$$

Therefore, the power factor angle at the load-1 is $34.92°$.

Step 5 of 6

Consider the expression for power factor angle.

$$\theta_1 = \angle\mathbf{V}_L - \angle\mathbf{I}_1$$

Substitute $34.92°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$\begin{aligned}34.92° &= 0° - \angle\mathbf{I}_1\\ \angle\mathbf{I}_1 &= 0° - 34.92°\\ \angle\mathbf{I}_1 &= -34.92°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $-34.92°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $182.93\angle -34.92°\,\text{A rms}$.

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $182.93\angle -34.92°\,\text{A rms}$ for $\mathbf{I}_1$ and $227.27\angle -28.36°\,\text{A rms}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I} &= 182.93\angle -34.92° + 227.27\angle -28.36°\\ &= 409.54\angle -31.29°\,\text{A rms}\end{aligned}$$

Therefore, the value of the line current is $409.54\angle -31.29°\,\text{A rms}$.

Step 6 of 6

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $409.54\angle -31.29°\,\text{A rms}$ for $\mathbf{I}$, $240\angle 0°\,\text{V rms}$ for $\mathbf{V}_L$, $0.1\,\Omega$ for R and $j0.3\,\Omega$ for X.

$$\begin{aligned}\mathbf{V}_S &= (409.54\angle -31.29°)(0.1 + j0.3) + 240\angle 0°\\ &= (409.54\angle -31.29°)(0.32\angle 71.57°) + 240\angle 0°\\ &= 131.05\angle 40.28° + 240\angle 0°\\ &= 350.38\angle 13.99°\,\text{V rms}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{350.38\angle 13.99°\,\text{V rms}}$.

Step 1 of 5

Refer to circuit diagram in Figure P9.83 in the textbook.

Draw the circuit with node notations and current directions.

Figure 1

Step 2 of 5

Consider the expression for the power absorbed by the load 1.

$$\mathbf{S}_1 = \mathbf{V}_L \mathbf{I}_1^*$$

Substitute $30\angle\cos^{-1}(0.9)\,\text{kVA}$ for $\mathbf{S}_1$ and $240\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$ in the equation.

$$30\angle\cos^{-1}(0.9)\,\text{k} = (240\angle 0°)\mathbf{I}_1^*$$

Solve for $\mathbf{I}_1^*$.

$$30\angle 25.84°\ \text{k} = (240\angle 0°)\mathbf{I}_1^*$$

$$\mathbf{I}_1^* = \frac{30\angle 25.84°\ \text{k}}{240\angle 0°}$$

$$\mathbf{I}_1^* = 125\angle 25.84°$$

$$\mathbf{I}_1 = (125\angle 25.84°)^*$$
$$= 125\angle -25.84°\ \text{A rms}$$

Therefore, the value of the load current $\mathbf{I}_1$ is $125\angle -25.84°\ \text{A rms}$.

Step 3 of 5

Consider the expression for load current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{P_2}{\mathbf{V}_L(\text{pf})_2}$$

Substitute $40\,\text{kW}$ for P_2, 0.795 for $(\text{pf})_2$ and $240\ \text{V rms}$ for $\mathbf{V}_L$.

$$\mathbf{I}_2 = \frac{40\ \text{k}}{(240)(0.795)}$$
$$= \frac{40\ \text{k}}{190.8}$$
$$= 209.64\ \text{A rms}$$

Therefore, the magnitude value of the load current $\mathbf{I}_2$ is $209.64\ \text{A rms}$.

Step 4 of 5

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.795 for pf.

$$\theta = \cos^{-1}(0.795)$$
$$= 37.35°$$

Therefore, the power factor angle at the load-2 is $37.35°$.

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_L - \angle\mathbf{I}_2$$

Substitute $37.35°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$37.35° = 0° - \angle\mathbf{I}_2$$
$$\angle\mathbf{I}_2 = 0° - 37.35°$$
$$\angle\mathbf{I}_2 = -37.35°$$

Therefore, the phase angle of the load current $\mathbf{I}_2$ is $37.35°$.

Hence, the phasor value of the load current $\mathbf{I}_2$ is $209.64\angle -37.35°\ \text{A rms}$.

Step 5 of 5

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $125\angle -25.84°\ \text{A rms}$ for $\mathbf{I}_1$ and $209.64\angle -37.35°\ \text{A rms}$ for $\mathbf{I}_2$.

$$\mathbf{I} = 125\angle -25.84° + 209.64\angle -37.35°$$
$$= 333.06\angle -33.06°\ \text{A rms}$$

Therefore, the value of the line current is $333.06\angle -33.06°\ \text{A rms}$.

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $333.06\angle -33.06°\ \text{A rms}$ for $\mathbf{I}$, $240\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$, $0.1\,\Omega$ for R and $j0.1\,\Omega$ for X.

$$\mathbf{V}_S = (333.06\angle -33.06°)(0.1 + j0.1) + 240\angle 0°$$
$$= (333.06\angle -33.06°)(0.14\angle 45°) + 240\angle 0°$$
$$= 46.63\angle 11.94° + 240\angle 0°$$
$$= 285.78\angle 1.94°\ \text{V rms}$$

Therefore, the value of the source voltage is $\boxed{285.78\angle 1.94°\ \text{V rms}}$.

Step 1 of 10

Refer to Figure P9.79 in the textbook.

Draw the modified circuit of Figure P9.79 with current notations.

Figure 1

Step 2 of 10

Consider the expression for the power absorbed by the load 2.

$$\mathbf{S}_2 = \mathbf{V}_L \mathbf{I}_2^*$$

Substitute $12\angle\cos^{-1}(0.9)\,\text{kVA}$ for $\mathbf{S}_2$ and $240\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$.

$$12\angle\cos^{-1}(0.9)\,\text{k} = (240\angle 0°)\mathbf{I}_2^*$$

Solve for $\mathbf{I}_2^*$.

$$12\angle 25.84°\ \text{k} = (240\angle 0°)\mathbf{I}_2^*$$

$$\mathbf{I}_2^* = \frac{12\angle 25.84°\ \text{k}}{240\angle 0°}$$

$$\mathbf{I}_2^* = 50\angle 25.84°$$

$$\begin{aligned}\mathbf{I}_2 &= (50\angle 25.84°)^* \\ &= 50\angle -25.84°\ \text{A rms}\end{aligned}$$

Therefore, the value of the load current $\mathbf{I}_2$ is $50\angle -25.84°\ \text{A rms}$.

Step 3 of 10

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\text{pf})_1}$$

Substitute $20\,\text{kW}$ for P_1, 0.7 for $(\text{pf})_1$ and $240\ \text{V rms}$ for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{20\,\text{k}}{(240)(0.7)} \\ &= \frac{20\,\text{k}}{168} \\ &= 119.05\ \text{A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $119.05\ \text{A rms}$.

Step 4 of 10

Consider the expression for the power factor angle.

$$\theta = -\cos^{-1}(\text{pf})$$

Substitute 0.7 for pf.

$$\begin{aligned}\theta &= -\cos^{-1}(0.7) \\ &= -45.57°\end{aligned}$$

Therefore, the power factor angle at the load-1 is $-45.57°$.

Step 5 of 10

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_L - \angle\mathbf{I}_1$$

Substitute $-45.57°$ for θ and $0°$ for $\angle\mathbf{V}_L$.

$$-45.57° = 0° - \angle\mathbf{I}_1$$

$$\angle\mathbf{I}_1 = 0° - (-45.57°)$$

$$\angle\mathbf{I}_1 = 45.57°$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $45.57°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $119.05\angle 45.57°\ \text{A rms}$.

Step 6 of 10

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $119.05\angle 45.57°\ \text{A rms}$ for $\mathbf{I}_1$ and $50\angle -25.84°\ \text{A rms}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I} &= 119.05\angle 45.57° + 50\angle -25.84° \\ &= 143.07\angle 26.23°\ \text{A rms}\end{aligned}$$

Therefore, the value of the line current is $143.07\angle 26.23°\ \text{A rms}$.

Step 7 of 10

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $143.07\angle 26.23°\ \text{A rms}$ for $\mathbf{I}$, $240\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$, $0.05\,\Omega$ for R and $0.2\,\Omega$ for X.

$$\begin{aligned}\mathbf{V}_S &= (143.07\angle 26.23°)(0.05 + j0.2) + 240\angle 0° \\ &= (143.07\angle 26.23°)(0.21\angle 75.96°) + 240\angle 0° \\ &= 30.05\angle 102.19° + 240\angle 0° \\ &= 235.49\angle 7.17°\ \text{V rms}\end{aligned}$$

Therefore, the value of the source voltage is $235.49\angle 7.17°\ \text{V rms}$.

Step 8 of 10

Consider the expression for the power supplied by the source.

$$\mathbf{S}_S = \mathbf{V}_S \mathbf{I}^*$$

Substitute $235.49\angle 7.17°\ \text{V rms}$ for $\mathbf{V}_S$ and $143.07\angle 26.23°\ \text{A rms}$ for $\mathbf{I}$.

$$\begin{aligned}\mathbf{S}_S &= (235.49\angle 7.17°)(143.07\angle 26.23°)^* \\ &= (235.49\angle 7.17°)(143.07\angle -26.23°) \\ &= 33.69\angle -19.06°\ \text{kVA}\end{aligned}$$

Therefore, the value of the power supplied by the source is $\boxed{33.69\angle -19.06°\ \text{kVA}}$.

Step 9 of 10

Consider the expression for power factor at the source.

$$(\text{pf})_S = \cos(\theta_S)$$

Substitute $-19.06°$ for θ_S.

$$\begin{aligned}(\text{pf})_S &= \cos(-19.06°) \\ &= 0.95\ \text{leading}\end{aligned}$$

Therefore, the value of the power factor at the source is $\boxed{0.95\ \text{leading}}$.

Step 10 of 10

Consider the value of the source voltage.

$$\mathbf{V}_S = 235.49\angle 7.17°\ \text{V rms}$$

Convert to time domain.

$$v_S(t) = \sqrt{2}(V_{\text{rms}})\cos(2\pi f t + \theta_v)$$

Substitute $235.49\ \text{V rms}$ for V_{rms}, $60\ \text{Hz}$ for f and $7.17°$ for θ_v.

$$\begin{aligned}v_S(t) &= \sqrt{2}(235.49)\cos(2\pi(60)t + 7.17°) \\ &= 333.03\cos(376.99t + 7.17°)\ \text{V}\end{aligned}$$

Therefore, the value of $v_S(t)$ is $\boxed{333.03\cos(376.99t + 7.17°)\ \text{V}}$.

Step 1 of 10

Refer to Figure P9.80 in the textbook.

Draw the modified circuit of Figure P9.80 with current notations.

Figure 1

Step 2 of 10

Consider the expression for the power absorbed by the load 2.

$$\mathbf{S}_2 = \mathbf{V}_L \mathbf{I}_2^*$$

Substitute $40\angle -\cos^{-1}(0.9)\,\text{kVA}$ for $\mathbf{S}_2$ and $480\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$.

$$40\angle -\cos^{-1}(0.9)\,\text{k} = (480\angle 0°)\mathbf{I}_2^*$$

Solve for $\mathbf{I}_2^*$.

$$40\angle -25.84°\ \text{k} = (480\angle 0°)\mathbf{I}_2^*$$

$$\mathbf{I}_2^* = \frac{40\angle -25.84°\ \text{k}}{480\angle 0°}$$

$$\mathbf{I}_2^* = 83.33\angle -25.84°$$

$$\mathbf{I}_2 = (83.33\angle -25.84°)^*$$
$$= 83.33\angle 25.84°\ \text{A rms}$$

Therefore, the value of the load current $\mathbf{I}_2$ is $83.33\angle 25.84°\ \text{A rms}$.

Step 3 of 10

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\text{pf})_1}$$

Substitute $40\,\text{kW}$ for P_1, 0.84 for $(\text{pf})_1$ and $480\ \text{V rms}$ for $\mathbf{V}_L$.

$$\mathbf{I}_1 = \frac{40\,\text{k}}{(480)(0.84)}$$
$$= \frac{40\,\text{k}}{403.2}$$
$$= 99.21\ \text{A rms}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $99.21\ \text{A rms}$.

Step 4 of 10

Consider the expression for the power factor angle.

$$\theta = \cos^{-1}(\text{pf})$$

Substitute 0.84 for pf.

$$\theta = \cos^{-1}(0.84)$$
$$= 32.86°$$

Therefore, the power factor angle at the load-1 is $32.86°$.

Step 5 of 10

Consider the expression for power factor angle.

$$\theta = \angle \mathbf{V}_L - \angle \mathbf{I}_1$$

Substitute $32.86°$ for θ and $0°$ for $\angle \mathbf{V}_L$.

$$32.86° = 0° - \angle \mathbf{I}_1$$
$$\angle \mathbf{I}_1 = 0° - 32.86°$$
$$\angle \mathbf{I}_1 = -32.86°$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $-32.86°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $99.21\angle -32.86°\ \text{A rms}$.

Step 6 of 10

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $99.21\angle -32.86°\ \text{A rms}$ for $\mathbf{I}_1$ and $83.33\angle 25.84°\ \text{A rms}$ for $\mathbf{I}_2$.

$$\mathbf{I} = 99.21\angle -32.86° + 83.33\angle 25.84°$$
$$= 159.3\angle -6.31°\ \text{A rms}$$

Therefore, the value of the line current is $159.3\angle -6.31°\ \text{A rms}$.

Step 7 of 10

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $159.3\angle -6.31°\ \text{A rms}$ for $\mathbf{I}$, $480\angle 0°\ \text{V rms}$ for $\mathbf{V}_L$, $0.15\,\Omega$ for R and $j0.3\,\Omega$ for X.

$$\mathbf{V}_S = (159.3\angle -6.31°)(0.15 + j0.3) + 480\angle 0°$$
$$= (159.3\angle -6.31°)(0.34\angle 63.44°) + 480\angle 0°$$
$$= 54.16\angle 57.13° + 480\angle 0°$$
$$= 511.42\angle 5.1°\ \text{V rms}$$

Therefore, the value of the source voltage is $511.42\angle 5.1°\ \text{V rms}$.

Step 8 of 10

Consider the expression for the power supplied by the source.

$$\mathbf{S}_S = \mathbf{V}_S \mathbf{I}^*$$

Substitute $511.42\angle 5.1°\ \text{V rms}$ for $\mathbf{V}_S$ and $159.3\angle -6.31°\ \text{A rms}$ for $\mathbf{I}$.

$$\mathbf{S}_S = (511.42\angle 5.1°)(159.3\angle -6.31°)^*$$
$$= (511.42\angle 5.1°)(159.3\angle 6.31°)$$
$$= 81.47\angle 11.41°\ \text{kVA}$$

Therefore, the value of the power supplied by the source is $\boxed{81.47\angle 11.41°\ \text{kVA}}$.

Step 9 of 10

Consider the expression for power factor at the source.

$$(\text{pf})_S = \cos(\theta_S)$$

Substitute $11.41°$ for θ_S.

$$(\text{pf})_S = \cos(11.41°)$$
$$= 0.98\ \text{lagging}$$

Therefore, the value of the power factor at the source is $\boxed{0.98\ \text{lagging}}$.

Step 10 of 10

Consider the value of the source voltage.

$$\mathbf{V}_S = 511.42\angle 5.1°\ \text{V rms}$$

Convert to time domain.

$$v_S(t) = \sqrt{2}(V_{\text{rms}})\cos(2\pi f t + \theta_v)$$

Substitute $511.42\ \text{V rms}$ for V_{rms}, $60\ \text{Hz}$ for f and $5.1°$ for θ_v.

$$v_S(t) = \sqrt{2}(511.42)\cos(2\pi(60)t + 5.1°)$$
$$= 723.25\cos(376.99t + 5.1°)\ \text{V}$$

Therefore, the value of $v_S(t)$ is $\boxed{723.25\cos(376.99t + 5.1°)\ \text{V}}$.

Step 1 of 12

Refer to circuit diagram in Figure P9.84 in the textbook.

Draw the circuit with node notations and current directions.

Figure 1

Step 2 of 12

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_L(\mathrm{pf})_1}$$

Substitute $30\,\mathrm{kW}$ for P_1, 0.8 for $(\mathrm{pf})_1$ and $480\,\mathrm{V\ rms}$ for $\mathbf{V}_L$ in the equation.

$$\begin{aligned}\mathbf{I}_1 &= \frac{30\,\mathrm{k}}{(480)(0.8)}\\ &= \frac{30\,\mathrm{k}}{384}\\ &= 78.13\,\mathrm{A\ rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $78.13\,\mathrm{A\ rms}$.

Step 3 of 12

Consider the expression for the power factor angle.

$$\theta_1 = -\cos^{-1}(\mathrm{pf})$$

Substitute 0.8 for pf in the equation.

$$\begin{aligned}\theta_1 &= -\cos^{-1}(0.8)\\ &= -36.87^\circ\end{aligned}$$

Therefore, the power factor angle at the load-1 is -36.87°.

Step 4 of 12

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_L - \angle\mathbf{I}_1$$

Substitute -36.87° for θ and 0° for $\angle\mathbf{V}_L$ in the equation.

$$\begin{aligned}-36.87^\circ &= 0^\circ - \angle\mathbf{I}_1\\ \angle\mathbf{I}_1 &= 0^\circ - (-36.87^\circ)\\ \angle\mathbf{I}_1 &= 36.87^\circ\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is 36.87°.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $78.13\angle 36.87^\circ\,\mathrm{A\ rms}$.

Step 5 of 12

Consider the expression for the power absorbed by the load 2.

$$\mathbf{S}_2 = \mathbf{V}_L\mathbf{I}_2^*$$

Substitute $20\angle\cos^{-1}(0.9)\,\mathrm{kVA}$ for $\mathbf{S}_2$ and $480\angle 0^\circ\,\mathrm{V\ rms}$ for $\mathbf{V}_L$ in the equation.

$$20\angle\cos^{-1}(0.9)\,\mathrm{k} = (480\angle 0^\circ)\mathbf{I}_2^*$$

Solve for $\mathbf{I}_2^*$.

$$\begin{aligned}20\angle 25.84^\circ\,\mathrm{k} &= (480\angle 0^\circ)\mathbf{I}_2^*\\ \mathbf{I}_2^* &= \frac{20\angle 25.84^\circ\,\mathrm{k}}{480\angle 0^\circ}\\ \mathbf{I}_2^* &= 41.67\angle 25.84^\circ\end{aligned}$$

$$\begin{aligned}\mathbf{I}_2 &= (41.67\angle 25.84^\circ)^*\\ &= 41.67\angle -25.84^\circ\,\mathrm{A\ rms}\end{aligned}$$

Therefore, the value of the load current $\mathbf{I}_2$ is $41.67\angle -25.84^\circ\,\mathrm{A\ rms}$.

Step 6 of 12

Consider the expression for load current $\mathbf{I}_3$.

$$\mathbf{I}_3 = \frac{P_3}{\mathbf{V}_L(\mathrm{pf})_3}$$

Substitute $10\,\mathrm{kW}$ for P_3, 0.8 for $(\mathrm{pf})_3$ and $480\,\mathrm{V\ rms}$ for $\mathbf{V}_L$ in the equation.

$$\begin{aligned}\mathbf{I}_3 &= \frac{10\,\mathrm{k}}{(480)(0.8)}\\ &= \frac{10\,\mathrm{k}}{384}\\ &= 26.04\,\mathrm{A\ rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_3$ is $26.04\,\mathrm{A\ rms}$.

Step 7 of 12

Consider the expression for the power factor angle.

$$\theta_3 = \cos^{-1}(\mathrm{pf})$$

Substitute 0.8 for pf in the equation.

$$\begin{aligned}\theta_3 &= \cos^{-1}(0.8)\\ &= 36.87^\circ\end{aligned}$$

Therefore, the power factor angle at the load-3 is 36.87°.

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_L - \angle\mathbf{I}_3$$

Substitute 36.87° for θ and 0° for $\angle\mathbf{V}_L$ in the equation.

$$\begin{aligned}36.87^\circ &= 0^\circ - \angle\mathbf{I}_3\\ \angle\mathbf{I}_3 &= 0^\circ - (36.87^\circ)\\ \angle\mathbf{I}_3 &= -36.87^\circ\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_3$ is -36.87°.

Hence, the phasor value of the load current $\mathbf{I}_3$ is $26.04\angle -36.87^\circ\,\mathrm{A\ rms}$.

Step 8 of 12

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3$$

Substitute $78.13\angle 36.87^\circ\,\mathrm{A\ rms}$ for $\mathbf{I}_1$, $41.67\angle -25.84^\circ\,\mathrm{A\ rms}$ for $\mathbf{I}_2$ and $26.04\angle -36.87^\circ\,\mathrm{A\ rms}$ for $\mathbf{I}_3$ in the equation.

$$\begin{aligned}\mathbf{I} &= 78.13\angle 36.87^\circ + 41.67\angle -25.84^\circ + 26.04\angle -36.87^\circ\\ &= 121.55\angle 6.18^\circ\,\mathrm{A\ rms}\end{aligned}$$

Therefore, the value of the line current is $121.55\angle 6.18^\circ\,\mathrm{A\ rms}$.

Step 9 of 12

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(R + jX) + \mathbf{V}_L$$

Substitute $121.55\angle 6.18^\circ\,\mathrm{A\ rms}$ for $\mathbf{I}$, $240\angle 0^\circ\,\mathrm{V\ rms}$ for $\mathbf{V}_L$, $0.1\,\Omega$ for R and $j0.2\,\Omega$ for X in the equation.

$$\begin{aligned}\mathbf{V}_S &= (121.55\angle 6.18^\circ)(0.1 + j0.2) + 480\angle 0^\circ\\ &= (121.55\angle 6.18^\circ)(0.22\angle 63.44^\circ) + 480\angle 0^\circ\\ &= 26.74\angle 69.62^\circ + 480\angle 0^\circ\\ &= 489.95\angle 2.93^\circ\,\mathrm{V\ rms}\end{aligned}$$

Therefore, the value of the source voltage is $489.95\angle 2.93^\circ\,\mathrm{V\ rms}$.

Step 10 of 12

Consider the expression for the power supplied by the source.

$$\mathbf{S}_S = \mathbf{V}_S\mathbf{I}^*$$

Substitute $489.95\angle 2.93^\circ\,\mathrm{V\ rms}$ for $\mathbf{V}_S$ and $121.55\angle 6.18^\circ\,\mathrm{A\ rms}$ for $\mathbf{I}$ in the equation.

$$\begin{aligned}\mathbf{S}_S &= (489.95\angle 2.93^\circ)(121.55\angle 6.18^\circ)^*\\ &= (489.95\angle 2.93^\circ)(121.55\angle -6.18^\circ)\\ &= 59.55\angle -3.25^\circ\,\mathrm{kVA}\end{aligned}$$

Therefore, the value of the power supplied by the source is $\boxed{59.55\angle -3.25^\circ\,\mathrm{kVA}}$.

Step 11 of 12

Consider the expression for power factor at the source.

$$(\mathrm{pf})_S = \cos(\theta_S)$$

Substitute -3.25° for θ_S in the equation.

$$\begin{aligned}(\mathrm{pf})_S &= \cos(-3.25^\circ)\\ &= 0.998\ \text{leading}\end{aligned}$$

Therefore, the value of the power factor at the source is $\boxed{0.998\ \text{leading}}$.

Step 12 of 12

Consider the value of the source voltage.

$$\mathbf{V}_S = 489.95\angle 2.93^\circ\,\mathrm{V\ rms}$$

Convert to time domain.

$$v_S(t) = \sqrt{2}(V_{\mathrm{rms}})\cos(2\pi ft + \theta_v)$$

Substitute $489.95\,\mathrm{V\ rms}$ for V_{rms}, $60\,\mathrm{Hz}$ for f and 2.93° for θ_v in the equation.

$$\begin{aligned}v_S(t) &= \sqrt{2}(489.95)\cos(2\pi(60)t + 2.93^\circ)\\ &= 692.89\cos(376.99t + 2.93^\circ)\,\mathrm{V}\end{aligned}$$

Therefore, the value of $v_S(t)$ is $\boxed{692.89\cos(376.99t + 2.93^\circ)\ \mathrm{V}}$.

Step 1 of 8

Refer to circuit diagram in Figure P9.85 in the textbook.

Draw the circuit with node notations and current directions.

Figure 1

Step 2 of 8

Consider the expression for load current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{P_2}{\mathbf{V}_2(\mathrm{pf})_2}$$

Substitute $20\,\mathrm{kW}$ for P_2, 0.8 for $(\mathrm{pf})_2$ and $220\,\mathrm{V\ rms}$ for $\mathbf{V}_2$ in the equation.

$$\begin{aligned}\mathbf{I}_2 &= \frac{20\,\mathrm{k}}{(220)(0.8)}\\ &= \frac{20\,\mathrm{k}}{176}\\ &= 113.64\ \mathrm{A\ rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_2$ is $113.64\ \mathrm{A\ rms}$.

Consider the expression for the power factor angle.

$$\theta_2 = \cos^{-1}(\mathrm{pf})$$

Substitute 0.8 for pf in the equation.

$$\begin{aligned}\theta_2 &= \cos^{-1}(0.8)\\ &= 36.87^\circ\end{aligned}$$

Therefore, the power factor angle at the load-2 is 36.87°.

Step 3 of 8

Consider the expression for power factor angle.

$$\theta_2 = \angle\mathbf{V}_2 - \angle\mathbf{I}_2$$

Substitute 36.87° for θ_2 and 0° for $\angle\mathbf{V}_2$ in the equation.

$$\begin{aligned}36.87^\circ &= 0^\circ - \angle\mathbf{I}_2\\ \angle\mathbf{I}_2 &= 0^\circ - (36.87^\circ)\\ \angle\mathbf{I}_2 &= -36.87^\circ\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_2$ is -36.87°.

Hence, the phasor value of the load current $\mathbf{I}_2$ is $113.64\angle -36.87^\circ\ \mathrm{A\ rms}$.

Step 4 of 8

Consider the expression for voltage $\mathbf{V}_1$.

$$\mathbf{V}_1 = \mathbf{I}_2(0.01 + j0.05) + \mathbf{V}_2$$

Substitute $113.64\angle -36.87^\circ\ \mathrm{A\ rms}$ for $\mathbf{I}_2$, $220\angle 0^\circ\ \mathrm{V\ rms}$ for $\mathbf{V}_2$, $0.01\,\Omega$ for R and $j0.05\,\Omega$ for X in the equation.

$$\begin{aligned}\mathbf{V}_1 &= (113.64\angle -36.87^\circ)(0.01 + j0.05) + 220\angle 0^\circ\\ &= (113.64\angle -36.87^\circ)(0.05\angle 78.69^\circ) + 220\angle 0^\circ\\ &= 5.68\angle 41.82^\circ + 220\angle 0^\circ\\ &= 224.27\angle 0.97^\circ\ \mathrm{V\ rms}\end{aligned}$$

Therefore, the value of the voltage $\mathbf{V}_1$ is $224.27\angle 0.97^\circ\ \mathrm{V\ rms}$.

Step 5 of 8

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_1(\mathrm{pf})_1}$$

Substitute $60\,\mathrm{kW}$ for P_1, 0.86 for $(\mathrm{pf})_1$ and $224.27\,\mathrm{V\ rms}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{I}_1 &= \frac{60\,\mathrm{k}}{(224.27)(0.86)}\\ &= \frac{60\,\mathrm{k}}{192.87}\\ &= 311.09\ \mathrm{A\ rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is $311.09\ \mathrm{A\ rms}$.

Consider the expression for the power factor angle.

$$\theta_1 = \cos^{-1}(\mathrm{pf})$$

Substitute 0.86 for pf in the equation.

$$\begin{aligned}\theta_1 &= \cos^{-1}(0.86)\\ &= 30.68^\circ\end{aligned}$$

Therefore, the power factor angle at the load-1 is 30.68°.

Step 6 of 8

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_1 - \angle\mathbf{I}_1$$

Substitute 30.68° for θ and 0° for $\angle\mathbf{V}_1$ in the equation.

$$\begin{aligned}30.68^\circ &= 0^\circ - \angle\mathbf{I}_1\\ \angle\mathbf{I}_1 &= 0^\circ - (30.68^\circ)\\ \angle\mathbf{I}_1 &= -30.68^\circ\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is -30.68°.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $311.09\angle -30.68^\circ\ \mathrm{A\ rms}$.

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $311.09\angle -30.68^\circ\ \mathrm{A\ rms}$ for $\mathbf{I}_1$ and $113.64\angle -36.87^\circ\ \mathrm{A\ rms}$ for $\mathbf{I}_2$ in the equation.

$$\begin{aligned}\mathbf{I} &= 311.09\angle -30.68^\circ + 113.64\angle -36.87^\circ\\ &= 424.25\angle -32.35^\circ\ \mathrm{A\ rms}\end{aligned}$$

Therefore, the value of the line current is $424.25\angle -32.35^\circ\ \mathrm{A\ rms}$.

Step 7 of 8

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(0.08 + j0.2) + \mathbf{V}_1$$

Substitute $424.25\angle -32.35^\circ\ \mathrm{A\ rms}$ for $\mathbf{I}$ and $224.27\angle 0.97^\circ\ \mathrm{V\ rms}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{V}_S &= (424.25\angle -32.35^\circ)(0.08 + j0.2) + 224.27\angle 0.97^\circ\\ &= (424.25\angle -32.35^\circ)(0.22\angle 68.2^\circ) + 224.27\angle 0.97^\circ\\ &= 93.34\angle 35.85^\circ + 224.27\angle 0.97^\circ\\ &= 305.54\angle 11.03^\circ\ \mathrm{V\ rms}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{305.54\angle 11.03^\circ\ \mathrm{V\ rms}}$.

Step 8 of 8

Consider the expression for power factor.

$$\mathrm{pf} = \cos(\angle\mathbf{V}_S - \angle\mathbf{I})$$

Substitute -32.35° for $\angle\mathbf{I}$ and 11.03° for $\angle\mathbf{V}_S$ in the equation.

$$\begin{aligned}\mathrm{pf} &= \cos(11.03^\circ - (-32.35^\circ))\\ &= \cos(11.03^\circ + 32.35^\circ)\\ &= \cos(43.38^\circ)\\ &= 0.727\ \mathrm{lagging}\end{aligned}$$

Therefore, the value of the power factor of the source is $\boxed{0.727\ \mathrm{lagging}}$.

Step 1 of 8

Refer to circuit diagram in Figure P9.86 in the textbook.

Draw the circuit with node notations and current directions.

Figure 1

Step 2 of 8

Consider the expression for load current $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{P_2}{\mathbf{V}_2(\text{pf})_2}$$

Substitute $18\,\text{kW}$ for P_2, 0.8 for $(\text{pf})_2$ and 220 V rms for $\mathbf{V}_2$ in the equation.

$$\begin{aligned}\mathbf{I}_2 &= \frac{18\text{ k}}{(220)(0.8)}\\ &= \frac{18\text{ k}}{176}\\ &= 102.27\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_2$ is 102.27 A rms.

Consider the expression for the power factor angle.

$$\theta_2 = \cos^{-1}(\text{pf})$$

Substitute 0.8 for pf in the equation.

$$\begin{aligned}\theta_2 &= \cos^{-1}(0.8)\\ &= 36.87°\end{aligned}$$

Therefore, the power factor angle at the load-2 is $36.87°$.

Step 3 of 8

Consider the expression for power factor angle.

$$\theta_2 = \angle\mathbf{V}_2 - \angle\mathbf{I}_2$$

Substitute $36.87°$ for θ_2 and $0°$ for $\angle\mathbf{V}_2$ in the equation.

$$\begin{aligned}36.87° &= 0° - \angle\mathbf{I}_2\\ \angle\mathbf{I}_2 &= 0° - (36.87°)\\ \angle\mathbf{I}_2 &= -36.87°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_2$ is $-36.87°$.

Hence, the phasor value of the load current $\mathbf{I}_2$ is $102.27\angle -36.87°\text{ A rms}$.

Step 4 of 8

Consider the expression for voltage $\mathbf{V}_1$.

$$\mathbf{V}_1 = \mathbf{I}_2(0.01 + j0.05) + \mathbf{V}_2$$

Substitute $102.27\angle -36.87°\text{ A rms}$ for $\mathbf{I}_2$, $220\angle 0°\text{ V rms}$ for $\mathbf{V}_2$, $0.01\,\Omega$ for R and $j0.05\,\Omega$ for X in the equation.

$$\begin{aligned}\mathbf{V}_1 &= (102.27\angle -36.87°)(0.01 + j0.05) + 220\angle 0°\\ &= (102.27\angle -36.87°)(0.05\angle 78.69°) + 220\angle 0°\\ &= 5.11\angle 41.82° + 220\angle 0°\\ &= 223.83\angle 0.87°\text{ V rms}\end{aligned}$$

Therefore, the value of the voltage $\mathbf{V}_1$ is $223.83\angle 0.87°\text{ V rms}$.

Step 5 of 8

Consider the expression for load current $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{P_1}{\mathbf{V}_1(\text{pf})_1}$$

Substitute $40\,\text{kW}$ for P_1, 0.86 for $(\text{pf})_1$ and $223.83\angle 0.87°\text{ V rms}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{I}_1 &= \frac{40\text{ k}}{(223.83)(0.86)}\\ &= \frac{40\text{ k}}{192.9}\\ &= 207.36\text{ A rms}\end{aligned}$$

Therefore, the magnitude value of the load current $\mathbf{I}_1$ is 207.36 A rms.

Consider the expression for the power factor angle.

$$\theta_1 = \cos^{-1}(\text{pf})$$

Substitute 0.86 for pf in the equation.

$$\begin{aligned}\theta_1 &= \cos^{-1}(0.86)\\ &= 30.68°\end{aligned}$$

Therefore, the power factor angle at the load-1 is $30.68°$.

Step 6 of 8

Consider the expression for power factor angle.

$$\theta = \angle\mathbf{V}_1 - \angle\mathbf{I}_1$$

Substitute $30.68°$ for θ and $0°$ for $\angle\mathbf{V}_1$ in the equation.

$$\begin{aligned}30.68° &= 0° - \angle\mathbf{I}_1\\ \angle\mathbf{I}_1 &= 0° - (30.68°)\\ \angle\mathbf{I}_1 &= -30.68°\end{aligned}$$

Therefore, the phase angle of the load current $\mathbf{I}_1$ is $-30.68°$.

Hence, the phasor value of the load current $\mathbf{I}_1$ is $207.36\angle -30.68°\text{ A rms}$.

Consider the expression for the line current.

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $207.36\angle -30.68°\text{ A rms}$ for $\mathbf{I}_1$ and $102.27\angle -36.87°\text{ A rms}$ for $\mathbf{I}_2$ in the equation.

$$\begin{aligned}\mathbf{I} &= 207.36\angle -30.68° + 102.27\angle -36.87°\\ &= 309.23\angle -32.72°\text{ A rms}\end{aligned}$$

Therefore, the value of the line current is $309.23\angle -32.72°\text{ A rms}$.

Step 7 of 8

Consider the expression for the source voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}(0.08 + j0.2) + \mathbf{V}_1$$

Substitute $309.23\angle -32.72°\text{ A rms}$ for $\mathbf{I}$ and $223.83\angle 0.87°\text{ V rms}$ for $\mathbf{V}_1$ in the equation.

$$\begin{aligned}\mathbf{V}_S &= (309.23\angle -32.72°)(0.08 + j0.2) + 223.83\angle 0.87°\\ &= (309.23\angle -32.72°)(0.22\angle 68.2°) + 223.83\angle 0.87°\\ &= 68.03\angle 35.48° + 223.83\angle 0.87°\\ &= 282.48\angle 8.73°\text{ V rms}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{282.48\angle 8.73°\text{ V rms}}$.

Step 8 of 8

Consider the expression for power factor.

$$\text{pf} = \cos(\angle\mathbf{V}_S - \angle\mathbf{I})$$

Substitute $-32.72°$ for $\angle\mathbf{I}$ and $8.73°$ for $\angle\mathbf{V}_S$ in the equation.

$$\begin{aligned}\text{pf} &= \cos(8.73° - (-32.72°))\\ &= \cos(8.73° + 32.72°)\\ &= \cos(41.45°)\\ &= 0.75\text{ lagging}\end{aligned}$$

Therefore, the value of the power factor of the source is $\boxed{0.75\text{ lagging}}$.

Step 1 of 3

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.8)\\ &= 36.86°\end{aligned}$$

Therefore, the value of θ_{old} is $36.86°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{\text{old}} = P_{\text{old}} \tan\theta_{\text{old}}$$

Substitute $40\,\text{kW}$ for P_{old} and $36.86°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (40\,\text{k})\tan 36.87°\\ &= (40\,\text{k})(0.75)\\ &= 30\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $30\,\text{kvar}$.

Step 2 of 3

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{\text{new}} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{\text{new}} = P_{\text{old}} \tan\theta_{\text{new}}$$

Substitute $40\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new} in the equation.

$$\begin{aligned}Q_{\text{new}} &= (40\text{k})\ \tan 25.84°\\ &= (40\text{k})(0.484)\\ &= 19.36\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $19.36\,\text{kvar}$.

Step 3 of 3

Calculate the value of the reactive power offered by the capacitor.

$$Q_{\text{cap}} = Q_{\text{new}} - Q_{\text{old}}$$

Substitute $19.36\,\text{kvar}$ for Q_{new} and $30\,\text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{\text{cap}} &= 19.36\ \text{k} - 30\ \text{kvar}\\ &= -10.64\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-10.64\,\text{kvar}$.

Consider the expression for the reactive power due to capacitor.

$$Q_{\text{cap}} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω in the equation.

$$\begin{aligned}Q_{\text{cap}} &= -(2\pi f)V_L^2 C\\ C &= \frac{-Q_{\text{cap}}}{j(2\pi f)V_L^2}\end{aligned}$$

Substitute $-10.64\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $270\,\text{V rms}$ for V_L in the equation.

$$\begin{aligned}C &= \frac{-(-10.64\,\text{k})}{(2\pi(60))(270)^2}\\ &= \frac{10.64\,\text{k}}{(376.99)(72.9\,\text{k})}\\ &= 387.15\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{387.15\ \mu\text{F}}$.

Step 1 of 4

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.8)\\ &= 36.86°\end{aligned}$$

Therefore, the value of θ_{old} is $36.86°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $18\,\text{kW}$ for P_{old} and $36.86°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (18\text{k})\ \tan 36.87°\\ &= (18\text{k})(0.75)\\ &= 13.5\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $13.5\,\text{kvar}$.

Step 2 of 4

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $18\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new} in the equation.

$$\begin{aligned}Q_{new} &= (18\text{k})\ \tan 25.84°\\ &= (18\text{k})(0.484)\\ &= 8.71\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $8.71\,\text{kvar}$.

Step 3 of 4

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $8.71\,\text{kvar}$ for Q_{new} and $13.5\,\text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{cap} &= 8.71\ \text{k} - 13.5\ \text{k}\\ &= -4.79\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-4.79\,\text{kvar}$.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω in the equation.

$$\begin{aligned}Q_{cap} &= -(2\pi f)V_L^2 C\\ C &= \frac{-Q_{cap}}{j(2\pi f)V_L^2}\end{aligned}$$

Substitute $-4.79\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $220\,\text{V rms}$ for V_L in the equation.

$$\begin{aligned}C &= \frac{-(-4.79\,\text{k})}{(2\pi(60))(220)^2}\\ &= \frac{4.79\,\text{k}}{(376.99)(48.4\,\text{k})}\\ &= 262.52\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{262.52\ \mu\text{F}}$.

Step 1 of 3

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.82)\\ &= 34.92°\end{aligned}$$

Therefore, the value of θ_{old} is $34.92°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $44\,\text{kW}$ for P_{old} and $34.92°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (44\text{k})\ \tan 34.92°\\ &= (44\text{k})(0.698)\\ &= 30.71\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $30.71\,\text{kvar}$.

Step 2 of 3

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$Q_{cap} = -(2\pi f)V_L^2 C$$

Substitute $600\,\mu\text{F}$ for C, $60\,\text{Hz}$ for f and $240\,\text{V rms}$ for V_L in the equation.

$$\begin{aligned}Q_{cap} &= -(2\pi(60))(240)^2(600\,\mu)\\ &= -13.03\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-13.03\,\text{kvar}$.

Calculate the expression for the reactive power after the capacitor is connected at the load.

$$Q_{new} = Q_{old} + Q_{cap}$$

Substitute $-13.03\,\text{kvar}$ for Q_{cap} and $30.71\,\text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{new} &= 30.71\ -13.03\ \text{k}\\ &= 17.41\ \text{kvar}\end{aligned}$$

Therefore, the value reactive power after the capacitor is connected at the load is $17.41\,\text{kvar}$.

Step 3 of 3

Calculate the value of the new power factor angle at the load.

$$\theta_{new} = \tan^{-1}\left(\frac{Q_{new}}{P_{old}}\right)$$

Substitute $44\,\text{kW}$ for P_{old} and $17.41\,\text{kvar}$ for Q_{new} in the equation.

$$\begin{aligned}\theta_{new} &= \tan^{-1}\left(\frac{17.41}{44}\right)\\ &= \tan^{-1}(0.396)\\ &= 21.60°\end{aligned}$$

Therefore, the value of θ_{new} is $21.60°$.

Calculate the value of the new power factor.

$$\begin{aligned}\text{pf}_{new} &= \cos(21.6)\\ &= 0.93\end{aligned}$$

Therefore, the value of new power factor is $\boxed{0.93}$.

Step 1 of 6

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.75)\\ &= 41.41°\end{aligned}$$

Therefore, the value of θ_{old} is $41.41°$.

Step 2 of 6

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $60\,\text{kW}$ for P_{old} and $41.41°$ for θ_{old}.

$$\begin{aligned}Q_{old} &= (60\,\text{k})\tan 41.41°\\ &= (60\,\text{k})(0.88)\\ &= 52.8\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $52.8\,\text{kvar}$.

Step 3 of 6

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Step 4 of 6

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $60\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new}.

$$\begin{aligned}Q_{new} &= (60\,\text{k})\tan 25.84°\\ &= (60\,\text{k})(0.484)\\ &= 29.04\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $29.04\,\text{kvar}$.

Step 5 of 6

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $29.04\,\text{kvar}$ for Q_{new} and $52.8\,\text{kvar}$ for Q_{old}.

$$\begin{aligned}Q_{cap} &= 29.04\,\text{k} - 52.8\,\text{k}\\ &= -23.76\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-23.76\,\text{kvar}$.

Step 6 of 6

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$Q_{cap} = -(2\pi f)V_L^2 C$$

$$C = \frac{-Q_{cap}}{j(2\pi f)V_L^2}$$

Substitute $-23.76\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $240\,\text{V rms}$ for V_L.

$$\begin{aligned}C &= \frac{-(-23.76\,\text{kvar})}{(2\pi(60))(240)^2}\\ &= \frac{23.76\,\text{k}}{(376.99)(57.6\,\text{k})}\\ &= 1094.19\,\mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{1094.19\,\mu\text{F}}$.

Step 1 of 4

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.75)\\ &= 41.41°\end{aligned}$$

Therefore, the value of θ_{old} is $41.41°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $124\,\text{kW}$ for P_{old} and $41.41°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (124\,\text{k})\ \tan 41.41°\\ &= (124\,\text{k})(0.88)\\ &= 109.12\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $109.12\ \text{kvar}$.

Step 2 of 4

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $124\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new} in the equation.

$$\begin{aligned}Q_{new} &= (124\,\text{k})\ \tan 25.84°\\ &= (124\,\text{k})(0.484)\\ &= 60.02\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $60.02\ \text{kvar}$.

Step 3 of 4

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $60.02\ \text{kvar}$ for Q_{new} and $109.12\ \text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{cap} &= 60.02\ \text{k} - 109.12\ \text{k}\\ &= -46.1\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-46.1\ \text{kvar}$.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω in the equation.

$$Q_{cap} = -(2\pi f)V_L^2 C$$

$$C = \frac{-Q_{cap}}{j(2\pi f)V_L^2}$$

Substitute $-46.1\ \text{kvar}$ for Q_{cap}, $60\ \text{Hz}$ for f and $480\ \text{V rms}$ for V_L in the equation.

$$\begin{aligned}C &= \frac{-(-46.1\,\text{k})}{(2\pi(60))(480)^2}\\ &= \frac{46.1\,\text{k}}{(376.99)(230.4\,\text{k})}\\ &= 530.75\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{530.75\ \mu\text{F}}$.

Step 1 of 6

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.76)\\ &= 40.54°\end{aligned}$$

Therefore, the value of θ_{old} is $40.54°$.

Step 2 of 6

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $60\,\text{kW}$ for P_{old} and $40.54°$ for θ_{old}.

$$\begin{aligned}Q_{old} &= (60\,\text{k})\tan 40.54°\\ &= (60\,\text{k})(0.855)\\ &= 51.3\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $51.3\,\text{kvar}$.

Step 3 of 6

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Step 4 of 6

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $60\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new}.

$$\begin{aligned}Q_{new} &= (60\,\text{k})\tan 25.84°\\ &= (60\,\text{k})(0.484)\\ &= 29.04\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $29.04\,\text{kvar}$.

Step 5 of 6

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $29.04\,\text{kvar}$ for Q_{new} and $51.3\,\text{kvar}$ for Q_{old}.

$$\begin{aligned}Q_{cap} &= 29.04\,\text{k} - 51.3\,\text{k}\\ &= -22.26\,\text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-22.26\,\text{kvar}$.

Step 6 of 6

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω.

$$Q_{cap} = -(2\pi f)V_L^2 C$$

$$C = \frac{-Q_{cap}}{f(2\pi f)V_L^2}$$

Substitute $-22.26\,\text{kvar}$ for Q_{cap}, $60\,\text{Hz}$ for f and $240\,\text{V rms}$ for V_L.

$$\begin{aligned}C &= \frac{-(-22.26\,\text{k})}{(2\pi(60))(240)^2}\\ &= \frac{22.26\,\text{k}}{(376.99)(57.6\,\text{k})}\\ &= 1025.11\,\mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{1025.11\,\mu\text{F}}$.

Step 1 of 3

Calculate the value of the power factor angle before the capacitor is connected.

$$\begin{aligned}\theta_{old} &= \cos^{-1}(0.8)\\ &= 36.86°\end{aligned}$$

Therefore, the value of θ_{old} is $36.86°$.

Consider the expression for the reactive power before the capacitor is connected to the load.

$$Q_{old} = P_{old}\tan\theta_{old}$$

Substitute $40\,\text{kW}$ for P_{old} and $36.86°$ for θ_{old} in the equation.

$$\begin{aligned}Q_{old} &= (40\text{k})\ \tan 36.87°\\ &= (40\text{k})(0.75)\\ &= 30\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power before the capacitor is connected to the load is $30\ \text{kvar}$.

Step 2 of 3

Calculate the value of the power factor angle after the capacitor is connected.

$$\begin{aligned}\theta_{new} &= \cos^{-1}(0.9)\\ &= 25.84°\end{aligned}$$

Therefore, the value of θ_{new} is $25.84°$.

Consider the expression for the reactive power after the capacitor is connected to the load.

$$Q_{new} = P_{old}\tan\theta_{new}$$

Substitute $40\,\text{kW}$ for P_{old} and $25.84°$ for θ_{new} in the equation.

$$\begin{aligned}Q_{new} &= (40\text{k})\ \tan 25.84°\\ &= (40\text{k})(0.484)\\ &= 19.36\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power after the capacitor is connected to the load is $19.36\ \text{kvar}$.

Step 3 of 3

Calculate the value of the reactive power offered by the capacitor.

$$Q_{cap} = Q_{new} - Q_{old}$$

Substitute $19.36\ \text{kvar}$ for Q_{new} and $30\ \text{kvar}$ for Q_{old} in the equation.

$$\begin{aligned}Q_{cap} &= 19.36\ \text{k} - 30\ \text{kvar}\\ &= -10.64\ \text{kvar}\end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-10.64\ \text{kvar}$.

Consider the expression for the reactive power due to capacitor.

$$Q_{cap} = -\omega V_L^2 C$$

Substitute $2\pi f$ for ω in the equation.

$$\begin{aligned}Q_{cap} &= -(2\pi f)V_L^2 C\\ C &= \frac{-Q_{cap}}{j(2\pi f)V_L^2}\end{aligned}$$

Substitute $-10.64\ \text{kvar}$ for Q_{cap}, $60\ \text{Hz}$ for f and $220\ \text{V rms}$ for V_L.

$$\begin{aligned}C &= \frac{-(-10.64\ \text{k})}{(2\pi(60))(220)^2}\\ &= \frac{10.64\ \text{k}}{(376.99)(48.4\ \text{k})}\\ &= 583.13\ \mu\text{F}\end{aligned}$$

Therefore, the value of the capacitor required to raise the power factor to 0.9 is $\boxed{583.13\ \mu\text{F}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$

The power consumed at load is, $P_L = 64\,\text{kW}$

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.68\,\text{pf lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.68)\\ &= 47.15^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}}.\tan\theta_{\text{old}}$$

Substitute $64\,\text{kW}$ for P_{old} and 47.15° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (64\times10^3)(\tan(47.15^\circ))\\ &= (100\times10^3)(1.078)\\ &= 107.8\,\text{KVAR}\end{aligned}$$

Determine the value of complex power.

$$\begin{aligned}S_{\text{old}} &= P_{\text{old}} + jQ_{\text{old}}\\ &= 64 + j107.8\ \text{kVA}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.92\,\text{lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.92)\\ &= 23.07^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}}.\tan(\theta_{\text{New}})$$

Substitute $64\,\text{kW}$ for P_{old} and 23.07° for θ_{new}.

$$\begin{aligned}Q_{\text{New}} &= (64\times10^3)\tan(23.07^\circ)\\ &= (64\times10^3)(0.4259)\\ &= 27.26\,\text{KVAR}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute $27.26\,\text{KVAR}$ for Q_{New} and $107.8\,\text{KVAR}$ for Q_{old}.

$$(27.26 - 107.8)\,\text{kVAR} = -\omega CV^2$$

$$80.54\,\text{kVAR} = 2\pi fCV^2$$

$$\begin{aligned}C &= \frac{80.54\times10^3}{2\pi fV^2}\\ &= \frac{80.54\times10^3}{2\pi\times60\times(220)^2}\\ &= 4.41\times10^{-3}\,\text{F}\\ &= 4.41\ \text{mF}\end{aligned}$$

Therefore, the capacitance value placed in parallel with the load to change the power factor to 0.92 lagging is $\boxed{4.41\ \text{mF}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$

The power consumed at load is, $P_L = 100\,\text{kW}$

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.8 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.8)\\ &= 36.86^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}}.\tan\theta_{\text{old}}$$

Substitute $100\,\text{kW}$ for P_{old} and 36.86° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (100\times10^3)(\tan(36.86)^\circ)\\ &= (100\times10^3)(0.75)\\ &= 75\,\text{KVAR}\end{aligned}$$

Determine the value of complex power.

$$\begin{aligned}S_{\text{old}} &= P_{\text{old}} + jQ_{\text{old}}\\ &= 100 + j75 \text{ kVA}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.95 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.95)\\ &= 18.19^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}}.\tan(\theta_{\text{New}})$$

Substitute $100\,\text{kW}$ for P_{old} and 18.19° for θ_{new}.

$$\begin{aligned}Q_{\text{New}} &= (100\times10^3)\tan(18.19^\circ)\\ &= 32.85\,\text{KVAR}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute $32.85\,\text{KVAR}$ for Q_{New} and $75\,\text{KVAR}$ for Q_{old}.

$$(32.85 - 75)\text{kVAR} = -\omega CV^2$$

$$49.27\,\text{kvar} = 2\pi fCV^2$$

$$\begin{aligned}C &= \frac{42.15\times10^3}{2\pi fV^2}\\ &= \frac{42.15\times10^3}{2\pi\times60\times(440)^2}\\ &= 571.51\times10^{-6}\,\text{F}\\ &= 571.51\,\mu\text{F}\end{aligned}$$

Therefore, the capacitance value placed in parallel with the load to change the power factor to 0.95 lagging is $\boxed{571.51\,\mu\text{F}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$

The power consumed at load is, $P_L = 100\,\text{kW}$

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.7 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.7)\\ &= 45.57°\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}} \cdot \tan\theta_{\text{old}}$$

Substitute $100\,\text{kW}$ for P_{old} and $45.57°$ for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (100\times10^3)(\tan(45.57)°)\\ &= (100\times10^3)(1.02)\\ &= 102\,\text{KVAR}\end{aligned}$$

Step 2 of 3

Write the following expression.

$$\begin{aligned}Q_{\text{New}} - Q_{\text{old}} &= Q_{\text{cap}}\\ Q_{\text{New}} - Q_{\text{old}} &= -\omega CV^2\\ Q_{\text{New}} - Q_{\text{old}} &= -2\pi fCV^2\end{aligned}$$

Substitute $102\,\text{KVAR}$ for Q_{old}, $3300\,\mu\text{F}$ for C, 220 V for V and 60 Hz for f.

$$\begin{aligned}Q_{\text{New}} - 102\,\text{kVAR} &= -2\pi(60)(3300\times10^{-6})(220)^2\\ Q_{\text{New}} - 102\,\text{kVAR} &= -5.43\,\text{kVAR}\\ Q_{\text{New}} &= 94.57\,\text{kVAR}\end{aligned}$$

Step 3 of 3

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}} \cdot \tan(\theta_{\text{New}})$$

Substitute $100\,\text{kW}$ for P_{old} and $94.57\,\text{kVAR}$ for Q_{new}.

$$\begin{aligned}94.57\,\text{kVAR} &= (100\times10^3)\tan(\theta_{\text{new}})\\ \tan(\theta_{\text{new}}) &= \frac{94.57}{100}\\ \theta_{\text{new}} &= \tan^{-1}(0.9457)\\ \theta_{\text{new}} &= 43.40°\end{aligned}$$

Determine the value of power factor.

$$\begin{aligned}\text{Power factor} &= \cos(\theta_{\text{new}})\\ &= \cos(43.40°)\\ &= 0.726 \text{ lagging}\end{aligned}$$

Therefore, the value of power factor is $\boxed{0.726 \text{ lagging}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$

The power consumed at load is, $P_L = 100\,\text{kW}$

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.707 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.707)\\ &= 45^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}}.\tan\theta_{\text{old}}$$

Substitute $100\,\text{kW}$ for P_{old} and 45° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (100\times10^3)(\tan(45^\circ))\\ &= (100\times10^3)(1)\\ &= 100\,\text{KVAR}\end{aligned}$$

Determine the value of complex power.

$$\begin{aligned}S_{\text{old}} &= P_{\text{old}} + jQ_{\text{old}}\\ &= 100 + j100\text{ kVA}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.92 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.92)\\ &= 23.07^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}}.\tan(\theta_{\text{New}})$$

Substitute $100\,\text{kW}$ for P_{old} and 23.07° for θ_{new}.

$$\begin{aligned}Q_{\text{New}} &= (100\times10^3)\tan(23.07^\circ)\\ &= 42.59\,\text{KVAR}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute $42.59\,\text{KVAR}$ for Q_{New} and 100KVAR for Q_{old}.

$$(42.59 - 100)\text{kVAR} = -\omega CV^2$$

$$57.41\text{kVAR} = 2\pi fCV^2$$

$$\begin{aligned}C &= \frac{57.41\times10^3}{2\pi fV^2}\\ &= \frac{57.41\times10^3}{2\pi\times60\times(480)^2}\\ &= 660.95\times10^{-6}\text{ F}\\ &= 660.95\ \mu\text{F}\end{aligned}$$

Therefore, the capacitance value placed in parallel with the load to change the power factor to 0.92 lagging is $\boxed{660.95\ \mu\text{F}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$

The power consumed at load is, $P_L = 300\,\text{kW}$

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.70 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.70)\\ &= 45.57^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}}.\tan\theta_{\text{old}}$$

Substitute $300\,\text{kW}$ for P_{old} and 45.57° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (300\times10^3)(\tan(45.57^\circ))\\ &= (300\times10^3)(1.02)\\ &= 306.06 \text{ kvar}\end{aligned}$$

Determine the value of complex power.

$$\begin{aligned}S_{\text{old}} &= P_{\text{old}} + jQ_{\text{old}}\\ &= 300 + j306.06 \text{ kvar}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.92 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.92)\\ &= 23.07^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}}.\tan(\theta_{\text{New}})$$

Substitute $300\,\text{kW}$ for P_{old} and 23.07° for θ_{new}.

$$\begin{aligned}Q_{\text{New}} &= (300\times10^3)\tan(23.07^\circ)\\ &= 127.79 \text{ kvar}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute 127.79 kvar for Q_{New} and 306.06 kvar for Q_{old}.

$$(127.79 - 306.06)\text{ kvar} = -\omega CV^2$$

$$178.26 \text{ kVAR} = 2\pi fCV^2$$

Rewrite the equation.

$$C = \frac{178.26\times10^3}{2\pi fV^2}$$

Substitute 60 for f and 480 for V

$$\begin{aligned}C &= \frac{178.26\times10^3}{2\pi\times60\times(480)^2}\\ &= 2.05\times10^{-3}\text{ F}\\ &= 2.05 \text{ mF}\end{aligned}$$

Therefore, the capacitance value placed in parallel with the load to change the power factor to 0.92 lagging is $\boxed{2.05 \text{ mF}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$.

The power consumed at load is, $P_L = 100\,\text{kW}$.

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.70 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.70)\\ &= 45.57^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}}.\tan\theta_{\text{old}}$$

Substitute $100\,\text{kW}$ for P_{old} and 45.57° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (100\times10^3)(\tan(45.57^\circ))\\ &= (100\times10^3)(1.02)\\ &= 102.02 \text{ kvar}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.92 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.92)\\ &= 23.07^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}}.\tan(\theta_{\text{New}})$$

Substitute $100\,\text{kW}$ for P_{old} and 23.07° for θ_{new} .

$$\begin{aligned}Q_{\text{New}} &= (100\times10^3)\tan(23.07^\circ)\\ &= 42.59 \text{ kvar}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute 42.59 kvar for Q_{New} and 102.02 kvar for Q_{old}.

$$(42.59 - 102.02)\text{kvar} = -\omega CV^2$$

$$59.43 \text{ kVAR} = 2\pi fCV^2$$

Rewrite the equation.

$$C = \frac{59.43\times10^3}{2\pi fV^2}$$

Substitute 60 for f and 220 for V

$$\begin{aligned}C &= \frac{59.43\times10^3}{2\pi\times60\times(220)^2}\\ &= 3.25\times10^{-3}\text{ F}\\ &= 3.25 \text{ mF}\end{aligned}$$

Therefore, the capacitance value placed in parallel with the load to change the power factor to 0.92 lagging is $\boxed{3.25 \text{ mF}}$.

Step 1 of 3

Assume the frequency is, $f = 60\,\text{Hz}$.

The power consumed at load is, $P_{\text{old}} = 5\,\text{kW}$.

The Load power factor is,

$$\cos\theta_{\text{old}} = 0.70 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{old}} &= \cos^{-1}(0.866)\\ &= 30^\circ\end{aligned}$$

Determine the value of reactive power.

$$Q_{\text{old}} = P_{\text{old}} \cdot \tan\theta_{\text{old}}$$

Substitute $5\,\text{kW}$ for P_{old} and 45.57° for θ_{old}.

$$\begin{aligned}Q_{\text{old}} &= (5\times10^3)(\tan(30^\circ))\\ &= (5\times10^3)(0.577)\\ &= 2.887 \text{ kvar}\end{aligned}$$

Step 2 of 3

The expression of S_{cap} is,

$$S_{\text{cap}} = 0 + jQ_{\text{cap}}$$

The required power factor is,

$$\cos\theta_{\text{New}} = 0.975 \text{ lagging}$$

$$\begin{aligned}\theta_{\text{New}} &= \cos^{-1}(0.975)\\ &= 12.84^\circ\end{aligned}$$

Determine the value of new reactive power.

$$Q_{\text{New}} = P_{\text{old}} \cdot \tan(\theta_{\text{New}})$$

Substitute $5\,\text{kW}$ for P_{old} and 12.84° for θ_{new} .

$$\begin{aligned}Q_{\text{New}} &= (5\times10^3)\tan(12.84^\circ)\\ &= 1.139 \text{ kvar}\end{aligned}$$

Step 3 of 3

Write the following expression to determine the value of capacitor.

$$Q_{\text{New}} - Q_{\text{old}} = Q_{\text{cap}}$$

$$Q_{\text{New}} - Q_{\text{old}} = -\omega CV^2$$

Substitute $1.139\,\text{kvar}$ for Q_{New} and $2.885\,\text{kvar}$ for Q_{old}.

$$(1.139 - 2.887)\text{kvar} = -\omega CV^2$$

$$1.747 \text{ kVAR} = 2\pi fCV^2$$

Rewrite the equation.

$$C = \frac{1.746\times10^3}{2\pi fV^2}$$

Substitute 60 for f and 240 for V

$$\begin{aligned}C &= \frac{1.747\times10^3}{2\pi\times60\times(240)^2}\\ &= 80.47\times10^{-6}\text{ F}\\ &= 80.47\ \mu\text{F}\end{aligned}$$

Therefore, the smallest capacitance value that meets the requirement is $\boxed{80.47\ \mu\text{F}}$.

Step 1 of 2

Consider Figure P6.100 (a) from the text book.

Calculate the value of the appliance resistance.

$$R = \frac{V_{ab}^{\ 2}}{P}$$

Substitute $240\ \text{V rms}$ for V_{ab} and $5100\ \text{W}$ for P.

$$\begin{aligned} R &= \frac{(240)^2}{5100} \\ &= 11.29\,\Omega \end{aligned}$$

Therefore, the value of the appliance resistance is $11.29\,\Omega$.

Step 2 of 2

Consider Figure P6.100 (b) from the text book.

Calculate the value of the power range.

$$P = \frac{V_{ab}^{\ 2}}{R}$$

Substitute $120\ \text{V rms}$ for V_{ab} and $11.29\ \text{W}$ for P.

$$\begin{aligned} P &= \frac{(240)^2}{11.29} \\ &= 1275.75\ \text{W} \end{aligned}$$

Therefore, the value of the power range is $1275.75\ \text{W}$.

Observe the values of the power range in two cases, the power range decreases by 4 times when the voltage is decreased by 2 times. Hence, the appliance cannot work.

Step 1 of 6

Refer to circuit diagram in Figure P9.103 in the text book.

Identify the currents in the circuit diagram.

Figure 1

Step 2 of 6

Calculate the value of $\mathbf{I}_{AN}$.

$$\mathbf{I}_{AN} = \frac{100\angle 0°}{120\angle 0°}$$
$$= 0.833\angle 0° \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{AN}$ is $0.833\angle 0° \text{ A rms}$.

Calculate the value of $\mathbf{I}_{BN}$.

$$\mathbf{I}_{BN} = \frac{100\angle 0°}{-120\angle 0°}$$
$$= -0.833\angle 0° \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{BN}$ is $-0.833\angle 0° \text{ A rms}$.

Step 3 of 6

Calculate the value of $\mathbf{I}_c$.

$$\mathbf{I}_c = \left(\frac{1\angle \cos^{-1}(0.9)\text{k}}{120\angle 0° + 120\angle 0°}\right)^*$$
$$= \left(\frac{1\angle 25.84\text{ k}}{240\angle 0°}\right)^*$$
$$= 4.17\angle -25.84° \text{ A rms}$$

Therefore, the value of $\mathbf{I}_c$ is $\boxed{4.17\angle -25.84° \text{ A rms}}$.

Step 4 of 6

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \mathbf{I}_{AN} + \mathbf{I}_c$$

Substitute $4.17\angle -25.84° \text{ A rms}$ for $\mathbf{I}_c$ and $0.833\angle 0° \text{ A rms}$ for $\mathbf{I}_{AN}$ in the equation.

$$\mathbf{I}_{aA} = 4.17\angle -25.84° + 0.833\angle 0°$$
$$= 4.93\angle -21.62° \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{4.93\angle -21.62° \text{ A rms}}$.

Step 5 of 6

Consider the expression for $\mathbf{I}_{nN}$.

$$\mathbf{I}_{nN} = -\mathbf{I}_{AN} - \mathbf{I}_{BN}$$

Substitute $0.833\angle 0° \text{ A rms}$ for $\mathbf{I}_{AN}$ and $-0.833\angle 0° \text{ A rms}$ for $\mathbf{I}_{BN}$ in the equation.

$$\mathbf{I}_{nN} = -0.833\angle 0° - (-0.833\angle 0° \text{ A rms})$$
$$= 0 \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{nN}$ is $\boxed{0 \text{ A rms}}$.

Step 6 of 6

Calculate the value o the total power absorbed by the loads.

$$P = 100 + 100 + 1000(0.9)$$
$$= 200 + 900$$
$$= 1.1 \text{ kW}$$

Therefore, the value of the total power absorbed by the loads is 1.1 kW.

Calculate the value of the energy utilized by the loads.

$$W = Pt$$

Substitute 1.1 kW for P and 24 h for t in the equation.

$$W = (1.1 \text{ kW})(24 \text{ h})$$
$$= 26.4 \text{ kWh}$$

Therefore, the value of the energy utilized by the loads is $\boxed{26.4 \text{ kWh}}$.

Step 1 of 2

Calculate the value of the rated current.

$$\mathbf{I} = \frac{P}{\mathbf{V}}$$

Substitute $8\,\mathrm{kW}$ for P and $120\,\mathrm{V\ rms}$ for $\mathbf{V}$ in the equation.

$$\begin{aligned} \mathbf{I} &= \frac{8\,\mathrm{k}}{120} \\ &= 67.67\ \mathrm{A\ rms} \end{aligned}$$

Therefore, the value of the rated current is $67.67\ \mathrm{A\ rms}$.

Calculate the value of the current that a circuit breaker can with stand.

$$\begin{aligned} \mathbf{I}_{\mathrm{breaker}} &= (100\% - 25\%)(20) \\ &= (75\%)(20) \\ &= 15\ \mathrm{A\ rms} \end{aligned}$$

Therefore, the value of the current that a circuit breaker can withstand is $15\ \mathrm{A\ rms}$.

Step 2 of 2

Calculate the number circuit breakers required so that the total rated current can be diverted in to several branches from the line.

$$n = \frac{\mathbf{I}}{\mathbf{I}_{\mathrm{breaker}}}$$

Substitute $15\ \mathrm{A\ rms}$ for $\mathbf{I}_{\mathrm{breaker}}$ and $67.67\ \mathrm{A\ rms}$ for $\mathbf{I}$ in the equation.

$$\begin{aligned} n &= \frac{67.67}{15} \\ &= 4.5 \\ &\approx 5 \end{aligned}$$

Therefore, the number of circuit breakers required are 5.

Hence, the number branches required are $\boxed{5}$.

Step 1 of 2

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 2

Calculate the current passing through the finger.

$$I = \frac{V_S}{R_{finger}}$$

Substitute $95\,\Omega$ for R_{finger} and assume 120 V rms for V_S.

$$I = \frac{120}{95}$$
$$= 1.26\text{ A rms}$$

Therefore, the value of the current through the limb is $\boxed{1.26\text{ A rms}}$.

The resistance offered by the cushion will be of infinite resistance. Hence, no current passes through them. Since body is not grounded, no current pass through the body and hence, not current will be observed in the vicinity of the heart.

9.114P

Refer to Figure P9.102 in the textbook.

The resistance of the gold ring is represented by R_3 .

Calculate the current in the circuit.

$$\begin{aligned} I &= \frac{V}{R_1 + R_2 + R_3 + R_4} \\ &= \frac{12\text{ V}}{0.012 + 0.012 + 0.012 + 0.012} \\ &= \frac{12\text{ V}}{0.048\ \Omega} \\ &= 250\text{ A} \end{aligned}$$

Find the power dissipated in the ring.

$$\begin{aligned} P_{\text{ring}} &= I^2 R_3 \\ &= (250)^2 (0.012) \\ &= 750\text{ W} \end{aligned}$$

Thus, the power dissipated in the gold ring is, $\boxed{750\text{ W}}$.

The instant dissipation of this power makes the ring heat and it causes severe burns to the mechanic.

Step 1 of 4

Consider the situation as shown in Figure 1.

Figure 1

Step 2 of 4

Consider the equivalent circuit diagram shown in Figure 2.

Figure 2

Step 3 of 4

Case 1: Skin is dry.

Calculate the current passing through the body.

$$I = \frac{V_S}{2R_{skin} + 2R_{arm}}$$

Substitute $100\,\Omega$ for R_{arm}, $15\,k\Omega$ for R_{skin} and assume 7200 V rms for V_S in the equation.

$$\begin{aligned} I &= \frac{V_S}{2(15000) + 2(100)} \\ &= \frac{V_S}{30000 + 200} \\ &= \frac{7200}{30200} \\ &= 238.41\text{ mA rms} \end{aligned}$$

Therefore, the value of the current through the body is $\boxed{238.41\text{ mA rms}}$.

Step 4 of 4

Case 2: Skin is wet.

Calculate the current passing through the body.

$$I = \frac{V_S}{2R_{skin} + 2R_{arm}}$$

Substitute $100\,\Omega$ for R_{arm}, $150\,\Omega$ for R_{skin} and assume 7200 V rms for V_S in the equation.

$$\begin{aligned} I &= \frac{V_S}{2(150) + 2(100)} \\ &= \frac{V_S}{300 + 200} \\ &= \frac{7200}{500} \\ &= 14.4\text{ A rms} \end{aligned}$$

Therefore, the value of the current through the body is $\boxed{14.4\text{ A rms}}$.

10.001

E

Step 1 of 2

Refer to Figure E10.1 from the text book.

Consider the expression for $v_1(t)$.

$$-v_1(t) = L_1 \frac{d(-i_1(t))}{dt} - M \frac{di_2(t)}{dt}$$

$$-v_1(t) = -L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}$$

$$v_1(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

Therefore, the expression for $v_1(t)$ is $\boxed{L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}}$.

Step 2 of 2

Consider the expression for $v_2(t)$.

$$v_2(t) = L_2 \frac{d(-i_2(t))}{dt} - M \frac{di_1(t)}{dt}$$

$$v_2(t) = -L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$$

Therefore, the expression for $v_2(t)$ is $\boxed{-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}}$.

Step 1 of 6

10.001 P

Refer to Figure P10.1 in the text book.

The modified circuit diagram of Figure P10.1 is shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law in first-loop in Figure 1, to derive the expression for $v_a(t)$.

$$-v_a(t)+L_1\frac{di_1(t)}{dt}-M\frac{di_2(t)}{dt}=0$$
$$v_a(t)=L_1\frac{di_1(t)}{dt}-M\frac{di_2(t)}{dt}$$

Thus, the expression for voltage, $v_a(t)$ is $\boxed{L_1\frac{di_1(t)}{dt}-M\frac{di_2(t)}{dt}}$.

Step 3 of 6

Apply Kirchhoff's voltage law in second-loop in Figure 1, to derive the voltage expression for $v_b(t)$.

$$v_b(t)+L_2\frac{di_2(t)}{dt}-M\frac{di_1(t)}{dt}=0$$
$$v_b(t)=-L_2\frac{di_2(t)}{dt}+M\frac{di_1(t)}{dt}$$

Thus, the expression for voltage, $v_b(t)$ is $\boxed{-L_2\frac{di_2(t)}{dt}+M\frac{di_1(t)}{dt}}$.

Step 4 of 6

The modified circuit diagram of Figure P10.1 is shown in Figure 1.

Figure 2

Step 5 of 6

Apply Kirchhoff's voltage law in first-loop in Figure 2, to derive the expression for $v_c(t)$.

$$v_c(t)+L_1\frac{di_1(t)}{dt}-M\frac{di_2(t)}{dt}=0$$
$$v_c(t)=-L_1\frac{di_1(t)}{dt}+M\frac{di_2(t)}{dt}$$

Thus, the expression for voltage, $v_c(t)$ is $\boxed{-L_1\frac{di_1(t)}{dt}+M\frac{di_2(t)}{dt}}$.

Step 6 of 6

Apply Kirchhoff's voltage law in second-loop in Figure 2, to derive the voltage expression for $v_d(t)$.

$$-v_d(t)+L_2\frac{di_2(t)}{dt}-M\frac{di_1(t)}{dt}=0$$
$$v_d(t)=L_2\frac{di_2(t)}{dt}-M\frac{di_1(t)}{dt}$$

Thus, the expression for voltage, $v_d(t)$ is $\boxed{L_2\frac{di_2(t)}{dt}-M\frac{di_1(t)}{dt}}$.

Step 1 of 10

Refer to Figure 10PFE-1 from the text book.

Consider the expression for the value of M .

$$M = k\sqrt{L_1 L_2}$$

Substitute $1\,\text{H}$ for L_1 , $2\,\text{H}$ for L_2 and 0.5 for k .

$$\begin{aligned} M &= (0.5)\sqrt{(1)(4)} \\ &= (0.5)\sqrt{4} \\ &= (0.5)(2) \\ &= 1\,\text{H} \end{aligned}$$

Therefore, the value of M is $1\,\text{H}$.

Step 2 of 10

Calculate the value of the impedance offered by the mutual inductance M .

$$X_M = j\omega M$$

Substitute $1\,\text{H}$ for M and $2\,\text{rad/s}$ for ω .

$$\begin{aligned} X_M &= j(2)(1) \\ &= j2\,\Omega \end{aligned}$$

Therefore, the value of the impedance offered by the mutual inductance M is $j2\,\Omega$.

Step 3 of 10

Calculate the value of the impedance offered by the inductance at the primary of the transformer.

$$X_{L_1} = j\omega L_1$$

Substitute $1\,\text{H}$ for L_1 and $2\,\text{rad/s}$ for ω .

$$\begin{aligned} X_{L_1} &= j(2)(1) \\ &= j2\,\Omega \end{aligned}$$

Therefore, the value of the impedance offered by the inductance at the primary of the transformer is $j2\,\Omega$.

Step 4 of 10

Calculate the value of the impedance offered by the inductance at the secondary of the transformer.

$$X_{L_2} = j\omega L_2$$

Substitute $4\,\text{H}$ for L_2 and $2\,\text{rad/s}$ for ω .

$$\begin{aligned} X_{L_2} &= j(2)(4) \\ &= j8\,\Omega \end{aligned}$$

Therefore, the value of the impedance offered by the inductance at the secondary of the transformer is $j8\,\Omega$.

Step 5 of 10

Calculate the value of the impedance offered by the capacitance.

$$X_C = \frac{1}{j\omega C}$$

Substitute $100\,\text{mH}$ for C and $2\,\text{rad/s}$ for ω .

$$\begin{aligned} X_C &= \frac{1}{j(2)(100\,\text{m})} \\ &= \frac{1}{j(200\,\text{m})} \\ &= -j5\,\Omega \end{aligned}$$

Therefore, the value of the impedance offered by the capacitance is $-j5\,\Omega$.

Step 6 of 10

Consider the value of the voltage source.

$$\mathbf{V}_S = 24\cos(2t + 0°)\,\text{V}$$

Rewrite in phasor notation.

$$\mathbf{V}_S = 24\angle 0°\,\text{V}$$

Therefore, he value of the voltage source in phasor notation is $24\angle 0°\,\text{V}$.

Step 7 of 10

Redraw the circuit diagram.

Figure 1

Step 8 of 10

Consider Kirchhoff's Voltage Law in Loop-2.

$$\begin{aligned} &\mathbf{I}_2(-j5 + 5 + j8) - \mathbf{I}_1(j2) = 0 \\ &\mathbf{I}_2(5 + j3) - \mathbf{I}_1(j2) = 0 \end{aligned}$$

Solve for $\mathbf{I}_2$ in terms of $\mathbf{I}_1$.

$$\begin{aligned} &\mathbf{I}_2(5 + j3) = \mathbf{I}_1(j2) \\ &\mathbf{I}_2 = \mathbf{I}_1\left(\frac{j2}{5 + j3}\right) \end{aligned}$$

Therefore, the expression for $\mathbf{I}_2$ is $\mathbf{I}_1\left(\frac{j2}{5 + j3}\right)$.

Step 9 of 10

Consider Kirchhoff's Voltage Law in Loop-1.

$$\begin{aligned} &-24\angle 0° + \mathbf{I}_1(4 + j2) - \mathbf{I}_2(j2) = 0 \\ &\mathbf{I}_1(4 + j2) - \mathbf{I}_2(j2) = 24\angle 0° \end{aligned}$$

Substitute $\mathbf{I}_1\left(\frac{j2}{5 + j3}\right)$ for $\mathbf{I}_2$.

$$\begin{aligned} &\mathbf{I}_1(4 + j2) - \mathbf{I}_1\left(\frac{j2}{5 + j3}\right)(j2) = 24\angle 0° \\ &\mathbf{I}_1(4 + j2) + \mathbf{I}_1\left(\frac{4}{5 + j3}\right) = 24\angle 0° \\ &\mathbf{I}_1(4 + j2) + \mathbf{I}_1(0.59 - j0.35) = 24\angle 0° \\ &\mathbf{I}_1(4 + j2 + 0.59 - j0.35) = 24\angle 0° \\ &\mathbf{I}_1(4.59 + j1.65) = 24\angle 0° \\ &\mathbf{I}_1(4.88\angle 19.77°) = 24\angle 0° \\ &\mathbf{I}_1 = \frac{24\angle 0°}{4.88\angle 19.77°} \\ &\mathbf{I}_1 = 4.92\angle -19.77°\,\text{A} \end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $4.92\angle -19.77°\,\text{A}$.

Step 10 of 10

Define input impedance $\mathbf{Z}_{IN}$.

$$\mathbf{Z}_{IN} = \frac{\mathbf{V}_S}{\mathbf{I}_1}$$

Substitute $4.92\angle -19.77°\,\text{A}$ for $\mathbf{I}_1$ and $24\angle 0°\,\text{V}$ for $\mathbf{V}_S$.

$$\begin{aligned} \mathbf{Z}_{IN} &= \frac{24\angle 0°}{4.92\angle -19.77°} \\ &= 4.88\angle 19.77° \end{aligned}$$

Therefore, the value of the input impedance is $\boxed{4.88\angle 19.77°}$.

Hence, the correct option is $\boxed{(a)}$.

10.002

E

Step 1 of 4

Refer to Figure E10.2 in the text book.

Apply Kirchhoff's voltage law to the left side loop of the circuit.

$$4\mathbf{I}_1 + 24\angle 0° + (j4)\mathbf{I}_1 + (j1)\mathbf{I}_2 = 0$$
$$(4+j4)(\mathbf{I}_1) + (j)(\mathbf{I}_2) + 24\angle 0° = 0$$
$$(4+j4)(\mathbf{I}_1) + (j)(\mathbf{I}_2) = -24\angle 0° \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law to the right side loop of the circuit.

$$j8\mathbf{I}_2 + 2\mathbf{I}_2 - (j4)\mathbf{I}_2 + (j)\mathbf{I}_1 = 0$$
$$(j)(\mathbf{I}_1) + (2+j8-j4)(\mathbf{I}_2) = 0$$
$$(j)(\mathbf{I}_1) = -(2+j4)(\mathbf{I}_2)$$
$$(\mathbf{I}_1) = (j2-4)(\mathbf{I}_2) \quad \text{..... (2)}$$

Step 2 of 4

Substitute $(j2-4)(\mathbf{I}_2)$ for $(\mathbf{I}_1)$ in equation (1).

$$(4+j4)\left[(j2-4)(\mathbf{I}_2)\right] + (j)(\mathbf{I}_2) = -24\angle 0°$$
$$\mathbf{I}_2(24+7j) = 24\angle 0°$$
$$\mathbf{I}_2 = \frac{24\angle 0°}{24+7j}$$
$$= 0.96\angle -16.26° \text{ A}$$

Thus, the value of current, $\mathbf{I}_2$ is $\boxed{0.96\angle -16.26° \text{ A}}$.

Step 3 of 4

Calculate the value of current $\mathbf{I}_1$ from equation (2).

$$(\mathbf{I}_1) = (j2-4)(\mathbf{I}_2)$$

Substitute $0.96\angle -16.26° \text{ A}$ for $\mathbf{I}_2$.

$$\mathbf{I}_1 = (j2-4)(0.96\angle -16.26°)$$
$$= (j2-4)(0.9216 - j0.2688)$$
$$= -3.14 + j2.92$$
$$= 4.29\angle 137.2° \text{ A}$$

Thus, the value of current $\mathbf{I}_1$ is $\boxed{4.29\angle 137.2° \text{ A}}$.

Step 4 of 4

Calculate the output voltage, $\mathbf{V}_O$.

$$\mathbf{V}_O = (-j4)(\mathbf{I}_2)$$

Substitute $0.96\angle -16.26° \text{ A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_O = (4\angle -90°)(0.96\angle -16.26° \text{ A})$$
$$= 3.84\angle -106.26° \text{ V}$$

Thus, the value of output voltage $\mathbf{V}_O$ is $\boxed{3.84\angle -106.26° \text{ V}}$.

Step 1 of 4

10.002 P

Refer to Figure P10.2 in the textbook.

Both the currents are entering the undotted terminals of the coil. Hence, the voltages set up by the currents at the undotted terminals of the coil will be positive.

(a)

Consider the expression for $v_a(t)$.

$$v_a(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

Therefore, the expression for $v_a(t)$ is $\boxed{L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}}$.

Step 2 of 4

Consider the expression for $v_b(t)$.

$$-v_b(t) = L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}$$

$$v_b(t) = -L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$$

Therefore, the expression for $v_b(t)$ is $\boxed{-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}}$.

Step 3 of 4

(b)

Consider the expression for $v_c(t)$.

$$v_c(t) = -v_a(t)$$

Substitute $L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$ for $v_a(t)$.

$$\begin{aligned} v_c(t) &= -\left[L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}\right] \\ &= -L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_c(t)$ is $\boxed{-L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}}$.

Step 4 of 4

Consider the expression for $v_d(t)$.

$$v_d(t) = -v_b(t)$$

Substitute $-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$ for $v_b(t)$.

$$\begin{aligned} v_d(t) &= -\left[-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}\right] \\ &= L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_d(t)$ is $\boxed{L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}}$.

Step 1 of 8

Refer to Figure 10PFE-2 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $48 + j32\,\Omega$ for $\mathbf{Z}_1$.

$$\mathbf{Z}_2 = n^2(48 + j32)\,\Omega$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $n^2(48 + j32)\,\Omega$.

Step 2 of 8

Consider the value of the voltage source transferred to secondary of the transformer.

$$\mathbf{V}_{s,2} = n(120\angle 0^\circ) \text{ ..... (1)}$$

Therefore, the value of the voltage source transferred to secondary of the transformer is $n(120\angle 0^\circ)$.

Step 3 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 8

For the maximum power at the load impedance, the value of the internal impedance of the circuit should be equal to the load impedance.

That is,

$$48n^2 + j32n^2 - j2 = 3$$
$$48n^2 + j(32n^2 - 2) = 3 + j0$$

Equate imaginary terms.

$$32n^2 - 2 = 0$$
$$32n^2 = 2$$
$$n^2 = \frac{2}{32}$$
$$n^2 = \frac{1}{16}$$
$$n = \sqrt{\frac{1}{16}}$$
$$n = \pm\frac{1}{4}$$

Transformer ratio cannot be negative. Hence, the value of the transformer ratio is $\frac{1}{4}$.

Step 5 of 8

Consider equation (1).

$$\mathbf{V}_{s,2} = n(120\angle 0^\circ)$$

Substitute $\frac{1}{4}$ for n.

$$\mathbf{V}_{s,2} = \left(\frac{1}{4}\right)(120\angle 0^\circ)$$
$$= 30\angle 0^\circ \text{ V}$$

Therefore, the value of the voltage source transferred to secondary of the transformer is $30\angle 0^\circ$ V.

Step 6 of 8

Consider the circuit diagram shown in Figure 1.

Figure 2

Step 7 of 8

Calculate the value of $\mathbf{V}_o$ using voltage division rule.

$$\mathbf{V}_o = (30\angle 0^\circ)\left(\frac{3}{3+3}\right)$$
$$= (30\angle 0^\circ)\left(\frac{3}{6}\right)$$
$$= (30\angle 0^\circ)\left(\frac{1}{2}\right)$$
$$= 15\angle 0^\circ \text{ V}$$

Therefore, the value of the voltage $\mathbf{V}_o$ is $15\angle 0^\circ$ V.

Step 8 of 8

Calculate the value of the power absorbed by the $3\,\Omega$ resistor.

$$P_{3\Omega} = \frac{1}{2}\left(\frac{\mathbf{V}_o^2}{3}\right)$$

Substitute $15\angle 0^\circ$ V for $\mathbf{V}_o$.

$$P_{3\Omega} = \frac{1}{2}\left(\frac{(15\angle 0^\circ)^2}{3}\right)$$
$$= \frac{225\angle 0^\circ}{6}$$
$$= 37.5 \text{ W}$$

Therefore, the value of the maximum power absorbed by the $3\,\Omega$ resistor is $\boxed{37.5 \text{ W}}$.

Therefore, the correct option is $\boxed{\text{(b)}}$.

Step 1 of 3

10.003
E

Refer to Figure E10.3 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the Kirchhoff's Voltage Law in Loop-1.

$$\mathbf{I}_1(R_1 + j\omega L_1) + (\mathbf{I}_1 - \mathbf{I}_2)R_2 - \mathbf{I}_2(j\omega M) + \mathbf{V}_1 = 0$$
$$\mathbf{I}_1(R_1 + j\omega L_1) + \mathbf{I}_1 R_2 - \mathbf{I}_2 R_2 - \mathbf{I}_2(j\omega M) + \mathbf{V}_1 = 0$$
$$\mathbf{I}_1(R_1 + j\omega L_1 + R_2) - \mathbf{I}_2(R_2 + j\omega M) = -\mathbf{V}_1$$

Therefore, the required Kirchhoff's Voltage Law equation is

$$\boxed{\mathbf{I}_1(R_1 + j\omega L_1 + R_2) - \mathbf{I}_2(R_2 + j\omega M) = -\mathbf{V}_1}.$$

Step 3 of 3

Consider the Kirchhoff's Voltage Law in Loop-2.

$$-\mathbf{V}_1 + (\mathbf{I}_2 - \mathbf{I}_1)R_2 + \mathbf{I}_2(j\omega L_2 + R_3) - \mathbf{I}_1(j\omega M) = 0$$
$$-\mathbf{V}_1 + \mathbf{I}_2 R_2 - \mathbf{I}_1 R_2 + \mathbf{I}_2(j\omega L_2 + R_3) - \mathbf{I}_1(j\omega M) = 0$$
$$-\mathbf{I}_1(R_2 + j\omega M) + \mathbf{I}_2(R_2 + j\omega L_2 + R_3) = \mathbf{V}_1$$

Therefore, the required Kirchhoff's Voltage Law equation is

$$\boxed{-\mathbf{I}_1(R_2 + j\omega M) + \mathbf{I}_2(R_2 + j\omega L_2 + R_3) = \mathbf{V}_1}.$$

Step 1 of 4

Refer to Figure P10.4 in the textbook.

Both the currents are entering the dotted terminals of the coil. Hence, the voltages set up by the currents at the dotted terminals of the coil will be positive.

(a)

Consider the expression for $v_a(t)$.

$$-v_a(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

$$v_a(t) = -L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}$$

Therefore, the expression for $v_a(t)$ is $\boxed{-L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}}$.

Step 2 of 4

Consider the expression for $v_b(t)$.

$$v_b(t) = -L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$$

Therefore, the expression for $v_b(t)$ is $\boxed{-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}}$.

Step 3 of 4

(b)

Consider the expression for $v_c(t)$.

$$v_c(t) = -v_a(t)$$

Substitute $-L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}$ for $v_a(t)$.

$$\begin{aligned} v_c(t) &= -\left[-L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}\right] \\ &= L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_c(t)$ is $\boxed{L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}}$.

Step 4 of 4

Consider the expression for $v_d(t)$.

$$v_d(t) = -v_b(t)$$

Substitute $-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$ for $v_b(t)$.

$$\begin{aligned} v_d(t) &= -\left[-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}\right] \\ &= L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_d(t)$ is $\boxed{L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}}$.

Step 1 of 8

10.03E

E

Refer to Figure 10PFE-3 from the text book.

Consider the circuit at the primary of the transformer.

Apply Thevenin's theorem to the circuit.

Consider the circuit diagram to calculate the open circuit voltage.

Figure 1

Step 2 of 8

Consider the expression for $\mathbf{V}_x$ in terms of $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_x &= \mathbf{V}_S\left(\frac{5\,\mathrm{k}}{5\,\mathrm{k}+1\,\mathrm{k}}\right)\\ &= \mathbf{V}_S\left(\frac{5\,\mathrm{k}}{6\,\mathrm{k}}\right)\\ &= \mathbf{V}_S\left(\frac{5}{6}\right)\end{aligned}$$

Therefore the expression for $\mathbf{V}_x$ of is $\mathbf{V}_S\left(\frac{5}{6}\right)$.

Step 3 of 8

Consider the expression for the value of $\mathbf{V}_{OC}$.

$$\mathbf{V}_{OC} = -0.04\mathbf{V}_x(10\,\mathrm{k})$$

Substitute $\mathbf{V}_S\left(\frac{5}{6}\right)$ for $\mathbf{V}_x$.

$$\begin{aligned}\mathbf{V}_{OC} &= -0.04\mathbf{V}_S\left(\frac{5}{6}\right)(10\,\mathrm{k})\\ &= -\left(\frac{2000}{6}\right)\mathbf{V}_S\\ &= -\left(\frac{1000}{3}\right)\mathbf{V}_S\end{aligned}$$

Therefore, the value of $\mathbf{V}_{OC}$ is $-\left(\frac{1000}{3}\right)\mathbf{V}_S$.

Step 4 of 8

Consider the circuit diagram to calculate the short circuit current.

Figure 2

Step 5 of 8

Consider the expression for the value of $\mathbf{I}_{SC}$.

$$\mathbf{I}_{SC} = -0.04\mathbf{V}_x$$

Substitute $\mathbf{V}_S\left(\frac{5}{6}\right)$ for $\mathbf{V}_x$.

$$\begin{aligned}\mathbf{I}_{SC} &= -0.04\mathbf{V}_S\left(\frac{5}{6}\right)\\ &= -\left(\frac{0.2}{6}\right)\mathbf{V}_S\\ &= -\left(\frac{1}{30}\right)\mathbf{V}_S\end{aligned}$$

Therefore, the value of $\mathbf{I}_{SC}$ is $-\left(\frac{1}{30}\right)\mathbf{V}_S$.

Step 6 of 8

Define the expression for the Thevenin's impedance.

$$\mathbf{Z}_{TH} = \frac{\mathbf{V}_{OC}}{\mathbf{I}_{SC}}$$

Substitute $-\left(\frac{1}{3}\right)\mathbf{V}_S$ for $\mathbf{I}_{SC}$ and $-\left(\frac{1000}{3}\right)\mathbf{V}_S$ for $\mathbf{V}_{OC}$.

$$\begin{aligned}\mathbf{Z}_{TH} &= \frac{-\left(\frac{1000}{3}\right)\mathbf{V}_S}{-\left(\frac{1}{30}\right)\mathbf{V}_S}\\ &= 10\,\mathrm{k}\Omega\end{aligned}$$

Therefore, the value of the Thevenin's impedance is $10\,\mathrm{k}\Omega$.

Step 7 of 8

Consider the circuit diagram shown in the Figure 3.

Figure 3

Step 8 of 8

Consider the expression for the turns ration in terms of impedances.

$$\begin{aligned}\left(\frac{1}{a}\right)^2 &= \frac{16}{10\,\mathrm{k}}\\ \frac{1}{a^2} &= \frac{16}{10\,\mathrm{k}}\\ a^2 &= \frac{10\,\mathrm{k}}{16}\\ a^2 &= 625\\ a &= \sqrt{625}\\ a &= 25\end{aligned}$$

Therefore, the value of a is $\boxed{25}$.

Therefore, the correct option is $\boxed{\text{(d)}}$.

Step 1 of 4

10.004

E

Refer to Figure E10.4 from the text book.

Consider the circuit diagram shown in Figure 1 and identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in Loop-1.

$$-24\angle 0^\circ + \mathbf{I}_1(2 + j2 - j3) - \mathbf{I}_2(j1.5) = 0$$
$$\mathbf{I}_1(2 - j1) - \mathbf{I}_2(j1.5) = 24\angle 0^\circ$$

Solve for $\mathbf{I}_1$.

$$\mathbf{I}_1(2 - j1) = 24\angle 0^\circ + \mathbf{I}_2(j1.5)$$
$$\mathbf{I}_1 = \frac{24\angle 0^\circ + \mathbf{I}_2(j1.5)}{2 - j1}$$

Therefore, the expression for $\mathbf{I}_1$ is $\frac{24\angle 0^\circ + \mathbf{I}_2(j1.5)}{2 - j1}$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in Loop-2.

$$\mathbf{I}_2(-j2 + j4 + 2 + 4 + j2) - \mathbf{I}_1(j1.5) + 10\angle 30^\circ = 0$$
$$\mathbf{I}_2(6 + j4) - \mathbf{I}_1(j1.5) + 10\angle 30^\circ = 0$$

Substitute $\frac{24\angle 0^\circ + \mathbf{I}_2(j1.5)}{2 - j1}$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(6 + j4) - \left(\frac{24\angle 0^\circ + \mathbf{I}_2(j1.5)}{2 - j1}\right)(j1.5) + 10\angle 30^\circ = 0$$
$$\mathbf{I}_2(6 + j4) - \frac{(24\angle 0^\circ)(j1.5)}{2 - j1} - \frac{\mathbf{I}_2(j1.5)(j1.5)}{2 - j1} + 10\angle 30^\circ = 0$$
$$\mathbf{I}_2(6 + j4) + \frac{\mathbf{I}_2(2.25)}{2 - j1} = \frac{(24\angle 0^\circ)(j1.5)}{2 - j1} - 10\angle 30^\circ$$
$$\mathbf{I}_2(6 + j4) + \mathbf{I}_2(0.9 + j0..45) = (24\angle 0^\circ)(-0.3 + j0.6) - 10\angle 30^\circ$$
$$\mathbf{I}_2(6 + j4 + 0.9 + j0..45) = (24\angle 0^\circ)(0.67\angle 116.57^\circ) - 10\angle 30^\circ$$
$$\mathbf{I}_2(6.9 + j4.5) = 16.08\angle 116.57^\circ - 10\angle 30^\circ$$
$$\mathbf{I}_2(8.21\angle 32.82^\circ) = 18.42\angle 149.38^\circ$$
$$\mathbf{I}_2 = \frac{18.42\angle 149.38^\circ}{8.21\angle 32.82^\circ}$$
$$\mathbf{I}_2 = 2.24\angle 116.56^\circ \text{ A}$$

Therefore, the value of $\mathbf{I}_2$ is $2.24\angle 116.56^\circ$ A.

Step 4 of 4

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O = \mathbf{I}_2(2) + 10\angle 30^\circ$$

Substitute $2.24\angle 116.56^\circ$ A for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_O &= (2.24\angle 116.56^\circ)(2) + 10\angle 30^\circ \\ &= 4.48\angle 116.56^\circ + 10\angle 30^\circ \\ &= 11.2\angle 53.5^\circ \text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{11.2\angle 53.5^\circ \text{ V}}$.

Step 1 of 4

Refer to Figure 10PFE-4 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $6 + j2\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{2}\right)^2(6+j2)\\ &= \frac{6+j2}{4}\\ &= 1.5 + j0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $1.5 + j0.5\,\Omega$.

Step 2 of 4

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_{s,2} = n\mathbf{V}_s$$

Substitute $120\angle 0°\ \text{V}$ for $\mathbf{V}_s$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{V}_{s,2} &= \left(\frac{1}{2}\right)(120\angle 0°)\\ &= 60\angle 0°\ \text{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $60\angle 0°\ \text{V}$.

Step 3 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 4

Calculate the value of $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{60\angle 0°}{1.5 + j0.5 + 1 - j1}\\ &= \frac{60\angle 0°}{2.5 - j0.5}\\ &= \frac{60\angle 0°}{2.55\angle -11.31°}\\ &= 23.54\angle 11.31°\ \text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{23.54\angle 11.31°\ \text{A}}$.

Therefore, the correct option is $\boxed{\text{(c)}}$.

Step 1 of 4

10.005

E

Refer to Figure P10.3 in the textbook.

Both the currents are entering the dotted terminals of the coil. Hence, the voltages set up by the currents at the dotted terminals of the coil will be positive.

(a)

Consider the expression for $v_a(t)$.

$$v_a(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

Therefore, the expression for $v_a(t)$ is $\boxed{L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}}$.

Step 2 of 4

Consider the expression for $v_b(t)$.

$$-v_b(t) = L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}$$

$$v_b(t) = -L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$$

Therefore, the expression for $v_b(t)$ is $\boxed{-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}}$.

Step 3 of 4

(b)

Consider the expression for $v_c(t)$.

$$v_c(t) = -v_a(t)$$

Substitute $L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$ for $v_a(t)$.

$$\begin{aligned} v_c(t) &= -\left[L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt} \right] \\ &= -L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_c(t)$ is $\boxed{-L_1 \frac{di_1(t)}{dt} - M \frac{di_2(t)}{dt}}$.

Step 4 of 4

Consider the expression for $v_d(t)$.

$$v_d(t) = -v_b(t)$$

Substitute $-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt}$ for $v_b(t)$.

$$\begin{aligned} v_d(t) &= -\left[-L_2 \frac{di_2(t)}{dt} - M \frac{di_1(t)}{dt} \right] \\ &= L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt} \end{aligned}$$

Therefore, the expression for $v_d(t)$ is $\boxed{L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}}$.

Step 1 of 3

Step 2 of 3

The two equations for the given network are as follows:

$$I_1(1+j4)-I_0 j1=10\angle 0° \quad .....(1)$$

$$-I_1 j1+I_0(2+j2)=0 \quad .....(2)$$

From equation (2) we have,

$$I_1=I_0\left(\frac{2+j2}{j1}\right)$$

$$I_1=I_0(2+j2)(-j1)$$

$$I_1=I_0(2-j2)$$

Step 3 of 3

Substituting I_1 in (1) we get,

$$I_0(2-j2)(1+j4)-I_0 j1=10\angle 0°$$

$$I_0(2+j8-j2+8-j1)=10\angle 0°$$

$$I_0(10+j5)=10\angle 0°$$

$$I_0=\frac{10\angle 0°}{(10+j5)}$$

$$I_0=\frac{10\angle 0°}{11.18\angle 26.565°}$$

$$I_0=0.894\angle -26.565°$$

$$\boxed{I_0=0.894\angle -26.565°\text{ A}}$$

Step 1 of 3

Refer to Figure 10PFE-5 from the text book.

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_{s,2} = n\mathbf{V}_s$$

Substitute $120\angle 0°\ \mathrm{V}$ for $\mathbf{V}_s$ and 2 for n .

$$\begin{aligned}\mathbf{V}_{s,2} &= (2)(120\angle 0°)\\ &= 240\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $240\angle 0°\ \mathrm{V}$.

Step 2 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 3

Calculate the value of $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{240\angle 0°}{10 + j10}\\ &= \frac{240\angle 0°}{14.14\angle 45°}\\ &= 16.97\angle -45°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{16.97\angle -45°\ \mathrm{A}}$.

Therefore, the correct option is $\boxed{\text{(a)}}$.

Step 1 of 8

Consider Figure E10.6 in the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 8

Consider the circuit to left of the terminals A and B.

Figure 2

Step 3 of 8

Calculate the value of the open circuit voltage $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AB} &= (3\angle 30°)(2) + 20\angle 30° \\ &= 6\angle 30° + 20\angle 30° \\ &= 26\angle 30°\ \text{V}\end{aligned}$$

Therefore, the value of the voltage $\mathbf{V}_{AB}$ is $26\angle 30°\ \text{V}$.

Step 4 of 8

Disconnect the sources for the circuit shown in Figure 2.

Figure 3

B

Calculate the value of $\mathbf{R}_{AB}$.

$$\begin{aligned}\mathbf{R}_{AB} &= 2 + 4 \\ &= 6\,\Omega\end{aligned}$$

Therefore, the value of the resistance $\mathbf{R}_{AB}$ is $6\,\Omega$.

Step 5 of 8

Replace the circuit to left of the terminals with Thevenin's circuit.

Figure 4

Step 6 of 8

Apply Kirchhoff's voltage Law to Loop-1.

$$-26\angle 30° + \mathbf{I}_1(6) + \mathbf{I}_1(j3) + (\mathbf{I}_1 + \mathbf{I}_2)(2 + j2) + \mathbf{I}_2(j1) = 0$$

$$\mathbf{I}_1(6 + j3 + 2 + j2) + \mathbf{I}_2(2 + j2 + j1) = 26\angle 30°$$

$$\mathbf{I}_1(8 + j5) = 26\angle 30° - \mathbf{I}_2(2 + j3)$$

$$\mathbf{I}_1 = \frac{26\angle 30° - \mathbf{I}_2(2 + j3)}{8 + j5}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\dfrac{26\angle 30° - \mathbf{I}_2(2 + j3)}{8 + j5}$.

Step 7 of 8

Apply Kirchhoff's voltage Law to Loop-2.

$$\mathbf{I}_2(4 - j1) + \mathbf{I}_2(j3) + \mathbf{I}_1(j1) + (\mathbf{I}_2 + \mathbf{I}_1)(2 + j2) - 10\angle 0° = 0$$

$$\mathbf{I}_2(4 - j1 + j3 + 2 + j2) + \mathbf{I}_1(j1 + 2 + j2) = 10\angle 0°$$

$$\mathbf{I}_2(6 + j4) + \mathbf{I}_1(2 + j3) = 10\angle 0°$$

Substitute $\dfrac{26\angle 30° - \mathbf{I}_2(2 + j3)}{8 + j5}$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(6 + j4) + \left(\frac{26\angle 30° - \mathbf{I}_2(2 + j3)}{8 + j5}\right)(2 + j3) = 10\angle 0°$$

$$\mathbf{I}_2(6 + j4) + \frac{(26\angle 30°)(2 + j3)}{8 + j5} - \frac{\mathbf{I}_2(2 + j3)(2 + j3)}{8 + j5} = 10\angle 0°$$

$$\mathbf{I}_2(6 + j4) + (26\angle 30°)(0.38\angle 24.3°) - \frac{\mathbf{I}_2(-5 + j12)}{8 + j5} = 10\angle 0°$$

$$\mathbf{I}_2(6 + j4) + 9.88\angle 54.3° - \mathbf{I}_2(0.23 + j1.36) = 10\angle 0°$$

$$\mathbf{I}_2(6 + j4 - 0.23 - j1.36) = 10\angle 0° - 9.88\angle 54.3°$$

$$\mathbf{I}_2(5.77 + j2.64) = 9.07\angle -62.2°$$

$$\mathbf{I}_2(6.35\angle 24.6°) = 9.07\angle -62.2°$$

$$\mathbf{I}_2 = \frac{9.07\angle -62.2°}{6.35\angle 24.6°}$$

$$\mathbf{I}_2 = 1.428\angle -86.8\ \text{A}$$

Therefore, the value of the current $\mathbf{I}_2$ is $1.428\angle -86.8\ \text{A}$.

Step 8 of 8

Calculate the value of the output voltage $\mathbf{V}_O$.

$$\mathbf{V}_O = -\mathbf{I}_2(-j1) + 10\angle 0°$$

Substitute $1.428\angle -86.78\ \text{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_O &= -(1.428\angle -86.759)(1\angle -90°) + 10\angle 0° \\ &= 1.428\angle 3.2 + 10\angle 0° \\ &= 11.42\angle 0.4°\ \text{V}\end{aligned}$$

Therefore, the value of the output voltage is $\boxed{11.42\angle 0.4°\ \text{V}}$.

Step 1 of 4

10.006 P

Consider Figure P10.6 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(1-j1+2+j1)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(3)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_1=\mathbf{I}_2\left(\frac{-3}{j1}\right)$$
$$\mathbf{I}_1=\mathbf{I}_2(j3)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_2(j3)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(1+j2)+\mathbf{I}_2(j1)=12\angle 0°$$

Substitute $\mathbf{I}_2(j3)$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(j3)(1+j2)+\mathbf{I}_2(j1)=12\angle 0°$$
$$\mathbf{I}_2(j3-6)+\mathbf{I}_2(j1)=12\angle 0°$$
$$\mathbf{I}_2(j4-6)=12\angle 0°$$
$$\mathbf{I}_2(7.21\angle 146.31°)=12\angle 0°$$

$$\mathbf{I}_2=\frac{12\angle 0°}{7.21\angle 146.31°}$$
$$\mathbf{I}_2=1.66\angle -146.31°\ \mathrm{A}$$

Therefore, the value of $\mathbf{I}_2$ is $1.66\angle -146.31°\ \mathrm{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_o$.

$$\mathbf{V}_o=\mathbf{I}_2(2)$$

Substitute $1.66\angle -146.31°\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_o=(1.66\angle -146.31°)(2)$$
$$=3.32\angle -146.31°\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{3.32\angle -146.31°\ \mathrm{V}}$.

Step 1 of 3

10.007

E

Refer to Figure E10.7 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(2+j2+(-j2\parallel j1))+\mathbf{I}_1(j1)=0$$

$$\mathbf{I}_2\left(2+j2+\frac{(-j2)(j1)}{-j2+j1}\right)+\mathbf{I}_1(j1)=0$$

$$\mathbf{I}_2\left(2+j2+\frac{2}{-j1}\right)+\mathbf{I}_1(j1)=0$$

$$\mathbf{I}_2(2+j2+j2)+\mathbf{I}_1(j1)=0$$

$$\mathbf{I}_2(2+j4)+\mathbf{I}_1(j1)=0$$

$$\mathbf{I}_2(2+j4)=-\mathbf{I}_1(j1)$$

$$\mathbf{I}_2=-\mathbf{I}_1(0.2+j0.1)$$

Therefore, the value of $\mathbf{I}_2$ is $-\mathbf{I}_1(0.2+j0.1)$.

Step 3 of 3

Consider the Kirchhoff's Voltage Law in loop-1.

$$-120\angle 0^\circ+\mathbf{I}_1(2-j1+j2)+\mathbf{I}_2(j1)=0$$

$$\mathbf{I}_1(2+j1)+\mathbf{I}_2(j1)=120\angle 0^\circ$$

Substitute $-\mathbf{I}_1(0.2+j0.1)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(2+j1)-\mathbf{I}_1(0.2+j0.1)(j1)=120\angle 0^\circ$$

$$\mathbf{I}_1(2+j1)-\mathbf{I}_1(-0.1+j0.2)=120\angle 0^\circ$$

$$\mathbf{I}_1(2+j1+0.1-j0.2)=120\angle 0^\circ$$

$$\mathbf{I}_1(2.1+j0.8)=120\angle 0^\circ$$

$$\mathbf{I}_1(2.25\angle 20.9^\circ)=120\angle 0^\circ$$

Define the expression for the input impedance.

$$Z_S=\frac{120\angle 0^\circ}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1(2.25\angle 20.9^\circ)$ for $120\angle 0^\circ$.

$$Z_S=\frac{\mathbf{I}_1(2.25\angle 20.9^\circ)}{\mathbf{I}_1}$$

$$=2.25\angle 20.9^\circ\ \Omega$$

Therefore, the value of Z_S is $\boxed{2.25\angle 20.9^\circ\ \Omega}$.

Step 1 of 4

10.007 P

Consider Figure P10.7 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(1+1+j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(2+j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_1=-\mathbf{I}_2\left(\frac{2+j2}{j1}\right)$$
$$\mathbf{I}_1=-\mathbf{I}_2(2-j2)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $-\mathbf{I}_2(2-j2)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(2+j2)+\mathbf{I}_2(j1)=10\angle 0°$$

Substitute $-\mathbf{I}_2(2-j2)$ for $\mathbf{I}_1$.

$$-\mathbf{I}_2(2-j2)(2+j2)+\mathbf{I}_2(j1)=10\angle 0°$$
$$-\mathbf{I}_2(8)+\mathbf{I}_2(j1)=10\angle 0°$$
$$\mathbf{I}_2(-8+j1)=10\angle 0°$$
$$\mathbf{I}_2(8.06\angle 172.88°)=10\angle 0°$$

$$\mathbf{I}_2=\frac{10\angle 0°}{8.06\angle 172.88°}$$
$$\mathbf{I}_2=1.24\angle -172.88°\ \text{A}$$

Therefore, the value of $\mathbf{I}_2$ is $1.24\angle -172.88°\ \text{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_o$.

$$\mathbf{V}_o=\mathbf{I}_2(1)$$

Substitute $1.24\angle -172.88°\ \text{A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_o=(1.24\angle -172.88°\ \text{A})(1)$$
$$=1.24\angle -172.88°\ \text{V}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{1.24\angle -172.88°\ \text{V}}$.

10.008

E

Step 1 of 8

Refer to Figure E10.8 from the text book.

Consider the Kirchhoff's Voltage Law for the circuit at secondary of the transformer.

$$\mathbf{I}_2(2-j2+j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(2)=-\mathbf{I}_1(j1)$$

$$\mathbf{I}_2=-\mathbf{I}_1(j0.5) \text{ ..... (1)}$$

Therefore, the value of $\mathbf{I}_2$ is $-\mathbf{I}_1(j0.5)$.

Step 2 of 8

Consider the Kirchhoff's Voltage Law for the circuit at primary of the transformer.

$$-12\angle 30^\circ+\mathbf{I}_1(2+j2)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_1(2+j2)+\mathbf{I}_2(j1)=12\angle 30^\circ$$

Substitute $-\mathbf{I}_1(j0.5)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(2+j2)-\mathbf{I}_1(j0.5)(j1)=12\angle 30^\circ$$
$$\mathbf{I}_1(2+j2)+\mathbf{I}_1(j0.5)=12\angle 30^\circ$$
$$\mathbf{I}_1(2+j2+j0.5)=12\angle 30^\circ$$
$$\mathbf{I}_1(2+j2.5)=12\angle 30^\circ$$

$$\mathbf{I}_1(3.2\angle 51.34^\circ)=12\angle 30^\circ$$
$$\mathbf{I}_1=\frac{12\angle 30^\circ}{3.2\angle 51.34^\circ}$$
$$\mathbf{I}_1=3.75\angle -21.34^\circ \text{ A}$$

Therefore, the value of $\mathbf{I}_1$ is $3.75\angle -21.34^\circ$ A.

Step 3 of 8

Consider the expression for the ω.

$$\omega=2\pi f$$

Substitute $j2\,\Omega$ for X_L and 60 Hz for f.

$$\omega=2\pi(60)$$
$$=376.99\text{ rad/s}$$

Therefore, the value of ω is 376.99 rad/s.

Step 4 of 8

Consider the value of the current $\mathbf{I}_1$.

$$\mathbf{I}_1=3.75\angle -21.34^\circ \text{ A}$$

Convert into time domain.

$$i_1(t)=3.75\cos(376.99t-21.34^\circ)\text{A}$$

Substitute 10 ms for t.

$$i_1(t)=3.75\cos(376.99(10\text{ m})-21.34^\circ)$$
$$=3.75\cos(3.77-21.34^\circ)\text{A}$$

But $3.77\text{ radians}=216.02^\circ$

$$i_1(t)=3.75\cos(216.02^\circ-21.34^\circ)$$
$$=3.75\cos(194.68^\circ)$$
$$=(3.75)(-0.97)$$
$$=-3.64\text{A}$$

Therefore, the value of $i_1(10\text{ m})$ is -3.64A.

Step 5 of 8

Consider equation (1).

$$\mathbf{I}_2=-\mathbf{I}_1(j0.5)$$

Substitute $3.75\angle -21.34^\circ$ A for $\mathbf{I}_1$.

$$\mathbf{I}_2=-(3.75\angle -21.34^\circ)(j0.5)$$
$$=-(3.75\angle -21.34^\circ)(0.5\angle 90^\circ)$$
$$=-1.88\angle 68.66^\circ$$
$$=1.88\angle -111.34^\circ \text{ A}$$

Therefore, the value of $\mathbf{I}_2$ is $1.88\angle -111.34^\circ$ A.

Step 6 of 8

Consider the value of the current $\mathbf{I}_2$.

$$\mathbf{I}_2=1.88\angle -111.34^\circ \text{ A}$$

Convert into time domain.

$$i_2(t)=1.88\cos(376.99t-111.34^\circ)\text{A}$$

Substitute 10 ms for t.

$$i_2(t)=1.88\cos(376.99(10\text{ m})-111.34^\circ)$$
$$=1.88\cos(3.77-111.34^\circ)\text{A}$$

But $3.77\text{ radians}=216.02^\circ$

$$i_2(t)=1.88\cos(216.02^\circ-111.34^\circ)$$
$$=1.88\cos(104.68^\circ)$$
$$=(1.88)(-0.25)$$
$$=-0.47\text{A}$$

Therefore, the value of $i_2(10\text{ m})$ is -0.47A.

Step 7 of 8

Consider the expression for the reactance due to inductance.

$$X_L=j\omega L$$

Substitute $2\pi f$ for ω.

$$X_L=j2\pi fL$$

Solve for L.

$$L=\frac{X_L}{j2\pi f}$$

Substitute $j2\,\Omega$ for X_L and 60 Hz for f.

$$L=\frac{j2}{j2\pi(f)60}$$
$$=\frac{2}{376.99}$$
$$=5.31\text{ mH}$$

Therefore, the value of L self inductance is 5.31 mH.

The value of mutual inductance M is half of the value of self inductance L. Hence the value of M is 2.66 mH.

Step 8 of 8

Consider the expression for the energy stored in the coupled inductors.

$$w(t)=\frac{1}{2}L_1i_1^2(t)+\frac{1}{2}L_2i_2^2(t)-Mi_1(t)i_2(t)$$

Substitute 10 ms for t.

$$w(1\text{ m})=\frac{1}{2}L_1i_1^2(10\text{ m})+\frac{1}{2}L_2i_2^2(10\text{ m})-Mi_1(10\text{ m})i_2(10\text{ m})$$

Substitute 5.31 mH for L_1 and L_2, -3.64 A for $i_1(10\text{ m})$, -0.47 A for $i_2(10\text{ m})$ and 2.66 mH for M.

$$w(10\text{ m})=\frac{1}{2}(5.31\text{ m})(-3.64)^2+\frac{1}{2}(5.31\text{ m})(-0.47)^2-(2.66\text{ m})(-3.64)(-0.47)$$
$$=\frac{1}{2}(5.31\text{ m})(13.25)+\frac{1}{2}(5.31\text{ m})(0.22)-4.55\text{ m}$$
$$=35.18\text{ m}+0.58\text{ m}-4.55\text{ m}$$
$$=31.21\text{ mJ}$$

Therefore, the value of the energy stored in the coupled inductors is $\boxed{31.21\text{ mJ}}$.

Step 1 of 4

Step 2 of 4

The mesh equations for the given network are as follows:

$(2+j4)I_1 - j2I_2 = V_1$ .....(1)

$-j2I_1 + (2+j2+2-j1)I_2 = 0$

$-j2I_1 + (4+j1)I_2 = 0$ .....(2)

Step 3 of 4

From equation (2) we have,

$$I_1 = \frac{(4+j1)}{j2} I_2$$

Substituting I_1 in equation (1) we get,

$$\frac{(2+j4)(4+j1)}{j2} I_2 - j2I_2 = V_1$$

$$(2+j4)(4+j1)I_2 - j2(j2)I_2 = j2V_1$$

$$I_2(8+j2+j16-4+4) = j2V_1$$

$$I_2(8+j18) = j2V_1$$

$$I_2 = \frac{j2V_1}{8+18j}$$

$$I_2 = \frac{jV_1}{4+9j}$$

Step 4 of 4

Now, $V_0 = 2I_2$

$$\therefore V_0 = 2\frac{jV_1}{4+9j}$$

$$\frac{V_0}{V_1} = \frac{2j}{4+9j}$$

$$\frac{V_0}{V_1} = \frac{2j}{(4^2+9^2)}(4-j9)$$

$$\frac{V_0}{V_1} = \frac{18+j8}{97}$$

$$\frac{V_0}{V_1} = \frac{19.6977\angle 23.962^\circ}{97}$$

$$\boxed{\frac{V_0}{V_1} = 0.203\angle 23.962^\circ}$$

Step 1 of 3

10.009

E

Refer to Figure E10.9 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the series combination of resistance and capacitance in the secondary circuit.

Substitute $2 - j2 + 2\,\Omega$ for $\mathbf{Z}_2$ and 2 for n .

$$\begin{aligned}\mathbf{Z}_1 &= \frac{2 - j2 + 2}{2^2} \\ &= \frac{2 - j2 + 2}{4} \\ &= 0.5 - j0.5 + 0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $0.5 - j0.5 + 0.5\,\Omega$.

Step 2 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 3

Calculate the value of $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{12\angle 0^\circ}{2 - j2 + 0.5 - j0.5 + 0.5} \\ &= \frac{12\angle 0^\circ}{3.91\angle -39.81^\circ} \\ &= 3.07\angle 39.81^\circ\,\text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{3.07\angle 39.81^\circ\,\text{A}}$.

Step 1 of 4

10.009 P

Consider Figure P10.9 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(1+j1+j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(1+j3)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_1=-\mathbf{I}_2\left(\frac{1+j3}{j1}\right)$$
$$\mathbf{I}_1=-\mathbf{I}_2(3-j1)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $-\mathbf{I}_2(3-j1)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(2+j2)+\mathbf{I}_2(j1)=10\angle 0°$$

Substitute $-\mathbf{I}_2(3-j1)$ for $\mathbf{I}_1$.

$$-\mathbf{I}_2(3-j1)(2+j2)+\mathbf{I}_2(j1)=10\angle 0°$$
$$-\mathbf{I}_2(6+j6-j2+2)+\mathbf{I}_2(j1)=10\angle 0°$$
$$\mathbf{I}_2(-8-j4+j1)=10\angle 0°$$
$$\mathbf{I}_2(-8-j3)=10\angle 0°$$
$$\mathbf{I}_2(8.54\angle -159.44°)=10\angle 0°$$
$$\mathbf{I}_2=\frac{10\angle 0°}{8.54\angle -159.44°}$$
$$\mathbf{I}_2=1.17\angle 159.44°\ \text{A}$$

Therefore, the value of $\mathbf{I}_2$ is $1.17\angle 159.44°\ \text{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_2(1)$$

Substitute $1.17\angle 159.44°\ \text{A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_O=(1.17\angle 159.44°)(1)$$
$$=1.17\angle 159.44°\ \text{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.17\angle 159.44°\ \text{V}}$.

Step 1 of 5

10.010

E

Refer to Figure E10.10 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the series combination of resistance and capacitance in the secondary circuit.

Substitute $2 - j2 + 2\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{2 - j2 + 2}{2^2}\\ &= \frac{2 - j2 + 2}{4}\\ &= 0.5 - j0.5 + 0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $0.5 - j0.5 + 0.5\,\Omega$.

Step 2 of 5

Transfer the output voltage to primary side.

$\mathbf{V}_o{}' = \frac{\mathbf{V}_o}{n}$ Substitute 2 for n.

$$\mathbf{V}_o{}' = \frac{\mathbf{V}_o}{2}$$

Therefore, the value of $\mathbf{V}_o{}'$ is $\frac{\mathbf{V}_o}{2}$.

Step 3 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 5

Calculate the value of $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{12\angle 0^\circ}{2 - j2 + 0.5 - j0.5 + 0.5}\\ &= \frac{12\angle 0^\circ}{3.91\angle -39.81^\circ}\\ &= 3.07\angle 39.81^\circ\,\text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $3.07\angle 39.81^\circ\,\text{A}$.

Step 5 of 5

Calculate the value of $\frac{\mathbf{V}_o}{2}$.

$$\frac{\mathbf{V}_o}{2} = \mathbf{I}_1(0.5)$$

Solve for $\mathbf{V}_o$.

$$\begin{aligned}\mathbf{V}_o &= \mathbf{I}_1(0.5)(2)\\ &= \mathbf{I}_1\end{aligned}$$

Substitute $3.07\angle 39.81^\circ\,\text{A}$ for $\mathbf{I}_1$.

$$\mathbf{V}_o = 3.07\angle 39.81^\circ\,\text{V}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{3.07\angle 39.81^\circ\,\text{V}}$.

Step 1 of 5

Consider Figure P10.10 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 5

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(1-j1+1+j6)-\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_3(2+j5)-\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_2=\mathbf{I}_3\left(\frac{2+j5}{j2}\right)$$
$$\mathbf{I}_2=\mathbf{I}_3(2.5-j1)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_3(2.5-j1)$.

Step 3 of 5

Consider Kirchhoff's Voltage Law in loop-1.

$$-24\angle 0°+\mathbf{I}_1(-j1)+(\mathbf{I}_1-\mathbf{I}_2)(2)=0$$
$$\mathbf{I}_1(2-j1)-\mathbf{I}_2(2)=24\angle 0°$$
$$\mathbf{I}_1(2-j1)=24\angle 0°+\mathbf{I}_2(2)$$
$$\mathbf{I}_1=\frac{24\angle 0°+\mathbf{I}_2(2)}{2-j1}$$

Substitute $\mathbf{I}_3(2.5-j1)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1=\frac{24\angle 0°+\mathbf{I}_3(2.5-j1)(2)}{2-j1}$$
$$=\frac{24\angle 0°+\mathbf{I}_3(5-j2)}{2-j1}$$

Therefore, the expression for $\mathbf{I}_1$ is $\dfrac{24\angle 0°+\mathbf{I}_3(5-j2)}{2-j1}$.

Step 4 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(2)+\mathbf{I}_2(2+j4)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(2+2+j4)-\mathbf{I}_1(2)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(4+j4)-\mathbf{I}_1(2)-\mathbf{I}_3(j2)=0$$

Substitute $\dfrac{24\angle 0°+\mathbf{I}_3(5-j2)}{2-j1}$ for $\mathbf{I}_1$ and $\mathbf{I}_3(2.5-j1)$ for $\mathbf{I}_2$.

$$\mathbf{I}_3(2.5-j1)(4+j4)-\left(\frac{24\angle 0°+\mathbf{I}_3(5-j2)}{2-j1}\right)(2)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_3(10+j10-j4+4)-\left(\frac{48\angle 0°}{2-j1}\right)-\mathbf{I}_3\left(\frac{10-j4}{2-j1}\right)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_3(14+j6)-\mathbf{I}_3(4.8+j0.4)-\mathbf{I}_3(j2)=\frac{48\angle 0°}{2-j1}$$
$$\mathbf{I}_3(14+j6-4.8-j0.4-j2)=\frac{48\angle 0°}{2-j1}$$
$$\mathbf{I}_3(9.2+j3.6)=\frac{48\angle 0°}{2-j1}$$
$$\mathbf{I}_3=\frac{48\angle 0°}{(2-j1)(9.2+j3.6)}$$
$$\mathbf{I}_3=\frac{48\angle 0°}{(18.4+j7.2-j9.2+3.6)}$$
$$\mathbf{I}_3=\frac{48\angle 0°}{(22-j2)}$$
$$\mathbf{I}_3=\frac{48\angle 0°}{22.09\angle -5.19°}$$
$$\mathbf{I}_3=2.17\angle 5.19°\text{ A}$$

Therefore, the value of $\mathbf{I}_3$ is $2.17\angle 5.19°$ A

Step 5 of 5

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_3(1)$$

Substitute $2.17\angle 5.19°$ A for $\mathbf{I}_3$.

$$\mathbf{V}_O=(2.17\angle 5.19°)(1)$$
$$=2.17\angle 5.19°\text{ V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{2.17\angle 5.19°\text{ V}}$.

Step 1 of 7

Refer to Figure E10.11 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_2$$

Substitute $32 + j16 - j24\,\Omega$ for $\mathbf{Z}_2$ and $\frac{1}{4}$ for n.

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{4}\right)^2(32 + j16 - j24)\\ &= \left(\frac{1}{16}\right)(32 + j16 - j24)\\ &= 2 + j1 - 1.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $2 + j1 - 1.5\,\Omega$.

Step 2 of 7

Transfer the source voltage to secondary side.

$\mathbf{V}_{s,2} = -n\mathbf{V}_s$ Substitute $\frac{1}{4}$ for and $100\angle 0°\text{ V}$ for $\mathbf{V}_s$.

$$\begin{aligned}\mathbf{V}_{s,2} &= -\left(\frac{1}{4}\right)(100\angle 0°)\\ &= -25\angle 0°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{s,2}$ is $-25\angle 0°\text{ V}$.

Step 3 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 7

Calculate the value of $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{-25\angle 0° - 20\angle -20°}{2 + j1 + 3 + j2 - j1.5}\\ &= \frac{-(25\angle 0° + 20\angle -20°)}{5 + j1.5}\\ &= \frac{-44.33\angle -8.88°}{5.22\angle 16.7°}\\ &= \frac{44.33\angle 171.12°}{5.22\angle 16.7°}\end{aligned}$$

$$\mathbf{I}_2 = 8.49\angle 154.42°\text{ A}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{8.49\angle 154.42°\text{ A}}$.

Step 5 of 7

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = -\frac{\mathbf{I}_2}{4}$$

Substitute $8.49\angle 154.42°\text{ A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_1 &= -\frac{8.49\angle 154.42°}{4}\\ &= -2.12\angle 154.42°\\ &= 2.12\angle -25.6°\text{ A}\end{aligned}$$

Therefore, the value of is $\boxed{2.12\angle -25.6°\text{ A}}$.

Step 6 of 7

Calculate the value of $\mathbf{V}_2$.

$$\mathbf{V}_2 = \mathbf{I}_2(3 + j2) + 20\angle -20°$$

Substitute $8.49\angle 154.42°\text{ A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_2 &= (8.49\angle 154.42°)(3 + j2) + 20\angle -20°\\ &= (8.49\angle 154.42°)(3.61\angle 33.69°) + 20\angle -20°\\ &= 30.65\angle -171.89° + 20\angle -20°\\ &= 16.06\angle -135.9°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{16.06\angle -135.9°\text{ V}}$.

Step 7 of 7

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1 = -4\mathbf{V}_2$$

Substitute $16.06\angle -135.9°\text{ V}$ for $\mathbf{V}_2$.

$$\begin{aligned}\mathbf{V}_1 &= -4(16.06\angle -135.9°)\\ &= -64.24\angle -135.9°\\ &= 64.24\angle 44.1°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{64.24\angle 44.1°\text{ V}}$.

Step 1 of 5

10.011 P

Consider Figure P10.11 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 5

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(8-j8+4)+\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_3(12-j8)+\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_2=-\mathbf{I}_3\left(\frac{12-j8}{j2}\right)$$
$$\mathbf{I}_2=-\mathbf{I}_3(4-j6)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $-\mathbf{I}_3(4-j6)$.

Step 3 of 5

Consider Kirchhoff's Voltage Law in loop-1.

$$-24\angle 0^\circ+\mathbf{I}_1(2)+(\mathbf{I}_1-\mathbf{I}_2)(-j2)=0$$
$$\mathbf{I}_1(2-j2)+\mathbf{I}_2(j2)=24\angle 0^\circ$$
$$\mathbf{I}_1(2-j2)=24\angle 0^\circ-\mathbf{I}_2(j2)$$
$$\mathbf{I}_1=\frac{24\angle 0^\circ-\mathbf{I}_2(j2)}{2-j2}$$

Substitute $-\mathbf{I}_3(4-j6)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1=\frac{24\angle 0^\circ+\mathbf{I}_3(4-j6)(j2)}{2-j1}$$
$$=\frac{24\angle 0^\circ+\mathbf{I}_3(12+j8)}{2-j2}$$

Therefore, the expression for $\mathbf{I}_1$ is $\frac{24\angle 0^\circ+\mathbf{I}_3(12+j8)}{2-j2}$.

Step 4 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(-j2)+\mathbf{I}_2(6+j4)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(-j2+6+j4)+\mathbf{I}_1(j2)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(6+j2)+\mathbf{I}_1(j2)+\mathbf{I}_3(j2)=0$$

Substitute $\frac{24\angle 0^\circ+\mathbf{I}_3(12+j8)}{2-j2}$ for $\mathbf{I}_1$ and $-\mathbf{I}_3(4-j6)$ for $\mathbf{I}_2$.

$$-\mathbf{I}_3(4-j6)(6+j2)+\left(\frac{24\angle 0^\circ+\mathbf{I}_3(12+j8)}{2-j2}\right)(j2)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_3(-36+j28)+(24\angle 0^\circ)\left(\frac{j2}{2-j2}\right)+\mathbf{I}_3\left(\frac{-16+j2}{2-j2}\right)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_3(-36+j28)+(24\angle 0^\circ)(-0.5+j0.5)+\mathbf{I}_3(-10+j2)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_3(-36+j28-10+j2+j2)=(24\angle 0^\circ)(-0.5+j0.5)$$
$$\mathbf{I}_3(-46+j32)=-(24\angle 0^\circ)(-0.5+j0.5)$$
$$\mathbf{I}_3=(24\angle 0^\circ)\left(\frac{0.5-j0.5}{-46+j32}\right)$$
$$\mathbf{I}_3=(24\angle 0^\circ)(0.013\angle 169.82^\circ)$$
$$\mathbf{I}_3=0.312\angle 169.82^\circ\ \mathrm{A}$$

Therefore, the value of $\mathbf{I}_3$ is $0.312\angle 169.82^\circ\ \mathrm{A}$

Step 5 of 5

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_3(4)$$

Substitute $0.312\angle 169.82^\circ\ \mathrm{A}$ for $\mathbf{I}_3$.

$$\mathbf{V}_O=(0.312\angle 169.82^\circ)(4)$$
$$=1.248\angle 169.82^\circ\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.248\angle 169.82^\circ\ \mathrm{V}}$.

Step 1 of 5

Refer to Figure E10.12 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $32 + j16 - j24\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{4}$ for n.

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{4}\right)^2(32 + j16 - j24)\\ &= \left(\frac{1}{16}\right)(32 + j16 - j24)\\ &= 2 + j1 - 1.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $2 + j1 - 1.5\,\Omega$.

Step 2 of 5

Transfer the source voltage to secondary side.

$\mathbf{V}_{s,2} = -n\mathbf{V}_s$ Substitute $\frac{1}{4}$ for n and $100\angle 0°\text{ V}$ for $\mathbf{V}_s$.

$$\begin{aligned}\mathbf{V}_{s,2} &= -\left(\frac{1}{4}\right)(100\angle 0°)\\ &= -25\angle 0°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{s,2}$ is $-25\angle 0°\text{ V}$.

Step 3 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 5

Calculate the value of $\mathbf{I}_o$.

$$\begin{aligned}\mathbf{I}_o &= \frac{-25\angle 0° - 20\angle -20°}{2 + j1 + 3 + j2 - j1.5}\\ &= \frac{-(25\angle 0° + 20\angle -20°)}{5 + j1.5}\\ &= \frac{-44.33\angle -8.88°}{5.22\angle 16.7°}\\ &= \frac{44.33\angle 171.12°}{5.22\angle 16.7°}\end{aligned}$$

$$\mathbf{I}_o = 8.49\angle 154.42°\text{ A}$$

Therefore, the value of $\mathbf{I}_o$ is $8.49\angle 154.42°\text{ A}$.

Step 5 of 5

Calculate the value of $\mathbf{V}_o$.

$$\mathbf{V}_o = \mathbf{I}_o(j2) + 20\angle -20°$$

Substitute $8.49\angle 154.42°\text{ A}$ for $\mathbf{I}_o$.

$$\begin{aligned}\mathbf{V}_o &= (8.49\angle 154.42°)(j2) + 20\angle -20°\\ &= (8.49\angle 154.42°)(2\angle 90°) + 20\angle -20°\\ &= 16.98\angle -115.58° + 20\angle -20°\\ &= 24.95\angle -62.65°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{24.95\angle -62.65°\text{ V}}$.

Step 1 of 6

10.012 P

Consider Figure P10.14 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 6

Consider Kirchhoff's Voltage Law in loop-4.

$$\mathbf{I}_4(2-j1+j3)+\mathbf{I}_3(-j1)=0$$
$$\mathbf{I}_4(2+j2)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_3(j1)=\mathbf{I}_4(2+j2)$$
$$\mathbf{I}_3=\mathbf{I}_4(2-j2)$$

Therefore, the expression for the current $\mathbf{I}_3$ is $\mathbf{I}_4(2-j2)$.

Step 3 of 6

Consider Kirchhoff's Voltage Law in loop-3.

$$(\mathbf{I}_3-\mathbf{I}_2)4+\mathbf{I}_3(-j2+j4)+\mathbf{I}_4(-j1)=0$$
$$-\mathbf{I}_2(4)+\mathbf{I}_3(4+j2)-\mathbf{I}_4(j1)=0$$
$$\mathbf{I}_2(4)=\mathbf{I}_3(4+j2)-\mathbf{I}_4(j1)$$
$$\mathbf{I}_2=\frac{\mathbf{I}_3(4+j2)-\mathbf{I}_4(j1)}{4}$$

Substitute $\mathbf{I}_4(2-j2)$ for $\mathbf{I}_3$.

$$\begin{aligned}\mathbf{I}_2&=\frac{\mathbf{I}_4(2-j2)(4+j2)-\mathbf{I}_4(j1)}{4}\\&=\mathbf{I}_4\left(\frac{12-j4-j1}{4}\right)\\&=\mathbf{I}_4\left(\frac{12-j5}{4}\right)\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_4\left(\frac{12-j5}{4}\right)$.

Step 4 of 6

Consider Kirchhoff's Voltage Law in loop-1.

$$12\angle 0°+\mathbf{I}_1(2+4)+(\mathbf{I}_1-\mathbf{I}_2)(12)=0$$
$$\mathbf{I}_1(2+4+12)-\mathbf{I}_2(12)=-12\angle 0°$$
$$\mathbf{I}_1(18)-\mathbf{I}_2(12)=12\angle 180°$$
$$\mathbf{I}_1=\frac{12\angle 180°+\mathbf{I}_2(12)}{18}$$

Substitute $\mathbf{I}_4\left(\frac{12-j5}{4}\right)$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_1&=\frac{12\angle 180°+\mathbf{I}_4\left(\frac{12-j5}{4}\right)(12)}{18}\\&=\frac{12\angle 180°+\mathbf{I}_4(12-j5)(3)}{18}\\&=\frac{12\angle 180°}{18}+\frac{\mathbf{I}_4(12-j5)(3)}{18}\\&=\frac{2\angle 180°}{3}+\frac{\mathbf{I}_4(12-j5)}{6}\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\frac{2\angle 180°}{3}+\frac{\mathbf{I}_4(12-j5)}{6}$.

Step 5 of 6

Consider Kirchhoff's Voltage Law in loop-2.

$$-24\angle 0°+(\mathbf{I}_2-\mathbf{I}_1)(12)+(\mathbf{I}_2-\mathbf{I}_3)(4)=0$$
$$-\mathbf{I}_1(12)+\mathbf{I}_2(12+4)-\mathbf{I}_3(4)=24\angle 0°$$
$$-\mathbf{I}_1(12)+\mathbf{I}_2(16)-\mathbf{I}_3(4)=24\angle 0°$$
$$-\mathbf{I}_1(3)+\mathbf{I}_2(4)-\mathbf{I}_3=6\angle 0°$$

Substitute $\frac{2\angle 180°}{3}+\frac{\mathbf{I}_4(12-j5)}{6}$ for $\mathbf{I}_1$, $\mathbf{I}_4\left(\frac{12-j5}{4}\right)$ for $\mathbf{I}_2$ and $\mathbf{I}_4(2-j2)$ for $\mathbf{I}_3$.

$$-\left(\frac{2\angle 180°}{3}+\frac{\mathbf{I}_4(12-j5)}{6}\right)(3)+\mathbf{I}_4\left(\frac{12-j5}{4}\right)(4)-\mathbf{I}_4(2-j2)=6\angle 0°$$
$$-(2\angle 180°+\mathbf{I}_4(6-j2.5))+\mathbf{I}_4(12-j5)-\mathbf{I}_4(2-j2)=6\angle 0°$$
$$-2\angle 180°-\mathbf{I}_4(6-j2.5)+\mathbf{I}_4(12-j5)-\mathbf{I}_4(2-j2)=6\angle 0°$$
$$\mathbf{I}_4(-6+j2.5+12-j5-2+j2)=6\angle 0°+2\angle 180°$$

$$\mathbf{I}_4(4-j0.5)=4\angle 0°$$
$$\mathbf{I}_4=\frac{4\angle 0°}{4-j0.5}$$
$$\mathbf{I}_4=\frac{4\angle 0°}{4.03\angle -7.13}$$
$$\mathbf{I}_4=0.99\angle 7.13$$

Therefore, the value of the current $\mathbf{I}_4$ is $0.99\angle 7.13$.

Step 6 of 6

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_4(2)$$

Substitute $0.99\angle 7.13\,\mathrm{A}$ for $\mathbf{I}_4$.

$$\begin{aligned}\mathbf{V}_O&=(0.99\angle 7.13)(2)\\&=1.98\angle 7.13°\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.98\angle 7.13°\,\mathrm{V}}$.

Step 1 of 7

Refer to Figure E10.13 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer having turns ratio 1:2.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $2 + j4\,\Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (2)^2(2 + j4)\\ &= (4)(2 + j4)\\ &= 8 + j16\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer having turns ratio 1:2 is $8 + j16\,\Omega$.

Step 2 of 7

Transfer the source voltage of $50\angle 0°$ to secondary side.

$\mathbf{V}_{S,2} = n\mathbf{V}_S$ Substitute 2 for n and $50\angle 0°\ \text{V}$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_{S,2} &= (2)(50\angle 0°)\\ &= 100\angle 0°\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{S,2}$ is $100\angle 0°\ \text{V}$.

Step 3 of 7

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer having turns ratio 4:1.

$$\mathbf{Z}_1^{\,1} = \frac{\mathbf{Z}_2^{\,1}}{n^2}$$

Substitute $0.5 - j0.5\,\Omega$ for $\mathbf{Z}_2^{\,1}$ and $\frac{1}{4}$ for n.

$$\begin{aligned}\mathbf{Z}_1^{\,1} &= \frac{0.5 - j0.5}{\left(\frac{1}{4}\right)^2}\\ &= (16)(0.5 - j0.5)\\ &= 8 - j8\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer having turns ratio 4:1 is $8 - j8\,\Omega$.

Step 4 of 7

Transfer the source voltage of $10\angle 30°$ to primary side.

$\mathbf{V}_{S,1} = -\frac{\mathbf{V}_S}{n}$ Substitute $\frac{1}{4}$ for n and $10\angle 30°\ \text{V}$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_{S,1} &= -\frac{10\angle 30°}{\frac{1}{4}}\\ &= -40\angle 30°\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{S,1}$ is $-40\angle 30°\ \text{V}$.

Step 5 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 6 of 7

Calculate the value of $\mathbf{I}_O$.

$$\begin{aligned}\mathbf{I}_O &= \frac{100\angle 0° - (-40\angle 30°)}{8 + j16 + 10 - j8 + 8 - j8 + 6 + j10}\\ &= \frac{100\angle 0° + 40\angle 30°}{32 + j10}\\ &= \frac{136.12\angle 8.45°}{33.53\angle 17.35°}\\ &= 4.06\angle -8.9°\ \text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_O$ is $4.06\angle -8.9°\ \text{A}$.

Step 7 of 7

Calculate the value of $\mathbf{V}_O$.

$$\mathbf{V}_O = \mathbf{I}_O(-j8 + 8 - j8 + 6) - 40\angle 30°$$

Substitute $4.06\angle -8.9°\ \text{A}$ for $\mathbf{I}_O$.

$$\begin{aligned}\mathbf{V}_O &= (4.06\angle -8.9°)(j14 - j16) - 40\angle 30°\\ &= (4.06\angle -8.9°)(21.3\angle -48.81°) - 40\angle 30°\\ &= 86.48\angle -57.71° - 40\angle 30°\\ &= 93.82\angle -83°\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{93.82\angle -83°\ \text{V}}$.

Step 1 of 4

10.013 P

Consider Figure P10.13 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(1-j1+j2)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_1(1+j1)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_1=-\mathbf{I}_2\left(\frac{j1}{1+j1}\right)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $-\mathbf{I}_2\left(\frac{j1}{1+j1}\right)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(1+j1+2)+\mathbf{I}_1(j1)+10\angle 0°=0$$
$$\mathbf{I}_2(3+j1)+\mathbf{I}_1(j1)=-10\angle 0°$$

Substitute $-\mathbf{I}_2\left(\frac{j1}{1+j1}\right)$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(3+j1)-\mathbf{I}_2\left(\frac{j1}{1+j1}\right)(j1)=-10\angle 0°$$
$$\mathbf{I}_2(3+j1)+\mathbf{I}_2\left(\frac{1}{1+j1}\right)=10\angle 180°$$
$$\mathbf{I}_2(3+j1+0.5-j0.5)=10\angle 180°$$
$$\mathbf{I}_2(3.5+j0.5)=10\angle 180°$$
$$\mathbf{I}_2(3.54\angle 8.13°)=10\angle 180°$$
$$\mathbf{I}_2=\frac{10\angle 180°}{3.54\angle 8.13°}$$
$$\mathbf{I}_2=2.83\angle 171.69°\text{ A}$$

Therefore, the value of $\mathbf{I}_2$ is $2.83\angle 171.69°$ A.

Step 4 of 4

Consider the expression for $\mathbf{V}_o$.

$$\mathbf{V}_o=10\angle 0°+\mathbf{I}_2(2)$$

Substitute $2.83\angle 171.69°$ A for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_o&=10\angle 0°+(2.83\angle 171.69°)(2)\\&=10\angle 0°+5.66\angle 171.69°\\&=4.48\angle 10.53°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{4.48\angle 10.53°\text{ V}}$.

Step 1 of 8

10.014 E

Consider Figure E10.6 from the text book.

Consider the circuit at secondary of the transformer.

Figure 1

Step 2 of 8

Calculate the value of the current $\mathbf{I}_o$.

$$\mathbf{I}_o = \frac{\mathbf{V}_o}{10}$$

Substitute $10\angle 30^\circ \text{ V}$ for $\mathbf{V}_o$.

$$\mathbf{I}_o = \frac{10\angle 30^\circ}{10}$$
$$\mathbf{I}_o = 1\angle 30^\circ \text{ A}$$

Therefore, the value of the current $\mathbf{I}_o$ is $1\angle 30^\circ \text{ A}$.

Step 3 of 8

Consider the expression for the current $\mathbf{I}_o$ using current division rule.

$$\mathbf{I}_o = \mathbf{I}_2\left(\frac{-j5}{-j5+j4+10}\right)$$
$$\mathbf{I}_o = \mathbf{I}_2\left(\frac{-j5}{10-j1}\right)$$
$$\mathbf{I}_2 = \mathbf{I}_o\left(\frac{10-j1}{-j5}\right)$$
$$\mathbf{I}_2 = \mathbf{I}_o\left(2.01\angle 84.29^\circ\right)$$

Substitute $1\angle 30^\circ \text{ A}$ for $\mathbf{I}_o$.

$$\mathbf{I}_2 = \left(1\angle 30^\circ\right)\left(2.01\angle 84.29^\circ\right)$$
$$= 2.01\angle 114.29^\circ \text{ A}$$

Therefore, the value of the current $\mathbf{I}_2$ is $2.01\angle 114.29^\circ \text{ A}$.

Step 4 of 8

Calculate the value of the current $\mathbf{I}_2$ referred to primary.

$$\mathbf{I}_1 = -n\mathbf{I}_2$$

Substitute $2.01\angle 114.29^\circ \text{ A}$ for $\mathbf{I}_2$ and $\frac{1}{2}$ for n.

$$\mathbf{I}_1 = -\left(\frac{1}{2}\right)\left(2.01\angle 114.29^\circ\right)$$
$$\mathbf{I}_1 = 1.005\angle -65.71^\circ \text{ A}$$

Therefore, the value of the secondary current when referred to primary is $1.005\angle -65.71^\circ \text{ A}$.

Step 5 of 8

Calculate the value of the Thevenin's impedance.

$$\mathbf{Z}_2 = 2 + \left(-j5 \| (10+j4)\right)$$
$$= 2 + \frac{(10+j4)(-j5)}{10+j4-j5}$$
$$= 2 + 2.475 - j4.753$$
$$= 4.475 - j4.753\ \Omega$$

Therefore, the value of the Thevenin's impedance is $4.475 - j4.753\ \Omega$.

Step 6 of 8

Calculate the value of the impedance $\mathbf{Z}_2$ referred to primary.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

Substitute $4.475 - j4.753\ \Omega$ for $\mathbf{Z}_2$ and $\frac{1}{2}$ for n.

$$\mathbf{Z}_1 = \frac{4.475 - j4.753}{\left(\frac{1}{2}\right)^2}$$
$$\mathbf{Z}_1 = (4)(4.475 - j4.753)$$
$$\mathbf{Z}_1 = 17.9 - j19.01\ \Omega$$

Therefore, the value of the secondary impedance when referred to primary is

$17.9 - j19.01\ \Omega$.

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 7 of 8

Consider the expression for the current $\mathbf{I}_1$ using current division rule.

$$\mathbf{I}_1 = \mathbf{I}_S\left(\frac{j5}{j5+4+17.9-j19.01}\right)$$
$$\mathbf{I}_1 = \mathbf{I}_S\left(\frac{j5}{21.9-j14.01}\right)$$
$$\mathbf{I}_S = \mathbf{I}_1\left(\frac{21.9-j14.01}{j5}\right)$$
$$\mathbf{I}_S = \mathbf{I}_1\left(5.2\angle -122.61^\circ\right)$$

Substitute $1.005\angle -65.71^\circ \text{ A}$ for $\mathbf{I}_1$.

$$\mathbf{I}_S = \left(1\angle -65.71^\circ\right)\left(5.2\angle -122.61^\circ\right)$$
$$= 5.2\angle -188.32^\circ \text{ A}$$

Therefore, the value of the current $\mathbf{I}_S$ is $5.2\angle -188.32^\circ \text{ A}$.

Step 8 of 8

Calculate the value of the voltage $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}_S(2) + (\mathbf{I}_S - \mathbf{I}_1)(j5)$$
$$= \mathbf{I}_S(2+j5) - \mathbf{I}_1(j5)$$

Substitute $5.2\angle -188.32^\circ \text{ A}$ for $\mathbf{I}_S$ and $1.005\angle -65.71^\circ \text{ A}$ for $\mathbf{I}_1$.

$$\mathbf{V}_S = \left(5.2\angle -188.32^\circ \text{ A}\right)(2+j5) - \left(1.005\angle -65.71^\circ\right)(j5)$$
$$= \left(5.2\angle -188.32^\circ \text{ A}\right)\left(5.39\angle 68.2^\circ\right) - \left(1.005\angle -65.71^\circ\right)\left(5\angle 90^\circ\right)$$
$$= 32.22\angle -125.3^\circ \text{ V}$$

Therefore, the value of the voltage $\mathbf{V}_S$ is $\boxed{32.22\angle -125.3^\circ \text{ V}}$.

10.014

P

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Step 1 of 4

10.015

E

Refer to Figure E10.15 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

Substitute $2\,\Omega$ for $\mathbf{Z}_1$ and 2 for n .

$$\begin{aligned}\mathbf{Z}_1 &= \frac{2}{(2)^2}\\ &= \frac{2}{4}\\ &= 0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $0.5\,\Omega$.

Step 2 of 4

Transfer the source voltage of $12\angle 0°\ \mathrm{V}$ to primary side.

$\mathbf{V}_{s,1} = -\frac{\mathbf{V}_s}{n}$ Substitute 2 for n and $12\angle 0°\ \mathrm{V}$ for $\mathbf{V}_s$.

$$\begin{aligned}\mathbf{V}_{s,1} &= -\frac{12\angle 0°}{2}\\ &= -6\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{s,1}$ is $-6\angle 0°\ \mathrm{V}$.

Step 3 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 4

Calculate the value of $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{36\angle 0° - (-6\angle 0°)}{2 - j2 + 0.5}\\ &= \frac{36\angle 0° + 6\angle 0°}{2.5 - j2}\\ &= \frac{42\angle 0°}{3.2\angle -38.66°}\\ &= 13.12\angle 38.66°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{13.12\angle 38.66°\ \mathrm{A}}$.

Step 1 of 6

10.015 P

Refer to Figure P10.15 in the text book.

Redraw the network by representing loop currents in Figure P10.15 as shown in Figure 1.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law in loop-1 in Figure 1.

$$-10\angle 0^\circ + 2\mathbf{I}_1 - j2(\mathbf{I}_1 - \mathbf{I}_2) = 0$$
$$2\mathbf{I}_1 - j2(\mathbf{I}_1 - \mathbf{I}_2) = 10\angle 0^\circ$$
$$(2 - j2)\mathbf{I}_1 + 2j\mathbf{I}_2 = 10\angle 0^\circ$$
$$\mathbf{I}_1 = \frac{10\angle 0^\circ - 2j\mathbf{I}_2}{2 - j2}$$

Step 3 of 6

Apply Kirchhoff's voltage law in loop-2 in Figure 1.

$$-j2(\mathbf{I}_2 - \mathbf{I}_1) + j2\mathbf{I}_2 + 1(\mathbf{I}_2 - \mathbf{I}_3) - j2\mathbf{I}_4 = 0$$
$$j2\mathbf{I}_1 + (-j2 + j2 + 1)\mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$
$$j2\mathbf{I}_1 + \mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$

Substitute $\left(\frac{10\angle 0^\circ - 2j\mathbf{I}_2}{2 - j2}\right)$ for $\mathbf{I}_1$ in the equation.

$$j2\left(\frac{10\angle 0^\circ - 2j\mathbf{I}_2}{2 - j2}\right) + \mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$
$$j2\left(\frac{10\angle 0^\circ}{2 - j2}\right) - j2\left(\frac{2j\mathbf{I}_2}{2 - j2}\right) + \mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$
$$(-5 + 5j) + (1 + j)\mathbf{I}_2 + \mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$

$$(-5 + 5j) + (2 + j)\mathbf{I}_2 - \mathbf{I}_3 - j2\mathbf{I}_4 = 0$$
$$\mathbf{I}_3 = (2 + j)\mathbf{I}_2 - j2\mathbf{I}_4 + (-5 + 5j)$$

Step 4 of 6

Apply Kirchhoff's voltage law in loop-3 in Figure 1.

$$-j1(\mathbf{I}_3) + 1(\mathbf{I}_3 - \mathbf{I}_2) + 1(\mathbf{I}_3 - \mathbf{I}_4) = 0$$
$$-\mathbf{I}_2 + (1 + 1 - j)\mathbf{I}_3 - \mathbf{I}_4 = 0$$
$$-\mathbf{I}_2 + (2 - j)\mathbf{I}_3 - \mathbf{I}_4 = 0$$

Substitute $[(2 + j)\mathbf{I}_2 - j2\mathbf{I}_4 + (-5 + 5j)]$ for $\mathbf{I}_3$ in the equation.

$$-\mathbf{I}_2 + (2 - j)[(2 + j)\mathbf{I}_2 - j2\mathbf{I}_4 + (-5 + 5j)] - \mathbf{I}_4 = 0$$
$$-\mathbf{I}_2 + (2 - j)(2 + j)\mathbf{I}_2 - j2(2 - j)\mathbf{I}_4 + (2 - j)(-5 + 5j) - \mathbf{I}_4 = 0$$
$$-\mathbf{I}_2 + 5\mathbf{I}_2 - 2\mathbf{I}_4 - j4\mathbf{I}_4 - 5 + 15j - \mathbf{I}_4 = 0$$
$$4\mathbf{I}_2 - (3 + j4)\mathbf{I}_4 - (5 - 15j) = 0$$

$$4\mathbf{I}_2 = (3 + j4)\mathbf{I}_4 + (5 - 15j)$$
$$\mathbf{I}_2 = \frac{(3 + j4)\mathbf{I}_4 + (5 - 15j)}{4}$$

Step 5 of 6

Apply Kirchhoff's voltage law in loop-4 in Figure 1.

$$1(\mathbf{I}_4 - \mathbf{I}_3) + j2\mathbf{I}_4 + 2\mathbf{I}_4 - j2\mathbf{I}_2 = 0$$
$$-j2\mathbf{I}_2 - \mathbf{I}_3 + (3 + j2)\mathbf{I}_4 = 0$$

Substitute $[(2 + j)\mathbf{I}_2 - j2\mathbf{I}_4 + (-5 + 5j)]$ for $\mathbf{I}_3$ in the equation.

$$-j2\mathbf{I}_2 - [(2 + j)\mathbf{I}_2 - j2\mathbf{I}_4 + (-5 + 5j)] + (3 + j2)\mathbf{I}_4 = 0$$
$$-j2\mathbf{I}_2 - (2 + j)\mathbf{I}_2 + j2\mathbf{I}_4 - (-5 + 5j) + (3 + j2)\mathbf{I}_4 = 0$$
$$-(2 + 3j)\mathbf{I}_2 + (3 + 4j)\mathbf{I}_4 - (-5 + 5j) = 0$$

Substitute $\left(\frac{(3 + j4)\mathbf{I}_4 + (5 - 15j)}{4}\right)$ for $\mathbf{I}_2$ in the equation.

$$-(2 + 3j)\left(\frac{(3 + j4)\mathbf{I}_4 + (5 - 15j)}{4}\right) + (3 + 4j)\mathbf{I}_4 - (-5 + 5j) = 0$$
$$-(2 + 3j)\left(\frac{(3 + j4)\mathbf{I}_4}{4}\right) - (2 + 3j)\left(\frac{(5 - 15j)}{4}\right) + (3 + 4j)\mathbf{I}_4 - (-5 + 5j) = 0$$
$$(1.5 - 4.25j)\mathbf{I}_4 - 13.75 + 3.75j + (3 + 4j)\mathbf{I}_4 + 5 - 5j = 0$$
$$(4.5 - 0.25j)\mathbf{I}_4 - 8.75 - 1.25j = 0$$

$$\mathbf{I}_4 = \frac{8.75 + 1.25j}{4.5 - 0.25j}$$
$$= 1.96\angle 11.31^\circ \text{ A}$$

Step 6 of 6

Determine the value of output voltage in the network.

$$\mathbf{V}_o = 2\mathbf{I}_4$$

Substitute $1.96\angle 11.31^\circ$ A for $\mathbf{I}_4$ in the equation.

$$\mathbf{V}_o = 2(1.96\angle 11.31^\circ)$$
$$= 3.92\angle 11.31^\circ \text{ V}$$

Thus, the value of output voltage in the network, $\mathbf{V}_o$ is $\boxed{3.92\angle 11.31^\circ \text{ V}}$.

Step 1 of 5

10.016

E

Refer to Figure E10.16 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $2 - j2\,\Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (2)^2(2 - j2)\\ &= (4)(2 - j2)\\ &= 8 - j8\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $8 - j8\,\Omega$.

Step 2 of 5

Transfer the source voltage to secondary side.

$\mathbf{V}_{s,2} = n\mathbf{V}_s$ Substitute 2 for n and $12\angle 0°\ \mathrm{V}$ for $\mathbf{V}_s$.

$$\begin{aligned}\mathbf{V}_{s,2} &= (2)(12\angle 0°)\\ &= 24\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{s,2}$ is $24\angle 0°\ \mathrm{V}$.

Step 3 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 5

Calculate the value of $\mathbf{I}_O$.

$$\begin{aligned}\mathbf{I}_O &= \frac{24\angle 0° - 4\angle 0°}{8 - j8 + 2}\\ &= \frac{20\angle 0°}{10 - j8}\\ &= \frac{24\angle 0°}{12.81\angle -38.66°}\\ &= 1.56\angle 38.66°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_O$ is $1.56\angle 38.66°\ \mathrm{A}$.

Step 5 of 5

Calculate the value of $\mathbf{V}_O$.

$$\mathbf{V}_O = \mathbf{I}_O(2)$$

Substitute $1.56\angle 38.66°\ \mathrm{A}$ for $\mathbf{I}_O$.

$$\begin{aligned}\mathbf{V}_O &= (1.56\angle 38.66°)(2)\\ &= 3.12\angle 38.66°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{3.12\angle 38.66°\ \mathrm{V}}$.

10.016
P

The mesh equations for the given network are as follows:

$(j2+1-j1)I_0 - j1(I_0 - I_1) + j1I_1 = 0$

$j2I_1 + I_0 = 0$ .....(i)

$j1I_0 + (1+j1+2)I_1 - j1(I_1 - I_0) = 2\angle 0°$

$3I_1 + j2I_0 = 2$ .....(ii)

From equation (i)

$I_1 = \frac{-1}{j2} I_0$

$I_1 = \frac{1}{2} jI_0$

Substituting I_1 in (ii) we get,

$3\left(\frac{1}{2}\right) jI_0 + j2I_0 = 2$

$3jI_0 + j4I_0 = 4$

$7jI_0 = 4$

$I_0 = \frac{4}{j7}$

$I_0 = \frac{4}{7\angle 90°}$

$I_0 = 0.5714\angle -90°$

$\boxed{I_0 = 0.5714\angle -90° \text{A}}$

Step 1 of 6

10.017 E

Refer to Figure E10.17 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Consider Kirchhoff's Current Law at node-1.

$$\frac{\mathbf{V}_1}{2}+\frac{\mathbf{V}_1-10\angle 0^\circ}{2}+\frac{\mathbf{V}_1-\mathbf{V}_2}{2}+\mathbf{I}_1=0$$

Substitute $-2\mathbf{V}_1$ for $\mathbf{V}_2$.

$$\frac{\mathbf{V}_1}{2}+\frac{\mathbf{V}_1-10\angle 0^\circ}{2}+\frac{\mathbf{V}_1-(-2\mathbf{V}_1)}{2}+\mathbf{I}_1=0$$

$$\mathbf{V}_1\left(\frac{1}{2}+\frac{1}{2}+\frac{\mathbf{I}-(-2)}{2}\right)+\mathbf{I}_1=\frac{10\angle 0^\circ}{2}$$

$$\mathbf{V}_1\left(\frac{1}{2}+\frac{1}{2}+\frac{3}{2}\right)+\mathbf{I}_1=\frac{10\angle 0^\circ}{2}$$

$$\mathbf{V}_1\left(\frac{5}{2}\right)+\mathbf{I}_1=\frac{10\angle 0^\circ}{2}$$

$$\mathbf{V}_1(2.5)+\mathbf{I}_1=5\angle 0^\circ$$

Solve for $\mathbf{I}_1$.

$\mathbf{I}_1=5\angle 0^\circ-\mathbf{V}_1(2.5)$ ..... (1)

Therefore, the expression for $\mathbf{I}_1$ in terms of $\mathbf{V}_1$ is $5\angle 0^\circ-\mathbf{V}_1(2.5)$.

Step 3 of 6

Consider Kirchhoff's Current Law at node-2.

$$\frac{\mathbf{V}_2}{j2}+\frac{\mathbf{V}_2-\mathbf{V}_1}{2}-\mathbf{I}_2=0$$

Substitute $-2\mathbf{V}_1$ for $\mathbf{V}_2$ and $-\frac{\mathbf{I}_1}{2}$ for $\mathbf{I}_2$.

$$\frac{-2\mathbf{V}_1}{j2}+\frac{-2\mathbf{V}_1-\mathbf{V}_1}{2}-\left(-\frac{\mathbf{I}_1}{2}\right)=0$$

$$\frac{\mathbf{V}_1}{j1}+\frac{3\mathbf{V}_1}{2}+\left(-\frac{\mathbf{I}_1}{2}\right)=0$$

$$\mathbf{V}_1\left(\frac{1}{j1}+\frac{3}{2}\right)-\frac{\mathbf{I}_1}{2}=0$$

$$\mathbf{V}_1(1.5-j1)-0.5\mathbf{I}_1=0$$

Substitute $5\angle 0^\circ-\mathbf{V}_1(2.5)$ for $\mathbf{I}_1$.

$$\mathbf{V}_1(1.5-j1)-0.5(5\angle 0^\circ-\mathbf{V}_1(2.5))=0$$

$$\mathbf{V}_1(1.5-j1)-2.5\angle 0^\circ+\mathbf{V}_1(1.25)=0$$

$$\mathbf{V}_1(1.5-j1+1.25)-2.5\angle 0^\circ=0$$

$$\mathbf{V}_1(2.75-j1)=2.5\angle 0^\circ$$

$$\begin{aligned}\mathbf{V}_1&=\frac{2.5\angle 0^\circ}{2.75-j1}\\&=\frac{2.5\angle 0^\circ}{2.93\angle -20^\circ}\\&=0.85\angle 20^\circ\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{0.85\angle 20^\circ\ \text{V}}$.

Step 4 of 6

Consider the expression for $\mathbf{V}_2$ in terms of $\mathbf{V}_1$.

$$\mathbf{V}_2=-2\mathbf{V}_1$$

Substitute $0.85\angle 20^\circ\ \text{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_2&=-2(0.85\angle 20^\circ)\\&=-1.7\angle 20^\circ\\&=1.7\angle -160^\circ\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{1.7\angle -160^\circ\ \text{V}}$.

Step 5 of 6

Consider equation (1).

$$\mathbf{I}_1=5\angle 0^\circ-\mathbf{V}_1(2.5)$$

Substitute $0.85\angle 20^\circ\ \text{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_1&=5\angle 0^\circ-(0.85\angle 20^\circ)(2.5)\\&=5\angle 0^\circ-2.13\angle 20^\circ\\&=3.09\angle -13.7^\circ\ \text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{3.09\angle -13.7^\circ\ \text{A}}$.

Step 6 of 6

Consider the expression for $\mathbf{I}_2$ in terms of $\mathbf{I}_1$.

$$\mathbf{I}_2=-\frac{\mathbf{I}_1}{2}$$

Substitute $3.09\angle -13.7^\circ\ \text{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_2&=-\frac{3.09\angle -13.7^\circ}{2}\\&=-1.55\angle -13.7^\circ\\&=1.55\angle 166.3^\circ\ \text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{1.55\angle 166.3^\circ\ \text{A}}$.

10.017
P

Step 1 of 6

Consider Figure P10.15 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 6

Consider Kirchhoff's Voltage Law in loop-4.

$$\mathbf{I}_4(j4)+(\mathbf{I}_4-\mathbf{I}_5)(2)+\mathbf{I}_4(2)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_4(j4+2+2)-\mathbf{I}_3(j2)-\mathbf{I}_5(2)=0$$
$$\mathbf{I}_3(j2)=\mathbf{I}_4(4+j4)-\mathbf{I}_5(2)$$
$$\mathbf{I}_3=\frac{\mathbf{I}_4(4+j4)-\mathbf{I}_5(2)}{(j2)}$$

Substitute $\mathbf{I}_5$ for $3\angle 0°\ \mathrm{A}$.

$$\begin{aligned}\mathbf{I}_3&=\frac{\mathbf{I}_4(4+j4)-(3\angle 0°)(2)}{j2}\\&=\frac{\mathbf{I}_4(4+j4)}{j2}-\frac{(3\angle 0°)(2)}{j2}\\&=\mathbf{I}_4(2-j2)-\frac{(3\angle 0°)(2)}{2\angle 90}\\&=\mathbf{I}_4(2-j2)-3\angle -90°\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_3$ is $\mathbf{I}_4(2-j2)-3\angle -90°$.

Step 3 of 6

Consider the following equation at the $2\angle 0°\ \mathrm{A}$ current source.

$$\mathbf{I}_3-\mathbf{I}_2=2\angle 0°$$
$$\mathbf{I}_2=\mathbf{I}_3-2\angle 0°$$

Substitute $\mathbf{I}_4(2-j2)-3\angle -90°$ for $\mathbf{I}_3$.

$$\begin{aligned}\mathbf{I}_2&=\mathbf{I}_4(2-j2)-3\angle -90°-2\angle 0°\\&=\mathbf{I}_4(2-j2)+3.61\angle 123.69°\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_4(2-j2)+3.61\angle 123.69°$.

Step 4 of 6

Consider Kirchhoff's Voltage Law in loop-1.

$$24\angle 0°+\mathbf{I}_1(6+6)+(\mathbf{I}_1-\mathbf{I}_2)(6)=0$$
$$\mathbf{I}_1(6+6+6)-\mathbf{I}_2(6)=-24\angle 0°$$
$$\mathbf{I}_1(18)-\mathbf{I}_2(6)=24\angle 180°$$
$$\mathbf{I}_1=\frac{24\angle 180°+\mathbf{I}_2(6)}{18}$$

Substitute $\mathbf{I}_4(2-j2)+3.61\angle 123.69°$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_1&=\frac{24\angle 180°+(\mathbf{I}_4(2-j2)+3.61\angle 123.69°)(6)}{3}\\&=\frac{4\angle 180°+\mathbf{I}_4(2-j2)+3.61\angle 123.69°}{3}\\&=\frac{6.71\angle 153.42°+\mathbf{I}_4(2-j2)}{3}\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\dfrac{6.71\angle 153.42°+\mathbf{I}_4(2-j2)}{3}$.

Step 5 of 6

Apply super mesh technique in loops 2 and 3.

$$\mathbf{I}_2(4)+(\mathbf{I}_2-\mathbf{I}_1)(6)+\mathbf{I}_3(j4-j1)+\mathbf{I}_4(j2)=0$$
$$\mathbf{I}_2(4+6)-\mathbf{I}_1(6)+\mathbf{I}_3(j3)+\mathbf{I}_4(j2)=0$$
$$\mathbf{I}_2(10)-\mathbf{I}_1(6)+\mathbf{I}_3(j3)+\mathbf{I}_4(j2)=0$$

Substitute $\dfrac{6.71\angle 153.42°+\mathbf{I}_4(2-j2)}{3}$ for $\mathbf{I}_1$, $\mathbf{I}_4(2-j2)+3.61\angle 123.69°$ for $\mathbf{I}_2$ and $\mathbf{I}_4(2-j2)-3\angle -90°$ for $\mathbf{I}_3$.

$$\begin{bmatrix}(\mathbf{I}_4(2-j2)+3.61\angle 123.69°)(10)-\left(\dfrac{6.71\angle 153.42°+\mathbf{I}_4(2-j2)}{3}\right)(6)+\\(\mathbf{I}_4(2-j2)-3\angle -90°)(j3)+\mathbf{I}_4(j2)\end{bmatrix}=0$$
$$\begin{bmatrix}(\mathbf{I}_4(2-j2)+3.61\angle 123.69°)(10)-(6.71\angle 153.42°+\mathbf{I}_4(2-j2))(2)+\\(\mathbf{I}_4(2-j2)-3\angle -90°)(j3)+\mathbf{I}_4(j2)\end{bmatrix}=0$$
$$\begin{bmatrix}\mathbf{I}_4(20-j20)+36.1\angle 123.69°-13.42\angle 153.42°-\mathbf{I}_4(4-j4)+\\\mathbf{I}_4(6+j3)-(3\angle -90°)(3\angle 90°)+\mathbf{I}_4(j2)\end{bmatrix}=0$$
$$\mathbf{I}_4(20-j20-4+j4+6+j3+j2)+36.1\angle 123.69°-13.42\angle 153.42°-9=0$$

$$\mathbf{I}_4(22-j11)+29.5\angle 125.19°=0$$
$$\mathbf{I}_4(22-j11)=-29.5\angle 125.19°$$
$$\mathbf{I}_4(24.6\angle -26.57°)=29.5\angle -54.81°$$
$$\mathbf{I}_4=\frac{29.5\angle -54.81°}{24.6\angle -26.57°}$$

$$\mathbf{I}_4=1.2\angle -28.24°\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_4$ is $1.2\angle -28.24°\ \mathrm{A}$.

Step 6 of 6

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=-\mathbf{I}_4(2)$$

Substitute $1.2\angle -28.24°\ \mathrm{A}$ for $\mathbf{I}_4$.

$$\begin{aligned}\mathbf{V}_O&=-(1.2\angle -28.24°)(2)\\&=-2.4\angle -28.24°\\&=2.4\angle 151.76°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{2.4\angle 151.76°\ \mathrm{V}}$.

Step 1 of 6

Consider Figure P10.17 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 6

Consider Kirchhoff's Voltage Law in loop-2.

$$-24\angle 0^\circ + (\mathbf{I}_2 + \mathbf{I}_1)(3) + (\mathbf{I}_2 - \mathbf{I}_3)(6) = 0$$
$$\mathbf{I}_2(3+6) + \mathbf{I}_1(3) - \mathbf{I}_3(6) = 24\angle 0^\circ$$
$$\mathbf{I}_2(9) + \mathbf{I}_1(3) - \mathbf{I}_3(6) = 24\angle 0^\circ$$
$$\mathbf{I}_2(9) = 24\angle 0^\circ - \mathbf{I}_1(3) + \mathbf{I}_3(6)$$

Substitute $4\angle 0^\circ\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(9) = 24\angle 0^\circ - (4\angle 0^\circ)(3) + \mathbf{I}_3(6)$$
$$\mathbf{I}_2(9) = 24\angle 0^\circ - 12\angle 0^\circ + \mathbf{I}_3(6)$$
$$\mathbf{I}_2(9) = 12\angle 0^\circ + \mathbf{I}_3(6)$$
$$\mathbf{I}_2 = \frac{4\angle 0^\circ + \mathbf{I}_3(2)}{3}$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\dfrac{4\angle 0^\circ + \mathbf{I}_3(2)}{3}$.

Step 3 of 6

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(-j1 + j2) + (\mathbf{I}_3 - \mathbf{I}_2)(6) + \mathbf{I}_4(j1) = 0$$
$$\mathbf{I}_3(6 + j1) - \mathbf{I}_2(6) + \mathbf{I}_4(j1) = 0$$
$$\mathbf{I}_3(6 + j1) = \mathbf{I}_2(6) - \mathbf{I}_4(j1)$$

Substitute $\dfrac{4\angle 0^\circ + \mathbf{I}_3(2)}{3}$ for $\mathbf{I}_2$.

$$\mathbf{I}_3(6 + j1) = \left(\frac{4\angle 0^\circ + \mathbf{I}_3(2)}{3}\right)(6) - \mathbf{I}_4(j1)$$
$$\mathbf{I}_3(6 + j1) = (4\angle 0^\circ + \mathbf{I}_3(2))(2) - \mathbf{I}_4(j1)$$
$$\mathbf{I}_3(6 + j1) = 8\angle 0^\circ + \mathbf{I}_3(4) - \mathbf{I}_4(j1)$$
$$\mathbf{I}_3(6 + j1 - 4) = 8\angle 0^\circ - \mathbf{I}_4(j1)$$
$$\mathbf{I}_3(2 + j1) = 8\angle 0^\circ - \mathbf{I}_4(j1)$$
$$\mathbf{I}_3 = \frac{8\angle 0^\circ - \mathbf{I}_4(j1)}{2 + j1}$$

Therefore, the expression for the current $\mathbf{I}_3$ is $\dfrac{8\angle 0^\circ - \mathbf{I}_4(j1)}{2 + j1}$.

Step 4 of 6

Consider Kirchhoff's Voltage Law in loop-5.

$$(\mathbf{I}_5 - \mathbf{I}_6)(3) + \mathbf{I}_5(1) + (\mathbf{I}_5 - \mathbf{I}_6)(-j4) = 0$$
$$\mathbf{I}_5(3 + 1 - j4) - \mathbf{I}_6(3) + \mathbf{I}_4(j4) = 0$$
$$\mathbf{I}_5(4 - j4) = \mathbf{I}_6(3) - \mathbf{I}_4(j4)$$

Substitute $2\angle 0^\circ\ \mathrm{V}$ for $\mathbf{I}_6$.

$$\mathbf{I}_5(4 - j4) = (2\angle 0^\circ)(3) - \mathbf{I}_4(j4)$$
$$\mathbf{I}_5(4 - j4) = 6\angle 0^\circ - \mathbf{I}_4(j4)$$
$$\mathbf{I}_5 = \frac{6\angle 0^\circ - \mathbf{I}_4(j4)}{4 - j4}$$

Therefore, the expression for the current $\mathbf{I}_5$ is $\dfrac{6\angle 0^\circ - \mathbf{I}_4(j4)}{4 - j4}$.

Step 5 of 6

Consider Kirchhoff's Voltage Law in loop-4.

$$\mathbf{I}_4(1) + (\mathbf{I}_4 - \mathbf{I}_5)(-j4) + \mathbf{I}_4(j2) + \mathbf{I}_3(j1) = 0$$
$$\mathbf{I}_4(1 - j4 + j2) + \mathbf{I}_5(j4) + \mathbf{I}_3(j1) = 0$$
$$\mathbf{I}_4(1 - j2) + \mathbf{I}_5(j4) + \mathbf{I}_3(j1) = 0$$

Substitute $\dfrac{6\angle 0^\circ - \mathbf{I}_4(j4)}{4 - j4}$ for $\mathbf{I}_5$ and $\dfrac{8\angle 0^\circ - \mathbf{I}_4(j1)}{2 + j1}$ for $\mathbf{I}_3$.

$$\mathbf{I}_4(1 - j2) + \left(\frac{6\angle 0^\circ - \mathbf{I}_4(j4)}{4 - j4}\right)(j4) + \left(\frac{8\angle 0^\circ - \mathbf{I}_4(j1)}{2 + j1}\right)(j1) = 0$$
$$\mathbf{I}_4(1 - j2) + \frac{(6\angle 0^\circ)(j4)}{4 - j4} - \frac{\mathbf{I}_4(j4)(j4)}{4 - j4} + \frac{(8\angle 0^\circ)(j1)}{2 + j1} - \frac{\mathbf{I}_4(j1)(j1)}{2 + j1} = 0$$
$$\mathbf{I}_4(1 - j2) + \frac{(6\angle 0^\circ)(j4)}{4 - j4} + \frac{\mathbf{I}_4(16)}{4 - j4} + \frac{(8\angle 0^\circ)(j1)}{2 + j1} + \frac{\mathbf{I}_4(1)}{2 + j1} = 0$$
$$\mathbf{I}_4\left(1 - j2 + \frac{16}{4 - j4} + \frac{1}{2 + j1}\right) + \frac{(6\angle 0^\circ)(j4)}{4 - j4} + \frac{(8\angle 0^\circ)(j1)}{2 + j1} = 0$$

$$\mathbf{I}_4(1 - j2 + 2 + j2 + 0.4 - j0.2) + (6\angle 0^\circ)(-0.5 + j0.5) + (8\angle 0^\circ)(0.2 + j0.4) = 0$$
$$\mathbf{I}_4(3.4 - j0.2) + (6\angle 0^\circ)(0.71\angle 135^\circ) + (8\angle 0^\circ)(0.45\angle 63.44^\circ) = 0$$
$$\mathbf{I}_4(3.41\angle 3.37^\circ) + 4.26\angle 135^\circ + 3.6\angle 63.44^\circ = 0$$
$$\mathbf{I}_4(3.41\angle 3.37^\circ) + 6.39\angle 102.68^\circ = 0$$

$$\mathbf{I}_4(3.41\angle 3.37^\circ) = -6.39\angle 102.68^\circ$$
$$\mathbf{I}_4 = \frac{-6.39\angle 102.68^\circ}{3.41\angle 3.37^\circ}$$
$$\mathbf{I}_4 = \frac{6.39\angle -77.32^\circ}{3.41\angle 3.37^\circ}$$
$$\mathbf{I}_4 = 1.87\angle -80.69^\circ\ \mathrm{A}$$

Therefore, the expression for the current $\mathbf{I}_4$ is $1.87\angle -80.69^\circ\ \mathrm{A}$.

Step 6 of 6

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O = \mathbf{I}_4(1)$$

Substitute $1.87\angle -80.69^\circ\ \mathrm{A}$ for $\mathbf{I}_4$.

$$\mathbf{V}_O = (1.87\angle -80.69^\circ)(1)$$
$$= 1.87\angle -80.69^\circ\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.87\angle -80.69^\circ\ \mathrm{V}}$.

Step 1 of 5

10.019

P

Refer to Figure P10.19 in the text book.

Redraw the network by representing loop currents in Figure P10.19 as shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's voltage law in loop-1 in Figure 1.

$$-120\angle 60^\circ + 1\mathbf{I}_1 - j1\mathbf{I}_1 + j4\mathbf{I}_1 + 3\mathbf{I}_1 + j1\mathbf{I}_2 = 0$$
$$1\mathbf{I}_1 - j1\mathbf{I}_1 + j4\mathbf{I}_1 + 3\mathbf{I}_1 + j1\mathbf{I}_2 = 120\angle 60^\circ$$
$$(1 - j1 + j4 + 3)\mathbf{I}_1 + j\mathbf{I}_2 = 120\angle 60^\circ$$

$$(4 + j3)\mathbf{I}_1 + j\mathbf{I}_2 = 120\angle 60^\circ \text{ ..... (1)}$$

Step 3 of 5

Apply Kirchhoff's voltage law in loop-2 in Figure 1.

$$2\mathbf{I}_2 + (1 + j2)(\mathbf{I}_2 - \mathbf{I}_3) + 2j\mathbf{I}_2 + j1\mathbf{I}_1 = 0$$
$$j\mathbf{I}_1 + (2 + 1 + j2 + 2j)\mathbf{I}_2 - (1 + j2)\mathbf{I}_3 = 0$$

$$j\mathbf{I}_1 + (3 + j4)\mathbf{I}_2 - (1 + j2)\mathbf{I}_3 = 0 \text{ ..... (2)}$$

Step 4 of 5

Apply Kirchhoff's voltage law in loop-3 in Figure 1.

$$(1 + j2)(\mathbf{I}_3 - \mathbf{I}_2) - 2j\mathbf{I}_3 = 0$$
$$-(1 + j2)\mathbf{I}_2 + (1 + j2 - 2j)\mathbf{I}_3 = 0$$
$$-(1 + j2)\mathbf{I}_2 + \mathbf{I}_3 = 0$$
$$\mathbf{I}_3 = (1 + j2)\mathbf{I}_2$$

Substitute $(1 + j2)\mathbf{I}_2$ for $\mathbf{I}_3$ in equation (2).

$$j\mathbf{I}_1 + (3 + j4)\mathbf{I}_2 - (1 + j2)(1 + j2)\mathbf{I}_2 = 0$$
$$j\mathbf{I}_1 + (3 + j4)\mathbf{I}_2 - (-3 + 4j)\mathbf{I}_2 = 0$$
$$j\mathbf{I}_1 + 6\mathbf{I}_2 = 0$$
$$\mathbf{I}_2 = -\frac{j\mathbf{I}_1}{6}$$

Step 5 of 5

Substitute $\left(-\frac{j\mathbf{I}_1}{6}\right)$ for $\mathbf{I}_2$ in equation (1), to determine the impedance seen by the source in the network.

$$(4 + j3)\mathbf{I}_1 + j\left(-\frac{j\mathbf{I}_1}{6}\right) = 120\angle 60^\circ$$
$$(4 + j3)\mathbf{I}_1 + \left(\frac{\mathbf{I}_1}{6}\right) = 120\angle 60^\circ$$
$$(4.167 + j3)\mathbf{I}_1 = 120\angle 60^\circ$$

$$\frac{120\angle 60^\circ}{\mathbf{I}_1} = 4.167 + j3$$

$$\mathbf{Z}_{in} = (4.167 + j3)\,\Omega \quad \left(\text{since } \mathbf{Z}_{in} = \frac{120\angle 60^\circ}{\mathbf{I}_1}\right)$$

Thus, the impedance seen by the source in the network, $\mathbf{Z}_{in}$ is $\boxed{(4.167 + j3)\,\Omega}$.

Step 1 of 4

10.020

P

Refer to Figure P10.20 in the text book.

Redraw the network by representing loop currents in Figure P10.20 as shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law in loop-1 in Figure 1.

$$-\mathbf{V}+2\mathbf{I}_1+j4\mathbf{I}_1-j1(\mathbf{I}_2-\mathbf{I}_1)+j2(\mathbf{I}_1-\mathbf{I}_2)+j1\mathbf{I}_1=0$$
$$-\mathbf{V}+2\mathbf{I}_1+j4\mathbf{I}_1-j1\mathbf{I}_2+j1\mathbf{I}_1+j2\mathbf{I}_1-j2\mathbf{I}_2+j1\mathbf{I}_1=0$$
$$-\mathbf{V}+(2+j4+j1+j2+j1)\mathbf{I}_1-(j1+j2)\mathbf{I}_2=0$$

$$-\mathbf{V}+(2+j8)\mathbf{I}_1-(j3)\mathbf{I}_2=0 \quad \text{..... (1)}$$

Step 3 of 4

Apply Kirchhoff's voltage law in loop-2 in Figure 1.

$$j2(\mathbf{I}_2-\mathbf{I}_1)+2\mathbf{I}_2-2j\mathbf{I}_2-j1\mathbf{I}_1=0$$
$$(-j2-j1)\mathbf{I}_1+(j2+2-j2)\mathbf{I}_2=0$$
$$(-j3)\mathbf{I}_1+2\mathbf{I}_2=0$$

$$\mathbf{I}_2=\frac{(j3)\mathbf{I}_1}{2}$$
$$\mathbf{I}_2=j1.5\mathbf{I}_1$$

Step 4 of 4

Substitute $j1.5\mathbf{I}_1$ for $\mathbf{I}_2$ in equation (1) to compute the input impedance of the network.

$$-\mathbf{V}+(2+j8)\mathbf{I}_1-(j3)(j1.5\mathbf{I}_1)=0$$
$$-\mathbf{V}+(2+j8)\mathbf{I}_1+4.5\mathbf{I}_1=0$$
$$-\mathbf{V}+(2+j12.5)\mathbf{I}_1=0$$
$$\mathbf{V}=(2+j12.5)\mathbf{I}_1$$

$$\frac{\mathbf{V}}{\mathbf{I}_1}=2+j12.5$$

$$\mathbf{Z}_{in}=2+j12.5 \quad \left(\text{since } \mathbf{Z}_{in}=\frac{\mathbf{V}}{\mathbf{I}_1}\right)$$

Thus, the input impedance of the network, $\mathbf{Z}_{in}$ is $\boxed{(2+j12.5)\Omega}$.

Step 1 of 3

10.021 P

Consider Figure P10.19 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 3

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(-j2+3+j2)+(\mathbf{I}_2-\mathbf{I}_1)(2)-\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(-j2+3+j2+2)-\mathbf{I}_1(2+j1)=0$$
$$\mathbf{I}_2(5)-\mathbf{I}_1(2+j1)=0$$
$$\mathbf{I}_1=\mathbf{I}_2\left(\frac{5}{2+j1}\right)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_2\left(\frac{5}{2+j1}\right)$.

Step 3 of 3

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(2-j4+j2)+(\mathbf{I}_1-\mathbf{I}_2)(2)-\mathbf{I}_2(j1)-32\angle 0°=0$$
$$\mathbf{I}_1(2-j4+j2+2)-\mathbf{I}_2(2+j1)=32\angle 0°$$
$$\mathbf{I}_1(4-j2)-\mathbf{I}_2(2+j1)=32\angle 0°$$

Substitute $\mathbf{I}_2\left(\frac{5}{2+j1}\right)$ for $\mathbf{I}_1$.

$$\mathbf{I}_2\left(\frac{5}{2+j1}\right)(4-j2)-\mathbf{I}_2(2+j1)=32\angle 0°$$
$$\mathbf{I}_2\left(\frac{20-j10}{2+j1}\right)-\mathbf{I}_2(2+j1)=32\angle 0°$$
$$\mathbf{I}_2(6-j8)-\mathbf{I}_2(2+j1)=32\angle 0°$$
$$\mathbf{I}_2(6-j8-2-j1)=32\angle 0°$$

$$\mathbf{I}_2(4-j9)=32\angle 0°$$
$$\mathbf{I}_2(9.85\angle -66.04°)=32\angle 0°$$
$$\mathbf{I}_2=\frac{32\angle 0°}{9.85\angle -66.04°}$$
$$\mathbf{I}_2=3.25\angle 66.04°\text{ A}$$

But $\mathbf{I}_2=\mathbf{I}_o$

$$\mathbf{I}_o=3.25\angle 66.04°\text{ A}$$

Therefore, the value of $\mathbf{I}_o$ is $\boxed{3.25\angle 66.04°\text{ A}}$.

Step 1 of 4

10.022 P

Consider Figure P10.20 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$(\mathbf{I}_2-\mathbf{I}_3)(2)+\mathbf{I}_2(j1)+(\mathbf{I}_2-\mathbf{I}_1)(1)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_2(1+j1+2)-\mathbf{I}_1(1)-\mathbf{I}_3(2+j1)=0$$

Substitute $4\angle 0°$ A for $\mathbf{I}_1$.

$$\mathbf{I}_2(3+j1)=4\angle 0°+\mathbf{I}_3(2+j1)$$
$$\mathbf{I}_2=\frac{4\angle 0°+\mathbf{I}_3(2+j1)}{3+j1}$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\dfrac{4\angle 0°+\mathbf{I}_3(2+j1)}{3+j1}$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_3(-j1+j1)+(\mathbf{I}_3-\mathbf{I}_2)(2)+(\mathbf{I}_3+\mathbf{I}_4)(1)-\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_3(-j1+j2+2+1)-\mathbf{I}_2(2+j1)+\mathbf{I}_4=0$$
$$\mathbf{I}_3(3)-\mathbf{I}_2(2+j1)+\mathbf{I}_4=0$$

Substitute $\dfrac{4\angle 0°+\mathbf{I}_3(2+j1)}{3+j1}$ for $\mathbf{I}_2$ and $6\angle 0°$ A for $\mathbf{I}_4$.

$$\mathbf{I}_3(3)-\left(\frac{4\angle 0°+\mathbf{I}_3(2+j1)}{3+j1}\right)(2+j1)+6\angle 0°=0$$
$$\mathbf{I}_3(3)-\left(\frac{4\angle 0°}{3+j1}\right)(2+j1)-\left(\frac{\mathbf{I}_3(2+j1)}{3+j1}\right)(2+j1)+6\angle 0°=0$$
$$\mathbf{I}_3(3)-(4\angle 0°)(0.7+j0.1)-\mathbf{I}_3(2+j1)(0.7+j0.1)+6\angle 0°=0$$
$$\mathbf{I}_3(3)-(4\angle 0°)(0.7+j0.1)-\mathbf{I}_3(1.3+j0.9)+6\angle 0°=0$$

$$\mathbf{I}_3(3-1.3-j0.9)-(4\angle 0°)(0.71\angle 8.13°)+6\angle 0°=0$$
$$\mathbf{I}_3(1.7-j0.9)-2.84\angle 8.13°+6\angle 0°=0$$
$$\mathbf{I}_3(1.92\angle -27.9°)=2.84\angle 8.13°-6\angle 0°$$
$$\mathbf{I}_3(1.92\angle -27.9°)=3.21\angle 172.82°$$

$$\mathbf{I}_3=\frac{3.21\angle 172.82°}{1.92\angle -27.9°}$$
$$\mathbf{I}_3=1.67\angle -159.28°\text{ A}$$

Therefore, the value of $\mathbf{I}_3$ is $1.67\angle -159.28°$ A.

Step 4 of 4

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=(\mathbf{I}_3+\mathbf{I}_4)(1)$$

Substitute $1.67\angle -159.28°$ A for $\mathbf{I}_3$ and $6\angle 0°$ A for $\mathbf{I}_4$.

$$\mathbf{V}_O=(1.67\angle -159.28°+6\angle 0°)(1)$$
$$=4.48\angle -7.58°\text{ V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{4.48\angle -7.58°\text{ V}}$.

Step 1 of 3

10.023 P

Consider Figure P10.21 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 3

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(-j1+1+j2)+(\mathbf{I}_3-\mathbf{I}_2)(-j2)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_3(-j1+1+j2-j2)+\mathbf{I}_2(j2+j1)=0$$
$$\mathbf{I}_3(1-j1)+\mathbf{I}_2(j3)=0$$
$$\mathbf{I}_2(j3)=-\mathbf{I}_3(1-j1)$$

$$\mathbf{I}_2=-\mathbf{I}_3\left(\frac{1-j1}{j3}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $-\mathbf{I}_3\left(\frac{1-j1}{j3}\right)$.

Step 3 of 3

Consider Kirchhoff's Voltage Law in loop-1.

$$(\mathbf{I}_2-\mathbf{I}_1)(1)+\mathbf{I}_2(-j1)+\mathbf{I}_2(j2)+(\mathbf{I}_2-\mathbf{I}_3)(-j2)+\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_2(1-j1-j2+j2)-\mathbf{I}_1(1)+\mathbf{I}_3(j2+j1)=0$$
$$\mathbf{I}_2(1-j1)-\mathbf{I}_1+\mathbf{I}_3(j3)=0$$

Substitute $4\angle 0°$ A for $\mathbf{I}_1$ and $-\mathbf{I}_3\left(\frac{1-j1}{j3}\right)$ for $\mathbf{I}_2$.

$$-\left(\frac{1-j1}{j3}\right)(1-j1)\mathbf{I}_3-4\angle 0°+(j3)=0$$

$$\left(\frac{2}{3}\right)\mathbf{I}_3+\mathbf{I}_3(j3)=4\angle 0°$$

$$\left(\frac{2}{3}+j3\right)\mathbf{I}_3=4\angle 0°$$

$$\mathbf{I}_3=\frac{4\angle 0°}{\frac{2}{3}+j3}$$

$$\mathbf{I}_3=\frac{4\angle 0°}{3.07\angle 77.47°}$$
$$=1.3\angle -77.47°\text{ A}$$

But $\mathbf{I}_2=\mathbf{I}_o$

$$\mathbf{I}_o=1.3\angle -77.47°\text{ A}$$

Therefore, the value of $\mathbf{I}_o$ is $\boxed{1.3\angle -77.47°\text{ A}}$.

Step 1 of 4

10.024 P

Consider Figure P10.23 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(2-j2+j2)-\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_1(2)-\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_1-\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_1=\mathbf{I}_2(j1)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_2(j1)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(j2)+(\mathbf{I}_2+\mathbf{I}_3)(-j1)-\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2(j2-j1)-\mathbf{I}_3(j1)-\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2(j1)-\mathbf{I}_3(j1)-\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2-\mathbf{I}_3-\mathbf{I}_1(2)=0$$

Substitute $\mathbf{I}_2(j1)$ for $\mathbf{I}_1$ and $4\angle 0°\,\mathrm{A}$ for $\mathbf{I}_3$.

$$\mathbf{I}_2-4\angle 0°-\mathbf{I}_2(j1)(2)=0$$
$$\mathbf{I}_2(1-j2)=4\angle 0°$$
$$\mathbf{I}_2=\frac{4\angle 0°}{1-j2}$$
$$\mathbf{I}_2=\frac{4\angle 0°}{2.24\angle -63.44°}$$
$$\mathbf{I}_2=1.79\angle 63.44°\,\mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_2$ is $1.79\angle 63.44°\,\mathrm{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_o$.

$$\mathbf{V}_o=(\mathbf{I}_2+\mathbf{I}_3)(-j1)$$

Substitute $1.79\angle 63.44°\,\mathrm{A}$ for $\mathbf{I}_2$ and $4\angle 0°\,\mathrm{A}$ for $\mathbf{I}_3$.

$$\begin{aligned}\mathbf{V}_o&=(1.79\angle 63.44°+4\angle 0°)(1\angle -90°)\\&=(5.06\angle 18.45°)(1\angle -90°)\\&=5.06\angle -71.55°\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{5.06\angle -71.55°\,\mathrm{V}}$.

Step 1 of 4

10.025 P

Consider Figure P10.28 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(j2+1+j1-j2)+\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_3(1+j1)+\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_3=-\mathbf{I}_2(1+j1)$$

Therefore, the expression for the current $\mathbf{I}_3$ is $-\mathbf{I}_2(1+j1)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(j2)+\mathbf{I}_2(-j1+j2)+\mathbf{I}_3(j2)=0$$
$$(\mathbf{I}_2-\mathbf{I}_1)(j2)+\mathbf{I}_2(j1)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(j2+j1)-\mathbf{I}_1(j2)+\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(j3)-\mathbf{I}_1(j2)+\mathbf{I}_3(j2)=0$$

Substitute $-\mathbf{I}_2(1+j1)$ for $\mathbf{I}_3$.

$$\mathbf{I}_2(j3)-\mathbf{I}_1(j2)-\mathbf{I}_2(1+j1)(j2)=0$$
$$\mathbf{I}_2(j3)-\mathbf{I}_1(j2)-\mathbf{I}_2(j2-2)=0$$
$$\mathbf{I}_2(j3-j2+2)-\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2(2+j1)-\mathbf{I}_1(j2)=0$$

$$\mathbf{I}_2(2+j1)=\mathbf{I}_1(j2)$$
$$\mathbf{I}_2=\mathbf{I}_1\left(\frac{j2}{2+j1}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_1\left(\frac{j2}{2+j1}\right)$.

Step 4 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$-32\angle 0°+(\mathbf{I}_1-\mathbf{I}_2)(j2)+\mathbf{I}_1(1)=0$$
$$\mathbf{I}_1(1+j2)-\mathbf{I}_2(j2)=32\angle 0°$$

Substitute $\mathbf{I}_1\left(\frac{j2}{2+j1}\right)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(1+j2)-\mathbf{I}_1\left(\frac{j2}{2+j1}\right)(j2)=32\angle 0°$$

$$\mathbf{I}_1(1+j2)+\mathbf{I}_1\left(\frac{4}{2+j1}\right)=32\angle 0°$$
$$\mathbf{I}_1(1+j2)+\mathbf{I}_1(1.6-j0.8)=32\angle 0°$$
$$\mathbf{I}_1(1+j2+1.6-j0.8)=32\angle 0°$$

$$\mathbf{I}_1(2.6+j1.2)=32\angle 0°$$

Define input impedance of the circuit.

$$Z_{in}=\frac{32\angle 0°}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1(2.6+j1.2)$ for $32\angle 0°$.

$$Z_{in}=\frac{\mathbf{I}_1(2.6+j1.2)}{\mathbf{I}_1}$$
$$=2.6+j1.2\,\Omega$$

Therefore, the value of the input impedance is $\boxed{2.6+j1.2\,\Omega}$.

Step 1 of 4

10.026 P

Consider Figure P10.25 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(j2-j2+j2+1)+(\mathbf{I}_2-\mathbf{I}_1)(-j1)-\mathbf{I}_2(j1)-\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_2(j2-j2+j2+1-j1-j1-j1)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(1-j1)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_1(j1)=-\mathbf{I}_2(1-j1)$$

$$\begin{aligned}\mathbf{I}_1&=-\mathbf{I}_2\left(\frac{1-j1}{j1}\right)\\&=-\mathbf{I}_2(-1-j1)\\&=\mathbf{I}_2(1+j1)\end{aligned}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_2(1+j1)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$-24\angle 0°+\mathbf{I}_1(1)+(\mathbf{I}_1-\mathbf{I}_2)(-j1)=0$$
$$\mathbf{I}_1(1-j1)+\mathbf{I}_2(j1)=24\angle 0°$$

Substitute $\mathbf{I}_2(1+j1)$ for $\mathbf{I}_1$.

$$\mathbf{I}_2(1+j1)(1-j1)+\mathbf{I}_2(j1)=24\angle 0°$$
$$\mathbf{I}_2(2)+\mathbf{I}_2(j1)=24\angle 0°$$
$$\mathbf{I}_2(2+j1)=24\angle 0°$$
$$\mathbf{I}_2=\frac{24\angle 0°}{2+j1}$$

$$\mathbf{I}_2=\frac{24\angle 0°}{2.24\angle 26.57°}$$
$$\mathbf{I}_2=10.71\angle -26.57°\text{ A}$$

Therefore, the value of the current $\mathbf{I}_1$ is $10.71\angle -26.57°\text{ A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_1(1)$$

Substitute $10.71\angle -26.57°\text{ A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_O&=(10.71\angle -26.57°)(1)\\&=10.71\angle -26.57°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{10.71\angle -26.57°\text{ V}}$.

Step 1 of 3

10.027 P

Consider Figure P10.26 form the text book.

Identify the currents in the circuit.

Step 2 of 3

Consider Kirchhoff's Voltage Law in loop-1.

$$-10\angle 30^\circ + \mathbf{I}_1(1 - j1) + 10\angle 0^\circ = 0$$
$$\mathbf{I}_1(1 - j1) = 10\angle 30^\circ - 10\angle 0^\circ$$
$$\mathbf{I}_1(1.41\angle -45^\circ) = 5.18\angle 105^\circ$$
$$\mathbf{I}_1 = \frac{5.18\angle 105^\circ}{1.41\angle -45^\circ}$$
$$\mathbf{I}_1 = 3.67\angle 150^\circ \text{ A}$$

Therefore, the value of the current $\mathbf{I}_1$ is $3.67\angle 150^\circ \text{ A}$.

Step 3 of 3

Consider the expression for $\mathbf{V}_o$.

$$\mathbf{V}_o = \mathbf{I}_1(-j1) + 10\angle 0^\circ$$

Substitute $3.67\angle 150^\circ \text{ A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_o &= (3.67\angle 150^\circ)(1\angle -90^\circ) + 10\angle 0^\circ \\ &= 3.67\angle 60^\circ + 10\angle 0^\circ \\ &= 12.25\angle 15.03^\circ \text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{12.25\angle 15.03^\circ \text{ V}}$.

Step 1 of 5

10.028 P

Consider Figure P10.27 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 5

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(j2+2)-\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_2(j2)=\mathbf{I}_3(2+j2)$$
$$\mathbf{I}_2=\mathbf{I}_3(1-j1)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_3(1-j1)$.

Step 3 of 5

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{I}_1(10)-100\angle 0°+(\mathbf{I}_1-\mathbf{I}_2)(-j10)+200\angle 0°=0$$
$$\mathbf{I}_1(10-j10)+\mathbf{I}_2(j10)+100\angle 0°=0$$

Substitute $\mathbf{I}_3(1-j1)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(10-j10)+\mathbf{I}_3(1-j1)(j10)=-100\angle 0°$$
$$\mathbf{I}_1(10-j10)+\mathbf{I}_3(10+j10)=-100\angle 0°$$
$$\mathbf{I}_1(10-j10)=-100\angle 0°-\mathbf{I}_3(10+j10)$$
$$\mathbf{I}_1=\frac{-100\angle 0°-\mathbf{I}_3(10+j10)}{10-j10}$$
$$\mathbf{I}_1=\frac{-10\angle 0°-\mathbf{I}_3(1+j1)}{1-j1}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\dfrac{-10\angle 0°-\mathbf{I}_3(1+j1)}{1-j1}$.

Step 4 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(-j10)-200\angle 0°+\mathbf{I}_2(j5)-\mathbf{I}_3(j2)=0$$
$$\mathbf{I}_2(-j10+j5)+\mathbf{I}_1(j10)-\mathbf{I}_3(j2)=200\angle 0°$$
$$\mathbf{I}_2(-j5)+\mathbf{I}_1(j10)-\mathbf{I}_3(j2)=200\angle 0°$$

Substitute $\dfrac{-10\angle 0°-\mathbf{I}_3(1+j1)}{1-j1}$ for $\mathbf{I}_1$ and $\mathbf{I}_3(1-j1)$ for $\mathbf{I}_2$.

$$\mathbf{I}_3(1-j1)(-j5)+\left(\frac{-10\angle 0°-\mathbf{I}_3(1+j1)}{1-j1}\right)(j10)-\mathbf{I}_3(j2)=200\angle 0°$$
$$\mathbf{I}_3(-5-j5)+\left(\frac{-(10\angle 0°)(j10)}{1-j1}\right)-\left(\frac{\mathbf{I}_3(1+j1)(j10)}{1-j1}\right)-\mathbf{I}_3(j2)=200\angle 0°$$
$$\mathbf{I}_3(-5-j5)+\left(\frac{\mathbf{I}_3(1-j1)(10)}{1-j1}\right)-\mathbf{I}_3(j2)=200\angle 0°+(10\angle 0°)(-5+j5)$$
$$\mathbf{I}_3(-5-j5)+\mathbf{I}_3(10)-\mathbf{I}_3(j2)=200\angle 0°+(10\angle 0°)(7.07\angle 135°)$$
$$\mathbf{I}_3(-5-j5+10-j2)=200\angle 0°+70.07\angle 135°$$
$$\mathbf{I}_3(5-j7)=158.4\angle 18.23°$$
$$\mathbf{I}_3(8.6\angle -54.46°)=158.4\angle 18.23°$$
$$\mathbf{I}_3=\frac{158.4\angle 18.23°}{8.6\angle -54.46°}$$
$$\mathbf{I}_3=18.42\angle 72.69°\text{ A}$$

Therefore, the value of the current $\mathbf{I}_3$ is $18.42\angle 72.69°$ A.

Step 5 of 5

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_3(2)$$

Substitute $18.42\angle 72.69°$ A for $\mathbf{I}_3$.

$$\mathbf{V}_O=(18.42\angle 72.69°)(2)$$
$$=36.84\angle 72.69°\text{ V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{36.84\angle 72.69°\text{ V}}$.

Step 1 of 4

10.029 P

Refer to the circuit diagram in Figure P10.29 in the textbook.

Indicate loop currents in the circuit.

Figure 1

Step 2 of 4

From Figure 1, it is clear that current, $\mathbf{I}_3$ is $2\angle 0°$ A .

Apply Kirchhoff's voltage law around loop 1.

$$12\angle 0° = (2-j)(\mathbf{I}_1-\mathbf{I}_2)+j2(\mathbf{I}_1-\mathbf{I}_3)-j1(\mathbf{I}_3-\mathbf{I}_2)$$

Substitute $2\angle 0°$ A for $\mathbf{I}_3$ in the equation.

$$12\angle 0° = (2-j)(\mathbf{I}_1-\mathbf{I}_2)+j2(\mathbf{I}_1-2\angle 0°)-j1(2\angle 0°-\mathbf{I}_2)$$

Rewrite the equation.

$$(2-j+j2)\mathbf{I}_1+(-2+j+j)\mathbf{I}_2 = 12+6j$$

$$(2+j)\mathbf{I}_1+(-2+2j)\mathbf{I}_2 = 12+6j \text{ ..... (1)}$$

Apply Kirchhoff's voltage law around loop 2.

$$2\mathbf{I}_2+(3+j2)(\mathbf{I}_2-2)+(2-j)(\mathbf{I}_2-\mathbf{I}_1)-j(2-\mathbf{I}_1)=0$$

Rewrite the equation.

$$(-2+2j)\mathbf{I}_1+(7+j)\mathbf{I}_2 = 6+6j \text{ ..... (2)}$$

Write the equations in Matrix form.

$$\begin{bmatrix} 2+j & -2+2j \\ -2+2j & 7+j \end{bmatrix}\begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} 12+6j \\ 6+6j \end{bmatrix}$$

Step 3 of 4

Solve equation (1) and (2) using MATLAB.

```
>> a=[2+1*i -2+2*i;-2+2*i 7+i];
>> b=[12+6*i;6+6*i];>> x=inv(a)*bx =   4.8996 - 2.2533i   1.4148 - 1.3886i
```

Thus, current through first loop is, $\mathbf{I}_1 = 4.8996 - j2.2533$ and

Current in second loop is $\mathbf{I}_2 = 1.4148 - j1.3886$.

Step 4 of 4

Apply Kirchhoff's voltage law around loop 3.

$$\left\{\begin{matrix} 2j(2\angle 0°-\mathbf{I}_1)+2j(2\angle 0°-\mathbf{I}_2)+3(2\angle 0°-\mathbf{I}_2)+ \\ \mathbf{V}_o - j(\mathbf{I}_2-2\angle 0°)-j(\mathbf{I}_1-2\angle 0°) \end{matrix}\right\}=0$$

$$\mathbf{I}_1(-3j)+\mathbf{I}_2(-3-3j)+(6+12j)+\mathbf{V}_o=0$$

Substitute $4.8996 - j2.2533$ for $\mathbf{I}_1$ and $1.4148 - j1.3886$ for $\mathbf{I}_2$.

$$(4.8996-j2.2533)(-3j)+(1.4148-j1.3886)(-3-3j)+(6+12j)+\mathbf{V}_o=0$$

Simplify the equation.

$$\begin{aligned}\mathbf{V}_o &= 9.17+j2.77 \\ &= 9.57\angle 16.80°\end{aligned}$$

Therefore, output voltage at the current source, $2\angle 0°$ A is $\boxed{9.57\angle 16.80°}$.

Step 1 of 5

10.030 P

Consider Figure P10.24 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 5

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(j2+1+1)-\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_3(2+j2)-\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_2(j1)=\mathbf{I}_3(2+j2)$$
$$\mathbf{I}_2=\mathbf{I}_3(2-j2)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_3(2-j2)$.

Step 3 of 5

Consider Kirchhoff's Voltage Law in loop-1.

$$-24\angle 0^\circ+\mathbf{I}_1(1)+(\mathbf{I}_1-\mathbf{I}_2)(-j1)=0$$
$$\mathbf{I}_1(1-j1)+\mathbf{I}_2(j1)=24\angle 0^\circ$$

Substitute $\mathbf{I}_3(2-j2)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(1-j1)+\mathbf{I}_3(2-j2)(j1)=24\angle 0^\circ$$
$$\mathbf{I}_1(1-j1)+\mathbf{I}_3(2+j2)=24\angle 0^\circ$$
$$\mathbf{I}_1(1-j1)=24\angle 0^\circ-\mathbf{I}_3(2+j2)$$
$$\mathbf{I}_1=\frac{24\angle 0^\circ-\mathbf{I}_3(2+j2)}{1-j1}$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\dfrac{24\angle 0^\circ-\mathbf{I}_3(2+j2)}{1-j1}$.

Step 4 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$(\mathbf{I}_2-\mathbf{I}_1)(-j1)+\mathbf{I}_2(j2+1+j1)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_2(-j1+j2+1+j1)+\mathbf{I}_1(j1)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_2(1+j2)+\mathbf{I}_1(j1)-\mathbf{I}_3(j1)=0$$

Substitute $\dfrac{24\angle 0^\circ-\mathbf{I}_3(2+j2)}{1-j1}$ for $\mathbf{I}_1$ and $\mathbf{I}_3(2-j2)$ for $\mathbf{I}_2$.

$$\mathbf{I}_3(2-j2)(1+j2)+\left(\frac{24\angle 0^\circ-\mathbf{I}_3(2+j2)}{1-j1}\right)(j1)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_3(6+j2)+\left(\frac{(24\angle 0^\circ)(j1)}{1-j1}\right)-\left(\frac{\mathbf{I}_3(2+j2)(j1)}{1-j1}\right)-\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_3(6+j2)+\left(\frac{\mathbf{I}_3(2-j2)}{1-j1}\right)-\mathbf{I}_3(j1)=\frac{(24\angle 0^\circ)(-j1)}{1-j1}$$
$$\mathbf{I}_3(6+j2)+\mathbf{I}_3(2)-\mathbf{I}_3(j1)=(24\angle 0^\circ)(0.5-j0.5)$$
$$\mathbf{I}_3(6+j2+2-j1)=(24\angle 0^\circ)(0.71\angle -45^\circ)$$
$$\mathbf{I}_3(8+j1)=17.04\angle -45^\circ$$
$$\mathbf{I}_3(8.06\angle 7.13^\circ)=17.04\angle -45^\circ$$
$$\mathbf{I}_3=\frac{17.04\angle -45^\circ}{8.06\angle 7.13^\circ}$$
$$\mathbf{I}_3=2.11\angle -52.13^\circ\ \mathrm{A}$$

Therefore, the value of the current $\mathbf{I}_3$ is $2.11\angle -52.13^\circ\ \mathrm{A}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_3(1)$$

Substitute $2.11\angle -52.13^\circ\ \mathrm{A}$ for $\mathbf{I}_3$.

$$\begin{aligned}\mathbf{V}_O&=(2.11\angle -52.13^\circ)(1)\\&=2.11\angle -52.13^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{2.11\angle -52.13^\circ\ \mathrm{V}}$.

Step 1 of 5

10.031 P

Consider Figure P10.22 form the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_3(-j1+1+j2)+(\mathbf{I}_3-\mathbf{I}_2)(1)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_3(-j1+1+j2+1)+\mathbf{I}_2(-1+j1)=0$$
$$\mathbf{I}_3(2+j1)+\mathbf{I}_2(-1+j1)=0$$
$$\mathbf{I}_2(-1+j1)=-\mathbf{I}_3(2+j1)$$

$$\mathbf{I}_2=-\mathbf{I}_3\left(\frac{2+j1}{-1+j1}\right)$$
$$=\mathbf{I}_3(0.5+j1.5)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_3(0.5+j1.5)$.

Step 3 of 5

Consider the following equation at the current source.

$$\mathbf{I}_2-\mathbf{I}_1=4\angle 30^\circ$$
$$\mathbf{I}_1=\mathbf{I}_2-4\angle 30^\circ$$

Substitute $\mathbf{I}_3(0.5+j1.5)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1=\mathbf{I}_3(0.5+j1.5)-4\angle 30^\circ$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_3(0.5+j1.5)-4\angle 30^\circ$.

Step 4 of 5

Consider super mesh technique in loops 1 and 2.

$$-6\angle 0^\circ+\mathbf{I}_1(1)+\mathbf{I}_2(j2)+(\mathbf{I}_2-\mathbf{I}_3)(1)+\mathbf{I}_3(j1)=0$$
$$-6\angle 0^\circ+\mathbf{I}_1+\mathbf{I}_2(1+j2)+\mathbf{I}_3(-1+j1)=0$$

Substitute $\mathbf{I}_3(0.5+j1.5)-4\angle 30^\circ$ for $\mathbf{I}_1$ and $\mathbf{I}_3(0.5+j1.5)$ for $\mathbf{I}_2$.

$$-6\angle 0^\circ+\mathbf{I}_3(0.5+j1.5)-4\angle 30^\circ+\mathbf{I}_3(0.5+j1.5)(1+j2)+\mathbf{I}_3(-1+j1)=0$$
$$\mathbf{I}_3(0.5+j1.5)+\mathbf{I}_3(-2.5+j2.5)+\mathbf{I}_3(-1+j1)=6\angle 0^\circ+4\angle 30^\circ$$
$$\mathbf{I}_3(0.5+j1.5-2.5+j2.5-1+j1)=9.67\angle 11.93^\circ$$
$$\mathbf{I}_3(-3+j5)=9.67\angle 11.93^\circ$$

$$\mathbf{I}_3(5.83\angle 120.96^\circ)=9.67\angle 11.93^\circ$$
$$\mathbf{I}_3=\frac{9.67\angle 11.93^\circ}{5.83\angle 120.96^\circ}$$
$$\mathbf{I}_3=1.66\angle -109.03^\circ\,\text{A}$$

Therefore, the value of $\mathbf{I}_3$ is $1.66\angle -109.03^\circ\,\text{A}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_3(1)$$

Substitute $1.66\angle -109.03^\circ\,\text{A}$ for $\mathbf{I}_3$.

$$\mathbf{V}_O=(1.66\angle -109.03^\circ)(1)$$
$$=1.66\angle -109.03^\circ\,\text{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.66\angle -109.03^\circ\,\text{V}}$.

Step 1 of 5

10.032 P

Consider Figure P10.32 form the text book.

Identify the series and parallel branches in the circuit.

Figure 1

Step 2 of 5

Redraw the circuit replacing the parallel and series impedances with their equivalent impedances.

$$1+(-j2)\|2$$
$$1+\frac{(-j4)}{(-j2)+2}$$

Figure 2

Step 3 of 5

Apply a voltage of 'V' volts to the input terminals of the Figure 3 and identify the currents.

Figure 3

Step 4 of 5

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(2-j1)+(\mathbf{I}_2-\mathbf{I}_1)(j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(2-j1+j2)-\mathbf{I}_1(j2+j1)=0$$
$$\mathbf{I}_2(2+j1)=\mathbf{I}_1(j3)$$
$$\mathbf{I}_2=\mathbf{I}_1\left(\frac{j3}{2+j1}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_1\left(\frac{j3}{2+j1}\right)$.

Step 5 of 5

Consider Kirchhoff's Voltage Law in loop-1.

$$-\mathbf{V}+\mathbf{I}_1(1+j1)+(\mathbf{I}_1-\mathbf{I}_2)(j2)+\mathbf{I}_1(j1)+(\mathbf{I}_1-\mathbf{I}_2)(j1)=0$$
$$\mathbf{I}_1(1+j1+j2+j1+j1)-\mathbf{I}_2(j2+j1)=\mathbf{V}$$
$$\mathbf{I}_1(1+j5)-\mathbf{I}_2(j3)=\mathbf{V}$$

Substitute $\mathbf{I}_1\left(\frac{j3}{2+j1}\right)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(1+j5)-\mathbf{I}_1\left(\frac{j3}{2+j1}\right)(j3)=\mathbf{V}$$
$$\mathbf{I}_1(1+j5)+\mathbf{I}_1\left(\frac{9}{2+j1}\right)=\mathbf{V}$$
$$\mathbf{I}_1(1+j5)+\mathbf{I}_1(3.6-j1.8)=\mathbf{V}$$
$$\mathbf{I}_1(1+j5+3.6-j1.8)=\mathbf{V}$$
$$\mathbf{I}_1(4.6+j3.2)=\mathbf{V}$$

Define input impedance of the circuit.

$$Z_{in}=\frac{\mathbf{V}}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1(4.6+j3.2)$ for $\mathbf{V}$.

$$Z_{in}=\frac{\mathbf{I}_1(4.6+j3.2)}{\mathbf{I}_1}$$
$$=4.6+j3.2\,\Omega$$

Therefore, the value of the input impedance is $\boxed{4.6+j3.2\,\Omega}$.

Step 1 of 6

Consider Figure P10.30 form the text book.

Identify the series and parallel branches in the circuit.

Figure 1

Step 2 of 6

Redraw the circuit replacing the parallel and series impedances with their equivalent impedances.

Figure 2

Step 3 of 6

Identify and simplify the parallel branches in Figure 2.

Figure 3

Step 4 of 6

Apply a voltage of 'V' volts to the input terminals of the Figure 3 and identify the currents.

Figure 4

Step 5 of 6

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(2+0.5-j0.5+1+1j+j2)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(3.5+j2.5)+\mathbf{I}_1(j1)=0$$
$$\mathbf{I}_2(3.5+j2.5)=-\mathbf{I}_1(j1)$$
$$\mathbf{I}_2=-\mathbf{I}_1\left(\frac{j1}{3.5+j2.5}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $-\mathbf{I}_1\left(\frac{j1}{3.5+j2.5}\right)$.

Step 6 of 6

Consider Kirchhoff's Voltage Law in loop-1.

$$-\mathbf{V}+\mathbf{I}_1(-j1+j3)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_1(j2)+\mathbf{I}_2(j1)=\mathbf{V}$$

Substitute $-\mathbf{I}_1\left(\frac{j1}{3.5+j2.5}\right)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(j2)-\mathbf{I}_1\left(\frac{j1}{3.5+j2.5}\right)(j1)=\mathbf{V}$$
$$\mathbf{I}_1(j2)+\mathbf{I}_1(0.19-j0.14)=\mathbf{V}$$
$$\mathbf{I}_1(j2+0.19-j0.14)=\mathbf{V}$$
$$\mathbf{I}_1(0.19+j1.86)=\mathbf{V}$$

Define input impedance of the circuit.

$$Z_{in}=\frac{\mathbf{V}}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1(0.19+j1.86)$ for $\mathbf{V}$.

$$Z_{in}=\frac{\mathbf{I}_1(0.19+j1.86)}{\mathbf{I}_1}$$
$$=0.19+j1.86\,\Omega$$

Therefore, the value of the input impedance is $\boxed{0.19+j1.86\,\Omega}$.

10.034

P

Step 1 of 2

The mutual inductance is given by,

$M = k\sqrt{L_1 L_2}$

Where, k is the coefficient of coupling

In this case, k is 0.9 as percentage of coupling is 90%.

M is the mutual inductance.

L_1 and L_2 are the two inductances of the two coils.

$L_1 = 10\text{mH}$

$L_2 = 20\text{mH}$

Step 2 of 2

$M = 0.9\sqrt{10\times10^{-3}\times20\times10^{-3}}$

$M = 0.9\times10^{-3}\sqrt{200}$

$M = 12.728\times10^{-3}$

$\boxed{M = 12.728\,\text{mH}}$

The inductance coupling between the two inductance is 100% , hence the value of coefficient of coupling is 1 .

Consider the formula for coefficient of coupling between two coils.

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Substitute 100% for k , $10\,\text{mH}$ for L_1 and $6\,\text{mH}$ for M .

$$1 = \frac{6\,\text{m}}{\sqrt{(10\,\text{m})L_2}}$$

$$\sqrt{(10\,\text{m})L_2} = 6\,\text{m}$$

$$(10\,\text{m})L_2 = (6\,\text{m})^2$$

$$(10\,\text{m})L_2 = 36\,\text{m}^2$$

$$(10)L_2 = 36\,\text{m}$$

$$L_2 = 3.6\,\text{mH}$$

Therefore, the value of the other inductor is $\boxed{3.6\,\text{mH}}$.

Step 1 of 4

Consider Figure P10.33 form the text book.

Identify the series and parallel branches in the circuit.

Figure 1

Step 2 of 4

Consider Kirchhoff's Voltage Law in loop-3.

$$\mathbf{I}_3(j4+3)+(\mathbf{I}_3-\mathbf{I}_2)(-j1)+\mathbf{I}_2(j1)=0$$
$$\mathbf{I}_3(j4+3-j1)+\mathbf{I}_2(j1+j1)=0$$
$$\mathbf{I}_3(3+j3)+\mathbf{I}_2(j2)=0$$
$$\mathbf{I}_3=-\mathbf{I}_2\left(\frac{j2}{3+j3}\right)$$

Therefore, the expression for the current $\mathbf{I}_3$ is $-\mathbf{I}_2\left(\frac{j2}{3+j3}\right)$.

Step 3 of 4

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(j4)+(\mathbf{I}_2-\mathbf{I}_3)(-j1)+(\mathbf{I}_2-\mathbf{I}_1)(-j2)+\mathbf{I}_3(j1)=0$$
$$\mathbf{I}_2(j4-j1-j2)+\mathbf{I}_1(j2)+\mathbf{I}_3(j1+j1)=0$$
$$\mathbf{I}_2(j1)+\mathbf{I}_1(j2)+\mathbf{I}_3(j2)=0$$

Substitute $-\mathbf{I}_2\left(\frac{j2}{3+j3}\right)$ for $\mathbf{I}_3$.

$$\mathbf{I}_2(j1)+\mathbf{I}_1(j2)-\mathbf{I}_2\left(\frac{j2}{3+j3}\right)(j2)=0$$
$$\mathbf{I}_2(j1)+\mathbf{I}_1(j2)+\mathbf{I}_2\left(\frac{4}{3+j3}\right)=0$$
$$\mathbf{I}_2\left(j1+\frac{4}{3+j3}\right)+\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2\left(\frac{3+j1}{3+j3}\right)+\mathbf{I}_1(j2)=0$$
$$\mathbf{I}_2\left(\frac{3+j1}{3+j3}\right)=-\mathbf{I}_1(j2)$$
$$\mathbf{I}_2=-\mathbf{I}_1(j2)\left(\frac{3+j3}{3+j1}\right)$$
$$\mathbf{I}_2=\mathbf{I}_1\left(\frac{6-j6}{3+j1}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_1\left(\frac{6-j6}{3+j1}\right)$.

Step 4 of 4

Consider Kirchhoff's Voltage Law in loop-1.

$$-\mathbf{V}+(\mathbf{I}_1-\mathbf{I}_2)(-j2)+\mathbf{I}_1(1)=0$$
$$\mathbf{I}_1(1-j2)+\mathbf{I}_2(j2)=\mathbf{V}$$

Substitute $\mathbf{I}_1\left(\frac{6-j6}{3+j1}\right)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1(1-j2)+\mathbf{I}_1\left(\frac{6-j6}{3+j1}\right)(j2)=\mathbf{V}$$
$$\mathbf{I}_1(1-j2)+\mathbf{I}_1\left(\frac{12+j12}{3+j1}\right)=\mathbf{V}$$
$$\mathbf{I}_1(1-j2)+\mathbf{I}_1(4.8-j2.4)=\mathbf{V}$$
$$\mathbf{I}_1(1-j2+4.8-j2.4)=\mathbf{V}$$
$$\mathbf{I}_1(5.8-j4.4)=\mathbf{V}$$

Define input impedance of the circuit.

$$Z_{in}=\frac{\mathbf{V}}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1(5.8-j4.4)$ for $\mathbf{V}$.

$$Z_{in}=\frac{\mathbf{I}_1(5.8-j4.4)}{\mathbf{I}_1}$$
$$=5.8-j4.4\,\Omega$$

Therefore, the value of the input impedance is $\boxed{5.8-j4.4\,\Omega}$.

Step 1 of 3

Consider Figure P10.34 form the text book.

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2(j2 - jX_C) + (\mathbf{I}_2 - \mathbf{I}_1)(j2) + (\mathbf{I}_1 - \mathbf{I}_2)(j1) - \mathbf{I}_2(j1) = 0$$
$$\mathbf{I}_2(j2 - jX_C + j2 - j1 - j1) + \mathbf{I}_1(-j2 + j1) = 0$$
$$\mathbf{I}_2(j2 - jX_C) + \mathbf{I}_1(-j1) = 0$$
$$\mathbf{I}_1 = \mathbf{I}_2(2 - X_C)$$

Therefore, the expression for the current $\mathbf{I}_1$ is $\mathbf{I}_2(2 - X_C)$.

Step 2 of 3

Consider Kirchhoff's Voltage Law in loop-1.

$$\mathbf{V} = \mathbf{I}_1(1) + (\mathbf{I}_1 - \mathbf{I}_2)(j2) + \mathbf{I}_2(j1)$$
$$\mathbf{V} = \mathbf{I}_1(1 + j2) + \mathbf{I}_2(-j2 + j1)$$
$$\mathbf{V} = \mathbf{I}_1(1 + j2) + \mathbf{I}_2(-j1)$$

Substitute $\mathbf{I}_2(2 - X_C)$ for $\mathbf{I}_1$.

$$\mathbf{V} = \mathbf{I}_2(2 - X_C)(1 + j2) + \mathbf{I}_2(-j1)$$
$$\mathbf{V} = \mathbf{I}_2((2 - X_C)(1 + j2) - j1)$$
$$\mathbf{V} = \mathbf{I}_2(2 + j4 - X_C - j2X_C - j1)$$

$$\mathbf{V} = \mathbf{I}_2((2 - X_C) + j(3 - 2X_C)) \text{ ..... (1)}$$

Therefore, the expression for the input voltage is $\mathbf{I}_2((2 - X_C) + j(3 - 2X_C))$.

Step 3 of 3

Consider the expression for the output voltage.

$$\mathbf{V}_O = \mathbf{I}_2(-jX_C) \text{ ..... (2)}$$

Therefore, the expression for the input voltage is $\mathbf{I}_2(-jX_C)$.

Calculate the ratio $\frac{\mathbf{V}_O}{\mathbf{V}}$.

$$\frac{\mathbf{V}_O}{\mathbf{V}} = \frac{\mathbf{I}_2(-jX_C)}{\mathbf{I}_2((2 - X_C) + j(3 - 2X_C))}$$
$$\frac{\mathbf{V}_O}{\mathbf{V}} = \frac{(-jX_C)}{((2 - X_C) + j(3 - 2X_C))}$$

Substitute $2\mathbf{V}$ for $\mathbf{V}_O$.

$$\frac{2\mathbf{V}}{\mathbf{V}} = \frac{-jX_C}{((2 - X_C) + j(3 - 2X_C))}$$
$$2 = \frac{-jX_C}{((2 - X_C) + j(3 - 2X_C))}$$
$$2((2 - X_C) + j(3 - 2X_C)) = -jX_C$$
$$2(2 - X_C) + j2(3 - 2X_C) = 0 - jX_C$$

Compare the real terms.

$$2 - X_C = 0$$
$$X_C = 2\Omega$$

Therefore, the value of X_C is $\boxed{2\Omega}$.

Step 1 of 9

10.038 P

Consider Figure P10.35 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 9

Consider Kirchhoff's Voltage Law in loop-2.

$$\mathbf{I}_2\left(4+10+j6+j50+\frac{1}{j\omega C}\right)-\mathbf{I}_1(j6)=0$$

$$\mathbf{I}_2\left(4+10+j6+j50-\frac{j}{\omega C}\right)-\mathbf{I}_1(j6)=0$$

$$\mathbf{I}_2\left(14+j\left(56-\frac{1}{\omega C}\right)\right)-\mathbf{I}_1(j6)=0$$

$$\mathbf{I}_2\left(14+j\left(56-\frac{1}{\omega C}\right)\right)=\mathbf{I}_1(j6)$$

$$\mathbf{I}_2=\mathbf{I}_1\left(\frac{j6}{14+j\left(56-\frac{1}{\omega C}\right)}\right)$$

Therefore, the expression for the current $\mathbf{I}_2$ is $\mathbf{I}_1\left(\frac{j6}{14+j\left(56-\frac{1}{\omega C}\right)}\right)$.

Step 3 of 9

Consider Kirchhoff's Voltage Law in loop-1.

$$24\angle 0^\circ=\mathbf{I}_1(12+j1)-\mathbf{I}_2(j6)$$

Substitute $\mathbf{I}_1\left(\frac{j6}{14+j\left(56-\frac{1}{\omega C}\right)}\right)$ for $\mathbf{I}_2$.

$$24\angle 0^\circ=\mathbf{I}_1(12+j1)-\mathbf{I}_1\left(\frac{j6}{14+j\left(56-\frac{1}{\omega C}\right)}\right)(j6)$$

$$24\angle 0^\circ=\mathbf{I}_1(12+j1)+\mathbf{I}_1\left(\frac{36}{14+j\left(56-\frac{1}{\omega C}\right)}\right)$$

$$24\angle 0^\circ=\mathbf{I}_1(12+j1)+\mathbf{I}_1\left(\frac{36}{14+j\left(56-\frac{1}{\omega C}\right)}\times\frac{14-j\left(56-\frac{1}{\omega C}\right)}{14-j\left(56-\frac{1}{\omega C}\right)}\right)$$

$$24\angle 0^\circ=\mathbf{I}_1(12+j1)+\mathbf{I}_1\left(\frac{(36)\left(14-j\left(56-\frac{1}{\omega C}\right)\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)$$

$$24\angle 0^\circ=\mathbf{I}_1\left(12+j1+\frac{(36)\left(14-j\left(56-\frac{1}{\omega C}\right)\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)$$

$$=\mathbf{I}_1\left(12+j1+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}-\frac{j(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)$$

$$=\mathbf{I}_1\left(\left(12+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)+j\left(1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)\right)$$

Step 4 of 9

Define the expression for the input impedance.

$$Z_{in}=\frac{24\angle 0^\circ}{\mathbf{I}_1}$$

Substitute $\mathbf{I}_1\left(\left(12+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)+j\left(1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)\right)$ for $24\angle 0^\circ$ V.

$$Z_{in}=\frac{\mathbf{I}_1\left(\left(12+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)+j\left(1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)\right)}{\mathbf{I}_1}$$

$$=\left(12+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)+j\left(1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)$$

Therefore, the expression for the input impedance is

$$\left(12+\frac{(36)(14)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right)+j\left(1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}\right).$$

Step 5 of 9

The value of the input impedance should be purely resistive, hence equate imaginary part of the impedance to zero.

$$1-\frac{(36)\left(56-\frac{1}{\omega C}\right)}{(14)^2+\left(56-\frac{1}{\omega C}\right)^2}=0$$

$$(14)^2+\left(56-\frac{1}{\omega C}\right)^2-(36)\left(56-\frac{1}{\omega C}\right)=0$$

Let $56-\frac{1}{\omega C}$ be A.

$$A^2-(36)A+(14)^2=0$$

$$A^2-36A+196=0$$

Solve for A.

$A_1=29.31$ and $A_2=6.69$.

Step 6 of 9

Calculate the value of ω.

$$\omega=2\pi f$$

Substitute 60 Hz for f.

$$\omega=2\pi(60)$$
$$=376.99\text{ rad/s}$$

Therefore, the value of ω is 376.99 rad/s.

Step 7 of 9

Consider the value A_1.

$$A_1=29.31.$$

Substitute $56-\frac{1}{\omega C}$ for A_1.

$$56-\frac{1}{\omega C}=29.31$$

$$\frac{1}{\omega C}=56-29.31$$

$$\frac{1}{\omega C}=26.69$$

$$C=\frac{1}{\omega(26.69)}$$

Substitute 376.99 rad/s for ω.

$$C=\frac{1}{(376.99)(26.69)}$$

$$C=99.38\ \mu\text{F}$$

Therefore, the value of the capacitor is $99.38\ \mu\text{F}$.

Step 8 of 9

Consider the value A_2.

$$A_2=6.69.$$

Substitute $56-\frac{1}{\omega C}$ for A_2.

$$56-\frac{1}{\omega C}=6.69$$

$$\frac{1}{\omega C}=56-6.69$$

$$\frac{1}{\omega C}=49.31$$

$$C=\frac{1}{\omega(49.31)}$$

Step 9 of 9

Substitute 376.99 rad/s for ω.

$$C=\frac{1}{(376.99)(49.31)}$$

$$C=53.79\ \mu\text{F}$$

Therefore, the value of the capacitor is $53.79\ \mu\text{F}$.

Therefore, the values of the capacitor needed for the input impedance to be purely resistive are $\boxed{53.79\ \mu\text{F}}$ and $\boxed{99.38\ \mu\text{F}}$.

Step 1 of 5

Refer to Figure P10.37 from the text book.

Consider the formula for coefficient of coupling between two coils.

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Substitute 0.6 for k, $2\,\text{H}$ for L_1 and $1\,\text{H}$ for L_2.

$$0.6 = \frac{M}{\sqrt{(2)(1)}}$$
$$M = (0.6)(\sqrt{2})$$
$$M = 0.849\,\text{H}$$

Therefore, the value of the mutual inductance is $0.849\,\text{H}$.

Step 2 of 5

Consider the value of the current $i_1(t)$.

$$i_1(t) = 8\cos(377t - 20°)\,\text{mA}$$

Rewrite in phasor notation.

$$\mathbf{I}_1 = 8\angle -20°\,\text{mA}$$

Therefore, the value of the current $\mathbf{I}_1$ is $8\angle -20°\,\text{mA}$.

Consider the value of the current $i_2(t)$.

$$i_2(t) = 4\cos(377t - 50°)\,\text{mA}$$

Rewrite in phasor notation.

$$\mathbf{I}_2 = 4\angle -40°\,\text{mA}$$

Therefore, the value of the current $\mathbf{I}_2$ is $4\angle -50°\,\text{mA}$.

Step 3 of 5

Consider Figure 1.

Figure 1

Step 4 of 5

Apply Kirchhoff's Voltage Law in loop 1.

$$\mathbf{V}_1 = \mathbf{I}_1(j\omega L_1) - \mathbf{I}_2(j\omega M)$$

Substitute $2\,\text{H}$ for L_1, $377\,\text{rad/s}$ for ω, $4\angle -50°\,\text{mA}$ for $\mathbf{I}_2$, $8\angle -20°\,\text{mA}$ for $\mathbf{I}_1$ and $0.849\,\text{H}$ for M.

$$\begin{aligned}\mathbf{V}_1 &= j(8\angle -20°\,\text{m})(377)(2) - j(4\angle -50°\,\text{m})(377)(0.849)\\ &= j(6032\angle -20°\,\text{m}) - j(1280.29\angle -50°\,\text{m})\\ &= j(6032\angle -20°\,\text{m} - 1280.29\angle -50°\,\text{m})\\ &= j(4964.68\angle -12.59°\,\text{m})\end{aligned}$$

$$\begin{aligned}\mathbf{V}_1 &= (1\angle 90°)(4964.68\angle -12.59°\,\text{m})\\ &= 4964.68\angle 77.41°\,\text{m}\\ &= 4.97\angle 77.41°\,\text{V}\end{aligned}$$

Rewrite in time domain representation.

$$v_1(t) = 4.97\cos(377 + 77.41°)\,\text{V}$$

Therefore, the value of $v_1(t)$ is $\boxed{4.97\cos(377 + 77.41°)\,\text{V}}$.

Step 5 of 5

Apply Kirchhoff's Voltage Law in loop 2.

$$\begin{aligned}\mathbf{V}_2 &= -(\mathbf{I}_2(j\omega L_2) - \mathbf{I}_1(j\omega M))\\ &= -\mathbf{I}_2(j\omega L_2) + \mathbf{I}_1(j\omega M)\end{aligned}$$

Substitute $1\,\text{H}$ for L_2, $377\,\text{rad/s}$ for ω, $4\angle -50°\,\text{mA}$ for $\mathbf{I}_2$, $8\angle -20°\,\text{mA}$ for $\mathbf{I}_1$ and $0.849\,\text{H}$ for M.

$$\begin{aligned}\mathbf{V}_2 &= -j(4\angle -50°\,\text{m})(377)(1) + j(8\angle -20°\,\text{m})(377)(0.849)\\ &= -j(1508\angle -50°\,\text{m}) + j(2560.58\angle -20°\,\text{m})\\ &= j(-1508\angle -50°\,\text{m} + 2560.58\angle -20°\,\text{m})\\ &= j(1463.75\angle 11.01°\,\text{m})\end{aligned}$$

$$\begin{aligned}\mathbf{V}_2 &= (1\angle 90°)(1463.75\angle 11.01°\,\text{m})\\ &= 1463.75\angle 101.01°\,\text{m}\\ &= 1.46\angle 101.01°\,\text{V}\end{aligned}$$

Rewrite in time domain representation.

$$v_2(t) = 1.46\cos(377 + 101.01°)\,\text{V}$$

Therefore, the value of $v_2(t)$ is $\boxed{1.46\cos(377 + 101.01°)\,\text{V}}$.

Step 1 of 4

Consider the formula for coefficient of coupling between two coils.

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Substitute 0.6 for k, $2\,\text{H}$ for L_1 and $1\,\text{H}$ for L_2.

$$0.6 = \frac{M}{\sqrt{(2)(1)}}$$
$$M = (0.6)(\sqrt{2})$$
$$M = 0.849\,\text{H}$$

Therefore, the value of the mutual inductance is $0.849\,\text{H}$.

Step 2 of 4

Consider the value of the current $i_1(t)$.

$$i_1(t) = 8\cos(377t - 20°)\,\text{mA}$$

Substitute $1\,\text{ms}$ for t.

$$\begin{aligned} i_1(1\,\text{m}) &= 8\cos(377(1\,\text{m}) - 20°)\,\text{m} \\ &= 8\cos(-19.62°)\,\text{m} \\ &= 8(0.94)\,\text{m} \\ &= 7.52\,\text{mA} \end{aligned}$$

Therefore, the value of $i_1(1\,\text{m})$ is $7.52\,\text{mA}$.

Step 3 of 4

Consider the value of the current $i_2(t)$.

$$i_2(t) = 4\cos(377t - 50°)\,\text{mA}$$

Substitute $1\,\text{ms}$ for t.

$$\begin{aligned} i_2(1\,\text{m}) &= 4\cos(377(1\,\text{m}) - 50°)\,\text{m} \\ &= 4\cos(-49.62°)\,\text{m} \\ &= 4(0.65)\,\text{m} \\ &= 2.6\,\text{mA} \end{aligned}$$

Therefore, the value of $i_2(1\,\text{m})$ is $2.6\,\text{mA}$.

Step 4 of 4

Consider the expression for the energy stored in the coupled inductors.

$$w(t) = \frac{1}{2}L_1 i_1^2(t) + \frac{1}{2}L_2 i_2^2(t) - M i_1(t) i_2(t)$$

Substitute $1\,\text{ms}$ for t.

$$w(1\,\text{m}) = \frac{1}{2}L_1 i_1^2(1\,\text{m}) + \frac{1}{2}L_2 i_2^2(1\,\text{m}) - M i_1(1\,\text{m}) i_2(1\,\text{m})$$

Substitute $2\,\text{H}$ for L_1, $1\,\text{H}$ for L_2, $7.52\,\text{mA}$ for $i_1(1\,\text{m})$, $2.6\,\text{mA}$ for $i_2(1\,\text{m})$ and $0.849\,\text{H}$ for M.

$$\begin{aligned} w(1\,\text{m}) &= \frac{1}{2}(2)(7.52\,\text{m})^2 + \frac{1}{2}(1)(2.6\,\text{m})^2 - (0.849)(7.52\,\text{m})(2.6\,\text{m}) \\ &= \frac{1}{2}(2)(56.55\,\mu) + \frac{1}{2}(1)(6.76\,\mu) - 16.6\,\mu \\ &= 56.55\,\mu + 3.38\,\mu - 16.6\,\mu \\ &= 43.33\,\mu\text{J} \end{aligned}$$

Therefore, the value of the energy stored in the coupled inductor is $\boxed{43.33\,\mu\text{J}}$.

10.041

P

Step 1 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 2 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 5 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 6 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 7 of 7

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 1 of 4

Consider the formula for coefficient of coupling between two coils.

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Substitute 0.8 for k, $2\,\text{H}$ for L_1 and L_2.

$$0.8 = \frac{M}{\sqrt{(2)(2)}}$$
$$M = (0.8)(2)$$
$$M = 1.6\,\text{H}$$

Therefore, the value of the mutual inductance is $1.6\,\text{H}$.

Step 2 of 4

Consider the value of the current $i_1(t)$.

$$i_1(t) = 10\cos(377t - 30°)\,\text{mA}$$

Substitute $1\,\text{ms}$ for t.

$$\begin{aligned} i_1(1\,\text{m}) &= 10\cos(377(1\,\text{m}) - 30°)\,\text{m} \\ &= 10\cos(-29.62°)\,\text{m} \\ &= 10(0.87)\,\text{m} \\ &= 8.7\,\text{mA} \end{aligned}$$

Therefore, the value of $i_1(1\,\text{m})$ is $8.7\,\text{mA}$.

Step 3 of 4

Consider the value of the current $i_2(t)$.

$$i_2(t) = 20\cos(377t - 45°)\,\text{mA}$$

Substitute $1\,\text{ms}$ for t.

$$\begin{aligned} i_2(1\,\text{m}) &= 20\cos(377(1\,\text{m}) - 45°)\,\text{m} \\ &= 20\cos(-44.62°)\,\text{m} \\ &= 20(0.71)\,\text{m} \\ &= 14.2\,\text{mA} \end{aligned}$$

Therefore, the value of $i_2(1\,\text{m})$ is $14.2\,\text{mA}$.

Step 4 of 4

Consider the expression for the energy stored in the coupled inductors.

$$w(t) = \frac{1}{2}L_1 i_1^2(t) + \frac{1}{2}L_2 i_2^2(t) - M i_1(t) i_2(t)$$

Substitute $1\,\text{ms}$ for t.

$$w(1\,\text{m}) = \frac{1}{2}L_1 i_1^2(1\,\text{m}) + \frac{1}{2}L_2 i_2^2(1\,\text{m}) - M i_1(1\,\text{m}) i_2(1\,\text{m})$$

Substitute $2\,\text{H}$ for L_1, $2\,\text{H}$ for L_2, $8.7\,\text{mA}$ for $i_1(1\,\text{m})$, $1.42\,\text{mA}$ for $i_2(1\,\text{m})$ and $1.6\,\text{H}$ for M.

$$\begin{aligned} w(1\,\text{m}) &= \frac{1}{2}(2)(8.7\,\text{m})^2 + \frac{1}{2}(1)(1.42\,\text{m})^2 - (1.6)(8.7\,\text{m})(1.42\,\text{m}) \\ &= \frac{1}{2}(2)(75.69\,\mu) + \frac{1}{2}(1)(2.02\,\mu) - 19.77\,\mu \\ &= 75.69\,\mu + 1.01\,\mu - 19.77\,\mu \\ &= 56.93\,\mu\text{J} \end{aligned}$$

Therefore, the value of the energy stored in the coupled inductor is $\boxed{56.93\,\mu\text{J}}$.

Step 1 of 6

10.043 P

Refer to Figure P10.44 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$Z_1 = \frac{Z_2}{n^2}$$

Z_2 represents the resistance in the secondary circuit.

Substitute $1\,\Omega$ for Z_2 and $\frac{1}{2}$ for n.

$$\begin{aligned} Z_1 &= \frac{1}{\left(\frac{1}{2}\right)^2} \\ &= 4\,\Omega \end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $4\,\Omega$.

Step 2 of 6

Consider the circuit diagram in Figure 1.

Figure 1

Step 3 of 6

Calculate the value of V_1 using voltage division rule.

$$\begin{aligned} V_1 &= (12\angle 30^\circ)\left(\frac{4}{1+4}\right) \\ &= (12\angle 30^\circ)\left(\frac{4}{5}\right) \\ &= (12\angle 30^\circ)(0.8\angle 0^\circ) \\ &= 9.6\angle 30^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_1 is $\boxed{9.6\angle 30^\circ \text{ V}}$.

Step 4 of 6

Calculate the expression for V_2 in terms of V_1.

$V_2 = -nV_1$ Substitute $\frac{1}{2}$ for n and $9.6\angle 30^\circ$ V for V_1.

$$\begin{aligned} V_2 &= -\left(\frac{1}{2}\right)(9.6\angle 30^\circ) \\ &= -4.8\angle 30^\circ \\ &= 4.8\angle -150^\circ \text{ V} \end{aligned}$$

Therefore, the value of V_2 is $\boxed{4.8\angle -150^\circ \text{ V}}$.

Step 5 of 6

Calculate the value of I_1.

$$I_1 = \frac{12\angle 30^\circ - V_1}{1}$$

Substitute $9.6\angle 30^\circ$ V for V_1.

$$\begin{aligned} I_1 &= \frac{12\angle 30^\circ - 9.6\angle 30^\circ}{1} \\ &= \frac{2.4\angle 30^\circ}{1} \\ &= 2.4\angle 30^\circ \text{ A} \end{aligned}$$

Therefore, the value of I_1 is $\boxed{2.4\angle 30^\circ \text{ A}}$.

Step 6 of 6

Calculate the expression for I_2 in terms of I_1.

$I_2 = -\frac{I_1}{n}$ Substitute $\frac{1}{2}$ for n and $2.4\angle 30^\circ$ A for I_1.

$$\begin{aligned} I_2 &= -\frac{2.4\angle 30^\circ}{\left(\frac{1}{2}\right)} \\ &= -4.8\angle 30^\circ \\ &= 4.8\angle -150^\circ \text{ A} \end{aligned}$$

Therefore, the value of I_2 is $\boxed{4.8\angle -150^\circ \text{ A}}$.

Step 1 of 6

Refer to Figure P10.42 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the series combination of resistance and inductance in the secondary circuit.

Substitute $3 + j1\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{3+j1}{2^2}\\ &= \frac{3+j1}{4}\\ &= \frac{3}{4}+\frac{j1}{4}\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $\frac{3}{4}+\frac{j1}{4}\Omega$.

Step 2 of 6

Consider the circuit diagram in Figure 1.

Figure 1

Step 3 of 6

Calculate the value of $\mathbf{V}_1$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_1 &= (12\angle 0^\circ)\left(\frac{\frac{3}{4}+\frac{j1}{4}}{1+\frac{3}{4}+\frac{j1}{4}}\right)\\ &= (12\angle 0^\circ)\left(\frac{0.75+j0.25}{1.75+j0.25}\right)\\ &= (12\angle 0^\circ)(0.45\angle 10.31^\circ)\\ &= 5.4\angle 10.31^\circ\,\text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{5.4\angle 10.31^\circ\,\text{V}}$.

Step 4 of 6

Calculate the expression for $\mathbf{V}_2$ in terms of $\mathbf{V}_1$.

$\mathbf{V}_2 = n\mathbf{V}_1$ Substitute 2 for n and $5.4\angle 10.31^\circ\,\text{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_2 &= 2(5.4\angle 10.31^\circ)\\ &= 10.8\angle 10.31^\circ\,\text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{10.8\angle 10.31^\circ\,\text{V}}$.

Step 5 of 6

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{12\angle 0^\circ - \mathbf{V}_1}{1}$$

Substitute $5.4\angle 10.31^\circ\,\text{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{12\angle 0^\circ - 5.4\angle 10.31^\circ}{1}\\ &= \frac{6.76\angle -8.22^\circ}{1}\\ &= 6.76\angle -8.22^\circ\,\text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{6.76\angle -8.22^\circ\,\text{A}}$.

Step 6 of 6

Calculate the expression for $\mathbf{I}_2$ in terms of $\mathbf{I}_1$.

$$\mathbf{I}_2 = \frac{\mathbf{I}_1}{n}$$

Substitute 2 for n and $6.76\angle -8.22^\circ\,\text{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{6.76\angle -8.22^\circ}{2}\\ &= 3.38\angle -8.22^\circ\,\text{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{3.38\angle -8.22^\circ\,\text{A}}$.

Step 1 of 4

10.045 P

Refer to Figure P10.41 from the text book.

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = -n\mathbf{V}_1$$

Negative sign is due to dot variation at the primary and secondary of the transformer.

Substitute $24\angle 45^\circ\ \mathrm{V}$ for $\mathbf{V}_1$ and 2 for n.

$$\begin{aligned}\mathbf{V}_2 &= -2(24\angle 45^\circ)\\ &= -48\angle 45^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-48\angle 45^\circ\ \mathrm{V}$.

Step 2 of 4

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the series combination of resistance and capacitance in the primary circuit.

Substitute $1\text{-}j1\,\Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (2)^2(1\text{-}j1)\\ &= 4(1\text{-}j1)\\ &= 4\text{-}j4\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $4\text{-}j4\,\Omega$.

Step 3 of 4

Consider the circuit diagram in Figure 1.

Figure 1

Step 4 of 4

Calculate the value of $\mathbf{V}_O$ using voltage division rule.

$$\mathbf{V}_O = \mathbf{V}_2\left(\frac{j3}{4-j4+2+j3}\right)$$

Substitute $-48\angle 45^\circ\ \mathrm{V}$ for $\mathbf{V}_2$.

$$\begin{aligned}\mathbf{V}_O &= -(48\angle 45^\circ)\left(\frac{j3}{6-j1}\right)\\ &= (48\angle 45^\circ)(0.49\angle -80.54^\circ)\\ &= 23.52\angle -35.54^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{23.52\angle -35.54^\circ\ \mathrm{V}}$.

Step 1 of 4

10.046 P

Refer to Figure P10.43 from the text book.

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = -n\mathbf{V}_1$$

Negative sign is due to dot variation at the primary and secondary of the transformer.

Substitute $10\angle 30^\circ\ \text{V}$ for $\mathbf{V}_1$ and 2 for n.

$$\begin{aligned}\mathbf{V}_2 &= -2(10\angle 30^\circ)\\ &= -20\angle 30^\circ\ \text{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-20\angle 30^\circ\ \text{V}$.

Step 2 of 4

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the series combination of resistance and capacitance in the primary circuit.

Substitute $1\text{-}j1\,\Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (2)^2(1\text{-}j1)\\ &= 4(1\text{-}j1)\\ &= 4\text{-}j4\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $4\text{-}j4\,\Omega$.

Step 3 of 4

Consider the circuit diagram in Figure 1.

Figure 1

Step 4 of 4

Calculate the value of $\mathbf{V}_O$ using voltage division rule.

$$\mathbf{V}_O = \mathbf{V}_2\left(\frac{j2}{4-j4+1+j2}\right)$$

Substitute $-20\angle 30^\circ\ \text{V}$ for $\mathbf{V}_2$.

$$\begin{aligned}\mathbf{V}_O &= -(20\angle 30^\circ)\left(\frac{j2}{5-j2}\right)\\ &= (20\angle 30^\circ)(0.37\angle -68.2^\circ)\\ &= 7.4\angle -38.2^\circ\ \text{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{7.4\angle -38.2^\circ\ \text{V}}$.

Step 1 of 6

10.047 P

Refer to Figure P10.45 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the series combination of resistance and inductance in the secondary circuit.

Substitute $4 + j4\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{4 + j4}{2^2}\\ &= \frac{4 + j4}{4}\\ &= 1 + j1\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $1 + j1\,\Omega$.

Step 2 of 6

Consider the circuit diagram in Figure 1.

Figure 1

Step 3 of 6

Apply Kirchhoff's Current Law at node 1.

$$\frac{\mathbf{V}_1}{-j1} + \frac{\mathbf{V}_1}{1 + j1} + \frac{\mathbf{V}_1 - 10\angle 30^\circ}{2} = 0$$

$$\mathbf{V}_1\left(\frac{1}{-j1} + \frac{1}{1 + j1} + \frac{1}{2}\right) = \frac{10\angle 30^\circ}{2}$$

$$\mathbf{V}_1(j1 + 0.5 - j0.5 + 0.5) = 5\angle 30^\circ$$

$$\mathbf{V}_1(1 + j0.5) = 5\angle 30^\circ$$

$$\mathbf{V}_1(1.12\angle 26.57^\circ) = 5\angle 30^\circ$$

$$\mathbf{V}_1 = \frac{5\angle 30^\circ}{1.12\angle 26.57^\circ}$$

$$\mathbf{V}_1 = 4.46\angle 3.43^\circ \text{ V}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{4.46\angle 3.43^\circ \text{ V}}$.

Step 4 of 6

Calculate the expression for $\mathbf{V}_2$ in terms of $\mathbf{V}_1$.

$\mathbf{V}_2 = n\mathbf{V}_1$ Substitute 2 for n and $4.46\angle 3.43^\circ$ V for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_2 &= (2)(4.46\angle 3.43^\circ)\\ &= 8.92\angle 3.43^\circ \text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{8.92\angle 3.43^\circ \text{ V}}$.

Step 5 of 6

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = \frac{\mathbf{V}_1}{1 + j1}$$

Substitute $4.46\angle 3.43^\circ$ V for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_1 &= \frac{4.46\angle 3.43^\circ}{1 + j1}\\ &= \frac{4.46\angle 3.43^\circ}{1.41\angle 45^\circ}\\ &= 3.16\angle -41.57^\circ \text{ A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{3.16\angle -41.57^\circ \text{ A}}$.

Step 6 of 6

Calculate the expression for $\mathbf{I}_2$ in terms of $\mathbf{I}_1$.

$$\mathbf{I}_2 = \frac{\mathbf{I}_1}{n}$$

Substitute 2 for n and $3.16\angle -41.57^\circ$ A for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{3.16\angle -41.57^\circ}{2}\\ &= 1.58\angle -41.57^\circ \text{ A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{1.58\angle -41.57^\circ \text{ A}}$.

Step 1 of 8

Refer to Figure P10.50 from the text book.

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = -n\mathbf{V}_1$$

Substitute $1\angle 0°\ \mathrm{V}$ for $\mathbf{V}_1$ and 2 for n.

$$\begin{aligned}\mathbf{V}_2 &= -(2)(1\angle 0°)\\ &= -2\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-2\angle 0°\ \mathrm{V}$.

Step 2 of 8

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the resistance in the primary circuit.

Substitute $1\,\Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (2)^2(1)\\ &= (4)(1)\\ &= 4\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $4\,\Omega$.

Step 3 of 8

Consider the circuit diagram in Figure 1.

Figure 1

Step 4 of 8

Consider Kirchhoff's Voltage Law in Loop-1.

$$\begin{aligned}&2\angle 0° + \mathbf{I}(4+1) + \mathbf{I}_2(2) = 0\\ &2\angle 0° + \mathbf{I}(5) + \mathbf{I}_2(2) = 0\end{aligned}$$

Substitute $\mathbf{I} + 1\angle 0°$ for $\mathbf{I}_2$.

$$\begin{aligned}&2\angle 0° + \mathbf{I}(5) + (\mathbf{I} + 1\angle 0°)(2) = 0\\ &2\angle 0° + \mathbf{I}(5) + 2\mathbf{I} + 2\angle 0° = 0\\ &\mathbf{I}(5+2) + 4\angle 0° = 0\\ &\mathbf{I}(7) + 4\angle 0° = 0\end{aligned}$$

$$\begin{aligned}&\mathbf{I} = \frac{-4\angle 0°}{7}\\ &\mathbf{I} = -0.571\angle 0°\\ &\mathbf{I} = 0.571\angle 180°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}$ is $0.571\angle 180°\ \mathrm{A}$.

Step 5 of 8

Calculate the value of $\mathbf{I}_2$.

$$\mathbf{I}_2 = \mathbf{I} + 1\angle 0°$$

Substitute $0.571\angle 180°\ \mathrm{A}$ for $\mathbf{I}$.

$$\begin{aligned}\mathbf{I}_2 &= 0.571\angle 180° + 1\angle 0°\\ &= 0.429\angle 0°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{0.429\angle 0°\ \mathrm{A}}$.

Step 6 of 8

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = -2\mathbf{I}$$

Substitute $0.571\angle 180°\ \mathrm{A}$ for $\mathbf{I}$.

$$\begin{aligned}\mathbf{I}_1 &= -(2)(0.571\angle 180°)\\ &= 1.142\angle 0°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{1.142\angle 0°\ \mathrm{A}}$.

Step 7 of 8

Calculate the value of $\mathbf{V}_2$.

$$\mathbf{V}_2 = 1\mathbf{I} + 2\mathbf{I}_2$$

Substitute $0.571\angle 180°\ \mathrm{A}$ for $\mathbf{I}$ and $0.429\angle 0°\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_2 &= 1(0.571\angle 180°) + 2(0.429\angle 0°)\\ &= 0.571\angle 180° + 0.858\angle 0°\\ &= 0.287\angle 0°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{0.287\angle 0°\ \mathrm{V}}$.

Step 8 of 8

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1 = -\frac{\mathbf{V}_2}{n}$$

Substitute 2 for n and $0.287\angle 0°\ \mathrm{V}$ for $\mathbf{V}_2$.

$$\begin{aligned}\mathbf{V}_1 &= -\frac{0.287\angle 0°}{2}\\ &= -0.143\angle 0°\\ &= 0.143\angle 180°\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{0.143\angle 180°\ \mathrm{V}}$.

Step 1 of 9

10.049 P

Refer to Figure P10.52 from the text book.

Calculate the impedance offered by the parallel combination of inductor and capacitor in the secondary circuit.

$$\begin{aligned} Z &= (j1)\|(-j1) \\ &= \frac{(j1)(-j1)}{(j1)+(-j1)} \\ &= \infty \end{aligned}$$

Therefore, the impedance offered by the parallel combination of inductor and capacitor in the secondary circuit is $\infty\,\Omega$.

Step 2 of 9

Consider the circuit diagram in Figure 1.

Figure 1

Step 3 of 9

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$Z_1 = \frac{Z_2}{n^2}$$

Z_2 represents the resistance in the secondary circuit.

Substitute $1\,\Omega$ for Z_2 and 2 for n .

$$\begin{aligned} Z_1 &= \frac{(1)}{(2)^2} \\ &= \frac{1}{4}\,\Omega \end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $\frac{1}{4}\,\Omega$.

Step 4 of 9

Calculate the expression for V_2 when referred to primary of the transformer.

$V_{2P} = -\frac{V_2}{n}$ Therefore, the value expression for V_2 when referred to primary of the transformer is $-\frac{V_2}{n}$.

Step 5 of 9

Transfer secondary side parameters to primary side.

Figure 2

Step 6 of 9

Consider Kirchhoff's Voltage Law in Loop-1.

$$\begin{aligned} &-24\angle 30^\circ + I_1(1 - j1) = 0 \\ &I_1(1.41\angle -45^\circ) = 24\angle 30^\circ \\ &I_1 = \frac{24\angle 30^\circ}{1.41\angle -45^\circ} \\ &I_1 = 17.02\angle 75^\circ\ \text{A} \end{aligned}$$

Therefore, the value of I_1 is $\boxed{17.02\angle 75^\circ\ \text{A}}$.

Step 7 of 9

Calculate the value of V_1 .

$$V_1 = I_1(-j1)$$

Substitute $17.02\angle 75^\circ\ \text{A}$ for I_1 .

$$\begin{aligned} V_1 &= (17.02\angle 75^\circ)(-j1) \\ &= (17.02\angle 75^\circ)(1\angle -90^\circ) \\ &= 17.02\angle -15^\circ\ \text{V} \end{aligned}$$

Therefore, the value of V_1 is $\boxed{17.02\angle -15^\circ\ \text{V}}$.

Step 8 of 9

Calculate the value of $-\frac{V_2}{2}$.

$$-\frac{V_2}{2} = V_1$$

Substitute $17.02\angle -15^\circ\ \text{V}$ for V_1 .

$$\begin{aligned} -\frac{V_2}{2} &= 17.02\angle -15^\circ \\ V_2 &= -2(17.02\angle -15^\circ) \\ V_2 &= -34.04\angle -15^\circ \\ V_2 &= 34.04\angle 165^\circ\ \text{V} \end{aligned}$$

Therefore, the value of V_2 is $\boxed{34.04\angle 165^\circ\ \text{V}}$.

Step 9 of 9

Calculate the value of I_2 .

$$I_2 = \frac{V_2}{-j1}$$

Substitute $34.04\angle 165^\circ\ \text{V}$ for V_2 .

$$\begin{aligned} I_2 &= \frac{34.04\angle 165^\circ}{-j1} \\ &= \frac{34.04\angle 165^\circ}{1\angle -90^\circ} \\ &= 34.04\angle -105^\circ\ \text{A} \end{aligned}$$

Therefore, the value of I_2 is $\boxed{34.04\angle -105^\circ\ \text{A}}$.

Step 1 of 7

Refer to Figure P10.54 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the resistance in the primary circuit.

Substitute $3\,\Omega$ for $\mathbf{Z}_1$ and 4 for n.

$$\begin{aligned}\mathbf{Z}_2 &= (4)^2(3)\\ &= (16)(3)\\ &= 48\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $48\,\Omega$.

Step 2 of 7

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = n\mathbf{V}_1$$

Substitute $12\angle 0^\circ\ \mathrm{V}$ for $\mathbf{V}_1$ and 4 for n.

$$\begin{aligned}\mathbf{V}_2 &= (4)(12\angle 0^\circ)\\ &= 48\angle 0^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $48\angle 0^\circ\ \mathrm{V}$.

Step 3 of 7

Transfer primary side parameters to secondary side.

Figure 1

Step 4 of 7

Calculate the value of $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{48\angle 0^\circ - 24\angle 0^\circ}{48+4}\\ &= \frac{24\angle 0^\circ}{52}\\ &= 0.462\angle 0^\circ\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $\boxed{0.462\angle 0^\circ\ \mathrm{A}}$.

Step 5 of 7

Calculate the expression for $\mathbf{I}_1$ in terms of $\mathbf{I}_2$.

$\mathbf{I}_1 = -n\mathbf{I}_2$ Substitute 4 for n and $0.462\angle 0^\circ\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{I}_1 &= -(4)(0.462\angle 0^\circ)\\ &= -1.84\angle 0^\circ\\ &= 1.84\angle 180^\circ\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $\boxed{1.84\angle 180^\circ\ \mathrm{A}}$.

Step 6 of 7

Calculate the value of $\mathbf{V}_2$.

$$\mathbf{V}_2 = 48\angle 0^\circ - \mathbf{I}_2(48)$$

Substitute $0.462\angle 0^\circ\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_2 &= 48\angle 0^\circ - (0.462\angle 0^\circ)(48)\\ &= 48\angle 0^\circ - 22.18\angle 0^\circ\\ &= 25.82\angle 0^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $\boxed{25.82\angle 0^\circ\ \mathrm{V}}$.

Step 7 of 7

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1 = \frac{\mathbf{V}_2}{n}$$

Substitute $25.82\angle 0^\circ\ \mathrm{V}$ for $\mathbf{V}_2$ and 4 for n.

$$\begin{aligned}\mathbf{V}_1 &= \frac{25.82\angle 0^\circ}{4}\\ &= 6.46\angle 0^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{6.46\angle 0^\circ\ \mathrm{V}}$.

Step 1 of 7

Refer to Figure P10.56 from the text book.

Convert delta connected resistors to star connection.

Calculate the value of each impedance in star connection.

$$\begin{aligned} Z_Y &= \frac{(12)(12)}{12+12+12} \\ &= \frac{(12)(12)}{3(12)} \\ &= \frac{12}{3} \\ &= 4\,\Omega \end{aligned}$$

Therefore, the value of each impedance in star connection is $4\,\Omega$.

Step 2 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 7

Calculate the value of $\mathbf{Z}$.

$$\begin{aligned} \mathbf{Z} &= 4 + [(4-j4)\|(4-j4)] \\ &= 4 + \left[\frac{(4-j4)(4-j4)}{(4-j4)+(4-j4)}\right] \\ &= 4 + \left[\frac{(4-j4)(4-j4)}{2(4-j4)}\right] \\ &= 4 + \left[\frac{(4-j4)}{2}\right] \end{aligned}$$

$$\begin{aligned} \mathbf{Z} &= 4 + 2 - j2 \\ &= 6 - j2\,\Omega \end{aligned}$$

Therefore, the value of $\mathbf{Z}$ is $6 - j2\,\Omega$.

Step 4 of 7

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 5 of 7

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with the capacitance in the secondary circuit.

Substitute $6 - j2\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned} \mathbf{Z}_2 &= \frac{6+j2}{2^2} \\ &= \frac{6+j2}{4} \\ &= 1.5 + j0.5\,\Omega \end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $1.5 + j0.5\,\Omega$.

Step 6 of 7

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 7 of 7

Calculate the value of $\mathbf{I}$.

$$\begin{aligned} \mathbf{I} &= \frac{120\angle 0^\circ}{4 - j2 + 1.5 - j0.5} \\ &= \frac{120\angle 0^\circ}{5.5 - j2.5} \\ &= \frac{120\angle 0^\circ}{6.04\angle -24.44^\circ} \\ &= 19.87\angle 24.44^\circ\ \text{A} \end{aligned}$$

Therefore, the value of $\mathbf{I}$ is $\boxed{19.87\angle 24.44^\circ\ \text{A}}$.

Step 1 of 5

10.052 P

Refer to Figure P10.58 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistances in series with the inductance in the secondary circuit.

Substitute $-j16+10+6\,\Omega$ for $\mathbf{Z}_{2,T2}$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{(-j16+10+6)}{(2)^2}\\ &= \frac{(-j16+10+6)}{4}\\ &= -j4+2.5+1.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $-j4+2.5+1.5\,\Omega$.

Step 2 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 5

Consider Kirchhoff's voltage Law in Loop 1.

$$\begin{aligned}&\mathbf{I}_1(1.6-j1.2-j4+2.5+1.5)+(\mathbf{I}_1-\mathbf{I}_2)(2)=0\\ &\mathbf{I}_1(1.6-j1.2-j4+2.5+1.5+2)-\mathbf{I}_2(2)=0\\ &\mathbf{I}_1(7.6-j5.2)-\mathbf{I}_2(2)=0\\ &\mathbf{I}_2(2)=\mathbf{I}_1(7.6-j5.2)\end{aligned}$$

$$\begin{aligned}&\mathbf{I}_2=\mathbf{I}_1\left(\frac{7.6-j5.2}{2}\right)\\ &\mathbf{I}_2=\mathbf{I}_1(3.8-j2.6)\end{aligned}$$

Therefore, the expression for $\mathbf{I}_2$ in term of $\mathbf{I}_1$ is $\mathbf{I}_1(3.8-j2.6)$.

Step 4 of 5

Consider Kirchhoff's voltage Law in Loop 2.

$$\begin{aligned}&\mathbf{I}_2(2-j2)+(\mathbf{I}_2-\mathbf{I}_1)(2)=32\angle 0°\\ &\mathbf{I}_2(2-j2+2)-\mathbf{I}_1(2)=32\angle 0°\\ &\mathbf{I}_2(4-j2)-\mathbf{I}_1(2)=32\angle 0°\end{aligned}$$

Substitute $\mathbf{I}_1(3.8-j2.6)$ for $\mathbf{I}_2$.

$$\begin{aligned}&\mathbf{I}_1(3.8-j2.6)(4-j2)-\mathbf{I}_1(2)=32\angle 0°\\ &\mathbf{I}_1(10-j18)-\mathbf{I}_1(2)=32\angle 0°\\ &\mathbf{I}_1(10-j18-2)=32\angle 0°\\ &\mathbf{I}_1(8-j18)=32\angle 0°\end{aligned}$$

$$\begin{aligned}&\mathbf{I}_1(19.7\angle -66.04°)=32\angle 0°\\ &\mathbf{I}_1=\frac{32\angle 0°}{19.7\angle -66.04°}\\ &\mathbf{I}_1=1.62\angle 66.04°\text{ A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $1.62\angle 66.04°$ A.

Step 5 of 5

Calculate the value of $-\frac{\mathbf{V}_o}{2}$.

$$-\frac{\mathbf{V}_o}{2}=\mathbf{I}_1(2.5)$$

Solve for $\mathbf{V}_o$.

$$\mathbf{V}_o=-\mathbf{I}_1(5)$$

Substitute $1.62\angle 66.04°$ A for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_o &= -(1.62\angle 66.04°)(5)\\ &= -8.1\angle 66.04°\\ &= 8.1\angle -113.6°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{8.1\angle -113.6°\text{ V}}$.

Step 1 of 9

Refer to Figure P10.48 from the text book.

Consider the circuit diagram at the primary of the transformer.

Apply Thevenin's theorem to the circuit shown in Figure 1.

Calculate the value of the open circuit voltage.

Figure 1

Step 2 of 9

Consider Kirchhoff's Current Law at node 1.

$$\frac{\mathbf{V}_1 - 36\angle 0^\circ}{2} - 6\angle 0^\circ = 0$$
$$\mathbf{V}_1 - 36\angle 0^\circ - 12\angle 0^\circ = 0$$
$$\mathbf{V}_1 - 48\angle 0^\circ = 0$$
$$\mathbf{V}_1 = 48\angle 0^\circ \text{ V}$$

But $\mathbf{V}_1 = \mathbf{V}_{OC}$

$$\mathbf{V}_{OC} = 48\angle 0^\circ \text{ V}$$

Therefore, the value of $\mathbf{V}_{OC}$ is $48\angle 0^\circ \text{ V}$.

Step 3 of 9

Deactivate the sources to calculate the Thevenin's impedance.

Figure 2

Step 4 of 9

Calculate the value of the Thevenin's impedance.

$$\mathbf{Z}_{TH} = 2 + (-j2)$$
$$= 2 - j2\,\Omega$$

Therefore, the value of the Thevenin's impedance is $2 - j2\,\Omega$.

Replace the primary circuit in Figure P10.48 with the Thevenin's circuit.

Figure 3

Step 5 of 9

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = n\mathbf{V}_1$$

Substitute $48\angle 0^\circ \text{ V}$ for $\mathbf{V}_1$ and $\frac{1}{2}$ for n .

$$\mathbf{V}_2 = \left(\frac{1}{2}\right)(48\angle 0^\circ)$$
$$= 24\angle 0^\circ \text{ V}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $24\angle 0^\circ \text{ V}$.

Step 6 of 9

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the series combination of resistance and capacitance in the primary circuit.

Substitute $2 - j2\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{2}$ for n .

$$\mathbf{Z}_2 = \left(\frac{1}{2}\right)^2(2 - j2)$$
$$= \left(\frac{1}{4}\right)(2 - j2)$$
$$= 0.5 - j0.5\,\Omega$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $0.5 - j0.5\,\Omega$.

Step 7 of 9

Consider the circuit diagram shown in Figure 5.

Figure 4

Step 8 of 9

Apply Kirchhoff's Current Law at node 1.

$$\frac{\mathbf{V} - 24\angle 0^\circ}{0.5 - j0.5} + \frac{\mathbf{V}}{4 + j4} + \frac{\mathbf{V}}{-j4} = 0$$
$$\mathbf{V}\left(\frac{1}{0.5 - j0.5} + \frac{1}{4 + j4} + \frac{1}{-j4}\right) = \frac{24\angle 0^\circ}{0.5 - j0.5}$$
$$\mathbf{V}(1 + j1 + j0.25 + 0.125 - j0.125) = \frac{24\angle 0^\circ}{0.5 - j0.5}$$
$$\mathbf{V}(1.125 + j1.125) = \frac{24\angle 0^\circ}{0.5 - j0.5}$$
$$\mathbf{V} = \frac{24\angle 0^\circ}{(0.5 - j0.5)(1.125 + j1.125)}$$
$$\mathbf{V} = \frac{24\angle 0^\circ}{1.125}$$
$$\mathbf{V} = 21.33\angle 0^\circ \text{ V}$$

Therefore, the value of $\mathbf{V}$ is $21.33\angle 0^\circ \text{ V}$.

Step 9 of 9

Calculate the value of $\mathbf{V}_O$

$$\mathbf{V}_O = \mathbf{V}\left(\frac{4}{4 + j4}\right)$$

Substitute $21.33\angle 0^\circ \text{ V}$ for $\mathbf{V}$.

$$\mathbf{V}_O = (21.33\angle 0^\circ)\left(\frac{4}{4 + j4}\right)$$
$$= (21.33\angle 0^\circ)(0.5 - j0.5)$$
$$= (21.33\angle 0^\circ)(0.71\angle -45^\circ)$$
$$= 15.14\angle -45^\circ \text{ V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{15.14\angle -45^\circ \text{ V}}$.

Step 1 of 11

Refer to Figure P10.47 from the text book.

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_2 = n\mathbf{V}_1$$

Substitute $36\angle 0^\circ\ \mathrm{V}$ for $\mathbf{V}_1$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{V}_2 &= \left(\frac{1}{2}\right)(36\angle 0^\circ)\\ &= 18\angle 0^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $18\angle 0^\circ\ \mathrm{V}$.

Step 2 of 11

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the series combination of resistance and capacitance in the primary circuit.

Substitute $6 - j8\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{2}\right)^2(6 - j8)\\ &= \left(\frac{1}{4}\right)(6 - j8)\\ &= 1.5 - j2\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $1.5 - j2\,\Omega$.

Step 3 of 11

Consider the circuit diagram in Figure 1 and identify the parallel branch.

Figure 1

Step 4 of 11

Convert the delta connected resistors to star connection.

Calculate the value of Z_2.

$$\begin{aligned}Z_2 &= \frac{(12)(18)}{12+6+18}\\ &= \left(\frac{12\times 18}{36}\right)\\ &= \left(\frac{12}{2}\right)\\ &= 6\,\Omega\end{aligned}$$

Therefore, the equivalent impedance of the parallel branch is $6\,\Omega$.

Step 5 of 11

Calculate the value of Z_3.

$$\begin{aligned}Z_3 &= \frac{(12)(6)}{12+6+18}\\ &= \left(\frac{12\times 6}{36}\right)\\ &= \left(\frac{12}{6}\right)\\ &= 2\,\Omega\end{aligned}$$

Therefore, the equivalent impedance of the parallel branch is $2\,\Omega$.

Step 6 of 11

Calculate the value of Z_4.

$$\begin{aligned}Z_4 &= \frac{(18)(6)}{12+6+18}\\ &= \left(\frac{18\times 6}{36}\right)\\ &= \left(\frac{18}{6}\right)\\ &= 3\,\Omega\end{aligned}$$

Therefore, the equivalent impedance of the parallel branch is $3\,\Omega$.

Step 7 of 11

Consider circuit diagram shown in Figure 2 and identify the parallel branches.

Figure 2

Step 8 of 11

Calculate the equivalent impedance of the parallel branches.

$$\begin{aligned}Z &= (2 + j4)\,\|\,(3 - j3)\\ &= \left(\frac{(2+j4)\times(3-j3)}{(2+j4)+(3-j3)}\right)\\ &= \left(\frac{18+j6}{5+j1}\right)\\ &= 3.69 + j0.46\,\Omega\end{aligned}$$

Therefore, the equivalent impedance of the parallel branch is $3.69 + j0.46\,\Omega$.

Step 9 of 11

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 10 of 11

Apply Kirchhoff's Current Law at node 1.

$$\frac{\mathbf{V}_1}{6+3.69+j0.46} + \frac{\mathbf{V}_1}{6} + \frac{\mathbf{V}_1 - 18\angle 0^\circ}{1.5 - j2} = 0$$

$$\mathbf{V}_1\left(\frac{1}{6.69+j0.46} + \frac{1}{6} + \frac{1}{1.5-j2}\right) = \frac{18\angle 0^\circ}{1.5-j2}$$

$$\mathbf{V}_1\left(\frac{(6)(1.5-j2)+(6.69+j0.46)(1.5-j2)+(6)(6.69+j0.46)}{(6)(6.69+j0.46)(1.5-j2)}\right) = \frac{18\angle 0^\circ}{(1.5-j2)}$$

$$\mathbf{V}_1\left(\frac{9 - j12 + 10.96 - j12.69 + 40.14 + j2.76}{(6)(6.69+j0.46)}\right) = 18\angle 0^\circ$$

$$\mathbf{V}_1\left(\frac{60.1 - j21.93}{40.14 + j2.76}\right) = 18\angle 0^\circ$$

$$\mathbf{V}_1(1.45 - j0.65) = 18\angle 0^\circ$$

$$\mathbf{V}_1(1.59\angle -24.15^\circ) = 18\angle 0^\circ$$

$$\mathbf{V}_1 = \frac{18\angle 0^\circ}{1.59\angle -24.15^\circ}$$

$$\mathbf{V}_1 = 11.32\angle 24.15^\circ\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_1$ is $\boxed{11.32\angle 24.15^\circ\ \mathrm{V}}$.

Step 11 of 11

Calculate the value of $\mathbf{I}_o$.

$$\mathbf{I}_o = \frac{\mathbf{V}_1}{6}$$

Substitute $11.32\angle 24.15^\circ\ \mathrm{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{I}_o &= \frac{11.32\angle 24.15^\circ}{6}\\ &= 1.89\angle 24.15^\circ\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_o$ is $\boxed{1.89\angle 24.15^\circ\ \mathrm{A}}$.

Step 1 of 12

Refer to Figure P10.51 in the text book.

Consider the circuit at primary of the transformer.

Figure 1

Step 2 of 12

Consider the relation between the voltages $\mathbf{V}_1$ and $\mathbf{V}_2$.

$$\mathbf{V}_1 - \mathbf{V}_2 = 4\angle 0°$$
$$\mathbf{V}_2 = \mathbf{V}_1 - 4\angle 0°$$

Therefore, the expression for the voltage $\mathbf{V}_2$ is $\mathbf{V}_1 - 4\angle 0°$.

Step 3 of 12

Apply super node analysis at nodes 1 and 2.

$$\frac{\mathbf{V}_2}{-j1} + \frac{\mathbf{V}_2 - 12\angle 0°}{1} + \frac{\mathbf{V}_1}{1} = 0$$
$$\mathbf{V}_2(j1) + \mathbf{V}_2 - 12\angle 0° + \mathbf{V}_1 = 0$$
$$\mathbf{V}_2(1 + j1) + \mathbf{V}_1 = 12\angle 0°$$

Substitute $\mathbf{V}_1 - 4\angle 0°$ for $\mathbf{V}_2$.

$$(\mathbf{V}_1 - 4\angle 0°)(1 + j1) + \mathbf{V}_1 = 12\angle 0°$$
$$\mathbf{V}_1(1 + j1 + 1) - (4\angle 0°)(1.414\angle 45°) = 12\angle 0°$$
$$\mathbf{V}_1(2.236\angle 26.56°) - 5.656\angle 45° = 12\angle 0°$$
$$\mathbf{V}_1(2.236\angle 26.56°) = 12\angle 0° + 5.656\angle 45°$$

$$\mathbf{V}_1(2.236\angle 26.56°) = 16.49\angle 14.04°$$
$$\mathbf{V}_1 = \frac{16.49\angle 14.04°}{2.236\angle 26.56°}$$
$$\mathbf{V}_1 = 7.375\angle -12.52° \text{ V}$$

Therefore, the value of the voltage $\mathbf{V}_1$ is $7.375\angle -12.52°$ V.

Step 4 of 12

Calculate the value of the voltage $\mathbf{V}_1$ referred to secondary.

$$\mathbf{V}_2 = -n\mathbf{V}_1$$

Substitute $7.375\angle -12.52°$ V for $\mathbf{V}_1$ and 2 for n.

$$\mathbf{V}_2 = -(2)(7.375\angle -12.52°)$$
$$\mathbf{V}_2 = 14.75\angle 167.48° \text{ V}$$

Therefore, the value of the primary voltage when referred to secondary is

$14.75\angle 167.48°$ V.

Step 5 of 12

Deactivate the sources from the circuit to calculate the Thevenin's impedance.

Figure 2

Step 6 of 12

Calculate the value of the Thevenin's impedance.

$$\mathbf{Z}_1 = (1 \| -j1 \| 1) + j1$$
$$= \frac{(1)(-j1)(1)}{(1)(-j1) + (1)(-j1) + (1)(1)} + j1$$
$$= \frac{-j1}{-j1 - j1 + 1} + j1$$
$$= \frac{-j1}{1 - j2} + j1$$

$$\mathbf{Z}_1 = \frac{-j1}{1 - j2} + j1$$
$$= 0.4 - j0.2 + j1$$
$$= 0.4 + j0.8\ \Omega$$

Therefore, the value of the Thevenin's impedance is $0.4 + j0.8\ \Omega$.

Step 7 of 12

Calculate the value of the impedance $\mathbf{Z}_1$ referred to secondary.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

Substitute $0.4 + j0.8\ \Omega$ for $\mathbf{Z}_1$ and 2 for n.

$$\mathbf{Z}_2 = (2)^2(0.4 + j0.8)$$
$$= (4)(0.4 + j0.8)$$
$$= 1.6 + j3.2\ \Omega$$

Therefore, the value of the primary impedance when referred to secondary is

$1.6 + j3.2\ \Omega$.

Step 8 of 12

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 9 of 12

Convert the current source to voltage source using source transformation technique.

Figure 4

Step 10 of 12

Calculate the value of the voltage $\mathbf{V}$.

$$\mathbf{V} = (1)(6\angle 0°)$$
$$= 6\angle 0° \text{ V}$$

Therefore, the value of the voltage $\mathbf{V}$ is $6\angle 0°$ V.

Step 11 of 12

Consider the nodal analysis at node-1.

$$\frac{\mathbf{V}_x - 14.75\angle 167.48°}{1.6 + 1 + j3.2} + \frac{\mathbf{V}_x}{-j1} + \frac{\mathbf{V}_x - \mathbf{V}}{1 + 1} = 0$$

Substitute $6\angle 0°$ V for $\mathbf{V}$.

$$\frac{\mathbf{V}_x - 14.75\angle 167.48°}{1.6 + 1 + j3.2} + \frac{\mathbf{V}_x}{-j1} + \frac{\mathbf{V}_x - 6\angle 0°}{1 + 1} = 0$$
$$\frac{\mathbf{V}_x - 14.75\angle 167.48°}{2.6 + j3.2} + \frac{\mathbf{V}_x}{-j1} + \frac{\mathbf{V}_x - 6\angle 0°}{2} = 0$$
$$\frac{\mathbf{V}_x - 14.75\angle 167.48°}{4.12\angle 50.91°} + \frac{\mathbf{V}_x}{1\angle -90°} + \frac{\mathbf{V}_x - 6\angle 0°}{2} = 0$$
$$\frac{\mathbf{V}_x}{4.12\angle 50.91°} - \frac{14.75\angle 167.48°}{4.12\angle 50.91°} + \frac{\mathbf{V}_x}{1\angle -90°} + \frac{\mathbf{V}_x}{2} - \frac{6\angle 0°}{2} = 0$$

$$\mathbf{V}_x\left(\frac{1}{4.12\angle 50.91°} + \frac{1}{1\angle -90°} + \frac{1}{2}\right) - \frac{14.75\angle 167.48°}{4.12\angle 50.91°} - \frac{6\angle 0°}{2} = 0$$
$$\mathbf{V}_x(0.243\angle -50.91° + 1\angle 90° + 0.5) - 3.58\angle 116.57° - 3\angle 0° = 0$$
$$\mathbf{V}_x(1.04\angle 51.15°) = 3.49\angle 66.40°$$
$$\mathbf{V}_x = \frac{3.49\angle 66.40°}{1.04\angle 51.15°}$$

$$\mathbf{V}_x = 3.36\angle 5.25° \text{ V}$$

Therefore, the value of the voltage $\mathbf{V}_x$ is $3.36\angle 5.25°$ V.

Step 12 of 12

Calculate the value of the current $\mathbf{I}_o$.

$$\mathbf{I}_o = \frac{14.75\angle 167.48° - \mathbf{V}_x}{1.6 + 1 + j3.2}$$

Substitute $3.36\angle 5.25°$ V for $\mathbf{V}_x$.

$$\mathbf{I}_o = \frac{14.75\angle 167.48° - 3.36\angle 5.25°}{2.6 + j3.2}$$
$$= \frac{14.75\angle 167.48° - 3.36\angle 5.25°}{4.12\angle 50.91°}$$
$$= \frac{17.98\angle 170.75°}{4.12\angle 50.91°}$$
$$= 4.36\angle 119.98° \text{ A}$$

Therefore, the value of the current $\mathbf{I}_o$ is $\boxed{4.36\angle 119.98° \text{ A}}$.

Step 1 of 7

Refer to Figure P10.55 from the text book.

Use source transformation technique in the primary circuit of the transformer and current source to voltage source.

Calculate the value of the voltage source in the primary circuit.

$$\begin{aligned}\mathbf{V}_S &= (2\angle -45^\circ)(4+j4)\\ &= (2\angle -45^\circ)(5.66\angle 45^\circ)\\ &= 11.32\angle 0^\circ\ \text{V}\end{aligned}$$

Therefore, the value of the voltage source in the primary circuit is $11.32\angle 0^\circ\ \text{V}$.

Step 2 of 7

Consider Figure 1.

Figure 1

Step 3 of 7

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_{S,2} = -n\mathbf{V}_S$$

Substitute $11.31\angle 0^\circ\ \text{V}$ for $\mathbf{V}_S$ and $\frac{1}{2}$ for n .

$$\begin{aligned}\mathbf{V}_{S,2} &= -\left(\frac{1}{2}\right)(11.31\angle 0^\circ)\\ &= -5.66\angle 0^\circ\ \text{V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-5.66\angle 0^\circ\ \text{V}$.

Step 4 of 7

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the resistance in series with the inductance in the primary circuit.

Substitute $4+j4\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{2}$ for n .

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{2}\right)^2(4+j4)\\ &= \left(\frac{1}{4}\right)(4+j4)\\ &= 1+j1\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $1+j1\,\Omega$.

Step 5 of 7

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 6 of 7

Consider nodal equation at node 1.

$$\frac{\mathbf{V}+5.66\angle 0^\circ}{1+1+j1}+\frac{\mathbf{V}+1\angle 60^\circ}{1}+\frac{\mathbf{V}}{-j1}=0$$

$$\frac{\mathbf{V}}{2+j1}+\frac{\mathbf{V}}{1}+\frac{\mathbf{V}}{-j1}+\frac{5.66\angle 0^\circ}{2+j1}+1\angle 60^\circ=0$$

$$\mathbf{V}\left(\frac{1}{2+j1}+\frac{1}{1}+\frac{1}{-j1}\right)=-\frac{5.66\angle 0^\circ}{2.24\angle 26.57^\circ}-1\angle 60^\circ$$

$$\mathbf{V}(0.4-j0.2+1+j1)=-2.53\angle -26.57^\circ-1\angle 60^\circ$$

$$\mathbf{V}(1.4+j0.8)=-(2.78\angle -5.49^\circ)$$

$$\mathbf{V}(1.61\angle 29.75^\circ)=2.78\angle 174.59^\circ$$

$$\mathbf{V}=\frac{2.78\angle 174.59^\circ}{1.61\angle 29.75^\circ}$$

$$\mathbf{V}=1.73\angle 144.84^\circ\ \text{V}$$

Therefore, the value of $\mathbf{V}$ is $1.73\angle 144.84^\circ\ \text{V}$.

Step 7 of 7

Calculate the value of current $\mathbf{I}$.

$$\mathbf{I}=\frac{\mathbf{V}}{-j1}$$

Substitute $1.73\angle 144.84^\circ\ \text{V}$ for $\mathbf{V}$.

$$\mathbf{I}=\frac{1.73\angle 144.84^\circ}{-j1}$$

$$\mathbf{I}=\frac{1.73\angle 144.84^\circ}{1\angle -90^\circ}$$

$$\mathbf{I}=1.73\angle -125.16^\circ\ \text{A}$$

Therefore, the value of $\mathbf{I}$ is $\boxed{1.73\angle -125.16^\circ\ \text{A}}$.

Step 1 of 3

10.058
P

Refer to Figure P10.53 from the text book.

Identify the currents in the circuit.

Figure 1

Step 2 of 3

Consider Kirchhoff's voltage Law in Loop-2.

$$\mathbf{I}_2(2-j2)-\mathbf{V}_2+(\mathbf{I}_2-\mathbf{I}_1)(2)=0$$

Here, $\mathbf{V}_2=\mathbf{V}_1$ and $\mathbf{I}_1=\mathbf{I}_2$ since $n=1$.

$$\mathbf{I}_2(2-j2)-\mathbf{V}_1+(\mathbf{I}_2-\mathbf{I}_2)(2)=0$$
$$\mathbf{I}_2(2-j2)-\mathbf{V}_1=0$$
$$\mathbf{V}_1=\mathbf{I}_2(2-j2)$$

Consider Kirchhoff's voltage Law in Loop-1.

$$-24\angle 0^\circ+\mathbf{I}_1(1-j1)+\mathbf{V}_1+(\mathbf{I}_1-\mathbf{I}_2)(2)=0$$

Substitute $\mathbf{I}_2(2-j2)$ for $\mathbf{V}_1$ and $\mathbf{I}_2$ for $\mathbf{I}_1$.

$$-24\angle 0^\circ+\mathbf{I}_2(1-j1)+\mathbf{I}_2(2-j2)+(\mathbf{I}_2-\mathbf{I}_2)(2)=0$$
$$-24\angle 0^\circ+\mathbf{I}_2(1-j1)+\mathbf{I}_2(2-j2)=0$$
$$\mathbf{I}_2(1-j1+2-j2)=24\angle 0^\circ$$
$$\mathbf{I}_2(3-j3)=24\angle 0^\circ$$

$$\mathbf{I}_2(4.24\angle -45^\circ)=24\angle 0^\circ$$

$$\mathbf{I}_2=\frac{24\angle 0^\circ}{4.24\angle -45^\circ}$$
$$=5.66\angle 45^\circ\ \mathrm{A}$$

Therefore, the value of $\mathbf{I}_2$ is $5.66\angle 45^\circ\ \mathrm{A}$.

Step 3 of 3

Calculate the value of $\mathbf{V}_O$.

$$\mathbf{V}_O=\mathbf{I}_2(2)$$

Substitute $5.66\angle 45^\circ\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\mathbf{V}_O=(5.66\angle 45^\circ)(2)$$
$$=11.32\angle 45^\circ\ \mathrm{V}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{11.32\angle 45^\circ\ \mathrm{V}}$.

Step 1 of 6

Refer to Figure P10.57 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer 1.

$$\mathbf{Z}_{2,T1} = n^2\mathbf{Z}_{1,T1}$$

$\mathbf{Z}_{1,T1}$ represents the resistance in series with the capacitance in the primary circuit.

Substitute $4 - j8\,\Omega$ for $\mathbf{Z}_{1,T1}$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_{2,T1} &= \left(\frac{1}{2}\right)^2(4 - j8)\\ &= \left(\frac{1}{4}\right)(4 - j8)\\ &= 1 - j2\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer 1 is $1 - j2\,\Omega$.

Step 3 of 6

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_{S,2} = -n\mathbf{V}_S$$

Substitute $32\angle 0°\text{ V}$ for $\mathbf{V}_S$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{V}_{S,2} &= -\left(\frac{1}{2}\right)(32\angle 0°)\\ &= -16\angle 0°\text{ V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-16\angle 0°\text{ V}$.

Step 4 of 6

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer 2.

$$\mathbf{Z}_{1,T2} = \frac{\mathbf{Z}_{2,T2}}{n^2}$$

$\mathbf{Z}_{2,T2}$ represents the resistance in series with the inductance in the secondary circuit.

Substitute $6 + j12\,\Omega$ for $\mathbf{Z}_{2,T2}$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_{1,T2} &= \frac{(6 + j12)}{\left(\frac{1}{2}\right)^2}\\ &= (4)(6 + j12)\\ &= 24 + j48\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer 2 is $24 + j48\,\Omega$.

Step 5 of 6

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 6 of 6

Calculate the value of $\mathbf{V}_O$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_O &= (-16\angle 0°)\left(\frac{6}{1 - j8 + 6 + j48 + 24 - j2}\right)\\ &= (-16\angle 0°)\left(\frac{6}{31 + j38}\right)\\ &= (-16\angle 0°)\left(\frac{6\angle 0°}{49.04\angle 50.79°}\right)\\ &= (-16\angle 0°)(0.12\angle -50.79°)\end{aligned}$$

$$\begin{aligned}\mathbf{V}_O &= (-16\angle 0°)(0.12\angle -50.79°)\\ &= -1.92\angle -50.79°\\ &= 1.92\angle 129.21°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{1.92\angle 129.21°\text{ V}}$.

Step 1 of 8

10.060 P

Refer to Figure P10.59 from the text book.

Consider Figure 1.

Figure 1

Step 2 of 8

Calculate the value of $\mathbf{Z}$.

$$\begin{aligned}\mathbf{Z} &= 2\|(2+j2)\\ &= \frac{(2)(2+j2)}{2+(2+j2)}\\ &= \frac{4+j4}{4+j2}\\ &= 1.2+j0.4\,\Omega\end{aligned}$$

Therefore, the value of $\mathbf{Z}$ is $1.2+j0.4\,\Omega$.

Step 3 of 8

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 4 of 8

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the series combination of resistance, inductance and capacitance in the secondary circuit.

Substitute $-j1+1+1.2+j0.4\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{-j1+1+1.2+j0.4}{(2)^2}\\ &= \frac{-j1+1+1.2+j0.4}{4}\\ &= -j0.25+0.25+0.3+j0.1\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $-j0.25+0.25+0.3+j0.1\,\Omega$.

Step 5 of 8

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 8

Consider Kirchhoff's voltage Law in Loop 1.

$$\mathbf{I}_1(1-j2-j0.25+0.25+j0.1+0.3)+(\mathbf{I}_1-\mathbf{I}_2)(2)=0$$
$$\mathbf{I}_1(1-j2-j0.25+0.25+j0.1+0.3+2)-\mathbf{I}_2(2)=0$$
$$\mathbf{I}_1(3.55-j2.35)-\mathbf{I}_2(2)=0$$
$$\mathbf{I}_2(2)=\mathbf{I}_1(3.55-j2.35)$$
$$\mathbf{I}_2=\mathbf{I}_1\left(\frac{3.55-j2.35}{2}\right)$$

Therefore, the expression for $\mathbf{I}_2$ in term of $\mathbf{I}_1$ is $\mathbf{I}_1\left(\frac{3.55-j2.35}{2}\right)$.

Step 7 of 8

Consider Kirchhoff's voltage Law in Loop 2.

$$\mathbf{I}_2(2)+(\mathbf{I}_2-\mathbf{I}_1)(2)=24\angle 0°$$
$$\mathbf{I}_2(2+2)-\mathbf{I}_1(2)=24\angle 0°$$
$$\mathbf{I}_2(4)-\mathbf{I}_1(2)=24\angle 0°$$

Substitute $\mathbf{I}_1\left(\frac{3.55-j2.35}{2}\right)$ for $\mathbf{I}_2$.

$$\mathbf{I}_1\left(\frac{3.55-j2.35}{2}\right)(4)-\mathbf{I}_1(2)=24\angle 0°$$
$$\mathbf{I}_1(3.55-j2.35)(2)-\mathbf{I}_1(2)=24\angle 0°$$
$$\mathbf{I}_1(7.1-j4.7-2)=24\angle 0°$$
$$\mathbf{I}_1(5.1-j4.7)=24\angle 0°$$
$$\mathbf{I}_1(6.94\angle -42.66°)=24\angle 0°$$
$$\mathbf{I}_1=\frac{24\angle 0°}{6.94\angle -42.66°}$$
$$\mathbf{I}_1=3.46\angle 42.66°\text{ A}$$

Therefore, the value of $\mathbf{I}_1$ is $3.46\angle 42.66°$ A.

Step 8 of 8

Calculate the value of $-\frac{\mathbf{V}_o}{2}$.

$$-\frac{\mathbf{V}_o}{2}=\mathbf{I}_1(0.25)$$

Solve for $\mathbf{V}_o$.

$$\mathbf{V}_o=-\mathbf{I}_1(0.5)$$

Substitute $3.46\angle 42.66°$ A for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{V}_o &= -(3.46\angle 42.66°)(0.5)\\ &= -1.73\angle 42.66°\\ &= 1.73\angle -137.34°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{1.73\angle -137.34°\text{ V}}$.

Step 1 of 4

10.061 P

Refer to the circuit diagram in Figure P10.61 in the textbook.

Primary and secondary voltages are related to the turn's ratio as,

$$\frac{\mathbf{V}_2}{\mathbf{V}_1} = n$$

Here $n = 2$ is the turns ratio

$$\frac{\mathbf{V}_2}{\mathbf{V}_1} = 2$$

Primary and secondary currents are related to the turn's ratio as,

$$\begin{aligned}\frac{\mathbf{I}_2}{\mathbf{I}_1} &= \frac{1}{n}\\ &= \frac{1}{2}\end{aligned}$$

Step 2 of 4

Reflect the secondary side into primary side

$$\begin{aligned}\mathbf{Z}_1 &= \frac{j4}{n^2} + \frac{2}{n^2}\\ &= \frac{j4}{2^2} + \frac{2}{2^2}\\ &= j + 0.5\end{aligned}$$

The modified circuit is as shown in Figure 1.

Figure 1

Step 3 of 4

Apply Kirchhoff's current law at node $\mathbf{V}_1$.

$$\frac{\mathbf{V}_1 - 24\angle 0^\circ}{6} + \frac{\mathbf{V}_1 - 12\angle 0^\circ}{3} + \frac{\mathbf{V}_1}{\mathbf{Z}_1 - j2} = 0$$

$$\frac{\mathbf{V}_1 - 24\angle 0^\circ}{6} + \frac{\mathbf{V}_1 - 12\angle 0^\circ}{3} + \frac{\mathbf{V}_1}{j + 0.5 - j2} = 0$$

$$\mathbf{V}_1\left(\frac{1}{6} + \frac{1}{3} + \frac{1}{0.5 - j}\right) = \frac{24\angle 0^\circ}{6} + \frac{12\angle 0^\circ}{3}$$

$$\mathbf{V}_1(0.9 + 0.8j) = 8\angle 0^\circ$$

Simplify the equation.

$$\begin{aligned}\mathbf{V}_1 &= \frac{8\angle 0^\circ}{0.9 + 0.8j}\\ &= 4.9655 - 4.4137j\end{aligned}$$

Step 4 of 4

Find the current $\mathbf{I}_1$ using ohm's law.

$$\begin{aligned}\mathbf{I}_1 &= \frac{\mathbf{V}_1}{j - j2 + 0.5}\\ &= \frac{4.9655 - 4.4137j}{0.5 - j}\\ &= 5.51 + 2.20j\end{aligned}$$

Thus, secondary current of the circuit is,

$$\begin{aligned}\mathbf{I}_2 &= \frac{\mathbf{I}_1}{n}\\ &= \frac{5.51 + 2.20j}{2}\\ &= 2.75 + 1.10j\\ &= 2.97\angle 21.80^\circ \text{ A}\end{aligned}$$

Thus, secondary current of the transformer, $\mathbf{I}_2$ is $\boxed{2.97\angle 21.80^\circ \text{ A}}$.

Step 1 of 5

Refer to the circuit diagram in Figure P10.62 in the textbook.

The $8\ \Omega$ resistor and $j12\ \Omega$ impedance can be reflected to primary of the second transformer.

$$Z_1 = \frac{8 + j12}{n^2}$$

Here n is the turn's ratio.

$$\begin{aligned} n &= \frac{N_2}{N_1} \\ &= \frac{2}{1} \\ &= 2 \end{aligned}$$

So, impedance Z_1 is,

$$\begin{aligned} Z_1 &= \frac{8 + j12\Omega}{2^2} \\ &= \frac{8}{4} + j\frac{12}{4} \\ &= 2 + j3 \end{aligned}$$

The modified circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 5

The $12\ \Omega$ resistor and $100\angle 0°\ \text{V}$ voltage source can be reflected to secondary side of the first transformer.

$$\begin{aligned} \mathbf{V}_{s1} &= n(100\angle 0°) \\ \mathbf{Z}_2 &= n^2(12) \end{aligned}$$

Here n is the turn's ratio.

$$\begin{aligned} n &= \frac{N_2}{N_1} \\ &= \frac{1}{2} \\ &= 0.5 \end{aligned}$$

So, voltage source $\mathbf{V}_{s1}$ and impedance Z_2 are,

$$\begin{aligned} \mathbf{V}_{s1} &= 0.5(100\angle 0°) \\ &= 50\angle 0°\ \text{V} \end{aligned}$$

And,

$$\begin{aligned} \mathbf{Z}_2 &= n(12) \\ &= 0.5^2(12) \\ &= 3\ \Omega \end{aligned}$$

The modified circuit diagram of Figure 1 is shown in Figure 2.

Figure 2

Step 3 of 5

Apply Kirchhoff's current law at node 1.

$$\frac{\mathbf{V}_1 - 50\angle 0°}{6} + 10\angle 0° + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j4} = 0$$

$$\mathbf{V}_1\left(\frac{1}{6} - \frac{1}{j4}\right) + \mathbf{V}_2\left(\frac{1}{j4}\right) = \frac{50\angle 0°}{6} - 10\angle 0°$$

$$\mathbf{V}_1(0.166 + j0.25) + \mathbf{V}_2(-j0.25) = 8.33\angle 0° - 10\angle 0°$$

$$\mathbf{V}_1(0.166 + j0.25) + \mathbf{V}_2(-j0.25) = -1.666 \text{ ..... (1)}$$

Apply Kirchhoff's current law at node 2.

$$\frac{\mathbf{V}_2 - \mathbf{V}_1}{-j4} + \frac{\mathbf{V}_2}{2} + \frac{\mathbf{V}_2}{2 + j3 - j} = 0$$

$$\mathbf{V}_1\left(\frac{1}{j4}\right) + \mathbf{V}_2\left(\frac{1}{-j4} + \frac{1}{2} + \frac{1}{2 + j2}\right) = 0$$

$$\mathbf{V}_1(-j0.25) + \mathbf{V}_2(0.75) = 0 \text{ ..... (2)}$$

Step 4 of 5

Write equation (1) and equation (2) in matrix form.

$$\begin{bmatrix} 0.166 + j0.25 & -j0.25 \\ -j0.25 & 0.75 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} -1.666 \\ 0 \end{bmatrix}$$

Solve equations (1) and (2) using MATLAB.

```
>> a=[0.166+0.25*i -0.25*i;-0.25*i 0.75]a =   0.1660 + 0.2500i 0.0000 - 0.2500i   0.0000 - 0.2500i 0.7500 +
0.0000i>> b=[-1.666;0]b =   -1.6660          0>> c=a\bc =  -3.3320 + 3.3409i  -1.1136 - 1.1107i
```

So, the voltage $\mathbf{V}_1 = -3.3320 + j3.3409$ and $\mathbf{V}_2 = -1.1136 - j1.1107$

Step 5 of 5

Use ohm's law to find the current through the $2\ \Omega$ resistor.

$$\mathbf{I} = \frac{\mathbf{V}_2}{2}$$

Substitute $-1.1136 - j1.1107$ for $\mathbf{V}_2$.

$$\begin{aligned} \mathbf{I} &= \frac{-1.1136 - j1.1107}{2} \\ &= -0.5568 - j0.55535 \\ &= 0.78\angle -135.07°\ \text{A} \end{aligned}$$

Thus, current flow through the $2\ \Omega$ resistor is $\boxed{0.78\angle -135.07°\ \text{A}}$.

Step 1 of 3

10.063 P

Refer to Figure P10.61 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with inductance in the secondary circuit.

Substitute $4 + j2\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{4 + j2}{(2)^2} \\ &= \frac{4 + j2}{4} \\ &= 1 + j0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $1 + j0.5\,\Omega$.

Step 2 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 3

Consider the expression for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_S &= \mathbf{I}_S(2 + 1 + j0.5) \\ &= \mathbf{I}_S(3 + j0.5)\end{aligned}$$

Therefore, the expression for $\mathbf{V}_S$ is $\mathbf{I}_S(3 + j0.5)$.

Define the expression for the input impedance $\mathbf{Z}_{IN}$.

$$\mathbf{Z}_{IN} = \frac{\mathbf{V}_S}{\mathbf{I}_S}$$

Substitute $\mathbf{I}_S(3 + j0.5)$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{Z}_{IN} &= \frac{\mathbf{I}_S(3 + j0.5)}{\mathbf{I}_S} \\ &= 3 + j0.5\,\Omega\end{aligned}$$

Therefore, the value of the input impedance is $\boxed{3 + j0.5\,\Omega}$.

Step 1 of 6

Refer to Figure P10.63 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer having turns ratio 1:4.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with the capacitance in the secondary circuit.

Substitute $48 - j32\,\Omega$ for $\mathbf{Z}_2$ and 4 for n .

$$\begin{aligned}\mathbf{Z}_1 &= \frac{48 - j32}{(4)^2} \\ &= \frac{48 - j32}{16} \\ &= 3 - j2\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer having the turns ration 1:4 is $3 - j2\,\Omega$.

Step 2 of 6

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 6

Refer Figure 1.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1^{\,1} = \frac{\mathbf{Z}_2^{\,1}}{n^2}$$

Substitute $j1 + 3 - j2 + 1\,\Omega$ for $\mathbf{Z}_2^{\,1}$ and $\frac{1}{2}$ for n .

$$\begin{aligned}\mathbf{Z}_1^{\,1} &= \frac{j1 + 3 - j2 + 1}{\left(\frac{1}{2}\right)^2} \\ &= (4)(4 - j1) \\ &= 16 - j4\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer $16 - j4\,\Omega$.

Step 4 of 6

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 5 of 6

Consider the expression for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_S &= \mathbf{I}_S(-j1 + 16 - j4) \\ &= \mathbf{I}_S(16 - j5)\end{aligned}$$

Therefore, the expression for $\mathbf{V}_S$ is $\mathbf{I}_S(16 - j5)$.

Step 6 of 6

Define the expression for the input impedance $\mathbf{Z}_{IN}$.

$$\mathbf{Z}_{IN} = \frac{\mathbf{V}_S}{\mathbf{I}_S}$$

Substitute $\mathbf{I}_S(16 - j5)$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{Z}_{IN} &= \frac{\mathbf{I}_S(16 - j5)}{\mathbf{I}_S} \\ &= 16 - j5\,\Omega\end{aligned}$$

Therefore, the value of the input impedance is $\boxed{16 - j5\,\Omega}$.

Step 1 of 7

Refer to Figure P10.60 from the text book.

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer having the turns ratio 2:1.

$$\mathbf{Z}_2 = n^2\mathbf{Z}_1$$

$\mathbf{Z}_1$ represents the capacitance in the primary circuit.

Substitute $-j2\,\Omega$ for $\mathbf{Z}_1$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_2 &= \left(\frac{1}{2}\right)^2(-j2)\\ &= \frac{-j2}{4}\\ &= -j0.5\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer having turns ratio 2:1 is $-j0.5\,\Omega$.

Step 2 of 7

Calculate the value of the voltage source when referred to secondary of the transformer having turns ratio 2:1.

$$\mathbf{V}_{s,2} = n\mathbf{V}_s$$

Substitute $32\angle 0°\text{ V}$ for $\mathbf{V}_s$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{V}_{s,2} &= \left(\frac{1}{2}\right)(32\angle 0°)\\ &= 16\angle 0°\text{ V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer having turns ratio 2:1 is $16\angle 0°\text{ V}$.

Step 3 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 7

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer.

$$\mathbf{Z}_2^{\,1} = n^2\mathbf{Z}_1^{\,1}$$

Substitute $-j0.5 + j2 + 4\,\Omega$ for $\mathbf{Z}_1^{\,1}$ and 4 for n.

$$\begin{aligned}\mathbf{Z}_2^{\,1} &= (4)^2(-j0.5 + j2 + 4)\\ &= (16)(4 + j1.5)\\ &= 64 + j24\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer is $64 + j24\,\Omega$.

Step 5 of 7

Calculate the value of the voltage source when referred to secondary of the transformer.

$$\mathbf{V}_{s,2} = -n\mathbf{V}_s$$

Substitute $16\angle 0°\text{ V}$ for $\mathbf{V}_s$ and 4 for n.

$$\begin{aligned}\mathbf{V}_{s,2} &= -(4)(16\angle 0°)\\ &= -64\angle 0°\text{ V}\end{aligned}$$

Therefore, the value of the voltage source when referred to secondary of the transformer is $-64\angle 0°\text{ V}$.

Step 6 of 7

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 7 of 7

Calculate the value of $\mathbf{V}_o$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_o &= (-64\angle 0°)\left(\frac{32}{64 + j24 + 32 - j16}\right)\\ &= (-64\angle 0°)\left(\frac{32}{96 + j8}\right)\\ &= (-64\angle 0°)\left(\frac{32}{96.33\angle 4.76°}\right)\\ &= (-64\angle 0°)(0.33\angle -4.76°)\end{aligned}$$

$$\begin{aligned}\mathbf{V}_o &= -21.12\angle -4.76°\\ &= 21.12\angle 175.24°\text{ V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_o$ is $\boxed{21.12\angle 175.24°\text{ V}}$.

Step 1 of 4

Refer to Figure P10.62 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with parallel combination of resistance and capacitance in the secondary circuit.

Substitute $1+(2\|-j2)\Omega$ for $\mathbf{Z}_2$ and $\frac{1}{4}$ for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{1+(2\|-j2)}{\left(\frac{1}{4}\right)^2}\\ &= (4)^2\left(1+\frac{(2)(-j2)}{2-j2}\right)\\ &= (16)(1+1-j1)\end{aligned}$$

$$\mathbf{Z}_1 = 32 - j16\,\Omega$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer is $32 - j16\,\Omega$.

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider the expression for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_S &= \mathbf{I}_S(1+(-j1)\|(32-j16))\\ &= \mathbf{I}_S\left(1+\frac{(-j1)(32-j16)}{(-j1)+(32-j16)}\right)\\ &= \mathbf{I}_S\left(1+\frac{-16-j32}{32-j17}\right)\\ &= \mathbf{I}_S(1+0.02-j0.99)\end{aligned}$$

$$\mathbf{V}_S = \mathbf{I}_S(1.02-j0.99)$$

Therefore, the expression for $\mathbf{V}_S$ is $\mathbf{I}_S(1.02-j0.99)$.

Step 4 of 4

Define the expression for the input impedance $\mathbf{Z}_{IN}$.

$$\mathbf{Z}_{IN} = \frac{\mathbf{V}_S}{\mathbf{I}_S}$$

Substitute $\mathbf{I}_S(1.02-j0.99)$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{Z}_{IN} &= \frac{\mathbf{I}_S(1.02-j0.99)}{\mathbf{I}_S}\\ &= 1.02-j0.99\,\Omega\end{aligned}$$

Therefore, the value of the input impedance is $\boxed{1.02-j0.99\,\Omega}$.

Step 1 of 5

10.067 P

Refer to Figure P10.64 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer having turns ratio 2:1.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with the inductance in the secondary circuit.

Substitute $4 + j2\,\Omega$ for $\mathbf{Z}_2$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{4 + j2}{\left(\frac{1}{2}\right)^2}\\ &= (2)^2(4 + j2)\\ &= (4)(4 + j2)\\ &= 16 + j8\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer having the turns ration 2:1 is $16 + j8\,\Omega$.

Step 2 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 5

Refer Figure 1.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer.

$$\mathbf{Z}_1' = \frac{\mathbf{Z}_2'}{n^2}$$

Substitute $4 - j4 + 16 + j8\,\Omega$ for $\mathbf{Z}_2'$ and $\frac{1}{4}$ for n.

$$\begin{aligned}\mathbf{Z}_1' &= \frac{4 - j4 + 16 + j8}{\left(\frac{1}{4}\right)^2}\\ &= (16)(20 + j4)\\ &= 320 + j64\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer $320 + j64\,\Omega$.

Step 4 of 5

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 5 of 5

Consider the expression for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{V}_S &= \mathbf{I}_S(20 + 320 + j64)\\ &= \mathbf{I}_S(340 + j64)\end{aligned}$$

Therefore, the expression for $\mathbf{V}_S$ is $\mathbf{I}_S(340 + j64)$.

Define the expression for the input impedance $\mathbf{Z}_{IN}$.

$$\mathbf{Z}_{IN} = \frac{\mathbf{V}_S}{\mathbf{I}_S}$$

Substitute $\mathbf{I}_S(340 + j64)$ for $\mathbf{V}_S$.

$$\begin{aligned}\mathbf{Z}_{IN} &= \frac{\mathbf{I}_S(340 + j64)}{\mathbf{I}_S}\\ &= 340 + j64\,\Omega\end{aligned}$$

Therefore, the value of the input impedance is $\boxed{340 + j64\,\Omega}$.

Recall that for maximum power transfer, the load resistance R_L must be matched with the source resistance R_s. The ideal transformer reflects its load back to primary with a scaling factor of n^2.

Here n is the turns ratio expressed as,

$$n = \frac{N_2}{N_1}$$

Match the reflected load $n^2 R_{\text{speaker}}$ with the required load impedance R_1.

$$R_1 = n^2 R_{\text{speaker}}$$

Substitute $8\ \Omega$ for R_{speaker} and 3200 for R_1.

$$3200 = 8n^2$$

Rewrite the equation.

$$n^2 = \frac{3200}{8}$$

$$n = \sqrt{400}$$

$$n = 20$$

Thus, required turns ratio of the idea transformer to impedance match is $\boxed{20:1}$.

Step 1 of 4

10.069 P

Refer to Figure P10.66 from the text book.

The value of the voltage $\mathbf{V}_2$ is equal to the value of $\mathbf{V}_O$. Hence, the value of $\mathbf{V}_2$ is $48\angle 30^\circ\ \mathrm{V}$.

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1 = -\frac{\mathbf{V}_2}{n}$$

Substitute $48\angle 30^\circ$ for $\mathbf{V}_2$ and 2 for n

$$\begin{aligned}\mathbf{V}_1 &= -\frac{48\angle 30^\circ}{2}\\ &= -24\angle 30^\circ\\ &= 24\angle -150^\circ\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $24\angle -150^\circ\mathrm{V}$.

Step 2 of 4

Calculate the value of $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{24}$$

Substitute $48\angle 30^\circ\ \mathrm{V}$ for $\mathbf{V}_2$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{48\angle 30^\circ}{24}\\ &= 2\angle 30^\circ\mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $2\angle 30^\circ\mathrm{A}$.

Step 3 of 4

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = -n\mathbf{I}_2$$

Substitute $2\angle 30^\circ\ \mathrm{V}$ for $\mathbf{I}_2$ and 2 for n

$$\begin{aligned}\mathbf{I}_1 &= -(2)(2\angle 30^\circ)\\ &= -4\angle 30^\circ\\ &= 4\angle -150^\circ\mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $4\angle -150^\circ\mathrm{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}_1(6 - j6) + \mathbf{V}_1$$

Substitute $4\angle -150^\circ\mathrm{A}$ for $\mathbf{I}_1$ and $24\angle -150^\circ\mathrm{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_S &= (4\angle -150^\circ)(6 - j6) + 24\angle -150^\circ\\ &= (4\angle -150^\circ)(8.49\angle -45^\circ) + 24\angle -150^\circ\\ &= 33.96\angle 165^\circ + 24\angle -150^\circ\\ &= 53.68\angle -176.57^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{53.68\angle -176.57^\circ\ \mathrm{V}}$.

Step 1 of 6

10.070 P

Refer to Figure P10.67 from the text book.

Figure 1

Step 2 of 6

Calculate the value of $\mathbf{I}_2$.

$$\mathbf{I}_2 = \frac{\mathbf{V}_O}{j1}$$

Substitute $4\angle 30^\circ\,\mathrm{V}$ for $\mathbf{V}_O$.

$$\begin{aligned}\mathbf{I}_2 &= \frac{4\angle 30^\circ}{j1}\\ &= \frac{4\angle 30^\circ}{1\angle 90^\circ}\\ &= 4\angle -60^\circ\mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $4\angle -60^\circ\mathrm{A}$.

Step 3 of 6

Calculate the value of $\mathbf{I}_1$.

$$\mathbf{I}_1 = -n\mathbf{I}_2$$

Substitute $4\angle -60^\circ\mathrm{A}$ for $\mathbf{I}_2$ and 2 for n

$$\begin{aligned}\mathbf{I}_1 &= -(2)(4\angle -60^\circ)\\ &= -8\angle -60^\circ\\ &= 8\angle 120^\circ\mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_1$ is $8\angle 120^\circ\mathrm{A}$.

Step 4 of 6

Calculate the value of $\mathbf{V}_2$.

$$\mathbf{V}_2 = \mathbf{V}_O + \mathbf{I}_2(1)$$

Substitute $4\angle 30^\circ\,\mathrm{V}$ for $\mathbf{V}_O$ and $4\angle -60^\circ\mathrm{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_2 &= 4\angle 30^\circ + (4\angle -60^\circ)(1)\\ &= 4\angle 30^\circ + 4\angle -60^\circ\\ &= 5.66\angle -15^\circ\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_2$ is $5.66\angle -15^\circ\,\mathrm{V}$.

Step 5 of 6

Calculate the value of $\mathbf{V}_1$.

$$\mathbf{V}_1 = -\frac{\mathbf{V}_2}{n}$$

Substitute $5.66\angle -15^\circ$ for $\mathbf{V}_2$ and 2 for n

$$\begin{aligned}\mathbf{V}_1 &= -\frac{5.66\angle -15^\circ}{2}\\ &= -2.88\angle -15^\circ\\ &= 2.88\angle 165^\circ\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_1$ is $2.88\angle 165^\circ\,\mathrm{V}$.

Step 6 of 6

Consider the expression for $\mathbf{V}_S$.

$$\mathbf{V}_S = \mathbf{I}_1(1 + j1) + \mathbf{V}_1$$

Substitute $8\angle 120^\circ\mathrm{A}$ for $\mathbf{I}_1$ and $2.88\angle 165^\circ\,\mathrm{V}$ for $\mathbf{V}_1$.

$$\begin{aligned}\mathbf{V}_S &= (8\angle 120^\circ)(1 + j1) + 2.88\angle 165^\circ\\ &= (8\angle 120^\circ)(1.41\angle 45^\circ) + 2.88\angle 165^\circ\\ &= 11.28\angle 165^\circ + 2.88\angle 165^\circ\\ &= 14.16\angle 165^\circ\,\mathrm{V}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{14.16\angle 165^\circ\,\mathrm{V}}$.

Step 1 of 3

Refer to Figure P10.68 in the text book for the circuit.

Apply source transformation to convert the current source in parallel with 2Ω resistance into voltage source, $V = 2(I_s)$ with a series resistance. Redraw the circuit as shown in Figure 1.

Figure 1

Step 2 of 3

The turns ratio, $n = 2$

The secondary current referred to primary is,

$$I_2' = \frac{I_2}{n} = 1\angle 30°$$

The primary impedance referred to secondary is,

$$Z_L' = \frac{Z_L}{n^2} = \frac{1 + j1}{4}$$

Redraw the circuit referred to primary.

Figure 2

Step 3 of 3

Apply Kirchhoff's voltage law to the loop.

$$-2\mathbf{I}_s + \left(2 - j2 + \frac{1}{4} + j\frac{1}{4}\right)2\mathbf{I}_2$$

$$\mathbf{I}_s = (2.25 - j1.75)\mathbf{I}_2$$

Substitute $2\angle 30°\ \mathrm{A}$ for $\mathbf{I}_2$.

$$\mathbf{I}_s = (2.25 - j1.75)(2\angle 30°)$$
$$= 5.7\angle -7.87°\ \mathrm{A}$$

Thus, the source current is $\boxed{\mathbf{I}_s = 5.7\angle -7.87°\ \mathrm{A}}$.

Step 1 of 7

10.072 P

Refer to Figure P10.69 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer having turns ratio 1:2.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with the capacitance in the secondary circuit.

Substitute $8 - j4\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{8 - j4}{(2)^2}\\ &= \frac{8 - j4}{4}\\ &= 2 - j1\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer having the turns ratio 1:2 is $2 - j1\,\Omega$.

Step 2 of 7

Calculate the value of the impedance of the primary circuit when referred to secondary of the transformer having turns ratio 2:1.

$$\mathbf{Z}_2{}' = n^2\mathbf{Z}_1{}'$$

Substitute $4\,\Omega$ for $\mathbf{Z}_1{}'$ and $\frac{1}{2}$ for n.

$$\begin{aligned}\mathbf{Z}_2{}' &= \left(\frac{1}{2}\right)^2(4)\\ &= \left(\frac{1}{4}\right)(4)\\ &= 1\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the primary circuit when referred to secondary of the transformer having turns ratio 2:1 is $1\,\Omega$.

Step 3 of 7

Consider the value of the voltage source transferred to secondary of the transformer.

$$\mathbf{V}_{s,2} = -\frac{\mathbf{V}_s}{2}$$

Therefore, the value of the voltage source transferred to secondary of the transformer is $-\frac{\mathbf{V}_s}{2}$.

Step 4 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 5 of 7

Consider Kirchhoff's Voltage Law in Loop-2.

$$\mathbf{I}_2(2 - j1 + 2) + (\mathbf{I}_2 - \mathbf{I}_s)(1) = 0$$

Here, $\mathbf{I}_2 - \mathbf{I}_s = -\mathbf{I}_1$.

$$\mathbf{I}_2(2 - j1 + 2) - \mathbf{I}_1(1) = 0$$

Substitute $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_2(4 - j1) - 4\angle 0° &= 0\\ \mathbf{I}_2(4 - j1) &= 4\angle 0°\\ \mathbf{I}_2 &= \frac{4\angle 0°}{4 - j1}\\ \mathbf{I}_2 &= \frac{4\angle 0°}{4.12\angle -14.04°}\\ \mathbf{I}_2 &= 0.97\angle 14.04°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $0.97\angle 14.04°\ \mathrm{A}$.

Step 6 of 7

Consider the expression for $\mathbf{I}_s$.

$$\mathbf{I}_s = \mathbf{I}_1 + \mathbf{I}_2$$

Substitute $0.97\angle 14.04°\ \mathrm{A}$ for $\mathbf{I}_2$ and $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$.

$$\begin{aligned}\mathbf{I}_s &= 4\angle 0° + 0.97\angle 14.04°\\ &= 4.95\angle 2.73°\ \mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_s$ is $4.95\angle 2.73°\ \mathrm{A}$.

Step 7 of 7

Consider the expression for $-\frac{\mathbf{V}_s}{2}$.

$$-\frac{\mathbf{V}_s}{2} = \mathbf{I}_s(1 - j1) + \mathbf{I}_1(1)$$

Substitute $4\angle 0°\ \mathrm{A}$ for $\mathbf{I}_1$ and $4.95\angle 2.73°\ \mathrm{A}$ for $\mathbf{I}_s$.

$$\begin{aligned}-\frac{\mathbf{V}_s}{2} &= (4\angle 0°)(1 - j1) + 4.95\angle 2.73°\\ &= (4\angle 0°)(1.41\angle -45°) + 4.95\angle 2.73°\\ &= 5.64\angle -45° + 4.95\angle 2.73°\\ &= 9.69\angle -22.79°\end{aligned}$$

$$\begin{aligned}\mathbf{V}_s &= -2(9.69\angle -22.79°)\\ &= -19.38\angle -22.79°\\ &= 19.38\angle 157.21°\ \mathrm{V}\end{aligned}$$

Therefore, the value of the source voltage is $\boxed{19.38\angle 157.21°\ \mathrm{V}}$.

Step 1 of 4

10.073 P

Refer to Figure P10.70 from the text book.

Calculate the value of the impedance of the secondary circuit when referred to primary of the transformer on left side of the circuit.

$$\mathbf{Z}_1 = \frac{\mathbf{Z}_2}{n^2}$$

$\mathbf{Z}_2$ represents the resistance in series with the capacitance in the secondary circuit.

Substitute $8 - j8\,\Omega$ for $\mathbf{Z}_2$ and 2 for n.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{8 - j8}{(2)^2}\\ &= \frac{8 - j8}{4}\\ &= 2 - j2\,\Omega\end{aligned}$$

Therefore, the value of the impedance of the secondary circuit when referred to primary of the transformer on the left side of the circuit is $2 - j2\,\Omega$.

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider Kirchhoff's Voltage Law in Loop-2.

$$\mathbf{I}_2(4 - j2 + 2) + (\mathbf{I}_2 - \mathbf{I}_1)(1 - j1) = 0$$

Here, $\mathbf{I}_2 - \mathbf{I}_1 = -\mathbf{I}_x$.

$$\mathbf{I}_2(4 - j2 + 2) - \mathbf{I}_x(1 - j1) = 0$$

Substitute $4\angle 30^\circ\,\mathrm{A}$ for $\mathbf{I}_x$.

$$\begin{aligned}&\mathbf{I}_2(6 - j2) - (4\angle 30^\circ)(1.41\angle -45^\circ) = 0\\ &\mathbf{I}_2(6.33\angle -18.44^\circ) = (4\angle 30^\circ)(1.41\angle -45^\circ)\\ &\mathbf{I}_2(6.33\angle -18.44^\circ) = 5.64\angle -15^\circ\\ &\mathbf{I}_2 = \frac{5.64\angle -15^\circ}{6.33\angle -18.44^\circ}\\ &\mathbf{I}_2 = 0.89\angle 3.44^\circ\,\mathrm{A}\end{aligned}$$

Therefore, the value of $\mathbf{I}_2$ is $0.89\angle 3.44^\circ\,\mathrm{A}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_O$.

$$\mathbf{V}_O = \mathbf{I}_2(4)$$

Substitute $0.89\angle 3.44^\circ\,\mathrm{A}$ for $\mathbf{I}_2$.

$$\begin{aligned}\mathbf{V}_O &= (0.89\angle 3.44^\circ)(4)\\ &= 3.56\angle 3.44^\circ\,\mathrm{V}\end{aligned}$$

Therefore, the value of $\mathbf{V}_O$ is $\boxed{3.56\angle 3.44^\circ\,\mathrm{V}}$.

Step 1 of 5

The given circuit is,

Step 2 of 5

The reflected impedance into the secondary side is,

$Z_2 = n^2 Z_1$

Where $n = 2$

$Z_2 = 4(3 - j2)$

$Z_2 = (12 - j8)\Omega$

The reflected voltage across the secondary side,

$V_R = nV_s$

$V_R = 2(24\angle 0^\circ)$

$V_R = 48\angle 0^\circ \text{V}$

Step 3 of 5

The equivalent circuit for the transformer and the secondary is shown below,

Step 4 of 5

The network shown above can be compared to the Thevenin's equivalent of a D.C source network as shown below.

Step 5 of 5

For maximum power transfer, the load impedance should be equal to the conjugate of the source network impedance,

i.e. $Z_L = Z_{th}^*$

Now, $Z_{Th} = (12 - j8)\Omega$

$\therefore Z_L = (12 + j8)\Omega$

$\boxed{Z_L = 14.42\angle 33.69^\circ\ \Omega}$

Step 1 of 2

10.075

P

Refer to Figure P10.75 in the text book for the transformer circuit.

To determine the load impedance for maximum power transfer, determine the Thevenin equivalent parameters at the load terminals.

Assume open circuit at the load terminals.

The open-circuit voltage at the secondary of the transformer is,

$$\begin{aligned}\mathbf{V}_2 &= n\mathbf{V}_1\\ &= (2)(12\angle 0^\circ)\\ &= 24\angle 0^\circ \text{ V}\end{aligned}$$

Determine the primary current $\mathbf{I}_1$ with short-circuited secondary.

$$\begin{aligned}\mathbf{I}_1 &= \frac{\mathbf{V}_1}{\mathbf{Z}_1}\\ &= \frac{12\angle 0^\circ}{3-j2}\\ &= 3.33\angle 33.7^\circ \text{ A}\end{aligned}$$

Determine the secondary short circuit current by transformation.

$$\begin{aligned}\mathbf{I}_2 &= \frac{1}{n}\mathbf{I}_1\\ &= \left(\frac{1}{2}\right)(3.33\angle 33.7^\circ)\\ &= 1.665\angle 33.7^\circ \text{ A}\end{aligned}$$

Step 2 of 2

Determine the Thevenin impedance.

$$\begin{aligned}\mathbf{Z}_2 &= \frac{\mathbf{V}_2}{\mathbf{I}_2}\\ &= \frac{24\angle 0^\circ}{1.665\angle 33.7^\circ}\\ &= 14.414\angle -33.7^\circ\\ &= 12 - j8\ \Omega\end{aligned}$$

For maximum power transfer, the load impedance must be complex conjugate of the Thevenin impedance.

$$\mathbf{Z}_L = 12 + j8\ \Omega$$

Thus, the load impedance $\mathbf{Z}_L$ for maximum power transfer is $\boxed{12 + j8\ \Omega}$.

10.076

P

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

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10.077

P

We don't have the solution to this problem yet.

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Ask an expert

11.001

E

Step 1 of 5

Consider the value of $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 120\angle 90^\circ \text{ V rms}$$

Compare with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V rms}$.

$\mathbf{V}_P = 120 \text{ V rms}$ and $\theta = 90^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ \text{ V rms}$$

Substitute 120 V rms for $\mathbf{V}_P$ and 90° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 90^\circ - 120^\circ \text{ V rms}\\ &= 120\angle -30^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $120\angle -30^\circ \text{ V rms}$.

Step 2 of 5

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120^\circ \text{ V rms}$$

Substitute 120 V rms for $\mathbf{V}_P$ and 90° for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 120\angle 90^\circ + 120^\circ \text{ V rms}\\ &= 120\angle 210^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $120\angle 210^\circ \text{ V rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn}$$

Substitute $120\angle 90^\circ \text{ V rms}$ for $\mathbf{V}_{an}$ and $120\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{bn}$.

$$\begin{aligned}\mathbf{V}_{ab} &= 120\angle 90^\circ - 120\angle -30^\circ\\ &= 208\angle 120^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{208\angle 120^\circ \text{ V rms}}$.

Step 4 of 5

Consider the expression for $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \mathbf{V}_{bn} - \mathbf{V}_{cn}$$

Substitute $120\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{bn}$ and $120\angle 210^\circ \text{ V rms}$ for $\mathbf{V}_{cn}$.

$$\begin{aligned}\mathbf{V}_{bc} &= 120\angle -30^\circ - 120\angle 210^\circ\\ &= 208\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bc}$ is $\boxed{208\angle 0^\circ \text{ V rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{ca}$.

$$\mathbf{V}_{ca} = \mathbf{V}_{cn} - \mathbf{V}_{an}$$

Substitute $120\angle 210^\circ \text{ V rms}$ for $\mathbf{V}_{cn}$ and $120\angle 90^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{ca} &= 120\angle 210^\circ - 120\angle 90^\circ\\ &= 208\angle -120^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{208\angle -120^\circ \text{ V rms}}$.

Step 1 of 2

Consider the value of $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 120\angle 15^\circ \text{ V rms}$$

Compare with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V rms}$.

$\mathbf{V}_P = 120$ and $\theta = 15^\circ$

Calculate the voltage, $\mathbf{V}_{bn}$.

$$\begin{aligned}\mathbf{V}_{bn} &= \mathbf{V}_P\angle(\theta - 120^\circ) \text{ V rms}\\ &= 120\angle(15^\circ - 120^\circ) \text{ V rms}\\ &= 120\angle -105^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is, $120\angle -105^\circ \text{ V rms}$.

Calculate the voltage, $\mathbf{V}_{cn}$.

$$\begin{aligned}\mathbf{V}_{cn} &= \mathbf{V}_P\angle\theta + 120^\circ \text{ V rms}\\ &= 120\angle 15^\circ + 120^\circ \text{ V rms}\\ &= 120\angle 135^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is, $120\angle 135^\circ \text{ V rms}$.

Step 2 of 2

Draw the phasor diagram as shown in Figure 1.

Figure 1

Hence, the phasor diagram of balanced 3 phase system is drawn.

11.01F

E

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

Ask an expert

11.002

E

Step 1 of 3

Consider the value of $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 208\angle 0^\circ \text{ V rms}$$

Compare with $\mathbf{V}_{ab} = \sqrt{3}\mathbf{V}_P\angle\theta \text{ V rms}$.

$$\mathbf{V}_P = \frac{208}{\sqrt{3}} \text{ and } \theta = 0^\circ$$

That is, $\mathbf{V}_P = 120 \text{ V rms}$ and $\theta = 0^\circ$.

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{V}_P\angle\theta - 30^\circ \text{ V rms}$$

Substitute 120 V rms for $\mathbf{V}_P$ and 0° for θ .

$$\begin{aligned}\mathbf{V}_{an} &= 120\angle 0^\circ - 30^\circ \text{ V rms}\\ &= 120\angle -30^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{120\angle -30^\circ \text{ V rms}}$.

Step 2 of 3

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 150^\circ \text{ V rms}$$

Substitute 120 V rms for $\mathbf{V}_P$ and 0° for θ .

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 0^\circ - 150^\circ \text{ V rms}\\ &= 120\angle -150^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{120\angle -150^\circ \text{ V rms}}$.

Step 3 of 3

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta - 270^\circ \text{ V rms}$$

Substitute 120 V rms for $\mathbf{V}_P$ and 0° for θ .

$$\begin{aligned}\mathbf{V}_{cn} &= 120\angle 0^\circ - 270^\circ \text{ V rms}\\ &= 120\angle -270^\circ \text{ V rms}\\ &= 120\angle -270^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{120\angle -270^\circ \text{ V rms}}$.

11.002
P

Step 1 of 2

Consider the line voltage.

$$\mathbf{V}_{bc} = 200\angle -30°$$

Calculate the line voltage

$$\mathbf{V}_{bc} = \mathbf{V}_{ab}\angle -120$$

Substitute $200\angle -30°$ for $\mathbf{V}_{bc}$ in equation.

$$200\angle -30° = \mathbf{V}_{ab}\angle -120$$
$$\mathbf{V}_{ab} = 200\angle 90°$$

Calculate the phase voltage , $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30°}$$

Substitute $200\angle 90°$ for $\mathbf{V}_{ab}$ in equation.

$$\mathbf{V}_{an} = \frac{200\angle 90°}{\sqrt{3}\angle 30°}$$
$$= 115.47\angle 60°$$

Thus, the line voltage $\mathbf{V}_{an}$ is $\boxed{115.47\angle 60°}$.

Calculate the phase voltage , $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_{an}\angle -120°$$

Substitute $115.47\angle 60°$ for V_{an} in equation.

$$\mathbf{V}_{bn} = 115.47\angle 60°\angle -120°$$
$$= 115.47\angle -60°$$

Thus, the line voltage $\mathbf{V}_{bn}$ is $\boxed{115.47\angle -60°}$.

Step 2 of 2

Calculate the phase voltage , $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_{an}\angle 120°$$

Substitute $115.47\angle 60°$ for V_{an} in equation.

$$\mathbf{V}_{bn} = 115.47\angle 60°\angle 120°$$
$$= 115.47\angle 180°$$

Thus, the line voltage $\mathbf{V}_{cn}$ is $\boxed{115.47\angle 180°}$.

Step 1 of 6

11.02FE

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 6

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(12+j12)(12+j12)}{(12+j12)+(12+j12)+(12+j12)} \\ &= \frac{(12+j12)(12+j12)}{3(12+j12)} \\ &= \frac{(12+j12)}{3} \\ &= 4+j4\,\Omega \end{aligned}$$

Convert Z_1 into polar form.

$$Z_1 = 5.66\angle 45^\circ\,\Omega$$

Therefore, the value of Z_1 is $5.66\angle 45^\circ\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 5.66\angle 45^\circ\,\Omega$ and $Z_3 = 5.66\angle 45^\circ\,\Omega$.

The power factor angle (θ) at the load is 45°.

Step 4 of 6

Consider the expression for $\mathbf{V}_L$.

$$\mathbf{V}_L = 230\angle 0^\circ \text{ V rms}$$

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{V}_{an} &= \frac{230}{\sqrt{3}}\angle 0^\circ - 30^\circ \text{ V rms} \\ &= 132.79\angle -30^\circ \text{ V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $132.79\angle -30^\circ \text{ V rms}$

Step 5 of 6

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 6

Consider the expression for the real power absorbed by the load.

$$P = 3\frac{|\mathbf{V}_{an}|^2}{|Z_1|}\cos\theta$$

Substitute 132.79 V rms for $|\mathbf{V}_{an}|$, 45° for θ and 5.66 for $|Z_1|$.

$$\begin{aligned} P &= 3\left(\frac{(132.79)^2}{5.66}\right)\cos 45^\circ \\ &= 3(3115.4)(0.71) \\ &= 6.64 \text{ kW} \end{aligned}$$

Therefore, the value of the real power absorbed by the load is 6.64 kW which is nearly equal to option (a). Hence, the correct option is $\boxed{\text{a}}$.

Step 1 of 6

Consider the circuit diagram shown in Figure 1.

Step 2 of 6

Figure 1

Step 3 of 6

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{8+j3}$$

Substitute $104.02\angle 26.6°\ \text{V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{104.02\angle 26.6°}{8+j3}\\ &= \frac{104.02\angle 26.6°}{8.54\angle 20.56°}\\ &= 12.18\angle 6.04°\ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $12.18\angle 6.04°\ \text{A rms}$.

Step 4 of 6

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(1+j1) + \mathbf{V}_{AN}$$

Substitute $12.18\angle 6.04°\ \text{A rms}$ for $\mathbf{I}_{aA}$ and $104.02\angle 26.6°\ \text{V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (12.18\angle 6.04°)(1+j1) + 104.02\angle 26.6°\\ &= (12.18\angle 6.04°)(1.42\angle 45°) + 104.02\angle 26.6°\\ &= 17.3\angle 51.04° + 104.02\angle 26.6°\\ &= 120\angle 30°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{120\angle 30°\ \text{V rms}}$.

Step 5 of 6

Compare $\mathbf{V}_{an} = 120\angle 30°\ \text{V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta\ \text{V}$.

$\mathbf{V}_P = 120\ \text{V rms}$ and $\theta = 30°$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120°$$

Substitute $120\ \text{V rms}$ for $\mathbf{V}_P$ and $30°$ for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 30° - 120°\\ &= 120\angle -90°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{120\angle -90°\ \text{V rms}}$.

Step 6 of 6

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120°$$

Substitute $120\ \text{V rms}$ for $\mathbf{V}_P$ and $30°$ for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 120\angle 30° + 120°\\ &= 120\angle 150° - 360°\\ &= 120\angle -210°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{120\angle -210°\ \text{V rms}}$.

11.003
P

Step 1 of 9

Consider the phase voltage, $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 120\angle 0^\circ \text{ V}$$

Calculate the phase voltage, $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_{an}\angle -120^\circ \text{ V}$$

Substitute $120\angle 0^\circ \text{ V}$ for $\mathbf{V}_{an}$ in equation.

$$\mathbf{V}_{bn} = 120\angle -120^\circ \text{ V}$$

Therefore the phase voltage $\mathbf{V}_{bn}$ is $\boxed{120\angle -120^\circ \text{ V}}$.

Step 2 of 9

Calculate the phase voltage, $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_{an}\angle 120^\circ \text{ V}$$

Substitute $120\angle 0^\circ \text{ V}$ for $\mathbf{V}_{an}$ in equation.

$$\mathbf{V}_{cn} = 120\angle 120^\circ \text{ V}$$

Therefore the phase voltage $\mathbf{V}_{cn}$ is $\boxed{120\angle 120^\circ \text{ V}}$.

Step 3 of 9

Calculate the line voltage, $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \sqrt{3}V_p\angle 30^\circ$$

Substitute 120 for V_p in equation.

$$\begin{aligned}\mathbf{V}_{ab} &= \sqrt{3}(120)\angle 30^\circ \\ &= 207.84\angle 30^\circ \text{ V}\end{aligned}$$

Therefore the line voltage $\mathbf{V}_{ab}$ is $\boxed{207.84\angle 30^\circ \text{ V}}$.

Step 4 of 9

Calculate the line voltage, $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \sqrt{3}V_p\angle -90^\circ$$

Substitute 120 for V_p in equation.

$$\begin{aligned}\mathbf{V}_{bc} &= \sqrt{3}(120)\angle -90^\circ \\ &= 207.84\angle -90^\circ \text{ V}\end{aligned}$$

Therefore the line voltage $\mathbf{V}_{bc}$ is $\boxed{207.84\angle -90^\circ \text{ V}}$.

Step 5 of 9

Calculate the line voltage,.

$$\mathbf{V}_{ca} = \sqrt{3}V_p\angle -210^\circ$$

Substitute 120 for V_p in equation.

$$\begin{aligned}\mathbf{V}_{ca} &= \sqrt{3}(120)\angle -210^\circ \\ &= 207.84\angle -210^\circ \text{ V}\end{aligned}$$

Therefore the line voltage $\mathbf{V}_{ca}$ is $\boxed{207.84\angle -210^\circ \text{ V}}$.

Step 6 of 9

Calculate the line current, $\mathbf{I}_a$.

$$\mathbf{I}_a = \frac{\mathbf{V}_{an}}{\mathbf{Z}_Y}$$

Substitute $120\angle 0^\circ$ for $\mathbf{V}_{an}$ and $50\angle 120^\circ$ for $\mathbf{Z}_Y$ in equation.

$$\begin{aligned}\mathbf{I}_a &= \frac{120}{50\angle 20^\circ} \\ &= 2.4\angle -20^\circ \text{ A}\end{aligned}$$

Therefore, the line current $\mathbf{I}_a$ is $\boxed{2.4\angle -20^\circ \text{ A}}$.

Step 7 of 9

Calculate the line current , $\mathbf{I}_b$,

$$\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$$

Substitute $2.4\angle -20^\circ \text{ A}$ for $\mathbf{I}_a$ in equation.

$$\begin{aligned}\mathbf{I}_b &= 2.4\angle -120^\circ - 20^\circ \\ &= 2.4\angle -140^\circ \text{ A}\end{aligned}$$

Therefore, the line current $\mathbf{I}_b$ is $\boxed{2.4\angle -140^\circ \text{ A}}$.

Step 8 of 9

Calculate the line current , $\mathbf{I}_c$.

$$\mathbf{I}_c = \mathbf{I}_a\angle -240^\circ$$

Substitute $2.4\angle -20^\circ \text{ A}$ for $\mathbf{I}_a$ in equation.

$$\begin{aligned}\mathbf{I}_c &= 2.4\angle -240^\circ - 20^\circ \\ &= 2.4\angle -260^\circ \text{ A}\end{aligned}$$

Therefore, the line current $\mathbf{I}_c$ is $\boxed{2.4\angle -260^\circ \text{ A}}$.

Step 9 of 9

In wye-wye connection the phase currents are same as line currents.

Step 1 of 2

Two balanced loads are connected in parallel. Load 1 is connected in delta and the phase impedance is,

$$Z_{\Delta 1} = 24 + j18\ \Omega$$

Convert the delta connected load into equivalent star load.

$$\begin{aligned} Z_{Y1} &= \frac{Z_{\Delta 1}}{3} \\ &= \frac{24 + j18}{3} \\ &= 8 + j6\ \Omega \end{aligned}$$

Load 2 is connected in star and the phase impedance is,

$$Z_{Y2} = 6 + j4\ \Omega$$

Calculate the per phase equivalent impedance of the parallel connected loads.

$$\begin{aligned} Z_Y &= Z_{Y1} \parallel Z_{Y2} \\ &= \frac{Z_{Y1} Z_{Y2}}{Z_{Y1} + Z_{Y2}} \end{aligned}$$

Substitute $8 + j6\ \Omega$ for Z_{Y1} and $6 + j4\ \Omega$ for Z_{Y2}.

$$\begin{aligned} Z_Y &= \frac{(8 + j6)(6 + j4)}{8 + j6 + 6 + j4} \\ &= \frac{24 + j68}{14 + j10} \\ &= 3.43 + j2.4\ \Omega \end{aligned}$$

Step 2 of 2

Calculate the line current.

$$\begin{aligned} I_L &= \frac{V_L}{\sqrt{3}(Z_Y)} \\ &= \frac{208}{\sqrt{3}(3.43 + j2.4)} \\ &= 28.68\angle -35^\circ \text{ A rms} \end{aligned}$$

Therefore, the correct option is $\boxed{(b)}$.

Step 1 of 4

11.004
E

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{277\angle 0^\circ}{60 - j40} \\ &= \frac{277\angle 0^\circ}{72.11\angle -33.69^\circ} \\ &= 3.84\angle 33.69^\circ\ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{3.84\angle 33.69^\circ\ \text{A rms}}$.

Step 3 of 4

Compare $\mathbf{I}_{aA} = 3.84\angle 33.69^\circ\ \text{A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\ \text{A}$.

$\mathbf{I}_P = 3.84\ \text{A rms}$ and $\theta = 33.69^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute $3.84\ \text{A rms}$ for $\mathbf{I}_P$ and 33.69° for θ .

$$\begin{aligned}\mathbf{I}_{bB} &= 3.84\angle 33.69^\circ - 120^\circ \\ &= 3.84\angle -86.31^\circ\ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{3.84\angle -86.31^\circ\ \text{A rms}}$.

Step 4 of 4

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute $3.84\ \text{A rms}$ for $\mathbf{I}_P$ and 33.69° for θ .

$$\begin{aligned}\mathbf{I}_{cC} &= 3.84\angle 33.69^\circ + 120^\circ \\ &= 3.84\angle 153.69^\circ\ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{3.84\angle 153.69^\circ\ \text{A rms}}$.

Step 1 of 4

Consider the value of $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 240\angle 90^\circ \text{ V rms}$$

Compare with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V rms}$.

$$\mathbf{V}_P = 240 \text{ and } \theta = 90^\circ$$

Step 2 of 4

<u>Line voltages:</u>

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \sqrt{3}\mathbf{V}_P\angle\theta + 30^\circ$$

Since $\mathbf{V}_P = 240$ and $\theta = 90^\circ$,

$$\begin{aligned}\mathbf{V}_{ab} &= \sqrt{3}(240)\angle 90^\circ + 30^\circ \\ &= 415.69\angle 120^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{415.69\angle 120^\circ \text{ V rms}}$.

Step 3 of 4

Consider the expression for $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \sqrt{3}\mathbf{V}_P\angle\theta - 90^\circ$$

Since $\mathbf{V}_P = 240$ and $\theta = 90^\circ$,

$$\begin{aligned}\mathbf{V}_{bc} &= \sqrt{3}(240)\angle 90^\circ - 90^\circ \\ &= 415.69\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bc}$ is $\boxed{415.69\angle 0^\circ \text{ V rms}}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_{ca}$.

$$\mathbf{V}_{ca} = \sqrt{3}\mathbf{V}_P\angle\theta - 210^\circ$$

Since $\mathbf{V}_P = 240$ and $\theta = 90^\circ$,

$$\begin{aligned}\mathbf{V}_{ca} &= \sqrt{3}(240)\angle 90^\circ - 210^\circ \\ &= 415.69\angle -120^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ca}$ is $\boxed{415.69\angle -120^\circ \text{ V rms}}$.

Step 1 of 1

11.04FE

Consider the expression for the single phase complex power.

$$S_1 = \frac{S}{3}$$

Substitute $24\angle 30^\circ \text{ kVA}$ for S .

$$\begin{aligned} S_1 &= \frac{24\angle 30^\circ \text{ k}}{3} \\ &= 8\angle 30^\circ \text{ k} \\ &= 6.93 + j4 \text{ kVA} \end{aligned}$$

Since real part represents the real power.

$$P = 6.93 \text{ kW } Q_{old} = 4.72 \text{ Mvar}$$

Therefore, the value of the real power is 6.93 kW .

Therefore, the correct option is $\boxed{\text{c}}$.

11.005
E

Step 1 of 9

Consider the circuit diagram shown in Figure 1.

Step 2 of 9

Figure 1

Step 3 of 9

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{20 - j24}$$

Substitute $125\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{125\angle 10^\circ}{20 - j24} \\ &= \frac{125\angle 10^\circ}{31.24\angle -50.19^\circ} \\ &= 4\angle 60.19^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $4\angle 60.19^\circ \text{ A rms}$.

Step 4 of 9

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(0.5 + j0.75) + \mathbf{V}_{AN}$$

Substitute $4\angle 60.19^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $125\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (4\angle 60.19^\circ)(0.5 + j0.75) + 125\angle 10^\circ \\ &= (4\angle 60.19^\circ)(0.90\angle 56.31^\circ) + 125\angle 10^\circ \\ &= 3.6\angle 116.5^\circ + 125\angle 10^\circ \\ &= 124.03\angle 11.6^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $124.03\angle 11.6^\circ \text{ V rms}$.

Step 5 of 9

Compare $\mathbf{V}_{an} = 124.03\angle 11.6^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V}$.

$\mathbf{V}_P = 124.03 \text{ V rms}$ and $\theta = 11.6^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ$$

Substitute 124.03 V rms for $\mathbf{V}_P$ and 11.6° for θ .

$$\begin{aligned}\mathbf{V}_{bn} &= 124.03\angle 11.6^\circ - 120^\circ \\ &= 124.03\angle -108.4^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $124.03\angle -108.4^\circ \text{ V rms}$.

Step 6 of 9

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120^\circ$$

Substitute 124.03 V rms for $\mathbf{V}_P$ and 11.6° for θ .

$$\begin{aligned}\mathbf{V}_{cn} &= 124.03\angle 11.6^\circ + 120^\circ \\ &= 124.03\angle 131.6^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $124.03\angle 131.6^\circ \text{ V rms}$.

Step 7 of 9

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn}$$

Substitute $124.03\angle 11.6^\circ \text{ V rms}$ for $\mathbf{V}_{an}$ and $124.03\angle -108.4^\circ \text{ V rms}$ for $\mathbf{V}_{bn}$.

$$\begin{aligned}\mathbf{V}_{ab} &= 124.03\angle 11.6^\circ - 124.03\angle -108.4^\circ \\ &= 214.8\angle 41.6^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{214.8\angle 41.6^\circ \text{ V rms}}$.

Step 8 of 9

Consider the expression for $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \mathbf{V}_{bn} - \mathbf{V}_{cn}$$

Substitute $124.03\angle -108.4^\circ \text{ V rms}$ for $\mathbf{V}_{bn}$ and $124.03\angle 131.6^\circ \text{ V rms}$ for $\mathbf{V}_{cn}$.

$$\begin{aligned}\mathbf{V}_{bc} &= 124.03\angle -108.4^\circ - 124.03\angle 131.6^\circ \\ &= 214.8\angle -78.4^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bc}$ is $\boxed{214.8\angle -78.4^\circ \text{ V rms}}$.

Step 9 of 9

Consider the expression for $\mathbf{V}_{ca}$.

$$\mathbf{V}_{ca} = \mathbf{V}_{cn} - \mathbf{V}_{an}$$

Since $124.03\angle 131.6^\circ \text{ V rms}$ for $\mathbf{V}_{cn}$ and $124.03\angle 11.6^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{ca} &= 124.03\angle 131.6^\circ - 124.03\angle 11.6^\circ \\ &= 214.8\angle 161.6^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ca}$ is $\boxed{214.8\angle 161.6^\circ \text{ V rms}}$.

Step 1 of 7

Line voltages:

Consider the value of $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 208\angle 60^\circ \text{ V rms}$$

Compare with $\mathbf{V}_{ab} = \sqrt{3}\mathbf{V}_P\angle\theta \text{ V rms}$.

$$\mathbf{V}_P = \frac{208}{\sqrt{3}} \text{ and } \theta = 60^\circ$$

That is, $\mathbf{V}_P = 120$ and $\theta = 60^\circ$.

Step 2 of 7

Consider the expression for $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \sqrt{3}\mathbf{V}_P\angle\theta - 120^\circ \text{ V rms}$$

Since $\mathbf{V}_P = 120$ and $\theta = 60^\circ$,

$$\begin{aligned}\mathbf{V}_{bc} &= \sqrt{3}(120)\angle 60 - 120^\circ \text{ V rms}\\ &= 208\angle -60^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bc}$ is $208\angle -60^\circ \text{ V rms}$.

Step 3 of 7

Consider the expression for $\mathbf{V}_{ca}$.

$$\mathbf{V}_{ca} = \sqrt{3}\mathbf{V}_P\angle\theta + 120^\circ \text{ V rms}$$

Since $\mathbf{V}_P = 120$ and $\theta = 60^\circ$,

$$\begin{aligned}\mathbf{V}_{ca} &= \sqrt{3}(120)\angle 60 + 120^\circ \text{ V rms}\\ &= 208\angle 180^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ca}$ is $208\angle 180^\circ \text{ V rms}$.

Step 4 of 7

Phase voltages:

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{V}_P\angle\theta - 30^\circ \text{ V rms}$$

Since $\mathbf{V}_P = 120$ and $\theta = 60^\circ$,

$$\begin{aligned}\mathbf{V}_{an} &= 120\angle 60^\circ - 30^\circ \text{ V rms}\\ &= 120\angle 30^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $120\angle 30^\circ \text{ V rms}$.

Step 5 of 7

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 150^\circ \text{ V rms}$$

Since $\mathbf{V}_P = 120$ and $\theta = 60^\circ$,

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 60^\circ - 150^\circ \text{ V rms}\\ &= 120\angle -90^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $120\angle -90^\circ \text{ V rms}$.

Step 6 of 7

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta - 270^\circ \text{ V rms}$$

Since $\mathbf{V}_P = 120$ and $\theta = 60^\circ$,

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 60^\circ - 270^\circ \text{ V rms}\\ &= 120\angle -210^\circ \text{ V rms}\\ &= 120\angle 150^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $120\angle 150^\circ \text{ V rms}$.

Step 7 of 7

Consider the phasor diagram shown in Figure 1.

Figure 1

Therefore, the required phasor representation is shown in Figure 1.

Consider the expression for the magnitude of complex power in terms of real and reactive powers.

$$S^2 = P^2 + Q^2$$

Substitute $100\,\text{kVA}$ for S and $90\,\text{kW}$ for P.

$$(100\text{ k})^2 = (90\text{ k})^2 + Q^2$$

Rewrite the equation.

$$\begin{aligned} Q^2 &= (100\text{ k})^2 - (90\text{ k})^2 \\ &= 10000\text{ k}^2 - 8100\text{ k}^2 \\ &= 1900\text{ k}^2 \end{aligned}$$

$$\begin{aligned} Q &= \sqrt{1900\text{k}^2} \\ &= 43.59\text{ kvar} \end{aligned}$$

Therefore, the value of the reactive power is 43.59 kvar.

Therefore, the correct option is $\boxed{\text{d}}$.

Step 1 of 6

11.006
E

Consider the circuit diagram shown in Figure 1.

Step 2 of 6

Figure 1

Step 3 of 6

Consider the expression for the current $\mathbf{I}_{aA}$ in the lines terms of power and line impedance.

$$\mathbf{I}_{aA} = \sqrt{\frac{P_{line}}{3(R_{line})}}$$

Substitute $650\ \mathrm{W}$ for P_{line} and $1\,\Omega$ for R_{line}.

$$\begin{aligned}\mathbf{I}_{aA} &= \sqrt{\frac{650}{3(1)}}\\ &= \sqrt{\frac{650}{3}}\\ &= \sqrt{216.67}\\ &= 14.72\ \mathrm{A\ rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $14.72\ \mathrm{A\ rms}$.

Step 4 of 6

Consider the expression for magnitude of the load impedance.

$$|Z_{load}| = \left|\frac{\mathbf{V}_{an}}{\mathbf{I}_{aA}}\right|$$

Substitute $14.72\ \mathrm{A\ rms}$ for $\mathbf{I}_{aA}$ and $117\ \mathrm{V\ rms}$ for $|\mathbf{V}_{an}|$.

$$\begin{aligned}|Z_{load}| &= \left|\frac{117}{14.72}\right|\\ &= 7.95\,\Omega\end{aligned}$$

Therefore, the value of the magnitude of the load impedance is $7.95\,\Omega$.

Step 5 of 6

Since, the power factor is 0.88 leading, calculate the impedance phase angle.

$$\begin{aligned}\theta &= -\cos^{-1}(0.88)\\ &= -28.36^\circ\end{aligned}$$

Therefore, the value of the phase angle of the load is -28.36°.

Step 6 of 6

Consider the expression for the load impedance.

$$Z_{load} = |Z_{load}|\angle\theta$$

Substitute -28.36° for θ and $7.95\,\Omega$ for $|Z_{load}|$.

$$\begin{aligned}Z_{load} &= 7.95\angle -28.36^\circ\\ &= 7 - j3.78\,\Omega\end{aligned}$$

Therefore, the required value of the load impedance is $\boxed{7 - j3.78\,\Omega}$.

Step 1 of 9

11.006 P

Consider the Figure P11.6 from the text book.

Reduce the delta network shown in dotted lines in Figure 1 into wye network by assuming the impedances as shown.

Figure 1

Step 2 of 9

Consider the expression for Z_a.

$$\begin{aligned} Z_a &= \frac{(1+j1)(2-j2)}{(1+j1)+(2-j2)+1} \\ &= \frac{4}{4-j1} \\ &= 0.94 + j0.24\,\Omega \end{aligned}$$

Therefore, the value of Z_a is $0.94 + j0.24\,\Omega$.

Step 3 of 9

Consider the expression for Z_b.

$$\begin{aligned} Z_b &= \frac{(1)(2-j2)}{(1+j1)+(2-j2)+1} \\ &= \frac{2-j2}{4-j1} \\ &= 0.59 - j0.35\,\Omega \end{aligned}$$

Therefore, the value of Z_b is $0.59 - j0.35\,\Omega$.

Step 4 of 9

Consider the expression for Z_c.

$$\begin{aligned} Z_c &= \frac{(1)(1+j1)}{(1+j1)+(2-j2)+1} \\ &= \frac{1+j1}{4-j1} \\ &= 0.18 + j0.29\,\Omega \end{aligned}$$

Therefore, the value of Z_c is $0.18 + j0.29\,\Omega$.

Step 5 of 9

Redraw the circuit as shown in Figure 2.

Figure 2

Redraw the circuit diagram by simplifying the Figure 2 as shown in Figure 3.

Figure 3

Step 6 of 9

Compare the Figures 2 and 3.

Calculate the value of Z_d.

$$\begin{aligned} Z_d &= 1 - j1 + 0.94 + j0.24 \\ &= 1.94 - j0.76\,\Omega \end{aligned}$$

Therefore, the value of Z_d is $1.94 - j0.76\,\Omega$.

Step 7 of 9

Calculate the value of Z_e.

$$\begin{aligned} Z_e &= 1 - j1 + 0.18 + j0.29 \\ &= 1.18 - j0.71\,\Omega \end{aligned}$$

Therefore, the value of Z_e is $1.18 - j0.71\,\Omega$.

Step 8 of 9

Calculate the value of Z_f.

$$\begin{aligned} Z_f &= 2 - j2 + 0.59 - j0.35 \\ &= 2.59 - j2.35\,\Omega \end{aligned}$$

Therefore, the value of Z_f is $2.59 - j2.35\,\Omega$.

Step 9 of 9

Refer Figure 3.

Consider the expression for Z.

$$Z = Z_d + (Z_e \parallel Z_f)$$

Substitute $2.59 - j2.35\,\Omega$ for Z_f, $1.18 - j0.71\,\Omega$ for Z_e and $1.94 - j0.76\,\Omega$ for Z_d.

$$\begin{aligned} Z &= (1.94 - j0.76) + [(1.18 - j0.71) \parallel (2.59 - j2.35)] \\ &= (1.94 - j0.76) + (0.82 - j0.56) \\ &= 2.76 - j1.32 \\ &= 3.06\angle -25.56^\circ\,\Omega \end{aligned}$$

Therefore, the value of Z is $\boxed{3.06\angle -25.56^\circ\,\Omega}$.

Step 1 of 4

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 208\angle 0^\circ \text{ V rms}$$

Calculate the value of $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{208}{\sqrt{3}}\angle 0^\circ - 30^\circ \text{ V rms} \\ &= 120\angle -30^\circ \text{ V rms}\end{aligned}$$

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider the expression for $\mathbf{V}_{AN}$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_{AN} &= \mathbf{V}_{an}\left(\frac{10+j4}{10+j4+0.1+j0.1}\right) \\ &= \mathbf{V}_{an}\left(\frac{10+j4}{10.1+j4.1}\right) \\ &= \mathbf{V}_{an}(0.988 - j0.005) \\ &= \mathbf{V}_{an}(0.988\angle -0.29^\circ)\end{aligned}$$

Substitute $120\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{AN} &= (120\angle -30^\circ)(0.988\angle -0.29^\circ) \\ &= 118.56\angle -30.29^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $118.56\angle -30.29^\circ \text{ V rms}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_{AB}$.

$$\mathbf{V}_{AB} = \sqrt{3}\mathbf{V}_{AN}\angle 30^\circ$$

Substitute $118.56\angle -30.29^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{AB} &= \sqrt{3}(118.56\angle -30.29^\circ)(1\angle 30^\circ) \\ &= \sqrt{3}(118.56\angle -30.29^\circ + 30^\circ) \\ &= 205.35\angle -0.29^\circ \text{ V rms}\end{aligned}$$

Therefore, the magnitude of the line voltage at the load is $\boxed{205.35 \text{ V rms}}$.

Step 1 of 7

11.007

P

Consider the Figure P11.9 in the text book.

Simplify the delta network shown in dotted lines in Figure 1 into wye network by assuming the impedances as shown.

Figure 1

Step 2 of 7

Consider the expression for Z_1 .

$$\begin{aligned} Z_1 &= \frac{(1-j1)(1-j1)}{(1-j1)+(1-j1)+(1)} \\ &= \frac{-j2}{3-j2} \\ &= 0.31-j0.46\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $0.31-j0.46\,\Omega$.

Step 3 of 7

Consider the expression for Z_2 .

$$\begin{aligned} Z_2 &= \frac{(1-j1)(1)}{(1-j1)+(1-j1)+(1)} \\ &= \frac{1-j1}{3-j2} \\ &= 0.39-j0.08\,\Omega \end{aligned}$$

Therefore, the value of Z_2 is $0.39-j0.08\,\Omega$.

Step 4 of 7

Consider the expression for Z_3 .

$$\begin{aligned} Z_3 &= \frac{(1-j1)(1)}{(1-j1)+(1-j1)+(1)} \\ &= \frac{1-j1}{3-j2} \\ &= 0.39-j0.08\,\Omega \end{aligned}$$

Therefore, the value of Z_3 is $0.39-j0.08\,\Omega$.

Step 5 of 7

Consider the simplified circuit diagram shown in Figure 2.

Figure 2

Step 6 of 7

Consider the simplified circuit diagram shown in Figure 3.
Figure 2

Step 7 of 7

Calculate the parallel combination of impedances Z_5 and Z_6.

$$Z = Z_4 + \frac{Z_5 Z_6}{Z_5 + Z_6}$$

Since $Z_4 = 2.31-j0.46\,\Omega$, $Z_5 = 2.39-j1.08\,\Omega$ and $Z_6 = 2.39-j1.08\,\Omega$,

$$\begin{aligned} Z &= 2.31-j0.46+\frac{(2.39-j1.08\,\Omega)(2.39-j1.08\,\Omega)}{(2.39-j1.08\,\Omega)+(2.39-j1.08\,\Omega)} \\ &= 2.31-j0.46+\frac{(2.39-j1.08\,\Omega)(2.39-j1.08\,\Omega)}{2(2.39-j1.08\,\Omega)} \\ &= 2.31-j0.46+\frac{(2.39-j1.08\,\Omega)}{2} \\ &= 2.31-j0.46+1.2-j0.54 \end{aligned}$$

$$\begin{aligned} Z &= 3.51-j1\,\Omega \\ &= 3.65\angle-15.9^\circ\,\Omega \end{aligned}$$

Therefore, the value of Z is $\boxed{3.65\angle-15.9^\circ\,\Omega}$.

Step 1 of 5

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 215\angle -10^\circ \text{ V rms}$$

Calculate the value of $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{215}{\sqrt{3}}\angle -10^\circ - 30^\circ \text{ V rms}\\ &= 124.13\angle -40^\circ \text{ V rms}\end{aligned}$$

Step 2 of 5

Convert the delta connected load to star connection.

$$\begin{aligned}Z_Y &= \frac{9+j6}{3}\\ &= 3+j2\ \Omega\end{aligned}$$

Therefore, the value of the star connected load is $3+j2\ \Omega$.

Step 3 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 5

Consider the expression for $\mathbf{V}_{AN}$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_{AN} &= \mathbf{V}_{an}\left(\frac{3+j2}{3+j2+0.05+j0.1}\right)\\ &= \mathbf{V}_{an}\left(\frac{3+j2}{3.05+j2.1}\right)\\ &= \mathbf{V}_{an}(0.974-j0.015)\\ &= \mathbf{V}_{an}(0.974\angle -0.88^\circ)\end{aligned}$$

Substitute $124.13\angle -40^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{AN} &= (124.13\angle -40^\circ)(0.974\angle -0.88^\circ)\\ &= 120.9\angle -40.88^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.9\angle -40.88^\circ \text{ V rms}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{AB}$.

$$\mathbf{V}_{AB} = \sqrt{3}\mathbf{V}_{AN}\angle 30^\circ$$

Substitute $120.9\angle -40.88^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{AB} &= \sqrt{3}(120.9\angle -40.88^\circ)(1\angle 30^\circ)\\ &= \sqrt{3}(120.9\angle -10.88^\circ)\\ &= 209.4\angle -10.29^\circ \text{ V rms}\end{aligned}$$

Therefore, the magnitude of the line voltage at the load is $\boxed{209.4 \text{ V rms}}$.

11.008
P

Step 1 of 4

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 120\angle 0^\circ \text{ V rms}$$

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{120\angle 0^\circ}{40 + j10}$$
$$= 2.91\angle -14.04^\circ \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{2.91\angle -14.04^\circ \text{ A rms}}$.

Step 3 of 4

Compare $\mathbf{I}_{aA} = 2.91\angle -14.04^\circ \text{ A}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta \text{ A}$.

$\mathbf{I}_P = 2.91$ and $\theta = -14.04^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 2.91 for $\mathbf{I}_P$ and -14.04° for θ.

$$\mathbf{I}_{bB} = 2.91\angle -14.04^\circ - 120^\circ$$
$$= 2.91\angle -134.04^\circ \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{2.91\angle -134.04^\circ \text{ A rms}}$.

Step 4 of 4

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 2.91 for $\mathbf{I}_P$ and -14.04° for θ.

$$\mathbf{I}_{cC} = 2.91\angle -14.04^\circ + 120^\circ$$
$$= 2.91\angle -105.96^\circ \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{2.91\angle -105.96^\circ \text{ A rms}}$.

11.009

E

Step 1 of 4

Consider the value of $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = 12\angle 40^\circ \text{ A rms}$$

Compare with $\mathbf{I}_{aA} = \mathbf{I}_P \angle \theta \text{ A rms}$.

$\mathbf{I}_P = 12 \text{ A rms}$ and $\theta = 40^\circ$

Step 2 of 4

Consider the expression for $\mathbf{I}_{AB}$.

$$\mathbf{I}_{AB} = \frac{\mathbf{I}_P}{\sqrt{3}} \angle \theta + 30^\circ$$

Substitute 12 A rms for $\mathbf{I}_P$ and 40° for θ .

$$\begin{aligned}\mathbf{I}_{AB} &= \frac{12}{\sqrt{3}} \angle 40^\circ + 30^\circ \\ &= 6.93\angle 70^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AB}$ is $\boxed{6.93\angle 70^\circ \text{ A rms}}$.

Step 3 of 4

Consider the expression for $\mathbf{I}_{BC}$.

$$\mathbf{I}_{BC} = \frac{\mathbf{I}_P}{\sqrt{3}} \angle \theta - 90^\circ$$

Substitute 12 A rms for $\mathbf{I}_P$ and 40° for θ .

$$\begin{aligned}\mathbf{I}_{BC} &= \frac{12}{\sqrt{3}} \angle 40^\circ - 90^\circ \\ &= 6.93\angle -50^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{BC}$ is $\boxed{6.93\angle -50^\circ \text{ A rms}}$.

Step 4 of 4

Consider the expression for $\mathbf{I}_{CA}$.

$$\mathbf{I}_{CA} = \frac{\mathbf{I}_P}{\sqrt{3}} \angle \theta - 210^\circ$$

Substitute 12 A rms for $\mathbf{I}_P$ and 40° for θ .

$$\begin{aligned}\mathbf{I}_{CA} &= \frac{12}{\sqrt{3}} \angle 40^\circ - 210^\circ \\ &= 6.93\angle -170^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{CA}$ is $\boxed{6.93\angle -170^\circ \text{ A rms}}$.

Step 1 of 4

11.009 P

Consider the Figure P11.7 from the text book.

Reduce the Wye network shown in dotted lines in Figure 1 into delta network by assuming the impedances as shown.

Figure 1

Step 2 of 4

Consider the expression for Z_{ab}.

$$\begin{aligned} Z_{ab} &= (1+j1)+(1+j1)+\frac{(1+j1)\cdot(1+j1)}{(1+j1)} \\ &= (1+j1)+(1+j1)+(1+j1) \\ &= 3+j3\,\Omega \end{aligned}$$

Therefore, the value of Z_{ab} is $\boxed{3+j3\,\Omega}$.

Step 3 of 4

Consider the expression for Z_{bc}.

$$\begin{aligned} Z_{bc} &= (1+j1)+(1+j1)+\frac{(1+j1)\cdot(1+j1)}{(1+j1)} \\ &= (1+j1)+(1+j1)+(1+j1) \\ &= 3+j3\,\Omega \end{aligned}$$

Therefore, the value of Z_{bc} is $\boxed{3+j3\,\Omega}$.

Step 4 of 4

Consider the expression for Z_{ca}.

$$\begin{aligned} Z_{ca} &= (1+j1)+(1+j1)+\frac{(1+j1)\cdot(1+j1)}{(1+j1)} \\ &= (1+j1)+(1+j1)+(1+j1) \\ &= 3+j3\,\Omega \end{aligned}$$

Therefore, the value of Z_{ca} is $\boxed{3+j3\,\Omega}$.

Step 1 of 12

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \frac{\mathbf{V}_{ab}}{\sqrt{3}}\angle -30^\circ$$

Substitute $480\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{ab}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{480}{\sqrt{3}}\angle 0^\circ - 30^\circ \\ &= 277\angle -30^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $277\angle -30^\circ \text{ V rms}$.

Step 2 of 12

Convert the delta connected load to wye connection.

$$Z_{\Delta-Y} = \frac{Z_\Delta}{3}$$

Substitute $30 - j12\,\Omega$ for Z_Δ.

$$\begin{aligned}Z_{\Delta-Y} &= \frac{30 - j12}{3} \\ &= 10 - j4\,\Omega\end{aligned}$$

Therefore, the value of $Z_{\Delta-Y}$ is $10 - j4\,\Omega$.

Step 3 of 12

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 12

Calculate the equivalent impedance of the two loads.

$$\begin{aligned}Z_{load} &= \frac{(15 + j8)(10 - j4)}{(15 + j8) + (10 - j4)} \\ &= \frac{182 + j20}{25 + j4} \\ &= 7.22 - j0.36\,\Omega\end{aligned}$$

Therefore, the equivalent value of the two loads is $7.22 - j0.36\,\Omega$.

Step 5 of 12

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 6 of 12

Calculate the value of $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{0.5 + j1 + 7.22 - j0.36} \\ &= \frac{\mathbf{V}_{an}}{7.72 + j0.64} \\ &= \frac{\mathbf{V}_{an}}{7.746\angle 4.74^\circ}\end{aligned}$$

Substitute $277\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{277\angle -30^\circ}{7.746\angle 4.74^\circ} \\ &= 35.78\angle -34.74^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{35.76\angle -34.74^\circ \text{ A rms}}$.

Step 7 of 12

Compare $\mathbf{I}_{aA} = 35.76\angle -34.74^\circ \text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta \text{ A rms}$

$\mathbf{I}_P = 35.76 \text{ A rms}$ and $\theta = -34.74^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 35.76 A rms for $\mathbf{I}_P$ and -34.74° for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 35.76\angle -34.74^\circ - 120^\circ \\ &= 35.76\angle -154.74^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{35.76\angle -154.74^\circ \text{ A rms}}$.

Step 8 of 12

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 35.76 A rms for $\mathbf{I}_P$ and -34.74° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 35.76\angle -34.74^\circ + 120^\circ \\ &= 35.76\angle 85.26^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{35.76\angle 85.26^\circ \text{ A rms}}$.

Step 9 of 12

Refer Figure 2.

Consider the expression for $\mathbf{I}_{AN2}$ using the current division rule.

$$\begin{aligned}\mathbf{I}_{AN2} &= \mathbf{I}_{aA}\left(\frac{15 + j8}{15 + j8 + 10 - j4}\right) \\ &= \mathbf{I}_{aA}\left(\frac{15 + j8}{25 + j4}\right) \\ &= \mathbf{I}_{aA}(0.635 + j0.219) \\ &= \mathbf{I}_{aA}(0.67\angle 19.03^\circ)\end{aligned}$$

Substitute $35.76\angle -34.74^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{AN2} &= (35.76\angle -34.74^\circ)(0.67\angle 19.03^\circ) \\ &= 23.96\angle -15.7^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AN2}$ is $23.96\angle -15.7^\circ \text{ A rms}$.

Step 10 of 12

Consider the expression for $\mathbf{V}_{AN}$ using the voltage division rule.

$$\mathbf{V}_{AN} = \mathbf{V}_{an}\left(\frac{Z_{load}}{Z_{load} + Z_{line}}\right)$$

Substitute $277\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$, $7.22 - j0.36\,\Omega$ for Z_{load} and $0.5 + j1\,\Omega$ for Z_{line}.

$$\begin{aligned}\mathbf{V}_{AN} &= (277\angle -30^\circ)\left(\frac{7.22 - j0.36}{7.22 - j0.36 + 0.5 + j1}\right) \\ &= (277\angle -30^\circ)\left(\frac{7.22 - j0.36}{7.72 + j0.64}\right) \\ &= (277\angle -30^\circ)(0.925 - j0.123) \\ &= (277\angle -30^\circ)(0.933\angle -7.57^\circ)\end{aligned}$$

$$\mathbf{V}_{AN} = 258.44\angle -37.57^\circ \text{ V rms}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $258.44\angle -37.57^\circ \text{ V rms}$.

Step 11 of 12

Consider the expression for the power factor angle at the delta load.

$$\begin{aligned}\theta &= \tan^{-1}\left(\frac{-12}{30}\right) \\ &= \tan^{-1}(-0.4) \\ &= -21.8^\circ\end{aligned}$$

Therefore, the value of the power factor angle is -21.8°.

Step 12 of 12

Consider the expression for the power absorbed by the delta load.

$$S = 3|\mathbf{V}_{AN}||\mathbf{I}_{AN2}|\angle\theta$$

Substitute -21.8° for θ, 258.44 V rms for $\mathbf{V}_{AN}$ and 23.96 A rms for $\mathbf{I}_{AN2}$.

$$\begin{aligned}S &= 3(258.44)(23.96)\angle -21.8^\circ \\ &= 18.58\angle -21.8^\circ \text{ kVA} \\ &= 17.25 - j6.9 \text{ kVA}\end{aligned}$$

Therefore, the value of power absorbed by the delta connected load is

$\boxed{17.25 - j6.9 \text{ kVA}}$.

Step 1 of 9

11.010
P

Consider the Figure P11.8 from the text book.

Simplify the delta network shown in dotted lines in Figure 1 into wye network by assuming the impedances as shown.

Figure 1

Step 2 of 9

Consider the expression for Z_1 .

$$\begin{aligned} Z_1 &= \frac{(1+j1)(1+j1)}{(1+j1)+(1+j1)+(-j2)} \\ &= \frac{j2}{2} \\ &= j1\Omega \end{aligned}$$

Therefore, the value of Z_1 is $j1\Omega$.

Step 3 of 9

Consider the expression for Z_2 .

$$\begin{aligned} Z_2 &= \frac{(1+j1)(-j2)}{(1+j1)+(1+j1)+(-j2)} \\ &= \frac{2-j2}{2} \\ &= 1-j1\,\Omega \end{aligned}$$

Therefore, the value of Z_2 is $1-j1\,\Omega$.

Step 4 of 9

Consider the expression for Z_3 .

$$\begin{aligned} Z_3 &= \frac{(1+j1)(-j2)}{(1+j1)+(1+j1)+(-j2)} \\ &= \frac{2-j2}{2} \\ &= 1-j1\,\Omega \end{aligned}$$

Therefore, the value of Z_3 is $1-j1\,\Omega$.

Step 5 of 9

Redraw Figure 1 as shown in Figure 2.

Figure 2

Step 6 of 9

Redraw Figure 2 as shown in Figure 3.
Figure 3

Step 7 of 9

Calculate the parallel combination of impedances Z_5 and Z_6.

$$Z_7 = \frac{Z_5 Z_6}{Z_5 + Z_6}$$

Since $Z_5 = 1-j3\,\Omega$ and $Z_6 = 1-j4\,\Omega$,

$$\begin{aligned} Z_7 &= \frac{(1-j3)(1-j4)}{(1-j3)+(1-j4)} \\ &= \frac{-11-j7}{2-j7} \\ &= 0.51-j1.72\,\Omega \end{aligned}$$

Therefore, the value of Z_7 is $0.51-j1.72\,\Omega$.

Step 8 of 9

Redraw Figure 3 as shown in Figure 4.

Figure 4

Step 9 of 9

Calculate the value of Z .

$$\begin{aligned} Z &= 2+0.51-j1.72+1/2 \\ &= 3.01-j1.72 \\ &= 3.47\angle-29.75^\circ\,\Omega \end{aligned}$$

Therefore, the value of Z is $\boxed{3.47\angle-29.75^\circ\,\Omega}$.

Step 1 of 4

Consider the expression for the total real power absorbed by the load.

$$P = \sqrt{3} V_L I_L \cos\theta$$

Substitute $12\,\text{kW}$ for P, 208 V rms for V_L and 0.8 for $\cos\theta$.

$$12\text{ k} = \sqrt{3}(208) I_L (0.8)$$
$$I_L = \frac{12\text{ k}}{\sqrt{3}(208)(0.8)}$$
$$I_L = \frac{12\text{ k}}{288.21}$$
$$I_L = 41.64\text{ A rms}$$

Therefore, the value of the line current is 41.64 A rms.

Step 2 of 4

Consider the expression for magnitude of the load impedance.

$$|Z_L| = \frac{V_P}{I_L}$$

Since $V_P = \frac{V_L}{\sqrt{3}}$,

$$|Z_L| = \frac{V_L}{\sqrt{3} I_L}$$

Substitute 41.64 A rms for I_L and 208 V rms for V_L.

$$\begin{aligned} |Z_L| &= \frac{208}{\sqrt{3}(41.64)} \\ &= \frac{208}{\sqrt{3}(41.64)} \\ &= \frac{208}{72.12} \\ &= 2.88\,\Omega \end{aligned}$$

Therefore, the value of the magnitude of the load impedance is $2.88\,\Omega$.

Step 3 of 4

Consider the expression for the power factor angle.

$$\begin{aligned} \theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ \end{aligned}$$

Therefore, the value of the power factor angle is 36.87°.

Step 4 of 4

Consider the expression for the load impedance.

$$Z_L = |Z_L| \angle\theta$$

Substitute 36.87° for θ and $2.88\,\Omega$ for $|Z_L|$.

$$Z_L = 2.88\angle 36.87^\circ\,\Omega$$

Therefore, the value of the load impedance is $\boxed{2.88\angle 36.87^\circ\,\Omega}$.

11.011
P

Step 1 of 6

Consider the line voltage.

$$V_L = \sqrt{3}V_p$$

Calculate the phase voltage.

$$V_P = \frac{V_L}{\sqrt{3}}$$

Substitute 100 V for V_L in equation.

$$\begin{aligned} V_P &= \frac{100}{\sqrt{3}} \\ &= 57.735\text{ V} \end{aligned}$$

Step 2 of 6

Calculate the line voltage , $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = V_P\angle\mathbf{V}_{an}$$

Substitute 57.735 V for V_P and $0°$ for $\angle V_{an}$ in equation.

$$\mathbf{V}_{an} = 57.735\angle 0°\text{ V}$$

Step 3 of 6

The line current for the a phase is ,

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{2+50+j30}$$

Substitute $57.735\angle 0°\text{ V}$ for $\mathbf{V}_{an}$ in equation.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{57.735\angle 0°\text{ V}}{52+j30} \\ &= \frac{57.735\angle 0°}{60\angle 29.98°} \\ &= 0.9617\angle -29.98°\text{ A} \end{aligned}$$

Step 4 of 6

Calculate the load voltage for the a phase is,

$$\mathbf{V}_{AN} = \mathbf{I}_{aA}(50+j30)$$

Substitute $0.9617\angle -29.98°\text{ A}$ for $\mathbf{I}_{aA}$ in equation.

$$\begin{aligned} \mathbf{V}_{AN} &= (0.9617\angle -29.98°)(50+j30) \\ &= 56.077\angle 0.982°\text{ V} \end{aligned}$$

Therefore, the load voltage for the *a* phase is $\boxed{56.077\angle 0.982°\text{ V}}$.

Step 5 of 6

Calculate the load voltage for the *b* phase system is,

$$\mathbf{V}_{BN} = \mathbf{V}_{AN}\angle -120°$$

Substitute $56.077\angle 0.982°\text{ V}$ for $\mathbf{V}_{AN}$ in equation.

$$\begin{aligned} \mathbf{V}_{BN} &= 56.077\angle -120° + 0.982° \\ &= 56.077\angle -119.018°\text{ V} \end{aligned}$$

Therefore, the load voltage for the *b* phase is $\boxed{56.077\angle -119.018°\text{ V}}$.

Step 6 of 6

Calculate the load voltage for the *c* phase system is,

$$\mathbf{V}_{CN} = \mathbf{V}_{AN}\angle -240°$$

Substitute $56.077\angle 0.982°\text{ V}$ for $\mathbf{V}_{AN}$ in equation.

$$\begin{aligned} \mathbf{V}_{CN} &= 56.077\angle -240° + 0.982° \\ &= 56.077\angle -239.014°\text{ V} \end{aligned}$$

Therefore, the load voltage for the *c* phase is $\boxed{56.077\angle -239.014°\text{ V}}$.

Step 1 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 7

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA}=\frac{\mathbf{V}_{AN}}{8+j3}$$

Substitute $104.02\angle 26.6°$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA}&=\frac{104.02\angle 26.6°}{8+j3}\\&=\frac{104.02\angle 26.6°}{8.54\angle 20.56°}\\&=12.18\angle 6.04°\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $12.18\angle 6.04°$ A rms.

Step 3 of 7

Consider the expression for the power factor angle at the laod.

$$\theta=\angle\mathbf{V}_{AN}-\angle\mathbf{I}_{aA}$$

Substitute $26.6°$ for $\angle\mathbf{V}_{AN}$ and $6.04°$ for $\angle\mathbf{I}_{aA}$.

$$\begin{aligned}\theta&=26.6°-6.04°\\&=20.56°\end{aligned}$$

Therefore, the value fo the power factor angle at the load is $20.56°$.

Step 4 of 7

Consider the expression for the power absorbed by the load.

$$S_{load}=|V_{AN}||\mathbf{I}_{aA}|\angle\theta$$

Substitute $20.56°$ for θ, 12.18 A rms for $|\mathbf{I}_{aA}|$ and 104.02 V rms for $|\mathbf{V}_{AN}|$.

$$\begin{aligned}S_{load}&=(104.02)(12.18)\angle 20.56°\\&=1266.96\angle 20.56°\\&=1186.26+j444.95\text{ VA}\end{aligned}$$

Therefore, the value of the complex power absorbed by the load is

$$\boxed{1186.26+j444.95\text{ VA}}.$$

Step 5 of 7

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an}=\mathbf{I}_{aA}(1+j1)+\mathbf{V}_{AN}$$

Substitute $12.18\angle 6.04°$ A rms for $\mathbf{I}_{aA}$ and $104.02\angle 26.6°$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an}&=(12.18\angle 6.04°)(1+j1)+104.02\angle 26.6°\\&=(12.18\angle 6.04°)(1.42\angle 45°)+104.02\angle 26.6°\\&=17.3\angle 51.04°+104.02\angle 26.6°\\&=119.98\angle 30.02°\text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $119.98\angle 30.02°$ V rms.

Step 6 of 7

Consider the expression for the power factor angle at the source.

$$\theta_S=\angle\mathbf{V}_{an}-\angle\mathbf{I}_{aA}$$

Substitute $30.02°$ for $\angle\mathbf{V}_{an}$ and $6.04°$ for $\angle\mathbf{I}_{aA}$.

$$\begin{aligned}\theta_S&=30.02°-6.04°\\&=23.98°\end{aligned}$$

Therefore, the value fo the power factor angle at the source is $23.98°$.

Step 7 of 7

Consider the expression for the power delivered by the source.

$$S_{source}=|V_{an}||\mathbf{I}_{aA}|\angle\theta_S$$

Substitute $23.98°$ for θ_S, 12.18 A rms for $|\mathbf{I}_{aA}|$ and 119.98 V rms for $|\mathbf{V}_{AN}|$.

$$\begin{aligned}S_{source}&=(119.98)(12.18)\angle 23.98°\\&=1461.36\angle 23.98°\\&=1335.23+j593.92\text{ VA}\end{aligned}$$

Therefore, the value of the complex power delivered by the source is

$$\boxed{1335.23+j593.92\text{ VA}}.$$

11.012
P

Step 1 of 5

Consider the expression for $\mathbf{V}_L$.

$$\mathbf{V}_L = 208\text{ V rms}$$

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{208}{\sqrt{3}}\angle 0° - 30°\text{ V rms}\\ &= 120\angle -30°\text{ V rms}\end{aligned}$$

Step 2 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle -30°}{36 + j12}\\ &= 3.16\angle -48.44°\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{3.16\angle -48.44°\text{ A rms}}$.

Step 4 of 5

Compare $\mathbf{I}_{aA} = 3.16\angle -48.44°\text{ A}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\text{ A}$.

$\mathbf{I}_P = 3.16$ and $\theta = -48.44°$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120°$$

Substitute 3.16 for $\mathbf{I}_P$ and $-48.44°$ for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 3.16\angle -48.44° - 120°\\ &= 3.16\angle -168.44°\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{3.16\angle -168.44°\text{ A rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120°$$

Substitute 3.16 for $\mathbf{I}_P$ and $-48.44°$ for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 3.16\angle -48.44° + 120°\\ &= 3.16\angle -71.56°\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{3.16\angle -71.56°\text{ A rms}}$.

11.013

E

Step 1 of 5

Consider the expression for $\mathbf{V}_{AN}$.

$$|\mathbf{V}_{AN}| = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute 480 V rms for $\mathbf{V}_{AB}$.

$$|\mathbf{V}_{AN}| = \frac{480}{\sqrt{3}}$$
$$= 277.13\text{ V rms}$$

Therefore, the value of $\mathbf{V}_{AN}$ is 277.13 V rms.

Step 2 of 5

Consider the expression for the power factor angle at load 1.

$$\theta = \cos^{-1}(0.8)$$
$$= 36.87°$$

Therefore, the value of the power factor angle at load 1 is $36.87°$.

Step 3 of 5

Consider the expression for the power factor angle at load 2.

$$\theta = \cos^{-1}(0.9)$$
$$= 25.84°$$

Therefore, the value of the power factor angle at load 2 is $25.84°$.

Step 4 of 5

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2}$$

Substitute $5\angle 36.87°\text{ kVA}$ for S_{load1} and $10\angle 25.84°\text{ kVA}$ for S_{load2}.

$$S_T = 5\angle 36.87°\text{ k} + 10\angle 25.84°\text{ k}$$
$$= 14.94\angle 29.51°\text{ kVA}$$

Therefore, the value of the total power dissipated at the load is $14.94\angle 29.51°\text{ kVA}$.

Step 5 of 5

Consider the expression for the power in terms of line current and line voltage.

$$|S_T| = 3|\mathbf{V}_{AN}|\mathbf{I}_{aA}$$

Substitute 14.94 kVA for $|S_T|$ and $277.13°\text{ V rms}$ for $|\mathbf{V}_{AN}|$.

$$14.94\text{ k} = 3(277.13)\mathbf{I}_{aA}$$
$$\mathbf{I}_{aA} = \frac{14.94\text{ k}}{3(277.13)}$$
$$\mathbf{I}_{aA} = 17.97\text{ A rms}$$

Therefore, the value of magnitude of line current is $\boxed{17.97\text{ A rms}}$.

11.013 P

Step 1 of 7

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = 120\angle 60^\circ \text{ V rms}$$

Compare $\mathbf{V}_{an} = 120\angle 60^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_p\angle\theta \text{ V}$.

$\mathbf{V}_p = 120$ and $\theta = 60^\circ$

Step 2 of 7

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_p\angle\theta - 120^\circ$$

Substitute 120 for $\mathbf{V}_p$ and 60° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 120\angle 60^\circ - 120^\circ \\ &= 120\angle -60^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{120\angle -60^\circ \text{ V rms}}$.

Step 3 of 7

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_p\angle\theta + 120^\circ$$

Substitute 120 for $\mathbf{V}_p$ and 60° for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 120\angle 60^\circ + 120^\circ \\ &= 120\angle 180^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{120\angle 180^\circ \text{ V rms}}$.

Step 4 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 5 of 7

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle 60^\circ}{12 + j16 + 0.8 + j1.4} \\ &= \frac{120\angle 60^\circ}{12.8 + j17.4} \\ &= 5.56\angle 6.34^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{5.56\angle 6.34^\circ \text{ A rms}}$.

Step 6 of 7

Compare $\mathbf{I}_{aA} = 5.56\angle 6.34^\circ \text{ A}$ with $\mathbf{I}_{aA} = \mathbf{I}_p\angle\theta \text{ A}$.

$\mathbf{I}_p = 5.56$ and $\theta = 6.34^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_p\angle\theta - 120^\circ$$

Substitute 5.56 for $\mathbf{I}_p$ and 6.34° for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 5.56\angle 6.34^\circ - 120^\circ \\ &= 5.56\angle -113.66^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{5.56\angle -113.66^\circ \text{ A rms}}$.

Step 7 of 7

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_p\angle\theta + 120^\circ$$

Substitute 5.56 for $\mathbf{I}_p$ and 6.34° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 5.56\angle 6.34^\circ + 120^\circ \\ &= 5.56\angle 126.34^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{5.56\angle 126.34^\circ \text{ A rms}}$.

11.014

E

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

Ask an expert

11.014
P

Step 1 of 5

It is given that,

The delta connected source phase voltage, $\mathbf{V}_{ab} = 120\angle 30^\circ \text{ V rms}$

The value of first load impedance, $\mathbf{Z}_1 = 10 + j\ \Omega$

The value of second load impedance, $\mathbf{Z}_2 = 20 + 5j\ \Omega$

Step 2 of 5

As the source is connected in delta and the loads are connected in wye, convert the delta connected source to wye.

Calculate the corresponding phase voltage for the Source in the wye network.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{\mathbf{V}_{ab}}{\sqrt{3}}\angle -30^\circ \\ &= \frac{(120\angle 30^\circ)}{\sqrt{3}}(1\angle -30^\circ) \\ &= \frac{120}{\sqrt{3}}\angle 0^\circ \text{ V rms}\end{aligned}$$

Since the source and loads are in parallel the same source voltage appears across the load.

As the load voltage sequence is same as that of the source voltage sequence. The load phase voltages will have same magnitude but 120° phase variation.

Therefore, the load phase voltages for the first load are

$$\boxed{\begin{aligned}\mathbf{V}_{A1n} &= \frac{120}{\sqrt{3}} \text{ V rms} \\ \mathbf{V}_{B1n} &= \frac{120}{\sqrt{3}}\angle -120^\circ \text{ V rms} \\ \mathbf{V}_{C1n} &= \frac{120}{\sqrt{3}}\angle -240^\circ \text{ V rms}\end{aligned}}$$

Step 3 of 5

Therefore, the load phase voltages for the second load are

$$\boxed{\begin{aligned}\mathbf{V}_{A2n} &= \frac{120}{\sqrt{3}} \text{ V rms} \\ \mathbf{V}_{B2n} &= \frac{120}{\sqrt{3}}\angle -120^\circ \text{ V rms} \\ \mathbf{V}_{C2n} &= \frac{120}{\sqrt{3}}\angle -240^\circ \text{ V rms}\end{aligned}}$$

Step 4 of 5

For load 1, since the source and load are in parallel the same source voltage appears across the load, calculate the current in the line '*a*'.

$$\begin{aligned}\mathbf{I}_{A1n} &= \frac{\mathbf{V}_{A1n}}{\mathbf{Z}_1} \\ &= \frac{120}{\sqrt{3}(10 + j1)} \\ &= \frac{120\angle 0^\circ}{\sqrt{3}(10.0498\angle 5.71^\circ)} \\ &= 6.893\angle -5.71^\circ \text{ A rms}\end{aligned}$$

Thus, the current, $\mathbf{I}_{A1n}$ in the line '*a*' for the load 1 is $\boxed{6.893\angle -5.71^\circ \text{ A rms}}$.

As the load is balanced load the current in the two lines '*b*' and '*c*' will have the same magnitude, but the phases will lag the line current in '*a*' by 120° and 240° respectively.

Thus, the current, $\mathbf{I}_{B1n}$ in the line '*b*' for the load 1 is $\boxed{6.893\angle -125.71^\circ \text{ A rms}}$.

Thus, the current, $\mathbf{I}_{C1n}$ in the line '*c*' for the load 1 is $\boxed{6.893\angle -245.71^\circ \text{ A rms}}$.

Step 5 of 5

For load 2, since the source and load are in parallel the same source voltage appears across the load, calculate the current in the line '*a*'.

$$\begin{aligned}\mathbf{I}_{A2n} &= \frac{\mathbf{V}_{A2n}}{Z_2} \\ &= \frac{120}{\sqrt{3}(20 + j5)} \\ &= \frac{120\angle 0^\circ}{\sqrt{3}(20.615\angle 14.036^\circ)} \\ &= 3.360\angle -14.036^\circ \text{ A rms}\end{aligned}$$

Thus, the current, $\mathbf{I}_{A2n}$ in the line '*a*' for the load 2 is $\boxed{3.36\angle -14.036^\circ \text{ A rms}}$.

As the load is balanced load the current in the two lines '*b*' and '*c*' will have the same magnitude, but the phases will lag the line current in '*a*' by 120° and 240° respectively.

Thus, the current $\mathbf{I}_{B2n}$ in the line '*b*' for the load 2 is $\boxed{3.36\angle -134.036^\circ \text{ A rms}}$.

Thus, the current $\mathbf{I}_{C2n}$ in the line '*c*' for the load 2 is $\boxed{3.36\angle -254.036^\circ \text{ A rms}}$.

11.015

E

Step 1 of 4

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute 24 MVA for $|S|$ and 0.78 for pf.

$$\begin{aligned} S_{old} &= \frac{24\text{ M}}{3}\angle\cos^{-1}(0.78) \\ &= 8\text{ M}\angle 38.74^\circ \\ &= 6.24 + j5.01\text{ MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 6.42\text{ MW} \quad Q_{old} = 5.01\text{ Mvar}$$

Therefore, the values of the real and reactive powers at the load are 6.24 MW and 5.01 Mvar respectively.

Step 2 of 4

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle\cos^{-1}(pf_{new})$$

Substitute 0.9 for pf_{new} and 6.24 MW for P.

$$\begin{aligned} S_{new} &= \frac{6.24\text{ M}}{0.9}\angle\cos^{-1}(0.9) \\ &= 6.97\text{ M}\angle 25.84^\circ \\ &= 6.27 + j3.04\text{ MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = 3.04\text{ Mvar}$$

The value of the new reactive power is 3.04 Mvar.

Step 3 of 4

The value of the new reactive power is due to the introduction of the capacitors in the circuit. Hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute 3.04 Mvar for Q_{new} and 5.01 Mvar for Q_{old}.

$$\begin{aligned} Q_C &= 3.04\text{ M} - 5.01\text{ M} \\ &= -1.97\text{ Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is -1.97 Mvar.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|V_{ab}|^2\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|V_{ab}|^2(2\pi f)C$$

Substitute $\frac{34.5}{\sqrt{3}}\text{ kvar}$ for V_{ab}, 60 Hz for f and -1.97 Mvar for Q_C.

$$\begin{aligned} -1.97\text{ M} &= -\left|\frac{34.5\text{ k}}{\sqrt{3}}\right|^2(2\pi(60))C \\ 1.97\text{ M} &= (1190.25\text{ M})(376.99)C \\ 1.97 &= (149570.78)C \\ C &= \frac{1.97}{149570.78} \\ C &= 13.17\ \mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{13.17\ \mu\text{F}}$.

Step 1 of 9

Calculate the reactance offered by the inductor.

$$X_L = 2\pi fL$$

Substitute $50\,\text{mH}$ for L and $60\,\text{Hz}$ for f.

$$\begin{aligned} X_L &= 2\pi(60)(50\,\text{m}) \\ &= 18.85\,\Omega \end{aligned}$$

Therefore, the value of X_L is $18.85\,\Omega$.

Step 2 of 9

Consider the expression for the load impedance.

$$Z_{load} = R + jX_L$$

Substitute $18.85\,\Omega$ for X_L and $20\,\Omega$ for R.

$$Z_{load} = 20 + j(18.85)\,\Omega$$

Therefore, the value of Z_{load} is $20 + j(18.85)\,\Omega$.

Step 3 of 9

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 9

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 5 of 9

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(20 + j18.85)(20 + j18.85)}{(20 + j18.85) + (20 + j18.85) + (20 + j18.85)} \\ &= \frac{(20 + j18.85)(20 + j18.85)}{3(20 + j18.85)} \\ &= \frac{(20 + j18.85)}{3} \\ &= 6.67 + j6.28\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $6.67 + j6.28\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 6.67 + j6.28\,\Omega$ and $Z_3 = 6.67 + j6.28\,\Omega$.

Step 6 of 9

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 7 of 9

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{6.67 + j6.28\,\Omega}$$

Substitute $120\angle 20^\circ\,\text{V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{120\angle 20^\circ}{9.16\angle 43.28^\circ} \\ &= 13.1\angle -23.28^\circ\,\text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{13.1\angle -23.28^\circ\,\text{A rms}}$.

Step 8 of 9

Compare $\mathbf{I}_{aA} = 13.1\angle -23.28^\circ\,\text{A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\,\text{A}$.

$\mathbf{I}_P = 13.1$ and $\theta = -23.28^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 13.1 for $\mathbf{I}_P$ and -23.28° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 13.1\angle -23.28^\circ - 120^\circ \\ &= 13.1\angle -143.28^\circ\,\text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{13.1\angle -143.28^\circ\,\text{A rms}}$.

Step 9 of 9

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 13.1 for $\mathbf{I}_P$ and -23.28° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 13.1\angle -23.28^\circ + 120^\circ \\ &= 13.1\angle 96.72^\circ\,\text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{13.1\angle 96.72^\circ\,\text{A rms}}$.

Step 1 of 3

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute $6\,\text{MVA}$ for $|S|$ and 0.75 for pf.

$$\begin{aligned} S_{old} &= \frac{6\,\text{M}}{3}\angle\cos^{-1}(0.75) \\ &= 2\,\text{M}\angle 41.41^\circ \\ &= 1.5 + j1.32\,\text{MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 1.5\,\text{MW} \quad Q_{old} = 1.32\,\text{Mvar}$$

Therefore, the values of the real and reactive powers at the load are $1.5\,\text{MW}$ and $1.32\,\text{Mvar}$ respectively.

Step 2 of 3

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle\cos^{-1}(pf_{new})$$

Substitute 0.98 for pf_{new} and $1.5\,\text{MW}$ for P.

$$\begin{aligned} S_{new} &= \frac{1.5\,\text{M}}{0.98}\angle\cos^{-1}(0.87) \\ &= 1.53\,\text{M}\angle 11.48^\circ \\ &= 1.5 + j0.31\,\text{MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = 0.31\,\text{Mvar}$$

The value of the new reactive power is $0.31\,\text{Mvar}$.

Step 3 of 3

The value of the new reactive power is due to the introduction of the capacitors in the circuit. Hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute $0.31\,\text{Mvar}$ for Q_{new} and $1.32\,\text{Mvar}$ for Q_{old}.

$$\begin{aligned} Q_C &= 0.31\,\text{M} - 1.32\,\text{M} \\ &= -1.01\,\text{Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-1.01\,\text{Mvar}$.

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|\text{V}_{ab}|^2\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|\text{V}_{ab}|^2(2\pi f)C$$

Substitute $13.8\,\text{kV rms}$ for V_{ab}, $60\,\text{Hz}$ for f and $-1.01\,\text{Mvar}$ for Q_C.

$$\begin{aligned} -1.01\,\text{M} &= -|13.8\,\text{k}|^2(2\pi(60))C \\ 1.01\,\text{M} &= (190.44\,\text{M})(376.99)C \\ 1.01 &= (71793.98)C \\ C &= \frac{1.01}{71\,793.98} \\ C &= 14.07\,\mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{14.07\,\mu\text{F}}$.

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 3 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA}=\frac{\mathbf{V}_{an}}{14+j12}$$

Substitute $120\angle 80^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA}&=\frac{120\angle 80^\circ}{18.44\angle 40.60^\circ}\\&=6.51\angle 39.4^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $6.51\angle 39.4^\circ$ A rms.

Since the line current is equal to the phase current in Wye-Wye connected system,

$$\mathbf{I}_{an}=6.51\angle 39.4^\circ \text{ A rms}$$

Therefore, the value of $\mathbf{I}_{an}$ is $\boxed{6.51\angle 39.4^\circ \text{ A rms}}$.

Step 4 of 5

Compare $\mathbf{I}_{aA}=6.51\angle 39.4^\circ$ A rms with $\mathbf{I}_{aA}=\mathbf{I}_p\angle\theta$ A.

$\mathbf{I}_p=6.51$ and $\theta=39.4^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB}=\mathbf{I}_p\angle\theta-120^\circ$$

Substitute $\mathbf{I}_{bn}$ for $\mathbf{I}_{bB}$, 6.51 for $\mathbf{I}_p$ and 39.4° for θ.

$$\begin{aligned}\mathbf{I}_{bn}&=6.51\angle 39.4^\circ-120^\circ\\&=6.51\angle -80.6^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bn}$ is $\boxed{6.51\angle -80.6^\circ \text{ A rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC}=\mathbf{I}_p\angle\theta+120^\circ$$

Substitute $\mathbf{I}_{cn}$ for $\mathbf{I}_{cC}$ 6.51 for $\mathbf{I}_p$ and 39.4° for θ.

$$\begin{aligned}\mathbf{I}_{cn}&=6.51\angle 39.4^\circ+120^\circ\\&=6.51\angle 159.4^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cn}$ is $\boxed{6.51\angle 159.4^\circ \text{ A rms}}$.

11.017
P

Step 1 of 6

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 208\angle 0^\circ \text{ V rms}$$

Consider the value for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{208}{\sqrt{3}}\angle 0^\circ - 30^\circ \text{ V rms} \\ &= 120.1\angle -30^\circ \text{ V rms}\end{aligned}$$

Step 2 of 6

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 6

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 4 of 6

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{1 + j5 + 25 + j25} \\ &= \frac{\mathbf{V}_{an}}{26 + j30}\end{aligned}$$

Substitute $120.1\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120.1\angle -30^\circ}{9.16\angle 49.09^\circ} \\ &= 13.11\angle -79.9^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{13.11\angle -79.9^\circ \text{ A rms}}$.

Step 5 of 6

Compare $\mathbf{I}_{aA} = 13.11\angle -79.9^\circ \text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_p\angle\theta \text{ A}$.

$\mathbf{I}_p = 13.11$ and $\theta = -79.9^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_p\angle\theta - 120^\circ$$

Substitute 13.11 for $\mathbf{I}_p$ and -79.9° for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 13.11\angle -79.9^\circ - 120^\circ \\ &= 39.7\angle -199.9^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{39.7\angle -199.9^\circ \text{ A rms}}$.

Step 6 of 6

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_p\angle\theta + 120^\circ$$

Substitute 13.11 for $\mathbf{I}_p$ and -79.9° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 13.11\angle -79.9^\circ + 120^\circ \\ &= 13.11\angle 40.1^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{13.11\angle 40.1^\circ \text{ A rms}}$.

11.018
P

Step 1 of 4

Consider the value for $\mathbf{V}_L$.

$$\mathbf{V}_L = 440\angle 70^\circ \text{ V rms}$$

Consider the value for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{440}{\sqrt{3}}\angle 70^\circ - 30^\circ \text{ V rms}\\ &= 250.03\angle 40^\circ \text{ V rms}\end{aligned}$$

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \mathbf{V}_{an} - \mathbf{I}_{aA}Z_{line}$$

Substitute $250.03\angle 40^\circ \text{ V rms}$ for $\mathbf{V}_{an}$, $16.68\angle 20.98^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $1.2 + j1.8\,\Omega$ for Z_{line}.

$$\begin{aligned}\mathbf{V}_{AN} &= 250.03\angle 40^\circ - (16.68\angle 20.98^\circ)(1.2 + j1.8)\\ &= 250.03\angle 40^\circ - (16.68\angle 20.98^\circ)(2.16\angle 56.31)\\ &= 250.03\angle 40^\circ - 36.03\angle 77.29^\circ\\ &= 222.44\angle 34.37^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $222.44\angle 34.37^\circ \text{ V rms}$.

Step 4 of 4

Consider the expression for Z_{load}.

$$Z_{load} = \frac{\mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $222.44\angle 34.37^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$ and $16.68\angle 20.98^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned}Z_{load} &= \frac{222.44\angle 34.37^\circ}{16.68\angle 20.98^\circ}\\ &= 13.34\angle 13.39^\circ\\ &= 12.97 + j3.09\,\Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{12.97 + j3.09\,\Omega}$.

11.019
P

Step 1 of 3

The load voltage of phase '*a*' is,

$$\mathbf{V}_{AN} = 110\angle 30^\circ \text{ Vrms}$$

Draw the per phase equivalent circuit.

Figure 1

Step 2 of 3

Calculate the line current, $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{AN}}{10+j10}\\ &= \frac{110\angle 30^\circ}{10+j10}\\ &= 7.778\angle -15^\circ \text{ Arms}\end{aligned}$$

Apply Kirchhoff's voltage law for loop in Figure 1.

$$-\mathbf{V}_{an} + (1+j1)\mathbf{I}_{aA} + \mathbf{V}_{AN} = 0$$
$$\mathbf{V}_{an} = (1+j1)\mathbf{I}_{aA} + \mathbf{V}_{AN}$$

Substitute $7.778\angle -15^\circ$ for $\mathbf{I}_{aA}$ and $110\angle 30^\circ$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (1+j1)(7.778\angle -15^\circ) + 110\angle 30^\circ\\ &= 10.99\angle 30^\circ + 110\angle 30^\circ\\ &= 121\angle 30^\circ \text{ Vrms}\end{aligned}$$

Therefore, the input phase voltage is,

$$\mathbf{V}_{an} = 121\angle 30^\circ \text{ Vrms}$$

Step 3 of 3

Calculate the input line voltage, $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \sqrt{3}\mathbf{V}_{an}\angle 30^\circ$$

Substitute $121\angle 30^\circ$ Vrms for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{ab} &= \sqrt{3}(121\angle 30^\circ)\angle 30^\circ\\ &= 209.57\angle 60^\circ \text{ Vrms}\end{aligned}$$

The corresponding input line voltages are,

$$\mathbf{V}_{bc} = 209.57\angle -60^\circ \text{ Vrms}$$
$$\mathbf{V}_{ca} = 209.57\angle 180^\circ \text{ Vrms}$$

Therefore, the line voltages of the input are,

$$\boxed{\begin{aligned}\mathbf{V}_{ab} &= 209.57\angle 60^\circ \text{ Vrms}\\ \mathbf{V}_{bc} &= 209.57\angle -60^\circ \text{ Vrms}\\ \mathbf{V}_{ca} &= 209.57\angle 180^\circ \text{ Vrms}\end{aligned}}.$$

11.020
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{10 + j13}$$

Substitute $108.58\angle 79.81°\ \text{V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{108.58\angle 79.81°}{10 + j13} \\ &= \frac{108.58\angle 79.81°}{16.4\angle 52.43°} \\ &= 6.62\angle 27.38°\ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $6.62\angle 27.38°\ \text{A rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(1 + j1.4) + \mathbf{V}_{AN}$$

Substitute $6.62\angle 27.38°\ \text{A rms}$ for $\mathbf{I}_{aA}$ and $108.58\angle 79.81°\ \text{V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (6.62\angle 27.38°)(1 + j1.4) + 108.58\angle 79.81° \\ &= (6.62\angle 27.38°)(1.72\angle 54.46°) + 108.58\angle 79.81° \\ &= 11.39\angle 61.84° + 108.58\angle 79.81° \\ &= 119.47\angle 78.12°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{119.47\angle 78.12°\ \text{V rms}}$.

Step 4 of 5

Compare $\mathbf{V}_{an} = 119.47\angle 78.12°\ \text{V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta\ \text{V}$.

$\mathbf{V}_P = 119.47$ and $\theta = 78.12°$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120°$$

Substitute 119.47 for $\mathbf{V}_P$ and $78.12°$ for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 119.47\angle 78.12° - 120° \\ &= 119.47\angle -41.88°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{119.47\angle -41.88°\ \text{V rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120°$$

Substitute 119.47 for $\mathbf{V}_P$ and $78.12°$ for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 119.47\angle 78.12° + 120° \\ &= 119.47\angle 198.12°\ \text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{119.47\angle 198.12°\ \text{V rms}}$.

Step 1 of 6

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 100\angle 0^\circ \text{ V rms}$$

Consider the value for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{100}{\sqrt{3}}\angle 0^\circ - 30^\circ \text{ V rms}\\ &= 57.74\angle -30^\circ \text{ V rms}\end{aligned}$$

Step 2 of 6

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 6

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 4 of 6

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{1 + j0 + 20 + j20}\\ &= \frac{\mathbf{V}_{an}}{21 + j20}\end{aligned}$$

Substitute $57.74\angle -30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{57.74\angle -30^\circ}{29\angle 43.6^\circ}\\ &= 1.99\angle -73.6^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{1.99\angle -73.6^\circ \text{ A rms}}$.

Step 5 of 6

Compare $\mathbf{I}_{aA} = 1.99\angle -73.6^\circ \text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta \text{ A}$.

$\mathbf{I}_P = 1.99$ and $\theta = -73.6^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 1.99 for $\mathbf{I}_P$ and -73.6° for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 1.99\angle -73.6^\circ - 120^\circ\\ &= 1.99\angle -193.6^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{1.99\angle -193.6^\circ \text{ A rms}}$.

Step 6 of 6

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 1.99 for $\mathbf{I}_P$ and -73.6° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 1.99\angle -73.6^\circ + 120^\circ\\ &= 1.99\angle 46.4^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{1.99\angle 46.4^\circ \text{ A rms}}$.

11.022
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{10 + j10}$$

Substitute $120\angle 60^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle 60^\circ}{10 + j10} \\ &= \frac{120\angle 60^\circ}{1.14\angle 45^\circ} \\ &= 8.49\angle 15^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $8.49\angle 15^\circ \text{ A rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(2 + j1.4) + \mathbf{V}_{AN}$$

Substitute $8.49\angle 15^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $120\angle 60^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (8.49\angle 15^\circ)(2 + j1.4) + 120\angle 60^\circ \\ &= (8.49\angle 15^\circ)(2.44\angle 34.99^\circ) + 120\angle 60^\circ \\ &= 20.72\angle 49.99^\circ + 120\angle 60^\circ \\ &= 140.45\angle 58.53^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{140.45\angle 58.53^\circ \text{ V rms}}$.

Step 4 of 5

Compare $\mathbf{V}_{an} = 140.45\angle 58.53^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V}$.

$\mathbf{V}_P = 140.45$ and $\theta = 58.53^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ$$

Substitute 140.45 for $\mathbf{V}_P$ and 58.53° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 140.45\angle 58.53^\circ - 120^\circ \\ &= 140.45\angle -61.47^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{140.45\angle -61.47^\circ \text{ V rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120^\circ$$

Substitute 140.45 for $\mathbf{V}_P$ and 58.53° for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 140.45\angle 58.53^\circ + 120^\circ \\ &= 140.45\angle 178.53^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{140.45\angle 178.53^\circ \text{ V rms}}$.

11.023 P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{14 + j12}$$

Substitute $440\angle 30^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{440\angle 30^\circ}{14 + j12} \\ &= \frac{440\angle 30^\circ}{18.44\angle 40.60^\circ} \\ &= 23.86\angle -10.6^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $23.86\angle -10.6^\circ \text{ A rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(1 + j1) + \mathbf{V}_{AN}$$

Substitute $23.86\angle -10.6^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $440\angle 30^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (23.86\angle -10.6^\circ)(1 + j1) + 440\angle 30^\circ \\ &= (23.86\angle -10.6^\circ)(1.41\angle 45) + 440\angle 30^\circ \\ &= 33.64\angle 34.4^\circ + 440\angle 30^\circ \\ &= 473.55\angle 30.31^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $473.55\angle 30.31^\circ \text{ V rms}$.

Step 4 of 5

Compare $\mathbf{V}_{an} = 473.55\angle 30.31^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_p\angle\theta \text{ V}$.

$\mathbf{V}_p = 473.55$ and $\theta = 30.31^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_p\angle\theta - 120^\circ$$

Substitute 473.55 for $\mathbf{V}_p$ and 30.31° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 473.55\angle 30.31^\circ - 120^\circ \\ &= 473.55\angle -89.69^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $473.55\angle -89.69^\circ \text{ V rms}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn}$$

Since $\mathbf{V}_{an} = 473.55\angle 30.31^\circ \text{ V rms}$ and $\mathbf{V}_{bn} = 473.55\angle -89.29^\circ \text{ V rms}$,

$$\begin{aligned}\mathbf{V}_{ab} &= 473.55\angle 30.31^\circ - 473.55\angle -89.29^\circ \\ &= 818.56\angle 60.51^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{818.56\angle 60.51^\circ \text{ V rms}}$.

11.024
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{10 + j13}$$

Substitute $110\angle 80^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{110\angle 80^\circ}{10 + j13} \\ &= \frac{110\angle 80^\circ}{16.4\angle 52.43^\circ} \\ &= 6.71\angle 27.57^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $6.71\angle 27.57^\circ \text{ A rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(1 + j1.4) + \mathbf{V}_{AN}$$

Substitute $6.71\angle 27.57^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $110\angle 80^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (6.71\angle 27.57^\circ)(1 + j1.4) + 110\angle 80^\circ \\ &= (6.71\angle 27.57^\circ)(1.72\angle 54.46^\circ) + 110\angle 80^\circ \\ &= 11.54\angle 82.03^\circ + 110\angle 80^\circ \\ &= 121.53\angle 80.2^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{121.53\angle 80.2^\circ \text{ V rms}}$.

Step 4 of 5

Compare $\mathbf{V}_{an} = 121.53\angle 80.2^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V}$.

$\mathbf{V}_P = 121.53$ and $\theta = 80.2^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ$$

Substitute 121.53 for $\mathbf{V}_P$ and 80.2° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 121.53\angle 80.2^\circ - 120^\circ \\ &= 121.53\angle -39.8^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{121.53\angle -39.8^\circ \text{ V rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120^\circ$$

Substitute 121.53 for $\mathbf{V}_P$ and 80.2° for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 121.53\angle 80.4^\circ + 120^\circ \\ &= 121.53\angle 200.4^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{121.53\angle 200.4^\circ \text{ V rms}}$.

11.025
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{8 + j12}$$

Substitute $116.63\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{116.63\angle 10^\circ}{8 + j12} \\ &= \frac{116.63\angle 10^\circ}{14.42\angle 56.31^\circ} \\ &= 8.09\angle -46.31^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $8.09\angle -46.31^\circ \text{ A rms}$.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(0.6 + j0.9) + \mathbf{V}_{AN}$$

Substitute $8.09\angle -46.31^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $116.63\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an} &= (8.09\angle -46.31^\circ)(0.6 + j0.9) + 116.63\angle 10^\circ \\ &= (8.09\angle -46.31^\circ)(1.08\angle 56.31^\circ) + 116.63\angle 10^\circ \\ &= 8.74\angle 10^\circ + 116.63\angle 10^\circ \\ &= 125.37\angle 10^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $125.37\angle 10^\circ \text{ V rms}$.

Step 4 of 5

Compare $\mathbf{V}_{an} = 125.37\angle 10^\circ \text{ V rms}$ with $\mathbf{V}_{an} = \mathbf{V}_P\angle\theta \text{ V}$.

$\mathbf{V}_P = 125.37$ and $\theta = 10^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ$$

Substitute 125.37 for $\mathbf{V}_P$ and 10° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 125.37\angle 10^\circ - 120^\circ \\ &= 125.37\angle -110^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $125.37\angle -110^\circ \text{ V rms}$.

Step 5 of 5

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn}$$

Since $\mathbf{V}_{an} = 125.37\angle 10^\circ \text{ V rms}$ and $\mathbf{V}_{bn} = 125.37\angle -110^\circ \text{ V rms}$,

$$\begin{aligned}\mathbf{V}_{ab} &= 125.37\angle 10^\circ - 125.37\angle -110^\circ \\ &= 217.15\angle 40^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{217.15\angle 40^\circ \text{ V rms}}$.

11.026
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA}=\frac{\mathbf{V}_{AN}}{14+j12}$$

Substitute $398.1\angle 17.99^\circ$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA}&=\frac{398.1\angle 17.99^\circ}{14+j12}\\&=\frac{398.1\angle 17.99^\circ}{18.44\angle 40.60^\circ}\\&=21.59\angle -22.61^\circ\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $21.59\angle -22.61^\circ$ A rms.

Step 3 of 5

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an}=\mathbf{I}_{aA}(1+j1.8)+\mathbf{V}_{AN}$$

Substitute $21.59\angle -22.61^\circ$ A rms for $\mathbf{I}_{aA}$ and $398.1\angle 17.99^\circ$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{an}&=(21.59\angle -22.61^\circ)(1+j1.8)+398.1\angle 17.99^\circ\\&=(21.59\angle -22.61^\circ)(2.06\angle 60.95)+398.1\angle 17.99^\circ\\&=44.48\angle 34.34^\circ+398.1\angle 17.99^\circ\\&=440.96\angle 19.62^\circ\text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $440.96\angle 19.62^\circ$ V rms.

Step 4 of 5

Compare $\mathbf{V}_{an}=440.96\angle 19.62^\circ$ V rms with $\mathbf{V}_{an}=\mathbf{V}_P\angle\theta$ V.

$\mathbf{V}_P=440.96$ and $\theta=19.62^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn}=\mathbf{V}_P\angle\theta-120^\circ$$

Substitute 440.96 for $\mathbf{V}_P$ and 19.62° for θ.

$$\begin{aligned}\mathbf{V}_{bn}&=440.96\angle 19.62^\circ-120^\circ\\&=440.96\angle -100.38^\circ\text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $440.96\angle -100.38^\circ$ V rms.

Step 5 of 5

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab}=\mathbf{V}_{an}-\mathbf{V}_{bn}$$

Since $\mathbf{V}_{an}=440.96\angle 19.62^\circ$ V rms and $\mathbf{V}_{bn}=440.96\angle -99.98^\circ$ V rms,

$$\begin{aligned}\mathbf{V}_{ab}&=440.96\angle 19.62^\circ-440.96\angle -99.98^\circ\\&=762.22\angle 49.82^\circ\text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{762.22\angle 49.82^\circ\text{ V rms}}$.

Step 1 of 11

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 11

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 11

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(24+j18)(24+j18)}{(24+j18)+(24+j18)+(24+j18)} \\ &= \frac{(24+j18)(24+j18)}{3(24+j18)} \\ &= \frac{(24+j18)}{3} \\ &= 8+j6\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $8+j6\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 8+j6\,\Omega$ and $Z_3 = 8+j6\,\Omega$.

Step 4 of 11

Consider the circuit diagram shown in Figure 3.

Step 5 of 11

Figure 3

Step 6 of 11

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{8+j6+0.5+j0.4} \\ &= \frac{\mathbf{V}_{an}}{8.5+j6.4} \end{aligned}$$

Substitute $120\angle 40^\circ\ \mathbf{V}\ \mathbf{rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{120\angle 40^\circ}{10.64\angle 36.98^\circ} \\ &= 11.28\angle 3.02^\circ\ \mathbf{A\ rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $11.28\angle 3.02^\circ\ \mathbf{A\ rms}$.

Step 7 of 11

Compare $\mathbf{I}_{aA} = 11.28\angle 3.02^\circ\ \mathbf{A\ rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\ \mathbf{A}$.

$\mathbf{I}_P = 11.28$ and $\theta = 3.02^\circ$

Consider the expression for $\mathbf{I}_{AB}$.

$$\mathbf{I}_{AB} = \frac{\mathbf{I}_P}{\sqrt{3}}\angle\theta + 30^\circ$$

Substitute $11.28\ \mathbf{A\ rms}$ for $\mathbf{I}_P$ and 3.02° for θ.

$$\begin{aligned} \mathbf{I}_{AB} &= \frac{11.28}{\sqrt{3}}\angle 3.02 + 30^\circ \\ &= 6.51\angle 33.02^\circ\ \mathbf{A\ rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{AB}$ is $\boxed{6.51\angle 33.02^\circ\ \mathbf{A\ rms}}$.

Step 8 of 11

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 11.28 for $\mathbf{I}_P$ and 3.02° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 11.28\angle 3.02^\circ - 120^\circ \\ &= 11.28\angle -116.98^\circ\ \mathbf{A\ rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $11.28\angle -116.98^\circ\ \mathbf{A\ rms}$.

Step 9 of 11

Compare $\mathbf{I}_{bB} = 11.28\angle -116.58^\circ\ \mathbf{A\ rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\ \mathbf{A}$.

$\mathbf{I}_P = 12$ and $\theta = -116.7^\circ$

Consider the expression for $\mathbf{I}_{BC}$.

$$\mathbf{I}_{BC} = \frac{\mathbf{I}_P}{\sqrt{3}}\angle\theta + 30^\circ$$

Substitute $11.28\ \mathbf{A\ rms}$ for $\mathbf{I}_P$ and -116.58° for θ.

$$\begin{aligned} \mathbf{I}_{BC} &= \frac{11.28}{\sqrt{3}}\angle -116.58^\circ + 30^\circ \\ &= 6.51\angle -86.58^\circ \end{aligned}$$

Therefore, the value of $\mathbf{I}_{BC}$ is $\boxed{6.51\angle -86.58^\circ\ \mathbf{A\ rms}}$.

Step 10 of 11

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 11.28 for $\mathbf{I}_P$ and 3.02° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 11.28\angle 3.02^\circ + 120^\circ \\ &= 11.28\angle 123.02^\circ\ \mathbf{A\ rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $11.28\angle 123.02^\circ\ \mathbf{A\ rms}$.

Step 11 of 11

Compare $\mathbf{I}_{bB} = 11.28\angle 123.02^\circ\ \mathbf{A\ rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\ \mathbf{A}$.

$\mathbf{I}_P = 11.28$ and $\theta = 123.02^\circ$

Consider the expression for $\mathbf{I}_{CA}$.

$$\mathbf{I}_{CA} = \frac{\mathbf{I}_P}{\sqrt{3}}\angle\theta + 30^\circ$$

Substitute $11.28\ \mathbf{A\ rms}$ for $\mathbf{I}_P$ and 123.02° for θ.

$$\begin{aligned} \mathbf{I}_{CA} &= \frac{11.28}{\sqrt{3}}\angle 123.02^\circ + 30^\circ \\ &= 6.51\angle 153.02^\circ \end{aligned}$$

Therefore, the value of $\mathbf{I}_{CA}$ is $\boxed{6.51\angle 153.02^\circ\ \mathbf{A\ rms}}$.

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{8 + j4}$$

Substitute $111.62\angle -1.33^\circ$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{111.62\angle -1.33^\circ}{8.94\angle 26.57^\circ} \\ &= 9.3\angle -27.9^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $9.3\angle -27.9^\circ$ A rms .

Step 3 of 3

Consider the expression for Z_{line} .

$$Z_{line} = \frac{\mathbf{V}_{an} - \mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $9.3\angle -27.9^\circ$ A rms for $\mathbf{I}_{aA}$, $111.62\angle -1.33^\circ$ V rms for $\mathbf{V}_{AN}$ and

$120\angle 0^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned}Z_{line} &= \frac{120\angle 0^\circ - 111.62\angle -1.33^\circ}{9.3\angle -27.9^\circ} \\ &= \frac{8.8\angle 17.12^\circ}{9.3\angle -27.9^\circ} \\ &= 0.95\angle 45.02^\circ \\ &= 0.67 + j0.67\,\Omega\end{aligned}$$

Therefore, the value of Z_{line} is $\boxed{0.67 + j0.67\,\Omega}$.

Step 1 of 6

11.029
P

Consider the circuit diagram shown in Figure 1.

Step 2 of 6

Figure 1

Step 3 of 6

Consider the expression for the current $\mathbf{I}_{aA}$ in the lines terms of power and line impedance.

$$\mathbf{I}_{aA} = \sqrt{\frac{P_{line}}{3(|Z_{line}|)}}$$

Substitute $400\ \mathrm{W}$ for P_{line} and $2 + j1\,\Omega$ for Z_{line}.

$$\begin{aligned}\mathbf{I}_{aA} &= \sqrt{\frac{400}{3(|2+j1|)}}\\ &= \sqrt{\frac{400}{3(2.24)}}\\ &= \sqrt{\frac{400}{6.72}}\\ &= \sqrt{59.52}\end{aligned}$$

$$\mathbf{I}_{aA} = 7.72\ \mathrm{A\ rms}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $7.72\ \mathrm{A\ rms}$.

Step 4 of 6

Consider the expression for magnitude of the load impedance.

$$|Z_{load}| = \left|\frac{\mathbf{V}_{an}}{\mathbf{I}_{aA}}\right|$$

Substitute $7.72\ \mathrm{A\ rms}$ for $\mathbf{I}_{aA}$ and $105.28\angle 31.56^\circ\ \mathrm{V\ rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}|Z_{load}| &= \left|\frac{105.28\angle 31.56^\circ}{7.72}\right|\\ &= \left|\frac{105.28}{7.72}\right|\\ &= 13.64\,\Omega\end{aligned}$$

Therefore, the value of the magnitude of the load impedance is $13.64\,\Omega$.

Step 5 of 6

Since, the power factor is 0.77 lagging, calculate the impedance phase angle.

$$\begin{aligned}\theta &= \cos^{-1}(0.77)\\ &= 39.65^\circ\end{aligned}$$

Therefore, the value of the phase angle of the load is 39.65°.

Step 6 of 6

Consider the expression for the load impedance.

$$Z_{load} = |Z_{load}|\angle\theta$$

Substitute 39.65° for θ and $13.64\,\Omega$ for $|Z_{load}|$.

$$\begin{aligned}Z_{load} &= 13.64\angle 39.65^\circ\\ &= 10.94 + j8.14\,\Omega\end{aligned}$$

Therefore, the required value of the load impedance is $\boxed{10.94 + j8.14\,\Omega}$.

11.030
P

Step 1 of 4

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 220\angle 30^\circ \text{ V rms}$$

Consider the value for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{220}{\sqrt{3}}\angle 30^\circ - 30 \text{ V rms} \\ &= 127.02\angle 0^\circ \text{ V rms}\end{aligned}$$

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{10 + j1}$$

Substitute $120\angle 0^\circ$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle 0^\circ}{10.05\angle 5.71^\circ} \\ &= 11.94\angle -5.71^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $11.94\angle -5.71^\circ$ A rms.

Step 4 of 4

Consider the expression for Z_{line}.

$$Z_{line} = \frac{\mathbf{V}_{an} - \mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $11.94\angle -5.71^\circ$ A rms for $\mathbf{I}_{aA}$, $120\angle 0^\circ$ V rms for $\mathbf{V}_{AN}$ and $127.02\angle 0^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned}Z_{line} &= \frac{127.02\angle 0^\circ - 120\angle 0^\circ}{11.94\angle -5.71^\circ} \\ &= \frac{7\angle 0^\circ}{11.94\angle -5.71^\circ} \\ &= 0.59\angle 5.71^\circ \\ &= 0.58 + j0.06\,\Omega\end{aligned}$$

Therefore, the value of Z_{line} is $\boxed{0.58 + j0.06\,\Omega}$.

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{20 + j12}$$

Substitute $111.40\angle -0.2°$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{111.49\angle -0.2°}{23.32\angle 30.96°} \\ &= 4.78\angle -31.16° \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $4.78\angle -31.16°$ A rms.

Step 3 of 5

Consider the expression for Z_{line}.

$$Z_{line} = \frac{\mathbf{V}_{an} - \mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $4.78\angle -31.16°$ A rms for $\mathbf{I}_{aA}$, $111.49\angle -0.2°$ V rms for $\mathbf{V}_{AN}$ and $120\angle 0°$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned}Z_{line} &= \frac{120\angle 0° - 111.49\angle -0.2°}{4.78\angle -31.16°} \\ &= \frac{8.52\angle 2.62°}{4.78\angle -31.16°} \\ &= 1.78\angle 31.78° \\ &= 1.52 + j0.94\Omega\end{aligned}$$

Therefore, the value of Z_{line} is $1.52 + j0.94\ \Omega$.

Step 4 of 5

Consider Figure 2 which represents the shorted circuited load.

Figure 2

Step 5 of 5

From Figure 2,

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{1.52 + j0.94}$$

Substitute $120\angle 0°$ V rms for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle 0°}{1.79\angle 31.74°} \\ &= 67.04\angle -31.74° \text{ A rms}\end{aligned}$$

Therefore, the magnitude value of short circuited load current is $\boxed{67.04 \text{ A rms}}$.

11.032
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Step 2 of 5

Figure 1

Step 3 of 5

Consider the expression for voltage drop across the line.

$$\mathbf{V}_{line} = \mathbf{I}_{aA}(Z_{line})$$

Substitute $7.10\angle -10.28°\text{ A rms}$ for $\mathbf{I}_{aA}$ and $0.8 + j1\,\Omega$ for Z_{line}.

$$\begin{aligned}\mathbf{V}_{line} &= (7.10\angle -10.28°)(0.8 + j1)\\ &= (7.10\angle -10.28°)(1.28\angle 51.34°)\\ &= 9.09\angle 41.06°\text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{line}$ is $9.09\angle 41.06°\text{ V rms}$.

Step 4 of 5

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \mathbf{V}_{an} - \mathbf{V}_{line}$$

Substitute $9.09\angle 41.06°\text{ V rms}$ for $\mathbf{V}_{line}$ and $120\angle 40°\text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{AN} &= 120\angle 40° - 9.09\angle 41.06°\\ &= 110.91\angle 39.91°\text{V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $110.91\angle 39.91°\text{V rms}$.

Step 5 of 5

Consider the expression for Z_{load}.

$$Z_{load} = \frac{\mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $110.91\angle 39.91°\text{V rms}$ for $\mathbf{V}_{AN}$ and $7.10\angle -10.28°\text{ A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned}Z_{load} &= \frac{110.91\angle 39.91°}{7.10\angle -10.28°}\\ &= 15.62\angle 50.19°\\ &= 10 + j12\,\Omega\end{aligned}$$

Therefore, the value of Z_{load} is $\boxed{10 + j12\,\Omega}$.

11.033

P

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Step 1 of 4

The phase voltage is,

$$\mathbf{V}_{an} = 200\angle 30^\circ \text{ V}$$

The per-phase impedance for delta load is,

$$\mathbf{Z}_\Delta = 50 + j70\ \Omega$$

Calculate the equivalent wye impedance for delta load.

$$\begin{aligned}\mathbf{Z}_{Y(equ\Delta)} &= \frac{\mathbf{Z}_\Delta}{3} \\ &= \frac{50 + j70\ \Omega}{3} \\ &= 16.67 + j23.33\ \Omega\end{aligned}$$

Step 2 of 4

The single phase equivalent circuit is shown in Figure 1.

Figure 1

Step 3 of 4

Calculate the equivalent impedance.

$$\begin{aligned}\mathbf{Z}_{eq} &= (16.67 + j23.33) \| (15 + j30) \\ &= \frac{(16.67 + j23.33)(15 + j30)}{16.67 + j23.33 + 15 + j30} \\ &= \frac{-449.85 + j850.05}{31.67 + j53.33} \\ &= 8.308 + j13.24\ \Omega\end{aligned}$$

Calculate the line current $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{Z_{eq}} \\ &= \frac{200\angle 30^\circ \text{ V}}{8.308 + j13.24\ \Omega} \\ &= \frac{200\angle 30^\circ \text{ V}}{15.63\angle 57.89^\circ\ \Omega} \\ &= 12.8\angle -27.89^\circ \text{ A}\end{aligned}$$

Step 4 of 4

Calculate the line current $\mathbf{I}_{bB}$.

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{aA}\angle -120^\circ \\ &= (12.8\angle -27.89^\circ)(\angle -120^\circ) \\ &= 12.8\angle -147.89^\circ \text{ A}\end{aligned}$$

Calculate the line current $\mathbf{I}_{cC}$.

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{aA}\angle 120^\circ \\ &= (12.8\angle -27.89^\circ)(\angle 120^\circ) \\ &= 12.8\angle 92.11^\circ \text{ A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 12.8\angle -27.89^\circ \text{ A} \\ \mathbf{I}_{bB} &= 20.07\angle -147.89^\circ \text{ A} \\ \mathbf{I}_{cC} &= 20.07\angle 92.11^\circ \text{ A}\end{aligned}}\ .$$

Step 1 of 4

The phase voltage is,

$$\mathbf{V}_{an} = 200\angle 30^\circ \text{ V}$$

The per-phase impedance for delta load is,

$$\mathbf{Z}_\Delta = 50 + j70\ \Omega$$

Calculate the equivalent wye impedance for delta load.

$$\begin{aligned}\mathbf{Z}_{Y(equ\Delta)} &= \frac{\mathbf{Z}_\Delta}{3}\\ &= \frac{50 + j70\ \Omega}{3}\\ &= 16.67 + j23.33\ \Omega\end{aligned}$$

Step 2 of 4

The single phase equivalent circuit is shown in Figure 1.

Figure 1

Step 3 of 4

Calculate the equivalent wye impedance.

$$\begin{aligned}\mathbf{Z}_{eq} &= (16.67 + j23.33) \| (15 + j30)\\ &= \frac{(16.67 + j23.33)(15 + j30)}{16.67 + j23.33 + 15 + j30}\\ &= \frac{-449.85 + j850.05}{31.67 + j53.33}\\ &= 8.308 + j13.24\ \Omega\end{aligned}$$

Calculate the line current, $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{Z_{eq}}\\ &= \frac{200\angle 30^\circ \text{ V}}{8.308 + j13.24\ \Omega}\\ &= \frac{200\angle 30^\circ \text{ V}}{15.63\angle 57.89^\circ\ \Omega}\\ &= 12.8\angle -27.89^\circ \text{ A}\end{aligned}$$

Step 4 of 4

Calculate the line current, $\mathbf{I}_{bB}$.

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{aA}\angle -120^\circ\\ &= (12.8\angle -27.89^\circ)(\angle -120^\circ)\\ &= 12.8\angle -147.89^\circ \text{ A}\end{aligned}$$

Calculate the line current, $\mathbf{I}_{cC}$.

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{aA}\angle 120^\circ\\ &= (12.8\angle -27.89^\circ)(\angle 120^\circ)\\ &= 12.8\angle 92.11^\circ \text{ A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 12.8\angle -27.89^\circ \text{ A}\\ \mathbf{I}_{bB} &= 12.8\angle -147.89^\circ \text{ A}\\ \mathbf{I}_{cC} &= 12.8\angle 92.11^\circ \text{ A}\end{aligned}}.$$

Therefore, the results obtained in equivalent wye connection and equivalent delta connection is same.

Step 1 of 2

Draw the balanced 3 phase wye-delta system.

Figure 1

Step 2 of 2

The phase current of load is,

$$\mathbf{I}_{AB} = 25\angle 60^\circ \text{ A}$$

Similarly,

$$\mathbf{I}_{BC} = 25\angle -60^\circ \text{ A}$$
$$\mathbf{I}_{CA} = 25\angle 180^\circ \text{ A}$$

Calculate the line currents.

$$\begin{aligned}\mathbf{I}_{aA} &= \mathbf{I}_{AB} - \mathbf{I}_{CA}\\ &= 25\angle 60^\circ - 25\angle 180^\circ\\ &= 43.3\angle 30^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{BC} - \mathbf{I}_{AB}\\ &= 25\angle -60^\circ - 25\angle 60^\circ\\ &= 43.3\angle -90^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{CA} - \mathbf{I}_{BC}\\ &= 25\angle 180^\circ - 25\angle -60^\circ\\ &= 43.3\angle 150^\circ \text{ A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 43.3\angle 30^\circ \text{ A}\\ \mathbf{I}_{bB} &= 43.3\angle -90^\circ \text{ A}\\ \mathbf{I}_{cC} &= 43.3\angle 150^\circ \text{ A}\end{aligned}}.$$

Step 1 of 4

Draw the balanced 3 phase wye-delta system.

Figure 1

Step 2 of 4

The load per phase is, $\mathbf{Z}_L = 20 + j10\ \Omega$.

The line voltages are,

$$\mathbf{V}_{ab} = 208\angle 30^\circ \text{ V}$$
$$\mathbf{V}_{bc} = 208\angle -90^\circ \text{ V}$$
$$\mathbf{V}_{ca} = 208\angle 150^\circ \text{ V}$$

Calculate the phase current, $\mathbf{I}_{AB}$ at the load.

$$\begin{aligned}\mathbf{I}_{AB} &= \frac{\mathbf{V}_{AB}}{\mathbf{Z}_L}\\ &= \frac{\mathbf{V}_{ab}}{\mathbf{Z}_L}\\ &= \frac{208\angle 30^\circ}{20 + j10}\\ &= 9.3\angle 3.435^\circ \text{ A}\end{aligned}$$

Step 3 of 4

Calculate the phase current, $\mathbf{I}_{BC}$ at the load.

$$\begin{aligned}\mathbf{I}_{BC} &= \frac{\mathbf{V}_{bc}}{\mathbf{Z}_L}\\ &= \frac{208\angle -90^\circ}{20 + j10}\\ &= 9.3\angle -116.56^\circ \text{ A}\end{aligned}$$

Calculate the phase current, $\mathbf{I}_{CA}$ at the load.

$$\begin{aligned}\mathbf{I}_{CA} &= \frac{\mathbf{V}_{ca}}{\mathbf{Z}_L}\\ &= \frac{208\angle 150^\circ}{20 + j10}\\ &= 9.3\angle 123.43^\circ \text{ A}\end{aligned}$$

Step 4 of 4

Calculate the line currents.

$$\begin{aligned}\mathbf{I}_{aA} &= \mathbf{I}_{AB} - \mathbf{I}_{CA}\\ &= 9.3\angle 3.435^\circ - 9.3\angle 123.43^\circ\\ &= 16.1\angle -26.56^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{BC} - \mathbf{I}_{AB}\\ &= 9.3\angle -116.56^\circ - 9.3\angle 3.435^\circ\\ &= 16.1\angle -146.56^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{CA} - \mathbf{I}_{BC}\\ &= 9.3\angle 123.43^\circ - 9.3\angle -116.56^\circ\\ &= 16.1\angle 93.46^\circ \text{ A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 16.1\angle -26.56^\circ \text{ A}\\ \mathbf{I}_{bB} &= 16.1\angle -146.56^\circ \text{ A}\\ \mathbf{I}_{cC} &= 16.1\angle 93.46^\circ \text{ A}\end{aligned}}.$$

Step 1 of 4

The phase voltage is, $\mathbf{V}_{an} = 120\angle 30°\ \text{V}$

The per-phase impedance for delta load is,

$$\mathbf{Z}_{\Delta} = 12 + j9\ \Omega$$

The per-phase impedance for wye load is,

$$\mathbf{Z}_{Y} = 6 + j3\ \Omega$$

Calculate the equivalent wye impedance for delta load.

$$\begin{aligned}\mathbf{Z}_{Y(\text{equ}\Delta)} &= \frac{\mathbf{Z}_{\Delta}}{3} \\ &= \frac{12 + j9}{3} \\ &= 4 + j3\ \Omega\end{aligned}$$

Step 2 of 4

The single phase equivalent circuit is shown in Figure 1.

Figure 1

Step 3 of 4

Calculate the equivalent wye impedance.

$$\begin{aligned}\mathbf{Z}_{eq} &= \left(\mathbf{Z}_{Y(\text{eq}\Delta)}\right) \| \left(\mathbf{Z}_{Y}\right) \\ &= (4 + j3) \| (6 + j3) \\ &= \frac{(4 + j3)(6 + j3)}{4 + j3 + 6 + j3} \\ &= \frac{15 + j30}{10 + j6}\end{aligned}$$

$$= 2.426 + j1.544\ \Omega$$

Calculate the line current, $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{Z_{eq}} \\ &= \frac{120\angle 30°\ \text{V}}{2.426 + j1.544\ \Omega} \\ &\quad 12 \\ &= \frac{120\angle 30°\ \text{V}}{2.875\angle 32.47°\ \Omega} \\ &= 41.74\angle -2.47°\ \text{A}\end{aligned}$$

Step 4 of 4

Calculate the line current, $\mathbf{I}_{bB}$.

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{aA}\angle -120° \\ &= (41.74\angle -2.47°)(\angle -120°) \\ &= 41.74\angle -122.47°\ \text{A}\end{aligned}$$

Calculate the line current, $\mathbf{I}_{cC}$.

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{aA}\angle 120° \\ &= (41.74\angle -2.47°)(\angle 120°) \\ &= 41.74\angle 117.53°\ \text{A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 41.74\angle -2.47°\ \text{A} \\ \mathbf{I}_{bB} &= 41.74\angle -122.47°\ \text{A} \\ \mathbf{I}_{cC} &= 41.74\angle 117.53°\ \text{A}\end{aligned}}\ .$$

Step 1 of 4

The line voltage is,

$$\mathbf{V}_{ab} = 100\angle -60^\circ \text{ V}$$

Calculate the a-phase voltage.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30^\circ} \\ &= \frac{100\angle -60^\circ \text{ V}}{\sqrt{3}\angle 30^\circ} \\ &= 57.735\angle -90^\circ \text{ V}\end{aligned}$$

The per-phase impedance for delta load is,

$$\mathbf{Z}_\Delta = 12 + j9\ \Omega$$

Calculate the equivalent wye impedance for delta load.

$$\begin{aligned}\mathbf{Z}_{Y(equ\Delta)} &= \frac{\mathbf{Z}_\Delta}{3} \\ &= \frac{12 + j9\ \Omega}{3} \\ &= 4 + j3\ \Omega\end{aligned}$$

Step 2 of 4

The single phase equivalent circuit is shown in Figure 1.

Figure 1

Step 3 of 4

Calculate the equivalent impedance.

$$\begin{aligned}\mathbf{Z}_{eq} &= (4 + j3\ \Omega) \| (6 + j3\ \Omega) \\ &= \frac{(4 + j3\ \Omega)(6 + j3\ \Omega)}{4 + j3\ \Omega + 6 + j3\ \Omega} \\ &= \frac{15 + j30\ \Omega}{10 + j6} \\ &= 2.426 + j1.544\ \Omega\end{aligned}$$

Calculate the line current $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{Z_{eq}} \\ &= \frac{57.735\angle -90^\circ \text{ V}}{2.426 + j1.544\ \Omega} \\ &= \frac{57.735\angle -90^\circ \text{ V}}{2.876\angle 32.47^\circ\ \Omega} \\ &= 20.07\angle -122.47^\circ \text{ A}\end{aligned}$$

Step 4 of 4

Calculate the line current $\mathbf{I}_{bB}$.

$$\begin{aligned}\mathbf{I}_{bB} &= \mathbf{I}_{aA}\left(\sqrt{3}\angle -120^\circ\right) \\ &= \left(20.07\angle -122.47^\circ \text{ A}\right)\left(\sqrt{3}\angle -120^\circ\right) \\ &= 34.769\angle 117.53^\circ \text{ A}\end{aligned}$$

Calculate the line current $\mathbf{I}_{cC}$.

$$\begin{aligned}\mathbf{I}_{cC} &= \mathbf{I}_{aA}\left(\sqrt{3}\angle 120^\circ\right) \\ &= \left(20.07\angle -122.47^\circ \text{ A}\right)\left(\sqrt{3}\angle 120^\circ\right) \\ &= 34.769\angle -2.47^\circ \text{ A}\end{aligned}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 20.07\angle -122.47^\circ \text{ A} \\ \mathbf{I}_{bB} &= 20.07\angle 117.53^\circ \text{ A} \\ \mathbf{I}_{cC} &= 20.07\angle -2.47^\circ \text{ A}\end{aligned}}\ .$$

11.040
P

Step 1 of 2

Calculate the load phase current.

$$\begin{aligned}\mathbf{I}_{AB} &= \frac{\mathbf{V}_{AB}}{\mathbf{Z}_{AB}} \\ &= \frac{115\angle 30^\circ \text{ V}}{10 + j5\ \Omega} \\ &= \frac{115\angle 30^\circ \text{ V}}{11.18\angle 26.56^\circ\ \Omega} \\ &= 10.285\angle 3.44^\circ \text{ A}\end{aligned}$$

Calculate the line current.

$$\begin{aligned}\mathbf{I}_{aA} &= \mathbf{I}_{AB}\left(\sqrt{3}\angle -30^\circ\right) \\ &= \left(10.285\angle 3.44^\circ \text{ A}\right)\left(\sqrt{3}\angle -30^\circ\right) \\ &= 17.815\angle -26.56^\circ \text{ A}\end{aligned}$$

Step 2 of 2

Calculate the source phase voltage.

$$\begin{aligned}\mathbf{V}_{ab} &= \mathbf{Z}_{\text{line}}\mathbf{I}_{aA} + \mathbf{V}_{AB} \\ &= \left(0.5 + j0.1\ \Omega\right)\left(17.815\angle -26.56^\circ \text{ A}\right) + 115\angle 30^\circ \text{ V} \\ &= \left(0.5 + j0.1\ \Omega\right)\left(15.935 - j7.965 \text{ A}\right) + 99.59 + j57.5 \text{ V} \\ &= 8.764 - j2.389 + 99.59 + j57.5 \text{ V}\end{aligned}$$

$$= 108.356 + j55.111 \text{ V}$$

$$= 121.565\angle 26.95^\circ \text{ V}$$

Therefore, the source phase voltage, $\mathbf{V}_{ab}$ is $\boxed{121.565\angle 26.95^\circ \text{ V}}$.

Step 1 of 5

11.041 P

The balanced Three-phase system with two loads is shown in Figure 1.

Figure 1

Step 2 of 5

Calculate the phase voltage of load 1.

$$\begin{aligned}\mathbf{V}_{AN1} &= \mathbf{I}_{AN1}\mathbf{Z}_{\mathrm{Y}}\\ &= (10\angle 30^\circ\ \mathrm{A})(6 + j2\ \Omega)\\ &= (10\angle 30^\circ\ \mathrm{A})(6.324\angle 18.43^\circ\ \Omega)\\ &= 63.24\angle 48.43^\circ\ \mathrm{V}\end{aligned}$$

Calculate the line voltage of load.

$$\begin{aligned}\mathbf{V}_{AB} &= \mathbf{V}_{AN1}\sqrt{3}\angle 30^\circ\\ &= (63.24\angle 48.43^\circ\ \mathrm{V})(\sqrt{3}\angle 30^\circ)\\ &= 109.53\angle 78.43^\circ\ \mathrm{V}\end{aligned}$$

Step 3 of 5

Calculate the phase current of load 2.

$$\begin{aligned}\mathbf{I}_{AB2} &= \frac{\mathbf{V}_{AB}}{\mathbf{Z}_{\Delta}}\\ &= \frac{109.53\angle 78.43^\circ\ \mathrm{V}}{9 + j3\ \Omega}\\ &= \frac{109.53\angle 78.43^\circ\ \mathrm{V}}{9.486\angle 18.43^\circ\ \Omega}\\ &= 11.546\angle 60^\circ\ \mathrm{A}\end{aligned}$$

Calculate the line current of load 2.

$$\begin{aligned}\mathbf{I}_{aA2} &= \mathbf{I}_{AB2}\sqrt{3}\angle -30^\circ\\ &= (11.546\angle 60^\circ\ \mathrm{A})(\sqrt{3}\angle -30^\circ)\\ &= 20\angle 30^\circ\ \mathrm{A}\end{aligned}$$

Step 4 of 5

Calculate the line current.

$$\begin{aligned}\mathbf{I}_{aA} &= \mathbf{I}_{AN1} + \mathbf{I}_{aA2}\\ &= 10\angle 30^\circ\ \mathrm{A} + 20\angle 30^\circ\ \mathrm{A}\\ &= 8.66 + j5 + 17.32 + j10\ \mathrm{A}\\ &= 25.98 + j15\ \mathrm{A}\end{aligned}$$

Calculate the source phase voltage $\mathbf{V}_{ab}$.

$$\begin{aligned}\mathbf{V}_{ab} &= (0.6 + j0.2\ \Omega)\mathbf{I}_{aA} + \mathbf{V}_{AB}\\ &= (0.6 + j0.2\ \Omega)(25.98 + j15\ \mathrm{A}) + 109.53\angle 78.43^\circ\ \mathrm{V}\\ &= 12.588 + j14.196 + 21.967 + j107.3\ \mathrm{V}\\ &= 34.55 + j121.5\ \mathrm{V}\\ &= 126.32\angle 74.123^\circ\ \mathrm{V}\end{aligned}$$

Step 5 of 5

Calculate the source phase voltage $\mathbf{V}_{bc}$.

$$\begin{aligned}\mathbf{V}_{bc} &= \mathbf{V}_{ab}\angle -120^\circ\\ &= (126.32\angle 74.123^\circ\ \mathrm{V})(\angle -120^\circ)\\ &= 126.32\angle -48.877^\circ\ \mathrm{V}\end{aligned}$$

Calculate the source phase voltage $\mathbf{V}_{ca}$.

$$\begin{aligned}\mathbf{V}_{ca} &= \mathbf{V}_{ab}\angle 120^\circ\\ &= (126.32\angle 74.123^\circ\ \mathrm{V})(\angle 120^\circ)\\ &= 126.32\angle 194.123^\circ\ \mathrm{V}\end{aligned}$$

Therefore, the phase voltages of source are,

$$\boxed{\begin{aligned}\mathbf{V}_{ab} &= 126.32\angle 74.123^\circ\ \mathrm{V}\\ \mathbf{V}_{bc} &= 126.32\angle -48.877^\circ\ \mathrm{V}\\ \mathbf{V}_{ca} &= 126.32\angle 194.123^\circ\ \mathrm{V}\end{aligned}}.$$

Step 1 of 8

Calculate the reactance offered by the inductor.

$$X_L = 2\pi fL$$

Substitute 20 mH for L and 60 Hz for f.

$$\begin{aligned} X_L &= 2\pi(60)(20\text{ m}) \\ &= 7.54\,\Omega \end{aligned}$$

Therefore, the value of X_L is $7.54\,\Omega$.

Consider the expression for the load impedance.

$$Z_{load} = R + jX_L$$

Substitute $18.85\,\Omega$ for X_L and $20\,\Omega$ for R.

$$Z_{load} = 20 + j(7.54)\Omega$$

Therefore, the value of Z_{load} is $20 + j(7.54)\Omega$.

Step 2 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 8

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 4 of 8

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(20 + j7.54)(20 + j7.54)}{(20 + j7.54) + (20 + j7.54) + (20 + j7.54)} \\ &= \frac{(20 + j7.54)(20 + j7.54)}{3(20 + j7.54)} \\ &= \frac{(20 + j7.54)}{3} \\ &= 6.67 + j2.51\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $6.67 + j2.51\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 6.67 + j2.51\,\Omega$ and $Z_3 = 6.67 + j2.51\,\Omega$.

Step 5 of 8

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 8

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{6.67 + j2.51\,\Omega}$$

Substitute $120\angle 30^\circ\text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{120\angle 30^\circ}{7.13\angle 20.62^\circ} \\ &= 16.83\angle 9.38^\circ\text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{16.83\angle 9.38^\circ\text{ A rms}}$.

Step 7 of 8

Compare $\mathbf{I}_{aA} = 16.83\angle 9.38^\circ\text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta\text{ A}$.

$\mathbf{I}_P = 16.83$ and $\theta = 9.38^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 16.83 for $\mathbf{I}_P$ and 9.38° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 16.83\angle 9.38^\circ - 120^\circ \\ &= 16.83\angle -110.62^\circ\text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{16.83\angle -110.62^\circ\text{ A rms}}$.

Step 8 of 8

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 16.83 for $\mathbf{I}_P$ and 9.38° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 16.83\angle 9.38^\circ + 120^\circ \\ &= 16.83\angle 129.38^\circ\text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{16.83\angle 129.38^\circ\text{ A rms}}$.

11.043 P

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{AN}}{16 + j20}$$

Substitute $110\angle 50^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{110\angle 50^\circ}{25.61\angle 51.34^\circ} \\ &= 4.29\angle -1.34^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $4.29\angle -1.34^\circ \text{ A rms}$.

Step 3 of 3

Consider the expression for Z_{line} .

$$Z_{line} = \frac{\mathbf{V}_{an} - \mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $4.29\angle -1.34^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$, $110\angle 50^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$ and $120\angle 50^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}Z_{line} &= \frac{120\angle 50^\circ - 110\angle 50^\circ}{4.29\angle -1.34^\circ} \\ &= \frac{10\angle 50^\circ}{4.29\angle -1.34^\circ} \\ &= 2.33\angle 51.34^\circ \\ &= 1.46 + j1.82\,\Omega\end{aligned}$$

Therefore, the value of Z_{line} is $\boxed{1.46 + j1.82\,\Omega}$.

Step 1 of 4

11.044 P

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}\left(Z_{line} + Z_{load}\right)$$

Substitute $9.6\angle -20^\circ$ A rms for $\mathbf{I}_{aA}$, $0.6 + j0.3\,\Omega$ for Z_{line} and $12 + j7\,\Omega$ for Z_{load}.

$$\begin{aligned}\mathbf{V}_{an} &= (9.6\angle -20^\circ)(0.6 + j0.3 + 12 + j7)\\ &= (9.6\angle -20^\circ)(12.6 + j7.3)\\ &= (9.6\angle -20^\circ)(14.56\angle 30.09^\circ)\\ &= 139.78\angle 10.09^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{139.78\angle 10.09^\circ \text{ V rms}}$.

Step 3 of 4

Compare $\mathbf{V}_{an} = 139.78\angle 10.09^\circ$ V rms with $\mathbf{V}_{an} = \mathbf{V}_p\angle\theta$ V.

$\mathbf{V}_p = 139.78$ and $\theta = 10.09^\circ$

Consider the expression for $\mathbf{V}_{bn}$.

$$\mathbf{V}_{bn} = \mathbf{V}_p\angle\theta - 120^\circ$$

Substitute 139.78 for $\mathbf{V}_p$ and 10.09° for θ.

$$\begin{aligned}\mathbf{V}_{bn} &= 139.78\angle 10.09^\circ - 120^\circ\\ &= 139.78\angle -109.91^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{1139.78\angle -109.91^\circ \text{ V rms}}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_p\angle\theta + 120^\circ$$

Substitute 139.78 for $\mathbf{V}_p$ and 10.09° for θ.

$$\begin{aligned}\mathbf{V}_{cn} &= 139.78\angle 10.09^\circ + 120^\circ\\ &= 139.78\angle 130.09^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{139.78\angle 130.09^\circ \text{ V rms}}$.

11.045
P

Step 1 of 4

Consider the expression for $\mathbf{V}_L$.

$$\mathbf{V}_L = 210\angle 40^\circ \text{ V rms}$$

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{210}{\sqrt{3}}\angle 40^\circ - 30^\circ \text{ V rms}\\ &= 121.24\angle 10^\circ \text{ V rms}\end{aligned}$$

Step 2 of 4

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 3 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \mathbf{V}_{an}\left(\frac{6+j4}{6+j4+0.2+j0.4}\right)\\ &= \mathbf{V}_{an}\left(\frac{6+j4}{6.2+j4.4}\right)\\ &= \mathbf{V}_{an}(0.95 - j0.03)\\ &= \mathbf{V}_{an}(0.95\angle -1.67^\circ)\end{aligned}$$

Substitute $121.24\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{AN} &= (121.24\angle 10^\circ)(0.95\angle -1.67^\circ)\\ &= 115.18\angle 8.33^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $115.18\angle 8.33^\circ \text{ V rms}$.

Step 4 of 4

Consider the expression for $\mathbf{V}_{AB}$.

$$\mathbf{V}_{AB} = \sqrt{3}\mathbf{V}_{AN}\angle 30^\circ$$

Substitute $115.18\angle 8.33^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{AB} &= \sqrt{3}(115.18\angle 8.33^\circ)(1\angle 30^\circ)\\ &= 199.5\angle 38.33^\circ \text{ V rms}\end{aligned}$$

Therefore, the magnitude value of the load voltage is $\boxed{199.5 \text{ V rms}}$.

11.046 P

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an} - \mathbf{V}_{AN}}{2 + j1.5}$$

Substitute $413.28\angle 29.78^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$ and $440\angle 30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{440\angle 30^\circ - 413.28\angle 29.78^\circ}{2.5\angle 36.87^\circ} \\ &= \frac{26.77\angle 33.4^\circ}{2.5\angle 36.87^\circ} \\ &= 10.71\angle -3.47^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $10.71\angle -3.47^\circ \text{ A rms}$.

Step 3 of 3

Consider the expression for Z_{load} .

$$Z_{load} = \frac{\mathbf{V}_{AN}}{\mathbf{I}_{aA}}$$

Substitute $10.71\angle -3.47^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$ and $413.28\angle 29.78^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}Z_{load} &= \frac{413.28\angle 29.78^\circ}{10.71\angle -3.47^\circ} \\ &= 38.59\angle 33.25^\circ \\ &= 32.27 + j21.16\,\Omega\end{aligned}$$

Therefore, the value of Z_{load} is $\boxed{32.27 + j21.16\,\Omega}$.

11.047
P

Step 1 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 8

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 8

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(20+j4)(20+j4)}{(20+j4)+(20+j4)+(20+j4)} \\ &= \frac{(20+j4)(20+j4)}{3(20+j4)} \\ &= \frac{(20+j4)}{3} \\ &= 6.67+j1.33\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $6.67+j1.33\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 6.67+j1.33\,\Omega$ and $Z_3 = 6.67+j1.33\,\Omega$.

Step 4 of 8

Consider the expression for $\mathbf{V}_L$.

$$\mathbf{V}_L = 115\angle 35^\circ \text{ V rms}$$

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{V}_{an} &= \frac{115}{\sqrt{3}}\angle 35^\circ - 30^\circ \text{ V rms} \\ &= 66.4\angle 5^\circ \text{ V rms} \end{aligned}$$

Step 5 of 8

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 8

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{6.67+j1.33}$$

Substitute $66.4\angle 5^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{66.4\angle 5^\circ}{6.8\angle 11.28^\circ} \\ &= 9.77\angle -6.28^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{9.77\angle -6.28^\circ \text{ A rms}}$.

Step 7 of 8

Compare $\mathbf{I}_{aA} = 9.77\angle -6.28^\circ$ A rms with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta$ A.

$\mathbf{I}_P = 9.77$ and $\theta = -6.28^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 9.77 for $\mathbf{I}_P$ and -6.28° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 9.77\angle -6.28^\circ - 120^\circ \\ &= 9.77\angle -126.28^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{9.77\angle -126.28^\circ \text{ A rms}}$.

Step 8 of 8

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 9.77 for $\mathbf{I}_P$ and -6.28° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 9.77\angle -6.28^\circ + 120^\circ \\ &= 9.77\angle 113.72^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{9.77\angle 113.72^\circ \text{ A rms}}$.

11.048
P

Step 1 of 3

Consider the value for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = 208\angle 10^\circ \text{ V rms}$$

Consider the value for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{208}{\sqrt{3}}\angle 10^\circ - 30^\circ \text{ V rms} \\ &= 120.09\angle -20^\circ \text{ V rms}\end{aligned}$$

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{V}_{AN}$ using voltage division rule.

$$\begin{aligned}\mathbf{V}_{AN} &= \mathbf{V}_{an}\left(\frac{3+j2}{3+j2+0.2+j0.4}\right) \\ &= \mathbf{V}_{an}\left(\frac{3+j2}{3{,}2+j2.4}\right) \\ &= \mathbf{V}_{an}(0.9-j0.05) \\ &= \mathbf{V}_{an}(0.9\angle -3.18^\circ)\end{aligned}$$

Since $\mathbf{V}_{an} = 120.09\angle -20^\circ \text{ V rms}$,

$$\begin{aligned}\mathbf{V}_{AN} &= (120.09\angle -20^\circ)(0.9\angle -3.18^\circ) \\ &= 108.08\angle -23.18^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $108.08\angle -23.18^\circ \text{ V rms}$.

Step 3 of 3

Consider the expression for $\mathbf{V}_{AB}$.

$$\mathbf{V}_{AB} = \sqrt{3}\mathbf{V}_{AN}\angle 30^\circ$$

Substitute $108.08\angle -23.18^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}\mathbf{V}_{AB} &= \sqrt{3}(108.08\angle -23.18^\circ)(1\angle 30^\circ) \\ &= \sqrt{3}(108.08\angle -23.18^\circ + 30^\circ) \\ &= 187.2\angle 6.82^\circ \text{ V rms}\end{aligned}$$

Therefore, the magnitude of the line voltage at the load is $\boxed{187.2 \text{ V rms}}$.

11.049 P

Refer to Figure 11.13 in the text book for the balanced three-phase wye-wye connection.

The source phase voltage is,

$$\mathbf{V}_{an} = 120\angle 40^\circ \text{ V rms}$$

The line current is,

$$\mathbf{I}_a = 6\angle 15^\circ \text{ A rms}$$

The line impedance is,

$$Z_{line} = 1 + j1$$

Write the formula for line current.

$$\mathbf{I}_a = \frac{\mathbf{V}_{an}}{Z_Y + Z_{line}}$$

Here, Z_Y is the load impedance.

$$6\angle 15^\circ = \frac{120\angle 40^\circ}{Z_Y + 1 + j1}$$

$$(Z_Y + 1 + j1)6\angle 15^\circ = 120\angle 40^\circ$$

$$Z_Y + 1 + j1 = 20\angle 25^\circ$$

$$Z_Y = 17.13 + j7.45 \ \Omega$$

Thus, the load impedance is $\boxed{17.13 + j7.45 \ \Omega}$.

Step 1 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 8

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 8

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(12+j6)(12+j6)}{(12+j6)+(12+j6)+(12+j6)} \\ &= \frac{(12+j6)(12+j6)}{3(12+j6)} \\ &= \frac{(12+j6)}{3} \\ &= 4+j2\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $4+j2\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 4+j2\,\Omega$ and $Z_3 = 4+j2\,\Omega$.

Step 4 of 8

Consider the expression for $\mathbf{V}_L$.

$$\mathbf{V}_L = 120\sqrt{3}\angle 40^\circ \text{ V rms}$$

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{V}_{an} &= \frac{120\sqrt{3}}{\sqrt{3}}\angle 40^\circ - 30^\circ \text{ V rms} \\ &= 120\angle 10^\circ \text{ V rms} \end{aligned}$$

Step 5 of 8

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 8

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{4+j2}$$

Substitute $120\angle 10^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{120\angle 10^\circ}{4.47\angle 26.57^\circ} \\ &= 26.85\angle -16.57^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{26.85\angle -16.57^\circ \text{ A rms}}$.

Step 7 of 8

Compare $\mathbf{I}_{aA} = 26.85\angle -16.57^\circ \text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta \text{ A}$.

$\mathbf{I}_P = 26.85$ and $\theta = -16.57^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 26.85 for $\mathbf{I}_P$ and -16.57° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 26.85\angle -16.57^\circ - 120^\circ \\ &= 26.85\angle -136.57^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{26.85\angle -136.57^\circ \text{ A rms}}$.

Step 8 of 8

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 26.85 for $\mathbf{I}_P$ and -16.57° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 26.85\angle -16.57^\circ + 120^\circ \\ &= 26.85\angle 103.43^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{26.85\angle 103.43^\circ \text{ A rms}}$.

11.051
P

Step 1 of 7

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 7

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 7

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(14+j7)(14+j7)}{(14+j7)+(14+j7)+(14+j7)} \\ &= \frac{(14+j7)(14+j7)}{3(14+j7)} \\ &= \frac{(14+j7)}{3} \\ &= 4.67+j2.33\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $4.67+j2.33\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 4.67+j2.33\,\Omega$ and $Z_3 = 4.67+j2.33\,\Omega$.

Step 4 of 7

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 5 of 7

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{V}_{an}}{4.67+j2.33}$$

Substitute $120\angle 80^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{120\angle 80^\circ}{5.22\angle 26.52^\circ} \\ &= 22.99\angle 53.48^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{22.99\angle 53.48^\circ \text{ A rms}}$.

Step 6 of 7

Compare $\mathbf{I}_{aA} = 22.99\angle 53.48^\circ$ A rms with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta$ A.

$\mathbf{I}_P = 22.99$ and $\theta = 53.48^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 22.99 for $\mathbf{I}_P$ and 53.48° for θ.

$$\begin{aligned} \mathbf{I}_{bB} &= 22.99\angle 53.48^\circ - 120^\circ \\ &= 22.99\angle -66.52^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{22.99\angle -66.52^\circ \text{ A rms}}$.

Step 7 of 7

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 22.99 for $\mathbf{I}_P$ and 53.48° for θ.

$$\begin{aligned} \mathbf{I}_{cC} &= 22.99\angle 53.48^\circ + 120^\circ \\ &= 22.99\angle 173.8^\circ \text{ A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{22.99\angle 173.8^\circ \text{ A rms}}$.

11.052
P

Step 1 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 8

Convert the delta connected load to Wye connection as shown in Figure 2.

Figure 2

Step 3 of 8

Consider the expression for Z_1.

$$\begin{aligned} Z_1 &= \frac{(9+j6)(9+j6)}{(9+j6)+(9+j6)+(9+j6)} \\ &= \frac{(9+j6)(9+j6)}{3(9+j6)} \\ &= \frac{(9+j6)}{3} \\ &= 3+j2\,\Omega \end{aligned}$$

Therefore, the value of Z_1 is $3+j2\,\Omega$.

Since the values of load impedance in all phases of delta connected system are same, the values of the load impedance in all phases of Wye connected system are also same. Hence, $Z_2 = 3+j2\,\Omega$ and $Z_3 = 3+j2\,\Omega$.

Step 4 of 8

Consider the expression for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \sqrt{3}\mathbf{I}_{AB}\angle -30^\circ$$

Substitute $15\angle 40^\circ\ \text{V rms}$ for $\mathbf{I}_{AB}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \sqrt{3}(15\angle 40^\circ)(1\angle -30^\circ) \\ &= 25.98\angle 10^\circ\ \text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $25.98\angle 10^\circ\ \text{A rms}$.

Step 5 of 8

Consider the circuit diagram shown in Figure 3.

Figure 3

Step 6 of 8

Consider the expression for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{V}_{an} &= \mathbf{I}_{aA}(0.3+j0.2+2+j2) \\ &= \mathbf{I}_{aA}(3.3+j2.2) \end{aligned}$$

Substitute $25.98\angle 10^\circ\ \text{A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned} \mathbf{V}_{an} &= (25.98\angle 10^\circ)(3.3+j2.2) \\ &= (25.98\angle 10^\circ)(3.97\angle 33.69^\circ) \\ &= 103.14\angle 43.69^\circ\ \text{V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $\boxed{103.14\angle 43.69^\circ\ \text{V rms}}$.

Step 7 of 8

Compare $\mathbf{v}_{an} = 103.14\angle 43.69^\circ\ \text{V rms}$ with $\mathbf{v}_{an} = \mathbf{V}_P\angle\theta\ \text{V}$.

$\mathbf{V}_P = 103.14$ and $\theta = 43.69^\circ$

Consider the expression for $\mathbf{V}_{bn}$:

$$\mathbf{V}_{bn} = \mathbf{V}_P\angle\theta - 120^\circ$$

Substitute 103.14 for $\mathbf{V}_P$ and 43.69° for θ.

$$\begin{aligned} \mathbf{V}_{bn} &= 103.14\angle 43.69^\circ - 120^\circ \\ &= 103.14\angle -76.31^\circ\ \text{V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{bn}$ is $\boxed{103.14\angle -76.31^\circ\ \text{V rms}}$.

Step 8 of 8

Consider the expression for $\mathbf{V}_{cn}$.

$$\mathbf{V}_{cn} = \mathbf{V}_P\angle\theta + 120^\circ$$

Substitute 103.14 for $\mathbf{V}_P$ and 43.69° for θ.

$$\begin{aligned} \mathbf{V}_{cn} &= 103.14\angle 43.69^\circ + 120^\circ \\ &= 103.14\angle 163.69^\circ\ \text{V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{cn}$ is $\boxed{103.14\angle 163.69^\circ\ \text{V rms}}$.

11.053
P

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{AB}$.

$$\mathbf{I}_{AB} = \frac{\mathbf{I}_{aA}}{\sqrt{3}}\angle 30^\circ \text{ A rms}$$

Substitute $28.10\angle -28.66^\circ$ A rms for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{AB} &= \frac{28.10\angle -28.66^\circ}{\sqrt{3}}\angle 30^\circ \\ &= \frac{28.10\angle -28.66^\circ + 30^\circ}{\sqrt{3}} \\ &= 16.22\angle 1.34^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AB}$ is $16.22\angle 1.34^\circ$ A rms.

Step 3 of 3

Consider the expression for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AB} &= I_{AB}(10+j8) \\ &= I_{AB}(12.81\angle 38.66^\circ)\end{aligned}$$

Substitute $16.22\angle 1.34^\circ$ A rms for $\mathbf{I}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AB} &= I_{AB}(12.81\angle 38.66^\circ) \\ &= (16.22\angle 1.34^\circ)(12.81\angle 38.66^\circ) \\ &= 207.78\angle 40^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AB}$ is $\boxed{207.78\angle 40^\circ \text{ V rms}}$.

Step 1 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the expression for Z_Y.

$$Z_Y = \frac{\mathbf{V}_{an}}{\mathbf{I}_{aA}}$$

Substitute $120\angle 0°\ \text{V rms}$ for $\mathbf{V}_{an}$ and $5\angle 20°\ \text{A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned} Z_Y &= \frac{120\angle 0°}{5\angle 20°} \\ &= 24\angle -20° \\ &= 22.55 - j8.21\,\Omega \end{aligned}$$

Therefore, the value of Z_Y is $22.55 - j8.21\,\Omega$.

Step 3 of 4

Convert the Wye connected load to delta connection as shown in Figure 2.

Figure 2

Step 4 of 4

Consider the expression for Z_Δ.

$$Z_\Delta = 3Z_Y$$

Substitute $22.55 - j8.21\,\Omega$ for Z_Y.

$$\begin{aligned} Z_\Delta &= 3(22.55 - j8.21) \\ &= 67.65 - j2.63\,\Omega \end{aligned}$$

Therefore, the value of Z_Δ is $\boxed{67.65 - j2.63\,\Omega}$.

11.055
P

Step 1 of 8

Consider the following figure.

Figure 1

Step 2 of 8

Convert the delta connected load to wye connection.

Figure 2

Step 3 of 8

Convert the value of the delta load to wye load.

$$Z_{\Delta-Y} = \frac{Z_\Delta}{3}$$

Since $Z_\Delta = 15 + j10\,\Omega$,

$$Z_{\Delta-Y} = \frac{15 + j10}{3}$$
$$= 5 + j3.33\,\Omega$$

The value of delta to wye converted load impedance is $5 + j3.33\,\Omega$.

Step 4 of 8

Calculate the value equivalent impedance per phase.

$$Z_{eq,1phase} = Z_{\Delta-Y} \parallel Z_Y$$

Since $Z_{\Delta-Y} = 5 + j3.33\,\Omega$ and $Z_Y = 6 + j3\,\Omega$,

$$Z_{eq,1phase} = (5 + j3.33) \parallel (6 + j3)$$
$$= \frac{(5 + j3.33)(6 + j3)}{5 + j3.33 + 6 + j3\,\Omega}$$
$$= \frac{20.01 + j34.98}{11 + j6.33}$$
$$= 2.74 + j1.6\,\Omega$$

Therefore, the value of $Z_{eq,1phase}$ is $2.74 + j1.6\,\Omega$.

Step 5 of 8

Consider the expression for the equivalent impedance for three phase circuit.

$$Z_{eq} = 3Z_{eq,1phase}$$

Since $2.74 + j1.6\,\Omega$ for $Z_{eq,1phase}$,

$$Z_{eq} = 3(2.74 + j1.6)$$
$$= 8.22 + j4.8\,\Omega$$

Therefore, the value of the equivalent wye load is $\boxed{8.22 + j4.8\,\Omega}$.

Step 6 of 8

Consider the following figure.
Convert wye connected load to delta connection.

Figure 1

Step 7 of 8

Convert the value of the wye load to delta load.

$$Z_{Y-\Delta} = 3Z_Y$$

Since $Z_Y = 6 + j3\,\Omega$,

$$Z_{Y-\Delta} = 3(6 + j3)$$
$$= 18 + j9\,\Omega$$

The value of wye to delta converted load impedance is $18 + j9\,\Omega$.

Step 8 of 8

Calculate the value equivalent impedance for three phase circuit.

$$Z_{eq} = Z_{Y-\Delta} \parallel Z_\Delta$$

Since $Z_\Delta = 15 + j10\,\Omega$ and $Z_{Y-\Delta} = 18 + j9\,\Omega$,

$$Z_{eq} = (15 + j10) \parallel (18 + j9)$$
$$= \frac{(15 + j10)(18 + j9)}{15 + j10 + 18 + j9\,\Omega}$$
$$= \frac{180 + j315}{33 + j19}$$
$$= 8.22 + j4.81\,\Omega$$

Therefore, the value of equivalent delta load is $\boxed{8.22 + j4.81\,\Omega}$.

11.056
P

Step 1 of 12

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \frac{\mathbf{V}_{ab}}{\sqrt{3}}\angle -30^\circ$$

Substitute $215\angle 50^\circ$ V rms for $\mathbf{V}_{ab}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{215}{\sqrt{3}}\angle 50^\circ - 30^\circ \\ &= 124.13\angle 20^\circ\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $124.13\angle 20^\circ$.

Step 2 of 12

Convert the delta connected load to wye connection.

$$Z_{\Delta-Y} = \frac{Z_\Delta}{3}$$

Substitute $18 + j12\,\Omega$ for Z_Δ.

$$\begin{aligned}Z_{\Delta-Y} &= \frac{18 + j12}{3} \\ &= 6 + j4\,\Omega\end{aligned}$$

Therefore, the value of $Z_{\Delta-Y}$ is $6 + j4\,\Omega$.

Step 3 of 12

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 12

Calculate the equivalent impedance of the two loads.

$$\begin{aligned}Z_{load} &= \frac{(5 + j3)(6 + j4)}{(5 + j3) + (6 + j4)} \\ &= \frac{18 + j38}{11 + j7} \\ &= 2.73 + j1.71\,\Omega\end{aligned}$$

Therefore, the equivalent value of the two loads is $2.73 + j1.71\,\Omega$.

Step 5 of 12

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 6 of 12

Calculate the value of $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{1 + j0.8 + 2.73 + j1.71} \\ &= \frac{\mathbf{V}_{an}}{3.73 + j2.51} \\ &= \frac{\mathbf{V}_{an}}{4.5\angle 33.94^\circ}\end{aligned}$$

Substitute $124.13\angle 20^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{124.13\angle 20^\circ}{4.5\angle 33.94^\circ} \\ &= 27.58\angle -13.94^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{27.58\angle -13.94^\circ \text{ A rms}}$.

Refer Figure 1.

Consider the expression for $\mathbf{I}_{AN1}$ using current division rule.

$$\begin{aligned}\mathbf{I}_{AN1} &= \mathbf{I}_{aA}\left(\frac{6 + j4}{6 + j3 + 5 + j3}\right) \\ &= \mathbf{I}_{aA}\left(\frac{6 + j4}{11 + j7}\right) \\ &= \mathbf{I}_{aA}(0.55 + j0.01) \\ &= \mathbf{I}_{aA}(0.55\angle 1.04^\circ)\end{aligned}$$

Substitute $27.58\angle -13.94^\circ$ A rms for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{AN1} &= (27.58\angle -13.94^\circ)(0.55\angle 1.04^\circ) \\ &= 15.17\angle -12.9^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AN1}$ is $\boxed{15.17\angle -12.9^\circ \text{ A rms}}$.

Step 7 of 12

Compare $\mathbf{I}_{AN1} = 15.17\angle -12.9^\circ$ A rms with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta$ A.

$\mathbf{I}_P = 15.17$ and $\theta = -12.9^\circ$

Consider the expression for $\mathbf{I}_{BN1}$.

$$\mathbf{I}_{BN1} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 15.17 for $\mathbf{I}_P$ and -12.9° for θ.

$$\begin{aligned}\mathbf{I}_{BN1} &= 15.17\angle -12.9^\circ - 120^\circ \\ &= 15.17\angle -132.9^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{BN1}$ is $\boxed{15.17\angle -132.9^\circ \text{ A rms}}$.

Step 8 of 12

Consider the expression for $\mathbf{I}_{CN1}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 15.17 for $\mathbf{I}_P$ and -12.9° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 15.17\angle -12.9^\circ + 120^\circ \\ &= 15.17\angle 107.1^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{15.17\angle 107.1^\circ \text{ A rms}}$.

Step 9 of 12

Consider the expression for $\mathbf{I}_{AN2}$.

$$\mathbf{I}_{AN2} = \mathbf{I}_{aA} - \mathbf{I}_{AN1}$$

Substitute $15.17\angle -12.9^\circ$ A rms for $\mathbf{I}_{AN1}$ and $27.58\angle -13.94^\circ$ A rms for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{AN2} &= 27.58\angle -13.94^\circ - 15.17\angle -12.9^\circ \\ &= 12.42\angle -15.21^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AN2}$ is $\boxed{12.42\angle -15.21^\circ \text{ A rms}}$.

Step 10 of 12

Convert the line current in the delta load into phase current.

$$\mathbf{I}_{AB2} = \frac{\mathbf{I}_{AN2}}{\sqrt{3}}\angle 30^\circ$$

Substitute $12.42\angle -15.21^\circ$ A rms for $\mathbf{I}_{AN2}$.

$$\begin{aligned}\mathbf{I}_{AB2} &= \frac{12.42}{\sqrt{3}}\angle -15.21^\circ + 30^\circ \\ &= 7.13\angle 14.79^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AB2}$ is $\boxed{7.13\angle 14.79^\circ \text{ A rms}}$.

Step 11 of 12

Compare $\mathbf{I}_{AB2} = 7.13\angle 14.79^\circ$ A rms with $\mathbf{I}_{AB} = \mathbf{I}_P\angle\theta$ A.

$\mathbf{I}_P = 7.13$ and $\theta = 14.79^\circ$

Consider the expression for $\mathbf{I}_{BC2}$.

$$\mathbf{I}_{BC2} = \mathbf{I}_P\angle\theta - 90^\circ$$

Substitute 7.13 for $\mathbf{I}_P$ and 14.79° for θ.

$$\begin{aligned}\mathbf{I}_{BC2} &= 7.13\angle 14.79^\circ - 90^\circ \\ &= 7.13\angle -75.21^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{BC2}$ is $\boxed{7.13\angle -75.21^\circ \text{ A rms}}$.

Step 12 of 12

Consider the expression for $\mathbf{I}_{CA2}$.

$$\mathbf{I}_{CA2} = \mathbf{I}_P\angle\theta - 210^\circ$$

Substitute 7.13 for $\mathbf{I}_P$ and 14.79° for θ.

$$\begin{aligned}\mathbf{I}_{CA2} &= 7.13\angle 14.79^\circ - 210^\circ \\ &= 7.13\angle -195.21^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{CA2}$ is $\boxed{7.13\angle -195.21^\circ \text{ A rms}}$.

11.057
P

Step 1 of 8

Convert the delta connected load to wye connection.

$$Z_{\Delta-Y} = \frac{Z_\Delta}{3}$$

Substitute $12 + j9\,\Omega$ for Z_Δ.

$$\begin{aligned} Z_{\Delta-Y} &= \frac{12 + j9}{3} \\ &= 4 + j3\,\Omega \end{aligned}$$

Therefore, the value of $Z_{\Delta-Y}$ is $4 + j3\,\Omega$.

Step 2 of 8

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 8

Consider the expression for $\mathbf{I}_{AN2}$.

$$\mathbf{I}_{AN2} = \sqrt{3}\mathbf{I}_{AB}\angle -30^\circ$$

Substitute $16\angle 45^\circ$ A rms for $\mathbf{I}_{AB}$.

$$\begin{aligned} \mathbf{I}_{AN2} &= \sqrt{3}(16)\angle 45^\circ - 30^\circ \\ &= 27.72\angle 15^\circ \text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{AN2}$ is $27.72\angle 15^\circ$A rms

Step 4 of 8

Consider the expression for $\mathbf{I}_{AN2}$ using current division rule.

$$\begin{aligned} \mathbf{I}_{AN2} &= \mathbf{I}_{aA}\left(\frac{4 + j2}{4 + j2 + 4 + j3}\right) \\ &= \mathbf{I}_{aA}\left(\frac{4 + j2}{8 + j5}\right) \\ &= \mathbf{I}_{aA}(0.47 - j0.04) \\ &= \mathbf{I}_{aA}(0.47\angle -5.44^\circ) \end{aligned}$$

Solve for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{I}_{AN2}}{0.47\angle -5.44^\circ}$$

Substitute $27.72\angle 15^\circ$A rms for $\mathbf{I}_{AN2}$.

$$\begin{aligned} \mathbf{I}_{aA} &= \frac{27.72\angle 15^\circ}{0.47\angle -5.44^\circ} \\ &= 58.98\angle 20.44^\circ \text{A rms} \end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $58.98\angle 20.44^\circ$A rms.

Step 5 of 8

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \mathbf{I}_{AN2}(Z_{\Delta-Y})$$

Substitute $27.72\angle 15^\circ$A rms for $\mathbf{I}_{AN2}$ and $4 + j3\,\Omega$ for $Z_{\Delta-Y}$.

$$\begin{aligned} \mathbf{V}_{AN} &= (27.72\angle 15^\circ)(4 + j3) \\ &= (27.72\angle 15^\circ)(5\angle 36.87^\circ) \\ &= 138.6\angle 51.87^\circ \text{V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $138.6\angle 51.87^\circ$V rms.

Step 6 of 8

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \mathbf{I}_{aA}(Z_{line}) + \mathbf{V}_{AN}$$

Substitute $138.6\angle 51.87^\circ$V rms for $\mathbf{V}_{AN}$, $58.98\angle 20.44^\circ$A rms for $\mathbf{I}_{aA}$ and $0.2 + j0.1\,\Omega$ for Z_{line}.

$$\begin{aligned} \mathbf{V}_{an} &= (58.98\angle 20.44^\circ)(0.2 + j0.1) + 138.6\angle 51.87^\circ \\ &= (58.98\angle 20.44^\circ)(0.22\angle 26.57^\circ) + 138.6\angle 51.87^\circ \\ &= 12.98\angle 47.01^\circ + 138.6\angle 51.87^\circ \\ &= 151.54\angle 51.45^\circ \text{ V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $151.54\angle 51.45^\circ$ V rms.

Step 7 of 8

Compare $V_{an} = 151.54\angle 41.45^\circ$ V rms with $\mathbf{V}_{ab} = \mathbf{V}_p\angle\theta$ V.

$\mathbf{V}_p = 151.54$ and $\theta = 51.45^\circ$

Consider the expression for $\mathbf{V}_{ab}$.

$$\mathbf{V}_{ab} = \sqrt{3}\mathbf{V}_p\angle 30^\circ$$

Substitute $151.54\angle 51.45^\circ$ V rms for $\mathbf{V}_{an}$.

$$\begin{aligned} \mathbf{V}_{ab} &= \sqrt{3}(151.54)\angle 51.45^\circ + 30^\circ \\ &= 262.8\angle 81.45^\circ \text{ V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{ab}$ is $\boxed{262.8\angle 81.45^\circ \text{ V rms}}$.

Consider the expression for $\mathbf{V}_{bc}$.

$$\mathbf{V}_{bc} = \sqrt{3}\mathbf{V}_p\angle -90^\circ$$

Substitute $151.54\angle 51.45^\circ$ V rms for $\mathbf{V}_p$.

$$\begin{aligned} \mathbf{V}_{bc} &= \sqrt{3}(151.54)\angle 51.45^\circ - 90^\circ \\ &= 262.8\angle -38.55^\circ \text{ V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{bc}$ is $\boxed{262.8\angle -38.55^\circ \text{ V rms}}$.

Step 8 of 8

Consider the expression for $\mathbf{V}_{ca}$.

$$\mathbf{V}_{ca} = \mathbf{V}_p\angle -210^\circ$$

Substitute $151.54\angle 51.45^\circ$ V rms for $\mathbf{V}_p$.

$$\begin{aligned} \mathbf{V}_{ca} &= 151.54\angle 51.45^\circ - 210^\circ \\ &= 262.8\angle -158.55^\circ \text{ V rms} \end{aligned}$$

Therefore, the value of $\mathbf{V}_{ca}$ is $\boxed{262.8\angle -158.55^\circ \text{ V rms}}$.

Step 1 of 12

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = \frac{\mathbf{V}_{ab}}{\sqrt{3}}\angle -30^\circ$$

Substitute $440\angle 60^\circ \text{ V rms}$ for $\mathbf{V}_{ab}$.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{440}{\sqrt{3}}\angle 60^\circ - 30^\circ \\ &= 254.03\angle 30^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{an}$ is $254.03\angle 30^\circ \text{ V rms}$.

Step 2 of 12

Convert the delta connected load to wye connection.

$$\mathbf{Z}_{\Delta-Y} = \frac{\mathbf{Z}_\Delta}{3}$$

Substitute $24 + j12\ \Omega$ for $\mathbf{Z}_\Delta$.

$$\begin{aligned}\mathbf{Z}_{\Delta-Y} &= \frac{24 + j12}{3} \\ &= 8 + j4\Omega\end{aligned}$$

Therefore, the value of $\mathbf{Z}_{\Delta-Y}$ is $8 + j4\Omega$.

Step 3 of 12

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 4 of 12

Calculate the equivalent impedance of the two loads.

$$\begin{aligned}\mathbf{Z}_{load} &= \frac{(12 + j8)(8 + j4)}{(12 + j8) + (8 + j4)} \\ &= \frac{64 + j112}{20 + j12} \\ &= 4.82 + j2.71\ \Omega\end{aligned}$$

Therefore, the equivalent value of the two loads is $4.82 + j2.71\ \Omega$.

Step 5 of 12

Consider the circuit diagram shown in Figure 2.

Figure 2

Step 6 of 12

Calculate the value of $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{1 + j0.08 + 4.82 + j2.71} \\ &= \frac{\mathbf{V}_{an}}{5.82 + j2.79} \\ &= \frac{\mathbf{V}_{an}}{6.45\angle 25.61^\circ}\end{aligned}$$

Substitute $254.03\angle 30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{254.03\angle 30^\circ}{6.45\angle 25.61^\circ} \\ &= 39.38\angle 4.39^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $\boxed{39.38\angle 4.39^\circ \text{ A rms}}$.

Step 7 of 12

Compare $\mathbf{I}_{aA} = 39.38\angle 4.39^\circ \text{ A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_P\angle\theta \text{ A rms}$

$\mathbf{I}_P = 35.76$ and $\theta = -34.74^\circ$

Consider the expression for $\mathbf{I}_{bB}$.

$$\mathbf{I}_{bB} = \mathbf{I}_P\angle\theta - 120^\circ$$

Substitute 39.38 for $\mathbf{I}_P$ and 4.39° for θ.

$$\begin{aligned}\mathbf{I}_{bB} &= 39.38\angle 4.39^\circ - 120^\circ \\ &= 39.38\angle -115.61^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bB}$ is $\boxed{39.38\angle -115.61^\circ \text{ A rms}}$.

Step 8 of 12

Consider the expression for $\mathbf{I}_{cC}$.

$$\mathbf{I}_{cC} = \mathbf{I}_P\angle\theta + 120^\circ$$

Substitute 39.38 for $\mathbf{I}_P$ and 4.39° for θ.

$$\begin{aligned}\mathbf{I}_{cC} &= 39.38\angle 4.39^\circ + 120^\circ \\ &= 39.38\angle 12.39^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{cC}$ is $\boxed{39.38\angle 12.39^\circ \text{ A rms}}$.

Step 9 of 12

Refer Figure 1.

Consider the expression for $\mathbf{I}_{AN1}$ using the current division rule.

$$\begin{aligned}\mathbf{I}_{AN1} &= \mathbf{I}_{aA}\left(\frac{8 + j4}{12 + j8 + 8 + j4}\right) \\ &= \mathbf{I}_{aA}\left(\frac{8 + j4}{20 + j12}\right) \\ &= \mathbf{I}_{aA}(0.38 - j0.03) \\ &= \mathbf{I}_{aA}(0.38\angle -4.51^\circ)\end{aligned}$$

Substitute $39.38\angle 4.39^\circ \text{ A rms}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{AN1} &= (39.38\angle 4.39^\circ)(0.38\angle -4.51^\circ) \\ &= 14.96\angle -0.12^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{AN1}$ is $14.96\angle -0.12^\circ \text{ A rms}$.

Step 10 of 12

Consider the expression for $\mathbf{V}_{AN}$ using the voltage division rule.

$$\mathbf{V}_{AN} = \mathbf{V}_{an}\left(\frac{\mathbf{Z}_{load}}{\mathbf{Z}_{load} + \mathbf{Z}_{line}}\right)$$

Substitute $254.03\angle 30^\circ \text{ V rms}$ for $\mathbf{V}_{an}$, $4.82 + j2.71\ \Omega$ for $\mathbf{Z}_{load}$ and $1 + j0.08\ \Omega$ for $\mathbf{Z}_{line}$.

$$\begin{aligned}\mathbf{V}_{AN} &= (254.03\angle 30^\circ)\left(\frac{4.82 + j2.71}{4.82 + j2.71 + 1 + j0.08}\right) \\ &= (254.03\angle 30^\circ)\left(\frac{4.82 + j2.71}{5.82 + j2.79}\right) \\ &= (254.03\angle 30^\circ)(0.56 + j0.32) \\ &= (254.03\angle 30^\circ)(0.65\angle 29.75^\circ)\end{aligned}$$

$$\mathbf{V}_{AN} = 165.12\angle 59.75^\circ \text{ V rms}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $165.12\angle 59.75^\circ \text{ V rms}$.

Step 11 of 12

Consider the expression for the power factor angle at the wye load.

$$\begin{aligned}\theta &= \tan^{-1}\left(\frac{6}{12}\right) \\ &= \tan^{-1}(0.5) \\ &= 26.57^\circ\end{aligned}$$

Therefore, the value of the power factor angle is 26.57°.

Step 12 of 12

Consider the expression for the power absorbed by the wye load.

$$S = 3|\mathbf{V}_{AN}||\mathbf{I}_{AN1}|\angle\theta$$

Substitute 26.57° for θ, 165.12 V rms for $\mathbf{V}_{AN}$ and 14.96 A rms for $\mathbf{I}_{AN1}$.

$$\begin{aligned}S &= 3(165.12)(14.96)\angle 26.57^\circ \\ &= 7.41\angle 26.57^\circ \text{ kVA} \\ &= 6.63 + j3.31 \text{ kVA}\end{aligned}$$

Therefore, the value of power absorbed by the wye connected load is

$\boxed{6.63 + j3.31 \text{ kVA}}$.

Step 1 of 1

11.059

P

Calculate the instantaneous power for a balanced three phase load.

$$
\begin{aligned}
p(t) &= 3\mathbf{V}_L\mathbf{I}_L\left[\cos(\theta_v-\theta_i)+\cos(2\omega t+\theta_v+\theta_i)\right] \\
&= (3)(240)(2)\left[\cos(0°-(-40°))+\cos(2\omega t+0°-40°)\right] \\
&= (1440)\left[\cos(40°)+\cos(2\omega t-40°)\right] \\
&= (1440)\left[0.766+\cos(2\omega t-40°)\right]
\end{aligned}
$$

$$= 720+1440\cos(2\omega t-40°)\ \text{W}$$

Therefore, the instantaneous power, $p(t)$ for a balanced three phase load is

$\boxed{720+1440\cos(2\omega t-40°)\ \text{W}}$.

11.060
P

Step 1 of 4

The apparent power of the source is,

$$\mathbf{S} = 1.2\ \text{kVA}$$

Calculate the per phase apparent power.

$$\begin{aligned}\mathbf{S}_{\phi} &= \frac{1.2\ \text{kVA}}{3}\\ &= 400\ \text{VA}\end{aligned}$$

Calculate the power factor angle of the source.

$$\begin{aligned}\theta &= \cos^{-1}(0.6)\\ &= 53.13^\circ\end{aligned}$$

Calculate the complex power.

$$\begin{aligned}S &= \mathbf{S}\cos\theta + j\mathbf{S}\sin\theta\\ &= (400\ \text{VA})\cos(53.13^\circ) + j(400\ \text{VA})\sin(53.13^\circ)\\ &= (400\ \text{VA})(0.6) + j(400\ \text{VA})(0.8)\\ &= 240 + j320\ \text{VA}\end{aligned}$$

Step 2 of 4

Calculate the phase voltage of the source.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30^\circ}\\ &= \frac{120\angle 45^\circ}{\sqrt{3}\angle 30^\circ}\\ &= 39.28\angle 15^\circ\ \text{V}\end{aligned}$$

Calculate the line current.

$$\begin{aligned}\mathbf{I}_{aA}^{*} &= \frac{S}{\mathbf{V}_{an}}\\ &= \frac{240 + j320\ \text{VA}}{39.28\angle 15^\circ\ \text{V}}\\ &= \frac{400\angle 53.13^\circ\ \text{VA}}{39.28\angle 15^\circ\ \text{V}}\\ &= 10.18\angle 38.13^\circ\ \text{A}\end{aligned}$$

Step 3 of 4

Calculate the phase current of load 1.

$$\begin{aligned}\mathbf{I}_{AN1}^{*} &= \frac{j800\ \text{var}}{\mathbf{V}_{an}}\\ &= \frac{800\angle 90^\circ\ \text{VA}}{39.28\angle 15^\circ\ \text{V}}\\ &= 20.36\angle 85^\circ\ \text{A}\end{aligned}$$

$$\mathbf{I}_{AN1} = 20.36\angle -85^\circ\ \text{A}$$

Calculate the phase current of load 2.

$$\begin{aligned}\mathbf{I}_{AN2} &= \mathbf{I}_{aA} - \mathbf{I}_{AN1}\\ &= 10.18\angle 38.13^\circ\ \text{A} - 20.36\angle -85^\circ\ \text{A}\\ &= 8 + j6.285 - 1.774 + j20.28\ \text{A}\\ &= 6.233 + j26.568\ \text{A}\end{aligned}$$

$$= 27.289\angle 76.796^\circ\ \text{A}$$

Step 4 of 4

Calculate the phase impedance of the load 2.

$$\begin{aligned}\mathbf{Z}_{\text{load2}} &= \frac{\mathbf{V}_{an}}{\mathbf{I}_{AN2}}\\ &= \frac{39.28\angle 15^\circ\ \text{V}}{27.289\angle 76.796^\circ\ \text{A}}\\ &= 1.439\angle -61.79^\circ\ \Omega\\ &= 0.68 - j1.268\ \Omega\end{aligned}$$

Therefore, the phase impedance of the load 2 is $\boxed{0.68 - j1.268\ \Omega}$.

Step 1 of 4

The apparent power of the source is,

$$\mathbf{S} = 1.2\ \text{kVA}$$

Calculate the per phase apparent power.

$$\begin{aligned}\mathbf{S}_\phi &= \frac{1.2\ \text{kVA}}{3}\\ &= 400\ \text{VA}\end{aligned}$$

Calculate the power factor angle of the source.

$$\begin{aligned}\theta &= \cos^{-1}(0.6)\\ &= 53.13°\end{aligned}$$

Calculate the complex power.

$$\begin{aligned}S &= \mathbf{S}\cos\theta + j\mathbf{S}\sin\theta\\ &= (400\ \text{VA})\cos(53.13°) + j(400\ \text{VA})\sin(53.13°)\\ &= (400\ \text{VA})(0.6) + j(400\ \text{VA})(0.8)\\ &= 240 + j320\ \text{VA}\end{aligned}$$

Step 2 of 4

Calculate the phase voltage of the source.

$$\begin{aligned}\mathbf{V}_{an} &= \frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30°}\\ &= \frac{120\angle 45°}{\sqrt{3}\angle 30°}\\ &= 39.28\angle 15°\ \text{V}\end{aligned}$$

Calculate the line current.

$$\begin{aligned}\mathbf{I}_{aA}^* &= \frac{S}{\mathbf{V}_{an}}\\ &= \frac{240 + j320\ \text{VA}}{39.28\angle 15°\ \text{V}}\\ &= \frac{400\angle 53.13°\ \text{VA}}{39.28\angle 15°\ \text{V}}\\ &= 10.18\angle 38.13°\ \text{A}\end{aligned}$$

Therefore,

$$\mathbf{I}_{aA} = 10.18\angle -38.13°\ \text{A}$$

Step 3 of 4

Calculate the phase current of load 1.

$$\begin{aligned}\mathbf{I}_{AN1}^* &= \frac{j800\ \text{var}}{\mathbf{V}_{an}}\\ &= \frac{800\angle 90°\ \text{VA}}{39.28\angle 15°\ \text{V}}\\ &= 20.36\angle 85°\ \text{A}\end{aligned}$$

Therefore,

$$\mathbf{I}_{AN1} = 20.36\angle -85°\ \text{A}$$

The magnitude of the current flowing through the load 1 is,

$$|\mathbf{I}_{AN1}| = 20.36\ \text{A}$$

Therefore, the magnitude of the current flowing through the load 1, $|\mathbf{I}_{AN1}|$ is $\boxed{20.36\ \text{A}}$.

Step 4 of 4

Calculate the phase current of load 2.

$$\mathbf{I}_{AN2} = \mathbf{I}_{aA} - \mathbf{I}_{AN1}$$

Substitute $10.18\angle -38.13°\ \text{A}$ for $\mathbf{I}_{aA}$ and $20.36\angle -85°\ \text{A}$ for $\mathbf{I}_{AN1}$.

$$\begin{aligned}\mathbf{I}_{AN2} &= \mathbf{I}_{aA} - \mathbf{I}_{AN1}\\ &= 10.18\angle -38.13° - 20.36\angle -85°\\ &= 8 - j6.285 - 1.774 + j20.28\\ &= 6.226 + j13.995\ \text{A}\end{aligned} \quad = 15.31\angle 66°\ \text{A}$$

The magnitude of the current flowing through the load 2 is,

$$|\mathbf{I}_{AN2}| = 15.31\ \text{A}$$

Therefore, the magnitude of the current flowing through the load 2, $|\mathbf{I}_{AN2}|$ is $\boxed{15.31\ \text{A}}$.

11.062

P

We don't have the solution to this problem yet.

Get help from a Chegg subject expert.

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11.063
P

Step 1 of 2

A balanced three phase load supplies power to two loads.

The load 1 parameters are:

$$4000 \text{ VA at } 0.9 \text{ pf lagging}$$

The load 2 parameters are:

$$3600 \text{ VA at } 0.85 \text{ pf lagging}$$

Compute the apparent power for load 1 in complex form.

$$\begin{aligned}\mathbf{S}_1 &= (4000 \text{ VA})(0.9) + j(3600 \text{ VA})\left(\sin\left(\cos^{-1}(0.9)\right)\right)\\ &= (4000 \text{ VA})(0.9) + j(3600 \text{ VA})(\sin(25.84))\\ &= (4000 \text{ VA})(0.9) + j(3600 \text{ VA})(0.436)\\ &= 3600 + j1569.2 \text{ VA}\end{aligned}$$

Compute the apparent power for load 2 in complex form.

$$\begin{aligned}\mathbf{S}_2 &= (4000 \text{ VA})(0.85) + j(3600 \text{ VA})\sin\left(\cos^{-1}(0.85)\right)\\ &= (4000 \text{ VA})(0.85) + j(3600 \text{ VA})\sin(31.788)\\ &= (4000 \text{ VA})(0.85) + j(3600 \text{ VA})(0.527)\\ &= (3400 + j1896.4) \text{ VA}\end{aligned}$$

Step 2 of 2

Calculate the total load apparent power.

$$\begin{aligned}\mathbf{S}_{\text{load}} &= \mathbf{S}_1 + \mathbf{S}_2\\ &= 3600 + j1569.2 + 3400 + j1896.4\\ &= 7000 + j3465.6 \text{ VA}\\ &= 7810.9\angle 26.33^\circ \text{ VA}\end{aligned}$$

Calculate the magnitude of the line current.

$$\mathbf{I}_L = \frac{|\mathbf{S}_{\text{load}}|}{\sqrt{3}\mathbf{V}_L}$$

Substitute 7810.9 for $|\mathbf{S}_{\text{load}}|$ and 208 V for $\mathbf{V}_L$.

$$\begin{aligned}\mathbf{I}_L &= \frac{7810.9}{\sqrt{3}(208)}\\ &= 21.68 \text{ A}\end{aligned}$$

Therefore, the magnitude of the line current, $\mathbf{I}_L$ is $\boxed{21.68 \text{ A}}$.

Step 1 of 4

The phase voltage is, $\mathbf{V}_{an} = 120\angle 20^\circ \text{ V}$.

The per-phase impedance for wye load 1 is,

$$\mathbf{Z}_{Y1} = 8 + j2\ \Omega$$

The per-phase impedance for wye load 2 is,

$$\mathbf{Z}_{Y2} = 12 + j3\ \Omega$$

The line impedance is zero.

The single phase equivalent circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Calculate the phase current through load 1.

$$\begin{aligned}\mathbf{I}_{AN1} &= \frac{\mathbf{V}_{an}}{\mathbf{Z}_{Y1}} \\ &= \frac{120\angle 20^\circ}{8 + j2} \\ &= 14.55\angle 5.96^\circ \text{ A}\end{aligned}$$

Similarly,

$$\begin{aligned}\mathbf{I}_{BN1} &= \mathbf{I}_{AN1}\angle -120^\circ \\ &= (14.55\angle 5.96^\circ)\angle -120^\circ \\ &= 14.55\angle -114.04^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{CN1} &= \mathbf{I}_{AN1}\angle 120^\circ \\ &= (14.55\angle 5.96^\circ)\angle 120^\circ \\ &= 14.55\angle 125.96^\circ \text{ A}\end{aligned}$$

Therefore, the phase currents in load 1 is,

$$\boxed{\begin{aligned}\mathbf{I}_{AN1} &= 14.55\angle 5.96^\circ \text{ A} \\ \mathbf{I}_{BN1} &= 14.55\angle -114.04^\circ \text{ A} \\ \mathbf{I}_{CN1} &= 14.55\angle 125.96^\circ \text{ A}\end{aligned}}.$$

Step 3 of 4

Calculate the phase current through load 2.

$$\begin{aligned}\mathbf{I}_{AN2} &= \frac{\mathbf{V}_{an}}{\mathbf{Z}_{Y2}} \\ &= \frac{120\angle 20^\circ}{12 + j3} \\ &= 9.7\angle 5.96^\circ \text{ A}\end{aligned}$$

Similarly,

$$\begin{aligned}\mathbf{I}_{BN2} &= \mathbf{I}_{AN2}\angle -120^\circ \\ &= (9.7\angle 5.96^\circ)\angle -120^\circ \\ &= 9.7\angle -114.04^\circ \text{ A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{CN2} &= \mathbf{I}_{AN2}\angle 120^\circ \\ &= (9.7\angle 5.96^\circ)\angle 120^\circ \\ &= 9.7\angle 125.96^\circ \text{ A}\end{aligned}$$

Therefore, the phase currents in load 2 is,

$$\boxed{\begin{aligned}\mathbf{I}_{AN2} &= 9.7\angle 5.96^\circ \text{ A} \\ \mathbf{I}_{BN2} &= 9.7\angle -114.04^\circ \text{ A} \\ \mathbf{I}_{CN2} &= 9.7\angle 125.96^\circ \text{ A}\end{aligned}}.$$

Step 4 of 4

Calculate the line currents.

$$\begin{aligned}\mathbf{I}_{aA} &= \mathbf{I}_{AN1} + \mathbf{I}_{AN2} \\ &= (14.55\angle 5.96^\circ) + (9.7\angle 5.96^\circ) \\ &= 24.25\angle 5.96^\circ \text{ A}\end{aligned}$$

Similarly,

$$\mathbf{I}_{bB} = 24.25\angle -114.04^\circ \text{ A}$$
$$\mathbf{I}_{cC} = 24.25\angle 125.96^\circ \text{ A}$$

Therefore, the line currents are,

$$\boxed{\begin{aligned}\mathbf{I}_{aA} &= 24.25\angle 5.96^\circ \text{ A} \\ \mathbf{I}_{bB} &= 24.25\angle -114.04^\circ \text{ A} \\ \mathbf{I}_{cC} &= 24.25\angle 125.96^\circ \text{ A}\end{aligned}}.$$

11.065

P

We don't have the solution to this problem yet.

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Step 1 of 6

Consider the following circuit arrangement for the balanced three phase system:

Figure 1

Step 2 of 6

Consider that the phase impedance of balanced delta load is, $21+j12\ \Omega$.

Use following expression to convert the balanced Δ -load to equivalent balanced Y -load.

$$\mathbf{Y}=\frac{\Delta}{3}$$

Find the phase impedance of Y-load 2.

$$\begin{aligned}\mathbf{Y}_2&=\frac{\Delta}{3}\\&=\frac{21+j12\ \Omega}{3}\\&=7+j4\ \Omega\end{aligned}$$

Draw the equivalent circuit arrangement for the balanced three phase system.

Figure 2

Step 3 of 6

Consider that the line voltage, $\mathbf{V}_{ab}=208\angle 60^\circ\ \text{Vrms}$.

Consider the following values for other line voltages by $abc-$ phase sequence:

$$\begin{aligned}\mathbf{V}_{bc}&=208\angle 60^\circ-120^\circ\ \text{Vrms}\\&=208\angle -60^\circ\ \text{Vrms}\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{ca}&=208\angle 60^\circ+120^\circ\ \text{Vrms}\\&=208\angle 180^\circ\ \text{Vrms}\end{aligned}$$

Use the following expression to find the phase voltages of the source:

$$\mathbf{V}_{an}=\frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30^\circ}$$

Find the phase voltages.

$$\begin{aligned}\mathbf{V}_{an}&=\frac{\mathbf{V}_{ab}}{\sqrt{3}\angle 30^\circ}\\&=\frac{208\angle 60^\circ}{\sqrt{3}\angle 30^\circ}\\&=120\angle 30^\circ\ \text{V}\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{bn}&=\frac{\mathbf{V}_{bc}}{\sqrt{3}\angle 30^\circ}\\&=\frac{208\angle -60^\circ}{\sqrt{3}\angle 30^\circ}\\&=120\angle -90^\circ\ \text{V}\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{cn}&=\frac{\mathbf{V}_{ca}}{\sqrt{3}\angle 30^\circ}\\&=\frac{208\angle 180^\circ}{\sqrt{3}\angle 30^\circ}\\&=120\angle 150^\circ\ \text{V}\end{aligned}$$

Step 4 of 6

Consider that the line impedance is, $1.2+j1\ \Omega$.

Consider that the phase impedance of balanced Y load 1 is, $8+j5\ \Omega$.

Draw the single equivalent of the balanced three phase system.

Figure 3

Step 5 of 6

Find the equivalent offered by the parallel combination of load 1 and load 2.

$$\begin{aligned}\mathbf{Z}_{eq}&=\mathbf{Z}_{Y1}\parallel\mathbf{Z}_{Y2}\\&=\frac{\mathbf{Z}_{Y1}\mathbf{Z}_{Y2}}{\mathbf{Z}_{Y1}+\mathbf{Z}_{Y2}}\end{aligned}$$

Substitute $8+j5\ \Omega$ for $\mathbf{Z}_{Y1}$, and $7+j4\ \Omega$ for $\mathbf{Z}_{Y2}$.

$$\begin{aligned}\mathbf{Z}_{eq}&=\frac{(8+j5)(7+j4)}{8+j5+7+j4}\\&=\frac{36+j6.7}{15+j9}\\&=3.735+j2.225\ \Omega\end{aligned}$$

Find the current through the circuit in Figure 3.

$$\begin{aligned}\mathbf{I}_{aA}&=\frac{\mathbf{V}_{an}}{(1.2+j1)+(3.735+j2.225)}\\&=\frac{120\angle 30^\circ\ \text{V}}{4.935+j3.225\ \Omega}\\&=\frac{120\angle 30^\circ\ \text{V}}{5.895\angle 33.166^\circ\ \Omega}\\&=20.35\angle -3.166^\circ\ \text{A}\end{aligned}$$

Step 6 of 6

Use the current division method to calculate the phase current.

$$\begin{aligned}\mathbf{I}_{aA1}&=\mathbf{I}_{aA}\left(\frac{Z_{Y2}}{Z_{Y1}+Z_{Y2}}\right)\\&=(20.35\angle -3.166^\circ)\left(\frac{7+j4}{8+j5+7+j4}\right)\\&=(20.35\angle -3.166^\circ)(0.46\angle -1.2^\circ)\\&=9.38\angle -4.385^\circ\ \text{A}\end{aligned}$$

Consider the following values for other line voltages by $abc-$ phase sequence:

$$\begin{aligned}\mathbf{I}_{bB1}&=9.38\angle -4.385^\circ-120^\circ\ \text{A}\\&=9.38\angle -124.385^\circ\ \text{A}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_{cC1}&=9.38\angle -4.385^\circ+120^\circ\ \text{A}\\&=9.38\angle 115.6^\circ\ \text{A}\end{aligned}$$

Thus, the following are the phase currents in the balanced wye load:

$$\boxed{\begin{aligned}\mathbf{I}_{aA1}&=9.38\angle -4.385^\circ\ \text{A}\\\mathbf{I}_{bB1}&=9.38\angle -124.385^\circ\ \text{A}\\\mathbf{I}_{cC1}&=9.38\angle 115.6^\circ\ \text{A}\end{aligned}}.$$

11.067
P

Step 1 of 5

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Consider the expression for $\mathbf{I}_{AN1}$ using current division rule.

$$\begin{aligned}\mathbf{I}_{AN1} &= \mathbf{I}_{aA}\left(\frac{10+j4}{10+j4+4+j4}\right)\\ &= \mathbf{I}_{aA}\left(\frac{10+j4}{14+j8}\right)\\ &= \mathbf{I}_{aA}(0.66-j0.09)\\ &= \mathbf{I}_{aA}(0.67\angle -7.77^\circ)\end{aligned}$$

Solve for $\mathbf{I}_{aA}$.

$$\mathbf{I}_{aA} = \frac{\mathbf{I}_{AN1}}{0.67\angle -7.77^\circ}$$

Substitute $10\angle 20^\circ \text{A rms}$ for $\mathbf{I}_{AN1}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{10\angle 20^\circ}{0.67\angle -7.77^\circ}\\ &= 14.93\angle 27.77^\circ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $14.93\angle 27.77^\circ \text{A rms}$.

Step 3 of 5

Compare $\mathbf{I}_{aA} = 14.93\angle 27.77^\circ \text{A rms}$ with $\mathbf{I}_{aA} = \mathbf{I}_p\angle\theta$.

$\mathbf{I}_p = 14.93$ and $\theta = 27.77^\circ$

Consider the expression for $\mathbf{I}_{ab}$.

$$\mathbf{I}_{ab} = \frac{\mathbf{I}_p}{\sqrt{3}}\angle\theta + 30^\circ$$

Substitute 27.77° for θ and 14.93 for $\mathbf{I}_p$.

$$\begin{aligned}\mathbf{I}_{ab} &= \frac{14.93}{\sqrt{3}}\angle 27.77^\circ + 30^\circ\\ &= 8.65\angle 57.77^\circ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{ab}$ is $\boxed{8.65\angle 57.77^\circ \text{A rms}}$.

Step 4 of 5

Consider the expression for $\mathbf{I}_{bc}$.

$$\mathbf{I}_{bc} = \frac{\mathbf{I}_p}{\sqrt{3}}\angle\theta - 90^\circ$$

Substitute 27.77° for θ and 14.93 for $\mathbf{I}_p$.

$$\begin{aligned}\mathbf{I}_{bc} &= \frac{14.93}{\sqrt{3}}\angle 27.77^\circ - 90^\circ\\ &= 8.65\angle -62.23^\circ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{bc}$ is $\boxed{8.65\angle -62.23^\circ \text{A rms}}$.

Step 5 of 5

Consider the expression for $\mathbf{I}_{ca}$.

$$\mathbf{I}_{ca} = \frac{\mathbf{I}_p}{\sqrt{3}}\angle\theta - 210^\circ$$

Substitute 27.77° for θ and 14.93 for $\mathbf{I}_p$.

$$\begin{aligned}\mathbf{I}_{ab} &= \frac{14.93}{\sqrt{3}}\angle 27.77^\circ - 210^\circ\\ &= 8.65\angle -182.23^\circ \text{A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{ab}$ is $\boxed{8.65\angle -182.23^\circ \text{A rms}}$.

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{aA}$ in terms of power loss.

$$\mathbf{I}_{aA} = \sqrt{\frac{P_{line}}{3(R_{load})}}$$

Substitute $16\,\Omega$ for R_{load} and 2000 W for P_{line}.

$$\begin{aligned}\mathbf{I}_{aA} &= \sqrt{\frac{2000}{3(16)}}\\ &= \sqrt{\frac{2000}{48}}\\ &= \sqrt{41.67}\\ &= 6.45^\circ\text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is 6.45° A rms.

Step 3 of 3

Consider the expression for the magnitude of the source voltage.

$$|\mathbf{V}_{an}| = I_{aA}\left(|Z_{line}| + |Z_{load}|\right)$$

Substitute 6.45 A rms for $\mathbf{I}_{aA}$, $0.5 + j0.2\,\Omega$ for Z_{line} and $16 + j10\,\Omega$ for Z_{load}.

$$\begin{aligned}|\mathbf{V}_{an}| &= (6.45)\left(|0.5 + j0.2| + |16 + j10|\right)\\ &= (6.45)\left(|0.54\angle 21.8| + |18.87\angle 32.01^\circ|\right)\\ &= (6.45)(0.54 + 18.87)\\ &= (6.45)(19.47)\end{aligned}$$

$$|\mathbf{V}_{an}| = 125.2\text{ V rms}$$

Therefore, the magnitude value of the source voltage is $\boxed{125.2\text{ V rms}}$.

11.069
P

Step 1 of 3

Consider the expression for $\mathbf{V}_{ab}$.

$$|\mathbf{V}_{an}| = \frac{\mathbf{V}_{ab}}{\sqrt{3}}$$

Substitute $208\ \mathrm{V\ rms}$ for $\mathbf{V}_{ab}$.

$$\begin{aligned}|\mathbf{V}_{an}| &= \frac{208}{\sqrt{3}} \\ &= 120.09\ \mathrm{V\ rms}\end{aligned}$$

Therefore, the value of the phase voltage is $120.09\ \mathrm{V\ rms}$.

Step 2 of 3

Consider the expression for the load power.

$$S = 3|V_{an}||I_{aA}|\angle\theta$$

Substitute $3600\angle 25°\ \mathrm{VA}$ for S, $120.09\ \mathrm{V\ rms}$ for $\mathbf{V}_{an}$ and $25°$ for θ.

$$3600\angle 25° = 3(120.09)(I_{aA})\angle 25°$$

$$I_{aA} = \frac{3600\angle 25°}{3(120.09)\angle 25°}$$

$$I_{aA} = \frac{3600\angle 25°}{360.27\angle 25°}$$

$$I_{aA} = 9.99\ \mathrm{A\ rms}$$

Therefore, the value of I_{aA} is $9.99\ \mathrm{A\ rms}$.

Step 3 of 3

Consider the impedance for the load impedance.

$$Z_{load} = \frac{\mathbf{V}_{an}}{\mathbf{I}_{aA}}\angle\theta$$

Substitute $9.99\ \mathrm{A\ rms}$ for I_{aA}, $120.09\ \mathrm{V\ rms}$ for $\mathbf{V}_{an}$ and $25°$ for θ.

$$\begin{aligned}Z_{load} &= \frac{120.09}{9.99}\angle 25° \\ &= 12.02\angle 25° \\ &= 10.89 + j5.08\ \Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{10.89 + j5.08\ \Omega}$.

11.070
P

Step 1 of 3

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{I}_{aA}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{\mathbf{V}_{an}}{1\angle 20^\circ + 100\angle 70^\circ} \\ &= \frac{\mathbf{V}_{an}}{100.65\angle 69.56^\circ}\end{aligned}$$

Substitute $120\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{an}$.

$$\begin{aligned}\mathbf{I}_{aA} &= \frac{120\angle 0^\circ}{100.65\angle 69.56^\circ} \\ &= 1.19225\angle -69.56^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of $\mathbf{I}_{aA}$ is $1.19225\angle -69.56^\circ \text{ A rms}$.

Step 3 of 3

Consider the expression for the power dissipated by the load.

$$S = 3|I_{aA}|^2 Z_{load}$$

Substitute 1.19 A rms for $|\mathbf{I}_{aA}|$ and $100\angle 70^\circ\,\Omega$ for Z_{load} .

$$\begin{aligned}S &= 3(1.19225)^2(100\angle 70^\circ) \\ &= 426.44\angle 70^\circ \\ &= 145.85 + j400.72 \text{ VA}\end{aligned}$$

Therefore, the value of the complex power dissipated by the load is

$\boxed{145.85 + j400.72 \text{ VA}}$.

Compare $S = 145.85 + j400.72 \text{ VA}$ with $S = P + jQ \text{ VA}$ where P represents the real power dissipated by the load and Q represents the reactive power dissipated by the load.

Here, $P = 145.85 \text{ W}$ and $Q = 400.72 \text{ Var}$.

Therefore, the values of the real and reactive powers dissipated by the load are

$\boxed{145.85 \text{ W}}$ and $\boxed{400.72 \text{ Var}}$ respectively.

Step 1 of 4

Consider the expression for $|\mathbf{V}_{an}|$.

$$|\mathbf{V}_{an}| = \frac{|\mathbf{V}_{ab}|}{\sqrt{3}}$$

Substitute $208\ \mathbf{V\ rms}$ for $|\mathbf{V}_{ab}|$.

$$\begin{aligned}|\mathbf{V}_{an}| &= \frac{208}{\sqrt{3}}\\ &= 120.09\ \mathbf{V\ rms}\end{aligned}$$

Therefore, the value of $|\mathbf{V}_{an}|$ is $120.09\ \mathbf{V\ rms}$.

Step 2 of 4

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 3 of 4

Consider the expression for the real power absorbed by the load.

$$P = 3(\mathbf{V}_{an})(\mathbf{I}_{aA})\cos\theta$$

Substitute $1800\ \mathbf{W}$ for P, $120.09\ \mathbf{V\ rms}$ for $\mathbf{V}_{an}$ and $6\ \mathbf{A}$ for $\mathbf{I}_{aA}$.

$$\begin{aligned}1800 &= 3(120.09)(6)\cos\theta\\ \cos\theta &= \frac{1800}{2161.62}\\ \cos\theta &= 0.83\\ \theta &= \cos^{-1}(0.8327)\\ \theta &= 33.62^\circ\end{aligned}$$

Therefore, the value of the power factor angle is 33.62°.

Step 4 of 4

Assume a lagging power factor.

Consider the expression for the load impedance.

$$Z_{load} = \frac{V_{an}}{I_{aA}}\angle\theta$$

Substitute $120.09\ \mathbf{V\ rms}$ for $\mathbf{V}_{an}$, $6\ \mathbf{A}$ for $\mathbf{I}_{aA}$ and 33.90° for θ.

$$\begin{aligned}Z_{load} &= \frac{120.09}{6}\angle 33.62^\circ\\ &= 20.02\angle 33.62^\circ\\ &= 16.67 + j11.08\ \Omega\end{aligned}$$

Therefore, the value of the load impedance is $\boxed{16.67 + j11.08\ \Omega}$.

Step 1 of 5

Consider the following circuit arrangement for the balanced three-phase system:

Figure 1

Step 2 of 5

Consider that the delta load consumes a total of 12 kVA power.

Find the per phase power consumed by load.

$$P_L = \frac{12\text{ kVA}}{3}$$
$$= 4\text{ kVA}$$

Find the phase angle of the power.

$$\phi = \cos^{-1}(pf)$$
$$= \cos^{-1}(0.7)$$
$$= 45.57°$$

Consider that the phase current through the load is, $10\angle -30°\text{ A rms}$.

Find the per phase voltage across the load.

$$\mathbf{V}_L = \frac{P_L}{\mathbf{I}_L^*}$$
$$= \frac{4000\angle 45.57°\text{ VA}}{10\angle 30°\text{ A rms}}$$
$$= 400\angle 15.57°\text{ V rms}$$

Find the phase impedance of the load.

$$\mathbf{Z}_L = \frac{\mathbf{V}_L}{\mathbf{I}_L}$$
$$= \frac{400\angle 15.57°}{10\angle -30°}$$
$$= 40\angle 45.57°\ \Omega$$
$$= 28 + j28.565\ \Omega$$

ad.

ing expression to find the line current:

$\angle -30°$

$-30°)(10\angle -30°)$

$\angle -60°$ A

hase power supplied by the source.

A

VA

e angle of the power.

$f)$

75)

e voltage of the source.

$$\mathbf{V}_{an} = \frac{P_S}{\mathbf{I}_{aA}^*}$$
$$= \frac{4.67\angle 41.4°}{17.32\angle -60°}$$
$$= 0.33\angle 101.4°\text{ V}$$

Use following expression to convert the balanced Δ -load to equivalent balanced $\mathbf{Y}$ -load.

$$\mathbf{Y} = \frac{\Delta}{3}$$

Find the phase impedance of Y-load.

$$\mathbf{Y} = \frac{\Delta}{3}$$
$$= \frac{28 + j28.565\ \Omega}{3}$$
$$= 9.34 + j9.52\ \Omega$$

Step 4 of 5

Draw the single equivalent of the balanced three phase system.

Figure 2

Step 5 of 5

Consider the following expression to find the value of line impedance:

$$\mathbf{Z}_S + \mathbf{Z}_L = \frac{\mathbf{V}_{an}}{\mathbf{I}_{aA}}$$
$$\mathbf{Z}_S + (9.34 + j9.52) = \frac{0.33\angle 101.4°\text{ V}}{17.32\angle -60°\text{ A}}$$
$$\mathbf{Z}_S = (-0.022 + j0.00743) - (9.34 + j9.52)$$
$$\mathbf{Z}_S = -9.36 - j9.51\ \Omega$$

Thus, the following are the per phase impedances of load and line:

$$\boxed{\begin{aligned}\mathbf{Z}_L &= 28 + j28.565\ \Omega \\ \mathbf{Z}_S &= -28.022 - 28.5575\ \Omega\end{aligned}}$$

Step 1 of 6

11.073 P

Consider the following circuit arrangement for the balanced three-phase system:

Figure 1

Step 2 of 6

Consider that the power absorbed by the load is, 3435 W.

Find the per phase power consumed by load.

$$\begin{aligned} P_{AN} &= \frac{P_L}{3} \\ &= \frac{3435\ \text{W}}{3} \\ &= 1145\ \text{W} \end{aligned}$$

Consider that the load impedance is, $10 + j2\ \Omega$.

Find the magnitude of the load current.

$$\begin{aligned} I_{AN} &= \sqrt{\frac{P_{AN}}{R}} \\ &= \sqrt{\frac{1145}{10}} \\ &= \sqrt{114.5} \\ &= 10.7\ \text{A} \end{aligned}$$

Step 3 of 6

Draw the single-phase equivalent of the balanced three-phase system.

Figure 2

Step 4 of 6

Consider that the power supplied by the source is, 3774 W.

Find the per phase power consumed by load.

$$\begin{aligned} P_{an} &= \frac{P_S}{3} \\ &= \frac{3774\ \text{W}}{3} \\ &= 1258\ \text{W} \end{aligned}$$

The current in the circuit in Figure 2 is same. Therefore, $I_{aA} = I_{AN}$.

Consider the following expression for the power supplied by the source:

$$V_{an} I_{aA} \cos\phi = 1258\ \text{W}$$

Substitute 120 V for V_{an} , and 10.7 A for I_{aA} .

$$(120\ \text{V})(10.7\ \text{A})\cos\phi = 1258\ \text{W}$$

$$\cos\phi = \frac{1258\ \text{W}}{1284}$$

$$\begin{aligned} \phi &= \cos^{-1}(0.98) \\ &= 11.55° \end{aligned}$$

Find the phase angle of the current.

$$\phi = \theta_V - \theta_I$$

Substitute $11.55°$ for ϕ , and $30°$ for θ_V to find the value of θ_I .

$$11.55° = 30° - \theta_I$$

$$\begin{aligned} \theta_I &= 30° - 11.55° \\ &= 18.45° \end{aligned}$$

Thus, the current, $\mathbf{I}_{aA}$ is, $10.7\angle 18.45°\ \text{A}$.

Step 5 of 6

Find the voltage across the load.

$$\begin{aligned} \mathbf{V}_{AN} &= \mathbf{I}_{aA} Z_L \\ &= (10.7\angle 18.45°\ \text{A})(10 + j2) \\ &= 94.73 + j54.163 \\ &= 109.12\angle 29.76°\ \text{V} \end{aligned}$$

Find the voltage across the line impedance.

$$\begin{aligned} \mathbf{V}_S &= \mathbf{V}_{an} - \mathbf{V}_{AN} \\ &= 120\angle 30°\ \text{V} - 109.12\angle 29.76° \\ &= 10.89\angle 32.4°\ \text{V} \end{aligned}$$

Calculate the line impedance.

$$\begin{aligned} Z_S &= \frac{\mathbf{V}_S}{\mathbf{I}_{aA}} \\ &= \frac{10.89\angle 32.4°\ \text{V}}{10.7\angle 18.45°\ \text{A}} \\ &= 1.017\angle 13.95° \\ &= 0.987 + j0.245\ \Omega \end{aligned}$$

Step 6 of 6

Check the value of source power at this value of line impedance.

$$\begin{aligned} P_{an} &= P_S + P_{AN} \\ &= I_{aA}^2 R_S + I_{aA}^2 R_L \\ &= I_{aA}^2 (R_S + R_L) \end{aligned}$$

Substitute 10.7 A for I_{aA} , $0.987\ \Omega$, and $10\ \Omega$ for R_L .

$$\begin{aligned} P_{an} &= (10.7)^2 (0.987 + 10) \\ &= (10.7)^2 (10.987) \\ &= 1258\ \text{W} \end{aligned}$$

Thus, the value of the line impedance, Z_S is $\boxed{0.987 + j0.245\ \Omega}$.

11.074
P

Step 1 of 2

Given

Line voltage, $V_L = 4.6\text{ kV rms}$

Plant 1: 300 kV A, 0.8 pf lagging

$$S_1 = 300\angle\cos^{-1}(0.8)$$

$$S_1 = 300\angle 36.869^\circ\ \text{kVA}$$

$$S_1 = (240 + j180)\ \text{kVA}$$

Plant 2: 350 kV A, 0.8 pf lagging

$$S_2 = 350\angle\cos^{-1}(0.8)$$

$$S_2 = 350\angle 36.869^\circ\ \text{kVA}$$

$$S_2 = (280 + j210)\ \text{kVA}$$

Step 2 of 2

Hence the total complex power is,

$$S = S_1 + S_2$$

$$S = (240 + j180)\text{k} + (280 + j210)\text{k}$$

$$S = (520 + j390)\text{k}$$

$$S = 650\angle 36.869^\circ\ \text{kVA}$$

Hence the line current is,

$$I_L = \frac{|S|}{\sqrt{3}V_L}$$

$$I_L = \frac{650\times10^3}{\sqrt{3}\times4.6\times10^3}$$

$$\boxed{I_L = 81.58\text{ A rms}}$$

11.075
P

Step 1 of 3

Given
Line voltage, $V_L = 4160\ \text{V rms}$

Load 1: 240 kVA, 0.8 pf lagging

$$S_1 = 240\times10^3\angle\cos^{-1}(0.8)$$
$$S_1 = 240\angle36.869^\circ\ \text{kVA}$$
$$S_1 = (192+j144)\ \text{kVA}$$

Load 2: 160 kVA, 0.92 pf lagging

$$S_2 = 160\times10^3\angle\cos^{-1}(0.92)$$
$$S_2 = 160\angle23.074^\circ\ \text{kVA}$$
$$S_2 = (147.2+j62.71)\ \text{kVA}$$

Load 3: S_3 160 kVA, 1 pf lagging

$$S_3 = S_3\angle\cos^{-1}(1)$$
$$S_3 = S_3\angle0^\circ$$
$$S_3 = S_3\ \text{in kVA}$$

Step 2 of 3

Hence the total complex power is,

$$S = S_1 + S_2 + S_3$$
$$S = (192+j144)\,\text{k}+(147.2+j62.71)\,\text{k}+S_3$$
$$S = (339.2+j206.71)\,\text{k}+S_3$$
$$S = (339.2+S_3+j206.71)\,\text{kVA}$$

Step 3 of 3

Hence the line current is,

$$I_L = \frac{|S|}{\sqrt{3}V_L}$$
$$I_L = \frac{\sqrt{(339.2+S_3)^2+(206.71)^2}\times10^3}{\sqrt{3}\times4160}$$
$$62 = \frac{\sqrt{(339.2+S_3)^2+(206.71)^2}\times10^3}{\sqrt{3}\times4160}$$
$$446.7305 = \sqrt{(339.2+S_3)^2+(206.71)^2}$$
$$(446.7305)^2 = (339.2+S_3)^2+(206.71)^2$$
$$(339.2+S_3)^2 = (446.7305)^2-(206.71)^2$$
$$339.2+S_3 = 396.03$$
$$\boxed{S_3 = 56.83\text{kVA}}$$

11.076
P

Step 1 of 6

Source is Y connected and supplies 14 kV A at 0.75 lagging power factor,

$$S = 14\times10^3\angle\cos^{-1}(0.75)$$

$$S = 14\times10^3\angle41.41^\circ$$

$$S = 14\angle41.41^\circ \text{ kVA}$$

Step 2 of 6

Load 1: Y connected and absorbs 9kVA at 0.6 lagging power factor,

$$S_1 = 9\times10^3\angle\cos^{-1}(0.6)$$

$$S_1 = 9\times10^3\angle53.13^\circ$$

$$S_1 = 9\angle53.13^\circ \text{ kVA}$$

The phase current is given as,

$$I_1 = 10\angle-30^\circ \text{ A rms}$$

Step 3 of 6

Therefore the voltage across the load 1 is,

$$S_1 = V_1 I_1^*$$

$$V_1 = \frac{S_1}{I_1^*}$$

$$V_1 = \frac{9\times10^3\angle53.13^\circ}{10\angle30^\circ}$$

$$V_1 = 900\angle23.13^\circ \text{V}$$

Step 4 of 6

Complex power consumed by Load 2:

$$S_2 = S - S_1$$

$$S_2 = \left(14\times10^3\angle41.41^\circ\right) - \left(9\times10^3\angle53.13^\circ\right)$$

$$S_2 = (10.5 + j9.26)10^3 - (5.4 + j7.2)10^3$$

$$S_2 = (5.1 + j2.06)10^3$$

$$S_2 = 5.5\times10^3\angle22^\circ$$

$$S_2 = 5.5\angle22^\circ \text{ kVA}$$

Step 5 of 6

Let us assume that the load 2 is also connected in Y,
Hence the current in the load 2 is,

$$S_2 = V_2 I_2^*$$

$$I_2^* = \frac{S_2}{V_2}$$

$$I_2^* = \frac{S_2}{V_1} \qquad \text{since the loads are in parallel}$$

$$I_2^* = \frac{5.5\times10^3\angle22^\circ}{900\angle23.13^\circ}$$

$$I_2^* = 6.11\angle-1.13^\circ$$

$$I_2 = 6.11\angle1.13^\circ \text{ A rms}$$

Step 6 of 6

Hence the impedance of the second load is,

$$Z_{Y2} = \frac{V_2}{I_2}$$

$$Z_{Y2} = \frac{900\angle23.13^\circ}{6.11\angle1.13^\circ}$$

$$Z_{Y2} = 147.3\angle22^\circ\Omega$$

Hence the impedance in the Δ connected load is,

$$Z_{\Delta2} = 3Z_{Y2}$$

$$Z_{\Delta2} = 3\left(147.3\angle22^\circ\right)$$

$$\boxed{Z_{\Delta2} = 441.9\angle22^\circ\Omega}$$

11.077
P

Step 1 of 3

Source is Y connected.

$V_{an} = 120\angle 20^\circ \text{ V}_{rms}$

The impedance of load 1 is,

$Z_{Y1} = (8+6j)$

$Z_{Y1} = 10\angle 36.869^\circ \ \Omega$

Since the load 1 is also connected in Y, the load phase voltage is same as the source phase voltage

$$\therefore I_1 = \frac{120\angle 20^\circ}{10\angle 36.869^\circ}$$

$$I_1 = 12\angle -16.869^\circ \text{ A rms}$$

Step 2 of 3

The complex power of load 2 is,

$S_2 = 600\angle 36^\circ \text{ VA}$

Since the load 2 is also connected in Y, the load phase voltage is same as the source phase voltage. Therefore the line current is,

$$S_2 = V_2 I_2^*$$

$$I_2^* = \frac{S_2}{V_2}$$

$$I_2^* = \frac{600\angle 36^\circ}{120\angle 20^\circ}$$

$$I_2^* = 5\angle 16^\circ$$

$$I_2 = 5\angle -16^\circ \text{ A rms}$$

Step 3 of 3

$\therefore$ Total line current,

$$I = I_1 + I_2$$

$$I = 12\angle -16.869^\circ + 5\angle -16^\circ$$

$$I = 11.4836 - j3.482 + 4.8063 - j1.3782$$

$$I = 16.2899 - j4.8602$$

$$\boxed{I = 16.99\angle -16.61^\circ \text{ A rms}}$$

$\therefore$ Complex Power of the source is,

$$S = V_{an} I^*$$

$$S = (120\angle 20^\circ)(16.99\angle 16.61^\circ)$$

$$\boxed{S = 2038.8\angle 36.61^\circ \text{ VA}}$$

11.078
P

Step 1 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 4

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.75) \\ &= 41.41^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is 41.41°.

Step 3 of 4

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2}$$

Substitute $60\angle 36.87^\circ \text{ kVA}$ for S_{load1} and $30\angle 41.41^\circ \text{ kVA}$ for S_{load2}.

$$\begin{aligned}S_T &= 60\angle 36.87^\circ \text{ k} + 30\angle 41.41^\circ \text{ k} \\ &= 89.94\angle 38.38^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $89.94\angle 38.38^\circ \text{ kVA}$.

Step 4 of 4

Consider the expression for the power in terms of line current and line voltage.

$$S_T = 3\mathbf{V}_{AN}\mathbf{I}_{aA}^*$$

Substitute $89.94\angle 38.38^\circ \text{ kVA}$ for S_T and $120.09\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}89.94\angle 38.38^\circ \text{ k} &= 3(120.09\angle 0^\circ)\mathbf{I}_{aA}^* \\ \mathbf{I}_{aA}^* &= \frac{89.94\angle 38.38^\circ \text{ k}}{3(120.09\angle 0^\circ)} \\ \mathbf{I}_{aA}^* &= 249.65\angle 38.38^\circ \\ \mathbf{I}_{aA} &= 249.65\angle -38.38^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of the line current is $\boxed{249.65\angle -38.38^\circ \text{ A rms}}$.

Consider the expression for the power factor.

$$\begin{aligned}PF &= \cos(38.38^\circ) \\ &= 0.78 \text{ lagging}\end{aligned}$$

Therefore, the value of the combined power factor is $\boxed{0.78 \text{ lagging}}$.

11.079
P

Step 1 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 4

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.6) \\ &= 53.13^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is 53.13°.

Step 3 of 4

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2}$$

Substitute $36\angle 36.87^\circ \text{ kVA}$ for S_{load1} and $18\angle 53.13^\circ \text{ kVA}$ for S_{load2}.

$$\begin{aligned}S_T &= 36\angle 36.87^\circ \text{ k} + 18\angle 53.13^\circ \text{ k} \\ &= 53.52\angle 42.27^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $53.52\angle 42.27^\circ \text{ kVA}$.

Step 4 of 4

Consider the expression for the power in terms of line current and line voltage.

$$S_T = 3\mathbf{V}_{AN}\mathbf{I}_{aA}^*$$

Substitute $53.52\angle 42.27^\circ \text{ kVA}$ for S_T and $120.09\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$53.52\angle 42.27^\circ \text{ k} = 3(120.09\angle 0^\circ)\mathbf{I}_{aA}^*$$

$$\mathbf{I}_{aA}^* = \frac{53.52}{3(120}$$

$$\mathbf{I}_{aA}^* = 148.56$$

$$\mathbf{I}_{aA} = 148.56$$

Therefore, the

Consider the

$$PF = \cos(42$$

$$= 0.74 \text{ lagging}$$

Therefore, the value of the combined power factor is $\boxed{0.74 \text{ lagging}}$.

$$\mathbf{I}_{aA}^* = \frac{53.52\angle 42.27^\circ \text{ k}}{3(120.09\angle 0^\circ)}$$

$$\mathbf{I}_{aA}^* = 148.56\angle 42.27^\circ$$

$$\mathbf{I}_{aA} = 148.56\angle -42.27^\circ \text{ A rms}$$

Therefore, the value of the line current is $\boxed{148.56\angle -42.27^\circ \text{ A rm}}$

Consider the expression for the power factor.

$$PF = \cos(42.27^\circ)$$

Step 1 of 7

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 7

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Step 3 of 7

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.6) \\ &= -53.13^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is -53.13°.

The value of the complex power at load 2 is $\frac{24}{0.6}\angle -53.13^\circ \text{ kVA}$.

Step 4 of 7

Consider the expression for the power factor angle at combined load.

$$\begin{aligned}\theta &= \cos^{-1}(1) \\ &= 0^\circ\end{aligned}$$

Therefore, the value of the power factor angle at combined load is 0°.

Step 5 of 7

Consider the expression for the total power dissipated at the loads.

$$S_T = 3|\mathbf{V}_{AN}||\mathbf{I}_{aA}|\angle 30.68^\circ$$

Substitute 120.09 V rms for $\mathbf{V}_{AN}$ and 166.8 A rms for $\mathbf{I}_{aA}$.

$$\begin{aligned}S_T &= 3(120.09)(166.8)\angle 0^\circ \\ &= 60.05\angle 0^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $60.05\angle 0^\circ \text{ kVA}$.

Step 6 of 7

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $30\angle 36.87^\circ \text{ kVA}$ for S_{load1}, $\frac{24}{0.6}\angle -53.13^\circ \text{ kVA}$ for S_{load2} and $60.05\angle 0^\circ \text{ kVA}$ for S_T.

$$\begin{aligned}60.05\angle 0^\circ \text{ k} &= 30\angle 36.87^\circ \text{ k} + \frac{24}{0.6}\angle -53.13^\circ \text{ k} + S_{load3} \\ 60.05\angle 0^\circ \text{ k} &= 50\angle -16.26^\circ \text{ k} + S_{load3}\end{aligned}$$

$$\begin{aligned}S_{load3} &= 60.05\angle 0^\circ \text{ k} - 50\angle -16.26^\circ \\ S_{load3} &= 18.47\angle 49.28^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the power dissipated at the load 3 is $18.47\angle 49.28^\circ \text{ kVA}$.

Step 7 of 7

Consider the expression for the power factor.

$$\begin{aligned}PF &= \cos(49.28^\circ) \\ &= 0.65 \text{ lagging}\end{aligned}$$

Therefore, the value of the source power factor is 0.65 lagging.

Therefore, the rating value of load 3 is $\boxed{18.47 \text{ kVA at } 0.65 \text{ pf lagging}}$.

11.081 P

Step 1 of 4

Consider that a balanced three-phase source serves four loads.

Consider load 1.

Find the phase angle of the power.

$$\begin{aligned}\phi_1 &= \cos^{-1}(pf)\\ &= \cos^{-1}(0.8)\\ &= 36.87^\circ\end{aligned}$$

Therefore, the complex power supplied to the load 1 is,

$$\begin{aligned}S_1 &= 18\text{ kVA}\angle 36.87^\circ\\ &= 18000\angle 36.87^\circ\\ &= 14400 + j10800\text{ VA}\end{aligned}$$

Consider load 2.

Find the phase angle of the power.

$$\begin{aligned}\phi_2 &= \cos^{-1}(pf)\\ &= \cos^{-1}(0.7)\\ &= 45.57^\circ\end{aligned}$$

Therefore, the complex power supplied to the load 2 is,

$$\begin{aligned}S_2 &= 10\text{ kVA}\angle 45.57^\circ\\ &= 10000\angle 45.57^\circ\\ &= 7000 + j7141.43\text{ VA}\end{aligned}$$

Step 2 of 4

Consider load 3.

Find the phase angle of the power.

$$\begin{aligned}\phi_3 &= \cos^{-1}(pf)\\ &= \cos^{-1}(1)\\ &= 0^\circ\end{aligned}$$

Therefore, the complex power supplied to the load 3 is,

$$\begin{aligned}S_3 &= 10\text{ kVA}\angle 0^\circ\\ &= 10000\angle 0^\circ\\ &= 10000 + j0\text{ VA}\end{aligned}$$

Consider load 4.

Find the phase angle of the power.

$$\begin{aligned}\phi_4 &= \cos^{-1}(pf)\\ &= \cos^{-1}(0.6)\\ &= 53.13^\circ\end{aligned}$$

Therefore, the complex power supplied to the load 4 is,

$$\begin{aligned}S_4 &= 16\text{ kVA}\angle 53.13^\circ\\ &= 16000\angle 53.13^\circ\\ &= 9600 + j12800\text{ VA}\end{aligned}$$

Calculate the total complex power at the load.

$$\begin{aligned}S_L &= S_1 + S_2 + S_3 + S_4\\ &= 14400 + j10800 + 7000 + j7141.43 + 10000 + 9600 + j12800\\ &= 41000 + j30741.43\text{ VA}\\ &= 51244.9\angle 36.8622^\circ\text{ VA}\end{aligned}$$

Step 3 of 4

Consider that the line voltage at the load is 208 V rms.

Consider the following expression for the total complex power at load:

$$S_T = \sqrt{3}V_L I_L$$

Substitute 51244.9 for S_T, and 208 V for V_L to find the value of I_L.

$$51244.9 = \sqrt{3}(280)I_L$$

$$\begin{aligned}I_L &= \frac{51244.9}{\sqrt{3}(280)}\\ &= \frac{51244.9}{484.97}\\ &= 105.665\text{ A}\end{aligned}$$

Calculate the complex power absorbed by the line impedance.

$$\begin{aligned}S_{Line} &= 3\left(R_{Line}I_L^2 + jX_{Line}I_L^2\right)\\ &= 3I_L^2\left(R_{Line} + jX_{Line}\right)\\ &= 3(105.665)^2(0.02 + j0.04)\\ &= 669.9 + j1339.8\text{ VA}\end{aligned}$$

The total complex power delivered by the source is,

$$\begin{aligned}S_S &= S_L + S_{Line}\\ &= 41000 + j30741.43 + 669.9 + j1339.8\\ &= 41669.9 + j32081.246\text{ VA}\\ &= 52588.8\angle 37.5923^\circ\text{ VA}\end{aligned}$$

Step 4 of 4

Consider the following expression for the total complex power at source:

$$S_S = \sqrt{3}V_S I_S$$

The current in the circuit is same. Therefore, $I_S = I_L$.

Substitute 52588.8 for S_S, and 105.665 A for I_S to find the value of V_S.

$$52588.8 = \sqrt{3}V_S(105.665)$$

$$\begin{aligned}V_S &= \frac{52588.8}{\sqrt{3}(105.665)}\\ &= \frac{52588.8}{183}\\ &= 287.343\text{ V}\end{aligned}$$

The phase angle of the complex power at source is 37.5923°.

Calculate the power factor at the source.

$$\begin{aligned}\text{Pf}_S &= \cos(37.5923^\circ)\\ &= 0.79\end{aligned}$$

Thus, the line voltage, V_S is, $\boxed{287.343\text{ V}}$ and the power factor at the source is $\boxed{0.79}$.

11.082
P

Step 1 of 5

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\mathbf{V}_{AN} = \frac{208\angle 0^\circ}{\sqrt{3}}$$
$$= 120.09\angle 0^\circ \text{ V rms}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 5

Consider the expression for the power factor angle at load 1.

$$\theta = \cos^{-1}(0.6)$$
$$= 53.13^\circ$$

Therefore, the value of the power factor angle at load 1 is 53.13°.

Consider the expression for the power factor angle at load 2.

$$\theta = \cos^{-1}(0.75)$$
$$= 41.41^\circ$$

Therefore, the value of the power factor angle at load 2 is 41.41°.

The value of the complex power at load 2 is $\frac{10}{0.75}\angle 41.41^\circ \text{ kVA}$

Step 3 of 5

Consider the expression for the power factor angle at combined load.

$$\theta = \cos^{-1}(0.88)$$
$$= 28.36^\circ$$

Therefore, the value of the power factor angle at combined load is 28.36°.

Step 4 of 5

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $24\angle 53.13^\circ \text{ kVA}$ for S_{load1}, $\frac{10}{0.75}\angle 41.41^\circ \text{ kVA}$ for S_{load2} and

$35.52\angle 28.36^\circ \text{ kVA}$ for S_T.

$$35.52\angle 28.36^\circ \text{ k} = 24\angle 53.13^\circ \text{ k} + \frac{10}{0.75}\angle 41.41^\circ \text{ k} + S_{load3}$$
$$35.52\angle 28.36^\circ \text{ k} = 37.15\angle 48.95^\circ \text{ kVA} + S_{load3}$$

$$S_{load3} = 35.52\angle 28.36^\circ \text{ k} - 37.15\angle 48.95^\circ \text{ k}$$
$$S_{load3} = 13.09\angle -58.39^\circ \text{ kVA}$$

Therefore, the value of the power dissipated at the load 3 is $13.09\angle -58.39^\circ \text{ kVA}$.

Step 5 of 5

Consider the expression for the power factor.

$$PF = \cos(-58.39^\circ)$$
$$= 0.52 \text{ leading}$$

Therefore, the value of the source power factor is 0.52 leading.

Therefore, the rating value of load 3 is $\boxed{13.09 \text{ kVA at } 0.52 \text{ pf leading}}$.

Step 1 of 6

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 6

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.7) \\ &= -45.57^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is -45.57°.

Consider the expression for the power factor angle at load 3.

$$\begin{aligned}\theta &= \cos^{-1}(1) \\ &= 0^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 3 is 0°.

Since power factor is 1, the value of power at load 3 is $10\angle 0^\circ \text{ kVA}$.

Step 3 of 6

Consider the expression for the power factor angle at load 4.

$$\begin{aligned}\theta &= \cos^{-1}(0.6) \\ &= 53.13^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 4 is 53.13°.

Consider the expression for the total power dissipated the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3} + S_{load4}$$

Substitute $20\angle 36.87^\circ \text{ kVA}$ for S_{load1}, $10\angle -45.57^\circ \text{ kVA}$ for S_{load2}, $10\angle 0^\circ \text{ kVA}$ for S_{load3} and $16\angle 53.13^\circ \text{ kVA}$ for S_{load4}.

$$\begin{aligned}S_T &= 20\angle 36.87^\circ \text{ k} + 10\angle -45.57^\circ \text{ k} + 10\angle 0^\circ \text{ k} + 16\angle 53.13^\circ \text{ k} \\ &= 46.12\angle 22.52^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $46.12\angle 22.52^\circ \text{ kVA}$.

Step 4 of 6

Consider the expression for the power in terms of line current and line voltage.

$$S_T = 3\mathbf{V}_{AN}\mathbf{I}_{aA}^*$$

Substitute $46.12\angle 22.52^\circ \text{ kVA}$ for S_T and $120.09\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$.

$$\begin{aligned}46.12\angle 22.52^\circ \text{ k} &= 3(120.09\angle 0^\circ)\mathbf{I}_{aA}^* \\ \mathbf{I}_{aA}^* &= \frac{46.12\angle 22.52^\circ \text{ k}}{3(120.09\angle 0^\circ)} \\ \mathbf{I}_{aA}^* &= 128.02\angle 22.52^\circ \\ \mathbf{I}_{aA} &= 128.02\angle -22.52^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of the line current is $128.02\angle -22.52^\circ \text{ A rms}$.

Step 5 of 6

Consider the expression for $\mathbf{V}_{an}$.

$$\mathbf{V}_{an} = I_{aA}Z_{line} + \mathbf{V}_{AN}$$

Substitute $128.02\angle -22.52^\circ \text{ A rms}$ for I_{aA}, $120.09\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AN}$ and $0.02 + j0.04\,\Omega$ for Z_{line}.

$$\begin{aligned}\mathbf{V}_{an} &= (128.02\angle -22.52^\circ)(0.02 + j0.04) + 120.09\angle 0^\circ \\ &= (128.02\angle -22.52^\circ)(0.05\angle 63.44^\circ) + 120.09\angle 0^\circ \\ &= 6.4\angle 40.92^\circ + 120.09\angle 0^\circ \\ &= 125\angle 1.92^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of the line voltage is $\boxed{125\angle 1.92^\circ \text{ V rms}}$.

Step 6 of 6

Consider the expression for the power factor.

$$PF = \cos(\angle \mathbf{V}_{an} - \angle \mathbf{I}_{aA})$$

Substitute 1.92° for $\angle \mathbf{V}_{an}$ and -22.52° for $\angle \mathbf{I}_{aA}$.

$$\begin{aligned}PF &= \cos(1.92^\circ - (-22.52^\circ)) \\ &= \cos(1.92^\circ + 22.52^\circ) \\ &= \cos(24.44^\circ) \\ &= 0.91 \text{ lagging}\end{aligned}$$

Therefore, the value of the source power factor is $\boxed{0.91 \text{ lagging}}$.

11.084
P

Step 1 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $13.8\angle 0^\circ \text{ kV rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{13.8\angle 0^\circ \text{ k}}{\sqrt{3}} \\ &= 7.97\angle 0^\circ \text{ kV rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $7.97\angle 0^\circ \text{ kV rms}$.

Step 2 of 4

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.9) \\ &= 25.84^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 25.84°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.85) \\ &= 31.79^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is 31.79°.

Consider the expression for the power factor angle at load 3.

$$\begin{aligned}\theta &= \cos^{-1}(0.9) \\ &= 25.84^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 3 is 25.84°.

Step 3 of 4

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $400\angle 25.84^\circ \text{ kVA}$ for S_{load1}, $200\angle 31.79^\circ \text{ kVA}$ for S_{load2} and $100\angle 25.84^\circ \text{ kVA}$ for S_{load3}.

$$\begin{aligned}S_T &= 400\angle 25.84^\circ \text{ k} + 200\angle 31.79^\circ \text{ k} + 100\angle 25.84^\circ \text{ k} \\ &= 699.23\angle 27.54^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $699.23\angle 27.54^\circ \text{ kVA}$.

Step 4 of 4

Consider the expression for the power in terms of line current and line voltage.

$$S_T = 3\mathbf{V}_{AN}\mathbf{I}_{aA}^*$$

Substitute $699.23\angle 27.54^\circ \text{ kVA}$ for S_T and $7.97\angle 0^\circ \text{ kV rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}699.23\angle 27.54^\circ \text{ k} &= 3(7.97\angle 0^\circ \text{ k})\mathbf{I}_{aA}^* \\ \mathbf{I}_{aA}^* &= \frac{699.23\angle 27.54^\circ \text{ k}}{3(7.97\angle 0^\circ \text{ k})} \\ \mathbf{I}_{aA}^* &= 29.24\angle 27.54^\circ \\ \mathbf{I}_{aA} &= 29.24\angle -27.54^\circ \text{ A rms}\end{aligned}$$

Therefore, the value of the line current is $\boxed{29.24\angle -27.54^\circ \text{ A rms}}$.

11.085
P

Step 1 of 4

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 4

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= -36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is 36.87°.

Consider the expression for the power factor angle at load 3.

$$\begin{aligned}\theta &= \cos^{-1}(0.75) \\ &= 41.41^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 3 is 41.41°.

Step 3 of 4

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $20\angle 36.87^\circ \text{ kVA}$ for S_{load1}, $4\angle -36.87^\circ \text{ kVA}$ for S_{load2} and $10\angle 41.41^\circ \text{ kVA}$ for S_{load3}.

$$\begin{aligned}S_T &= 20\angle 36.87^\circ \text{ k} + 4\angle -36.87^\circ \text{ k} + 10\angle 41.41^\circ \text{ k} \\ &= 31.24\angle 31.27^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the total power dissipated at the load is $31.24\angle 31.27^\circ \text{ kVA}$.

Step 4 of 4

Since the line impedance is negligible, the total power supplied by the source is dissipated at the loads and hence the power factor at the source is equal to the power factor at the load.

Consider the expression for the power factor.

$$\begin{aligned}PF &= \cos(31.27^\circ) \\ &= 0.86 \text{ lagging}\end{aligned}$$

Therefore, the value of the source power factor is $\boxed{0.86 \text{ lagging}}$.

11.086
P

Step 1 of 5

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ \text{ V rms}$ for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ \text{ V rms}$.

Step 2 of 5

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.6) \\ &= -53.13^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is -53.13°.

Step 3 of 5

The value of the complex power at load 2 is $\frac{24}{0.6}\angle -53.13^\circ \text{ kVA}$.

Step 4 of 5

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $30\angle 36.87^\circ \text{ kVA}$ for S_{load1}, $\frac{24}{0.6}\angle -53.13^\circ \text{ kVA}$ for S_{load2} and $60\angle 0^\circ \text{ kVA}$ for S_T.

$$60\angle 0^\circ \text{ k} = 30\angle 36.87^\circ \text{ k} + \frac{24}{0.6}\angle -53.13^\circ \text{ k} + S_{load3}$$

$$60\angle 0^\circ \text{ k} = 50\angle -16.26^\circ \text{ kVA} + S_{load3}$$

$$S_{load3} = 60\angle 0^\circ \text{ k} - 50\angle -16.26^\circ \text{ k}$$

$$S_{load3} = 18.44\angle 49.4^\circ \text{ kVA}$$

Therefore, the value of the power dissipated at the load 3 is $18.44\angle 49.4^\circ \text{ kVA}$.

Step 5 of 5

Consider the expression for the power factor.

$$\begin{aligned}PF &= \cos(49.4^\circ) \\ &= 0.65 \text{ lagging}\end{aligned}$$

Therefore, the value of the source power factor is 0.65 lagging.

Therefore, the rating value of load 3 is $\boxed{18.44 \text{ kVA at } 0.65 \text{ pf lagging}}$.

Step 1 of 6

Consider the expression for $\mathbf{V}_{AN}$.

$$\mathbf{V}_{AN} = \frac{\mathbf{V}_{AB}}{\sqrt{3}}$$

Substitute $208\angle 0^\circ$ V rms for $\mathbf{V}_{AB}$.

$$\begin{aligned}\mathbf{V}_{AN} &= \frac{208\angle 0^\circ}{\sqrt{3}} \\ &= 120.09\angle 0^\circ \text{ V rms}\end{aligned}$$

Therefore, the value of $\mathbf{V}_{AN}$ is $120.09\angle 0^\circ$ V rms.

Step 2 of 6

Consider the expression for the power factor angle at load 1.

$$\begin{aligned}\theta &= \cos^{-1}(0.8) \\ &= 36.87^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 1 is 36.87°.

The value of the complex power at load 1 is $\frac{24}{0.8}\angle 36.87^\circ$ kVA.

Step 3 of 6

Consider the expression for the power factor angle at load 2.

$$\begin{aligned}\theta &= \cos^{-1}(0.7) \\ &= -45.57^\circ\end{aligned}$$

Therefore, the value of the power factor angle at load 2 is -45.57°.

Step 4 of 6

Consider the expression for the power factor angle at combined load.

$$\begin{aligned}\theta &= \cos^{-1}(0.86) \\ &= 30.68^\circ\end{aligned}$$

Therefore, the value of the power factor angle at combined load is 30.68°.

Step 5 of 6

Consider the expression for the total power dissipated at the loads.

$$S_T = S_{load1} + S_{load2} + S_{load3}$$

Substitute $10\angle -45.57^\circ$ kVA for S_{load2}, $\frac{24}{0.8}\angle 36.87^\circ$ kVA for S_{load1} and

$41.93\angle 30.68^\circ$ kVA for S_T.

$$41.93\angle 30.68^\circ \text{ k} = \frac{24}{0.8}\angle 36.87^\circ \text{ k} + 10\angle -45.57^\circ \text{ k} + S_{load3}$$

$$41.93\angle 30.68^\circ \text{ k} = 32.85\angle 19.30^\circ \text{ kVA} + S_{load3}$$

$$\begin{aligned}S_{load3} &= 41.93\angle 30.68^\circ \text{ k} - 32.85\angle 19.30^\circ \text{ k} \\ S_{load3} &= 11.69\angle 64.36^\circ \text{ kVA}\end{aligned}$$

Therefore, the value of the power dissipated at the load 3 is $11.69\angle 64.36^\circ$ kVA.

Step 6 of 6

Consider the expression for the power factor.

$$\begin{aligned}PF &= \cos(64.34^\circ) \\ &= 0.43 \text{ lagging}\end{aligned}$$

Therefore, the value of the source power factor is 0.3 lagging.

Therefore, the rating value of load 3 is $\boxed{11.69 \text{ kVA at } 0.43 \text{ pf lagging}}$.

11.088
P

Step 1 of 3

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute 20 MVA for $|S|$ and 0.707 for pf.

$$\begin{aligned} S_{old} &= \frac{20\text{ M}}{3}\angle\cos^{-1}(0.707) \\ &= 6.67\text{ M}\angle 45^\circ \\ &= 4.72 + j4.72\text{ MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 4.72\text{ MW}$$

$$Q_{old} = 4.72\text{ Mvar}$$

Therefore, the values of the real and reactive powers at the load are 4.72 MW and 4.72 Mvar respectively.

Step 2 of 3

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle -\cos^{-1}(pf_{new}) \text{ (angle is negitive since power factor is leading)}$$

Substitute 0.87 for pf_{new} and 4.72 MW for P.

$$\begin{aligned} S_{new} &= \frac{4.72\text{ M}}{0.87}\angle -\cos^{-1}(0.87) \\ &= 5.43\text{ M}\angle -29.54^\circ \\ &= 4.72 - j2.68\text{ MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = -2.68\text{ Mvar}$$

The value of the new reactive power is -2.68 Mvar.

Step 3 of 3

The value of the new reactive power is due to the introduction of the capacitors in the circuit. Hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute -2.68 Mvar for Q_{new} and 4.72 Mvar for Q_{old}.

$$\begin{aligned} Q_C &= -2.68\text{ M} - 4.72\text{ M} \\ &= -7.4\text{ Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is -7.4 Mvar.

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|V_{ab}|^2\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|V_{ab}|^2(2\pi f)C$$

Substitute 34.5 kV rms for V_{ab}, 60 Hz for f and -7.4 Mvar for Q_C.

$$\begin{aligned} -7.4\text{ M} &= -|34.5\text{ k}|^2(2\pi(60))C \\ 7.4\text{ M} &= (1190.25\text{ M})(376.99)C \\ 7.4 &= (448712.35)C \end{aligned}$$

$$C = \frac{7.4}{448712.35}$$

$$C = 16.49\ \mu\text{F}$$

Therefore, the value of the capacitor is $\boxed{16.49\ \mu\text{F}}$.

11.089
P

Step 1 of 3

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute $6\,\text{MVA}$ for $|S|$ and 0.8 for pf.

$$\begin{aligned} S_{old} &= \frac{6\,\text{M}}{3}\angle\cos^{-1}(0.8) \\ &= 2\,\text{M}\angle 36.87^\circ \\ &= 1.6 + j1.2\,\text{MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 1.6\,\text{MW} \quad Q_{old} = 1.2\,\text{Mvar}$$

Therefore, the values of the real and reactive powers at the load are $1.6\,\text{MW}$ and $1.2\,\text{Mvar}$ respectively.

Step 2 of 3

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle\cos^{-1}(pf_{new})$$

Substitute 0.9 for pf_{new} and $1.6\,\text{MW}$ for P.

$$\begin{aligned} S_{new} &= \frac{1.6\,\text{M}}{0.9}\angle\cos^{-1}(0.9) \\ &= 1.78\,\text{M}\angle 25.84^\circ \\ &= 1.6 + j0.78\,\text{MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = 0.78\,\text{Mvar}$$

The value of the new reactive power is $0.78\,\text{Mvar}$.

Step 3 of 3

The value of the new reactive power is due to the introduction of the capacitors in the circuit. hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute $0.78\,\text{Mvar}$ for Q_{new} and $1.2\,\text{Mvar}$ for Q_{old}.

$$\begin{aligned} Q_C &= 0.78\,\text{M} - 1.2\,\text{M} \\ &= -0.42\,\text{Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-0.42\,\text{Mvar}$.

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|\text{V}_{ab}|^2\,\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|\text{V}_{ab}|^2(2\pi f)C$$

Substitute $4.6\,\text{kV rms}$ for V_{ab}, $60\,\text{Hz}$ for f and $-0.42\,\text{Mvar}$ for Q_C.

$$\begin{aligned} -0.42\,\text{M} &= -|4.6\,\text{k}|^2(2\pi(60))C \\ 0.42\,\text{M} &= (21.16\,\text{M})(376.99)C \\ 0.42 &= (7977.11)C \\ C &= \frac{0.42}{7977.11} \\ C &= 52.65\,\mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{52.65\,\mu\text{F}}$.

Step 1 of 4

Consider the following circuit arrangement for the balanced three-phase system:

Figure 1

Step 2 of 4

Consider that a balanced three-phase source serves a load.

Find the phase angle of the power.

$$\begin{aligned}\phi &= \cos^{-1}(pf)\\ &= \cos^{-1}(0.8)\\ &= 36.87°\end{aligned}$$

Consider the following expression for P :

$$\begin{aligned}P &= S\cos\phi\\ 50000 &= S(0.8)\\ S &= 62500\end{aligned}$$

Therefore, the complex power supplied to the load is,

$$\begin{aligned}S &= P + jQ\\ &= 50000 + j(62500)\sin(36.87°)\\ &= 50000 + j(62500)(0.6)\\ &= 50000 + j37500 \text{ VA}\end{aligned}$$

Step 3 of 4

Consider that the source voltage completely appears at load, since there is no line impedance.

Consider the following expression for the total complex power at load:

$$S_T = V_L I_L$$

Substitute 62500 for S_T , and 220 V for V_L to find the value of I_L .

$$62500 = (220)I_L$$

$$\begin{aligned}I_L &= \frac{62500}{220}\\ &= 284 \text{ A}\end{aligned}$$

Find the phase angle of the current.

$$\phi = \theta_V - \theta_I$$

Substitute $36.87°$ for ϕ , and $0°$ for θ_V to find the value of θ_I .

$$36.87° = 0° - \theta_I$$

$$\theta_I = -36.87°$$

Thus, the current, $\mathbf{I}_{aA}$ is, $284\angle -36.87° \text{ A}$.

Step 4 of 4

Calculate the load impedance.

$$\begin{aligned}Z_L &= \frac{\mathbf{V}_{AN}}{\mathbf{I}_{aA}}\\ &= \frac{220\angle 0°}{284\angle -36.87° \text{ A}}\\ &= 0.774\angle 36.87° \ \Omega\\ &= 0.619 + j0.464 \ \Omega\end{aligned}$$

Calculate the total impedance of the load including the $-j2\ \Omega$ capacitance.

$$\begin{aligned}Z_{eq} &= (0.619 + j0.464) \| -j2\\ &= \frac{(0.619 + j0.464)(-j2)}{0.619 + j0.464 - j2}\\ &= 0.9 + j0.24 \ \Omega\end{aligned}$$

Find the phase angle of the impedance.

$$\begin{aligned}\theta &= \tan^{-1}\left(\frac{0.24}{0.9}\right)\\ &= \tan^{-1}(0.267)\\ &= 14.887°\end{aligned}$$

Calculate the power factor.

$$\begin{aligned}\text{pf} &= \cos\theta\\ &= \cos(14.887°)\\ &= 0.966\end{aligned}$$

Thus, the power factor of the combined load seen by the source is, $\boxed{0.966}$.

11.091
P

Step 1 of 4

Consider the expression for single phase power at the load.

$$S = \frac{P}{pf}\angle\cos^{-1}(pf)$$

Substitute $50\,\text{kW}$ for P and 0.8 for pf.

$$\begin{aligned} S &= \frac{50\,\text{k}}{0.8}\angle\cos^{-1}(0.8) \\ &= 62.5\,\text{k}\angle 36.87^\circ \\ &= 50 + j37.5\,\text{kVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q = 37.5\,\text{kvar}$$

Therefore, the value of the reactive power at the load is $37.5\,\text{kvar}$.

Step 2 of 4

Convert the delta connected capacitors to wye connection.

$$(X_C)_Y = \frac{X_C}{3}$$

Substitute $-j2\,\Omega$ for X_C.

$$(X_C)_Y = -j\left(\frac{2}{3}\right)\Omega$$

Therefore, the value of $(X_C)_Y$ is $-j\left(\frac{2}{3}\right)\Omega$.

Step 3 of 4

Consider the expression for the reactive power offered by the capacitors in each phase.

$$Q_C = \frac{|\mathbf{V}_{an}|^2}{(X_C)_Y}$$

Substitute $220\,\text{V rms}$ for $\mathbf{V}_{an}$ and $-j\left(\frac{2}{3}\right)\Omega$ for $(X_C)_Y$.

$$\begin{aligned} Q_C &= \frac{|220|^2}{-\left(\frac{2}{3}\right)} \\ &= \frac{48400\times 3}{-2} \\ &= -72.6\,\text{kvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is $-72.6\,\text{kvar}$.

Calculate the value of the new reactive power obtained by the combination of the load and the capacitors.

$$Q_{new} = Q + Q_C$$

Substitute $-72.6\,\text{kvar}$ for Q_C and $37.5\,\text{kvar}$ for Q.

$$\begin{aligned} Q_{new} &= 37.5\,\text{k} - 72.6\,\text{k} \\ &= -38.1\,\text{kvar} \end{aligned}$$

Therefore, the value of the new reactive power is $-38.1\,\text{kvar}$.

Step 4 of 4

Consider the expression for the new complex power consumed by the load.

$$S_{new} = P + jQ_{new}$$

Substitute $-38.1\,\text{kvar}$ for Q_{new} and $50\,\text{kW}$ for P.

$$\begin{aligned} S_{new} &= 50\,\text{k} - j38.1\,\text{k} \\ &= 50 - j38.1\,\text{k} \\ &= 62.86\angle -37.31^\circ\,\text{kVA} \end{aligned}$$

Therefore, the value of new power consumed by the load is $62.86\angle -37.31^\circ\,\text{kVA}$.

Consider the expression for the new power factor at the load.

$$\begin{aligned} pf_{new} &= \cos(-37.31^\circ) \\ &= 0.8\text{ leading} \end{aligned} \quad \text{(leading since power factor angle is negitive)}$$

Therefore, the value of the new power factor at the load is $\boxed{0.8\text{ leading}}$.

Step 1 of 4

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute 20 MVA for $|S|$ and 0.707 for pf.

$$\begin{aligned} S_{old} &= \frac{20\text{ M}}{3}\angle\cos^{-1}(0.707) \\ &= 6.67\text{ M}\angle 45^\circ \\ &= 4.72 + j4.72\text{ MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 4.72\text{ MW } Q_{old} = 4.72\text{ Mvar}$$

Therefore, the values of the real and reactive powers at the load are 4.72 MW and 4.72 Mvar respectively.

Step 2 of 4

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle\cos^{-1}(pf_{new})$$

Substitute 0.87 for pf_{new} and 4.72 MW for P.

$$\begin{aligned} S_{new} &= \frac{4.72\text{ M}}{0.87}\angle\cos^{-1}(0.87) \\ &= 5.43\text{ M}\angle 29.54^\circ \\ &= 4.72 + j2.68\text{ MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = 2.68\text{ Mvar}$$

The value of the new reactive power is 2.68 Mvar.

Step 3 of 4

The value of the new reactive power is due to the introduction of the capacitors in the circuit. hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute 2.68 Mvar for Q_{new} and 4.72 Mvar for Q_{old}.

$$\begin{aligned} Q_C &= 2.68\text{ M} - 4.72\text{ M} \\ &= -2.05\text{ Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is -2.05 Mvar.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|\mathbf{V}_{ab}|^2\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|\mathbf{V}_{ab}|^2(2\pi f)C$$

Substitute 34.5 kV rms for V_{ab}, 60 Hz for f and -2.05 Mvar for Q_C.

$$\begin{aligned} -2.05\text{ M} &= -|34.5\text{ k}|^2(2\pi(60))C \\ 2.05\text{ M} &= (1190.25\text{ M})(376.99)C \\ 2.05 &= (448712.35)C \end{aligned}$$

$$\begin{aligned} C &= \frac{2.05}{448712.35} \\ &= 4.57\ \mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{4.57\ \mu\text{F}}$.

11.093
P

Step 1 of 4

Consider the expression for single phase power at the load.

$$S_{old} = \frac{|S|}{3}\angle\cos^{-1}(pf)$$

Substitute 6 MVA for $|S|$ and 0.8 for pf.

$$\begin{aligned} S_{old} &= \frac{6\text{ M}}{3}\angle\cos^{-1}(0.8) \\ &= 2\text{ M}\angle 36.87^\circ \\ &= 1.6 + j1.2\text{ MVA} \end{aligned}$$

Since real part represents the real power and imaginary part represents the reactive power.

$$P = 1.6\text{ MW}\ Q_{old} = 1.2\text{ Mvar}$$

Therefore, the values of the real and reactive powers at the load are 1.6 MW and 1.2 Mvar respectively.

Step 2 of 4

Consider the expression for the new complex power consumed by the load and the capacitors.

$$S_{new} = \frac{P}{pf_{new}}\angle -\cos^{-1}(pf_{new})\ \text{(angle is negitive since power factor is leading)}$$

Substitute 0.9 for pf_{new} and 1.6 MW for P.

$$\begin{aligned} S_{new} &= \frac{1.6\text{ M}}{0.9}\angle -\cos^{-1}(0.9) \\ &= 1.78\text{ M}\angle -25.84^\circ \\ &= 1.6 - j0.78\text{ MVA} \end{aligned}$$

Since imaginary part represents the reactive power.

$$Q_{new} = -0.78\text{ Mvar}$$

The value of the new reactive power is -0.78 Mvar.

Step 3 of 4

The value of the new reactive power is due to the introduction of the capacitors in the circuit. hence, the reactive power offered by the capacitor is the difference of the old and the new reactive powers available at the load.

Consider the expression for the reactive power due to capacitor.

$$Q_C = Q_{new} - Q_{old}$$

Substitute -0.78 Mvar for Q_{new} and 1.2 Mvar for Q_{old}.

$$\begin{aligned} Q_C &= -0.78\text{ M} - 1.2\text{ M} \\ &= -1.98\text{ Mvar} \end{aligned}$$

Therefore, the value of the reactive power offered by the capacitor is -1.98 Mvar.

Step 4 of 4

Consider the expression for the reactive power due to capacitor.

$$Q_C = -|\mathbf{V}_{ab}|^2\omega C$$

Since $\omega = 2\pi f$,

$$Q_C = -|\mathbf{V}_{ab}|^2(2\pi f)C$$

Substitute 4.6 kV rms for V_{ab}, 60 Hz for f and -1.98 Mvar for Q_C.

$$\begin{aligned} -1.98\text{ M} &= -|4.6\text{ k}|^2(2\pi(60))C \\ 1.98\text{ M} &= (21.16\text{ M})(376.99)C \\ 1.98 &= (7977.11)C \end{aligned}$$

Rewrite the equation.

$$\begin{aligned} C &= \frac{1.98}{7977.11} \\ &= 248.2\ \mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{248.2\ \mu\text{F}}$.

11.094

P

We don't have the solution to this problem yet.

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12.001

E

Refer to Figure 12.7(b) in the textbook.

Calculate the driving point impedance $\mathbf{Z}(s)$ seen from the input terminals of the circuit.

$$\mathbf{Z}(s) = R_{\text{in}} + \frac{1}{sC_{\text{in}}}$$

Substitute $1\ \text{M}\Omega$ for R_{in} and $3.18\ \text{nF}$ for C_{in}.

$$\begin{aligned}\mathbf{Z}(s) &= 1\ \text{M}\Omega + \frac{1}{s(3.18\ \text{nF})} \\ &= 1\ \text{M}\Omega + \frac{314.47\times10^{6}}{s} \\ &= 1\ \text{M}\Omega + \frac{100\pi\times10^{6}}{s} \\ &= \left(1+\frac{100\pi}{s}\right)\text{M}\Omega\end{aligned}$$

Therefore, the value of the driving point impedance of the circuit is $\boxed{\left(1+\frac{100\pi}{s}\right)\text{M}\Omega}$.

Step 1 of 3

12.001
P

Consider Figure P12.1 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 3

Calculate the expression for the driving point input impedance Z .

$$\begin{aligned}
\mathbf{Z} &= R + \left(\frac{1}{sC} \| sL\right) \\
&= R + \frac{\left(\frac{1}{sC}\right)(sL)}{\frac{1}{sC} + sL} \\
&= R + \frac{\frac{sL}{sC}}{\frac{1+s^2LC}{sC}} \\
&= R + \frac{sL}{1+s^2LC}
\end{aligned}$$

Step 3 of 3

Simplify further.

$$\begin{aligned}
\mathbf{Z} &= \frac{R\left(1+s^2LC\right)+sL}{1+s^2LC} \\
&= \frac{R+s^2RLC+sL}{1+s^2LC} \\
&= \frac{RLC\left(s^2+\frac{s}{RC}+\frac{1}{LC}\right)}{LC\left(s^2+\frac{1}{LC}\right)} \\
&= \frac{R\left(s^2+\frac{s}{RC}+\frac{1}{LC}\right)}{\left(s^2+\frac{1}{LC}\right)}
\end{aligned}$$

Therefore, the expression for the driving point input impedance is $\boxed{\frac{R\left(s^2+\frac{s}{RC}+\frac{1}{LC}\right)}{\left(s^2+\frac{1}{LC}\right)}}$.

Step 1 of 4

12.01E

Consider Figure 12PFE-1 from the text book.

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $10\ \mu\text{F}$ for C and $1\ \text{mH}$ for L.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(1\ \text{m})(10\ \mu)}}\\ &= \frac{1}{\sqrt{10\ \text{n}}}\\ &= 10000\ \text{rad/s}\end{aligned}$$

Therefore, the value of the resonant frequency is $10000\ \text{rad/s}$.

Step 2 of 4

Consider the circuit diagram in phasor representation of the parameters.

Figure 1

Step 3 of 4

Calculate the value of current in the circuit at resonance.

$$\mathbf{I} = \frac{12\angle 0^\circ}{R + j\omega L + \frac{1}{j\omega C}}$$

At resonance, the circuit acts as purely resistice.

$$\mathbf{I} = \frac{12\angle 0^\circ}{R}$$

Substitute $2\ \Omega$ for R.

$$\begin{aligned}\mathbf{I} &= \frac{12\angle 0^\circ}{2}\\ &= 6\angle 0^\circ\ \text{A}\end{aligned}$$

Therefore, the value of the current in the circuit at resonance is $6\angle 0^\circ\ \text{A}$.

Step 4 of 4

Calculate the value of the output voltage.

$$\mathbf{V}_o = i(j\omega)\left(\frac{1}{j\omega C}\right)$$

Substitute $6\angle 0^\circ\ \text{A}$ for $i(j\omega)$, $10\ \mu\text{F}$ for C and $10000\ \text{rad/s}$ for ω.

$$\begin{aligned}\mathbf{V}_o &= (6\angle 0^\circ)\left(\frac{1}{j(10000)(10\ \mu)}\right)\\ &= (6\angle 0^\circ)\left(\frac{1}{j0.1}\right)\\ &= (6\angle 0^\circ)\left(\frac{1}{0.1\angle 90^\circ}\right)\\ &= 60\angle -90^\circ\ \text{V}\end{aligned}$$

Therefore, the value of the output voltage is $\boxed{60\angle -90^\circ\ \text{V}}$.

Therefore, the correct option is $\boxed{\text{(a)}}$.

Step 1 of 4

Refer to Figure 12.7 in the textbook.

Use voltage division rule to find an expression for the output voltage $\mathbf{V}_o(s)$.

$$\begin{aligned}\mathbf{V}_o(s) &= 1000\mathbf{V}_{in}(s)\left(\frac{\frac{1}{sC_o}}{R_o+\frac{1}{sC_o}}\right)\\ &= 1000\mathbf{V}_{in}(s)\left(\frac{\frac{1}{sC_o}}{\frac{sC_oR_o+1}{sC_o}}\right)\\ &= 1000\mathbf{V}_{in}(s)\left(\frac{1}{sC_oR_o+1}\right)\\ &= \frac{1000\mathbf{V}_{in}(s)}{C_oR_o}\left(\frac{1}{s+\frac{1}{C_oR_o}}\right)\end{aligned}$$

Solve for $\mathbf{V}_{in}(s)$.

$$\mathbf{V}_{in}(s)=\frac{\mathbf{V}_o(s)}{1000}C_oR_o\left(s+\frac{1}{C_oR_o}\right) \quad \text{..... (1)}$$

Therefore, the expression for the voltage $\mathbf{V}_{in}(s)$ is $\frac{\mathbf{V}_o(s)}{1000}C_oR_o\left(s+\frac{1}{C_oR_o}\right)$.

Step 2 of 4

Use voltage division rule to find an expression for the input voltage $\mathbf{V}_{in}(s)$.

$$\begin{aligned}\mathbf{V}_{in}(s) &= \mathbf{V}_s(s)\left(\frac{R_{in}}{R_{in}+\frac{1}{sC_{in}}}\right)\\ &= \frac{\mathbf{V}_s(s)}{R_{in}}\left(\frac{R_{in}}{1+\frac{1}{sC_{in}R_{in}}}\right)\\ &= \mathbf{V}_s(s)\left(\frac{1}{1+\frac{1}{sC_{in}R_{in}}}\right)\\ &= \mathbf{V}_s(s)\left(\frac{s}{s+\frac{1}{C_{in}R_{in}}}\right)\end{aligned}$$

Therefore, the expression for the voltage is $\mathbf{V}_{in}(s)$ is $\mathbf{V}_s(s)\left(\frac{s}{s+\frac{1}{C_{in}R_{in}}}\right)$.

Step 3 of 4

Recall equation (1).

$$\mathbf{V}_{in}(s)=\frac{\mathbf{V}_o(s)}{1000}C_oR_o\left(s+\frac{1}{C_oR_o}\right)$$

Substitute $\mathbf{V}_s(s)\left(\frac{s}{s+\frac{1}{C_{in}R_{in}}}\right)$ for $\mathbf{V}_{in}(s)$.

$$\mathbf{V}_s(s)\left(\frac{s}{s+\frac{1}{C_{in}R_{in}}}\right)=\frac{\mathbf{V}_o(s)}{1000}C_oR_o\left(s+\frac{1}{C_oR_o}\right)$$

Solve for $\frac{\mathbf{V}_o(s)}{\mathbf{V}_s(s)}$.

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_s(s)}=\frac{1000s}{C_oR_o\left(s+\frac{1}{C_oR_o}\right)\left(s+\frac{1}{C_{in}R_{in}}\right)}$$

Substitute $1\ \text{M}\Omega$ for R_{in}, $100\ \Omega$ for R_o, $79.58\ \text{nF}$ for C_o and $3.18\ \text{nF}$ for C_{in}.

$$\begin{aligned}\frac{\mathbf{V}_o(s)}{\mathbf{V}_s(s)} &= \frac{1000s}{(79.58\ \text{n})(100)\left(s+\frac{1}{(79.58\ \text{n})(100)}\right)\left(s+\frac{1}{(1\ \text{M})(3.18\ \text{n})}\right)}\\ &= \frac{1000s}{(7.958\ \mu)\left(s+\frac{1}{(79.58\ \mu)}\right)\left(s+\frac{1}{(3.18\ \text{m})}\right)}\\ &= \frac{125659713.5s}{(s+12565.97135)(s+314.4654)}\\ &= \frac{(4\times10^7)\pi s}{(s+2\pi(20000))(s+2\pi(50))}\end{aligned}$$

Step 4 of 4

Compare the transfer function $\frac{\mathbf{V}_o(s)}{\mathbf{V}_s(s)}$ with $\frac{K_o(s-z_1)}{(s-p_1)(s-p_2)}$.

$K_o=(4\times10^7)\pi$.

$z_1=0\ \text{Hz}$

$p_1=-50\ \text{Hz}$

$p_2=-20000\ \text{Hz}$

Therefore, the values of the K_o, z_1, p_1 and p_2 are $\boxed{(4\times10^7)\pi}$, $\boxed{0\ \text{Hz}}$, $\boxed{-50\ \text{Hz}}$ and $\boxed{-20000\ \text{Hz}}$ respectively.

Step 1 of 4

12.002 P

Consider Figure P12.2 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 4

Calculate the expression for the driving point input impedance Z .

$$\begin{aligned}
\mathbf{Z} &= R + \left(\frac{1}{sC_1} \| \left(sL + \frac{1}{sC_2}\right)\right) \\
&= R + \frac{\left(\frac{1}{sC_1}\right)\left(sL + \frac{1}{sC_2}\right)}{\frac{1}{sC_1} + sL + \frac{1}{sC_2}} \\
&= R + \frac{\frac{s^2LC_2 + 1}{s^2C_1C_2}}{\frac{sC_2 + s^3LC_1C_2 + sC_1}{s^2C_1C_2}} \\
&= R + \frac{s^2LC_2 + 1}{sC_2 + s^3LC_1C_2 + sC_1}
\end{aligned}$$

Step 3 of 4

Simplify further.

$$\begin{aligned}
\mathbf{Z} &= R + \frac{s^2LC_2 + 1}{sC_2 + s^3LC_1C_2 + sC_1} \\
&= \frac{R\left(sC_2 + s^3LC_1C_2 + sC_1\right) + s^2LC_2 + 1}{sC_2 + s^3LC_1C_2 + sC_1} \\
&= \frac{sRC_2 + s^3LRC_1C_2 + sRC_1 + s^2LC_2 + 1}{sC_2 + s^3LC_1C_2 + sC_1} \\
&= \frac{s^3LRC_1C_2 + s^2LC_2 + sR(C_1 + C_2) + 1}{sC_2 + s^3LC_1C_2 + sC_1}
\end{aligned}$$

Step 4 of 4

Simplify further.

$$\begin{aligned}
\mathbf{Z} &= \frac{s^3LRC_1C_2 + s^2LC_2 + sR(C_1 + C_2) + 1}{s^3LC_1C_2 + s(C_1 + C_2)} \\
&= \frac{LRC_1C_2\left(s^3 + s^2\frac{1}{RC_1} + s\frac{(C_1 + C_2)}{LC_1C_2} + \frac{1}{LRC_1C_2}\right)}{sLC_1C_2\left(s^2 + \frac{C_1 + C_2}{LC_1C_2}\right)} \\
&= \frac{R\left(s^3 + s^2\frac{1}{RC_1} + s\frac{(C_1 + C_2)}{LC_1C_2} + \frac{1}{LRC_1C_2}\right)}{s\left(s^2 + \frac{C_1 + C_2}{LC_1C_2}\right)}
\end{aligned}$$

Therefore, the expression for the driving point input impedance is

$$\boxed{\frac{R\left(s^3 + s^2\frac{1}{RC_1} + s\frac{(C_1 + C_2)}{LC_1C_2} + \frac{1}{LRC_1C_2}\right)}{s\left(s^2 + \frac{C_1 + C_2}{LC_1C_2}\right)}}.$$

Step 1 of 1

12.02FE

Consider Figure 12PFE-2 from the text book.

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{R}{L}$$

Substitute $20\ \mathrm{mH}$ for L and $200\ \mathrm{rad/s}$ for R.

$$200 = \frac{R}{(20\ \mathrm{m})}$$

$$\mathrm{R} = (200)(20\ \mathrm{m})$$

$$\mathrm{R} = 4\ \Omega$$

Therefore, the required value of the resistor is $\boxed{4\ \Omega}$.

Therefore, the correct option is $\boxed{(\mathrm{c})}$.

Step 1 of 2

Refer to Figure E12.3 in the textbook.

Consider the expression for the output voltage $\mathbf{V}_o(s)$ in terms of $\mathbf{V}_i(s)$ using voltage division rule.

$$\mathbf{V}_o(s) = \mathbf{V}_i(s)\left[\frac{R_2 \parallel \frac{1}{sC_2}}{R_1 + \frac{1}{sC_1} + \left(R_2 \parallel \frac{1}{sC_2}\right)}\right]$$

Simplify the expression to find the system function.

$$\begin{aligned}
\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)} &= \frac{\dfrac{\dfrac{R_2}{sC_2}}{R_2 + \dfrac{1}{sC_2}}}{R_1 + \dfrac{1}{sC_1} + \dfrac{\dfrac{R_2}{sC_2}}{R_2 + \dfrac{1}{sC_2}}} \\
&= \frac{\dfrac{\dfrac{R_2}{sC_2}}{R_2 + \dfrac{1}{sC_2}}}{\dfrac{\left(R_1 + \dfrac{1}{sC_1}\right)\left(R_2 + \dfrac{1}{sC_2}\right) + \dfrac{R_2}{sC_2}}{R_2 + \dfrac{1}{sC_2}}} \\
&= \frac{\dfrac{R_2}{sC_2}}{\left(R_1 + \dfrac{1}{sC_1}\right)\left(R_2 + \dfrac{1}{sC_2}\right) + \dfrac{R_2}{sC_2}}
\end{aligned}$$

Step 2 of 2

Simplify the expression further.

$$\begin{aligned}
\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)} &= \frac{\dfrac{R_2}{sC_2}}{\dfrac{(sC_1R_1+1)(sC_2R_2+1)+sC_1R_2}{(sC_1)(sC_2)}} \\
&= \frac{sC_1R_2}{s^2C_1R_1C_2R_2 + s(C_2R_2 + C_1R_1) + 1 + sC_1R_2} \\
&= \frac{sC_1R_2}{s^2C_1R_1C_2R_2 + s(C_2R_2 + C_1R_1 + C_1R_2) + 1} \\
&= \frac{sC_1R_2}{C_1R_1C_2R_2\left(s^2 + s\left(\dfrac{C_2R_2 + C_1R_1 + C_1R_2}{C_1R_1C_2R_2}\right) + \dfrac{1}{C_1R_1C_2R_2}\right)}
\end{aligned}$$

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)} = \frac{s}{R_1C_2\left(s^2 + s\left(\dfrac{C_1R_2 + C_2R_2 + C_1R_1}{R_1R_2C_1C_2}\right) + \dfrac{1}{R_1R_2C_1C_2}\right)}$$

Therefore, the voltage transfer function of the network is

$$\boxed{\frac{s}{R_1C_2\left(s^2 + s\left(\dfrac{C_1R_2 + C_2R_2 + C_1R_1}{R_1R_2C_1C_2}\right) + \dfrac{1}{R_1R_2C_1C_2}\right)}}.$$

Step 1 of 3

12.003 P

Consider Figure P12.3 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 3

Consider the expression for the output voltage in terms of input voltage using voltage division rule.

$$\mathbf{V}_O(s)=\mathbf{V}_i(s)\left(\frac{R_2+sL}{\left(R_1\|\frac{1}{sC}\right)+R_2+sL}\right)$$

$$=V_i(s)\left(\frac{R_2+sL}{\left(\frac{\frac{R_1}{sC}}{R_1+\frac{1}{sC}}\right)+R_2+sL}\right)$$

$$=V_i(s)\left(\frac{R_2+sL}{\left(\frac{\frac{R_1}{sC}}{\frac{sR_1C+1}{sC}}\right)+R_2+sL}\right)$$

$$=V_i(s)\left(\frac{R_2+sL}{\left(\frac{R_1}{sR_1C+1}\right)+R_2+sL}\right)$$

Step 3 of 3

Simplify further.

$$\mathbf{V}_O(s)=\mathbf{V}_i(s)\left(\frac{(R_2+sL)(sR_1C+1)}{R_1+(R_2+sL)(sR_1C+1)}\right)$$

$$=V_i(s)\left(\frac{s^2(R_1LC)+s(R_1R_2C+L)+R_2}{s^2(R_1LC)+s(R_1R_2C+L)+R_2+R_1}\right)$$

$$=V_i(s)\frac{(R_1LC)}{(R_1LC)}\left(\frac{s^2+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2}{R_1LC}}{s^2(R_1LC)+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2+R_1}{R_1LC}}\right)$$

$$=V_i(s)\left(\frac{s^2+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2}{R_1LC}}{s^2(R_1LC)+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2+R_1}{R_1LC}}\right)$$

Solve for $\frac{\mathbf{V}_O(s)}{\mathbf{V}_i(s)}$.

$$\frac{\mathbf{V}_O(s)}{\mathbf{V}_i(s)}=\frac{s^2+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2}{R_1LC}}{s^2(R_1LC)+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2+R_1}{R_1LC}}$$

Therefore, the expression for the voltage transfer function $\frac{\mathbf{V}_O(s)}{\mathbf{V}_i(s)}$ is

$$\boxed{\frac{s^2+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2}{R_1LC}}{s^2(R_1LC)+s\left(\frac{R_1R_2C+L}{R_1LC}\right)+\frac{R_2+R_1}{R_1LC}}}.$$

Step 1 of 3

Consider Figure 12PFE-3 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Consider the expression for $\mathbf{V}_o$ in terms of $\mathbf{V}_s$.

$$\mathbf{V}_o = \mathbf{V}_s\left(\frac{X_C}{R+X_C}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{X_C}{R+X_C}$$

Consider the magnitude values.

$$\left|\frac{\mathbf{V}_o}{\mathbf{V}_s}\right| = \frac{X_C}{\sqrt{R^2+(X_C)^2}}$$

At -3Db of the DC level, the circuit will be at half power frequency. Hence, the output will be $\frac{1}{\sqrt{2}}\mathbf{V}_s$.

$$\left|\frac{\mathbf{V}_s}{\sqrt{2}\mathbf{V}_s}\right| = \frac{X_C}{\sqrt{R^2+(X_C)^2}}$$

$$\frac{1}{\sqrt{2}} = \frac{X_C}{\sqrt{R^2+(X_C)^2}}$$

$$\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{(X_C)^2}{R^2+(X_C)^2}$$

$$\frac{1}{2} = \frac{(X_C)^2}{R^2+(X_C)^2}$$

$$R^2+(X_C)^2 = 2(X_C)^2$$

$$R^2 = 2(X_C)^2-(X_C)^2$$

$$R^2 = (X_C)^2$$

$$R = X_C$$

$$\frac{1}{2\pi fC} = R$$

$$2\pi fC = \frac{1}{R}$$

$$f = \frac{1}{2\pi RC} \quad \text{..... (1)}$$

Therefore, the expression for the frequency at -3Db below the DC level is $\frac{1}{2\pi RC}$.

Step 3 of 3

Recall equation (1).

$$f = \frac{1}{2\pi RC}$$

Substitute $1\ \mu\text{F}$ for C and $5\ \text{k}\Omega$ for R.

$$f = \frac{1}{2\pi(1\ \mu)(5\ \text{k})}$$

$$= \frac{1}{31.42\ \text{m}}$$

$$\approx 32\ \text{Hz}$$

Therefore, the required value of the frequency is $\boxed{32\ \text{Hz}}$.

Therefore, the correct option is $\boxed{\text{(d)}}$.

Step 1 of 7

Consider the transfer function.

$$\begin{aligned}G(j\omega) &= \frac{10^4(j\omega+2)}{(j\omega+10)(j\omega+100)}\\ &= \frac{10^4(2)(0.5j\omega+1)}{(10)(100)(0.1j\omega+1)(0.01j\omega+1)}\\ &= \frac{20(0.5j\omega+1)}{(0.1j\omega+1)(0.01j\omega+1)}\end{aligned}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
20	-	0	-
$0.5j\omega+1$	$\omega_{c1}=\frac{1}{0.5}=2\text{ rad/sec}$	20	$\Delta\omega_1=0+20=20$
$\frac{1}{0.1j\omega+1}$	$\omega_{c2}=\frac{1}{0.1}=10\text{ rad/sec}$	-20	$\Delta\omega_2=-20+20=0$
$\frac{1}{0.01j\omega+1}$	$\omega_{c3}=\frac{1}{0.01}=100\text{ rad/sec}$	-20	$\Delta\omega_3=-20+0=-20$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.001 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1000 rad/sec.

Calculate the magnitude value at the corner frequency of 0.001 rad/sec.

$$\begin{aligned}A_{\omega_l} &= 20\log 20\\ &= 26.02\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 0.001 rad/sec is 26.02 dB.

Step 3 of 7

Calculate the magnitude value at the corner frequency of 2 rad/sec.

$$\begin{aligned}A_{\omega_{c1}} &= 20\log 20\\ &= 26.02\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 2 rad/sec is 26.02 dB.

Step 4 of 7

Calculate the magnitude value at the corner frequency of 10 rad/sec.

$$A_{\omega_{c2}} = \left[\Delta\omega_1 \times \log\frac{\omega_{c2}}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute 20 db/dec for $\Delta\omega_1$, 10 rad/sec for ω_{c2}, 2 rad/sec for ω_{c1} and 20 dB for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}} &= \left[20\times\log\frac{10}{2}\right]+26.02\\ &= [20\times\log 5]+26.02\\ &= 13.98+26.02\\ &= 40\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 10 rad/sec is 40 dB.

Step 5 of 7

Calculate the magnitude value at the corner frequency of 100 rad/sec.

$$A_{\omega_{c3}} = \left[\Delta\omega_2 \times \log\frac{\omega_{c3}}{\omega_{c2}}\right] + A_{\omega_{c2}}$$

Substitute 0 db/dec for $\Delta\omega_2$, 100 rad/sec for ω_{c3}, 10 rad/sec for ω_{c2} and 40 dB for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_{c3}} &= \left[0\times\log\frac{100}{10}\right]+40\\ &= 40\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 100 rad/sec is 40 dB.

Step 6 of 7

Calculate the magnitude value at the corner frequency of 1000 rad/sec.

$$A_{\omega_h} = \left[\Delta\omega_3 \times \log\frac{\omega_h}{\omega_{c3}}\right] + A_{\omega_{c3}}$$

Substitute -20 db/dec for $\Delta\omega_3$, 100 rad/sec for ω_{c3}, 1000 rad/sec for ω_h and 40 dB for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_h} &= \left[-20\times\log\frac{1000}{100}\right]+40\\ &= [-20\times\log 10]+40\\ &= -20+40\\ &= 20\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 1000 rad/sec is 20 dB.

Step 7 of 7

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 3

Consider Figure P12.8 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 3

Calculate the value of $\mathbf{I}_O(s)$ in terms of $\mathbf{I}_s$ using current division rule.

$$\begin{aligned}\mathbf{I}_O(s) &= \mathbf{I}_s(s)\left(\frac{2+2s}{2+2s+\frac{1}{s}+4}\right)\\ &= \mathbf{I}_s(s)\left(\frac{2s(s+1)}{2(s^2+3s+0.5)}\right)\\ &= \mathbf{I}_s(s)\left(\frac{s(s+1)}{s^2+3s+0.5}\right)\end{aligned}$$

Therefore, the value of $\mathbf{I}_O(s)$ is $\mathbf{I}_s(s)\left(\frac{s(s+1)}{s^2+3s+0.5}\right)$.

Step 3 of 3

Calculate the value of $\mathbf{V}_O(s)$.

$$\mathbf{V}_O(s) = 4\mathbf{I}_O(s)$$

Substitute $\mathbf{I}_s(s)\left(\frac{s(s+1)}{s^2+3s+0.5}\right)$ for $\mathbf{I}_O(s)$.

$$\mathbf{V}_O(s) = 4\mathbf{I}_s(s)\left(\frac{s(s+1)}{s^2+3s+0.5}\right)$$

Solve for $\frac{\mathbf{V}_O(s)}{\mathbf{I}_s(s)}$.

$$\frac{\mathbf{V}_O(s)}{\mathbf{I}_s(s)} = \frac{4s(s+1)}{s^2+3s+0.5}$$

Therefore, the value of $\frac{\mathbf{V}_O(s)}{\mathbf{I}_s(s)}$ is $\boxed{\frac{4s(s+1)}{s^2+3s+0.5}}$.

12.04FE

Step 1 of 2

Refer to Figure 12*PFE*-4 in the text book for the band-pass filter circuit.

Write the formula for resonant frequency.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Equate the resonant frequency to 1000 rad/s.

$$\omega_0 = \frac{1}{\sqrt{LC}} = 1000$$
$$LC = 10^{-6}$$

Substitute $10 \times 10^{-6}\ \text{F}$ for *C*.

$$L\left(10 \times 10^{-6}\right) = 10^{-6}$$
$$L = 0.1\ \text{H}$$

Step 2 of 2

Write the formula for band width of the filter.

$$\text{BW} = \frac{R}{L}$$

Substitute 100 rad/s for BW.

$$\text{BW} = \frac{R}{L} = 100$$
$$R = 100L$$

Substitute 0.1 H for *L*.

$$R = 10\ \Omega$$

Thus, the component values are,

$$\boxed{\begin{array}{l} R = 10\ \Omega \\ L = 0.1\ \text{H} \end{array}}.$$

Step 1 of 6

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{5(j\omega+10)}{j\omega(j\omega+100)}$$
$$=\frac{5(10)(0.1j\omega+1)}{j\omega(100)(0.01j\omega+1)}$$
$$=\frac{0.5(0.1j\omega+1)}{j\omega(0.01j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{0.5}{j\omega}$	-	-20	-
$0.1j\omega+1$	$\omega_{c1}=\frac{1}{0.1}$ $=10\text{ rad/sec}$	20	$\Delta\omega_1=20-20$ $=0$
$\frac{1}{0.01j\omega+1}$	$\omega_{c2}=\frac{1}{0.01}$ $=100\text{ rad/sec}$	-20	$\Delta\omega_2=0-20$ $=-20$

Step 2 of 6

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.1 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1000 rad/sec.

Calculate the magnitude value at the corner frequency of 0.1 rad/sec.

$$A_{\omega_l}=20\log\left(\frac{0.5}{0.1}\right)$$
$$=20\log(5)$$
$$=13.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.1 rad/sec is 13.98 dB.

Step 3 of 6

Calculate the magnitude value at the corner frequency of 10 rad/sec.

$$A_{\omega_{c1}}=20\log\left(\frac{0.5}{10}\right)$$
$$=20\log(0.05)$$
$$=-26.02\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 1 rad/sec is -26.02 dB.

Step 4 of 6

Calculate the magnitude value at the corner frequency of 100 rad/sec.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute 0 db/dec for $\Delta\omega_1$, 100 rad/sec for ω_{c2}, 10 rad/sec for ω_{c1} and -26.02 dB for $A_{\omega_{c1}}$.

$$A_{\omega_{c2}}=\left[0\times\log\frac{100}{10}\right]-26.02$$
$$=-26.02\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 100 rad/sec is -26.02 dB.

Step 5 of 6

Calculate the magnitude value at the corner frequency of 1000 rad/sec.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute -20 db/dec for $\Delta\omega_2$, 100 rad/sec for ω_{c2}, 1000 rad/sec for ω_h and -26.02 dB for $A_{\omega_{c2}}$.

$$A_{\omega_h}=\left[-20\times\log\frac{1000}{100}\right]-26.02$$
$$=-20-26.02$$
$$=-46.02\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 1000 rad/sec is -46.02 dB.

Step 6 of 6

Consider the bode plot shown in Figure 1.

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 2

12.005 P

Refer to Figure P12.5 in the textbook.

Draw the circuit diagram with notations.

Figure 1

Step 2 of 2

Calculate the driving impedance at the input terminals, $\mathbf{Z}_i$.

$$\begin{aligned}\mathbf{Z}_i &= (sL) + \left(R \parallel \frac{1}{sC}\right)\\ &= (sL) + \left(\frac{R \times \frac{1}{sC}}{R + \frac{1}{sC}}\right)\\ &= (sL) + \left(\frac{R}{1+sRC}\right)\\ &= \frac{(sL)(1+sRC)+R}{1+sRC}\\ &= \frac{s^2RLC + sL + R}{1+sRC}\end{aligned}$$

Thus, the driving impedance at the input terminals, $\mathbf{Z}_i$ is $\boxed{\frac{s^2RLC + sL + R}{1+sRC}}$.

Step 1 of 4

Consider Figure 12PFE-5 in the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 4

Consider the expression for $\mathbf{V}_o$ in terms of $\mathbf{V}_s$.

$$\mathbf{V}_o = \mathbf{V}_s\left(\frac{jX_C}{R + jX_C}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{jX_C}{R + jX_C}$$

Here,

X_C is the capacitive reactance given by $\frac{1}{\omega C}$.

Consider the magnitude values.

$$\left|\frac{\mathbf{V}_o}{\mathbf{V}_s}\right| = \frac{X_C}{\sqrt{R^2 + (X_C)^2}}$$

Step 3 of 4

At -3Db of the DC level, the circuit is at half power frequency. Hence, the output is $\frac{1}{\sqrt{2}}\mathbf{V}_s$.

$$\left|\frac{\mathbf{V}_s}{\sqrt{2}\mathbf{V}_s}\right| = \frac{X_C}{\sqrt{R^2 + (X_C)^2}}$$

$$\frac{1}{\sqrt{2}} = \frac{X_C}{\sqrt{R^2 + (X_C)^2}}$$

$$\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{(X_C)^2}{R^2 + (X_C)^2}$$

$$\frac{1}{2} = \frac{(X_C)^2}{R^2 + (X_C)^2}$$

$$R^2 + (X_C)^2 = 2(X_C)^2$$

$$R^2 = 2(X_C)^2 - (X_C)^2$$

$$R^2 = (X_C)^2$$

$$R = X_C$$

Substitute $\frac{1}{\omega C} = \frac{1}{2\pi fC}$ for X_C

$$\frac{1}{2\pi fC} = R$$

$$2\pi fC = \frac{1}{R}$$

$$f = \frac{1}{2\pi RC} \quad \text{..... (1)}$$

Therefore, the expression for the frequency at -3Db below the DC level is $\frac{1}{2\pi RC}$.

Step 4 of 4

Recall equation (1).

$$f = \frac{1}{2\pi RC}$$

Substitute $10\ \mu\text{F}$ for C and $2\ \text{k}\Omega$ for R.

$$f = \frac{1}{2\pi(10\ \mu)(2\ \text{k})}$$

$$= \frac{1}{126.66\ \text{m}}$$

$$\approx 8\ \text{Hz}$$

Therefore, the required value of the frequency is $\boxed{8\ \text{Hz}}$.

Therefore, the correct option is $\boxed{\text{(a)}}$.

Step 1 of 5

Consider the transfer function.

$$\mathbf{H}(j\omega)=\frac{250(0.02j\omega+1)}{(j\omega)^2}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{250}{(j\omega)^2}$	-	-40	-
$0.02j\omega+1$	$\omega_{c1}=\frac{1}{0.02}$ $=50\text{ rad/sec}$	20	$\Delta\omega_1=20-40$ $=-20$

Step 2 of 5

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 1 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1000 rad/sec.

Calculate the magnitude value at the corner frequency of 1 rad/sec.

$$\begin{aligned}A_{\omega_l}&=20\log\frac{250}{1^2}\\&=20\log 250\\&=47.96\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 1 rad/sec is 47.96 dB.

Step 3 of 5

Calculate the magnitude value at the corner frequency of 50 rad/sec.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\frac{250}{50^2}\\&=20\log\frac{250}{2500}\\&=20\log 0.1\\&=-20\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 50 rad/sec is -20 dB.

Step 4 of 5

Calculate the magnitude value at the corner frequency of 1000 rad/sec.

$$A_{\omega_h}=\left[\Delta\omega_1\times\log\frac{\omega_h}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute -20 db/dec for $\Delta\omega_1$, 1000 rad/sec for ω_h, 50 rad/sec for ω_{c1} and -20 dB for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_h}&=\left[-20\times\log\frac{1000}{50}\right]-20\\&=-26.02-20\\&=-46.02\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 1000 rad/sec is -46.02 dB.

Step 5 of 5

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 2

12.006 P

Refer to Figure P12.5 in the textbook.

Draw the circuit diagram with notations.

Figure 1

Step 2 of 2

Apply nodal analysis at the node $\mathbf{V}_o(s)$.

$$\frac{\mathbf{V}_o(s)}{R}+\frac{\mathbf{V}_o(s)}{\left(\frac{1}{sC}\right)}+\frac{\mathbf{V}_o(s)-\mathbf{V}_{in}(s)}{sL}=0$$

$$\mathbf{V}_o(s)\left[\frac{1}{R}+sC+\frac{1}{sL}\right]=\frac{\mathbf{V}_{in}(s)}{sL}$$

$$\mathbf{V}_o(s)\left[\frac{s^2RLC+sL+R}{sRL}\right]=\frac{\mathbf{V}_{in}(s)}{sL}$$

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_{in}(s)}=\frac{R}{s^2RLC+sL+R}$$

Thus, the transfer function of the circuit is $\boxed{\frac{R}{s^2RLC+sL+R}}$.

Step 1 of 6

Consider the network function.

$$G(j\omega)=\frac{10j\omega}{(j\omega+1)(j\omega+10)}$$
$$=\frac{10j\omega}{10(j\omega+1)(0.1j\omega+1)}$$
$$=\frac{j\omega}{(j\omega+1)(0.1j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$j\omega$	-	20	-
$\frac{1}{j\omega+1}$	$\omega_{c1}=\frac{1}{1}$ $=1\,\text{rad/sec}$	-20	$\Delta\omega_1=20-20$ $=0$
$\frac{1}{0.1j\omega+1}$	$\omega_{c2}=\frac{1}{0.1}$ $=10\,\text{rad/sec}$	-20	$\Delta\omega_2=0-20$ $=-20$

Step 2 of 6

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $100\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$A_{\omega_l}=20\log(0.1)$$
$$=-20\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 3 of 6

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$A_{\omega_{c1}}=20\log(1)$$
$$=0\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 4 of 6

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_{c2}, $1\ \text{rad/sec}$ for ω_{c1} and $0\ \text{dB}$ for $A_{\omega_{c2}}$.

$$A_{\omega_{c2}}=\left[0\times\log\frac{10}{1}\right]+0$$
$$=0\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 5 of 6

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_2$, $10\ \text{rad/sec}$ for ω_{c2}, $100\ \text{rad/sec}$ for ω_h and $0\ \text{dB}$ for $A_{\omega_{c2}}$.

$$A_{\omega_h}=\left[-20\times\log\frac{100}{10}\right]-0$$
$$=-20\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 6 of 6

Consider the bode plot shown in Figure 1.

Figure 1

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 5

Consider Figure P12.4 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 5

Identify the delta connected resistors and convert them to star connection.

Calculate the value of $\mathbf{Z}$.

$$\mathbf{Z} = \frac{(3)(3)}{3+3+3}$$
$$= \frac{9}{9}$$
$$= 1\,\Omega$$

Therefore, the value of $\mathbf{Z}$ is $1\,\Omega$.

Step 3 of 5

Consider Figure 2.

Figure 2

Step 4 of 5

Calculate the value of $\mathbf{Z}_i$.

$$\mathbf{Z}_i = \frac{1}{s} + 1 + \left[(1+s) \| (1+3)\right]$$
$$= \frac{1}{s} + 1 + \left[(1+s) \| 4\right]$$
$$= \frac{1}{s} + 1 + \left[\frac{(1+s)4}{(1+s)+4}\right]$$
$$= \frac{1}{s} + 1 + \frac{4s+4}{s+5}$$

Step 5 of 5

Simplify further.

$$\mathbf{Z}_i = \frac{s+5+s(s+5)+s(4s+4)}{s(s+5)}$$
$$= \frac{s+5+s^2+5s+4s^2+4s}{s(s+5)}$$
$$= \frac{5s^2+10s+5}{s(s+5)}$$
$$= \frac{5(s^2+2s+1)}{s(s+5)}\,\Omega$$

Therefore, the value of $\mathbf{Z}_i$ is $\boxed{\frac{5(s^2+2s+1)}{s(s+5)}\,\Omega}$.

Step 1 of 9

Consider the network function.

$$G(j\omega)=\frac{0.2(j\omega+1)}{j\omega\left(\left(\frac{j\omega}{12}\right)^2+\frac{j\omega}{36}+1\right)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/s)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{0.2}{j\omega}$	-	-20	-
$j\omega+1$	$\omega_{c1}=1$ rad/sec	20	$\Delta\omega_1=-20+20$ $=0$
$\frac{1}{\left(\frac{j\omega}{12}\right)^2+\frac{j\omega}{36}+1}$	$\omega_{c2}=12$ rad/sec	-40 (Due to Quadratic pole)	$\Delta\omega_2=-40+0$ $=-40$

Step 2 of 9

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.01 rad/s.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 100 rad/s.

Calculate the magnitude value at the corner frequency of 0.01 rad/s.

$$\begin{aligned}A_{\omega_l}&=20\log\left(\frac{0.2}{0.01}\right)\\&=20\log 20\\&=26.02\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 0.01 rad/s is 26.02 dB.

Step 3 of 9

Calculate the magnitude value at the corner frequency of 1 rad/s.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\left(\frac{0.2}{1}\right)\\&=-13.98\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 1 rad/s is -13.98 dB.

Step 4 of 9

Calculate the approximate magnitude value at the corner frequency of 12 rad/s.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute 0 db/dec for $\Delta\omega_1$, 12 rad/s for ω_{c2}, 1 rad/sec for ω_{c1} and -13.98 dB for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}}&=\left[0\times\log\frac{12}{1}\right]-13.98\\&=0-13.98\\&=-13.98\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 12 rad/s is -13.98 dB.

Step 5 of 9

Calculate the magnitude value at the corner frequency of 100 rad/s.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute -40 db/dec for $\Delta\omega_2$, 100 rad/sec for ω_h, 12 rad/s for ω_{c2} and -13.98 dB for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_h}&=\left[-40\times\log\frac{100}{12}\right]-13.98\\&=-40(0.921)-13.98\\&=-36.84-13.98\\&=-50.82\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 100 rad/s is -50.82 dB.

Step 6 of 9

Consider the term of quadratic poles.

$$\left(\frac{j\omega}{12}\right)^2+\frac{j\omega}{36}+1$$

Compare to $\left(\frac{j\omega}{\omega_n}\right)^2+\frac{j2\xi\omega}{\omega_n}+1$.

$$\omega_n=12\text{ rad/s}$$

and

$$\frac{2\xi}{\omega_n}=\frac{1}{36}\quad\text{..... (1)}$$

Step 7 of 9

Consider expression (1).

$$\frac{2\xi}{\omega_n}=\frac{1}{36}$$

Substitute 12 rad/s for ω_n.

$$\begin{aligned}\frac{2\xi}{12}&=\frac{1}{36}\\2\xi&=\frac{1}{3}\\\xi&=\frac{1}{6}\end{aligned}$$

Therefore, the value of damping ratio ξ is $\frac{1}{6}$.

Step 8 of 9

Calculate the value of magnitude due to the damping ratio at 12 rad/s.

$$G(12)=20\log\left(\frac{1}{2\xi}\right)$$

Substitute $\frac{1}{6}$ for ξ.

$$\begin{aligned}G(12)&=20\log\left(\frac{1}{2\left(\frac{1}{6}\right)}\right)\\&=20\log(3)\\&=9.54\text{ dB}\end{aligned}$$

Therefore, the actual magnitude value at 12 rad/s is 9.54 dB.

Step 9 of 9

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 6

12.008
P

Consider Figure P12.5 from the text book.

Draw the circuit using Laplace representation of the parameters.

Figure 1

Step 2 of 6

Open the terminals 3-4.

Redraw the circuit diagram as shown in Figure 2.

Figure 2

Step 3 of 6

Calculate the value of $\mathbf{Z}(s)$ across the terminals 1-2.

$$\mathbf{Z}(s)=(2+2s)\|\left(1+\frac{1}{s}\right)$$
$$=\frac{(2+2s)\left(1+\frac{1}{s}\right)}{(2+2s)+\left(1+\frac{1}{s}\right)}$$
$$=\frac{4+2s+\frac{2}{s}}{3+2s+\frac{1}{s}}$$
$$=\frac{\frac{2s^2+4s+2}{s}}{\frac{2s^2+3s+1}{s}}$$

$$\mathbf{Z}(s)=\frac{2s^2+4s+2}{2s^2+3s+1}$$
$$=\frac{2(s^2+2s+1)}{2(s^2+1.5s+0.5)}$$
$$=\frac{s^2+2s+1}{s^2+1.5s+0.5}$$

Therefore, the value of $\mathbf{Z}(s)$ when the terminals 3-4 are opened is $\boxed{\frac{s^2+2s+1}{s^2+1.5s+0.5}}$.

Step 4 of 6

Short the terminals 3-4.

Figure 3

Step 5 of 6

Redraw the circuit diagram as shown in Figure 4.

Figure 4

Step 6 of 6

Calculate the value of $\mathbf{Z}(s)$ across the terminals 1-2.

$$\mathbf{Z}(s)=(1\|2)+\left(2s\|\frac{1}{s}\right)$$
$$=\frac{(1)(2)}{1+2}+\frac{(2s)\left(\frac{1}{s}\right)}{2s+\frac{1}{s}}$$
$$=\frac{2}{3}+\frac{2s}{2s^2+1}$$
$$=\frac{2(2s^2+1)+6s}{3(2s^2+1)}$$

$$\mathbf{Z}(s)=\frac{4s^2+6s+2}{3(s^2+1)}$$
$$=\frac{4\left(s^2+\frac{6}{4}s+\frac{2}{4}\right)}{6\left(s^2+\frac{1}{2}\right)}$$
$$=\frac{2\left(s^2+\frac{3}{2}s+\frac{1}{2}\right)}{3\left(s^2+\frac{1}{2}\right)}$$

Therefore, the value of $\mathbf{Z}(s)$ when the terminals 3-4 are shorted is $\boxed{\frac{2\left(s^2+\frac{3}{2}s+\frac{1}{2}\right)}{3\left(s^2+\frac{1}{2}\right)}}$.

Step 1 of 3

Refer to Figure E12.9 in the textbook.

The plot at the initial point has a slope of -20 which represents a pole of corner frequency $0\ \text{rad/sec}$.

Hence, the pole will be similar to $\frac{A}{j\omega}$.

At $\omega = 5\ \text{rad/sec}$, the value of the gain is $0\ \text{dB}$. Hence,

$$\left|\mathbf{G}(j\omega)\right| = 0\ \text{dB}$$

But $\left|\mathbf{G}(j\omega)\right| = 20\log\frac{A}{5}$

$$20\log\frac{A}{5} = 0$$

$$\log\frac{A}{5} = \frac{0}{20}$$

$$\log\frac{A}{5} = 0$$

$$\frac{A}{5} = 10^0$$

$$A = 5\times 1$$

$$A = 5$$

Therefore, the value of A is 5.

Step 2 of 3

Calculate the change in slope of the line at $\omega_{c1} = 5\ \text{rad/sec}$.

$$0-(-20)$$

$$0+20$$

$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+5$.

Calculate the change in slope of the line at $\omega_{c2} = 20\ \text{rad/sec}$.

$$-20-0$$

$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+20}$.

Calculate the change in slope of the line at $\omega_{c3} = 50\ \text{rad/sec}$.

$$0-(-20)$$

$$0+20$$

$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+50$.

Calculate the change in slope of the line at $\omega_{c4} = 100\ \text{rad/sec}$.

$$-20-0$$

$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+100}$.

Step 3 of 3

Consider the expression for the transfer function having gain K.

$$\mathbf{G}(j\omega) = \frac{K(j\omega+5)(j\omega+50)}{(j\omega)(j\omega+20)(j\omega+100)}$$

$$= \frac{K(5)(50)\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{50}+1\right)}{(j\omega)(20)(100)\left(\frac{j\omega}{20}+1\right)\left(\frac{j\omega}{100}+1\right)}$$

$$\mathbf{G}(j\omega) = \frac{K\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{50}+1\right)}{(8)(j\omega)\left(\frac{j\omega}{20}+1\right)\left(\frac{j\omega}{100}+1\right)}$$

Equate the term $\frac{K}{8}$ to 5.

$$\frac{K}{8} = 5$$

Solve for K.

$$K = 40$$

Substitute 40 for K in the expression of $\mathbf{G}(j\omega)$.

$$\mathbf{G}(j\omega) = \frac{40\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{50}+1\right)}{(8)(j\omega)\left(\frac{j\omega}{20}+1\right)\left(\frac{j\omega}{100}+1\right)}$$

$$= \frac{5\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{50}+1\right)}{(j\omega)\left(\frac{j\omega}{20}+1\right)\left(\frac{j\omega}{100}+1\right)}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is $\boxed{\frac{5\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{50}+1\right)}{(j\omega)\left(\frac{j\omega}{20}+1\right)\left(\frac{j\omega}{100}+1\right)}}$.

Step 1 of 9

(a)

The transfer function is,

$$H(j\omega)=\frac{1}{j\omega+\alpha}$$
$$=\frac{\left(\frac{1}{\alpha}\right)}{1+j\frac{\omega}{\alpha}}$$

There is only one pole at α .

The magnitude at 0 frequency is,

$$K=20\log\left(\frac{1}{\alpha}\right)$$

There is no pole or zero at zero frequency. So, the slope is 0 dB and there is -20 dB/decade from the frequency of α because of pole.

Step 2 of 9

Draw the magnitude plot for the transfer function.

Figure 1

Thus, the magnitude plot for the transfer function is shown in Figure 1.

Step 3 of 9

The phase angle is $0°$ due to no pole or zero at zero frequency and becomes $-90°$ due to pole at α .

Draw the phase plot for the transfer function.

Figure 2

Thus, the phase plot for the transfer function is shown in Figure 2.

Step 4 of 9

(b)

The transfer function is,

$$H(j\omega)=\frac{j\omega+\alpha}{j\omega+\beta}$$
$$=\frac{\alpha\left(1+j\frac{\omega}{\alpha}\right)}{\beta\left(1+j\frac{\omega}{\beta}\right)}$$
$$=\frac{\alpha}{\beta}\left[\frac{1+j\frac{\omega}{\alpha}}{1+j\frac{\omega}{\beta}}\right]$$

There is one pole at β and there is one zero at α and pole occurs first because $\alpha>\beta$.

The magnitude at 0 frequency is,

$$K=20\log\left(\frac{\alpha}{\beta}\right)$$

There is no pole or zero at zero frequency. So, the slope is 0 dB and there is -20 dB from the frequency of α because of pole and -20 dB becomes 0 dB at the frequency, β due to zero.

Step 5 of 9

Draw the magnitude plot.

Figure 3

Thus, the magnitude plot for the transfer function is shown in Figure 3.

Step 6 of 9

The phase angle is $0°$ due to no pole or zero at zero frequency and becomes $-90°$ due to pole at β and again $0°$ due to zero at α .
Draw the phase plot for the transfer function.

Figure 4

Thus, the phase plot for the transfer function is shown in Figure 4.

Step 7 of 9

(c)

The transfer function is,

$$H(j\omega)=\frac{j\omega}{j\omega+\alpha}$$
$$=\frac{1}{\alpha}\left(\frac{j\omega}{1+j\frac{\omega}{\alpha}}\right)$$

There is one pole at α and zero at zero frequency.

The magnitude at 0 frequency is,

$$K=20\log\left(\frac{1}{\alpha}\right)$$

There is one zero at zero frequency. So, the slope is $+20\text{ dB/decade}$ and the slope becomes 0 dB due to pole at α .

Step 8 of 9

Draw the magnitude plot for the transfer function.

Figure 5

Thus, the magnitude plot for the transfer function is shown in Figure 5.

Step 9 of 9

The phase angle is $+90°$ due to zero at zero frequency and becomes $0°$ due to pole at α .

Draw the phase plot for the transfer function.

Figure 6

Thus, the phase plot for the transfer function is shown in Figure 6.

Step 1 of 3

Refer to Figure E12.10 in the textbook for the magnitude characteristic.

From the magnitude plot, it is observed that the initial slope is $0\ \text{dB/decade}$ and therefore, there is no pole and zero at the origin and characteristic level is $-10\ \text{dB}$.

Calculate the gain factor, K_0 .

$$20\log_{10} K_0 = -10$$
$$\log_{10} K_0 = -0.5$$
$$K_0 = 10^{-0.5}$$
$$K_0 = 0.3162$$

One pole provides $-20\ \text{dB/decade}$ and one zero provides $+20\ \text{dB/decade}$.

Step 2 of 3

The $+20\ \text{dB/decade}$ slope starting at $\omega = 5\ \text{rad/s}$ indicates that the first zero has a break frequency or corner frequency at $\omega = 5\ \text{rad/s}$. Therefore, one of the factor in the numerator is $\left(\frac{j\omega}{5}+1\right)$.

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 12\ \text{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 12\ \text{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{12}+1\right)$.

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 25\ \text{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 25\ \text{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{25}+1\right)$.

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 40\ \text{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 40\ \text{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{40}+1\right)$.

Step 3 of 3

The composite transfer function from the magnitude plot is,

$$\begin{aligned}\mathbf{H}(j\omega) &= \frac{K_0\left(\frac{j\omega}{5}+1\right)}{\left(\frac{j\omega}{12}+1\right)\left(\frac{j\omega}{25}+1\right)\left(\frac{j\omega}{40}+1\right)} \\ &= \frac{0.3162\left(\frac{j\omega}{5}+1\right)}{\left(\frac{j\omega}{12}+1\right)\left(\frac{j\omega}{25}+1\right)\left(\frac{j\omega}{40}+1\right)}\end{aligned}$$

Therefore, transfer function $\mathbf{H}(j\omega)$ is,

$$\boxed{\frac{0.3162\left(\frac{j\omega}{5}+1\right)}{\left(\frac{j\omega}{12}+1\right)\left(\frac{j\omega}{25}+1\right)\left(\frac{j\omega}{40}+1\right)}}.$$

12.010

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Step 1 of 1

Refer to Figure E12.11 in the textbook.

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $100\ \text{mH}$ for L and $1800\ \text{rad/sec}$ for ω_0 .

$$1800 = \frac{1}{\sqrt{(100\ \text{mH})C}}$$

$$(1800)^2 = \left(\frac{1}{\sqrt{(100\ \text{mH})C}}\right)^2$$

$$324\times10^4 = \frac{1}{(100\ \text{mH})C}$$

$$C = \frac{1}{(100\ \text{mH})(324\times10^4)}$$

$$C = \frac{1}{324000}$$
$$= 3.09\ \mu\text{F}$$

Therefore, the value of the capacitor is $\boxed{3.09\ \mu\text{F}}$.

Step 1 of 7

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{j\omega 4+1}{j\omega 20+1}$$
$$=\frac{(1)(j\omega 4+1)}{j\omega 20+1}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
1	-	0	-
$\frac{1}{1+20j\omega}$	$\omega_{c1}=\frac{1}{20}$ $=0.05\text{ rad/sec}$	-20	$\Delta\omega_1=0-20$ $=-20$
$1+4j\omega$	$\omega_{c2}=\frac{1}{4}$ $=0.25\text{ rad/sec}$	20	$\Delta\omega_2=-20+20$ $=0$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.01 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1 rad/sec.

Calculate the magnitude value at the corner frequency of 0.01 rad/sec.

$$A_{\omega_l}=20\log(1)$$
$$=0\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.01 rad/sec is 0 dB.

Step 3 of 7

Calculate the magnitude value at the corner frequency of 0.05 rad/sec.

$$A_{\omega_{c1}}=20\log(1)$$
$$=0\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.05 rad/sec is 0 dB.

Step 4 of 7

Calculate the magnitude value at the corner frequency of 0.25 rad/sec.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute -20 db/dec for $\Delta\omega_1$, 0.25 rad/sec for ω_{c2}, 0.05 rad/sec for ω_{c1} and 0 dB for $A_{\omega_{c2}}$.

$$A_{\omega_{c2}}=\left[-20\times\log\frac{0.25}{0.05}\right]+0$$
$$=-20\times\log 5$$
$$=-20\times 0.699$$
$$=-13.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.25 rad/sec is -13.98 dB.

Step 5 of 7

Calculate the magnitude value at the corner frequency of 1 rad/sec.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute 0 db/dec for $\Delta\omega_2$, 0.25 rad/sec for ω_{c2}, 1 rad/sec for ω_h and -13.98 dB for $A_{\omega_{c2}}$.

$$A_{\omega_h}=\left[0\times\log\frac{0.5}{0.25}\right]-13.98$$
$$=-13.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.5 rad/sec is -13.98 dB.

Step 6 of 7

Phase plot analysis:

Consider the expression for the phase angle of the function.

$$\phi=\tan^{-1}(4\omega)-\tan^{-1}(20\omega)$$

Consider Table-2 to calculate the values of phase angle at different frequencies.

Table-2

corner frequency ω(rad/sec)	$\tan^{-1}(4\omega)-\tan^{-1}(20\omega)$ (degrees)
0.01	00.00
0.05	-09.02
0.10	-33.69
0.25	-41.69
1.00	-11.17

Step 7 of 7

Consider the bode plot shown in Figure 1.

Magnitude plot

Phase plot

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 6

The network function is,

$$\begin{aligned}\mathbf{H}(s) &= \frac{1}{(j\omega+5)(j\omega+10)}\\ &= \frac{1}{50\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{10}+1\right)}\\ &= \frac{0.02}{\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{10}+1\right)}\end{aligned}$$

From the transfer function, the breakaway frequencies are,

$$\omega_1 = 5 \text{ rad/sec}$$
$$\omega_2 = 10 \text{ rad/sec}$$

Step 2 of 6

The term $\left(\frac{j\omega}{5}+1\right)$ in the numerator causes an asymptote of slope -20 dB/decade originating from $\omega = 5 \text{ rad/sec}$.

Therefore net slope is -20dB/decade up to next frequency $\omega_2 = 10 \text{ rad/sec}$.

The term $\left(\frac{j\omega}{10}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 10 \text{ rad/sec}$.

Therefore, net slope is $(-20-20) = -40\text{dB/decade}$.

Write the magnitude expression.

$$\begin{aligned}20\log_{10}|\mathbf{H}(j\omega)| &= 20\log_{10}|0.02| - 20\log_{10}\left|\frac{j\omega}{5}+1\right| - 20\log_{10}\left|\frac{j\omega}{10}+1\right|\\ &= 20(-1.698) - 20\log_{10}\left|\frac{j\omega}{5}+1\right| - 20\log_{10}\left|\frac{j\omega}{10}+1\right|\\ &= -33.979 - 20\log_{10}\left|\frac{j\omega}{5}+1\right| - 20\log_{10}\left|\frac{j\omega}{10}+1\right|\end{aligned}$$

Step 3 of 6

The magnitude plot of the network function is shown in Figure 1.

Figure 1

Step 4 of 6

Write the expression for the phase angle.

$$\angle H(j\omega) = -\tan^{-1}\left(\frac{\omega}{5}\right) - \tan^{-1}\left(\frac{\omega}{10}\right)$$

The phase angles at different frequencies are shown in Table 1.

$\omega(\text{rad/s})$	$\angle\mathbf{H}(j\omega)$
0.1	$-1.718°$
1	$-17°$
10	$-108.43°$
100	$-171.43°$
1000	$-179°$

Step 5 of 6

The phase of the network function is shown in Figure 2.

Figure 2: Phase plot

Step 6 of 6

The Bode plot is shown in Figure 3.

Figure 3: Bode plot

Therefore, the Bode plot for the network function is shown in Figure 3.

Step 1 of 5

Refer to Figure E12.13 in the text book.

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $100\ \mu\text{F}$ for L and $10000\ \text{rad/sec}$ for ω_0 in the equation.

$$10000 = \frac{1}{\sqrt{(100\ \mu)L}}$$

$$(10000)^2 = \left(\frac{1}{\sqrt{(100\ \mu)L}}\right)^2$$

$$10^8 = \frac{1}{(100\ \mu)L}$$

$$L = \frac{1}{(100\ \mu)(1\times10^8)}$$

$$= \frac{1}{10000}$$

$$= 100\ \mu\text{H}$$

Therefore, the value of the capacitor is $\boxed{100\ \mu\text{H}}$.

Step 2 of 5

Draw the circuit diagram in phasor representation of the parameters.

Figure 1

Step 3 of 5

Calculate the value of $\mathbf{I}(j\omega)$.

$$\mathbf{I}(j\omega) = \frac{30\angle0^\circ}{R + j\omega L + \frac{1}{j\omega C}} \quad \text{..... (1)}$$

At resonance frequency, the circuit acts as purely resistive.

$$\mathbf{I}(j\omega) = \frac{30\angle0^\circ}{R}$$

Substitute $5\ \Omega$ for R in the equation.

$$\mathbf{I}(j\omega) = \frac{30\angle0^\circ}{5}$$

$$= 6\angle0^\circ\ \text{A}$$

Convert to time domain.

$$i(t) = 6\cos(10000t)\ \text{A}$$

Therefore, the value of the current at resonance is $\boxed{6\cos(10000t)\ \text{A}}$.

Step 4 of 5

Recall equation (1).

$$\mathbf{I}(j\omega) = \frac{30\angle0^\circ}{R + j\omega L + \frac{1}{j\omega C}}$$

Substitute $\frac{\omega_0}{3}$ for ω in the equation.

$$\mathbf{I}\left(j\frac{\omega_0}{3}\right) = \frac{30\angle0^\circ}{R + j\frac{\omega_0 L}{3} + \frac{1}{j\frac{\omega_0 C}{3}}}$$

Substitute $5\ \Omega$ for R , $100\ \mu\text{H}$ for L , $100\ \mu\text{F}$ for C and $10000\ \text{rad/sec}$ for ω_0 in the equation.

$$\mathbf{I}\left(j\frac{\omega_0}{3}\right) = \frac{30\angle0^\circ}{5 + j\frac{(10000)(100\ \mu)}{3} + \frac{1}{j\frac{(10000)(100\ \mu)}{3}}}$$

$$= \frac{30\angle0^\circ}{5 + j\frac{1}{3} + \frac{1}{j\frac{1}{3}}}$$

$$= \frac{30\angle0^\circ}{5 + j0.33 - j3}$$

$$= \frac{30\angle0^\circ}{5.67\angle-28.07^\circ}$$

$$= 5.294\angle28.09^\circ\ \text{A}$$

Convert to time domain.

$$i(t) = 5.294\cos\left(\frac{10000}{3}t + 28.09^\circ\right)$$

$$= 5.294\cos(3333.33t + 28.09^\circ)\ \text{A}$$

Therefore, the value of the current at frequency $\frac{\omega_0}{3}$ is $\boxed{5.294\cos(3333.33t + 28.09^\circ)\ \text{A}}$.

Step 5 of 5

Recall equation (1).

$$\mathbf{I}(j\omega) = \frac{30\angle0^\circ}{R + j\omega L + \frac{1}{j\omega C}}$$

Substitute $3\omega_0$ for ω in the equation.

$$\mathbf{I}(j3\omega_0) = \frac{30\angle0^\circ}{R + j3\omega_0 L + \frac{1}{j3\omega_0 C}}$$

Substitute $5\ \Omega$ for R , $100\ \mu\text{H}$ for L , $100\ \mu\text{F}$ for C and $10000\ \text{rad/sec}$ for ω_0 .

$$\mathbf{I}(j3\omega_0) = \frac{30\angle0^\circ}{5 + j3(10000)(100\ \mu) + \frac{1}{j3(10000)(100\ \mu)}}$$

$$= \frac{30\angle0^\circ}{5 + j3 + \frac{1}{j3}}$$

$$= \frac{30\angle0^\circ}{5 + j2.667}$$

$$= \frac{30\angle0^\circ}{5.667\angle28.07^\circ}$$

$$= 5.294\angle-28.07^\circ\ \text{A}$$

Convert to time domain.

$$i(t) = 5.294\cos(3(10000)t - 28.09^\circ)$$

$$= 5.294\cos(30000t - 28.09^\circ)\ \text{A}$$

Therefore, the value of the current at frequency $3\omega_0$ is $\boxed{5.294\cos(30000t - 28.09^\circ)\ \text{A}}$.

Step 1 of 7

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{10j\omega+1}{j\omega(0.01j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{1}{j\omega}$	-	-20	-
$10j\omega+1$	$\omega_{c1}=\frac{1}{10}$ $=0.1\,\text{rad/sec}$	20	$\Delta\omega_1=20-20$ $=0$
$\frac{1}{0.01j\omega+1}$	$\omega_{c2}=\frac{1}{0.01}$ $=100\,\text{rad/sec}$	-20	$\Delta\omega_2=0-20$ $=-20$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.01\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $1000\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_l}&=20\log\left(\frac{1}{0.01}\right)\\&=20\log(100)\\&=40\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$ is $40\ \text{dB}$.

Step 3 of 7

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\left(\frac{1}{0.1}\right)\\&=20\log(10)\\&=20\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $20\ \text{dB}$.

Step 4 of 7

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $100\ \text{rad/sec}$ for ω_{c2}, $10\ \text{rad/sec}$ for ω_{c1} and $20\ \text{dB}$ for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}}&=\left[0\times\log\frac{100}{10}\right]+20\\&=20\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $20\ \text{dB}$.

Step 5 of 7

Calculate the magnitude value at the corner frequency of $1000\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_2$, $100\ \text{rad/sec}$ for ω_{c2}, $1000\ \text{rad/sec}$ for ω_h and $20\ \text{dB}$ for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_h}&=\left[-20\times\log\frac{1000}{100}\right]+20\\&=-20+20\\&=0\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1000\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 6 of 7

Phase plot analysis:
Consider the expression for the phase angle of the function.

$$\phi=-90^\circ+\tan^{-1}(10\omega)-\tan^{-1}(0.01\omega)$$

Consider Table-2 to calculate the values of phase angle at different frequencies.

Table-2

corner frequency $\omega(\text{rad/sec})$	$-90^\circ+\tan^{-1}(10\omega)-\tan^{-1}(0.01\omega)$ (degrees)
0000.01	-84.30
0000.10	-45.06
0001.00	-06.28
0010.00	-06.28
0100.00	-45.06
1000.00	-84.30

Step 7 of 7

Consider the bode plot shown in Figure 1.

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 3

Refer to Figure E12.11 in the text book.

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $3\ \Omega$ for R, $100\ \text{mH}$ for L and $1800\ \text{rad/sec}$ for ω_0 in the equation.

$$\begin{aligned} Q &= \frac{(1800)(100\ \text{m})}{3} \\ &= (600)(100\ \text{m}) \\ &= 60 \end{aligned}$$

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $1800\ \text{rad/s}$ for ω_0 and 60 for Q in the equation.

$$\begin{aligned} \text{BW} &= \frac{1800}{60} \\ &= 30\ \text{rad/s} \end{aligned}$$

Therefore, the value of the bandwidth is $\boxed{30\ \text{rad/s}}$.

Step 2 of 3

Consider the formula for the lower half power frequency.

$$\omega_{LO} = \omega_0 \left[-\frac{1}{2Q} + \sqrt{\left(\frac{1}{2Q}\right)^2 + 1} \right]$$

Substitute $1800\ \text{rad/sec}$ for ω_0 and 60 for Q in the equation.

$$\begin{aligned} \omega_{LO} &= (1800)\left[-\frac{1}{2(60)} + \sqrt{\left(\frac{1}{2(60)}\right)^2 + 1} \right] \\ &= (1800)\left[-\frac{1}{120} + \sqrt{\left(\frac{1}{120}\right)^2 + 1} \right] \\ &= (1800)\left[-(8.333\ \text{m}) + \sqrt{(8.333\ \text{m})^2 + 1} \right] \\ &= (1800)\left[-(8.333\ \text{m}) + \sqrt{69.44\ \mu + 1} \right] \end{aligned}$$

$$\begin{aligned} &= (1800)\left[-(8.333\ \text{m}) + \sqrt{1} \right] \\ &= (1800)\left[-(8.333\ \text{m}) + 1 \right] \\ &= (1800)[0.991667] \\ &= 1785\ \text{rad/s} \end{aligned}$$

Therefore, the value of the lower half power frequency is $\boxed{1785\ \text{rad/s}}$.

Step 3 of 3

Consider the formula for the higher half power frequency in terms of the lower half power frequency and the bandwidth.

$$\omega_{HI} = \text{BW} + \omega_{LO}$$

Substitute $60\ \text{rad/s}$ for BW and $1785\ \text{rad/s}$ for ω_{LO} in the equation.

$$\begin{aligned} \omega_{HI} &= 60 + 1785\ \text{rad/s} \\ &= 1815\ \text{rad/s} \end{aligned}$$

Therefore, the value of the higher half power frequency is $\boxed{1815\ \text{rad/s}}$.

Step 1 of 7

The network function is,

$$\mathbf{H}(s)=\frac{j\omega+40}{(j\omega+1)(j\omega+2)}$$
$$=\frac{40\left(\frac{j\omega}{40}+1\right)}{2\left(\frac{j\omega}{1}+1\right)\left(\frac{j\omega}{2}+1\right)}$$
$$=\frac{20\left(\frac{j\omega}{40}+1\right)}{\left(\frac{j\omega}{1}+1\right)\left(\frac{j\omega}{2}+1\right)}$$

From the transfer function, the breakaway frequencies are,

$\omega_1 = 1$ rad/sec
$\omega_2 = 2$ rad/sec
$\omega_2 = 40$ rad/sec

Step 2 of 7

The term $\left(\frac{j\omega}{1}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 1$ rad/sec .

Therefore net slope is -20dB/decade up to next frequency $\omega_2 = 10$ rad/sec .

The term $\left(\frac{j\omega}{2}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 2$ rad/sec .

Therefore, net slope is $(-20-20) = -40$dB/decade .

The term $\left(\frac{j\omega}{40}+1\right)$ in the numerator causes an asymptote of slope 20 dB/decade originating from $\omega = 40$ rad/sec .

Therefore, net slope is $(20-40) = -20$dB/decade .

Step 3 of 7

Write the magnitude expression.

$$20\log_{10}|\mathbf{H}(j\omega)| = \left[\begin{array}{l} 20\log_{10}|20| - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{2}+1\right| + 20\log_{10}\left|\frac{j\omega}{40}+1\right| \end{array}\right]$$
$$= 20(1.3) - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - 20\log_{10}\left|\frac{j\omega}{2}+1\right| + 20\log_{10}\left|\frac{j\omega}{40}+1\right|$$
$$= 26 - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - 20\log_{10}\left|\frac{j\omega}{2}+1\right| + 20\log_{10}\left|\frac{j\omega}{40}+1\right|$$

Step 4 of 7

The magnitude plot of the network function is shown in Figure 1.

Figure 1: Magnitude plot

Step 5 of 7

Write the expression for the phase angle.

$$\angle H(j\omega) = -\tan^{-1}\left(\frac{\omega}{1}\right) - \tan^{-1}\left(\frac{\omega}{2}\right) + \tan^{-1}\left(\frac{\omega}{40}\right)$$

The phase angles at different frequencies are shown in Table 1.

ω(rad/s)	$\angle\mathbf{H}(j\omega)$
0.1	−8.429°
1	−70.13°
10	−148.94°
100	−110.08°
1000	−92.12°

Step 6 of 7

The phase of the network function is shown in Figure 2.

Figure 2: Phase plot

Step 7 of 7

The Bode plot is shown in Figure 3.

Figure 3: Bode plot

Therefore, the Bode plot for the network function is shown in Figure 3.

12.015

E

Step 1 of 3

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $100\ \mu\text{F}$ for C and $40\ \text{mH}$ for L.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(100\ \mu)(40\ \text{m})}}\\ &= \frac{1}{\sqrt{4\times10^{-6}}}\\ &= \frac{1}{2\times10^{-3}}\\ &= 500\ \text{rad/s}\end{aligned}$$

Therefore, the value of the resonant frequency is $\boxed{500\ \text{rad/s}}$.

Step 2 of 3

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $2\ \Omega$ for R, $40\ \text{mH}$ for L and $500\ \text{rad/s}$ for ω_0.

$$\begin{aligned}Q &= \frac{(500)(40\ \text{m})}{2}\\ &= (500)(20\ \text{m})\\ &= 10\end{aligned}$$

Therefore, the value of the quality factor Q is 10.

Step 3 of 3

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $500\ \text{rad/sec}$ for ω_0 and 10 for Q in the equation.

$$\begin{aligned}\text{BW} &= \frac{500}{10}\\ &= 50\ \text{rad/s}\end{aligned}$$

Therefore, the value of the bandwidth is $\boxed{50\ \text{rad/s}}$.

Step 1 of 7

The network function is,

$$\mathbf{H}(s)=\frac{(j\omega+8)(j\omega+2)}{-\omega^2}$$
$$=\frac{16\left(\frac{j\omega}{8}+1\right)\left(\frac{j\omega}{2}+1\right)}{-\omega^2}$$
$$=\frac{16\left(\frac{j\omega}{2}+1\right)\left(\frac{j\omega}{8}+1\right)}{-\omega^2}$$

From the transfer function, the breakaway frequencies are,

$$\omega_1=2\text{ rad/sec}$$
$$\omega_2=8\text{ rad/sec}$$

Step 2 of 7

The term $-\omega^2$ causes an asymptote of slope of -40 dB/decade passing 0 dB at $\omega=1\text{ rad/sec}$.

The term $\left(\frac{j\omega}{2}+1\right)$ in the numerator causes an asymptote of slope 20 dB/decade originating from $\omega=2\text{ rad/sec}$.

Therefore net slope is $(20-40)=-20\text{dB/decade}$ up to next frequency $\omega_2=8\text{ rad/sec}$.

The term $\left(\frac{j\omega}{8}+1\right)$ in the numerator causes an asymptote of slope 20 dB/decade originating from $\omega=8\text{ rad/sec}$.

Therefore, net slope is $(20-20)=0\text{dB/decade}$.

Step 3 of 7

Write the magnitude expression.

$$20\log_{10}|\mathbf{H}(j\omega)|=\begin{bmatrix}20\log_{10}|16|+20\log_{10}\left|\frac{j\omega}{2}+1\right|+\\ 20\log_{10}\left|\frac{j\omega}{8}+1\right|-40\log_{10}|j\omega|\end{bmatrix}$$
$$20(1.2)+20\log_{10}\left|\frac{j\omega}{2}+1\right|+20\log_{10}\left|\frac{j\omega}{8}+1\right|-40\log_{10}|j\omega|$$
$$=24+20\log_{10}\left|\frac{j\omega}{2}+1\right|+20\log_{10}\left|\frac{j\omega}{8}+1\right|-40\log_{10}|j\omega|$$

Step 4 of 7

The magnitude plot of the network function is shown in Figure 1.

Figure 1: Magnitude plot

Step 5 of 7

Write the expression for the phase angle.

$$\angle H(j\omega)=-180^\circ+\tan^{-1}\left(\frac{\omega}{2}\right)+\tan^{-1}\left(\frac{\omega}{8}\right)$$

The phase angles at different frequencies are shown in Table 1.

$\omega(\text{rad/s})$	$\angle\mathbf{H}(j\omega)$
0.1	−176.42°
1	−146.3°
10	−50°
100	−5.72°
1000	−0.57°

Step 6 of 7

The phase of the network function is shown in Figure 2.

Figure 2: Phase plot

Step 7 of 7

The Bode plot is shown in Figure 3.

Figure 3: Bode plot

Therefore, the Bode plot for the network function is shown in Figure 3.

12.016

E

Step 1 of 3

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{\omega_0}{Q}$$

Substitute $4000\ \mathrm{rad/sec}$ for ω_0 and $100\ \mathrm{rad/s}$ for BW in the equation.

$$100 = \frac{4000}{Q}$$

$$\begin{aligned} Q &= \frac{4000}{100} \\ &= 40 \end{aligned}$$

Therefore, the value of the quality factor is 40.

Step 2 of 3

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $4\ \Omega$ for R, 40 for Q and $4000\ \mathrm{rad/s}$ for ω_0 in the equation.

$$40 = \frac{(4000)L}{4}$$

$$40 = (1000)L$$

$$\begin{aligned} L &= \frac{40}{1000} \\ &= 40\ \mathrm{mH} \end{aligned}$$

Therefore, the value of the inductor L is $\boxed{40\ \mathrm{mH}}$.

Step 3 of 3

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $40\ \mathrm{mH}$ for L and $4000\ \mathrm{rad/sec}$ for ω_0 in the equation.

$$4000 = \frac{1}{\sqrt{(40\ \mathrm{m})C}}$$

$$(4000)^2 = \left(\frac{1}{\sqrt{(40\ \mathrm{m})C}}\right)^2$$

$$16 \times 10^6 = \frac{1}{(40\ \mathrm{m})C}$$

$$\begin{aligned} C &= \frac{1}{(40\ \mathrm{m})(16 \times 10^6)} \\ &= \frac{1}{640000} \\ &= 1.56\ \mu\mathrm{F} \end{aligned}$$

Therefore, the value of the capacitor C is $\boxed{1.56\ \mu\mathrm{F}}$.

Step 1 of 7

Consider the network function.

$$\begin{aligned}G(j\omega) &= \frac{400(j\omega+2)(j\omega+50)}{-\omega^2(j\omega+100)^2}\\ &= \frac{400(j\omega+2)(j\omega+50)}{(j\omega)^2(j\omega+100)^2}\\ &= \frac{(400)(2)(50)(0.5j\omega+1)(0.02j\omega+1)}{(100)^2(j\omega)^2(0.01j\omega+1)^2}\\ &= \frac{4(0.5j\omega+1)(0.02j\omega+1)}{(j\omega)^2(0.01j\omega+1)^2}\end{aligned}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{4}{(j\omega)^2}$	-	-40	-
$0.5j\omega+1$	$\omega_{c1}=\frac{1}{0.5}$ $=2$ rad/sec	20	$\Delta\omega_1=-40+20$ $=-20$
$0.02j\omega+1$	$\omega_{c2}=\frac{1}{0.02}$ $=50$ rad/sec	20	$\Delta\omega_2=-20+20$ $=0$
$\frac{1}{(0.01j\omega+1)^2}$	$\omega_{c3}=\frac{1}{0.01}$ $=100$ rad/sec	-40	$\Delta\omega_3=-40+0$ $=-40$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.1 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1000 rad/sec.

Calculate the magnitude value at the corner frequency of 0.1 rad/sec.

$$\begin{aligned}A_{\omega_l} &= 20\log\left(\frac{4}{(0.1)^2}\right)\\ &= 20\log(400)\\ &= 52.04 \text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 0.1 rad/sec is 52.04 dB.

Step 3 of 7

Calculate the magnitude value at the corner frequency of 2 rad/sec.

$$\begin{aligned}A_{\omega_{c1}} &= 20\log\left(\frac{4}{(2)^2}\right)\\ &= 20\log\left(\frac{4}{4}\right)\\ &= 0 \text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 2 rad/sec is 0 dB.

Step 4 of 7

Calculate the magnitude value at the corner frequency of 50 rad/sec.

$$A_{\omega_{c2}} = \left[\Delta\omega_1 \times \log\frac{\omega_{c2}}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute -20 db/dec for $\Delta\omega_1$, 50 rad/sec for ω_{c2}, 2 rad/sec for ω_{c1} and 0 dB for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}} &= \left[-20\times\log\frac{50}{2}\right]+0\\ &= -20\log 25\\ &= -27.96 \text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 50 rad/sec is -27.96 dB.

Step 5 of 7

Calculate the magnitude value at the corner frequency of 100 rad/sec.

$$A_{\omega_{c3}} = \left[\Delta\omega_2 \times \log\frac{\omega_{c3}}{\omega_{c2}}\right] + A_{\omega_{c2}}$$

Substitute 0 db/dec for $\Delta\omega_2$, 100 rad/sec for ω_{c3}, 50 rad/sec for ω_{c2} and -27.96 dB for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_{c3}} &= \left[0\times\log\frac{100}{50}\right]-27.96\\ &= -27.96 \text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 100 rad/sec is -27.96 dB.

Step 6 of 7

Calculate the magnitude value at the corner frequency of 1000 rad/sec.

$$A_{\omega_h} = \left[\Delta\omega_3 \times \log\frac{\omega_h}{\omega_{c3}}\right] + A_{\omega_{c3}}$$

Substitute -40 db/dec for $\Delta\omega_3$, 100 rad/sec for ω_{c3}, 1000 rad/sec for ω_h and -27.96 dB for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_h} &= \left[-40\times\log\frac{1000}{100}\right]-27.98\\ &= -40-27.98\\ &= -67.98 \text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 1000 rad/sec is -67.98 dB.

Step 7 of 7

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

12.017

E

Step 1 of 3

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $150\ \mu\text{F}$ for C and $20\ \text{mH}$ for L in the equation.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(150\ \mu)(20\ \text{m})}} \\ &= \frac{1}{\sqrt{3\times10^{-6}}} \\ &= \frac{1}{1.732\times10^{-3}} \\ &\approx 577\ \text{rad/s}\end{aligned}$$

Therefore, the value of the resonant frequency is $\boxed{577\ \text{rad/s}}$.

Step 2 of 3

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{1}{RC}$$

Substitute $150\ \mu\text{F}$ for C and $2\ \text{k}\Omega$ for R in the equation.

$$\begin{aligned}\text{BW} &= \frac{1}{(2\ \text{k})(150\ \mu)} \\ &= \frac{1}{0.3} \\ &= 3.33\ \text{rad/s}\end{aligned}$$

Therefore, the value of the bandwidth is $\boxed{3.33\ \text{rad/s}}$.

Step 3 of 3

Consider the formula for the quality factor Q of the circuit in terms of the resonant frequency and bandwidth.

$$Q = \frac{\omega_0}{\text{BW}}$$

Substitute $3.33\ \text{rad/s}$ for BW and $577\ \text{rad/s}$ for ω_0 in the equation.

$$\begin{aligned}Q &= \frac{577}{3.33} \\ &\approx 173\end{aligned}$$

Therefore, the value of the quality factor Q is $\boxed{173}$.

12.017
P

Step 1 of 7

The network function is,

$$\mathbf{H}(s)=\frac{-\omega^2 10^4}{(j\omega+1)(j\omega+10)(j\omega+100)}$$
$$=\frac{-\omega^2 10^4}{1000\left(\frac{j\omega}{1}+1\right)\left(\frac{j\omega}{10}+1\right)\left(\frac{j\omega}{100}+1\right)}$$
$$=\frac{-10\omega^2}{\left(\frac{j\omega}{1}+1\right)\left(\frac{j\omega}{10}+1\right)\left(\frac{j\omega}{100}+1\right)}$$

From the transfer function, the breakaway frequencies are,

$\omega_1 = 1$ rad/sec
$\omega_2 = 10$ rad/sec
$\omega_3 = 100$ rad/sec

Step 2 of 7

The term $-\omega^2$ causes an asymptote of slope of 40 dB/decade passing 20 dB at $\omega = 1$ rad/sec .

The term $\left(\frac{j\omega}{1}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 1$ rad/sec .

Therefore net slope is $(-20+40) = 20$dB/decade up to next frequency $\omega_2 = 10$ rad/sec .

The term $\left(\frac{j\omega}{10}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 10$ rad/sec .

Therefore net slope is $(-20+20) = 0$dB/decade up to next frequency $\omega_3 = 100$ rad/sec .

The term $\left(\frac{j\omega}{100}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 100$ rad/sec .

Therefore, net slope is $(-20+0) = -20$dB/decade .

Step 3 of 7

Write the magnitude expression.

$$20\log_{10}|\mathbf{H}(j\omega)| = \begin{bmatrix} 20\log_{10}|10| + 40\log_{10}|j\omega| - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{100}+1\right| \end{bmatrix}$$
$$= \begin{bmatrix} 20(1) + 40\log_{10}|j\omega| - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{100}+1\right| \end{bmatrix}$$
$$= \begin{bmatrix} 20 + 40\log_{10}|j\omega| - 20\log_{10}\left|\frac{j\omega}{1}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{100}+1\right| \end{bmatrix}$$

Step 4 of 7

The magnitude plot of the network function is shown in Figure 1.

Figure 1: Magnitude plot

Step 5 of 7

Write the expression for the phase angle.

$$\angle H(j\omega) = 180° - \tan^{-1}\left(\frac{\omega}{1}\right) - \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}\left(\frac{\omega}{100}\right)$$

The phase angles at different frequencies are shown below.

ω(rad/s)	$\angle\mathbf{H}(j\omega)$
0.1	173.66°
1	128.72°
10	45°
10^2	−38.72°
10^3	−83.66°
10^4	−89.36°

Step 6 of 7

The phase of the network function is shown in Figure 2.

Figure 2: Phase plot

Step 7 of 7

The Bode plot is shown in Figure 3.

Figure 3: Bode plot

Therefore, the Bode plot for the network function is shown in Figure 3.

12.018

E

Step 1 of 3

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{1}{RC}$$

Substitute $1000\ \mathrm{rad/s}$ for BW and $6\ \mathrm{k\Omega}$ for R in the equation.

$$1000 = \frac{1}{(6\ \mathrm{k})C}$$

$$\begin{aligned} C &= \frac{1}{(6\ \mathrm{k})(1000)} \\ &= \frac{1}{6\times10^{6}} \\ &= 0.167\ \mu\mathrm{F} \end{aligned}$$

Therefore, the value of the capacitor is $\boxed{0.167\ \mu\mathrm{F}}$.

Step 2 of 3

Consider the formula for the quality factor Q.

$$Q = R\sqrt{\frac{C}{L}}$$

Substitute $6\ \mathrm{k\Omega}$ for R, $0.167\ \mu\mathrm{F}$ for C and 120 for Q in the equation.

$$120 = (6\ \mathrm{k})\sqrt{\frac{0.167\mu}{L}}$$

$$\frac{120}{6\ \mathrm{k}} = \sqrt{\frac{0.167\mu}{L}}$$

$$20\ \mathrm{m} = \sqrt{\frac{0.167\mu}{L}}$$

$$(20\ \mathrm{m})^2 = \left(\sqrt{\frac{0.167\mu}{L}}\right)^2$$

$$400\ \mu = \frac{0.167\mu}{L}$$

$$L = 417.5\ \mu\mathrm{H}$$

Therefore, the value of the inductor L is $\boxed{417.5\ \mu\mathrm{H}}$.

Step 3 of 3

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $0.167\ \mu\mathrm{F}$ for C and $417.5\ \mu\mathrm{H}$ for L in the equation.

$$\begin{aligned} \omega_0 &= \frac{1}{\sqrt{(0.167\ \mu)(417.5\ \mu)}} \\ &= \frac{1}{\sqrt{6.973\times10^{-11}}} \\ &= \frac{1}{8.35003\times10^{-6}} \\ &= 119760\ \mathrm{rad/s} \end{aligned}$$

Therefore, the value of the resonant frequency is $\boxed{119760\ \mathrm{rad/s}}$.

Step 1 of 7

The network function is,

$$\begin{aligned}\mathbf{H}(s) &= \frac{(j\omega+4)^2}{-\omega^2\left(\frac{j\omega}{10}+1\right)\left(\frac{j\omega}{20}+1\right)}\\ &= \frac{4^2\left(\frac{j\omega}{4}+1\right)^2}{-\omega^2\left(\frac{j\omega}{10}+1\right)\left(\frac{j\omega}{20}+1\right)}\\ &= \frac{16\left(\frac{j\omega}{4}+1\right)^2}{-\omega^2\left(\frac{j\omega}{10}+1\right)\left(\frac{j\omega}{20}+1\right)}\end{aligned}$$

From the transfer function, the breakaway frequencies are,

$\omega_1 = 4$ rad/sec
$\omega_2 = 10$ rad/sec
$\omega_3 = 20$ rad/sec

Step 2 of 7

The term $-\omega^2$ causes an asymptote of slope of -40 dB/decade .

The term $\left(\frac{j\omega}{4}+1\right)^2$ in the numenator causes an asymptote of slope 40 dB/decade originating from $\omega = 4$ rad/sec .

Therefore, the net slope is $(-40+40) = 0$dB/decade up to next frequency $\omega_2 = 10$ rad/sec .

The term $\left(\frac{j\omega}{10}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 10$ rad/sec .

Therefore, the net slope is $(-20+0) = -20$dB/decade up to next frequency $\omega_3 = 20$ rad/sec .

The term $\left(\frac{j\omega}{20}+1\right)$ in the denominator causes an asymptote of slope -20 dB/decade originating from $\omega = 20$ rad/sec .

Therefore, the net slope is $(-20-20) = -40$dB/decade .

Step 3 of 7

Write the magnitude expression.

$$\begin{aligned}20\log_{10}|\mathbf{H}(j\omega)| &= \left[\begin{array}{l}20\log_{10}|16| - 40\log_{10}|j\omega| + 40\log_{10}\left|\frac{j\omega}{4}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{20}+1\right|\end{array}\right]\\ &= \left[\begin{array}{l}20(1.2) - 40\log_{10}|j\omega| + 40\log_{10}\left|\frac{j\omega}{4}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{20}+1\right|\end{array}\right]\\ &= \left[\begin{array}{l}24 - 40\log_{10}|j\omega| + 40\log_{10}\left|\frac{j\omega}{4}+1\right| - \\ 20\log_{10}\left|\frac{j\omega}{10}+1\right| - 20\log_{10}\left|\frac{j\omega}{20}+1\right|\end{array}\right]\end{aligned}$$

Step 4 of 7

The magnitude plot of the network function is shown in Figure 1.

Figure 1: Magnitude plot

Step 5 of 7

Write the expression for the phase angle.

$$\angle H(j\omega) = -180° + 2\tan^{-1}\left(\frac{\omega}{4}\right) - \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}\left(\frac{\omega}{20}\right)$$

The phase angles at different frequencies are shown below.

ω(rad/s)	$\angle\mathbf{H}(j\omega)$
0.1	−178°
1	−160.5°
10	−115°
10^2	−167.56°
10^3	−178.74°
10^4	−179.87°

Step 6 of 7

The phase of the network function is shown in Figure 2.

Figure 2: Phase plot

Step 7 of 7

The Bode plot is shown in Figure 3.

Figure 3: Bode plot

Therefore, the Bode plot for the network function is shown in Figure 3.

Step 1 of 2

Refer to Figure E12.19 in the text book.

Consider the formula for the resistance in terms of admittance.

$$R = \frac{1}{Y}$$

Substitute $5\ \text{mS}$ for Y in the equation.

$$\begin{aligned} R &= \frac{1}{5\ \text{m}} \\ &= 200\ \Omega \end{aligned}$$

Therefore, the value of resistance is $\boxed{200\ \Omega}$.

Step 2 of 2

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $0.1\ \text{mH}$ for L and $12000\ \text{rad/sec}$ for ω_0 in the equation.

$$12000 = \frac{1}{\sqrt{(0.1\ \text{m})C}}$$

$$(12000)^2 = \left(\frac{1}{\sqrt{(0.1\ \text{m})C}}\right)^2$$

$$144 \times 10^6 = \frac{1}{(0.1\ \text{m})C}$$

$$\begin{aligned} C &= \frac{1}{(0.1\ \text{m})(144 \times 10^6)} \\ &= \frac{1}{14400} \\ &= 69.44\ \mu\text{F} \end{aligned}$$

Therefore, the value of the capacitor C is $\boxed{69.44\ \mu\text{F}}$.

Step 1 of 7

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{j\omega}{(j\omega+1)(0.1j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$j\omega$	-	20	-
$\frac{1}{j\omega+1}$	$\omega_{c1}=\frac{1}{1}$ $=1\,\text{rad/sec}$	-20	$\Delta\omega_1=20-20$ $=0$
$\frac{1}{0.1j\omega+1}$	$\omega_{c2}=\frac{1}{0.1}$ $=10\,\text{rad/sec}$	-20	$\Delta\omega_2=0-20$ $=-20$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $100\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$A_{\omega_l}=20\log(0.1)$$
$$=-20\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 3 of 7

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$A_{\omega_{c1}}=20\log(1)$$
$$=0\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 4 of 7

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_{c2}, $1\ \text{rad/sec}$ for ω_{c1} and $0\ \text{dB}$ for $A_{\omega_{c2}}$.

$$A_{\omega_{c2}}=\left[0\times\log\frac{10}{1}\right]+0$$
$$=0\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 5 of 7

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_2$, $10\ \text{rad/sec}$ for ω_{c2}, $100\ \text{rad/sec}$ for ω_h and $0\ \text{dB}$ for $A_{\omega_{c2}}$.

$$A_{\omega_h}=\left[-20\times\log\frac{100}{10}\right]-0$$
$$=-20\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 6 of 7

Phase plot analysis:

Consider the expression for the phase angle of the function.

$$\phi=90^\circ-\tan^{-1}(\omega)-\tan^{-1}(0.1\omega)$$

Consider Table-2 to calculate the values of phase angle at different frequencies.

Table-2

corner frequency $\omega(\text{rad/sec})$	$90^\circ-\tan^{-1}(\omega)-\tan^{-1}(0.1\omega)$ (degrees)
000.1	83.72
001.0	39.29
010.0	-39.29
100.0	-83.72

\

Step 7 of 7

Consider the bode plot shown in Figure 1.

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 3

Consider the expression for the change in the resistor value due to the magnitude scaled factor.

$$R' = K_M R$$

Substitute 100 for K_M and $10\ \Omega$ for R.

$$\begin{aligned} R' &= (100)(10) \\ &= 10\ \text{k}\Omega \end{aligned}$$

Therefore, the new value of the resistance is $\boxed{10\ \text{k}\Omega}$.

Step 2 of 3

Consider the expression for the change in the inductor value due to the magnitude scaled factor and the frequency scaled factor

$$L' = \frac{K_M L}{K_F}$$

Substitute 100 for K_M, 10000 for K_F and $1\ \text{H}$ for L.

$$\begin{aligned} L' &= \frac{(100)(1)}{10000} \\ &= \frac{1}{100} \\ &= 10\ \text{mH} \end{aligned}$$

Therefore, the new value of the inductance is $\boxed{10\ \text{mH}}$.

Step 3 of 3

Consider the expression for the change in the capacitor value due to the magnitude scaled factor and the frequency scaled factor

$$C' = \frac{C}{K_M K_F}$$

Substitute 100 for K_M, 10000 for K_F and $2\ \text{F}$ for C.

$$\begin{aligned} C' &= \frac{(2)}{(10000)(100)} \\ &= \frac{2}{1000000} \\ &= 2\ \mu\text{F} \end{aligned}$$

Therefore, the new value of the capacitance is $\boxed{2\ \mu\text{F}}$.

Step 1 of 7

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{100(j\omega)}{(j\omega+1)(j\omega+10)(j\omega+50)}$$
$$=\frac{100(j\omega)}{(10)(50)(j\omega+1)(0.1j\omega+1)(0.2j\omega+1)}$$
$$=\frac{0.2(j\omega)}{(j\omega+1)(0.1j\omega+1)(0.2j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$0.2j\omega$	-	20	-
$\frac{1}{j\omega+1}$	$\omega_{c1}=\frac{1}{1}$ $=1\text{ rad/sec}$	-20	$\Delta\omega_1=20-20$ $=0$
$\frac{1}{0.1j\omega+1}$	$\omega_{c2}=\frac{1}{0.1}$ $=10\text{ rad/sec}$	-20	$\Delta\omega_2=0-20$ $=-20$
$\frac{1}{0.02j\omega+1}$	$\omega_{c3}=\frac{1}{0.02}$ $=50\text{ rad/sec}$	-20	$\Delta\omega_3=-20-20$ $=-40$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.01 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 1000 rad/sec.

Calculate the magnitude value at the corner frequency of 0.01 rad/sec.

$A_{\omega_l}=20\log(0.2\times0.01)$ $=-53.98\text{ dB}$ Therefore, the magnitude value at the corner frequency of 0.01 rad/sec is -20 dB.

Step 3 of 7

Calculate the magnitude value at the corner frequency of 1 rad/sec.

$$A_{\omega_{c1}}=20\log(0.2\times1)$$
$$=-13.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 1 rad/sec is -13.98 dB.

Step 4 of 7

Calculate the magnitude value at the corner frequency of 10 rad/sec.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute 0 db/dec for $\Delta\omega_1$, 10 rad/sec for ω_{c2}, 1 rad/sec for ω_{c1} and -13.98 dB for $A_{\omega_{c1}}$.

$$A_{\omega_{c2}}=\left[0\times\log\frac{10}{1}\right]-13.98$$
$$=-13.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 10 rad/sec is -13.98 dB.

Step 5 of 7

Calculate the magnitude value at the corner frequency of 50 rad/sec.

$$A_{\omega_{c3}}=\left[\Delta\omega_2\times\log\frac{\omega_{c3}}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute -20 db/dec for $\Delta\omega_2$, 50 rad/sec for ω_{c3}, 10 rad/sec for ω_{c2} and -13.98 dB for $A_{\omega_{c2}}$.

$$A_{\omega_{c3}}=\left[-20\times\log\frac{50}{10}\right]-13.98$$
$$=-27.98\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 50 rad/sec is -27.98 dB.

Step 6 of 7

Calculate the magnitude value at the corner frequency of 1000 rad/sec.

$$A_{\omega_h}=\left[\Delta\omega_3\times\log\frac{\omega_h}{\omega_{c3}}\right]+A_{\omega_{c3}}$$

Substitute -40 db/dec for $\Delta\omega_3$, 50 rad/sec for ω_{c3}, 1000 rad/sec for ω_h and -27.98 dB for $A_{\omega_{c3}}$.

$$A_{\omega_h}=\left[-40\times\log\frac{1000}{50}\right]-27.98$$
$$=-80.02\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 1000 rad/sec is -80.02 dB.

Step 7 of 7

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 7

Consider the Figure E12.21 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 7

Consider the expression the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_s\left(\frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{\frac{1}{j\omega C}}{\frac{j\omega CR+1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{1}{j\omega CR+1}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{1}{CR\left(j\omega+\frac{1}{CR}\right)}$$

Substitute $\mathbf{G}_v(j\omega)$ for $\frac{\mathbf{V}_o}{\mathbf{V}_s}$, $10\ \mathrm{k\Omega}$ for R and $20\ \mu\mathrm{F}$ for C.

$$\mathbf{G}_v(j\omega) = \frac{1}{(20\ \mu)(10\ \mathrm{k})\left(j\omega+\frac{1}{(20\ \mu)(10\ \mathrm{k})}\right)}$$

$$= \frac{1}{(200\ \mathrm{m})\left(j\omega+\frac{1}{200\ \mathrm{m}}\right)}$$

$$\mathbf{G}_v(j\omega) = \frac{5}{j\omega+5} \quad \text{..... (1)}$$

Therefore, the transfer function of the circuit is $\frac{5}{j\omega+5}$.

Step 3 of 7

Recall equation (1).

$$\mathbf{G}_v(j\omega) = \frac{5}{j\omega+5}$$

$$= \frac{5}{5(0.02j\omega+1)}$$

$$= \frac{1}{0.02j\omega+1}$$

<u>Magnitude plot analysis:</u>

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
1	-	0	-
$\frac{1}{0.02j\omega+1}$	$\omega_{c1} = \frac{1}{0.02} = 5\ \mathrm{rad/sec}$	-20	$\Delta\omega_1 = 0-20 = -20$

Step 4 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \mathrm{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $100\ \mathrm{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \mathrm{rad/sec}$.

$$A_{\omega_l} = 20\log(1) = 0\ \mathrm{dB}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \mathrm{rad/sec}$ is $0\ \mathrm{dB}$.

Step 5 of 7

Calculate the magnitude value at the corner frequency of $5\ \mathrm{rad/sec}$.

$$A_{\omega_{c1}} = 20\log(1) = 0\ \mathrm{dB}$$

Therefore, the magnitude value at the corner frequency of $5\ \mathrm{rad/sec}$ is $0\ \mathrm{dB}$.

Step 6 of 7

Calculate the magnitude value at the corner frequency of $100\ \mathrm{rad/sec}$.

$$A_{\omega_h} = \left[\Delta\omega_1 \times \log\frac{\omega_h}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute $-20\ \mathrm{db/dec}$ for $\Delta\omega_1$, $100\ \mathrm{rad/sec}$ for ω_h, $5\ \mathrm{rad/sec}$ for ω_{c1} and $0\ \mathrm{dB}$ for $A_{\omega_{c1}}$.

$$A_{\omega_h} = \left[-20\times\log\frac{100}{5}\right] + 0$$

$$= -20\times\log 20$$

$$= -26.02\ \mathrm{dB}$$

Therefore, the magnitude value at the corner frequency of $100\ \mathrm{rad/sec}$ is $-26.02\ \mathrm{dB}$.

Step 7 of 7

Consider the bode plot shown in Figure 1.

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 7

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{20(0.1j\omega+1)}{j\omega(j\omega+1)(0.01j\omega+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{20}{j\omega}$	-	-20	-
$\frac{1}{j\omega+1}$	$\omega_{c1}=\frac{1}{1}$ $=1\,\text{rad/sec}$	-20	$\Delta\omega_1=-20-20$ $=-40$
$0.1j\omega+1$	$\omega_{c2}=\frac{1}{0.1}$ $=10\,\text{rad/sec}$	20	$\Delta\omega_2=-40+20$ $=-20$
$\frac{1}{0.01j\omega+1}$	$\omega_{c3}=\frac{1}{0.01}$ $=100\,\text{rad/sec}$	-20	$\Delta\omega_3=-20-20$ $=-40$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.01\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $1000\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_l}&=20\log\left(\frac{20}{0.01}\right)\\&=20\log(2000)\\&=66.02\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 3 of 7

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\left(\frac{20}{1}\right)\\&=26.02\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $26.02\ \text{dB}$.

Step 4 of 7

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $-40\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_{c2}, $1\ \text{rad/sec}$ for ω_{c1} and $26.02\ \text{dB}$ for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}}&=\left[-40\times\log\frac{10}{1}\right]+26.02\\&=-40+26.02\\&=-13.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $-13.98\ \text{dB}$.

Step 5 of 7

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_{c3}}=\left[\Delta\omega_2\times\log\frac{\omega_{c3}}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_2$, $100\ \text{rad/sec}$ for ω_{c3}, $10\ \text{rad/sec}$ for ω_{c2} and $-13.98\ \text{dB}$ for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_{c3}}&=\left[-20\times\log\frac{100}{10}\right]-13.98\\&=-20-13.98\\&=-33.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $-33.98\ \text{dB}$.

Step 6 of 7

Calculate the magnitude value at the corner frequency of $1000\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_3\times\log\frac{\omega_h}{\omega_{c3}}\right]+A_{\omega_{c3}}$$

Substitute $-40\ \text{db/dec}$ for $\Delta\omega_3$, $100\ \text{rad/sec}$ for ω_{c3}, $1000\ \text{rad/sec}$ for ω_h and $-33.98\ \text{dB}$ for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_h}&=\left[-40\times\log\frac{1000}{100}\right]-33.98\\&=-40-33.98\\&=-73.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1000\ \text{rad/sec}$ is $-73.98\ \text{dB}$.

Step 7 of 7

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 6

Refer to Figure E12.22 in the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Consider the expression the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_s\left(\frac{R}{R+\frac{1}{j\omega C}}\right)$$

$$\begin{aligned}\frac{\mathbf{V}_o}{\mathbf{V}_s} &= \frac{R}{\frac{j\omega CR+1}{j\omega C}}\\ &= \frac{j\omega CR}{j\omega CR+1}\\ &= \frac{j\omega CR}{CR\left(j\omega+\frac{1}{CR}\right)}\\ &= \frac{j\omega}{j\omega+\frac{1}{CR}}\end{aligned}$$

Substitute $\mathbf{G}_v(j\omega)$ for $\frac{\mathbf{V}_o}{\mathbf{V}_s}$, $25\ \mathrm{k\Omega}$ for R and $20\ \mu\mathrm{F}$ for C in the equation.

$$\begin{aligned}\mathbf{G}_v(j\omega) &= \frac{j\omega}{j\omega+\frac{1}{(20\ \mu)(25\ \mathrm{k})}}\\ &= \frac{j\omega}{\left(j\omega+\frac{1}{500\ \mathrm{m}}\right)}\end{aligned}$$

$$= \frac{j\omega}{j\omega+2} \quad \text{..... (1)}$$

Therefore, the transfer function of the circuit is $\frac{j\omega}{j\omega+2}$.

Step 3 of 6

Recall equation (1).

$$\begin{aligned}\mathbf{G}_v(j\omega) &= \frac{j\omega}{j\omega+2}\\ &= \frac{j\omega}{2(0.5j\omega+1)}\\ &= \frac{0.5j\omega}{0.5j\omega+1}\end{aligned}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$0.5j\omega$	-	20	-
$\frac{1}{0.5j\omega+1}$	$\omega_{c1}=\frac{1}{0.5}$ $=2$ rad/sec	−20	$\Delta\omega_1 = 20-20$ $=0$

Step 4 of 6

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.1 rad/sec.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 100 rad/sec.

Calculate the magnitude value at the corner frequency of 0.1 rad/sec.

$A_{\omega_l} = 20\log(0.5\times 0.1)$ Therefore, the magnitude value at the corner frequency of 0.1 rad/sec is $= -26.02$ dB
-26.02 dB.

Step 5 of 6

Calculate the magnitude value at the corner frequency of 2 rad/sec.

$$\begin{aligned}A_{\omega_{c1}} &= 20\log(0.5\times 2)\\ &= 0\ \mathrm{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 2 rad/sec is 0 dB.

Calculate the magnitude value at the corner frequency of 100 rad/sec.

$$A_{\omega_h} = \left[\Delta\omega_1 \times \log\frac{\omega_h}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute 0 db/dec for $\Delta\omega_1$, 100 rad/sec for ω_h, 2 rad/sec for ω_{c1} and 0 dB for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_h} &= \left[0\times\log\frac{100}{2}\right]+0\\ &= 0\ \mathrm{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of 100 rad/sec is 0 dB.

Step 6 of 6

Consider the bode plot shown in Figure 2.

Figure 2

Therefore, the required bode plot is shown in Figure 2.

Step 1 of 6

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{100}{(j\omega)^2(j\omega 2+1)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{100}{(j\omega)^2}$	-	-40	-
$\frac{1}{j\omega 2+1}$	$\omega_{c1}=\frac{1}{2}$ $=0.5\text{ rad/sec}$	-20	$\Delta\omega_1=-40-20$ $=-60$

Step 2 of 6

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.01\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $100\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_l}&=20\log\left(\frac{100}{(0.01)^2}\right)\\&=20\log\left(10^6\right)\\&=120\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$ is 120 dB.

Step 3 of 6

Calculate the magnitude value at the corner frequency of $0.5\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\left(\frac{100}{(0.5)^2}\right)\\&=20\log(400)\\&=52.04\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.5\ \text{rad/sec}$ is 52.04 dB.

Step 4 of 6

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_1\times\log\frac{\omega_h}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $-60\ \text{db/dec}$ for $\Delta\omega_1$, $100\ \text{rad/sec}$ for ω_h, $0.5\ \text{rad/sec}$ for ω_{c1} and 52.04 dB for A_{ω_l}.

$$\begin{aligned}A_{\omega_h}&=\left[-60\times\log\frac{100}{0.5}\right]+52.04\\&=-86.02\text{ dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is -86.02 dB.

Step 5 of 6

Phase plot analysis:

Consider the expression for the phase angle of the function.

$$\phi=-180^\circ-\tan^{-1}(2\omega)$$

Consider Table-2 to calculate the values of phase angle at different frequencies.

Table-2

corner frequency $\omega(\text{rad/sec})$	$-180^\circ-\tan^{-1}(2\omega)$ (degrees)
0000.01	-181.15
0000.50	-225.00
0001.00	-243.44
0010.00	-267.14
0100.00	-269.71

Step 6 of 6

Consider the bode plot shown in Figure 1.

Figure 1

Therefore, the required bode plot is shown in Figure 1.

Step 1 of 3

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Refer to Figure E12.23 in the textbook.

Calculate the transfer function.

$$G_v(j\omega) = \frac{R}{R + j\omega L + \frac{1}{j\omega C}}$$
$$= \frac{\omega RC}{\omega RC + j\left(\omega^2 LC - 1\right)}$$

The magnitude of the transfer function is,

$$M(\omega) = \frac{\omega RC}{\sqrt{(\omega RC)^2 + \left(\omega^2 LC - 1\right)^2}}$$

The band pass filter allows the magnitudes between lower cutoff frequencies and higher cutoff frequencies.

Calculate the center frequency.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$
$$= \frac{1}{\sqrt{(1)\left(1\times10^{-6}\right)}}$$
$$= 1000 \text{ rad/sec}$$

Step 2 of 3

Calculate the lower cutoff frequency.

$$\omega_L = \frac{-\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + 4\omega_0^2}}{2}$$
$$= \frac{-\frac{1000}{1} + \sqrt{\left(\frac{1000}{1}\right)^2 + 4(1000)^2}}{2}$$
$$= \frac{-1000 + 1000\sqrt{5}}{2}$$
$$= 618 \text{ rad/sec}$$

Calculate the upper cutoff frequency.

$$\omega_H = \frac{\frac{R}{L} + \sqrt{\left(\frac{R}{L}\right)^2 + 4\omega_0^2}}{2}$$
$$= \frac{\frac{1000}{1} + \sqrt{\left(\frac{1000}{1}\right)^2 + 4(1000)^2}}{2}$$
$$= \frac{1000 + 1000\sqrt{5}}{2}$$
$$= 1618 \text{ rad/sec}$$

Step 3 of 3

Draw the magnitude bode plot.

Figure 1

Step 1 of 5

Consider the transfer function.

$$G(j\omega) = \frac{-\omega^2}{(j\omega+1)^3}$$
$$= \frac{(j\omega)^2}{(j\omega+1)^3}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$(j\omega)^2$	-	40	-
$\frac{1}{(j\omega+1)^3}$	$\omega_{c1} = \frac{1}{1}$ $= 1\,\text{rad/sec}$	-60	$\Delta\omega_1 = -60+40$ $= -20$

Step 2 of 5

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $10\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$A_{\omega_l} = 20\log(0.1)^2$$
$$= 20\log(0.01)$$
$$= 40\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $40\ \text{dB}$.

Step 3 of 5

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$A_{\omega_{c1}} = 20\log(1)^2$$
$$= 0\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $0\ \text{dB}$.

Step 4 of 5

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_h} = \left[\Delta\omega_1 \times \log\frac{\omega_h}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_h, $1\ \text{rad/sec}$ for ω_{c1} and $0\ \text{dB}$ for $A_{\omega_{c1}}$.

$$A_{\omega_h} = \left[-20\times\log\frac{10}{1}\right] - 0$$
$$= -20\ \text{dB}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 5 of 5

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 3

Refer to Figure E12.24 in the text book.

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o(s)=\mathbf{V}_i(s)\left(\frac{R_2 \parallel sL}{R_1+R_2 \parallel sL}\right)$$

$$\begin{aligned}\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}&=\frac{R_2 \parallel sL}{R_1+R_2 \parallel sL}\\&=\frac{\dfrac{R_2\cdot sL}{R_2+sL}}{R_1+\dfrac{R_2\cdot sL}{R_2+sL}}\\&=\frac{\dfrac{R_2\cdot sL}{R_2+sL}}{\dfrac{R_1(R_2+sL)+R_2\cdot sL}{R_2+sL}}\\&=\frac{sLR_2}{R_1(R_2+sL)+sLR_2}\\&=\frac{sLR_2}{sL(R_1+R_2)+R_1R_2}\\&=\frac{sLR_2}{R_1R_2\left(s\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+1\right)}\\&=\frac{s\left(\dfrac{L}{R_1}\right)}{s\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+1}\quad\text{..... (1)}\end{aligned}$$

Therefore, the expression for the voltage transfer function is $\boxed{\dfrac{s\left(\dfrac{L}{R_1}\right)}{s\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+1}}$.

Step 2 of 3

Recall equation (1).

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}=\frac{s\left(\dfrac{L}{R_1}\right)}{s\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+1}$$

Substitute $0\ \text{rad/s}$ for s in the equation.

$$\begin{aligned}\frac{\mathbf{V}_o(0)}{\mathbf{V}_i(0)}&=\frac{(0)\left(\dfrac{L}{R_1}\right)}{(0)\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+1}\\&=\frac{0}{0+1}\\&=0\end{aligned}$$

Therefore, the value of the voltage gain at $\omega=0\ \text{rad/s}$ is 0.

Step 3 of 3

Recall equation (1).

$$\begin{aligned}\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}&=\frac{s\left(\dfrac{L}{R_1}\right)}{s\left(\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+\dfrac{1}{s}\right)}\\&=\frac{\left(\dfrac{L}{R_1}\right)}{\left(\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+\dfrac{1}{s}\right)}\end{aligned}$$

Substitute $\infty\ \text{rad/s}$ for ω in the equation.

$$\begin{aligned}\frac{\mathbf{V}_o(\infty)}{\mathbf{V}_i(\infty)}&=\frac{\left(\dfrac{L}{R_1}\right)}{\left(\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+\dfrac{1}{\infty}\right)}\\&=\frac{\left(\dfrac{L}{R_1}\right)}{\left(\left[\dfrac{L(R_1+R_2)}{R_1R_2}\right]+0\right)}\\&=\frac{\left(\dfrac{L}{R_1}\right)}{\dfrac{L(R_1+R_2)}{R_1R_2}}\\&=\frac{R_2}{R_1+R_2}\end{aligned}$$

Therefore, the value of the voltage gain at $\omega=\infty\ \text{rad/s}$ is $\dfrac{R_2}{R_1+R_2}$ which is greater than 0.

As the value of the frequency is increased, the value of the voltage gain also increases which represents the characteristics of the high pass filter. Hence the network is a $\boxed{\textbf{high pass filter}}$.

Step 1 of 2

The transfer function is,

$$G(j\omega) = \frac{10(j\omega+2)(j\omega+100)}{j\omega(-\omega^2+4j\omega+100)}$$

Re-write the transfer function in standard form.

$$\begin{aligned} G(j\omega) &= \frac{10(j\omega+2)(j\omega+100)}{j\omega\left[(j\omega)^2+4j\omega+100\right]} \\ &= \frac{10\times 2\times 100(1+j0.5\omega)(1+j0.01\omega)}{j\omega\times 100\times\left[\left(\frac{j\omega}{10}\right)^2+\left(\frac{j\omega}{25}\right)+1\right]} \\ &= \frac{20(1+j0.5\omega)(1+j0.01\omega)}{j\omega\left[\left(\frac{j\omega}{10}\right)^2+2(0.2)\left(\frac{j\omega}{10}\right)+1\right]} \end{aligned}$$

The corner frequencies are $2, 10 \text{ and } 100 \text{ rad/s}$

A pole at origin has a magnitude of $-20\log_{10}\omega$

The zero at $\omega = 2 \text{ rad/s}$ has a slope of $+20 \text{ dB/decade}$ and a magnitude of $+20\log_{10}|1+j0.5\omega|$.

The complex poles at $\omega = 10 \text{ rad/s}$ has slope of -40 dB/decade. It contributes a magnitude of

$$-20\log_{10}\left|\left(\frac{j\omega}{10}\right)^2+2(0.2)\left(\frac{j\omega}{10}\right)+1\right|.$$

The zero at $\omega = 100 \text{ rad/s}$ has a slope of $+20 \text{ dB/decade}$. It contributes a magnitude of

$$-20\log_{10}|1+j0.01\omega|$$

Step 2 of 2

Draw the Bode magnitude plot.

Figure 2

Thus, the Bode magnitude plot is drawn.

Step 1 of 6

Consider the network function.

$$\begin{aligned} G(j\omega) &= \frac{10j\omega}{(j\omega+1)(j\omega+10)^2} \\ &= \frac{10j\omega}{10^2(j\omega+1)(0.1j\omega+1)^2} \\ &= \frac{0.1j\omega}{(j\omega+1)(0.1j\omega+1)^2} \end{aligned}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$0.1j\omega$	-	20	-
$\frac{1}{j\omega+1}$	$\omega_{c1} = \frac{1}{1} = 1\,\text{rad/sec}$	-20	$\Delta\omega_1 = -20+20 = 0$
$\frac{1}{(0.1j\omega+1)^2}$	$\omega_{c3} = \frac{1}{0.1} = 10\,\text{rad/sec}$	-40	$\Delta\omega_3 = -40+0 = -40$

Step 2 of 6

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $100\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$\begin{aligned} A_{\omega_l} &= 20\log((0.1)(0.1)) \\ &= 20\log(0.01) \\ &= -40\ \text{dB} \end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $-40\ \text{dB}$.

Step 3 of 6

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$\begin{aligned} A_{\omega_{c1}} &= 20\log((0.1)(1)) \\ &= 20\log(0.1) \\ &= -20\ \text{dB} \end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 4 of 6

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c2}} = \left[\Delta\omega_1 \times \log\frac{\omega_{c2}}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_{c2}, $1\ \text{rad/sec}$ for ω_{c1} and $-20\ \text{dB}$ for $A_{\omega_{c1}}$.

$$\begin{aligned} A_{\omega_{c2}} &= \left[0 \times \log\frac{10}{1}\right] - 20 \\ &= -20\ \text{dB} \end{aligned}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 5 of 6

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_h} = \left[\Delta\omega_2 \times \log\frac{\omega_h}{\omega_{c2}}\right] + A_{\omega_{c2}}$$

Substitute $-40\ \text{db/dec}$ for $\Delta\omega_2$, $10\ \text{rad/sec}$ for ω_{c3}, $100\ \text{rad/sec}$ for ω_h and $-20\ \text{dB}$ for $A_{\omega_{c3}}$.

$$\begin{aligned} A_{\omega_h} &= \left[-40 \times \log\frac{100}{10}\right] - 20 \\ &= -40 - 20 \\ &= -60\ \text{dB} \end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $-60\ \text{dB}$.

Step 6 of 6

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 7

Consider the transfer function.

$$\begin{aligned}G(j\omega) &= \frac{-\omega^2 10^4}{(j\omega+1)^2(j\omega+10)(j\omega+100)^2}\\ &= \frac{(j\omega)^2 10^4}{(10)(100)^2(j\omega+1)^2(0.1j\omega+1)(0.01j\omega+1)^2}\\ &= \frac{0.1(j\omega)^2}{(j\omega+1)^2(0.1j\omega+1)(0.01j\omega+1)^2}\end{aligned}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$0.1(j\omega)^2$	-	40	-
$\frac{1}{(j\omega+1)^2}$	$\omega_{c1} = \frac{1}{1} = 1\,\text{rad/sec}$	-40	$\Delta\omega_1 = -40+40 = 0$
$\frac{1}{0.1j\omega+1}$	$\omega_{c2} = \frac{1}{0.1} = 10\,\text{rad/sec}$	-20	$\Delta\omega_2 = 0-20 = -20$
$\frac{1}{(0.01j\omega+1)^2}$	$\omega_{c3} = \frac{1}{0.01} = 100\,\text{rad/sec}$	-40	$\Delta\omega_3 = -40-20 = -60$

Step 2 of 7

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.1\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $1000\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_l} &= 20\log(0.1)(0.1)^2\\ &= 20\log(0.1)^3\\ &= -60\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $-60\ \text{dB}$.

Step 3 of 7

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_{c1}} &= 20\log(0.1)(1)\\ &= 20\log(0.1)\\ &= -20\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 4 of 7

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c2}} = \left[\Delta\omega_1 \times \log\frac{\omega_{c2}}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $10\ \text{rad/sec}$ for ω_{c2}, $1\ \text{rad/sec}$ for ω_{c1} and $-20\ \text{dB}$ for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}} &= \left[0\times\log\frac{100}{1}\right]-20\\ &= -20\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $-20\ \text{dB}$.

Step 5 of 7

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_{c3}} = \left[\Delta\omega_2 \times \log\frac{\omega_{c3}}{\omega_{c2}}\right] + A_{\omega_{c2}}$$

Substitute $-20\ \text{db/dec}$ for $\Delta\omega_2$, $100\ \text{rad/sec}$ for ω_{c3}, $10\ \text{rad/sec}$ for ω_{c2} and $-20\ \text{dB}$ for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_{c3}} &= \left[-20\times\log\frac{100}{10}\right]-20\\ &= -20-20\\ &= -40\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $-40\ \text{dB}$.

Step 6 of 7

Calculate the magnitude value at the corner frequency of $1000\ \text{rad/sec}$.

$$A_{\omega_h} = \left[\Delta\omega_3 \times \log\frac{\omega_h}{\omega_{c3}}\right] + A_{\omega_{c3}}$$

Substitute $-60\ \text{db/dec}$ for $\Delta\omega_3$, $100\ \text{rad/sec}$ for ω_{c3}, $1000\ \text{rad/sec}$ for ω_h and $-40\ \text{dB}$ for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_h} &= \left[-60\times\log\frac{1000}{100}\right]-40\\ &= -60-40\\ &= -100\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1000\ \text{rad/sec}$ is $-100\ \text{dB}$.

Step 7 of 7

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

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Step 1 of 3

It is given that,

The transfer function is, $\mathbf{H}(j\omega) = \dfrac{+6.4}{(j\omega+1)(-\omega^2+8j\omega+16)}$

Write the equation in the standard form:

$$\mathbf{H}(j\omega) = \frac{6.4}{(j\omega+1)\left[\left(\frac{j\omega}{4}\right)^2+\left(\frac{j\omega}{2}\right)+1\right]16}$$

$$= \frac{0.4}{(j\omega+1)\left[\left(\frac{j\omega}{4}\right)^2+\left(\frac{j\omega}{2}\right)+1\right]}$$

Step 2 of 3

For the quadratic term in the transfer function calculate the natural frequency ω_n and the damping coefficient ζ.

$$\left(\frac{j\omega}{4}\right)^2+\left(\frac{j\omega}{2}\right)+1=0 \quad \text{..... (1)}$$

The standard form of the quadratic equation is,

$$\left(\frac{j\omega}{\omega_n}\right)^2+\frac{2j\zeta\omega}{\omega_n}+1=0$$

Comparing the standard form with equation (1), we obtain the natural frequency ω_n and ζ.

$$\omega_n = 4\,\text{rad/sec}$$
$$\zeta = 1$$

Thus, the Corner frequencies of the circuit are,

$$\omega_1 = 1\,\text{rad/sec}$$

Due to the pole $\omega_2 = 2\,\text{rad/sec}$ there is a slope of $(j\omega+1)$, starting from $-20\,\text{db/decade}$

Due to the quadratic pole there is a slope of $\omega = 1\,\text{rad/sec}$.

Since $-40\,\text{db/decade}$, the net slope is therefore $\zeta = 1$

Due to the presence of $-40-20=-60\,\text{db/decade}$ in the numerator

$$k_0 = 0.4$$

Step 3 of 3

The resulting magnitude diagram is shown in Figure 1.

$$20\log k_0 = 20\log 0.4$$
$$= -7.95\ \text{dB}$$

Figure 1

Step 1 of 8

Consider the transfer function.

$$\mathbf{H}(j\omega)=\frac{0.5(10j\omega+1)(j\omega+1)}{(j\omega)(0.1j\omega+1)(0.01j\omega+1)^2}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/sec)	Slope (dB/dec)	Change in slope (dB/dec)
$\frac{0.5}{j\omega}$	-	-20	-
$10j\omega+1$	$\omega_{c1}=\frac{1}{10}$ $=0.1\,\text{rad/sec}$	20	$\Delta\omega_1=20-20$ $=0$
$j\omega+1$	$\omega_{c2}=\frac{1}{1}$ $=1\,\text{rad/sec}$	20	$\Delta\omega_2=20+0$ $=20$
$\frac{1}{0.1j\omega+1}$	$\omega_{c3}=\frac{1}{0.1}$ $=10\,\text{rad/sec}$	-20	$\Delta\omega_3=-20+20$ $=0$
$\frac{1}{(0.01j\omega+1)^2}$	$\omega_{c4}=\frac{1}{0.01}$ $=100\,\text{rad/sec}$	-40	$\Delta\omega_4=-40+0$ $=-40$

Step 2 of 8

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be $0.01\ \text{rad/sec}$.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be $1000\ \text{rad/sec}$.

Calculate the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_l}&=20\log\frac{0.5}{0.01}\\&=20\log 50\\&=33.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.01\ \text{rad/sec}$ is $33.98\ \text{dB}$.

Step 3 of 8

Calculate the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$.

$$\begin{aligned}A_{\omega_{c1}}&=20\log\frac{0.5}{0.1}\\&=20\log 5\\&=13.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $0.1\ \text{rad/sec}$ is $13.98\ \text{dB}$.

Step 4 of 8

Calculate the magnitude value at the corner frequency of $1\ \text{rad/sec}$.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_1$, $1\ \text{rad/sec}$ for ω_{c2}, $0.1\ \text{rad/sec}$ for ω_{c1} and $13.98\ \text{dB}$ for $A_{\omega_{c1}}$.

$$\begin{aligned}A_{\omega_{c2}}&=\left[0\times\log\frac{1}{0.1}\right]+13.98\\&=0+13.98\\&=13.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1\ \text{rad/sec}$ is $13.98\ \text{dB}$.

Step 5 of 8

Calculate the magnitude value at the corner frequency of $10\ \text{rad/sec}$.

$$A_{\omega_{c3}}=\left[\Delta\omega_2\times\log\frac{\omega_{c3}}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute $20\ \text{db/dec}$ for $\Delta\omega_2$, $10\ \text{rad/sec}$ for ω_{c3}, $1\ \text{rad/sec}$ for ω_{c2} and $13.98\ \text{dB}$ for $A_{\omega_{c2}}$.

$$\begin{aligned}A_{\omega_{c3}}&=\left[20\times\log\frac{10}{1}\right]+13.98\\&=20+13.98\\&=33.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $10\ \text{rad/sec}$ is $33.98\ \text{dB}$.

Step 6 of 8

Calculate the magnitude value at the corner frequency of $100\ \text{rad/sec}$.

$$A_{\omega_{c4}}=\left[\Delta\omega_3\times\log\frac{\omega_{c4}}{\omega_{c3}}\right]+A_{\omega_{c3}}$$

Substitute $0\ \text{db/dec}$ for $\Delta\omega_3$, $10\ \text{rad/sec}$ for ω_{c3}, $100\ \text{rad/sec}$ for ω_{c4} and $33.98\ \text{dB}$ for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_{c4}}&=\left[0\times\log\frac{100}{10}\right]+33.98\\&=0+33.98\\&=33.98\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $100\ \text{rad/sec}$ is $33.98\ \text{dB}$.

Step 7 of 8

Calculate the magnitude value at the corner frequency of $1000\ \text{rad/sec}$.

$$A_{\omega_h}=\left[\Delta\omega_4\times\log\frac{\omega_h}{\omega_{c4}}\right]+A_{\omega_{c4}}$$

Substitute $-40\ \text{db/dec}$ for $\Delta\omega_4$, $100\ \text{rad/sec}$ for ω_{c4}, $1000\ \text{rad/sec}$ for ω_h and $33.98\ \text{dB}$ for $A_{\omega_{c3}}$.

$$\begin{aligned}A_{\omega_h}&=\left[-40\times\log\frac{1000}{100}\right]+33.98\\&=-40+33.98\\&=-6.02\ \text{dB}\end{aligned}$$

Therefore, the magnitude value at the corner frequency of $1000\ \text{rad/sec}$ is $-6.02\ \text{dB}$.

Step 8 of 8

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 4

Consider the following transfer function.

$$\mathbf{H}(j\omega)=\frac{+81(j\omega+0.1)}{(j\omega)(-\omega^2+3.6j\omega+81)}$$

Express $\mathbf{H}(j\omega)$ in the standard form.

$$\begin{aligned}\mathbf{H}(j\omega)&=\frac{+81\left(\frac{j\omega}{0.1}+1\right)(0.1)}{(j\omega)\left((j\omega)^2+3.6j\omega+81\right)}\\&=\frac{+81\left(\frac{j\omega}{0.1}+1\right)(0.1)}{(j\omega)(81)\left(\frac{(j\omega)^2}{81}+\frac{3.6}{81}j\omega+1\right)}\\&=\frac{0.1\left(\frac{j\omega}{0.1}+1\right)}{(j\omega)\left[\left(\frac{j\omega}{9}\right)^2+\left(\frac{j\omega}{22.5}\right)+1\right]}\end{aligned}$$

It is observed that the initial low frequency slope due to the pole at the origin is -20 dB/decade. Due to the presence of constant 0.1 in the numerator, the magnitude of the slope further decreases by the magnitude, $-20\text{ dB}\ \left(20\log_{10}0.1=-20\text{ dB}\right)$.

So, the net slope insects the 0 dB line at $\omega=0.1\text{ rad/sec}$.

Step 2 of 4

At the corner or break frequency $\omega=0.1\text{ rad/s}$, the slope changes from -20 dB/decade to 0 dB/decade due to the presence of zero term, $\left(\frac{j\omega}{0.1}+1\right)$ in the numerator of the transfer function.

The quadratic term in the denominator is $\left(\frac{j\omega}{9}\right)^2+\left(\frac{j\omega}{22.5}\right)+1$. This quadratic term is a second order term. So, it provides -40 dB/decade as it is present in the denominator of the transfer function. So, the slope changes from 0 dB/decade to -40 dB/decade due to quadratic term.

The centre frequency of the quadratic term is $\omega=9\text{ rad/sec}$.

It is noted that the quadratic term causes a ripple of ζ.

Step 3 of 4

Compare the term $\left(\frac{j\omega}{9}\right)^2+\left(\frac{j\omega}{22.5}\right)+1$ with the standard quadratic expression $\left(\frac{s^2}{\omega_n^2}\right)+\frac{2\zeta\omega_n s}{\omega_n^2}+1$.

Therefore,

$$\frac{2\zeta}{\omega_n}=\frac{1}{22.5}$$
$$\frac{2\zeta}{9}=\frac{1}{22.5}$$
$$\zeta=\frac{9}{(2)(22.5)}$$
$$\zeta=0.2$$

Step 4 of 4

Draw the magnitude characteristics of the Bode plot.

Figure 1

Therefore, the magnitude characteristics have been drawn.

Step 1 of 9

Consider the network function.

$$\mathbf{H}(j\omega)=\frac{6.4(j\omega)}{(j\omega+1)(-\omega^2+8j\omega+64)}$$
$$=\frac{6.4(j\omega)}{64(j\omega+1)\left(\left(\frac{j\omega}{8}\right)^2+\left(\frac{j\omega}{8}\right)+1\right)}$$
$$=\frac{0.1(j\omega)}{(j\omega+1)\left(\left(\frac{j\omega}{8}\right)^2+\left(\frac{j\omega}{8}\right)+1\right)}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/s)	Slope (dB/dec)	Change in slope (dB/dec)
$0.1j\omega$	-	20	-
$\frac{1}{j\omega+1}$	$\omega_{c1}=1$ rad/sec	-20	$\Delta\omega_1=-20+20$ $=0$
$\frac{1}{\left(\frac{j\omega}{8}\right)^2+\frac{j\omega}{8}+1}$	$\omega_{c2}=8$ rad/sec	-40 (Due to Quadratic pole)	$\Delta\omega_2=-40+0$ $=-40$

Step 2 of 9

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.01 rad/s.

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 100 rad/s.

Calculate the magnitude value at the corner frequency of 0.01 rad/s.

$$A_{\omega_l}=20\log(0.1\times0.01)$$
$$=20\log0.001$$
$$=-60\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.01 rad/s is -60 dB.

Step 3 of 9

Calculate the magnitude value at the corner frequency of 1 rad/s.

$$A_{\omega_{c1}}=20\log(0.1\times1)$$
$$=-20\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 1 rad/s is -20 dB.

Step 4 of 9

Calculate the approximate magnitude value at the corner frequency of 8 rad/s.

$$A_{\omega_{c2}}=\left[\Delta\omega_1\times\log\frac{\omega_{c2}}{\omega_{c1}}\right]+A_{\omega_{c1}}$$

Substitute 0 db/dec for $\Delta\omega_1$, 8 rad/s for ω_{c2}, 1 rad/sec for ω_{c1} and -20 dB for $A_{\omega_{c1}}$.

$$A_{\omega_{c2}}=\left[0\times\log\frac{8}{1}\right]-20$$
$$=0-20$$
$$=-20\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 8 rad/s is -20 dB.

Step 5 of 9

Calculate the magnitude value at the corner frequency of 100 rad/s.

$$A_{\omega_h}=\left[\Delta\omega_2\times\log\frac{\omega_h}{\omega_{c2}}\right]+A_{\omega_{c2}}$$

Substitute -40 db/dec for $\Delta\omega_2$, 100 rad/sec for ω_h, 8 rad/s for ω_{c2} and -20 dB for $A_{\omega_{c2}}$.

$$A_{\omega_h}=\left[-40\times\log\frac{100}{8}\right]-20$$
$$=-40(1.097)-20$$
$$=-43.88-20$$
$$=-63.88\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 100 rad/s is -63.88 dB.

Step 6 of 9

Consider the term of quadratic poles.

$$\left(\frac{j\omega}{8}\right)^2+\frac{j\omega}{8}+1$$

Compare to $\left(\frac{j\omega}{\omega_n}\right)^2+\frac{j2\xi\omega}{\omega_n}+1$.

$$\omega_n=8\text{ rad/s}$$

and

$$\frac{2\xi}{\omega_n}=\frac{1}{8}\quad\text{..... (1)}$$

Step 7 of 9

Consider expression (1).

$$\frac{2\xi}{\omega_n}=\frac{1}{8}$$

Substitute 8 rad/s for ω_n.

$$\frac{2\xi}{8}=\frac{1}{8}$$
$$2\xi=1$$
$$\xi=\frac{1}{2}$$

Therefore, the value of damping ratio ξ is $\frac{1}{2}$.

Step 8 of 9

Calculate the value of magnitude due to the damping ratio at 8 rad/s.

$$\mathbf{H}(8)=20\log\left(\frac{1}{2\xi}\right)$$

Substitute $\frac{1}{2}$ for ξ.

$$\mathbf{H}(8)=20\log\left(\frac{1}{2\left(\frac{1}{2}\right)}\right)$$
$$=20\log(1)$$
$$=0\text{ dB}$$

Therefore, the actual magnitude value at 8 rad/s is 0 dB.

Step 9 of 9

Consider the magnitude characteristic of the bode plot shown in Figure 1.

Figure 1

Therefore, the required magnitude characteristic of bode plot is shown in Figure 1.

Step 1 of 2

12.031 P

Refer to Figure P12.31 in the textbook for the magnitude characteristics.

From the magnitude plot, it is observed that the initial slope is $0\ \mathbf{dB/decade}$ and therefore, there is no pole and zero at the origin and characteristic level is $40\ \mathbf{dB}$.

Calculate the gain factor, K_0.

$$20\log_{10} K_0 = 40$$
$$\log_{10} K_0 = 2$$
$$K_0 = 10^2$$
$$K_0 = 100$$

One pole provides $-20\ \mathbf{dB/decade}$ and one zero provides $20\ \mathbf{dB/decade}$.

The $+20\ \mathbf{dB/decade}$ slope starting at $\omega = 3\ \mathbf{rad/s}$ indicates that the first zero has a break frequency or corner frequency at $\omega = 3\ \mathbf{rad/s}$. Therefore, one of the factor in the numerator is $\left(\frac{j\omega}{3}+1\right)$.

The slope changes by $-20\ \mathbf{dB/decade}$ at $\omega = 5\ \mathbf{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 5\ \mathbf{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{5}+1\right)$.

Step 2 of 2

The slope changes by $-20\ \mathbf{dB/decade}$ at $\omega = 8\ \mathbf{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 8\ \mathbf{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{8}+1\right)$.

The slope changes by $+20\ \mathbf{dB/decade}$ at $\omega = 10\ \mathbf{rad/s}$ indicates that there is a zero with corner

$\omega = 10\ \mathbf{rad/s}$. Therefore, the numerator has a factor of $\left(\frac{j\omega}{10}+1\right)$.

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$\omega = 3\ \mathbf{rad/s}$ indic e transfer function from the magnitude plot is,

fore, one of the fi $\dfrac{0\left(\frac{j\omega}{3}+1\right)\left(\frac{j\omega}{10}+1\right)}{\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{8}+1\right)}$

at $\omega = 5\ \mathbf{rad/s}$ i

ator has a factor

Therefore, transfer function $\mathbf{H}(j\omega)$ is $\boxed{\dfrac{100\left(\frac{j\omega}{3}+1\right)\left(\frac{j\omega}{10}+1\right)}{\left(\frac{j\omega}{5}+1\right)\left(\frac{j\omega}{8}+1\right)}}$.

Step 1 of 2

Refer to Figure P12.31 in the textbook for the magnitude characteristics.

From the magnitude plot, it is observed that the initial slope is $-20\ \mathbf{dB/decade}$ (negative slope) and therefore, there is a pole at the origin. So, the term $j\omega$ is the denominator. This negative slope intersects the $0\ \mathbf{dB}$ line at $\omega = \frac{1}{K_0}$. Therefore,

$$4 = \frac{1}{K_0}$$

$$K_0 = 0.25$$

One pole provides $-20\ \mathbf{dB/decade}$ and one zero provides $20\ \mathbf{dB/decade}$.

The $0\ \mathbf{dB/decade}$ slope starting at $\omega = 3\ \mathbf{rad/s}$ indicates that the first zero has a break frequency or corner frequency at $\omega = 3\ \mathbf{rad/s}$. Therefore, one of the factor in the numerator is $\left(\frac{j\omega}{3}+1\right)$.

The slope changes by $+40\ \mathbf{dB/decade}$ at $\omega = 5\ \mathbf{rad/s}$ indicates that there is a double zero with corner frequency at $\omega = 5\ \mathbf{rad/s}$. Therefore, the numerator has a factor of $\left(\frac{j\omega}{5}+1\right)^2$.

Step 2 of 2

The slope changes by $0\ \mathbf{dB/decade}$ at $\omega = 5.5\ \mathbf{rad/s}$ indicates that there is a double pole with corner frequency at $\omega = 5.5\ \mathbf{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{5.5}+1\right)^2$.

The slope changes by $-20\ \mathbf{dB/decade}$ at $\omega = 7\ \mathbf{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 7\ \mathbf{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{7}+1\right)$.

The composite transfer function from the magnitude plot is,

$$\mathbf{H}(j\omega) = \frac{0.25\left(\frac{j\omega}{3}+1\right)\left(\frac{j\omega}{5}+1\right)^2}{(j\omega)\left(\frac{j\omega}{5.5}+1\right)^2\left(\frac{j\omega}{7}+1\right)}$$

Therefore, transfer function $\mathbf{H}(j\omega)$ is $\boxed{\frac{0.25\left(\frac{j\omega}{3}+1\right)\left(\frac{j\omega}{5}+1\right)^2}{(j\omega)\left(\frac{j\omega}{5.5}+1\right)^2\left(\frac{j\omega}{7}+1\right)}}$.

12.033

P

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12.034

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Step 1 of 7

Consider the Figure P12.31 from the text book.

Calculate the change in slope of the line at $\omega_{c1} = 10 \text{ rad/sec}$.

$$-20-0$$
$$-20 \text{ rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+10}$.

Step 2 of 7

Calculate the change in slope of the line at $\omega_{c2} = 100 \text{ rad/sec}$.

$$0-(-20)$$
$$20 \text{ rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+100$.

Step 3 of 7

Calculate the change in slope of the line at $\omega_{c3} = 1000 \text{ rad/sec}$.

$$20-0$$
$$20 \text{ rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+1000$.

Step 4 of 7

Calculate the change in slope of the line at $\omega_{c4} = 10000 \text{ rad/sec}$.

$$0-(20)$$
$$-20 \text{ rad/sec}$$

The value of change in slope is negative which represents the presence of pole

$$\frac{1}{j\omega+10000}.$$

Step 5 of 7

Consider the expression for the gain at initial point.

$$|\mathbf{H}(j\omega)| = 0 \text{ dB}$$

But $|\mathbf{H}(j\omega)| = 20\log A$

$$20\log A = 0$$
$$\log A = \frac{0}{20}$$
$$\log A = 0$$
$$A = 10^0$$
$$A = 1$$

Therefore, the value of A is 3.16.

Step 6 of 7

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega+100)(j\omega+1000)}{(j\omega+10)(j\omega+10000)} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(100)(1000)(0.01j\omega+1)(0.001j\omega+1)}{(10)(10000)(0.1j\omega+1)(0.0001j\omega+1)}$$
$$= \frac{K(0.01j\omega+1)(0.001j\omega+1)}{(0.1j\omega+1)(0.0001j\omega+1)}$$

Equate the term K to 1.

$$K = 1$$

Therefore, the value of K is 1.

Step 7 of 7

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega+100)(j\omega+1000)}{(j\omega+10)(j\omega+10000)}$$

Substitute 1 for K.

$$\mathbf{H}(j\omega) = \frac{1(j\omega+100)(j\omega+1000)}{(j\omega+10)(j\omega+10000)}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is $\boxed{\frac{(j\omega+100)(j\omega+1000)}{(j\omega+10)(j\omega+10000)}}$.

Step 1 of 8

Consider the Figure P12.32 from the text book.

The plot at the initial point has a slope of $20\,\text{dB/dec}$ which represents a zero of corner frequency $0\ \text{rad/sec}$. Hence, the zero will be similar to $A(j\omega)$.

Step 2 of 8

Calculate the change in slope of the line at $\omega_{c1} = 4\ \text{rad/sec}$.

$$0-20$$
$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+4}$.

Step 3 of 8

Calculate the change in slope of the line at $\omega_{c2} = 20\ \text{rad/sec}$.

$$-20-0$$
$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+20$.

Step 4 of 8

Calculate the change in slope of the line at $\omega_{c3} = 100\ \text{rad/sec}$.

$$0-20$$
$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+100}$.

Step 5 of 8

Calculate the change in slope of the line at $\omega_{c3} = 600\ \text{rad/sec}$.

$$-40-0$$
$$-40\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+600}$.

Here, the value of change in slope is double the value of presence of a single pole. Hence, there exists a double pole $\frac{1}{(j\omega+600)^2}$.

Step 6 of 8

At $\omega = 10\ \text{rad/sec}$, the value of the gain is $0\ \text{dB}$. Hence,

$$|\mathbf{H}(j\omega)| = 0\ \text{dB}$$

But $|\mathbf{H}(j\omega)| = 20\log A(10)$

$$20\log A(10) = 0$$
$$\log A(10) = \frac{0}{20}$$
$$A(10) = 10^0$$
$$A(10) = 1$$
$$A = 0.1$$

Therefore, the value of A is 0.1.

Step 7 of 8

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega)(j\omega+20)}{(j\omega+4)(j\omega+100)(j\omega+600)^2} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(20)(j\omega)(0.05j\omega+1)}{(4)(100)(600)^2(0.25j\omega+1)(0.01j\omega+1)(1.667j\omega+1)^2}$$
$$= \frac{K(j\omega)(0.05j\omega+1)}{(20)(600)^2(0.25j\omega+1)(0.01j\omega+1)(1.667j\omega+1)^2}$$

Equate the term $\frac{K}{(20)(600)^2}$ to 0.1.

$$\frac{K}{(20)(600)^2} = 0.1$$

Solve for K.

$$K = (0.1)(20)(600)^2$$
$$= (2)(360000)$$
$$= 720000$$

Therefore, the value of K is 720000.

Step 8 of 8

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega)(j\omega+20)}{(j\omega+4)(j\omega+100)(j\omega+600)^2}$$

Substitute 720000 for K.

$$\mathbf{H}(j\omega) = \frac{720000(j\omega)(j\omega+20)}{(j\omega+4)(j\omega+100)(j\omega+600)^2}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is

$$\boxed{\frac{720000(j\omega)(j\omega+20)}{(j\omega+4)(j\omega+100)(j\omega+600)^2}}.$$

Step 1 of 7

Consider the Figure P12.33 from the text book.

The plot at the initial point has a slope of -20 which represents a pole of corner frequency $0\ \text{rad/sec}$.

Hence, the pole will be similar to $\frac{A}{j\omega}$.

Step 2 of 7

Calculate the change in slope of the line at $\omega_{c1} = 50\ \text{rad/sec}$.

$$0-(-20)$$
$$0+20$$
$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+50$.

Step 3 of 7

Calculate the change in slope of the line at $\omega_{c2} = 400\ \text{rad/sec}$.

$$-40-0$$
$$-40\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+400}$.

Here, the value of change in slope is double the value of presence of a single pole. Hence, there exists a double pole $\frac{1}{(j\omega+400)^2}$.

Step 4 of 7

Calculate the change in slope of the line at $\omega_{c3} = 1000\ \text{rad/sec}$.

$$-20-(-40)$$
$$-20+40$$
$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+1000$.

Step 5 of 7

At $\omega = 0.4\ \text{rad/sec}$, the value of the gain is $40\ \text{dB}$. Hence,

$$|\mathbf{H}(j\omega)| = 40\ \text{dB}$$

But $|\mathbf{H}(j\omega)| = 20\log\frac{A}{0.4}$

$$20\log\frac{A}{0.4} = 40$$
$$\log\frac{A}{0.4} = \frac{40}{20}$$
$$\log\frac{A}{0.4} = 2$$
$$\frac{A}{0.4} = 10^2$$
$$A = 0.4\times10^2$$
$$A = 40$$

Therefore, the value of A is 40.

Step 6 of 7

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega+50)(j\omega+1000)}{(j\omega)(j\omega+400)^2} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(1000)(50)(0.02j\omega+50)(0.001j\omega+1000)}{(400)^2(j\omega)(0.0025j\omega+1)^2}$$
$$= \frac{K(0.3125)(0.02j\omega+50)(0.001j\omega+1000)}{(j\omega)(0.0025j\omega+1)^2}$$

Equate the term $K(0.3125)$ to 40.

$$K(0.3125) = 40$$

Solve for K.

$$K = \frac{40}{0.3125}$$
$$= 128$$

Therefore, the value of K is 128.

Step 7 of 7

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega+50)(j\omega+1000)}{(j\omega)(j\omega+400)^2}$$

Substitute 128 for K.

$$\mathbf{H}(j\omega) = \frac{128(j\omega+50)(j\omega+1000)}{(j\omega)(j\omega+400)^2}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is

$$\boxed{\frac{128(j\omega+50)(j\omega+1000)}{(j\omega)(j\omega+400)^2}}.$$

Step 1 of 3

Refer to Figure P12.38 in the textbook.

From the magnitude plot, it is observed that the slope is $0\ \text{dB/decade}$ at $\omega = 12\ \text{rad/s}$.

Calculate the gain factor, K_0.

$$\frac{1}{K_0} = 12\ \text{rad/s}$$

$$K_0 = \frac{1}{12}$$

$$K_0 = 0.0833$$

One pole provides $-20\ \text{dB/decade}$ and one zero provides $+20\ \text{dB/decade}$.

Step 2 of 3

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 0\ \text{rad/s}$ indicates that there is a pole with zero frequency at $\omega = 0\ \text{rad/s}$. Therefore, the denominator has a factor of $j\omega$.

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 1\ \text{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 1\ \text{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{1}+1\right)$.

The slope changes by $+20\ \text{dB/decade}$ at $\omega = 8\ \text{rad/s}$ indicates that there is a zero with corner frequency at $\omega = 8\ \text{rad/s}$. Therefore, the numerator has a factor of $\left(\frac{j\omega}{8}+1\right)$.

The slope changes by $+20\ \text{dB/decade}$ at $\omega = 60\ \text{rad/s}$ indicates that there is a zero with corner frequency at $\omega = 60\ \text{rad/s}$. Therefore, the numerator has a factor of $\left(\frac{j\omega}{60}+1\right)$.

The slope changes by $-20\ \text{dB/decade}$ at $\omega = 400\ \text{rad/s}$ indicates that there is a pole with corner frequency at $\omega = 400\ \text{rad/s}$. Therefore, the denominator has a factor of $\left(\frac{j\omega}{400}+1\right)$.

Step 3 of 3

The composite transfer function from the magnitude plot is,

$$\begin{aligned}\mathbf{H}(j\omega) &= \frac{K_0\left(\frac{j\omega}{60}+1\right)\left(\frac{j\omega}{8}+1\right)}{j\omega\left(\frac{j\omega}{400}+1\right)\left(\frac{j\omega}{1}+1\right)} \\ &= \frac{0.0833\left(\frac{j\omega}{60}+1\right)\left(\frac{j\omega}{8}+1\right)}{j\omega\left(\frac{j\omega}{400}+1\right)(j\omega+1)}\end{aligned}$$

Therefore, transfer function $\mathbf{H}(j\omega)$ is,

$$\boxed{\frac{0.0833\left(\frac{j\omega}{60}+1\right)\left(\frac{j\omega}{8}+1\right)}{j\omega\left(\frac{j\omega}{400}+1\right)(j\omega+1)}}.$$

Step 1 of 6

Consider the Figure P12.35 from the text book.

The plot at the initial point has a slope of -40 which represents a pole of corner frequency $0\ \text{rad/sec}$.

Hence, the pole will be similar to $\frac{A}{(j\omega)^2}$.

Step 2 of 6

Calculate the change in slope of the line at $\omega_{c1} = 5\ \text{rad/sec}$.

$$-20-(-40)$$
$$-20+40$$
$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+5$.

Step 3 of 6

Calculate the change in slope of the line at $\omega_{c2} = 50\ \text{rad/sec}$.

$$-40-(-20)$$
$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+50}$.

Step 4 of 6

At $\omega = 10\ \text{rad/sec}$, the value of the gain is $0\ \text{dB}$. Hence,

$$|\mathbf{H}(j\omega)| = 0\ \text{dB}$$

But $|\mathbf{H}(j\omega)| = 20\log\frac{A}{(10)^2}$

$$20\log\frac{A}{(10)^2} = 0$$
$$\log\frac{A}{100} = \frac{0}{20}$$
$$\log\frac{A}{100} = 0$$
$$\frac{A}{100} = 10^0$$
$$A = 100\times10^0$$
$$A = 100$$

Therefore, the value of A is 100.

Step 5 of 6

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega+5)}{(j\omega)^2(j\omega+50)} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(5)(0.2j\omega+1)}{(j\omega)^2(50)(0.02j\omega+1)}$$
$$= \frac{K(0.1)(0.2j\omega+1)}{(j\omega)^2(0.02j\omega+1)}$$

Equate the term $K(0.1)$ to 100.

$$K(0.1) = 100$$

Solve for K.

$$K = \frac{100}{0.1}$$
$$= 1000$$

Therefore, the value of K is 1000.

Step 6 of 6

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega+5)}{(j\omega)^2(j\omega+50)}$$

Substitute 1000 for K.

$$\mathbf{H}(j\omega) = \frac{1000(j\omega+5)}{(j\omega)^2(j\omega+50)}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is $\boxed{\frac{1000(j\omega+5)}{(j\omega)^2(j\omega+50)}}$.

Step 1 of 7

Consider Figure P12.36 from the text book.

The plot at the initial point has a slope of -20 which represents a pole of corner frequency $0\ \text{rad/sec}$.

Hence, the pole will be similar to $\frac{A}{j\omega}$.

Step 2 of 7

Rise in the magnitude plot at $20\ \text{rad/s}$ indicates the presence of quadratic pole with a slope of -40. Hence, the change in slope is -60.

Consider the expression for the term of quadratic pole.

$$\frac{1}{\left((j\omega)^2 + j2\xi\omega_{c1}\omega + \omega_{c1}{}^2\right)}$$

Substitute $20\ \text{rad/s}$ for ω_{c1} and 0.1 for ξ.

$$\frac{1}{\left((j\omega)^2 + j2(0.1)(20)\omega + (20)^2\right)}$$

$$\frac{1}{\left((j\omega)^2 + j4\omega + 400\right)}$$

Therefore, the expression for quadratic pole is $\frac{1}{\left((j\omega)^2 + j4\omega + 400\right)}$.

Step 3 of 7

Calculate the change in slope of the line at $\omega_{c2} = 100\ \text{rad/sec}$.

$$\begin{aligned}\text{Change in slope} &= -20-(-60)\\ &= -20+60\\ &= 40\ \text{rad/sec}\end{aligned}$$

The value of change in slope is positive which represents the presence of double zero $(j\omega+100)^2$.

Step 4 of 7

Calculate the change in slope of the line at $\omega_{c3} = 900\ \text{rad/sec}$.

$$\begin{aligned}\text{Change in slope} &= -40-(-20)\\ &= -40+20\\ &= -20\ \text{rad/sec}\end{aligned}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+900}$.

Step 5 of 7

At $\omega = 0.8\ \text{rad/sec}$, the value of the gain is $20\ \text{dB}$. Hence,

$$|\mathbf{G}(j\omega)| = 0\ \text{dB}$$

But $|\mathbf{G}(j\omega)| = 20\log\frac{A}{0.8}$

$$20\log\frac{A}{0.8} = 20$$

$$\log\frac{A}{0.8} = \frac{20}{20}$$

$$\log\frac{A}{0.8} = 1$$

$$\frac{A}{0.8} = 10^1$$

$$A = 0.8\times 10$$

$$A = 8$$

Therefore, the value of A is 8.

Step 6 of 7

Consider the expression for the transfer function having gain K.

$$\mathbf{G}(j\omega) = \frac{K(j\omega+100)^2}{(j\omega)(j\omega+900)\left((j\omega)^2 + j4\omega + 400\right)} \quad \text{..... (1)}$$

$$\mathbf{G}(j\omega) = \frac{K(100)^2(0.01j\omega+1)^2}{(900)(400)(j\omega)\left(\frac{j\omega}{900}+1\right)\left(\left(\frac{j\omega}{20}\right)^2 + \frac{j\omega}{100}+1\right)}$$

Equate the term $\frac{K(100)^2}{(900)(400)}$ to 8.

$$\frac{K(100)^2}{(900)(400)} = 8$$

$$\frac{K}{36} = 8$$

$$K = 288$$

Therefore, the value of K is 288.

Step 7 of 7

Consider the expression (1).

$$\mathbf{G}(j\omega) = \frac{K(j\omega+100)^2}{(j\omega)(j\omega+900)\left((j\omega)^2 + j4\omega + 400\right)}$$

Substitute 288 for K.

$$\mathbf{G}(j\omega) = \frac{288(j\omega+100)^2}{(j\omega)(j\omega+900)\left((j\omega)^2 + j4\omega + 400\right)}$$

Therefore, the expression for the transfer function $\mathbf{G}(j\omega)$ is

$$\boxed{\frac{288(j\omega+100)^2}{(j\omega)(j\omega+900)\left((j\omega)^2 + j4\omega + 400\right)}}.$$

Step 1 of 5

Consider the Figure P12.37 from the text book.

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $10\ \text{mH}$ for L and $1600\ \text{rad/sec}$ for ω_0 .

$$1600 = \frac{1}{\sqrt{(10\ \text{m})C}}$$

$$(1600)^2 = \left(\frac{1}{\sqrt{(10\ \text{m})C}}\right)^2$$

$$256\times10^4 = \frac{1}{(10\ \text{m})C}$$

$$C = \frac{1}{(10\ \text{m})(256\times10^4)}$$

$$C = \frac{1}{25600}$$
$$= 39.0625\ \mu\text{F}$$

Therefore, the value of the capacitor is $\boxed{39.0625\ \mu\text{F}}$.

Step 2 of 5

Draw the circuit diagram in phasor representation of the parameters.

Figure 1

Step 3 of 5

Calculate the value of $\mathbf{I}(j\omega)$.

$$\mathbf{I}(j\omega) = \frac{24\angle30^\circ}{R + j\omega L - \frac{1}{j\omega C}} \quad \text{..... (1)}$$

At resonance frequency, the circuit acts as purely resistive.

$$\mathbf{I}(j\omega) = \frac{24\angle30^\circ}{R}$$

Substitute $2\ \Omega$ for R .

$$\mathbf{I}(j\omega) = \frac{24\angle30^\circ}{2}$$
$$= 12\angle30^\circ\ \text{A}$$

Therefore, the value of the current at resonance is $\boxed{12\angle30^\circ\ \text{A}}$.

Step 4 of 5

Recall equation (1).

$$\mathbf{I}(j\omega) = \frac{24\angle30^\circ}{R + j\omega L - \frac{1}{j\omega C}}$$

Substitute $\frac{\omega_0}{4}$ for ω .

$$\mathbf{I}\left(j\frac{\omega_0}{4}\right) = \frac{24\angle30^\circ}{R + j\frac{\omega_0 L}{4} - \frac{1}{j\frac{\omega_0 C}{4}}}$$

Substitute $2\ \Omega$ for R , $10\ \text{mH}$ for L , $39.0625\ \mu\text{F}$ for C and $1600\ \text{rad/sec}$ for ω_0 .

$$\mathbf{I}\left(j\frac{\omega_0}{4}\right) = \frac{24\angle30^\circ}{2 + j\frac{(1600)(10\ \text{m})}{4} + \frac{1}{j\frac{(1600)(39.0625\ \mu)}{4}}}$$

$$= \frac{24\angle30^\circ}{2 + j\frac{16}{4} + \frac{1}{j\frac{62.5\ \text{m}}{4}}}$$

$$= \frac{24\angle30^\circ}{2 + j\frac{16}{4} - j\frac{4}{62.5\ \text{m}}}$$

$$= \frac{24\angle30^\circ}{2 + j4 - j64}$$

$$\mathbf{I}\left(j\frac{\omega_0}{4}\right) = \frac{24\angle30^\circ}{2 - j60}$$
$$= \frac{24\angle30^\circ}{60.03\angle-88.09^\circ}$$
$$= 0.4\angle118.09^\circ\ \text{A}$$

Therefore, the value of $\mathbf{I}\left(j\frac{\omega_0}{4}\right)$ is $\boxed{0.4\angle118.09^\circ\ \text{A}}$.

Step 5 of 5

Recall equation (1).

$$\mathbf{I}(j\omega) = \frac{24\angle30^\circ}{R + j\omega L + \frac{1}{j\omega C}}$$

Substitute $4\omega_0$ for ω .

$$\mathbf{I}(j4\omega_0) = \frac{24\angle30^\circ}{R + j4\omega_0 L + \frac{1}{j4\omega_0 C}}$$

Substitute $2\ \Omega$ for R , $10\ \text{mH}$ for L , $39.0625\ \mu\text{F}$ for C and $1600\ \text{rad/sec}$ for ω_0 .

$$\mathbf{I}(j4\omega_0) = \frac{24\angle30^\circ}{2 + j4(1600)(10\ \text{m}) + \frac{1}{j4(1600)(39.0625\ \mu)}}$$

$$= \frac{24\angle30^\circ}{2 + j64 + \frac{1}{j0.25}}$$

$$= \frac{24\angle30^\circ}{2 + j64 - j4}$$

$$= \frac{24\angle30^\circ}{2 + j60}$$

$$\mathbf{I}(j4\omega_0) = \frac{24\angle30^\circ}{60.03\angle88.09^\circ}$$
$$= 0.4\angle-58.09^\circ\ \text{A}$$

Therefore, the value of $\mathbf{I}(j4\omega_0)$ is $\boxed{0.4\angle-58.09^\circ\ \text{A}}$.

Step 1 of 7

Consider the Figure P12.27 from the text book.

Calculate the change in slope of the line at $\omega_{c1} = 1 \text{ rad/sec}$.

$$20 - 0$$
$$20 \text{ rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega + 1$.

Step 2 of 7

Calculate the change in slope of the line at $\omega_{c2} = 10 \text{ rad/sec}$.

$$0 - 20$$
$$-20 \text{ rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega + 10}$.

Step 3 of 7

Calculate the change in slope of the line at $\omega_{c3} = 80 \text{ rad/sec}$.

$$-40 - 0$$
$$-40 \text{ rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega + 80}$.

Here, the value of change in slope is double the value of presence of a single pole. Hence, there exists a double pole $\frac{1}{(j\omega + 80)^2}$.

Step 4 of 7

Calculate the change in slope of the line at $\omega_{c4} = 120 \text{ rad/sec}$.

$$-20 - (-40)$$
$$-20 + 40$$
$$20 \text{ rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega + 120$.

Step 5 of 7

Consider the expression for the gain at initial point.

$$|\mathbf{H}(j\omega)| = 40 \text{ dB}$$

But $|\mathbf{H}(j\omega)| = 20\log A$

$$20\log A$$
$$\log A = \frac{40}{20}$$
$$\log A = 2$$
$$A = 10^2$$
$$A = 100$$

Therefore, the value of A is 100.

Step 6 of 7

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega + 1)(j\omega + 120)}{(j\omega + 10)(j\omega + 80)^2} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(120)(j\omega + 1)\left(\frac{j\omega}{120} + 1\right)}{(10)(80)^2\left(\frac{j\omega}{10} + 1\right)\left(\frac{j\omega}{80} + 1\right)^2}$$
$$= \frac{K(1.875 \times 10^{-3})(j\omega + 1)\left(\frac{j\omega}{120} + 1\right)}{\left(\frac{j\omega}{10} + 1\right)\left(\frac{j\omega}{80} + 1\right)^2}$$

Equate the term $K(1.875 \times 10^{-3})$ to 100.

$$K(1.875 \times 10^{-3}) = 100$$

Solve for K.

$$K = \frac{100}{1.875 \times 10^{-3}}$$
$$= 53.33 \times 10^3$$

Therefore, the value of K is 53.33×10^3.

Step 7 of 7

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega + 1)(j\omega + 120)}{(j\omega + 10)(j\omega + 80)^2}$$

Substitute 53.33×10^3 for K.

$$\mathbf{H}(j\omega) = \frac{(53.33 \times 10^3)(j\omega + 1)(j\omega + 120)}{(j\omega + 10)(j\omega + 80)^2}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is

$$\boxed{\frac{(53.33 \times 10^3)(j\omega + 1)(j\omega + 120)}{(j\omega + 10)(j\omega + 80)^2}}.$$

Step 1 of 7

Consider the Figure P12.29 from the text book.

The plot at the initial point has a slope of -20 which represents a pole of corner frequency $0\ \text{rad/sec}$.

Hence, the pole will be similar to $\frac{A}{j\omega}$.

Step 2 of 7

Calculate the change in slope of the line at $\omega_{c1} = 0.1\ \text{rad/sec}$.

$$-40-(-20)$$
$$-40+20$$
$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+0.1}$.

Step 3 of 7

Calculate the change in slope of the line at $\omega_{c2} = 1\ \text{rad/sec}$.

$$-20-(-40)$$
$$20\ \text{rad/sec}$$

The value of change in slope is positive which represents the presence of zero $j\omega+1$.

Step 4 of 7

Calculate the change in slope of the line at $\omega_{c3} = 50\ \text{rad/sec}$.

$$-40-(-20)$$
$$-20\ \text{rad/sec}$$

The value of change in slope is negative which represents the presence of pole $\frac{1}{j\omega+50}$.

Step 5 of 7

At $\omega = 5\ \text{rad/sec}$, the value of the gain is $0\ \text{dB}$. Hence,

$$\left|\mathbf{H}(j\omega)\right| = 0\ \text{dB}$$

But $\left|\mathbf{H}(j\omega)\right| = 20\log\frac{A}{5}$

$$20\log\frac{A}{5}$$
$$\log\frac{A}{5} = \frac{0}{20}$$
$$\log\frac{A}{5} = 0$$
$$A = 5$$

Therefore, the value of A is 5.

Step 6 of 7

Consider the expression for the transfer function having gain K.

$$\mathbf{H}(j\omega) = \frac{K(j\omega+1)}{(j\omega)(j\omega+0.1)(j\omega+50)} \quad \text{..... (1)}$$

$$\mathbf{H}(j\omega) = \frac{K(j\omega+1)}{(0.1)(50)(j\omega)(10j\omega+1)(0.02j\omega+1)}$$
$$= \frac{K(0.2)(j\omega+1)}{(j\omega)(10j\omega+1)(0.02j\omega+1)}$$

Equate the term $K(0.2)$ to 1.

$$K(0.2) = 5$$

Solve for K.

$$K = \frac{5}{0.2}$$
$$= 25$$

Therefore, the value of K is 25.

Step 7 of 7

Consider the expression (1).

$$\mathbf{H}(j\omega) = \frac{K(j\omega+1)}{(j\omega)(j\omega+0.1)(j\omega+50)}$$

Substitute 25 for K.

$$\mathbf{H}(j\omega) = \frac{25(j\omega+1)}{(j\omega)(j\omega+0.1)(j\omega+50)}$$

Therefore, the expression for the transfer function $\mathbf{H}(j\omega)$ is

$$\boxed{\frac{25(j\omega+1)}{(j\omega)(j\omega+0.1)(j\omega+50)}}.$$

Step 1 of 3

Calculate the value of resonant frequency, ω_0 .

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{LC}}\\ &= \frac{1}{\sqrt{(250\times10^{-3})(100\times10^{-6})}}\\ &= 200 \text{ rad/s}\end{aligned}$$

Calculate the value of capacitive impedance.

$$\begin{aligned}\mathbf{Z}_C &= \frac{1}{j\omega C}\\ &= \frac{1}{j(200)(100\times10^{-6})}\\ &= -j50\ \Omega\end{aligned}$$

Calculate the value of inductive impedance.

$$\begin{aligned}\mathbf{Z}_L &= j\omega L\\ &= j(200)(250\times10^{-3})\\ &= j50\ \Omega\end{aligned}$$

The input voltage is,

$$\mathbf{V}_i = 12\angle 0^\circ \text{ V}$$

Step 2 of 3

Draw the circuit in phasor domain.

Figure 1

Step 3 of 3

Apply voltage division rule to calculate the output voltage.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{\mathbf{Z}_L}{\mathbf{Z}_C+\mathbf{Z}_L+R}\right)\mathbf{V}_i\\ &= \left(\frac{j50}{1+j50-j50}\right)(12\angle 0^\circ)\\ &= (j50)(12\angle 0^\circ)\\ &= 600\angle 90^\circ\end{aligned}$$

Convert the phasor domain to time domain.

$$v_o(t) = 600\cos(200t+90^\circ) \text{ V}$$

Thus, the output voltage, $v_o(t)$, at the resonant frequency is $\boxed{600\cos(200t+90^\circ) \text{ V}}$.

Step 1 of 4

Consider the Figure P12.42 from the text book.

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $10\ \mu\text{F}$ for C and $2\ \text{mH}$ for L.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(10\ \mu)(2\ \text{m})}}\\ &= \frac{1}{\sqrt{2\times10^{-8}}}\\ &= \frac{1}{1.414\times10^{-4}}\\ &= 7071.07\ \text{rad/sec}\end{aligned}$$

Therefore, the value of the resonant frequency is $\boxed{7071.07\ \text{rad/sec}}$.

Step 2 of 4

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $1\ \Omega$ for R , $2\ \text{mH}$ for L and $7071.07\ \text{rad/sec}$ for ω_0 .

$$\begin{aligned}Q &= \frac{(7071.07)(2\ \text{m})}{1}\\ &= (7071.07)(2\ \text{m})\\ &= 14.14\end{aligned}$$

Therefore, the value of the quality factor Q is $\boxed{14.14}$.

Step 3 of 4

Consider the formula for $\omega_{\max}$.

$$\omega_{\max} = \omega_0\sqrt{1-\frac{1}{2Q^2}}$$

Substitute $7071.07\ \text{rad/sec}$ for ω_0 and 14.14 for Q.

$$\begin{aligned}\omega_{\max} &= (7071.07)\sqrt{1-\frac{1}{2(14.14)^2}}\\ &= (7071.07)\sqrt{1-\frac{1}{2(199.94)}}\\ &= (7071.07)\sqrt{1-\frac{1}{399.88}}\\ &= (7071.07)\sqrt{1-2.5\ \text{m}}\end{aligned}$$

$$\begin{aligned}\omega_{\max} &= (7071.07)\sqrt{0.9975}\\ &= (7071.07)(0.9987)\\ &= 7062.2\ \text{rad/sec}\end{aligned}$$

Therefore, the value of $\omega_{\max}$ is $\boxed{7062.2\ \text{rad/sec}}$.

Step 4 of 4

Consider the formula for $|\mathbf{V}_o|_{\max}$.

$$|\mathbf{V}_o|_{\max} = \frac{Q|\mathbf{V}_s|}{\sqrt{1-\frac{1}{4Q^2}}}$$

Substitute 14.14 for Q and $6\ \text{V}$ for $|\mathbf{V}_s|$.

$$\begin{aligned}|\mathbf{V}_o|_{\max} &= \frac{(14.14)(6)}{\sqrt{1-\frac{1}{4(14.14)^2}}}\\ &= \frac{84.84}{\sqrt{1-\frac{1}{4(199.94)}}}\\ &= \frac{84.84}{\sqrt{1-\frac{1}{799.76}}}\\ &= \frac{84.84}{\sqrt{1-1.25\ \text{m}}}\end{aligned}$$

$$\begin{aligned}|\mathbf{V}_o|_{\max} &= \frac{84.84}{\sqrt{0.9988}}\\ &= \frac{84.84}{\sqrt{0.9988}}\\ &= \frac{84.84}{0.999}\\ &= 84.92\ \text{V}\end{aligned}$$

Therefore, the value of $|\mathbf{V}_o|_{\max}$ is $\boxed{84.92\ \text{V}}$.

12.047
P

Step 1 of 3

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $20\ \mu\text{F}$ for C and $1000\ \text{rad/sec}$ for ω_0.

$$1000 = \frac{1}{\sqrt{(20\ \mu)L}}$$

$$(1000)^2 = \left(\frac{1}{\sqrt{(20\ \mu)L}}\right)^2$$

$$1\times10^6 = \frac{1}{(20\ \mu)L}$$

$$L = \frac{1}{(20\ \mu)(1\times10^6)}$$

$$L = \frac{1}{20}$$
$$= 50\ \text{mH}$$

Therefore, the value of the inductor is $\boxed{50\ \text{mH}}$.

Step 2 of 3

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $2.4\ \Omega$ for R, $50\ \text{mH}$ for L and $1000\ \text{rad/sec}$ for ω_0.

$$Q = \frac{(1000)(50\ \text{m})}{2.4}$$
$$= \frac{50}{2.4}$$
$$= 20.83$$

Therefore, the value of the quality factor Q is $\boxed{20.83}$.

Step 3 of 3

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $1000\ \text{rad/sec}$ for ω_0 and 20.83 for Q.

$$\text{BW} = \frac{1000}{20.83}$$
$$= 48\ \text{rad/sec}$$

Therefore, the value of the bandwidth is $\boxed{48\ \text{rad/sec}}$.

12.048
P

Step 1 of 3

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{\omega_0}{Q}$$

Substitute $10000\ \mathrm{rad/sec}$ for ω_0 and 120 for Q.

$$\begin{aligned}\mathrm{BW} &= \frac{10000}{120}\\ &= 83.33\ \mathrm{rad/sec}\end{aligned}$$

Therefore, the value of the bandwidth is $\boxed{83.33\ \mathrm{rad/sec}}$.

Step 2 of 3

Consider the formula for the lower half power frequency.

$$\omega_{\mathrm{LO}} = \omega_0\left[-\frac{1}{2Q} + \sqrt{\left(\frac{1}{2Q}\right)^2 + 1}\right]$$

Substitute $10000\ \mathrm{rad/sec}$ for ω_0 and 120 for Q.

$$\begin{aligned}\omega_{\mathrm{LO}} &= (10000)\left[-\frac{1}{2(120)} + \sqrt{\left(\frac{1}{2(120)}\right)^2 + 1}\right]\\ &= (10000)\left[-\frac{1}{240} + \sqrt{\left(\frac{1}{240}\right)^2 + 1}\right]\\ &= (10000)\left[-(4.167\ \mathrm{m}) + \sqrt{(4.167\ \mathrm{m})^2 + 1}\right]\\ &= (10000)\left[-(4.167\ \mathrm{m}) + \sqrt{17.36\ \mu + 1}\right]\end{aligned}$$

$$\begin{aligned}\omega_{\mathrm{LO}} &= (10000)\left[-(4.167\ \mathrm{m}) + \sqrt{1}\right]\\ &= (10000)\left[-(4.167\ \mathrm{m}) + 1\right]\\ &= (10000)[0.995633]\\ &= 9958.33\ \mathrm{rad/sec}\end{aligned}$$

Therefore, the value of the lower half power frequency is $\boxed{9958.33\ \mathrm{rad/sec}}$.

Step 3 of 3

Consider the formula for the higher half power frequency in terms of the lower half power frequency and the bandwidth.

$$\omega_{\mathrm{HI}} = \mathrm{BW} + \omega_{\mathrm{LO}}$$

Substitute $83.33\ \mathrm{rad/sec}$ for BW and $9958.33\ \mathrm{rad/sec}$ for ω_{LO}.

$$\begin{aligned}\omega_{\mathrm{HI}} &= 83.33 + 9958.33\\ &= 10041.66\ \mathrm{rad/sec}\end{aligned}$$

Therefore, the value of the higher half power frequency is $\boxed{10041.66\ \mathrm{rad/sec}}$.

12.049
P

Step 1 of 5

Consider the Figure P12.44 from the text book.

Consider the formula for the resonant frequency ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $10\ \text{mH}$ for L and $1000\ \text{rad/sec}$ for ω_0 .

$$1000 = \frac{1}{\sqrt{(10\ \text{m})C}}$$

$$(1000)^2 = \left(\frac{1}{\sqrt{(10\ \text{m})C}}\right)^2$$

$$1\times10^6 = \frac{1}{(10\ \text{m})C}$$

$$C = \frac{1}{(10\ \text{m})(1\times10^6)}$$

$$C = \frac{1}{10000}$$
$$= 100\ \mu\text{F}$$

Therefore, the value of the capacitor is $\boxed{100\ \mu\text{F}}$.

Step 2 of 5

Draw the circuit diagram in phasor representation of the parameters.

Figure 1

Step 3 of 5

Calculate the value of $\mathbf{I}(j\omega)$.

$$\mathbf{I}(j\omega) = \frac{36\angle45^\circ}{R + j\omega L - \frac{1}{j\omega C}}$$

At resonance frequency, the circuit acts as purely resistive.

$$\mathbf{I}(j\omega) = \frac{|36\angle45^\circ|}{R}$$

Substitute $12\ \text{A}$ for $\mathbf{I}(j\omega)$.

$$12 = \frac{36}{R}$$
$$R = \frac{36}{12}$$
$$R = 3\ \Omega$$

Therefore, the value of the resistor is $3\ \Omega$.

Step 4 of 5

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $3\ \Omega$ for R . $10\ \text{mH}$ for L and $1000\ \text{rad/sec}$ for ω_0 .

$$Q = \frac{(1000)(10\ \text{m})}{3}$$
$$= \frac{10}{3}$$
$$= 3.33$$

Therefore, the value of the quality factor Q is $\boxed{3.33}$.

Step 5 of 5

Consider the formula for the bandwidth BW .

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $1000\ \text{rad/sec}$ for ω_0 and 3.33 for Q .

$$\text{BW} = \frac{1000}{3.33}$$
$$= 300.3\ \text{rad/sec}$$

Therefore, the value of the bandwidth is $\boxed{300.3\ \text{rad/sec}}$.

12.050
P

Step 1 of 2

Consider the formula for the resistance in terms of admittance.

$$R = \frac{1}{Y}$$

Substitute $1\ \text{mS}$ for Y.

$$R = \frac{1}{1\ \text{m}}$$
$$= 1000\ \Omega$$

Therefore, the value of resistance is $\boxed{1000\ \Omega}$.

Step 2 of 2

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $2\ \mu\text{F}$ for C and $20000\ \text{rad/s}$ for ω_0.

$$20000 = \frac{1}{\sqrt{(2\ \mu\text{F})L}}$$

$$(20000)^2 = \left(\frac{1}{\sqrt{(2\ \mu\text{F})L}}\right)^2$$

$$4\times10^8 = \frac{1}{(2\ \mu\text{F})L}$$

$$L = \frac{1}{(2\times10^{-6})(4\times10^8)}$$

$$L = \frac{1}{800}$$
$$= 12.5\ \text{mH}$$

Therefore, the value of the inductor is $\boxed{12.5\ \text{mH}}$.

12.051
P

Step 1 of 10

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{1}{RC}$$

Substitute $10\ \mu\mathrm{F}$ for C and $1\ \mathrm{k\Omega}$ for R.

$$\begin{aligned}\mathrm{BW} &= \frac{1}{(1\ \mathrm{k\Omega})(10\ \mu\mathrm{F})}\\ &= \frac{1}{0.01}\\ &= 100\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the capacitor is $\boxed{100\ \mathrm{rad/s}}$.

Step 2 of 10

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $10\ \mu\mathrm{F}$ for C and $400\ \mathrm{mH}$ for L.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(400\ \mathrm{mH})(10\ \mu\mathrm{F})}}\\ &= \frac{1}{\sqrt{4\times10^{-6}}}\\ &= \frac{1}{2\times0^{-3}}\\ &= 500\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the resonant frequency is $500\ \mathrm{rad/s}$.

Step 3 of 10

Consider the formula for the quality factor Q of the circuit in terms of the resonant frequency and bandwidth.

$$Q = \frac{\omega_0}{\mathrm{BW}}$$

Substitute $100\ \mathrm{rad/s}$ for BW and $500\ \mathrm{rad/s}$ for ω_0.

$$\begin{aligned}Q &= \frac{500}{100}\\ &= 5\end{aligned}$$

Therefore, the value of the quality factor Q is 5.

Step 4 of 10

Consider the formula for the lower half power frequency.

$$\omega_{\mathrm{LO}} = \omega_0\left[-\frac{1}{2Q} + \sqrt{\left(\frac{1}{2Q}\right)^2 + 1}\right]$$

Substitute $500\ \mathrm{rad/s}$ for ω_0 and 5 for Q.

$$\begin{aligned}\omega_{\mathrm{LO}} &= (500)\left[-\frac{1}{2(5)} + \sqrt{\left(\frac{1}{2(5)}\right)^2 + 1}\right]\\ &= (500)\left[-\frac{1}{10} + \sqrt{\left(\frac{1}{10}\right)^2 + 1}\right]\\ &= (500)\left[-(0.1) + \sqrt{(0.1)^2 + 1}\right]\\ &= (500)\left[-(0.1) + \sqrt{0.01 + 1}\right]\end{aligned}$$

$$\begin{aligned}\omega_{\mathrm{LO}} &= (500)\left[-(0.1) + \sqrt{1.01}\right]\\ &= (500)\left[-(0.1) + 1.005\right]\\ &= (500)[0.905]\\ &= 452.5\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the lower half power frequency is $\boxed{452.5\ \mathrm{rad/s}}$.

Step 5 of 10

Consider the formula for the higher half power frequency in terms of the lower half power frequency and the bandwidth.

$$\omega_{\mathrm{HI}} = \mathrm{BW} + \omega_{\mathrm{LO}}$$

Substitute $100\ \mathrm{rad/s}$ for BW and $452.5\ \mathrm{rad/s}$ for ω_{LO}.

$$\begin{aligned}\omega_{\mathrm{HI}} &= 100 + 452.5\\ &= 552.5\ \mathrm{rad/s}\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the higher half power frequency is $\boxed{552.5\ \mathrm{rad/s}}$.

Step 6 of 10

Consider the circuit diagram for the parallel combination of resistor capacitor and inductor as shown in Figure 1.

Figure 1

Step 7 of 10

Consider the expression for the admittance of the network at lower half power frequency.

$$Y(j\omega_{\mathrm{LO}}) = \frac{1}{R} + \frac{1}{j\omega_{\mathrm{LO}}L} + j\omega_{\mathrm{LO}}C$$

Substitute $452.5\ \mathrm{rad/s}$ for ω_{LO}, $1\ \mathrm{k\Omega}$ for R, $10\ \mu\mathrm{F}$ for C and $400\ \mathrm{mH}$ for L.

$$\begin{aligned}Y(j\omega_{\mathrm{LO}}) &= \frac{1}{1\ \mathrm{k}} + \frac{1}{j(452.5)(400\ \mathrm{m})} + j(452.5)(10\ \mu)\\ &= 0.001 + \frac{1}{j(181)} + j(4.525\ \mathrm{m})\\ &= 0.001 - j(5.525\ \mathrm{m}) + j(4.525\ \mathrm{m})\\ &= 1 - j1\ \mathrm{mS}\end{aligned}$$

Therefore, the value of the admittance at the lower half power frequency is $1 - j1\ \mathrm{mS}$.

Step 8 of 10

Consider the expression for the voltage across the network at lower half power frequency.

$$\mathrm{V}(j\omega_{\mathrm{LO}}) = \frac{2}{Y(j\omega_{\mathrm{LO}})}$$

Substitute $1 - j1\ \mathrm{mS}$ for $Y(j\omega_{\mathrm{LO}})$.

$$\begin{aligned}\mathrm{V}(j\omega_{\mathrm{LO}}) &= \frac{2}{1 - j1\ \mathrm{m}}\\ &= \frac{2}{\sqrt{2}\angle -45^\circ\ \mathrm{m}}\\ &= \sqrt{2}\angle 45^\circ\ \mathrm{kV}\end{aligned}$$

Therefore, the value of the voltage across the circuit at lower half power frequency is

$\boxed{\sqrt{2}\angle 45^\circ\ \mathrm{kV}}$.

Step 9 of 10

Consider the expression for the admittance of the network at higher half power frequency.

$$Y(j\omega_{\mathrm{HI}}) = \frac{1}{R} + \frac{1}{j\omega_{\mathrm{HI}}L} + j\omega_{\mathrm{HI}}C$$

Substitute $552.5\ \mathrm{rad/s}$ for ω_{HI}, $1\ \mathrm{k\Omega}$ for R, $10\ \mu\mathrm{F}$ for C and $400\ \mathrm{mH}$ for L.

$$\begin{aligned}Y(j\omega_{\mathrm{HI}}) &= \frac{1}{1\ \mathrm{k}} + \frac{1}{j(552.5)(400\ \mathrm{m})} + j(552.5)(10\ \mu)\\ &= 0.001 + \frac{1}{j(221)} + j(5.525\ \mathrm{m})\\ &= 0.001 - j4.525\ \mathrm{m} + j(5.525\ \mathrm{m})\\ &= 1 + j1\ \mathrm{mS}\end{aligned}$$

Therefore, the value of the admittance at the higher half power frequency is $1 + j1\ \mathrm{mS}$.

Step 10 of 10

Consider the expression for the voltage across the network at higher half power frequency.

$$\mathrm{V}(j\omega_{\mathrm{HI}}) = \frac{2}{Y(j\omega_{\mathrm{HI}})}$$

Substitute $1 + j1\ \mathrm{mS}$ for $Y(j\omega_{\mathrm{HI}})$.

$$\begin{aligned}\mathrm{V}(j\omega_{\mathrm{HI}}) &= \frac{2}{1 + j1\ \mathrm{m}}\\ &= \frac{2}{\sqrt{2}\angle 45^\circ\ \mathrm{m}}\\ &= \sqrt{2}\angle -45^\circ\ \mathrm{kV}\end{aligned}$$

Therefore, the value of the voltage across the circuit at higher half power frequency is

$\boxed{\sqrt{2}\angle -45^\circ\ \mathrm{kV}}$.

12.052
P

Step 1 of 6

Consider the Figure P12.43 from the text book.

Consider the formula for the resonant frequency ω_0.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $5\ \mu\text{F}$ for C and $50\ \text{mH}$ for L.

$$\omega_0 = \frac{1}{\sqrt{(5\ \mu)(50\ \text{m})}}$$
$$\omega_0 = \frac{1}{\sqrt{2.5\times10^{-7}}}$$
$$\omega_0 = \frac{1}{5\times10^{-4}}$$
$$\omega_0 = 2000\ \text{rad/sec}$$

Therefore, the value of the resonant frequency is $\boxed{2000\ \text{rad/sec}}$.

Step 2 of 6

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $100\ \Omega$ for R, $50\ \text{mH}$ for L and $2000\ \text{rad/sec}$ for ω_0.

$$Q = \frac{(2000)(50\ \text{m})}{100}$$
$$= \frac{100}{100}$$
$$= 1$$

Therefore, the value of the quality factor Q is $\boxed{1}$.

Step 3 of 6

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $2000\ \text{rad/sec}$ for ω_0 and 1 for Q.

$$\text{BW} = \frac{2000}{1}$$
$$= 2000\ \text{rad/sec}$$

Therefore, the value of the bandwidth is $\boxed{2000\ \text{rad/sec}}$.

Step 4 of 6

Draw the circuit diagram in phasor representation of the parameters.

Figure 1

Step 5 of 6

Calculate the value of $\mathbf{I}(j\omega)$.

$$\mathbf{I}(j\omega) = \frac{12\angle0^\circ}{R + j\omega L - \frac{1}{j\omega C}}$$

At resonance frequency, the circuit acts as purely resistive.

$$\mathbf{I}(j\omega) = \frac{12\angle0^\circ}{R}$$

Substitute $100\ \Omega$ for R.

$$\mathbf{I}(j\omega) = \frac{12\angle0^\circ}{100}$$
$$= 0.12\angle0^\circ\ \text{A}$$

Therefore, the value of the current at resonance is $0.12\angle0^\circ\ \text{A}$.

Step 6 of 6

Consider the formula for the average power dissipated by the circuit at resonance.

$$P = \frac{|\mathbf{I}(j\omega)|^2 R}{2}$$

Substitute $100\ \Omega$ for R and $0.12\ \text{A}$ for $|\mathbf{I}(j\omega)|$.

$$P = \frac{(0.12)^2(100)}{2}$$
$$= \frac{(0.0144)(100)}{2}$$
$$= \frac{1.44}{2}$$
$$= 0.72\ \text{W}$$

Therefore, the value of the average power dissipated by the circuit at resonance is

$\boxed{0.72\ \text{W}}$.

Step 1 of 4

Refer to Figure P12.53 in the textbook.

Apply voltage division rule to calculate the output voltage.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{\mathbf{Z}_C}{\mathbf{Z}_R+\mathbf{Z}_L+\mathbf{Z}_C}\right)\mathbf{V}_i \\ &= \left(\frac{-jX_C}{R+jX_L-jX_C}\right)\mathbf{V}_i \\ &= \left(\frac{-jX_C}{R+j(X_L-X_C)}\right)\mathbf{V}_i\end{aligned}$$

Calculate the magnitude of the output voltage,

$$|\mathbf{V}_o| = \left(\frac{X_C}{\sqrt{R^2+(X_L-X_C)^2}}\right)\mathbf{V}_i$$

Magnitude of the output voltage is inversely proportional to the value of the resistor. So, the value of the resistor should be low for maximum output voltage.

The value of the resistor is small when the resistors are connected in parallel.

Thus, to get the maximum voltage, the resistor bank is connected in $\boxed{\text{Parallel manner}}$.

Step 2 of 4

Calculate the equivalent resistance, R.

$$R = R_1 \parallel R_2 \parallel R_3$$

Substitute $12\ \Omega$ for R_1, $6\ \Omega$ for R_2 and $4\ \Omega$ for R_3.

$$\begin{aligned}R &= 12 \parallel 6 \parallel 4 \\ &= \left(\frac{12\times 6}{12+6}\right)\parallel 4 \\ &= 4 \parallel 4 \\ &= \frac{4\times 4}{4+4}\end{aligned}$$

$$R = 2\ \Omega$$

Calculate the value of angular frequency, ω.

$$\begin{aligned}\omega &= 2\pi f \\ &= 2\pi(200) \\ &= 1256.6\ \text{rad/s}\end{aligned}$$

Step 3 of 4

Calculate the value of capacitive impedance.

$$\mathbf{Z}_C = \frac{1}{j\omega C}$$

Substitute $1256.6\ \text{rad/s}$ for ω and $50\ \mu\text{F}$ for C.

$$\begin{aligned}\mathbf{Z}_C &= \frac{1}{j(1256.6)(50\times 10^{-6})} \\ &= -j15.9\ \Omega\end{aligned}$$

Calculate the value of inductive impedance.

$$\mathbf{Z}_L = j\omega L$$

Substitute $1256.6\ \text{rad/s}$ for ω and $500\ \mu\text{H}$ for L.

$$\begin{aligned}\mathbf{Z}_L &= j(1256.6)(500\times 10^{-6}) \\ &= j0.6283\ \Omega\end{aligned}$$

Step 4 of 4

Calculate the output voltage, $\mathbf{V}_o$.

$$\mathbf{V}_o = \left(\frac{\mathbf{Z}_C}{R+\mathbf{Z}_L+\mathbf{Z}_C}\right)\mathbf{V}_i$$

Substitute $j0.6283\ \Omega$ for $\mathbf{Z}_L$, $-j15.9\ \Omega$ for $\mathbf{Z}_C$, $2\ \Omega$ for R and $12\angle 0°$ for $\mathbf{V}_i$.

$$\begin{aligned}\mathbf{V}_o &= \left(\frac{-j15.9}{2+j0.6283-j15.9}\right)(12\angle 0°) \\ &= \frac{-j189.6}{2-j15.272} \\ &= 12.2-j1.598 \\ &= 12.31\angle -7.461°\ \text{V}\end{aligned}$$

Thus, the output voltage is $\boxed{12.31\angle -7.461°\ \text{V}}$.

12.054
P

Step 1 of 3

Consider Figure P12.46 in the text book.

Consider the formula for the resonant frequency, ω_0 .

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $20\ \mu\text{F}$ for C and $1600\ \text{rad/sec}$ for ω_0 .

$$1600 = \frac{1}{\sqrt{(20\ \mu)L}}$$

$$(1600)^2 = \left(\frac{1}{\sqrt{(20\ \mu)L}}\right)^2$$

$$256\times10^4 = \frac{1}{(20\ \mu)L}$$

$$L = \frac{1}{(20\ \mu)(256\times10^4)}$$

$$L = \frac{1}{51.2}$$
$$= 19.53\ \text{mH}$$

Therefore, the value of the inductor is $\boxed{19.53\ \text{mH}}$.

Step 2 of 3

Consider the formula for the quality factor Q of the circuit.

$$Q = \frac{\omega_0 L}{R}$$

Substitute $5\ \Omega$ for R , $19.53\ \text{mH}$ for L and $1600\ \text{rad/sec}$ for ω_0 .

$$Q = \frac{(1600)(19.53\ \text{m})}{5}$$
$$= \frac{31.248}{5}$$
$$= 6.25$$

Therefore, the value of the quality factor Q is $\boxed{6.25}$.

Step 3 of 3

Consider the formula for the bandwidth BW .

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $1600\ \text{rad/sec}$ for ω_0 and 6.25 for Q .

$$\text{BW} = \frac{1600}{6.25}$$
$$= 256\ \text{rad/s}$$

Therefore, the value of the bandwidth is $\boxed{256\ \text{rad/s}}$.

12.055
P

Step 1 of 2

Refer to Figure P12.55 in the textbook.

The expression for the resonant frequency, ω_0 is,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$LC = \frac{1}{\omega_0^2}$$

$$L = \frac{1}{\omega_0^2 C}$$

Substitute $2000\ \text{rad/s}$ for ω_0 and $25\ \mu\text{F}$ for C.

$$\begin{aligned} L &= \frac{1}{(2000)^2\left(25\times10^{-6}\right)} \\ &= \frac{1}{100} \\ &= 10\times10^{-3} \\ &= 10\ \text{mH} \end{aligned}$$

Thus, the value of the inductor is $\boxed{10\ \text{mH}}$.

Step 2 of 2

The expression for the Quality factor, Q is,

$$Q = \frac{\omega_0 L}{R}$$

$$R = \frac{\omega_0 L}{Q}$$

Substitute $2000\ \text{rad/s}$ for ω_0, $10\ \text{mH}$ for L and 40 for Q.

$$\begin{aligned} R &= \frac{(2000)\left(10\times10^{-3}\right)}{40} \\ &= 0.5\ \Omega \end{aligned}$$

Thus, the value of the resistor is $\boxed{0.5\ \Omega}$.

12.056 P

Step 1 of 2

Refer to Figure P12.55 in the textbook.

The expression for the Quality factor, Q is,

$$Q = \frac{\omega_0 L}{R}$$

$$L = \frac{RQ}{\omega_0}$$

Substitute $7200\ \text{rad/s}$ for ω_0 , $6\ \Omega$ for R and 60 for Q .

$$L = \frac{(60)(6)}{(7200)}$$

$$= 50 \times 10^{-3}$$

$$= 50\ \text{mH}$$

Thus, the value of the inductor is $\boxed{50\ \text{mH}}$.

Step 2 of 2

The expression for the resonant frequency, ω_0 is,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$LC = \frac{1}{\omega_0^2}$$

$$C = \frac{1}{\omega_0^2 L}$$

Substitute $7200\ \text{rad/s}$ for ω_0 and $50\ \text{mH}$ for L .

$$C = \frac{1}{(7200)^2 (50 \times 10^{-3})}$$

$$= 385.8 \times 10^{-9}$$

$$= 385.8\ \text{nF}$$

Thus, the value of the capacitor is $\boxed{385.8\ \text{nF}}$.

Step 1 of 5

Refer to Figure P12.57 in the text book.

Write the expression of the Q for series RLC circuit.

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Substitute $1\ \Omega$ for R, $100\ \mu\text{F}$ for C and $2.5\ \text{mH}$ for L.

$$\begin{aligned} Q &= \frac{1}{1}\sqrt{\frac{2.5\times10^{-3}}{100\times10^{-6}}} \\ &= \sqrt{\frac{25\times10^{-4}}{10^{-4}}} \\ &= \sqrt{25} \\ &= 5 \end{aligned}$$

Thus, the value of the Q is $\boxed{5}$.

Step 2 of 5

Use voltage division principle and write the expression for the phasor voltage $\mathbf{V}_o$.

$$\mathbf{V}_o = \frac{20}{\left(R + \left(\frac{1}{\omega C}\right)\angle -90^\circ + (\omega L)\angle 90^\circ\right)}\left(\left(\frac{1}{\omega C}\right)\angle -90^\circ + (\omega L)\angle 90^\circ\right)$$

Substitute $2000\ \text{rad/s}$ for ω, $1\ \Omega$ for R, $100\ \mu\text{F}$ for C and $2.5\ \text{mH}$ for L.

$$\begin{aligned} \mathbf{V}_o &= \frac{20}{\left(1 + \left(\frac{1}{(2000)(100\times10^{-6})}\right)\angle -90^\circ + (2000)(2.5\times10^{-3})\angle 90^\circ\right)}\left(\left(\frac{1}{(2000)(100\times10^{-6})}\right)\angle -90^\circ + \left((2000)(2.5\times10^{-3})\right)\angle 90^\circ\right) \\ &= \frac{20}{(1 + 5\angle -90^\circ + 5\angle 90^\circ)}(5\angle -90^\circ + 5\angle 90^\circ) \\ &= \frac{20}{(1+0)}(0) \\ &= 0\ \text{V} \end{aligned}$$

Thus, the phasor voltage $\mathbf{V}_o$ is $\boxed{0\ \text{V}}$.

Step 3 of 5

The frequency $2000\ \text{rad/s}$ is the resonant frequency of the circuit.

Calculate the phasor current at the resonant frequency.

$$\begin{aligned} \mathbf{I} &= \frac{20}{R} \\ &= \frac{20}{1} \\ &= 20\angle 0^\circ\ \text{A} \end{aligned}$$

Determine the voltage across the resistor at the resonant frequency.

$$\begin{aligned} \mathbf{V}_R &= \mathbf{I}R \\ &= (20\angle 0^\circ)(1) \\ &= 20\angle 0^\circ\ \text{V} \end{aligned}$$

Thus, the voltage across the resistor is $\boxed{20\angle 0^\circ\ \text{V}}$.

Step 4 of 5

Determine the voltage across the capacitor.

$$\begin{aligned} \mathbf{V}_C &= \frac{\mathbf{I}}{j\omega_o C} \\ &= \frac{20\angle 0^\circ}{j(2000)(100\times10^{-6})} \\ &= \frac{20\angle 0^\circ}{(0.2)\angle 90^\circ} \\ &= 100\angle -90^\circ\ \text{V} \end{aligned}$$

Thus, the voltage across the capacitor is $\boxed{100\angle -90^\circ\ \text{V}}$.

Step 5 of 5

Determine the voltage across the inductor.

$$\begin{aligned} \mathbf{V}_L &= (j\omega_o L)\mathbf{I} \\ &= \left(j(2000)(2.5\times10^{-3})\right)(20\angle 0^\circ) \\ &= (5\angle 90^\circ)(20\angle 0^\circ) \\ &= 100\angle 90^\circ\ \text{V} \end{aligned}$$

Thus, the voltage across the inductor is $\boxed{100\angle 90^\circ\ \text{V}}$.

12.058
P

Step 1 of 3

Write the expression of the bandwidth.

$$\text{BW} = 2\%\left(f_o\right)$$

Substitute $1\ \text{MHz}$ for f_o.

$$\begin{aligned}\text{BW} &= 2\%\left(1\times10^6\right)\\ &= \frac{2}{100}\left(1\times10^6\right)\\ &= \left(20\times10^3\right)\\ &= 20\ \text{kHz}\end{aligned}$$

Express the bandwidth in rad/s.

$$\begin{aligned}\text{BW} &= 2\pi\left(20\times10^3\right)\\ &= 40000\pi\ \text{rad/s}\end{aligned}$$

Step 2 of 3

Write the expression of the bandwidth of the series RLC circuit.

$$\text{BW} = \frac{\omega_0}{Q}$$

Substitute $\frac{\omega_0 L}{R}$ for Q.

$$\begin{aligned}\text{BW} &= \frac{\omega_0}{\left(\frac{\omega_0 L}{R}\right)}\\ &= \frac{R}{L}\end{aligned}$$

Substitute $40000\pi\ \text{rad/s}$ for BW and $100\ \Omega$ for R.

$$40000\pi = \frac{100}{L}$$

$$\begin{aligned}L &= \frac{100}{40000\pi}\\ &= \frac{0.25\times10^{-2}}{\pi}\\ &= 795.775\ \mu\text{H}\end{aligned}$$

Thus, the value of the inductance L is $\boxed{795.775\ \mu\text{H}}$.

Step 3 of 3

Write the expression of the resonant frequency of the series RLC circuit.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Substitute $1\ \text{MHz}$ for f_0 and $795.775\ \mu\text{H}$ for L.

$$1\times10^6 = \frac{1}{2\pi\sqrt{\left(795.775\times10^{-6}\right)C}}$$

$$\begin{aligned}C &= \frac{1}{2\pi\sqrt{\left(795.775\times10^{-6}\right)\left(1\times10^6\right)}}\\ &= \frac{1}{177.245}\\ &= 5.64\ \text{mF}\end{aligned}$$

Thus, the value of the capacitance is $\boxed{5.64\ \text{mF}}$.

Step 1 of 2

Refer to Figure

Determine the expression of the input impedance of the circuit.

$$Z = j\omega L + \left(\frac{1}{j\omega C} \| R\right)$$

$$= j\omega L + \frac{\left(\frac{1}{j\omega C}\right)(R)}{\left(\frac{1}{j\omega C}\right) + R}$$

$$= j\omega L + \frac{R}{1 + Rj\omega C}$$

$$= \frac{j\omega L(1 + j\omega RC) + R}{(1 + j\omega RC)}$$

Simplify further.

$$Z = \frac{j\omega L - \omega^2 RLC + R}{(1 + j\omega RC)}$$

Step 2 of 2

Multiply the numerator and the denominator by $(1 - j\omega RC)$.

$$Z = \frac{(j\omega L - \omega^2 RLC + R)(1 - j\omega RC)}{(1 + j\omega RC)(1 - j\omega RC)}$$

$$= \frac{(j\omega L - \omega^2 RLC + R) + \omega^2 RLC + j\omega^3 L(RC)^2 - j\omega R^2 C}{1 + (\omega RC)^2}$$

$$= \frac{R + j\left(\omega^3 L(RC)^2 + \omega L - \omega R^2 C\right)}{1 + (\omega RC)^2}$$

$$= \frac{R}{1 + (\omega RC)^2} + j\frac{\left(\omega^3 L(RC)^2 + \omega L - \omega R^2 C\right)}{1 + (\omega RC)^2}$$

Equate the imaginary part of the input impedance to zero.

$$\frac{\left(\omega^3 L(RC)^2 + \omega L - \omega R^2 C\right)}{1 + (\omega RC)^2} = 0$$

$$\left(\omega^3 L(RC)^2 + \omega L - \omega R^2 C\right)$$

$$\omega^2 L(RC)^2 = R^2 C - L$$

$$\omega_0^2 = \frac{R^2 C - L}{L(RC)^2}$$

Simplify further.

$$\omega_0 = \frac{\sqrt{\frac{R^2 C}{L} - 1}}{RC}$$

$$= \sqrt{\frac{1}{LC} - \frac{1}{(RC)^2}}$$

Thus, the frequency at which the input impedance of the network is real is $\boxed{\sqrt{\frac{1}{LC} - \frac{1}{(RC)^2}}}$.

Step 1 of 6

Consider Figure P12.53 from the text book.

Calculations at $R_S = \infty$:

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $50\ \mu\text{F}$ for C and $20\ \text{mH}$ for L .

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{(20\ \text{m})(50\ \mu)}}\\ &= \frac{1}{\sqrt{1\ \mu}}\\ &= \frac{1}{1\ \text{m}}\\ &= 1000\ \text{rad/s}\end{aligned}$$

Therefore, the value of the resonant frequency is $1000\ \text{rad/s}$.

Step 2 of 6

Consider the formula for the bandwidth BW .

$$\text{BW} = \frac{1}{R_{eq}C}$$

Substitute $R_S \parallel R$ for R_{eq} .

$$\begin{aligned}\text{BW} &= \frac{1}{(R_S \parallel R)C}\\ &= \frac{1}{\left(\frac{R_S R}{R_S + R}\right)C}\\ &= \frac{1}{\frac{R_S}{R_S}\left(\frac{R}{1 + R/R_S}\right)C}\\ &= \frac{1}{\left(\frac{R}{1 + R/R_S}\right)C}\end{aligned}$$

Substitute $50\ \mu\text{F}$ for C , $1\ \text{k}\Omega$ for R and ∞ for R_S .

$$\begin{aligned}\text{BW} &= \frac{1}{\left(\frac{1\ \text{k}}{1 + 1\ \text{k}/\infty}\right)(50\ \mu)}\\ &= \frac{1}{\left(\frac{1\ \text{k}}{1 + 0}\right)(50\ \mu)}\\ &= \frac{1}{(1\ \text{k})(50\ \mu)}\\ &= \frac{1}{0.05}\end{aligned}$$

$$\text{BW} = 20\ \text{rad/s}$$

Therefore, the value of the bandwidth BW is $\boxed{20\ \text{rad/s}}$.

Step 3 of 6

Consider the formula for the quality factor Q of the circuit in terms of the resonant frequency and bandwidth.

$$Q = \frac{\omega_0}{\text{BW}}$$

Substitute $20\ \text{rad/s}$ for BW and $1000\ \text{rad/s}$ for ω_0 .

$$\begin{aligned}Q &= \frac{1000}{20}\\ &= 50\end{aligned}$$

Therefore, the value of the quality factor Q is $\boxed{50}$.

Calculations at $R_S = 10\ \text{k}\Omega$:

As the formula for the resonant frequency does not contain the term of R_S , there will not be any change in the value of ω_0 . Therefore, the value of ω_0 is $\boxed{1000\ \text{rad/s}}$.

Step 4 of 6

Consider the formula for the bandwidth BW .

$$\text{BW} = \frac{1}{R_{eq}C}$$

Substitute $R_S \parallel R$ for R_{eq} .

$$\begin{aligned}\text{BW} &= \frac{1}{(R_S \parallel R)C}\\ &= \frac{1}{\left(\frac{R_S R}{R_S + R}\right)C}\end{aligned}$$

Step 5 of 6

Substitute $50\ \mu\text{F}$ for C , $1\ \text{k}\Omega$ for R and ∞ for R_S .

$$\begin{aligned}\text{BW} &= \frac{1}{\left(\frac{(10\ \text{k})(1\ \text{k})}{10\ \text{k} + 1\ \text{k}}\right)(50\ \mu)}\\ &= \frac{1}{\left(\frac{10\ \text{M}}{11\ \text{k}}\right)(50\ \mu)}\\ &= \frac{1}{(909.09)(50\ \mu)}\\ &= \frac{1}{45.4545\ \text{m}}\end{aligned}$$

$$\text{BW} = 22\ \text{rad/s}$$

Therefore, the value of the bandwidth BW is $\boxed{22\ \text{rad/s}}$.

Step 6 of 6

Consider the formula for the quality factor Q of the circuit in terms of the resonant frequency and bandwidth.

$$Q = \frac{\omega_0}{\text{BW}}$$

Substitute $22\ \text{rad/s}$ for BW and $1000\ \text{rad/s}$ for ω_0 .

$$\begin{aligned}Q &= \frac{1000}{22}\\ &= 45.45\end{aligned}$$

Therefore, the value of the quality factor Q is $\boxed{45.45}$.

Step 1 of 3

Consider Figure P12.55 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 3

Calculate the value of $\mathbf{Z}_{eq}$.

$$\begin{aligned}\mathbf{Z}_{eq} &= \left(R+\frac{1}{j\omega C}\right)\| j\omega L \\ &= \frac{\left(R+\frac{1}{j\omega C}\right)(j\omega L)}{R+\frac{1}{j\omega C}+j\omega L} \\ &= \frac{\frac{L}{C}+j\omega LR}{R+j\left(\omega L-\frac{1}{\omega C}\right)}\end{aligned}$$

At resonance, the circuit resembles purely resistive circuit. hence, the phasor terms of the impedance is equal to zero. That is,

$$\frac{\angle\tan^{-1}\left(\frac{\omega_0 LR}{\frac{L}{C}}\right)}{\angle\tan^{-1}\left(\frac{\omega_0 L-\frac{1}{\omega_0 C}}{R}\right)}=0$$

$$\angle\tan^{-1}(\omega_0 RC)-\angle\tan^{-1}\left(\frac{\omega_0 L-\frac{1}{\omega_0 C}}{R}\right)=0$$

$$\angle\tan^{-1}(\omega_0 RC)=\angle\tan^{-1}\left(\frac{\omega_0^2 LC-1}{\omega_0 RC}\right)$$

$$\omega_0 RC=\frac{\omega_0^2 LC-1}{\omega_0 RC}$$

Step 3 of 3

Simplify the expression further.

$$\omega_0^2 R^2C^2=\omega_0^2 LC-1$$

$$\omega_0^2 R^2C^2-\omega_0^2 LC=-1$$

$$\omega_0^2\left(R^2C^2-LC\right)=-1$$

$$\omega_0^2=\frac{-1}{R^2C^2-LC}$$

$$\omega_0^2=\frac{1}{LC-R^2C^2}$$

$$\omega_0=\sqrt{\frac{1}{LC-R^2C^2}}$$

$$\omega_0-\sqrt{\frac{1}{LC-R^2C^2}}=0$$

Therefore, the required equation for the non-zero resonant frequency is

$$\boxed{\omega_0-\sqrt{\frac{1}{LC-R^2C^2}}=0}.$$

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Step 1 of 3

Refer to Figure P12.62 in the text book.

Determine the admittance of the circuit.

$$Y(j\omega)=(j\omega C)+\frac{1}{R}+\frac{1}{j\omega L}$$
$$=\frac{1}{R}+j\left(\omega C-\frac{1}{\omega L}\right)$$

Obtain the minimum admittance by equating the imaginary part of $Y(j\omega)$ is equal to zero.

Step 2 of 3

Equate the imaginary part of the admittance $Y(j\omega)$ to zero.

$$\left(\omega C-\frac{1}{\omega L}\right)=0$$
$$\frac{\omega^2 LC-1}{\omega L}=0$$
$$\omega^2 LC=1$$
$$\omega_M=\frac{1}{\sqrt{LC}}$$

Thus, the frequency ω_M at which the magnitude of impedance $Z(j\omega)$ is a maximum is $\boxed{\frac{1}{\sqrt{LC}}}$.

Step 3 of 3

Write the expression of the admittance of the circuit at the frequency ω_M.

$$Y(j\omega)=\frac{1}{R}$$

The expression for the impedance of the circuit at the frequency ω_M is,

$$Z(j\omega)=R$$

Calculate the phase of the impedance of the circuit at the frequency ω_M.

$$\angle Z(j\omega)=\tan^{-1}\left(\frac{0}{R}\right)$$
$$=\tan^{-1}(0)$$
$$=0°$$

Thus, the phase of the impedance of the circuit at the frequency ω_M is $\boxed{0°}$.

Step 1 of 4

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{1}{RC}$$

Substitute $80\ \mathrm{rad/s}$ for BW and $200\ \Omega$ for R.

$$80 = \frac{1}{(200)C}$$

$$C = \frac{1}{(200)(80)}$$

$$C = \frac{1}{16000}$$

$$C = 62.5\ \mu\mathrm{F}$$

Therefore, the value of the capacitor is $\boxed{62.5\ \mu\mathrm{F}}$.

Step 2 of 4

Consider the formula for the higher half power frequency in terms of the lower half power frequency and the bandwidth.

$$\omega_{\mathrm{HI}} = \omega_{\mathrm{LO}} + \mathrm{BW}$$

Substitute $80\ \mathrm{rad/s}$ for BW and $800\ \mathrm{rad/s}$ for ω_{LO}.

$$\begin{aligned}\omega_{\mathrm{HI}} &= 800 + 80\\ &= 880\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the higher half power frequency is $880\ \mathrm{rad/s}$.

Step 3 of 4

Consider the formula for the resonant frequency in terms of half power frequencies.

$$\omega_o = \sqrt{\omega_{\mathrm{HI}}\omega_{\mathrm{LO}}}$$

Substitute $880\ \mathrm{rad/s}$ for ω_{HI} and $800\ \mathrm{rad/s}$ for ω_{LO}.

$$\begin{aligned}\omega_o &= \sqrt{(880)(800)}\\ &= \sqrt{704000}\\ &= 839.05\ \mathrm{rad/s}\end{aligned}$$

Therefore, the value of the higher half power frequency is $839.05\ \mathrm{rad/s}$.

Step 4 of 4

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $62.5\ \mu\mathrm{F}$ for C and $839.05\ \mathrm{rad/s}$ for ω_0.

$$839.05 = \frac{1}{\sqrt{(62.5\ \mu)L}}$$

$$(839.05)^2 = \left(\frac{1}{\sqrt{(62.5\ \mu)L}}\right)^2$$

$$704\times10^3 = \frac{1}{(62.5\ \mu)L}$$

$$L = \frac{1}{(62.5\ \mu)(704\times10^3)}$$

$$\begin{aligned}L &= \frac{1}{44}\\ &= 22.73\ \mathrm{mH}\end{aligned}$$

Therefore, the value of the inductor is $\boxed{22.73\ \mathrm{mH}}$.

Step 1 of 6

Write the expression of the bandwidth of the parallel RLC circuit.

$$\mathrm{BW} = \frac{1}{RC}$$

Substitute $2\ \mathrm{k\Omega}$ for R and $10\ \mu\mathrm{F}$ for C.

$$\begin{aligned}\mathrm{BW} &= \frac{1}{(2\times10^{3})(10\times10^{-6})}\\ &= \frac{1}{20\times10^{-3}}\\ &= \frac{1000}{20}\\ &= 50\ \mathrm{rad/s}\end{aligned}$$

Thus, the bandwidth of the parallel RLC circuit is $\boxed{50\ \mathrm{rad/s}}$.

Step 2 of 6

Determine the quality factor of the parallel RLC circuit.

$$\begin{aligned}Q &= R\sqrt{\frac{C}{L}}\\ &= (2\times10^{3})\left(\sqrt{\frac{10\times10^{-6}}{100\times10^{-3}}}\right)\\ &= (2\times10^{3})(10^{-2})\\ &= 20\end{aligned}$$

Determine the resonant frequency of the parallel RLC circuit.

$$\begin{aligned}\omega_0 &= \frac{1}{\sqrt{LC}}\\ &= \frac{1}{\sqrt{(10\times10^{-6})(100\times10^{-3})}}\\ &= \frac{1}{10^{-3}}\\ &= 1000\ \mathrm{rad/s}\end{aligned}$$

Step 3 of 6

Write the expression of the upper half-power frequency.

$$\omega_{\mathrm{HI}} = \omega_0\left[\frac{1}{2Q} + \sqrt{\frac{1}{(2Q)^2}+1}\right]$$

Substitute 20 for Q and $1000\ \mathrm{rad/s}$ for ω_0.

$$\begin{aligned}\omega_{\mathrm{HI}} &= (1000)\left[\frac{1}{2(20)} + \sqrt{\frac{1}{(2(20))^2}+1}\right]\\ &= (1000)\left[\frac{1}{40} + \sqrt{\frac{1}{1600}+1}\right]\\ &= (1000)(1.0253)\\ &= 1025.3\ \mathrm{Hz}\end{aligned}$$

Step 4 of 6

Write the expression of the lower half-power frequency.

$$\omega_{\mathrm{LO}} = \omega_0\left[\frac{-1}{2Q} + \sqrt{\frac{1}{(2Q)^2}+1}\right]$$

Substitute 20 for Q and $1000\ \mathrm{rad/s}$ for ω_0.

$$\begin{aligned}\omega_{\mathrm{LO}} &= (1000)\left[\frac{-1}{2(20)} + \sqrt{\frac{1}{(2(20))^2}+1}\right]\\ &= (1000)\left[\frac{-1}{40} + \sqrt{\frac{1}{1600}+1}\right]\\ &= (1000)(0.9753)\\ &= 975.3\ \mathrm{Hz}\end{aligned}$$

Thus, the half-power frequencies are $\boxed{975.3\ \mathrm{Hz}}$ and $\boxed{1025.3\ \mathrm{Hz}}$.

Step 5 of 6

Refer to Figure 12.33 in the text book.

The admittance of the parallel RLC circuit is minimum at the resonant frequency.

The voltage response of the parallel RLC circuit is maximum at the resonant frequency.

Calculate the voltage of the parallel RLC circuit response at the resonant frequency.

$$\begin{aligned}V_{\max} &= IY\\ &= (4)\left(\frac{1}{R}\right)\\ &= (4)\left(\frac{1}{2\times10^{3}}\right)\\ &= 2\ \mathrm{mV}\end{aligned}$$

Step 6 of 6

The admittance of the parallel RLC circuit is increased by a factor of $\sqrt{2}$ at the half-power frequencies.
The voltage of the parallel RLC circuit is decreased by a factor of $\sqrt{2}$ at the half-power frequencies.

Calculate the voltage response of the parallel RLC circuit at the half-power frequencies.

$$\begin{aligned}V_{\text{half-power}} &= \frac{(V_{\max})}{\sqrt{2}}\\ &= \frac{(2\ \mathrm{mV})}{\sqrt{2}}\\ &= 2(0.707)\mathrm{mV}\\ &= 1.414\ \mathrm{mV}\end{aligned}$$

Thus, the voltage across the network at the half-power frequencies is $\boxed{1.414\ \mathrm{mV}}$.

Step 1 of 3

At resonance, the circuit acts as purely resistive circuit. Hence, the impedance value of the circuit is equal to the resistance value. Therefore, the value of the resistance in the circuit is $\boxed{2000\ \Omega}$.

Step 2 of 3

Consider the formula for the bandwidth BW.

$$\mathrm{BW} = \frac{1}{RC}$$

Substitute $20\ \mathrm{rad/s}$ for BW and $2000\ \Omega$ for R.

$$20 = \frac{1}{(2000)C}$$

$$C = \frac{1}{(2000)(20)}$$

$$C = \frac{1}{40000}$$

$$C = 25\ \mu\mathrm{F}$$

Therefore, the value of the capacitor is $\boxed{25\ \mu\mathrm{F}}$.

Step 3 of 3

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $25\ \mu\mathrm{F}$ for C and $2\ \mathrm{Mrad/s}$ for ω_0.

$$2\ \mathrm{M} = \frac{1}{\sqrt{(62.5\ \mu)L}}$$

$$(2\ \mathrm{M})^2 = \left(\frac{1}{\sqrt{(25\ \mu)L}}\right)^2$$

$$4\times10^{12} = \frac{1}{(25\ \mu)L}$$

$$L = \frac{1}{(25\ \mu)(4\times10^{12})}$$

$$L = \frac{1}{100\ \mathrm{M}}$$

$$= 10\ \mathrm{nH}$$

Therefore, the value of the inductor is $\boxed{10\ \mathrm{nH}}$.

Step 1 of 5

Consider Figure P12.54 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 5

Calculate the value of Z_{eq} .

$$Z_{eq} = \left(R_1 + \frac{1}{j\omega C}\right) \| \left(R_2 + j\omega L\right)$$

$$= \frac{\left(R_1 + \frac{1}{j\omega C}\right)\left(R_2 + j\omega L\right)}{R_1 + \frac{1}{j\omega C} + R_2 + j\omega L}$$

$$= \frac{R_1R_2 + \frac{L}{C} + j\omega R_1 L + \frac{R_2}{j\omega C}}{R_1 + + R_2 + j\omega L + \frac{1}{j\omega C}}$$

$$= \frac{R_1R_2 + \frac{L}{C} + j\left(\omega R_1 L - \frac{R_2}{\omega C}\right)}{R_1 + + R_2 + j\left(\omega L - \frac{1}{j\omega C}\right)}$$

Step 3 of 5

At resonance, the circuit resembles purely resistive circuit. Hence, the phasor terms of the impedance is equal to zero. That is,

$$\frac{\angle \tan^{-1}\left(\frac{\omega_0 R_1 L - \frac{R_2}{\omega_0 C}}{R_1R_2 + \frac{L}{C}}\right)}{\angle \tan^{-1}\left(\frac{\omega_0 L - \frac{1}{\omega_0 C}}{R_1 + R_2}\right)} = 0$$

$$\angle \tan^{-1}\left(\frac{\omega_0 R_1 L - \frac{R_2}{\omega_0 C}}{R_1R_2 + \frac{L}{C}}\right) - \angle \tan^{-1}\left(\frac{\omega_0 L - \frac{1}{\omega_0 C}}{R_1 + R_2}\right) = 0$$

$$\angle \tan^{-1}\left(\frac{\omega_0 R_1 L - \frac{R_2}{\omega_0 C}}{R_1R_2 + \frac{L}{C}}\right) = \angle \tan^{-1}\left(\frac{\omega_0 L - \frac{1}{\omega_0 C}}{R_1 + R_2}\right)$$

$$\frac{\omega_0 R_1 L - \frac{R_2}{\omega_0 C}}{R_1R_2 + \frac{L}{C}} = \frac{\omega_0 L - \frac{1}{\omega_0 C}}{R_1 + R_2}$$

Step 4 of 5

Substitute $2\ \text{rad/s}$ for ω_0 , $4\ \Omega$ for R_1 , $6\ \Omega$ for R_2 and $4\ \text{H}$ for L .

$$\frac{(2)(4)(4) - \frac{6}{(2)C}}{(4)(6) + \frac{(4)}{C}} = \frac{(2)(4) - \frac{1}{(2)C}}{4+6}$$

$$\frac{32 - \frac{3}{C}}{24 + \frac{4}{C}} = \frac{8 - \frac{1}{2C}}{10}$$

$$\frac{\frac{32C-3}{C}}{\frac{12C+4}{C}} = \frac{\frac{16C-1}{2C}}{10}$$

$$\frac{32C-3}{24C+4} = \frac{16C-1}{10(2C)}$$

$$\frac{32C-3}{6C+1} = \frac{16C-1}{5C}$$

$$(32C-3)(5C) = (16C-1)(6C+1)$$

$$160C^2 - 15C = 96C^2 + 10C - 1$$

$$64C^2 - 25C + 1 = 0$$

Step 5 of 5

Solve for C .

$$C = \frac{-(-25) \pm \sqrt{(-25)^2 - 4(64)(1)}}{2(64)}$$

$$= \frac{25 \pm \sqrt{625 - 256}}{128}$$

$$= \frac{25 \pm \sqrt{369}}{128}$$

$$= \frac{25 \pm 19.21}{128}$$

$$C = 0.1953 \pm 0.1501$$

Therefore,

$$C = 0.1953 + 0.1501$$
$$= 345.4\ \text{mF}$$

And

$$C = 0.1953 - 0.1501$$
$$= 45.2\ \text{mF}$$

Therefore, the values of the capacitor are $\boxed{345.4\ \text{mF}}$ and $\boxed{45.2\ \text{mF}}$.

Step 1 of 11

Consider Figure P12.52 from the text book.

Consider the formula for the resonant frequency in terms of inductor and capacitor.

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substitute $500\ \mu\text{F}$ for C and $1000\,\text{rad/s}$ for ω_0.

$$1000 = \frac{1}{\sqrt{(500\ \mu\text{F})L}}$$

$$(1000)^2 = \left(\frac{1}{\sqrt{(500\ \mu\text{F})L}}\right)^2$$

$$1\times10^6 = \frac{1}{(500\ \mu\text{F})L}$$

$$L = \frac{1}{(500\times10^{-6})(1\times10^6)}$$

$$L = \frac{1}{500}$$
$$= 2\ \text{mH}$$

Therefore, the value of the inductor is $\boxed{2\ \text{mH}}$.

Step 2 of 11

Consider the formula for the bandwidth BW.

$$\text{BW} = \frac{1}{RC}$$

Substitute $500\ \mu\text{F}$ for C and $200\ \Omega$ for R.

$$\text{BW} = \frac{1}{(500\ \mu\text{F})(200)}$$
$$= \frac{1}{0.1}$$
$$= 10\ \text{rad/s}$$

Therefore, the value of the bandwidth BW is $\boxed{10\ \text{rad/s}}$.

Step 3 of 11

Consider the formula for the quality factor Q of the circuit in terms of the resonant frequency and bandwidth.

$$Q = \frac{\omega_0}{\text{BW}}$$

Substitute $10\ \text{rad/s}$ for BW and $1000\ \text{rad/s}$ for ω_0.

$$Q = \frac{1000}{10}$$
$$= 100$$

Therefore, the value of the quality factor Q is $\boxed{100}$.

Step 4 of 11

Use superposition technique to calculate the value of the output voltage at each frequency of the source current.

Consider the circuit diagram represented in terms of phasor values as shown in Figure 1.

Figure 1

Step 5 of 11

Consider the expression for the admittance of the network at frequency of $1000\ \text{rad/s}$.

$$Y(j1000) = \frac{1}{R} + \frac{1}{(j1000)L} + (j1000)C$$

Substitute $200\ \Omega$ for R, $500\ \mu\text{F}$ for C and $2\ \text{mH}$ for L.

$$Y(j1000) = \frac{1}{200} + \frac{1}{(j1000)(2\ \text{m})} + (j1000)(500\ \mu)$$
$$= 0.005 + \frac{1}{j2} + j0.5$$
$$= 0.005 - j0.5 + j(9.5125\ \text{m})$$
$$= 5\ \text{mS}$$

Therefore, the value of the admittance at frequency of $1000\ \text{rad/s}$ is $5\ \text{mS}$.

Step 6 of 11

Consider the expression for the voltage across the network at frequency of $1000\ \text{rad/s}$.

$$\text{V}_1(j\omega) = \frac{1\angle0^\circ}{Y(j1000)}$$

Substitute $5\ \text{mS}$ for $Y(j1000)$.

$$\text{V}_1(j\omega) = \frac{1\angle0}{5\ \text{m}}$$
$$= 200\ \text{V}$$

Step 7 of 11

Convert the voltage to time domain.

$$v_1(t) = 200\cos1000t\ \text{V}$$

Therefore, the value of the voltage across the network at frequency of $1000\ \text{rad/s}$ is

$200\cos1000t\ \text{V}$.

Step 8 of 11

Consider the circuit diagram represented in terms of phasor values as shown in Figure 2.

Figure 2

Step 9 of 11

Consider the expression for the admittance of the network at frequency of $1500\ \text{rad/s}$.

$$Y(j1500) = \frac{1}{R} + \frac{1}{(j1500)L} + (j1500)C$$

Substitute $200\ \Omega$ for R, $500\ \mu\text{F}$ for C and $2\ \text{mH}$ for L.

$$Y(j1500) = \frac{1}{200} + \frac{1}{(j1500)(2\ \text{m})} + (j1500)(500\ \mu)$$
$$= 0.005 + \frac{1}{j3} + j0.75$$
$$= 0.005 - j0.33 + j0.75$$
$$= 0.005 + j0.42\ \text{S}$$

Therefore, the value of the admittance at frequency of $1500\ \text{rad/s}$ is $0.005 + j0.42\ \text{S}$.

Step 10 of 11

Consider the expression for the voltage across the network at frequency of $1500\ \text{rad/s}$.

$$\text{V}_2(j\omega) = \frac{1\angle0^\circ}{Y(j1500)}$$

Substitute $0.005 + j0.42\ \text{S}$ for $Y(j1500)$.

$$\text{V}_2(j\omega) = \frac{1\angle0}{0.005 + j0.42}$$
$$= \frac{1\angle0}{0.42\angle89.32^\circ}$$
$$= 2.38\angle-89.32^\circ\ \text{V}$$

Convert the voltage to time domain.

$$v_2(t) = 2.38\cos1500t\ \text{V}$$

Therefore, the value of the voltage across the network at frequency of $1500\ \text{rad/s}$ is

$2.38\cos1500t\ \text{V}$.

Step 11 of 11

Consider the expression for the total output voltage.

$$v_o(t) = v_1(t) + v_2(t)$$

Substitute $2.38\cos1500t\ \text{V}$ for $v_2(t)$ and $200\cos1000t\ \text{V}$ for $v_1(t)$.

$$v_o(t) = 200\cos1000t + 2.38\cos1500t\ \text{V}$$

Therefore, the value of the output voltage is $\boxed{200\cos1000t + 2.38\cos1500t\ \text{V}}$.

The difference in the magnitude values of two output voltages $v_1(t)$ and $v_2(t)$ are due to the values of the admittances due to the frequencies $1000\ \text{rad/s}$ and $1500\ \text{rad/s}$ respectively.

Step 1 of 3

Refer to Figure P12.56 in the text book.

The new resonant frequency of the circuit is,

$$\omega_{new} = 10^4 \omega_{old}$$

Compare the equation with $\omega_{new} = k_f \omega_{old}$.

Where,

k_f is the scaled factor

The value of the scaled factor is,

$$k_f = 10^4$$

Compute the expression for the new resonant frequency using scaled factor.

$$\begin{aligned}\omega_{new} &= k_f \omega_{old} \\ &= k_f \left(\frac{1}{\sqrt{LC}} \right) \\ &= \frac{1}{\sqrt{\frac{LC}{(k_f)^2}}}\end{aligned}$$

$$\omega_{new} = \frac{1}{\sqrt{\left(\frac{L}{k_f}\right)\left(\frac{C}{k_f}\right)}} \quad \text{..... (1)}$$

Step 2 of 3

Consider the other expression for new resonant frequency.

$$\omega_{new} = \frac{1}{\sqrt{L_{new} C_{new}}} \quad \text{..... (2)}$$

Compare equation (1) and equation (2).

Calculate the new value of the inductor, L_{new} .

$$L_{new} = \frac{L}{k_f}$$

Substitute $\frac{1}{2}$ H for L and 10^4 for k_f .

$$\begin{aligned}L_{new} &= \frac{\frac{1}{2}}{10^4} \\ &= 50 \times 10^{-6} \\ &= 50\ \mu\text{H}\end{aligned}$$

Thus, the new value of the inductor, L_{new} is $\boxed{50\ \mu\text{H}}$.

Step 3 of 3

Calculate the new value of the capacitor, C_{new} .

$$C_{new} = \frac{C}{k_f}$$

Substitute $\frac{1}{8}$ F for C and 10^4 for k_f .

$$\begin{aligned}C_{new} &= \frac{\frac{1}{8}}{10^4} \\ &= 12.5 \times 10^{-6} \\ &= 12.5\ \mu\text{F}\end{aligned}$$

Thus, the new value of the capacitor, C_{new} is $\boxed{12.5\ \mu\text{F}}$.

The value of the resistor is independent of the resonant frequency. So, the value of the resistor is not changed.

$$\begin{aligned}R_{new} &= R \\ &= 2\ \Omega\end{aligned}$$

Thus, the new value of the resistor, R_{new} is $\boxed{2\ \Omega}$.

12.069
P

Step 1 of 4

Consider Figure P12.57 from the text book.

Consider the expression for the scaling factor.

$$K = \frac{\mathbf{Z}_{new}}{\mathbf{Z}_{old}}$$

Substitute $10^4 \mathbf{Z}_{old}$ for $\mathbf{Z}_{new}$.

$$\begin{aligned} K &= \frac{10^4 \mathbf{Z}_{old}}{\mathbf{Z}_{old}} \\ &= 10^4 \end{aligned}$$

Therefore, the value of the scaling factor is 10^4.

Step 2 of 4

Consider the expression for the new value of the resistance.

$$R_{new} = KR_{old}$$

Substitute $2\ \Omega$ for R_{old} and 10^4 for K

$$\begin{aligned} R_{new} &= (10^4)(2) \\ &= 20\ \text{k}\Omega \end{aligned}$$

Therefore, the new value of the resistance is $\boxed{20\ \text{k}\Omega}$.

Step 3 of 4

Consider the expression for the new value of the inductance.

$$L_{new} = KL_{old}$$

Substitute $\frac{1}{2}$ H for L_{old} and 10^4 for K

$$\begin{aligned} L_{new} &= (10^4)\left(\frac{1}{2}\right) \\ &= 5\ \text{kH} \end{aligned}$$

Therefore, the new value of the inductance is $\boxed{5\ \text{kH}}$.

Step 4 of 4

Consider the expression for the new value of the capacitance.

$$C_{new} = \frac{C_{old}}{K}$$

Substitute $\frac{1}{8}$ F for C_{old} and 10^4 for K

$$\begin{aligned} C_{new} &= \left(\frac{1}{8}\right)\left(\frac{1}{10^4}\right) \\ &= 12.5\ \mu\text{F} \end{aligned}$$

Therefore, the new value of the capacitance is $\boxed{12.5\ \mu\text{F}}$.

Step 1 of 3

12.070
P

Refer to Figure P12.70 in the textbook for the network.

Draw the circuit in frequency domain representation.

Figure 1

Step 2 of 3

Apply voltage divider rule.

$$\mathbf{V}_o(j\omega)=\left(\frac{R_2+\frac{1}{j\omega C}}{R_1+R_2+\frac{1}{j\omega C}}\right)\mathbf{V}_i(j\omega)$$

The voltage transfer function of the Figure 1 is,

$$\begin{aligned}\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)}&=\frac{R_2+\frac{1}{j\omega C}}{R_1+R_2+\frac{1}{j\omega C}}\\&=\frac{\frac{j\omega CR_2+1}{j\omega C}}{\frac{j\omega C(R_1+R_2)+1}{j\omega C}}\\&=\frac{j\omega CR_2+1}{j\omega C(R_1+R_2)+1}\end{aligned}$$

Therefore, the voltage transfer function of the network is, $\boxed{\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)}=\frac{j\omega CR_2+1}{j\omega C(R_1+R_2)+1}}$.

Step 3 of 3

Substitute 0 for $j\omega$ in the voltage transfer function.

$$\begin{aligned}\frac{\mathbf{V}_o(0)}{\mathbf{V}_i(0)}&=\frac{(0)CR_2+1}{(0)C(R_1+R_2)+1}\\&=\frac{0+1}{0+1}\\&=1\end{aligned}$$

Substitute ∞ for $j\omega$ in the voltage transfer function.

$$\begin{aligned}\frac{\mathbf{V}_o(\infty)}{\mathbf{V}_i(\infty)}&=\frac{j\omega CR_2+1}{j\omega C(R_1+R_2)+1}\\&=\frac{CR_2+\frac{1}{j\omega}}{C(R_1+R_2)+\frac{1}{j\omega}}\\&=\frac{CR_2+0}{C(R_1+R_2)+0}\\&=\frac{R_2}{R_1+R_2}\end{aligned}$$

Here, observe that the frequency response is maximum at zero frequency and minimum at infinity. So, network represents low pass filter type.

Therefore, the type of the filter that the network represents is, $\boxed{\text{the low pass filter}}$.

Step 1 of 4

Consider Figure P12.60 from the text book.

Consider the circuit diagram in terms of the phasor representation of the parameters.

Figure 1

Step 2 of 4

Consider the expression for the $\mathbf{V}_o(j\omega)$ in terms of $\mathbf{V}_i(j\omega)$ using voltage division rule.

$$\begin{aligned}
\mathbf{V}_o(j\omega) &= \mathbf{V}_i(j\omega)\left(\frac{R_2}{R_1 \parallel \frac{1}{j\omega C} + R_2}\right) \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2}{\left(\frac{\frac{R_1}{j\omega C}}{R_1 + \frac{1}{j\omega C}}\right) + R_2} \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2}{\frac{\frac{R_1}{j\omega C}}{\frac{j\omega CR_1 + 1}{j\omega C}} + R_2} \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2}{\frac{R_1}{j\omega CR_1 + 1} + R_2}
\end{aligned}$$

$$\begin{aligned}
\mathbf{V}_o(j\omega) &= \mathbf{V}_i(j\omega)\left(\frac{R_2(j\omega CR_1 + 1)}{R_1 + R_2(j\omega CR_1 + 1)}\right) \\
&= \mathbf{V}_i(j\omega)\left(\frac{CR_1R_2\left(j\omega + \frac{1}{CR_1}\right)}{j\omega CR_1R_2 + R_1 + R_2}\right) \\
&= \mathbf{V}_i(j\omega)\left(\frac{CR_1R_2\left(j\omega + \frac{1}{CR_1}\right)}{CR_1R_2\left(j\omega + \frac{R_1 + R_2}{CR_1R_2}\right)}\right) \\
&= \mathbf{V}_i(j\omega)\left(\frac{j\omega + \frac{1}{CR_1}}{j\omega + \frac{R_1 + R_2}{CR_1R_2}}\right)
\end{aligned}$$

$$\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} = \frac{j\omega + \frac{1}{CR_1}}{j\omega + \frac{1}{(R_1 \parallel R_2)C}} \quad \text{..... (1)}$$

Therefore, the voltage transfer function of the network is $\boxed{\frac{j\omega + \frac{1}{CR_1}}{j\omega + \frac{1}{(R_1 \parallel R_2)C}}}$.

Step 3 of 4

Recall equation (1).

$$\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} = \frac{j\omega + \frac{1}{CR_1}}{j\omega + \frac{1}{(R_1 \parallel R_2)C}}$$

Assume ω to be $0\ \text{rad/s}$.

$$\begin{aligned}
\frac{\mathbf{V}_o(0)}{\mathbf{V}_i(0)} &= \frac{0 + \frac{1}{CR_1}}{0 + \frac{1}{(R_1 \parallel R_2)C}} \\
&= \frac{\frac{1}{CR_1}}{\frac{R_1 + R_2}{(R_1R_2)C}} \\
&= \frac{R_2}{R_1 + R_2}
\end{aligned}$$

Notice that $\frac{\mathbf{V}_o(0)}{\mathbf{V}_i(0)}$ is less than 1 what so ever the values of R_1 and R_2.

Step 4 of 4

Recall equation (1).

$$\begin{aligned}
\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} &= \frac{j\omega + \frac{1}{CR_1}}{j\omega + \frac{1}{(R_1 \parallel R_2)C}} \\
&= \frac{j\omega\left(1 + \frac{1}{j\omega CR_1}\right)}{j\omega\left(1 + \frac{1}{j\omega(R_1 \parallel R_2)C}\right)} \\
&= \frac{1 + \frac{1}{j\omega CR_1}}{1 + \frac{1}{j\omega(R_1 \parallel R_2)C}}
\end{aligned}$$

Assume ω to be $\infty\ \text{rad/s}$.

$$\begin{aligned}
\frac{\mathbf{V}_o(\infty)}{\mathbf{V}_i(\infty)} &= \frac{1 + \frac{1}{(\infty)CR_1}}{1 + \frac{1}{(\infty)(R_1 \parallel R_2)C}} \\
&= \frac{1 + 0}{1 + 0} \\
&= 1
\end{aligned}$$

Therefore, the value of the transfer function at $\omega = \infty\ \text{rad/s}$ is 1.

The value of the voltage gain increases with the increase in the value of ω, which represents the characteristics of a high pass filter. Hence, the network is a

$\boxed{\text{high pass filter}}$.

Step 1 of 10

Consider Figure P12.59 from the text book.

Consider Figure 1.

Figure 1

Step 2 of 10

Consider the expression for output voltage.

$$\mathbf{V}_o = \mathbf{V}_I\left(\frac{100 \parallel \frac{1}{s(1\text{ m})}}{\left(100 \parallel \frac{1}{s(1\text{ m})}\right)+10s}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{\frac{\frac{100}{s(1\text{ m})}}{100+\frac{1}{s(1\text{ m})}}}{\frac{\frac{100}{s(1\text{ m})}}{100+\frac{1}{s(1\text{ m})}}+10s}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{\frac{\frac{100}{s(1\text{ m})}}{\frac{0.1s+1}{s(1\text{ m})}}}{\frac{\frac{100}{s(1\text{ m})}}{\frac{0.1s+1}{s(1\text{ m})}}+10s}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{\frac{100}{0.1s+1}}{\frac{100}{0.1s+1}+10s}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{\frac{100}{0.1s+1}}{\frac{100}{0.1s+1}+10s}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{\frac{100}{0.1s+1}}{100+10s(0.1s+1)}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{0.1s+1}{100+10s(0.1s+1)}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(s) = \frac{100}{s^2+10s+100}$$

Substitute $j\omega$ for s .

$$\frac{\mathbf{V}_o}{\mathbf{V}_I}(j\omega) = \frac{100}{(j\omega)^2+10(j\omega)+100}$$

Therefore, the expression for $\frac{\mathbf{V}_o}{\mathbf{V}_I}(j\omega)$ is $\frac{100}{(j\omega)^2+10(j\omega)+100}$.

Step 3 of 10

Define the transfer function.

$$\mathbf{G}_v(j\omega) = \frac{100}{(j\omega)^2+10(j\omega)+100}$$

$$= \frac{100}{(100)\left(\left(\frac{j\omega}{10}\right)^2+\left(\frac{j\omega}{10}\right)+1\right)}$$

$$= \frac{1}{\left(\frac{j\omega}{10}\right)^2+\left(\frac{j\omega}{10}\right)+1}$$

Magnitude plot analysis:

Consider Table-1 to calculate the frequencies and slopes for different terms in the function.

Table-1

Term	Corner frequency (rad/s)	Slope (dB/dec)	Change in slope (dB/dec)
1	-	0	-
$\frac{1}{\left(\frac{j\omega}{10}\right)^2+\frac{j\omega}{10}+1}$	$\omega_{c1} = 10\text{ rad/s}$	-40 (Due to Quadratic pole)	$\Delta\omega_1 = -40+0 = -40$

Step 4 of 10

Assume a lower corner frequency ω_l such that $\omega_l \ll \omega_{c1}$. Let ω_l to be 0.01 rad/s .

Assume a higher corner frequency ω_h such that $\omega_h \gg \omega_{c2}$. Let ω_h to be 100 rad/s .

Calculate the magnitude value at the corner frequency of 0.01 rad/s .

$$A_{\omega_l} = 20\log(1) = 0\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 0.01 rad/s is 0 dB .

Step 5 of 10

Calculate the magnitude value at the corner frequency of 10 rad/s .

$$A_{\omega_{c1}} = 20\log(1) = 0\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 10 rad/s is 0 dB .

Step 6 of 10

Calculate the magnitude value at the corner frequency of 100 rad/s .

$$A_{\omega_h} = \left[\Delta\omega_1 \times \log\frac{\omega_h}{\omega_{c1}}\right] + A_{\omega_{c1}}$$

Substitute -40 db/dec for $\Delta\omega_1$, 100 rad/s for ω_h , 10 rad/s for ω_{c1} and 0 dB for $A_{\omega_{c1}}$.

$$A_{\omega_h} = \left[-40\times\log\frac{100}{10}\right]+0 = -40\text{ dB}$$

Therefore, the magnitude value at the corner frequency of 100 rad/s is -40 dB .

Step 7 of 10

Consider the term of quadratic poles.

$$\left(\frac{j\omega}{10}\right)^2+\frac{j\omega}{10}+1$$

Compare to $\left(\frac{j\omega}{\omega_n}\right)^2+\frac{j2\xi\omega}{\omega_n}+1$.

$$\omega_n = 10\text{ rad/s}$$

and

$$\frac{2\xi}{\omega_n} = \frac{1}{10} \quad \text{..... (1)}$$

Step 8 of 10

Consider expression (1).

$$\frac{2\xi}{\omega_n} = \frac{1}{10}$$

Substitute 10 rad/s for ω_n .

$$\frac{2\xi}{10} = \frac{1}{10}$$

$$2\xi = 1$$

$$\xi = \frac{1}{2}$$

Therefore, the value of damping ratio ξ is $\frac{1}{2}$.

Step 9 of 10

Calculate the value of magnitude due to the damping ratio at 10 rad/s .

$$\mathbf{G}(10) = 20\log\left(\frac{1}{2\xi}\right)$$

Substitute $\frac{1}{2}$ for ξ .

$$\mathbf{G}(10) = 20\log\left(\frac{1}{2\left(\frac{1}{2}\right)}\right) = 20\log(1) = 0\text{ dB}$$

Therefore, the actual magnitude value at 10 rad/s is 0 dB .

Step 10 of 10

Consider the magnitude characteristic of the bode plot shown in Figure 2.

Figure 2

Therefore, the required magnitude characteristic of bode plot is shown in Figure 2.

Step 1 of 4

Consider Figure P12.61 from the text book.

Figure 1

Step 2 of 4

Consider the expression for the $\mathbf{V}_o(j\omega)$ in terms of $\mathbf{V}_i(j\omega)$ using voltage division rule.

$$\begin{aligned}
\mathbf{V}_o(j\omega) &= \mathbf{V}_i(j\omega)\left(\frac{R_2}{R_1 \parallel j\omega L + R_2}\right) \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2}{\left(\frac{j\omega L R_1}{R_1 + j\omega L}\right) + R_2} \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2(R_1 + j\omega L)}{j\omega L R_1 + R_2(R_1 + j\omega L)} \\
&= \mathbf{V}_i(j\omega)\cdot\frac{R_2 L\left(j\omega + \frac{R_1}{L}\right)}{j\omega L R_1 + R_1 R_2 + j\omega L R_2}
\end{aligned}$$

$$\begin{aligned}
\mathbf{V}_o(j\omega) &= \mathbf{V}_i(j\omega)\cdot\frac{R_2 L\left(j\omega + \frac{R_1}{L}\right)}{R_1 R_2 + j\omega L(R_1 + R_2)} \\
&= \mathbf{V}_i(j\omega)\left(\frac{R_2 L\left(j\omega + \frac{R_1}{L}\right)}{R_1 R_2 + j\omega L(R_1 + R_2)}\right) \\
&= \mathbf{V}_i(j\omega)\left(\frac{R_2 L\left(j\omega + \frac{R_1}{L}\right)}{L(R_1 + R_2)\left(j\omega + \frac{R_1 R_2}{L(R_1 + R_2)}\right)}\right) \\
&= \mathbf{V}_i(j\omega)\left(\frac{R_2\left(j\omega + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(j\omega + \frac{R_1 \parallel R_2}{L}\right)}\right)
\end{aligned}$$

$$\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} = \frac{R_2\left(j\omega + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(j\omega + \frac{R_1 \parallel R_2}{L}\right)} \quad \text{..... (1)}$$

Therefore, the voltage transfer function of the network is $\boxed{\dfrac{R_2\left(j\omega + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(j\omega + \frac{R_1 \parallel R_2}{L}\right)}}$.

Step 3 of 4

Recall equation (1).

$$\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} = \frac{R_2\left(j\omega + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(j\omega + \frac{R_1 \parallel R_2}{L}\right)}$$

Assume ω to be 0 rad/s .

$$\begin{aligned}
\frac{\mathbf{V}_o(0)}{\mathbf{V}_i(0)} &= \frac{R_2\left(0 + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(0 + \frac{R_1 \parallel R_2}{L}\right)} \\
&= \frac{\frac{R_2 R_1}{L}}{(R_1 + R_2)\left(\frac{R_1 R_2}{(R_1 + R_2)L}\right)} \\
&= 1
\end{aligned}$$

Therefore, the value of the transfer function at $\omega = 0$ rad/s is 1 .

Step 4 of 4

Recall equation (1).

$$\begin{aligned}
\frac{\mathbf{V}_o(j\omega)}{\mathbf{V}_i(j\omega)} &= \frac{R_2\left(j\omega + \frac{R_1}{L}\right)}{(R_1 + R_2)\left(j\omega + \frac{R_1 \parallel R_2}{L}\right)} \\
&= \frac{j\omega R_2\left(1 + \frac{R_1}{j\omega L}\right)}{j\omega(R_1 + R_2)\left(1 + \frac{R_1 \parallel R_2}{j\omega L}\right)} \\
&= \frac{R_2\left(1 + \frac{R_1}{j\omega L}\right)}{(R_1 + R_2)\left(1 + \frac{R_1 \parallel R_2}{j\omega L}\right)}
\end{aligned}$$

Assume ω to be ∞ rad/s .

$$\begin{aligned}
\frac{\mathbf{V}_o(\infty)}{\mathbf{V}_i(\infty)} &= \frac{R_2\left(1 + \frac{R_1}{(\infty)L}\right)}{(R_1 + R_2)\left(1 + \frac{R_1 \parallel R_2}{(\infty)L}\right)} \\
&= \frac{R_2(1 + 0)}{(R_1 + R_2)(1 + 0)} \\
&= \frac{R_2}{R_1 + R_2}
\end{aligned}$$

Notice that $\dfrac{\mathbf{V}_o(\infty)}{\mathbf{V}_i(\infty)}$ is less than 1 what so ever the values of R_1 and R_2 .

The value of the voltage gain decreases with the increase in the value of ω , which represents the characteristics of a low pass filter. Hence, the network is a

$\boxed{\text{low pass filter}}$.

Step 1 of 5

Refer to circuit diagram in Figure P12.62 in the textbook.

Compare the circuit in the Figure P12.62 with the circuit in the Figure 1.

Figure 1: Equivalent of the circuit in the Figure P12.62

Step 2 of 5

From the circuit in the Figure 1,

$$Z_L = j\omega(10)\Omega,$$

$$Z_C = \frac{1000}{j\omega}\Omega,$$

$$R = 100\Omega$$

The total impedance of output can be calculated as follows:

$$\begin{aligned} Z &= \frac{R \cdot Z_L}{R + Z_L} \\ &= \frac{100 \cdot j\omega(10)}{100 + j\omega(10)} \\ &= \frac{100 \cdot j\omega}{10 + j\omega} \end{aligned}$$

Step 3 of 5

Calculate the transfer function, $G_v(j\omega)$.

$$\begin{aligned} G_v(j\omega) &= \frac{V_o}{V_i}(j\omega) \\ &= \frac{Z}{Z + Z_C} \\ &= \frac{\dfrac{(100)(j\omega)}{10 + j\omega}}{\dfrac{(100)(j\omega)}{10 + j\omega} + \dfrac{1000}{j\omega}} \\ &= \frac{\left(\dfrac{j\omega}{10 + j\omega}\right)}{\dfrac{j\omega}{10 + j\omega} + \dfrac{10}{j\omega}} \end{aligned}$$

$$\begin{aligned} &= \frac{\dfrac{j\omega}{10 + j\omega}}{\dfrac{(j\omega)^2 + 10(10 + j\omega)}{(10 + j\omega)(j\omega)}} \\ &= \frac{(j\omega)^2}{(j\omega)^2 + 10(10 + j\omega)} \\ &= \frac{(j\omega)^2}{(j\omega)^2 + 10j\omega + 100} \end{aligned}$$

Step 4 of 5

Compare the obtained transfer function with the second order general transfer function.

$$\omega_c = 10,$$
$$2\zeta\omega_c = 10$$
$$2\zeta(10) = 10$$

$$\begin{aligned} \zeta &= \frac{1}{2} \\ &= 0.5 \end{aligned}$$

The sketch of the transfer characteristics of the filter is as shown in the Figure 2.

Figure 2

Step 5 of 5

Therefore, the required sketch of the transfer characteristics is shown in Figure 2.
The filter is a high pass filter.

Step 1 of 6

Consider Figure P12.63 from the text book.

Consider the circuit diagram shown in Figure 1.

Figure 1

Step 2 of 6

Consider the expression for V_1 using current division rule.

$$\begin{aligned} V_1 &= V_i(j\omega)\left(\frac{R_1}{R_1+R_1}\right) \\ &= V_i(j\omega)\left(\frac{R_1}{2R_1}\right) \\ &= \frac{V_i(j\omega)}{2} \end{aligned}$$

Therefore, the expression for the voltage V_1 is $\frac{V_i(j\omega)}{2}$.

Step 3 of 6

Consider the expression for V_2 using current division rule.

$$\begin{aligned} V_2 &= V_i(j\omega)\left(\frac{R_2}{R_2+\frac{1}{j\omega C}}\right) \\ &= V_i(j\omega)\left(\frac{j\omega CR_1}{j\omega CR_1+1}\right) \end{aligned}$$

Therefore, the expression for the voltage V_2 is $V_i(j\omega)\left(\frac{j\omega CR_1}{j\omega CR_1+1}\right)$.

Step 4 of 6

Consider the expression for $V_o(j\omega)$.

$$V_o(j\omega) = V_1 - V_2$$

Substitute $V_i(j\omega)\left(\frac{j\omega CR_1}{j\omega CR_1+1}\right)$ for V_2 and $\frac{V_i(j\omega)}{2}$ for V_1.

$$\begin{aligned} V_o(j\omega) &= \frac{V_i(j\omega)}{2} - V_i(j\omega)\left(\frac{j\omega CR_1}{j\omega CR_1+1}\right) \\ &= V_i(j\omega)\left(\frac{1}{2} - \frac{j\omega CR_1}{j\omega CR_1+1}\right) \\ &= V_i(j\omega)\left(\frac{j\omega CR_1+1-2j\omega CR_1}{2(j\omega CR_1+1)}\right) \\ &= V_i(j\omega)\left(\frac{1-j\omega CR_1}{2(j\omega CR_1+1)}\right) \end{aligned}$$

$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{1-j\omega CR_1}{2(j\omega CR_1+1)} \quad \text{..... (1)}$$

Therefore, the voltage transfer function of the network is $\boxed{\frac{1-j\omega CR_1}{2(j\omega CR_1+1)}}$.

Step 5 of 6

Recall equation (1).

$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{1-j\omega CR_1}{2(j\omega CR_1+1)}$$

Consider absolute value of the transfer function.

$$\left|\frac{V_o(j\omega)}{V_i(j\omega)}\right| = \left|\frac{1-j\omega CR_1}{2(j\omega CR_1+1)}\right|$$

Assume ω to be 0 rad/s.

$$\begin{aligned} \left|\frac{V_o(0)}{V_i(0)}\right| &= \left|\frac{1-(0)CR_1}{2((0)CR_1+1)}\right| \\ &= \left|\frac{1}{(2)(1)}\right| \\ &= \frac{1}{2} \end{aligned}$$

Therefore, the value of the transfer function at $\omega = 0$ rad/s is $\frac{1}{2}$.

Step 6 of 6

Recall equation (1).

$$\begin{aligned} \frac{V_o(j\omega)}{V_i(j\omega)} &= \frac{1-j\omega CR_1}{2(j\omega CR_1+1)} \\ &= \frac{j\omega\left(\frac{1}{j\omega}-CR_1\right)}{2j\omega\left(CR_1+\frac{1}{j\omega}\right)} \\ &= \frac{\left(\frac{1}{j\omega}-CR_1\right)}{2\left(CR_1+\frac{1}{j\omega}\right)} \end{aligned}$$

Consider absolute value of the transfer function.

$$\left|\frac{V_o(j\omega)}{V_i(j\omega)}\right| = \left|\frac{\left(\frac{1}{j\omega}-CR_1\right)}{2\left(CR_1+\frac{1}{j\omega}\right)}\right|$$

Assume ω to be ∞ rad/s.

$$\begin{aligned} \left|\frac{V_o(\infty)}{V_i(\infty)}\right| &= \left|\frac{\left(\frac{1}{\infty}-CR_1\right)}{2\left(CR_1+\frac{1}{\infty}\right)}\right| \\ &= \left|\frac{(0-CR_1)}{2(CR_1+0)}\right| \\ &= \left|\frac{(0-CR_1)}{2(CR_1+0)}\right| \\ &= \left|\frac{-1}{2}\right| \end{aligned}$$

$$\left|\frac{V_o(\infty)}{V_i(\infty)}\right| = \frac{1}{2}$$

Therefore, the value of the transfer function at $\omega = \infty$ rad/s is $\frac{1}{2}$.

The absolute value of the voltage gain remains for any value of ω. Hence, the network is an $\boxed{\text{all pass filter}}$.

Step 1 of 6

Consider Figure P12.64 from the text book.

Consider the Figure 1.

Figure 1

Step 2 of 6

Consider the nodal equation at node 1.

$$\frac{V_1(s)-V_i(s)}{R}+\frac{V_1(s)}{\frac{1}{2Cs}}+\frac{V_1(s)-V_o(s)}{R}=0$$

$$\frac{V_1(s)-V_i(s)}{R}+2CsV_1(s)+\frac{V_1(s)-V_o(s)}{R}=0$$

$$V_1(s)\left(\frac{1}{R}+2Cs+\frac{1}{R}\right)-\frac{V_i(s)}{R}-\frac{V_o(s)}{R}=0$$

$$V_1(s)\left(\frac{2}{R}+2Cs\right)=\frac{V_i(s)}{R}+\frac{V_o(s)}{R}$$

$$V_1(s)\left(\frac{2+2sCR}{R}\right)=\frac{V_i(s)+V_o(s)}{R}$$

$$V_1(s)(2+2sCR)=V_i(s)+V_o(s)$$

$$V_1(s)=\frac{V_i(s)+V_o(s)}{2(1+sCR)}$$

Therefore, the expression for $V_1(s)$ is $\frac{V_i(s)+V_o(s)}{2(1+sCR)}$.

Step 3 of 6

Consider the nodal equation at node 2.

$$\frac{V_2(s)-V_i(s)}{\frac{1}{sC}}+\frac{V_2(s)}{\frac{R}{2}}+\frac{V_1(s)-V_o(s)}{\frac{1}{sC}}=0$$

$$sC\left(V_2(s)-V_i(s)\right)+\frac{2}{R}V_1(s)+sC\left(V_2(s)-V_o(s)\right)=0$$

$$V_2(s)\left(sC+sC+\frac{2}{R}\right)-sCV_i(s)-sCV_o(s)=0$$

$$V_2(s)\left(\frac{2}{R}+2sC\right)=sCV_i(s)+sCV_o(s)$$

$$V_2(s)\left(\frac{2+2sCR}{R}\right)=sC\left(V_i(s)+V_o(s)\right)$$

$$V_2(s)(2+2sCR)=sCR\left(V_i(s)+V_o(s)\right)$$

$$V_2(s)=\frac{sCR\left(V_i(s)+V_o(s)\right)}{2+2sCR}$$

$$V_2(s)=\frac{V_i(s)+V_o(s)}{2\left(1+\frac{1}{sCR}\right)}$$

Therefore, the expression for $V_2(s)$ is $\frac{V_i(s)+V_o(s)}{2\left(1+\frac{1}{sCR}\right)}$.

Step 4 of 6

Consider the nodal equation at node 3.

$$\frac{V_o(s)-V_1(s)}{R}+\frac{V_o(s)-V_2(s)}{\frac{1}{sC}}=0$$

$$\frac{V_o(s)-V_1(s)}{R}+sC\left(V_o(s)-V_2(s)\right)=0$$

Step 5 of 6

Substitute $\frac{V_i(s)+V_o(s)}{2\left(1+\frac{1}{sCR}\right)}$ for $V_2(s)$ and $\frac{V_i(s)+V_o(s)}{2(1+sCR)}$ for $V_1(s)$.

$$\frac{1}{R}\left(V_o(s)-\left(\frac{V_i(s)+V_o(s)}{2(1+sCR)}\right)\right)+sC\left(V_o(s)-\left(\frac{V_i(s)+V_o(s)}{2\left(1+\frac{1}{sCR}\right)}\right)\right)=0$$

$$\frac{1}{R}\left(V_o(s)-\frac{V_i(s)}{2(1+sCR)}-\frac{V_o(s)}{2(1+sCR)}\right)+sC\left(V_o(s)-\frac{V_i(s)}{2\left(1+\frac{1}{sCR}\right)}-\frac{V_o(s)}{2\left(1+\frac{1}{sCR}\right)}\right)=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(1-\frac{1}{2(1+sCR)}\right)-\frac{V_i(s)}{2(1+sCR)}\right)+\\ sC\left(V_o(s)\left(1-\frac{1}{2\left(1+\frac{1}{sCR}\right)}\right)-\frac{V_i(s)}{2\left(1+\frac{1}{sCR}\right)}\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(\frac{2(1+sCR)-1}{2(1+sCR)}\right)-\frac{V_i(s)}{2(1+sCR)}\right)+\\ sC\left(V_o(s)\left(\frac{2\left(1+\frac{1}{sCR}\right)-1}{2\left(\frac{sCR+1}{sCR}\right)}\right)-\frac{V_i(s)}{2\left(\frac{sCR+1}{sCR}\right)}\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(\frac{2(1+sCR)-1}{2(1+sCR)}\right)-\frac{V_i(s)}{2(1+sCR)}\right)+\\ sC\left(V_o(s)(sCR)\left(\frac{2\left(1+\frac{1}{sCR}\right)-1}{2(sCR+1)}\right)-\frac{V_i(s)(sCR)}{2(sCR+1)}\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(2(1+sCR)-1\right)-V_i(s)\right)+\\ sC\left(V_o(s)(sCR)\left(2\left(1+\frac{1}{sCR}\right)-1\right)-V_i(s)(sCR)\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(2(1+sCR)-1\right)-V_i(s)\right)+\\ sC\left(V_o(s)(sCR)\left(\frac{2(sCR+1)-sCR}{sCR}\right)-V_i(s)(sCR)\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\frac{1}{R}\left(V_o(s)\left(2(1+sCR)-1\right)-V_i(s)\right)+\\ sC\left(V_o(s)\left(2(sCR+1)-sCR\right)-V_i(s)(sCR)\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}\left(V_o(s)\left(2(1+sCR)-1\right)-V_i(s)\right)+\\ sCR\left(V_o(s)\left(2(sCR+1)-sCR\right)-V_i(s)(sCR)\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}V_o(s)\left(2(1+sCR)-1+(sCR)\left(2(sCR+1)-sCR\right)\right)-\\ V_i(s)\left(1+(sCR)(sCR)\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}V_o(s)\left(2+2sCR-1+\left(2s^2C^2R^2+2sCR-s^2C^2R^2\right)\right)-\\ V_i(s)\left(1+s^2C^2R^2\right)\end{array}\right]=0$$

$$\left[\begin{array}{l}V_o(s)\left(2+2sCR-1+s^2C^2R^2+2sCR\right)-\\ V_i(s)\left(1+s^2C^2R^2\right)\end{array}\right]=0$$

$$V_o(s)\left(s^2C^2R^2+4sCR+1\right)-V_i(s)\left(1+s^2C^2R^2\right)=0$$

$$V_o(s)C^2R^2\left(s^2+\frac{4sCR}{C^2R^2}+\frac{1}{C^2R^2}\right)=V_i(s)C^2R^2\left(s^2+\frac{1}{C^2R^2}\right)$$

$$V_o(s)\left(s^2+\frac{4s}{RC}+\frac{1}{(RC)^2}\right)=V_i(s)\left(s^2+\frac{1}{(RC)^2}\right)$$

$$\frac{V_o(s)}{V_i(s)}=\frac{s^2+\frac{1}{(RC)^2}}{s^2+\frac{4s}{RC}+\frac{1}{(RC)^2}}\quad\text{..... (1)}$$

Therefore, the expression for the voltage gain is $\boxed{\frac{s^2+\frac{1}{(RC)^2}}{s^2+\frac{4s}{RC}+\frac{1}{(RC)^2}}}$.

Step 6 of 6

Recall equation (1).

$$\frac{V_o(s)}{V_i(s)}=\frac{s^2+\frac{1}{(RC)^2}}{s^2+\frac{4s}{RC}+\frac{1}{(RC)^2}}$$

Substitute $100\,\text{nF}$ for C and $1590\,\Omega$ for R.

$$\frac{V_o(s)}{V_i(s)}=\frac{s^2+\frac{1}{((1590)(100\text{n}))^2}}{s^2+\frac{4s}{(1590)(100\text{n})}+\frac{1}{((1590)(100\text{n}))^2}}$$

$$=\frac{s^2+\frac{1}{2.5281\times10^{-8}}}{s^2+\frac{4s}{1.59\times10^{-4}}+\frac{1}{2.5281\times10^{-8}}}$$

$$=\frac{s^2+39.55\text{ M}}{s^2+(25.16\text{ k})s+39.55\text{ M}}$$

Therefore, the transfer function is $\boxed{\frac{s^2+39.55\text{ M}}{s^2+(25.16\text{ k})s+39.55\text{ M}}}$.

Step 1 of 3

Consider Figure 1 which is the basic circuit of a low pass filter.

Figure 1

Step 2 of 3

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{in}\left(\frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}$$

$$= \frac{\frac{1}{j\omega C}}{\frac{j\omega CR+1}{j\omega C}}$$

$$= \frac{1}{j\omega CR+1}$$

$$= \frac{1}{CR}\left(\frac{1}{j\omega+\frac{1}{CR}}\right)$$

Step 3 of 3

The value of the cutoff frequency should be equal to $\frac{1}{CR}$.

$$\omega_{cutoff} = \frac{1}{CR}$$

Substitute $2\pi f_{cutoff}$ for ω_{cutoff} in the equation.

$$2\pi f_{cutoff} = \frac{1}{CR}$$

Select any value of cutoff frequency between $15\,\text{kHz}$ and $16\,\text{kHz}$.

Let the value of cutoff frequency be $15.5\,\text{kHz}$.

$$2\pi(15.5\,\text{k}) = \frac{1}{CR}$$

Assume the value of resistor to be $1\,\text{k}\Omega$.

$$2\pi(15.5\,\text{k}) = \frac{1}{C(1\,\text{k})}$$

$$C = \frac{1}{2\pi(15.5\,\text{k})(1\,\text{k})}$$

$$C = \frac{1}{97.389\,\text{M}}$$

$$C = 10.268\,\text{nF}$$

Therefore, the required values of the resistor and the capacitor are $\boxed{1\,\text{k}\Omega}$ and $\boxed{10.268\,\text{nF}}$ respectively.

This value of capacitor is due to assumption of cutoff frequency and the value of resistor. However many solutions may exist depending upon the values of resistor and cutoff frequency chosen.

Step 1 of 4

Consider Figure 1 which is the basic circuit of a low pass filter.

Figure 1

Step 2 of 4

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{in}\left(\frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}$$

$$= \frac{\frac{1}{j\omega C}}{\frac{j\omega CR+1}{j\omega C}}$$

$$= \frac{1}{j\omega CR+1}$$

Consider magnitude values.

$$\left|\frac{\mathbf{V}_o}{\mathbf{V}_{in}}\right| = \frac{1}{\sqrt{(\omega CR)^2+1}}$$

Substitute $2\pi f$ for ω in the equation.

$$\left|\frac{\mathbf{V}_o}{\mathbf{V}_{in}}\right| = \frac{1}{\sqrt{(2\pi fCR)^2+1}}$$

Step 3 of 4

On further simplification:

Substitute 159 Hz for f , 4.24 volts for $|\mathbf{V}_o|$ and 6 volts for $|\mathbf{V}_{in}|$ in the equation.

$$\frac{4.64}{6} = \frac{1}{\sqrt{(2\pi(159)CR)^2+1}}$$

$$\left(\frac{4.64}{6}\right)^2 = \left(\frac{1}{\sqrt{(2\pi(159)CR)^2+1}}\right)^2$$

$$\left(\frac{4.64}{6}\right)^2 = \frac{1}{(2\pi(159)CR)^2+1}$$

$$(2\pi(159)CR)^2+1 = \left(\frac{6}{4.64}\right)^2$$

$$(2\pi(159)CR)^2 = \left(\frac{6}{4.64}\right)^2-1$$

$$2\pi(159)CR = \sqrt{\left(\frac{6}{4.64}\right)^2-1}$$

$$2\pi(159)CR = \sqrt{(1.4151)^2-1}$$

$$2\pi(159)CR = \sqrt{2.0025-1}$$

Step 4 of 4

On further simplification:

$$2\pi(159)CR = \sqrt{1.0025}$$

$$2\pi(159)CR \approx 1$$

$$CR \approx \frac{1}{2\pi(159)}$$

$$CR \approx 1\text{ m}$$

Assume the value of resistor to be $1\text{ k}\Omega$.

$$C(1\text{ k}) = 1\text{ m}$$

$$C = \frac{1\text{ m}}{1\text{ k}}$$

$$C = 1\ \mu\text{F}$$

Therefore, the required values of the resistor and the capacitor are $\boxed{1\text{ k}\Omega}$ and $\boxed{1\ \mu\text{F}}$ respectively.

This value of capacitor is due to assumption of cutoff frequency and the value of resistor. However many solutions may exist depending upon the values of resistor and cutoff frequency chosen.

Step 1 of 3

Consider Figure 1 which is the basic circuit of a high pass filter.

Figure 1

Step 2 of 3

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{in}\left(\frac{R}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{R}{R+\frac{1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{R}{\frac{j\omega CR+1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{j\omega CR}{j\omega CR+1}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{1}{CR}\left(\frac{j\omega CR}{j\omega+\frac{1}{CR}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{j\omega}{j\omega+\frac{1}{CR}}$$

Step 3 of 3

The value of the cutoff frequency should be equal to $\frac{1}{CR}$.

$$\omega_{cutoff} = \frac{1}{CR}$$

Substitute $2\pi f_{cutoff}$ for ω_{cutoff}.

$$2\pi f_{cutoff} = \frac{1}{CR}$$

Select any value of cutoff frequency between 159 kHz and 161 kHz.

Let the value of cutoff frequency be 160 kHz.

$$2\pi(160\text{ k}) = \frac{1}{CR}$$

Assume the value of resistor to be $1\,\Omega$.

$$2\pi(160\text{ k}) = \frac{1}{C(1)}$$

$$C = \frac{1}{2\pi(160\text{ k})}$$

$$C = \frac{1}{1005309.69}$$

$$C = 0.9947\ \mu\text{F}$$

Therefore, the required values of the resistor and the capacitor are $\boxed{1\,\Omega}$ and $\boxed{0.9947\ \mu\text{F}}$ respectively.

This value of capacitor is due to assumption of cutoff frequency and the value of resistor. However many solutions may exist depending upon the values of resistor and cutoff frequency chosen.

Step 1 of 3

Consider Figure 1 which is the basic circuit of a high pass filter.

Figure 1

Step 2 of 3

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{in}\left(\frac{R}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{R}{R+\frac{1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{R}{\frac{j\omega CR+1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{j\omega CR}{j\omega CR+1}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{1}{CR}\left(\frac{j\omega CR}{j\omega+\frac{1}{CR}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{j\omega}{j\omega+\frac{1}{CR}}$$

Step 3 of 3

The value of the cutoff frequency should be equal to $\frac{1}{CR}$.

$$\omega_{cutoff} = \frac{1}{CR}$$

Substitute $2\pi f_{cutoff}$ for ω_{cutoff}.

$$2\pi f_{cutoff} = \frac{1}{CR}$$

Select any value of cutoff frequency between 159 kHz and 161 kHz.

Let the value of cutoff frequency be 160 kHz.

$$2\pi(160\text{ k}) = \frac{1}{CR}$$

Assume the value of resistor to be $1\,\Omega$.

$$2\pi(160\text{ k}) = \frac{1}{C(1)}$$

$$C = \frac{1}{2\pi(160\text{ k})}$$

$$C = \frac{1}{1005309.69}$$

$$C = 0.9947\ \mu\text{F}$$

Therefore, the required values of the resistor and the capacitor are $\boxed{1\,\Omega}$ and $\boxed{0.9947\ \mu\text{F}}$ respectively.

This value of capacitor is due to assumption of cutoff frequency and the value of resistor. However many solutions may exist depending upon the values of resistor and cutoff frequency chosen.

Step 1 of 3

12.081
P

Consider Figure P12.81 from the text book.

Consider Figure 1.

Figure 1

Step 2 of 3

Consider the expression for the output voltage using voltage division rule.

$$\mathbf{V}_o = \mathbf{V}_{in}\left(\frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{\frac{1}{j\omega C}}{\frac{j\omega CR+1}{j\omega C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{1}{j\omega CR+1}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_{in}} = \frac{1}{CR}\left(\frac{1}{j\omega+\frac{1}{CR}}\right)$$

Step 3 of 3

The value of the cutoff frequency 3-dB should be equal to $\frac{1}{CR}$.

$$\omega_{cutoff} = \frac{1}{CR}$$

Substitute $2\pi f_{cutoff}$ for ω_{cutoff}.

$$2\pi f_{cutoff} = \frac{1}{CR}$$

Substitute 23.16 kHz for f_{cutoff}.

$$2\pi(23.16\text{ k}) = \frac{1}{CR}$$

Assume the value of resistor to be $10\text{ k}\Omega$.

$$2\pi(23.16\text{ k}) = \frac{1}{C(10\text{ k})}$$

$$C = \frac{1}{2\pi(23.16\text{ k})(10\text{ k})}$$

$$C = \frac{1}{1455.186\text{ M}}$$

$$C = 687.2\text{ pF}$$

Therefore, the required values of the resistor and the capacitor are $\boxed{10\text{ k}\Omega}$ and $\boxed{687.2\text{ pF}}$ respectively.

This value of capacitor is due to assumption of cutoff frequency and the value of resistor. However many solutions may exist depending upon the values of resistor and cutoff frequency chosen.

Step 1 of 1

13.001

E

Consider the function.

$$f(t)=e^{-at}$$

Consider the formula for Laplace transform.

$$\mathsf{L}\left[f(t)\right]=\int_0^\infty f(t)e^{-st}dt$$

Substitute e^{-at} for $f(t)$.

$$\begin{aligned}\mathsf{L}\left[e^{-at}\right]&=\int_0^\infty e^{-at}\cdot e^{-st}dt\\&=\int_0^\infty e^{-(a+s)t}dt\\&=\left.\frac{e^{-(a+s)t}}{-(a+s)}\right|_0^\infty\\&=\frac{e^{-(a+s)(\infty)}-e^{-(a+s)(0)}}{-(a+s)}\end{aligned}$$

$$\begin{aligned}\mathsf{L}\left[e^{-at}\right]&=\frac{0-1}{-(a+s)}\\&=\frac{-1}{-(a+s)}\\&=\frac{1}{s+a}\end{aligned}$$

Therefore, the Laplace transform of the function e^{-at} is $\boxed{\frac{1}{s+a}}$.

13.001
P

Step 1 of 3

Consider the function.

$$f(t)=\left[t-1+e^{-(t-1)}\right]u(t-1)$$

Let $t-1+e^{-(t-1)}$ be $g(t)$.

$$f(t)=g(t)u(t-1)$$

Apply Laplace Transform.

$$\mathrm{L}\left[f(t)\right]=\mathrm{L}\left[g(t)u(t-1)\right]$$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow \mathrm{L}\left[f(t)\right]=e^{-t_0 s}\mathrm{L}\left[g(t+t_0)\right]$.

$$F(s)=e^{-s}\mathrm{L}\left[g(t+1)\right]$$

Substitute $(t+1-1)+e^{-(t+1-1)}$ for $g(t+1)$.

$$\begin{aligned}F(s)&=e^{-s}\mathrm{L}\left[(t+1-1)+e^{-(t+1-1)}\right]\\&=e^{-s}\mathrm{L}\left[t+e^{-t}\right]\end{aligned}$$

$$F(s)=e^{-s}\left\{\mathrm{L}\left[t\right]+\mathrm{L}\left[e^{-t}\right]\right\}\text{ ..... (1)}$$

Step 2 of 3

Consider function t.

Apply Laplace transform for t.

$$\mathrm{L}\left[t\right]=\frac{1}{s^2}$$

Therefore, the Laplace transform of t is $\frac{1}{s^2}$.

Consider e^{-t}.

Apply Laplace transform.

$$\mathrm{L}\left[e^{-t}\right]=\frac{1}{s+1}$$

Therefore, the Laplace transform of e^{-t} is $\frac{1}{s+1}$.

Step 3 of 3

Consider the expression (1).

$$F(s)=e^{-s}\left\{\mathrm{L}\left[t\right]+\mathrm{L}\left[e^{-t}\right]\right\}$$

Substitute $\frac{1}{s^2}$ for $\mathrm{L}\left[t\right]$ and $\frac{1}{s+1}$ for $\mathrm{L}\left[e^{-at}\right]$.

$$F(s)=e^{-s}\left\{\frac{1}{s^2}+\frac{1}{s+1}\right\}$$

Therefore, the Laplace Transform of $\left[t-1+e^{-(t-1)}\right]u(t-1)$ is $\boxed{e^{-s}\left\{\frac{1}{s^2}+\frac{1}{s+1}\right\}}$.

13.01E

E

Step 1 of 4

Consider the following function:

$$\mathbf{V}_O(s)=\frac{12}{s(s^2+3s+2)}$$

Simplify the expression.

$$\mathbf{V}_O(s)=\frac{12}{s(s+1)(s+2)}$$

Assume $\frac{12}{s(s+1)(s+2)}$ to be $\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2}$.

$$\frac{12}{s(s+1)(s+2)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$\begin{aligned}A&=(s)\left[\frac{12}{(s)(s+1)(s+2)}\right]\Bigg|_{s=0}\\&=\left[\frac{12}{(s+1)(s+2)}\right]\Bigg|_{s=0}\\&=\frac{12}{(0+1)(0+2)}\\&=\frac{12}{2}\\A&=6\end{aligned}$$

Therefore, the value of A is 6.

Step 2 of 4

Calculate the value of B.

$$\begin{aligned}B&=(s+1)\left[\frac{12}{(s)(s+1)(s+2)}\right]\Bigg|_{s=-1}\\&=\left[\frac{12}{s(s+2)}\right]\Bigg|_{s=-1}\\&=\frac{12}{(-1)(-1+2)}\\&=\frac{12}{(-1)(1)}\\B&=-12\end{aligned}$$

Therefore, the value of B is -12.

Step 3 of 4

Calculate the value of C.

$$\begin{aligned}C&=(s+2)\left[\frac{12}{(s)(s+1)(s+2)}\right]\Bigg|_{s=-2}\\&=\left[\frac{12}{s(s+1)}\right]\Bigg|_{s=-2}\\&=\frac{12}{(-2)(-2+1)}\\&=\frac{12}{(-2)(-1)}\\C&=\frac{12}{2}\\&=6\end{aligned}$$

Therefore, the value of C is 6.

Step 4 of 4

Consider the function (1).

$$\frac{12}{s(s+1)(s+2)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2}$$

Substitute $\mathbf{V}_O(s)$ for $\frac{12}{s(s+1)(s+2)}$, -12 for B, 6 for C and 6 for A.

$$\mathbf{V}_O(s)=\frac{6}{s}-\frac{12}{s+1}+\frac{6}{s+2}$$

Apply inverse Laplace transform.

Apply the property $L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$v_o(t)=\left[6-12e^{-t}+6e^{-2t}\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{12}{s(s^2+3s+2)}$ is $\boxed{\left[6-12e^{-t}+6e^{-2t}\right]u(t)}$.

Therefore, the correct option is $\boxed{\text{c}}$.

13.002

E

Step 1 of 2

Consider the function.

$$f(t) = \sin \omega t$$

Consider the sine function in the exponential notation.

$$f(t) = \frac{e^{j\omega t} - e^{-j\omega t}}{2j}$$

Consider the formula for Laplace transform.

$$\mathrm{L}\left[f(t)\right] = \int_0^\infty f(t) e^{-st} dt$$

Substitute $\frac{e^{j\omega t} - e^{-j\omega t}}{2j}$ for $f(t)$.

$$\begin{aligned}
\mathrm{L}\left[\sin \omega t\right] &= \int_0^\infty \left(\frac{e^{j\omega t} - e^{-j\omega t}}{2j}\right) \cdot e^{-st} dt \\
&= \frac{1}{2j} \int_0^\infty \left(e^{j\omega t} - e^{-j\omega t}\right) \cdot e^{-st} dt \\
&= \frac{1}{2j} \int_0^\infty \left(e^{j\omega t} \cdot e^{-st} - e^{-j\omega t} \cdot e^{-st}\right) dt \\
&= \frac{1}{2j} \left\{ \int_0^\infty \left(e^{-(s-j\omega)t}\right) dt - \int_0^\infty \left(e^{-(s+j\omega)t}\right) dt \right\}
\end{aligned}$$

Step 2 of 2

Simplify further.

$$\begin{aligned}
\mathrm{L}\left[\sin \omega t\right] &= \frac{1}{2j} \left\{ \left. \frac{e^{-(s-j\omega)t}}{-(s-j\omega)} \right|_0^\infty - \left. \frac{e^{-(s+j\omega)t}}{-(s+j\omega)} \right|_0^\infty \right\} \\
&= \frac{1}{2j} \left\{ \frac{e^{-(s-j\omega)(\infty)} - e^{-(s-j\omega)(0)}}{-(s-j\omega)} - \frac{e^{-(s+j\omega)(\infty)} - e^{-(s+j\omega)(0)}}{-(s+j\omega)} \right\} \\
&= \frac{1}{2j} \left\{ \frac{0-1}{-(s-j\omega)} - \frac{0-1}{-(s+j\omega)} \right\} \\
&= \frac{1}{2j} \left\{ \frac{1}{s-j\omega} - \frac{1}{s+j\omega} \right\}
\end{aligned}$$

$$\begin{aligned}
\mathrm{L}\left[\sin \omega t\right] &= \frac{1}{2j} \left\{ \frac{(s+j\omega) - (s+j\omega)}{(s-j\omega)(s+j\omega)} \right\} \\
&= \frac{1}{2j} \left\{ \frac{s+j\omega - s + j\omega}{s^2 - j^2\omega^2} \right\} \\
&= \frac{1}{2j} \left\{ \frac{2j\omega}{s^2 + \omega^2} \right\} \\
&= \frac{\omega}{s^2 + \omega^2}
\end{aligned}$$

Therefore, the Laplace transform of the function $\sin \omega t$ is $\boxed{\frac{\omega}{s^2 + \omega^2}}$.

Step 1 of 6

Consider the following function:

$$f(t)=te^{-(t-a)}u(t-a)-e^{-t}u(t-a)$$

Apply Laplace transform.

$$F(s)=\mathcal{L}\left\{te^{-(t-a)}u(t-a)\right\}-\mathcal{L}\left\{e^{-t}u(t-a)\right\} \text{ ..... (1)}$$

Consider the function $te^{-(t-a)}u(t-a)$.

Let $te^{-(t-a)}$ be $g(t)$ and $te^{-(t-a)}u(t-a)$ be $f_1(t)$.

$$f_1(t)=g(t)u(t-a)$$

Apply Laplace Transform.

$$\mathcal{L}\left[f_1(t)\right]=\mathcal{L}\left[g(t)u(t-a)\right]$$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow\mathcal{L}\left[f(t)\right]=e^{-t_0s}\mathcal{L}\left[g(t+t_0)\right]$.

$$F_1(s)=e^{-as}\mathcal{L}\left[g(t+a)\right]$$

Substitute $(t+a)e^{-(t+a-a)}$ for $g(t+a)$.

$$\begin{aligned}F_1(s)&=e^{-as}\mathcal{L}\left[(t+a)e^{-(t+a-a)}\right]\\&=e^{-as}\mathcal{L}\left[(t+a)\cdot e^{-t}\right]\\&=e^{-as}\mathcal{L}\left[t\cdot e^{-t}+ae^{-t}\right]\\&=e^{-as}\left\{\mathcal{L}\left[t\cdot e^{-t}\right]+\mathcal{L}\left[ae^{-t}\right]\right\}\end{aligned}$$

$$F_1(s)=e^{-as}\left\{\mathcal{L}\left[t\cdot e^{-t}\right]+a\mathcal{L}\left[e^{-t}\right]\right\} \text{ ..... (2)}$$

Step 2 of 6

Consider the function $t\cdot e^{-t}$.

Apply Laplace transform for t.

$$\mathcal{L}\left[t\right]=\frac{1}{s^2}$$

Apply the property, $f(t)=e^{-at}g(t)\Rightarrow\mathcal{L}\left[f(t)\right]=G(s+a)$ for $t\cdot e^{-t}$.

$$\mathcal{L}\left[t\cdot e^{-t}\right]=\frac{1}{(s+1)^2}$$

Therefore, the Laplace transform of $t\cdot e^{-t}$ is $\frac{1}{(s+1)^2}$.

Step 3 of 6

Consider the function e^{-t}.

Apply Laplace transform.

$$\mathcal{L}\left[e^{-t}\right]=\frac{1}{s+1}$$

Therefore, the Laplace transform of e^{-t} is $\frac{1}{s+1}$.

Consider the expression (2).

$$F_1(s)=e^{-as}\left\{\mathcal{L}\left[t\cdot e^{-t}\right]+a\mathcal{L}\left[e^{-t}\right]\right\}$$

Substitute $\frac{1}{(s+1)^2}$ for $\mathcal{L}\left[t\cdot e^{-t}\right]$ and $\frac{1}{s+1}$ for $\mathcal{L}\left[e^{-t}\right]$.

$$F_1(s)=e^{-as}\left\{\frac{1}{(s+1)^2}+\frac{a}{s+1}\right\}$$

Therefore, the Laplace Transform of $te^{-(t-a)}u(t-a)$ is $e^{-as}\left\{\frac{1}{(s+1)^2}+\frac{a}{s+1}\right\}$.

Step 4 of 6

Consider the function $e^{-t}u(t-a)$.

Let e^{-t} be $h(t)$ and $e^{-t}u(t-a)$ be $f_2(t)$.

$$f_2(t)=h(t)u(t-a)$$

Apply Laplace Transform.

$$\mathcal{L}\left[f_2(t)\right]=\mathcal{L}\left[h(t)u(t-a)\right]$$

Apply the property, $f(t)=h(t)u(t-t_0)\Rightarrow\mathcal{L}\left[f(t)\right]=e^{-t_0s}\mathcal{L}\left[h(t+t_0)\right]$.

$$F_2(s)=e^{-as}\mathcal{L}\left[h(t+a)\right]$$

Substitute $e^{-(t+a)}$ for $h(t+a)$.

$$\begin{aligned}F_2(s)&=e^{-as}\mathcal{L}\left[e^{-(t+a)}\right]\\&=e^{-as}\mathcal{L}\left[e^{-t}\cdot e^{-a}\right]\\&=e^{-as-a}\mathcal{L}\left[e^{-t}\right]\end{aligned}$$

$$F_2(s)=e^{-a(s+1)}\mathcal{L}\left[e^{-t}\right] \text{ ..... (3)}$$

Consider the function e^{-t}.

Apply Laplace transform for e^{-t}.

$$\mathcal{L}\left[t\right]=\frac{1}{s+1}$$

Therefore, the Laplace transform of e^{-t} is $\frac{1}{(s+1)}$.

Step 5 of 6

Consider the expression (3).

$$F_2(s)=e^{-a(s+1)}\mathcal{L}\left[e^{-t}\right]$$

Substitute $\frac{1}{(s+1)}$ for $\mathcal{L}\left[e^{-t}\right]$.

$$F_2(s)=e^{-a(s+1)}\left(\frac{1}{s+1}\right)$$

Therefore, the Laplace Transform of $e^{-t}u(t-a)$ is $e^{-a(s+1)}\left(\frac{1}{s+1}\right)$.

Step 6 of 6

Consider the function (1).

$$F(s)=\mathcal{L}\left\{te^{-(t-a)}u(t-a)\right\}-\mathcal{L}\left\{e^{-t}u(t-a)\right\}$$

Substitute $e^{-as}\left\{\frac{1}{(s+1)^2}+\frac{a}{s+1}\right\}$ for $\mathcal{L}\left\{te^{-(t-a)}u(t-a)\right\}$ and $e^{-a(s+1)}\left(\frac{1}{s+1}\right)$ for $\mathcal{L}\left\{e^{-t}u(t-a)\right\}$.

$$F(s)=e^{-as}\left\{\frac{1}{(s+1)^2}+\frac{a}{s+1}\right\}-e^{-a(s+1)}\left(\frac{1}{s+1}\right)$$

Therefore, the Laplace transform of $te^{-(t-a)}u(t-a)-e^{-t}u(t-a)$ is,

$$\boxed{e^{-as}\left\{\frac{1}{(s+1)^2}+\frac{a}{s+1}\right\}-e^{-a(s+1)}\left(\frac{1}{s+1}\right)}.$$

13.02E

E

Step 1 of 4

Consider the following function:

$$\mathbf{V}_O(s)=\frac{120}{s(s+10)(s+20)}$$

Assume $\frac{120}{s(s+10)(s+20)}$ to be $\frac{A}{s}+\frac{B}{s+10}+\frac{C}{s+20}$.

$$\frac{120}{s(s+10)(s+20)}=\frac{A}{s}+\frac{B}{s+10}+\frac{C}{s+20} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$\begin{aligned}A&=(s)\left[\frac{120}{(s)(s+10)(s+20)}\right]\Bigg|_{s=0}\\&=\left[\frac{120}{(s+10)(s+20)}\right]\Bigg|_{s=0}\\&=\frac{120}{(0+10)(0+20)}\\&=\frac{120}{200}\\A&=0.6\end{aligned}$$

Therefore, the value of A is 0.6.

Step 2 of 4

Calculate the value of B.

$$\begin{aligned}B&=(s+10)\left[\frac{120}{(s)(s+10)(s+20)}\right]\Bigg|_{s=-10}\\&=\left[\frac{120}{s(s+20)}\right]\Bigg|_{s=-10}\\&=\frac{120}{(-10)(-10+20)}\\&=\frac{120}{(-10)(10)}\\B&=\frac{120}{(-100)}\\&=-1.2\end{aligned}$$

Therefore, the value of B is -1.2.

Step 3 of 4

Calculate the value of C.

$$\begin{aligned}C&=(s+20)\left[\frac{120}{(s)(s+10)(s+20)}\right]\Bigg|_{s=-20}\\&=\left[\frac{120}{s(s+10)}\right]\Bigg|_{s=-20}\\&=\frac{120}{(-20)(-20+10)}\\&=\frac{120}{(-20)(-10)}\\C&=\frac{120}{200}\\&=0.6\end{aligned}$$

Therefore, the value of C is 0.6.

Step 4 of 4

Consider the function (1).

$$\frac{120}{s(s+10)(s+20)}=\frac{A}{s}+\frac{B}{s+10}+\frac{C}{s+20}$$

Substitute $\mathbf{V}_O(s)$ for $\frac{120}{s(s+10)(s+20)}$, -1.2 for B, 0.6 for C and 0.6 for A.

$$\mathbf{V}_O(s)=\frac{0.6}{s}-\frac{1.2}{s+10}+\frac{0.6}{s+20}$$

Apply inverse Laplace transform.

Apply the property $L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$v_O(t)=\left[0.6-1.2e^{-10t}+0.6e^{-20t}\right]u(t)$$

Substitute 100 ms for t.

$$\begin{aligned}v_O(t)&=0.6-1.2e^{-10(100\text{ m})}+0.6e^{-20(100\text{ m})}\\&=0.6-1.2e^{-1}+0.6e^{-2}\\&=0.6-1.2(0.37)+0.6(0.14)\\&=0.6-0.44+0.08\end{aligned}$$

$$v_O(t)=0.24\text{ V}$$

Therefore, the Inverse Laplace transform of $\frac{120}{s(s+10)(s+20)}$ is $\boxed{0.24\text{ V}}$.

Therefore, the correct option is $\boxed{\text{d}}$.

Step 1 of 1

Consider the function.

$$f(t)=\frac{1}{2}\left(t-4e^{-2t}\right)$$

Consider the formula for Laplace transform.

$$\mathsf{L}\left[f(t)\right]=\int_0^\infty f(t)e^{-st}dt$$

Substitute $\frac{1}{2}\left(t-4e^{-2t}\right)$ for $f(t)$.

$$\begin{aligned}
\mathsf{L}\left[f(t)\right]&=\int_0^\infty \frac{1}{2}\left(t-4e^{-2t}\right)\cdot e^{-st}dt\\
&=\int_0^\infty \frac{1}{2}\left(te^{-st}\right)dt-\int_0^\infty \frac{1}{2}\left(4e^{-2t}\cdot e^{-st}\right)dt\\
&=\frac{1}{2}\int_0^\infty te^{-st}dt-2\int_0^\infty e^{-(2+s)t}dt\\
&=\frac{1}{2}\left(t\int_0^\infty e^{-st}dt-\int_0^\infty \frac{d(t)}{dt}\left(\int e^{-st}dt\right)dt\right)-2\left.\frac{e^{-(2+s)t}}{-(2+s)}\right|_0^\infty
\end{aligned}$$

$$\begin{aligned}
\mathbf{F}(s)&=\frac{1}{2}\left(\left[\frac{te^{-st}}{s}\right]_0^\infty-\int_0^\infty \frac{e^{-st}}{-s}dt\right)-2\left(\frac{e^{-(2+s)(\infty)}-e^{-(2+s)(0)}}{-(2+s)}\right)\\
&=\frac{1}{2}\left(\frac{(\infty)e^{-s(\infty)}-(0)e^{-s(0)}}{s}+\frac{1}{s}\left(\frac{e^{-st}}{-s}\right)_0^\infty\right)-2\left(\frac{e^{-(2+s)(\infty)}-e^{-(2+s)(0)}}{-(2+s)}\right)\\
&=\frac{1}{2}\left(\frac{0-0}{s}+\frac{1}{s}\left(\frac{e^{-s(\infty)}-e^{-s(0)}}{-s}\right)\right)-2\left(\frac{0-1}{-(2+s)}\right)\\
&=\frac{1}{2}\left(\frac{1}{s}\left(\frac{0-1}{-s}\right)\right)-2\left(\frac{0-1}{-(2+s)}\right)
\end{aligned}$$

$$\begin{aligned}
\mathbf{F}(s)&=\frac{1}{2}\left(\frac{1}{s}\left(\frac{1}{s}\right)\right)-2\left(\frac{1}{2+s}\right)\\
&=\frac{1}{2s^2}-\frac{2}{s+2}
\end{aligned}$$

Therefore, the Laplace transform of the function $\frac{1}{2}\left(t-4e^{-2t}\right)$ is $\boxed{\frac{1}{2s^2}-\frac{2}{s+2}}$.

13.003
P

Step 1 of 3

Consider the following function:

$$f(t)=\left\{e^{-(t-2)}-e^{-2(t-2)}\right\}u(t-2)$$

Let $e^{-(t-2)}-e^{-2(t-2)}$ be $g(t)$.

$$f(t)=g(t)u(t-2)$$

Apply Laplace Transform.

$$\mathsf{L}\left[f(t)\right]=\mathsf{L}\left[g(t)u(t-a)\right]$$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow \mathsf{L}\left[f(t)\right]=e^{-t_0 s}\mathsf{L}\left[g(t+t_0)\right]$.

$$F(s)=e^{-2s}\mathsf{L}\left[g(t+a)\right]$$

Substitute $e^{-(t+2-2)}-e^{-2(t+2-2)}$ for $g(t+a)$.

$$\begin{aligned}F(s)&=e^{-2s}\mathsf{L}\left[e^{-(t+2-2)}-e^{-2(t+2-2)}\right]\\&=e^{-2s}\mathsf{L}\left[e^{-t}-e^{-2t}\right]\end{aligned}$$

$$F(s)=e^{-2s}\left\{\mathsf{L}\left[e^{-t}\right]-\mathsf{L}\left[e^{-2t}\right]\right\}\text{ ..... (1)}$$

Step 2 of 3

Consider the function e^{-t}.

Apply Laplace transform for e^{-t}.

$$\mathsf{L}\left[e^{-t}\right]=\frac{1}{s+1}$$

Therefore, the Laplace transform of e^{-t} is $\frac{1}{s+1}$.

Consider the function e^{-2t}.

Apply Laplace transform.

$$\mathsf{L}\left[e^{-2t}\right]=\frac{1}{s+2}$$

Therefore, the Laplace transform of e^{-2t} is $\frac{1}{s+2}$.

Step 3 of 3

Consider expression (1).

$$F(s)=e^{-2s}\left\{\mathsf{L}\left[e^{-t}\right]-\mathsf{L}\left[e^{-2t}\right]\right\}$$

Substitute $\frac{1}{s+2}$ for e^{-2t} and $\frac{1}{s+1}$ for e^{-t}.

$$\begin{aligned}F(s)&=e^{-2s}\left\{\frac{1}{s+1}-\frac{1}{s+2}\right\}\\&=e^{-2s}\left\{\frac{s+2-s-1}{(s+1)(s+2)}\right\}\\&=e^{-2s}\left\{\frac{1}{s^2+3s+2}\right\}\end{aligned}$$

Therefore, the Laplace transform of $\left\{e^{-(t-2)}-e^{-2(t-2)}\right\}u(t-2)$ is $\boxed{e^{-2s}\left\{\frac{1}{s^2+3s+2}\right\}}$.

Step 1 of 1

13.03FE

Consider the following function:

$$\mathbf{V}_o(s)=\frac{12(s+2)}{s(s+1)(s+3)(s+4)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{12(s+2)}{s(s+1)(s+3)(s+4)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
v_o(\infty)&=\lim_{s\to 0} s\left(\frac{12(s+2)}{s(s+1)(s+3)(s+4)}\right)\\
&=\lim_{s\to 0}\left(\frac{12(s+2)}{(s+1)(s+3)(s+4)}\right)\\
&=\frac{12(0+2)}{(0+1)(0+3)(0+4)}\\
&=\frac{(12)(2)}{(1)(3)(4)}
\end{aligned}$$

$$v_o(\infty)=2$$

Therefore, the final value for the function is $\boxed{2}$.

Therefore, the correct option is $\boxed{\text{b}}$.

13.004
E

Step 1 of 3

Consider the function.

$$f(t)=te^{-(t-1)}u(t-1)-e^{-(t-1)}u(t-1)$$
$$=\left[te^{-(t-1)}-e^{-(t-1)}\right]u(t-1)$$

Let $te^{-(t-1)}-e^{-(t-1)}$ is $g(t)$.

$$f(t)=g(t)u(t-1)$$

Apply Laplace Transform.

$$\mathrm{L}\left[f(t)\right]=\mathrm{L}\left[g(t)u(t-1)\right]$$

Recall shifting property.

$$f(t)=g(t)u(t-t_0)$$
$$=\mathrm{L}\left[f(t)\right]$$
$$=e^{-t_0 s}\mathrm{L}\left[g(t+t_0)\right]$$

So, function $f(t)$ becomes:

$$F(s)=e^{-s}\mathrm{L}\left[g(t+1)\right]$$

Substitute $(t+1)e^{-(t+1-1)}-e^{-(t+1-1)}$ for $g(t+1)$.

$$F(s)=e^{-s}\mathrm{L}\left[(t+1)e^{-(t+1-1)}-e^{-(t+1-1)}\right]$$
$$=e^{-s}\mathrm{L}\left[(t+1)e^{-t}-e^{-t}\right]$$
$$=e^{-s}\mathrm{L}\left[(t+1)e^{-t}-e^{-t}\right]$$
$$=e^{-s}\mathrm{L}\left[te^{-t}+e^{-t}-e^{-t}\right]$$

Rewrite the expression.

$$F(s)=e^{-s}\mathrm{L}\left[te^{-t}\right] \text{ ..... (1)}$$

Step 2 of 3

Consider function te^{-t}.

Apply Laplace transform.

$$\mathrm{L}\left[te^{-t}\right]=\int_0^\infty te^{-t}e^{-st}dt$$
$$=\int_0^\infty te^{-(s+1)t}dt$$
$$=t\int_0^\infty e^{-(s+1)t}dt-\int_0^\infty\frac{d(t)}{dt}\left(\int e^{-(s+1)t}dt\right)dt$$
$$=\left[\frac{te^{-(s+1)t}}{(s+1)}\right]_0^\infty-\int_0^\infty\frac{e^{-(s+1)t}}{-(s+1)}dt$$

Simplify further.

$$\mathrm{L}\left[te^{-t}\right]=\frac{(\infty)e^{-(s+1)(\infty)}-(0)e^{-(s+1)(0)}}{(s+1)}+\frac{1}{(s+1)}\left(\frac{e^{-(s+1)t}}{-(s+1)}\right)_0^\infty$$
$$=\left(\frac{0-0}{(s+1)}+\frac{1}{(s+1)}\left(\frac{e^{-(s+1)(\infty)}-e^{-(s+1)(0)}}{-(s+1)}\right)\right)$$
$$=\left(\frac{1}{(s+1)}\left(\frac{0-1}{-(s+1)}\right)\right)$$
$$=\left(\frac{1}{(s+1)}\left(\frac{1}{(s+1)}\right)\right)$$

$$\mathrm{L}\left[te^{-t}\right]=\frac{1}{(s+1)^2}$$

Therefore, the Laplace transform of te^{-t} is $\frac{1}{(s+1)^2}$.

Step 3 of 3

Consider the expression (1).

$$F(s)=e^{-s}\mathrm{L}\left[te^{-t}\right]$$

Substitute $\frac{1}{(s+1)^2}$ for $\mathrm{L}\left[t\right]$.

$$F(s)=e^{-s}\left\{\frac{1}{(s+1)^2}\right\}$$
$$=\frac{e^{-s}}{(s+1)^2}$$

Therefore, the Laplace Transform of $te^{-(t-1)}u(t-1)-e^{-(t-1)}u(t-1)$ is $\boxed{\frac{e^{-s}}{(s+1)^2}}$.

13.004
P

Step 1 of 5

Consider the following function:

$f(t)=te^{-at}u(t-1)$ ..... (1)

Let t be $g(t)$ and $tu(t-1)$ be $f_1(t)$

$f_1(t)=g(t)u(t-1)$

Apply Laplace Transform.

$\mathsf{L}\left[f_1(t)\right]=\mathsf{L}\left[g(t)u(t-a)\right]$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow \mathsf{L}\left[f(t)\right]=e^{-t_0s}\mathsf{L}\left[g(t+t_0)\right]$.

$F_1(s)=e^{-s}\mathsf{L}\left[g(t+a)\right]$

Substitute $t+1$ for $g(t+a)$.

$F_1(s)=e^{-s}\mathsf{L}\left[t+1\right]$

$F_1(s)=e^{-s}\left\{\mathsf{L}\left[t\right]-\mathsf{L}\left[1\right]\right\}$ ..... (2)

Step 2 of 5

Consider the function t.

Apply Laplace transform for t.

$\mathsf{L}\left[t\right]=\frac{1}{s^2}$

Therefore, the Laplace transform of t is $\frac{1}{s^2}$.

Step 3 of 5

Consider the function 1.

Apply Laplace transform.

$\mathsf{L}\left[1\right]=\frac{1}{s}$

Therefore, the Laplace transform of 1 is $\frac{1}{s}$.

Step 4 of 5

Consider expression (2).

$F_1(s)=e^{-s}\left\{\mathsf{L}\left[t\right]-\mathsf{L}\left[1\right]\right\}$

Substitute $\frac{1}{s}$ for $\mathsf{L}\left[1\right]$ and $\frac{1}{s^2}$ for $\mathsf{L}\left[t\right]$.

$F_1(s)=e^{-s}\left\{\frac{1}{s^2}+\frac{1}{s}\right\}$

Therefore, the Laplace transform of $tu(t-1)$ is $e^{-s}\left\{\frac{1}{s^2}+\frac{1}{s}\right\}$.

Step 5 of 5

Consider expression (1).

$f(t)=te^{-at}u(t-1)$

Substitute $f_1(t)$ for $\mathsf{L}\left[tu(t-1)\right]$.

$F(s)=e^{-at}f_1(t)$

Apply Laplace transform and use the property, $f(t)=e^{-at}g(t)\Rightarrow \mathsf{L}\left[f(t)\right]=G(s+a)$.

$F(s)=F_1(s+a)$

Substitute $e^{-(s+a)}\left\{\frac{1}{(s+a)^2}+\frac{1}{s+a}\right\}$ for $F_1(s+a)$.

$F(s)=e^{-(s+a)}\left\{\frac{1}{(s+a)^2}+\frac{1}{s+a}\right\}$

Therefore, the Laplace transform of $te^{-at}u(t-1)$ is $\boxed{e^{-(s+a)}\left\{\frac{1}{(s+a)^2}+\frac{1}{s+a}\right\}}$.

Step 1 of 4

Consider the following function:

$$V_O(s)=\frac{2s}{(s+1)^2(s+4)}$$

Assume $\frac{2s}{(s+1)^2(s+4)}$ to be $\frac{A}{s+4}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$.

$$\frac{2s}{(s+1)^2(s+4)}=\frac{A}{s+4}+\frac{B}{s+1}+\frac{C}{(s+1)^2} \quad \text{..... (1)}$$

$$\frac{2s}{(s+1)^2(s+4)}=\frac{A(s+1)^2+B(s+1)(s+4)+C(s+4)}{(s+1)(s+4)^2}$$

$$2s=A(s+1)^2+B(s+1)(s+4)+C(s+4) \quad \text{..... (2)}$$

Substitute -4 for s.

$$2(-4)=A(-4+1)^2+B(-4+1)(-4+4)+C(-4+4)$$
$$-8=A(-3)^2+B(0)+C(0)$$
$$-8=A(9)$$
$$A=\frac{-8}{9}$$

Therefore, the value of A is $\frac{-8}{9}$.

Step 2 of 4

Consider equation (2).

$$2s=A(s+1)^2+B(s+1)(s+4)+C(s+4)$$

Substitute -1 for s.

$$2(-1)=A(-1+1)^2+B(-1+1)(-1+4)+C(-1+4)$$
$$-2=A(0)+B(3)(0)+C(3)$$
$$-2=0+0+C(3)$$
$$C=\frac{-2}{3}$$

Therefore, the value of C is $\frac{-2}{3}$.

Step 3 of 4

Consider equation (2).

$$2s=A(s+1)^2+B(s+1)(s+4)+C(s+4)$$

Substitute 0 for s, $\frac{-2}{3}$ for C and $\frac{-8}{9}$ for A.

$$2(0)=\left(\frac{-8}{9}\right)(0+1)^2+B(0+1)(0+4)+\left(\frac{-2}{3}\right)(0+4)$$
$$0=\left(\frac{-8}{9}\right)(1)+B(4)+\left(\frac{-8}{3}\right)$$
$$0=-\frac{8}{9}+B(4)-\frac{8}{3}$$
$$B(4)=0+\frac{8}{9}+\frac{8}{3}$$
$$B(4)=\frac{8+24}{9}$$
$$B(4)=\frac{32}{9}$$
$$B=\frac{8}{9}$$

Therefore, the value of B is $\frac{8}{9}$.

Step 4 of 4

Consider equation (1).

$$\frac{2s}{(s+1)^2(s+4)}=\frac{A}{s+4}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$$

Substitute $V_O(s)$ for $\frac{2s}{(s+1)^2(s+4)}$, $\frac{8}{9}$ for B, $-\frac{2}{3}$ for C and $\frac{-8}{9}$ for A

$$V_O(s)=\frac{-8}{9(s+4)}+\frac{8}{9(s+1)}-\frac{2}{3(s+1)^2}$$

Apply inverse Laplace transform.

$$L^{-1}\left[V_O(s)\right]=\frac{-8}{9}L^{-1}\left[\frac{1}{s+4}\right]+\frac{8}{9}L^{-1}\left[\frac{1}{s+1}\right]-\frac{2}{3}L^{-1}\left[\frac{1}{(s+1)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$v_O(t)=\left(\frac{-8}{9}e^{-4t}+\frac{8}{9}e^{-t}-\frac{2}{3}te^{-t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{2s}{(s+4)(s+1)^2}$ is,

$$\boxed{\left(\frac{-8}{9}e^{-4t}+\frac{8}{9}e^{-t}-\frac{2}{3}te^{-t}\right)u(t)}$$

Therefore, the correct option is $\boxed{a}$.

13.005

E

Step 1 of 5

Consider the function.

$$\begin{aligned} f(t) &= e^{-4t}\left(t - e^{-t}\right) \\ &= te^{-4t} - e^{-t} \cdot e^{-4t} \\ &= te^{-4t} - e^{-5t} \end{aligned}$$

Let te^{-4t} to be $f_1(t)$ and e^{-5t} to be $f_2(t)$.

$f(t) = f_1(t) - f_2(t)$ ..... (1)

Step 2 of 5

Consider function $f_1(t)$.

$f_1(t) = te^{-4t}$

Apply Laplace transform.

$\mathsf{L}\left\{f_1(t)\right\} = \mathsf{L}\left\{te^{-4t}\right\}$ ..... (2)

Let t to be $g(t)$.

$g(t) = t$

Apply Laplace transform.

$G(s) = \frac{1}{s^2}$

Therefore, the Laplace transform of function is t is $\frac{1}{s^2}$.

Step 3 of 5

Consider the expression (2).

$\mathsf{L}\left\{f_1(t)\right\} = \mathsf{L}\left\{te^{-4t}\right\}$

Substitute t for $g(t)$.

$\mathsf{L}\left\{f_1(t)\right\} = \mathsf{L}\left\{e^{-4t}g(t)\right\}$

Apply the property, $\mathsf{L}\left\{e^{-at}g(t)\right\} = G(s+a)$.

$\mathbf{F}_1(s) = G(s+4)$

Substitute $\frac{1}{(s+4)^2}$ for $G(s+4)$ since $\frac{1}{s^2}$ for $G(s)$.

$\mathbf{F}_1(s) = \frac{1}{(s+4)^2}$

Therefore, the Laplace transform of the function $f_1(t)$ is $\frac{1}{(s+4)^2}$.

Step 4 of 5

Consider function $f_2(t)$.

$f_2(t) = e^{-5t}$

Apply Laplace transform.

$\mathsf{L}\left\{f_2(t)\right\} = \mathsf{L}\left\{e^{-5t}\right\}$

$\mathbf{F}_2(s) = \frac{1}{s+5}$

Therefore, the Laplace transform of function $f_2(t)$ is $\frac{1}{s+5}$.

Step 5 of 5

Consider expression (1).

$f(t) = f_1(t) - f_2(t)$

Apply Laplace transform.

$\mathbf{F}(s) = \mathbf{F}_1(s) - \mathbf{F}_2(s)$

Substitute $\frac{1}{s+5}$ for $\mathbf{F}_2(s)$ and $\frac{1}{(s+4)^2}$ for $\mathbf{F}_1(s)$.

$\mathbf{F}(s) = \frac{1}{(s+4)^2} - \frac{1}{s+5}$

Therefore, the Laplace transform of the function $e^{-4t}\left(t - e^{-t}\right)$ is $\boxed{\frac{1}{(s+4)^2} - \frac{1}{s+5}}$.

13.005
P

Step 1 of 2

Consider the following function:

$f(t) = e^{-at}\, u(t-1)$ ..... (1)

Let $u(t-1)$ be $f_1(t)$.

$f_1(t) = u(t-1)$

Apply Laplace Transform.

$\mathsf{L}\left[f_1(t)\right] = \mathsf{L}\left[u(t-1)\right]$

Apply the property, $f(t) = g(t)u(t-t_0) \Rightarrow \mathsf{L}\left[f(t)\right] = e^{-t_0 s}\mathsf{L}\left[g(t+t_0)\right]$.

$F_1(s) = e^{-as}\mathsf{L}\left[1\right]$

$F_1(s) = e^{-s}\left\{\dfrac{1}{s}\right\}$

Step 2 of 2

Consider expression (1).

$f(t) = e^{-at}\, u(t-1)$

Substitute $f_1(t)$ for $u(t-1)$.

$f(t) = e^{-at} f_1(t)$

Apply Laplace transform and use the property, $f(t) = e^{-at}g(t) \Rightarrow \mathsf{L}\left[f(t)\right] = G(s+a)$ for $e^{-at} f_1(t)$.

$F(s) = F_1(s+a)$

Substitute $e^{-(s+a)}\left\{\dfrac{1}{s+1}\right\}$ for $F_1(s+a)$.

$F(s) = e^{-(s+a)}\left\{\dfrac{1}{s+1}\right\}$

Therefore, the Laplace transform of $e^{-at}\, u(t-1)$ is $\boxed{e^{-(s+a)}\left\{\dfrac{1}{s+1}\right\}}$.

13.05E

E

Step 1 of 5

Consider the differential equation.

$$\frac{d^2x(t)}{dt^2}+\frac{6dx(t)}{dt}+8x(t)=2e^{-3t},\ x(0)=0\ ,\ \frac{dx(0)}{dt}=0$$

Apply Laplace transform.

$$s^2X(s)-sX(0)-X'(0)+6[sX(s)-X'(0)]+8X(s)=\frac{2}{s+3}$$

Substitute 0 for $X(0)$ and 0 for $X'(0)$.

$$s^2X(s)-0-0+6[sX(s)-0]+8X(s)=\frac{2}{s+3}$$

$$s^2X(s)+6sX(s)+8X(s)=\frac{2}{s+3}$$

$$(s^2+6s+8)X(s)=\frac{2}{s+3}$$

$$(s+2)(s+4)X(s)=\frac{2}{s+3}$$

$$X(s)=\frac{2}{(s+2)(s+3)(s+4)}\ \text{.....}\ (1)$$

Step 2 of 5

Assume $\frac{2}{(s+2)(s+3)(s+4)}$ to be $\frac{A}{s+2}+\frac{B}{s+3}+\frac{C}{s+4}$.

$$\frac{2}{(s+2)(s+3)(s+4)}=\frac{A}{s+2}+\frac{B}{s+3}+\frac{C}{s+4}\ \text{.....}\ (2)$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$A=(s+2)\left[\frac{2}{(s+2)(s+3)(s+4)}\right]\Bigg|_{s=-2}$$

$$=\left[\frac{2}{(s+3)(s+4)}\right]\Bigg|_{s=-2}$$

$$=\frac{2}{(-2+3)(-2+4)}$$

$$=\frac{2}{(1)(2)}$$

$$A=1$$

Therefore, the value of A is 1.

Step 3 of 5

Calculate the value of B.

$$B=(s+3)\left[\frac{2}{(s+2)(s+3)(s+4)}\right]\Bigg|_{s=-3}$$

$$=\left[\frac{2}{(s+2)(s+4)}\right]\Bigg|_{s=-3}$$

$$=\frac{2}{(-3+2)(-3+4)}$$

$$=\frac{2}{(-1)(1)}$$

$$B=-2$$

Therefore, the value of B is -2.

Step 4 of 5

Calculate the value of C.

$$C=(s+4)\left[\frac{2}{(s+2)(s+3)(s+4)}\right]\Bigg|_{s=-4}$$

$$=\left[\frac{2}{(s+2)(s+3)}\right]\Bigg|_{s=-4}$$

$$=\frac{2}{(-4+2)(-4+3)}$$

$$=\frac{2}{(-2)(-1)}$$

$$C=1$$

Therefore, the value of C is 1.

Step 5 of 5

Consider expression (2).

$$\frac{2}{(s+2)(s+3)(s+4)}=\frac{A}{s+2}+\frac{B}{s+3}+\frac{C}{s+4}$$

Substitute $\frac{2}{(s+2)(s+3)(s+4)}$ for $X(s)$, 1 for A and C and -2 for B

$$X(s)=\frac{1}{s+2}-\frac{2}{s+3}+\frac{1}{s+4}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{X(s)\}=\mathcal{L}\left\{\frac{1}{s+2}\right\}-2\mathcal{L}\left\{\frac{1}{s+3}\right\}+\mathcal{L}\left\{\frac{1}{s+4}\right\}$$

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$x(t)=\left[e^{-2t}-2e^{-3t}+e^{-4t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left[e^{-2t}-2e^{-3t}+e^{-4t}\right]u(t)}$.

Therefore, the correct option is $\boxed{\text{c}}$.

13.006
E

Step 1 of 3

Consider the function.

$$F(s)=\frac{10(s+6)}{(s+1)(s+3)}$$

Assume $\frac{10(s+6)}{(s+1)(s+3)}$ to be $\frac{A}{s+1}+\frac{B}{s+3}$.

$$\frac{10(s+6)}{(s+1)(s+3)}=\frac{A}{s+1}+\frac{B}{s+3} \quad \text{..... (1)}$$

$$10(s+6)=A(s+3)+B(s+1) \quad \text{..... (2)}$$

Substitute -1 for s.

$$10(-1+6)=A(-1+3)+B(-1+1)$$
$$10(5)=A(2)+B(0)$$
$$50=A(2)$$
$$A=\frac{50}{2}$$
$$A=25$$

Therefore, the value of A is 25.

Step 2 of 3

Consider equation (1).

$$10(s+6)=A(s+3)+B(s+1)$$

Substitute -3 for s.

$$10(-3+6)=A(-3+3)+B(-3+1)$$
$$10(3)=A(0)+B(-2)$$
$$30=B(-2)$$
$$B=-\frac{30}{2}$$
$$B=-15$$

Therefore, the value of B is -15.

Step 3 of 3

Consider equation (1).

$$\frac{10(s+6)}{(s+1)(s+3)}=\frac{A}{s+1}+\frac{B}{s+3}$$

Substitute $F(s)$ for $\frac{10(s+6)}{(s+1)(s+3)}$, -15 for B and 25 for A

$$F(s)=\frac{25}{s+1}+\frac{(-15)}{s+3}$$
$$=\frac{25}{s+1}-\frac{15}{s+3}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=25\mathcal{L}^{-1}\left[\frac{1}{s+1}\right]-15\mathcal{L}^{-1}\left[\frac{1}{s+3}\right]$$

Apply the property, $\mathcal{L}^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(25e^{-t}-15e^{-3t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{10(s+6)}{(s+1)(s+3)}$ is $\boxed{\left(25e^{-t}-15e^{-3t}\right)u(t)}$.

Step 1 of 1

13.006 P

Consider the following function:

$$f(t)=e^{-at}\delta(t-1)$$

Consider the formula for Laplace transform.

$$\mathrm{L}\left[f(t)\right]=\int_0^\infty f(t)e^{-st}dt$$

Substitute $e^{-at}\delta(t-1)$ for $f(t)$.

$$\begin{aligned}F(s)&=\int_0^\infty e^{-at}\delta(t-1)e^{-st}dt\\&=\int_0^\infty e^{-(a+s)t}\delta(t-1)dt\end{aligned}$$

Integration exists only at the value of $t=1$ Since $\delta(t-1)=\begin{cases}1 & t=1\\0 & t\neq 1\end{cases}$.

$$\begin{aligned}F(s)&=\int_{t=1} e^{-(a+s)t}(1)dt\\&=\int_{t=1} e^{-(a+s)t}dt\\&=\left.\frac{e^{-(a+s)t}}{-(s+a)}\right|_{t=1}\\&=\frac{e^{-(a+s)(1)}}{-(s+a)}\end{aligned}$$

$$F(s)=-\frac{e^{-(s+a)}}{s+a}$$

Therefore, the Laplace transform of the function $e^{-at}\delta(t-1)$ is $\boxed{-\frac{e^{-(s+a)}}{s+a}}$.

Step 1 of 3

13.007

E

Consider the transfer function $\mathbf{F}(s)$ in the Laplace domain.

$$\mathbf{F}(s)=\frac{12(s+2)}{s(s+1)}$$

Step 2 of 3

Expand the transfer function using partial fraction expansion.

$$\frac{12(s+2)}{s(s+1)}=\frac{K_0}{s}+\frac{K_1}{(s+1)}$$

To evaluate K_0, multiply both sides of the equation by s and substitute $s=0$

$$\left.\frac{12(s+2)}{(s+1)}\right|_{s=0}=K_0+\left.\frac{sK_1}{(s+1)}\right|_{s=0}$$

$$K_0=\frac{(12)(2)}{(1)}$$

$$K_0=24$$

To evaluate K_1, multiply both sides of the equation by s and then substitute $s=0$.

$$\left.\frac{12(s+2)}{s}\right|_{s+1=0}=K_0\left.\left(\frac{s+1}{s}\right)\right|_{s+1=0}+K_1$$

$$K_1=\frac{(12)(-1+2)}{(-1)}$$

$$K_1=-12$$

Thus, the expanded transfer function of $\mathbf{F}(s)$ is,

$$\mathbf{F}(s)=\frac{24}{s}-\frac{12}{(s+1)}$$

Step 3 of 3

To find the time domain expression, find the inverse Laplace transform of the function $\mathbf{F}(s)$.

$$\begin{aligned}f(t)&=\mathcal{L}^{-1}\{\mathbf{F}(s)\}\\&=\mathcal{L}^{-1}\left\{\frac{24}{s}-\frac{12}{(s+1)}\right\}\\&=24u(t)-12e^{-t}u(t)\end{aligned}$$

Thus, the time domain function $f(t)$ is $\boxed{12(2-e^{-t})u(t)}$.

13.007

P

The Laplace transform of the function $f(t) = e^{-at} \sin \omega t$ is

$$F(s) = \int_0^\infty e^{-at} \sin \omega t \, e^{-st} \, dt$$

$$F(s) = \int_0^\infty e^{-(a+s)t} \left[\frac{e^{j\omega t} - e^{-j\omega t}}{2j} \right] dt$$

$$F(s) = \frac{1}{2j} \int_0^\infty \left[e^{-(a+s)t} \, e^{j\omega t} - e^{-(a+s)t} \, e^{-j\omega t} \right] dt$$

$$F(s) = \frac{1}{2j} \int_0^\infty \left[e^{-(a+s-j\omega t)} - e^{-(a+s+j\omega)t} \right] dt$$

$$F(s) = \frac{1}{2j} \left[\frac{1}{-(a+s-j\omega)} e^{-(a+s-j\omega)t} - \frac{1}{1(a+s+j\omega)} e^{-(a+s+j\omega)t} \right]_0^\infty$$

$$F(s) = \frac{1}{2j} \left[0+0+\frac{1}{(a+s-j\omega)} - \frac{1}{(a+s+j\omega)} \right]$$

$$= \frac{1}{2j} \left[\frac{2j\omega}{(s+a)^2 + \omega^2} \right]$$

$$F(s) = \frac{\omega}{(s+a)^2 + \omega^2}$$

13.008
E

Step 1 of 4

Consider the function.

$$F(s)=\frac{s^2+5s+1}{s(s+1)(s+4)}$$

Assume $\frac{s^2+5s+1}{s(s+1)(s+4)}$ to be $\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+4}$.

$$\frac{s^2+5s+1}{s(s+1)(s+4)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+4} \quad \text{..... (1)}$$

$$\frac{s^2+5s+1}{s(s+1)(s+4)}=\frac{A(s+1)(s+4)+B(s)(s+4)+C(s)(s+1)}{s(s+1)(s+4)}$$

$$s^2+5s+1=A(s+1)(s+4)+B(s)(s+4)+C(s)(s+1) \quad \text{..... (2)}$$

Substitute 0 for s.

$$(0)^2+5(0)+1=A(0+1)(0+4)+B(0)(0+4)+C(0)(0+1)$$
$$0-0+1=A(1)(4)+B(0)+C(0)$$
$$1=A(4)$$
$$A=\frac{1}{4}$$
$$A=0.25$$

Therefore, the value of A is 0.25.

Step 2 of 4

Consider equation (2).

$$s^2+5s+1=A(s+1)(s+4)+B(s)(s+4)+C(s)(s+1)$$

Substitute -1 for s.

$$(-1)^2+5(-1)+1=A(-1+1)(-1+4)+B(-1)(-1+4)+C(-1)(-1+1)$$
$$1-5+1=A(0)(3)+B(-1)(3)+C(-1)(0)$$
$$-3=0+B(-3)+0$$
$$B=\frac{-3}{-3}$$
$$B=1$$

Therefore, the value of B is 1.

Step 3 of 4

Consider equation (2).

$$s^2+5s+1=A(s+1)(s+4)+B(s)(s+4)+C(s)(s+1)$$

Substitute -4 for s.

$$(-4)^2+5(-4)+1=A(-4+1)(-4+4)+B(-4)(-4+4)+C(-4)(-4+1)$$
$$16-20+1=A(-3)(0)+B(-4)(0)+C(-4)(-3)$$
$$-3=0+0+C(12)$$
$$C=-\frac{3}{12}$$
$$C=-0.25$$

Therefore, the value of C is -0.25.

Step 4 of 4

Consider equation (1).

$$\frac{s^2+5s+1}{s(s+1)(s+4)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+4}$$

Substitute $F(s)$ for $\frac{s^2+5s+1}{s(s+1)(s+4)}$, 1 for B, -0.25 for C and 0.25 for A

$$F(s)=\frac{0.25}{s}+\frac{1}{s+1}-\frac{0.25}{s+4}$$

Apply inverse Laplace transform.

$$F(s)=0.25\mathcal{L}^{-1}\left[\frac{1}{s}\right]+\mathcal{L}^{-1}\left[\frac{1}{s+1}\right]-0.25\mathcal{L}^{-1}\left[\frac{1}{s+4}\right]$$

Apply the property's, $\mathcal{L}^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(0.25+e^{-t}-0.25e^{-4t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s^2+5s+1}{s(s+1)(s+4)}$ is

$$\boxed{\left(0.25+e^{-t}-0.25e^{-4t}\right)u(t)}.$$

13.008

P

Step 1 of 1

The Laplace transform of the function $f(t) = e^{-at}$ is

$$F(s) = \int_0^\infty e^{-at} e^{-st} dt$$

$$F(s) = \int_0^\infty e^{-(a+s)t} \, dt$$

$$F(s) = -\frac{1}{(s+a)} e^{-(a+s)t} \Big|_0^\infty$$

$$F(s) = -\frac{1}{s+a}[0-1]$$

$$\boxed{F(s) = \frac{1}{s+a}}$$

13.009

E

Step 1 of 2

Consider the function.

$$F(s)=\frac{s}{s^2+4s+8}$$
$$=\frac{s}{(s+2-j2)(s+2+j2)}$$

Assume $\frac{s}{(s+2-j2)(s+2+j2)}$ to be $\frac{A}{s+2-j2}+\frac{A^*}{s+2+j2}$.

$$\frac{s}{(s+2-j2)(s+2+j2)}=\frac{A}{s+2-j2}+\frac{A^*}{s+2+j2} \quad \text{..... (1)}$$

Use residue's method to find the values of A and A^*.

Calculate the value of A.

$$A=(s+2-j2)\left[\frac{s}{(s+2-j2)(s+2+j2)}\right]\Bigg|_{s=-2+j2}$$
$$=\left[\frac{s}{(s+2+j2)}\right]\Bigg|_{s=-2+j2}$$
$$=\frac{-2+j2}{(-2+j2+2+j2)}$$
$$=\frac{-2+j2}{j4}$$

$$A=0.707\angle 45^\circ$$

Therefore, the value of A is $0.707\angle 45^\circ$.

As A^* is the conjugate value of A, the value of A^* is $0.707\angle -45^\circ$.

Step 2 of 2

Consider the function (1).

$$\frac{s}{(s+2-j2)(s+2+j2)}=\frac{A}{s+2-j2}+\frac{A^*}{s+2+j2}$$

Substitute $F(s)$ for $\frac{s}{(s+2-j2)(s+2+j2)}$, $0.707\angle -45^\circ$ for A^* and $0.707\angle 45^\circ$ for A.

$$F(s)=\frac{0.707\angle 45^\circ}{s+2-j2}+\frac{0.707\angle -45^\circ}{s+2+j2}$$

Apply inverse Laplace transform.

Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$f(t)=\left[2(0.707)e^{-2t}\cos(2t+45^\circ)\right]u(t)$$
$$=1.41e^{-2t}\cos(2t+45^\circ)u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s}{s^2+4s+8}$ is $\boxed{1.41e^{-2t}\cos(2t+45^\circ)u(t)}$.

Step 1 of 1

Write the expression of the Laplace transform of $f(t)$.

$$F(s)=\int_0^\infty f(t)e^{-st}dt$$

Substitute $te^{-at}\sin(\omega t)\delta(t-4)$ for $f(t)$.

$$\begin{aligned}F(s)&=\int_0^\infty\left(te^{-at}\sin(\omega t)\delta(t-4)\right)e^{-st}dt\\&=\int_0^\infty\left(te^{-at}\sin(\omega t)e^{-st}\right)\delta(t-4)dt\\&=\int_0^\infty\left(4e^{-4a}\sin(4\omega)e^{-4s}\right)\delta(t-4)dt\\&=\left(4e^{-4a}\sin(4\omega)e^{-4s}\right)\left(\int_0^\infty\delta(t-4)dt\right)\end{aligned}$$

Simplify further.

$$\begin{aligned}F(s)&=\left(4e^{-4a}\sin(4\omega)e^{-4s}\right)(1)\\&=4e^{-4(s+a)}\sin(4\omega)\end{aligned}$$

Thus, the Laplace transform of $f(t)$ is $\boxed{4e^{-4(s+a)}\sin(4\omega)}$.

Step 1 of 3

Consider the function.

$$F(s)=\frac{4(s+3)}{(s+1)(s^2+2s+5)}$$
$$=\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j1)}$$

Assume $\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j1)}$ to be $\frac{A}{s+1}+\frac{B}{s+1-j2}+\frac{B^*}{s+1+j2}$.

$$\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j1)}=\frac{A}{s+1}+\frac{B}{s+1-j2}+\frac{B^*}{s+1+j2} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of A.

$$A=(s+1)\left[\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j2)}\right]\Bigg|_{s=-1}$$
$$=\left[\frac{4(s+3)}{(s+1-j2)(s+1+j2)}\right]\Bigg|_{s=-1}$$
$$=\frac{4(-1+3)}{(-1+1-j2)(-1+1+j2)}$$
$$=\frac{4(2)}{(-j2)(j2)}$$

Simplify further.

$$A=\frac{8}{4}$$
$$=2$$

Therefore, the value of A is 2.

Step 2 of 3

Calculate the value of B.

$$B=(s+1-j2)\left[\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j2)}\right]\Bigg|_{s=-1+j2}$$
$$=\left[\frac{4(s+3)}{(s+1)(s+1+j2)}\right]\Bigg|_{s=-1+j2}$$
$$=\frac{4(-1+j2+3)}{(-1+j2+1)(-1+j2+1+j2)}$$
$$=\frac{4(2+j2)}{(j2)(j4)}$$

Simplify further.

$$B=\frac{(8+j8)}{(-8)}$$
$$=\sqrt{2}\angle-135^\circ$$

Therefore, the value of B is $\sqrt{2}\angle-135^\circ$.

As B^* is the conjugate value of B, the value of B^* is $\sqrt{2}\angle 135^\circ$.

Step 3 of 3

Consider the function (1).

$$\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j1)}=\frac{A}{s+1}+\frac{B}{s+1-j2}+\frac{B^*}{s+1+j2}$$

Substitute $F(s)$ for $\frac{4(s+3)}{(s+1)(s+1-j2)(s+1+j1)}$, $1.41\angle 135^\circ$ for B^*, $1.41\angle-135^\circ$ for B and 2 for A.

$$F(s)=\frac{2}{s+1}+\frac{\sqrt{2}\angle-135^\circ}{s+1-j2}+\frac{\sqrt{2}\angle 135^\circ}{s+1+j2}$$

Apply inverse Laplace transform.

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$f(t)=\left[2e^{-t}+2\sqrt{2}e^{-t}\cos(2t-135^\circ)\right]u(t)$ Therefore, the Inverse Laplace transform of $\frac{4(s+3)}{(s+1)(s^2+2s+5)}$ is

$$\boxed{\left[2e^{-t}+2\sqrt{2}e^{-t}\cos(2t-135^\circ)\right]u(t)}.$$

Step 1 of 4

Consider the function.

$$f(t)=e^{-at}\sin\omega t u(t-1)$$

Let $e^{-at}\sin\omega t$ be $g(t)$.

$$f(t)=g(t)u(t-1)$$

Apply Laplace Transform.

$$\mathrm{L}\left[f(t)\right]=\mathrm{L}\left[g(t)u(t-1)\right]$$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow \mathrm{L}\left[f(t)\right]=e^{-t_0 s}\mathrm{L}\left[g(t+t_0)\right]$.

$$F(s)=e^{-s}\mathrm{L}\left[g(t+1)\right]$$

Substitute $e^{-a(t+1)}\sin\omega(t+1)$ for $g(t+1)$.

$$\begin{aligned}F(s)&=e^{-s}\mathrm{L}\left[e^{-a(t+1)}\sin\omega(t+1)\right]\\&=e^{-s}\mathrm{L}\left[e^{-at}\cdot e^{-a}\cdot\sin(\omega t+\omega)\right]\\&=e^{-(s+a)}\mathrm{L}\left[e^{-at}\cdot(\sin(\omega t)\cos(\omega)+\cos(\omega t)\sin(\omega))\right]\\&=e^{-(s+a)}\left\{\mathrm{L}\left[e^{-at}\cdot\sin(\omega t)\cos(\omega)\right]+\mathrm{L}\left[e^{-at}\cdot\cos(\omega t)\sin(\omega)\right]\right\}\end{aligned}$$

$$F(s)=e^{-(s+a)}\left\{\cos(\omega)\cdot\mathrm{L}\left[e^{-at}\cdot\sin(\omega t)\right]+\sin(\omega)\cdot\mathrm{L}\left[e^{-at}\cdot\cos(\omega t)\right]\right\}\text{ ..... (1)}$$

Step 2 of 4

Consider $e^{-at}\cdot\sin(\omega t)$.

Apply Laplace transform for $\sin(\omega t)$.

$$\mathrm{L}\left[\sin(\omega t)\right]=\frac{\omega}{s^2+\omega^2}$$

Apply the property, $f(t)=e^{-at}g(t)\Rightarrow \mathrm{L}\left[f(t)\right]=G(s+a)$ for $e^{-at}\cdot\sin(\omega t)$.

$$\mathrm{L}\left[e^{-at}\cdot\sin(\omega t)\right]=\frac{\omega}{(s+a)^2+\omega^2}$$

Therefore, the Laplace transform of $e^{-at}\cdot\sin(\omega t)$ is $\dfrac{\omega}{(s+a)^2+\omega^2}$.

Step 3 of 4

Consider $e^{-at}\cdot\cos(\omega t)$.

Apply Laplace transform for $\cos(\omega t)$.

$$\mathrm{L}\left[\cos(\omega t)\right]=\frac{s}{s^2+\omega^2}$$

Apply the property, $f(t)=e^{-at}g(t)\Rightarrow \mathrm{L}\left[f(t)\right]=G(s+a)$ for $e^{-at}\cdot\cos(\omega t)$.

$$\mathrm{L}\left[e^{-at}\cdot\cos(\omega t)\right]=\frac{s+a}{(s+a)^2+\omega^2}$$

Therefore, the Laplace transform of $e^{-at}\cdot\cos(\omega t)$ is $\dfrac{s+a}{(s+a)^2+\omega^2}$.

Step 4 of 4

Consider the expression (1).

$$F(s)=e^{-(s+a)}\left\{\cos(\omega)\cdot\mathrm{L}\left[e^{-at}\cdot\sin(\omega t)\right]+\sin(\omega)\cdot\mathrm{L}\left[e^{-at}\cdot\cos(\omega t)\right]\right\}$$

Substitute $\dfrac{\omega}{(s+a)^2+\omega^2}$ for $\mathrm{L}\left[e^{-at}\cdot\sin(\omega t)\right]$ and $\dfrac{s+a}{(s+a)^2+\omega^2}$ for $\mathrm{L}\left[e^{-at}\cdot\cos(\omega t)\right]$.

$$\begin{aligned}F(s)&=e^{-(s+a)}\left\{\cos(\omega)\cdot\left(\frac{\omega}{(s+a)^2+\omega^2}\right)+\sin(\omega)\cdot\left(\frac{s+a}{(s+a)^2+\omega^2}\right)\right\}\\&=e^{-(s+a)}\left\{\frac{\omega\cos(\omega)+(s+a)\sin(\omega)}{(s+a)^2+\omega^2}\right\}\end{aligned}$$

Therefore, the Laplace Transform of $e^{-at}\sin\omega t u(t-1)$ is,

$$\boxed{e^{-(s+a)}\left\{\frac{\omega\cos(\omega)+(s+a)\sin(\omega)}{(s+a)^2+\omega^2}\right\}}.$$

13.011

E

Step 1 of 3

Consider the function.

$$F(s)=\frac{s}{(s+1)^2}$$

Assume $\frac{s}{(s+1)^2}$ to be $\frac{A}{s+1}+\frac{B}{(s+1)^2}$.

$$\frac{s}{(s+1)^2}=\frac{A}{s+1}+\frac{B}{(s+1)^2} \quad \text{..... (1)}$$

$$\frac{s}{(s+1)^2}=\frac{A(s+1)+B}{(s+1)^2}$$

$$s=A(s+1)+B \quad \text{..... (2)}$$

Substitute -1 for s.

$$-1=A(-1+1)+B$$
$$-1=A(0)+B$$
$$-1=0+B$$
$$B=-1$$

Therefore, the value of B is -1.

Step 2 of 3

Consider equation (2).

$$s=A(s+1)+B$$

Substitute 0 for s and -1 for B

$$0=A(0+1)-1$$
$$0=A-1$$
$$0+1=A$$
$$A=1$$

Therefore, the value of A is 1.

Step 3 of 3

Consider equation (3).

$$\frac{s}{(s+1)^2}=\frac{A}{s+1}+\frac{B}{(s+1)^2}$$

Substitute $F(s)$ for $\frac{s}{(s+1)^2}$, -1 for B and 1 for A.

$$F(s)=\frac{1}{s+1}-\frac{1}{(s+1)^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=\mathcal{L}^{-1}\left[\frac{1}{s+1}\right]-\mathcal{L}^{-1}\left[\frac{1}{(s+1)^2}\right]$$

Apply the property's, $\mathcal{L}^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $\mathcal{L}^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$f(t)=\left(e^{-t}-te^{-t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s}{(s+1)^2}$ is $\boxed{\left(e^{-t}-te^{-t}\right)u(t)}$.

13.011
P

Step 1 of 3

Consider the following function:

$$f(t)=te^{-at}u(t-4)$$

Let te^{-at} be $g(t)$.

$$f(t)=g(t)u(t-4)$$

Apply Laplace Transform.

$$\mathcal{L}\left[f(t)\right]=\mathcal{L}\left[g(t)u(t-4)\right]$$

Apply the property, $f(t)=g(t)u(t-t_0)\Rightarrow \mathcal{L}\left[f(t)\right]=e^{-t_0 s}\mathcal{L}\left[g(t+t_0)\right]$.

$$F(s)=e^{-4s}\mathcal{L}\left[g(t+4)\right]$$

Substitute $(t+4)e^{-a(t+4)}$ for $g(t+4)$.

$$\begin{aligned}F(s)&=e^{-4s}\mathcal{L}\left[(t+4)e^{-a(t+4)}\right]\\&=e^{-4s}\mathcal{L}\left[(t+4)\cdot e^{-at}\cdot e^{-4a}\right]\\&=e^{-4(s+a)}\mathcal{L}\left[t\cdot e^{-at}+4e^{-at}\right]\\&=e^{-4(s+a)}\left\{\mathcal{L}\left[t\cdot e^{-at}\right]+\mathcal{L}\left[4e^{-at}\right]\right\}\end{aligned}$$

$$F(s)=e^{-4(s+a)}\left\{\mathcal{L}\left[t\cdot e^{-at}\right]+4\mathcal{L}\left[e^{-at}\right]\right\}\text{ ..... (1)}$$

Step 2 of 3

Consider $t\cdot e^{-at}$.

Apply Laplace transform for t.

$$\mathcal{L}\left[t\right]=\frac{1}{s^2}$$

Apply the property, $f(t)=e^{-at}g(t)\Rightarrow \mathcal{L}\left[f(t)\right]=G(s+a)$ for $t\cdot e^{-at}$.

$$\mathcal{L}\left[t\cdot e^{-at}\right]=\frac{1}{(s+a)^2}$$

Therefore, the Laplace transform of $t\cdot e^{-at}$ is $\frac{1}{(s+a)^2}$.

Consider e^{-at}.

Apply Laplace transform.

$$\mathcal{L}\left[e^{-at}\right]=\frac{1}{s+a}$$

Therefore, the Laplace transform of e^{-at} is $\frac{1}{s+a}$.

Step 3 of 3

Consider the expression (1).

$$F(s)=e^{-4(s+a)}\left\{\mathcal{L}\left[t\cdot e^{-at}\right]+4\mathcal{L}\left[e^{-at}\right]\right\}$$

Substitute $\frac{1}{(s+a)^2}$ for $\mathcal{L}\left[t\cdot e^{-at}\right]$ and $\frac{1}{s+a}$ for $\mathcal{L}\left[e^{-at}\right]$.

$$F(s)=e^{-4(s+a)}\left\{\frac{1}{(s+a)^2}+\frac{4}{s+a}\right\}$$

Therefore, the Laplace Transform of $te^{-at}u(t-4)$ is $\boxed{e^{-4(s+a)}\left\{\frac{1}{(s+a)^2}+\frac{4}{s+a}\right\}}$.

13.012

E

Step 1 of 4

Consider the function.

$$F(s)=\frac{s+2}{s^2(s+1)}$$

Assume $\frac{s+2}{s^2(s+1)}$ to be $\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1}$.

$$\frac{s+2}{s^2(s+1)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1} \quad \text{..... (1)}$$

$$\frac{s+2}{s^2(s+1)}=\frac{As(s+1)+B(s+1)+Cs^2}{s^2(s+1)}$$

$$s+2=As(s+1)+B(s+1)+Cs^2 \quad \text{..... (2)}$$

Substitute -1 for s.

$$-1+2=A(-1)(-1+1)+B(-1+1)+C(-1)^2$$
$$1=A(0)+B(0)+C(1)$$
$$1=C(1)$$
$$C=1$$

Therefore, the value of C is 1.

Step 2 of 4

Consider equation (2).

$$s+2=As(s+1)+B(s+1)+Cs^2$$

Substitute 0 for s.

$$0+2=A(0)(0+2)+B(0+1)+C(0)^2$$
$$2=A(0)+B(1)+C(0)$$
$$2=B$$
$$B=2$$

Therefore, the value of B is 2.

Step 3 of 4

Consider equation (2).

$$s+2=As(s+1)+B(s+1)+Cs^2$$

Substitute 1 for s, 1 for C and 2 for B.

$$1+2=A(1)(1+1)+(2)(1+1)+(1)(1)^2$$
$$3=A(2)+4+1$$
$$A(2)=3-4-1$$
$$A(2)=-2$$

$$A=-1$$

Therefore, the value of A is -1.

Step 4 of 4

Consider equation (1).

$$\frac{s+2}{s^2(s+1)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1}$$

Substitute $F(s)$ for $\frac{s+2}{s^2(s+1)}$, 2 for B, -1 for A and 1 for C.

$$F(s)=\frac{-1}{s}+\frac{2}{s^2}+\frac{1}{(s+1)}$$

Apply inverse Laplace transform.

$$\mathrm{L}^{-1}[F(s)]=-\mathrm{L}^{-1}\left[\frac{1}{s}\right]+2\mathrm{L}^{-1}\left[\frac{1}{s^2}\right]+\mathrm{L}^{-1}\left[\frac{1}{(s+1)}\right]$$

Apply the property's, $\mathrm{L}^{-1}\left[\frac{1}{s}\right]=1$, $\mathrm{L}^{-1}\left[\frac{1}{s^2}\right]=t$ and $\mathrm{L}^{-1}\left[\frac{1}{(s+a)}\right]=e^{-at}$

$$f(t)=\left((-1)(1)+2t+e^{-t}\right)u(t)$$
$$=\left(-1+2t+e^{-t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+2}{s^2(s+1)}$ is $\boxed{\left(-1+2t+e^{-t}\right)u(t)}$.

Step 1 of 1

13.012 P

Refer to Table 13.2 in the text book.

Write the expression of the property 3 of the Laplace transform.

$$L\ \left[f(at)\right]=\frac{1}{a}F\left(\frac{s}{a}\right)$$

Write the expression of the function $F(s)$.

$$F(s)=\frac{1}{(s+1)^2+1}$$

Determine the Laplace transform of $e^{-2t}\sin 2t$.

$$L\ \left[e^{-2t}\sin 2t\right]=\frac{1}{2}F\left(\frac{s}{2}\right)$$

Replace s by $\frac{s}{2}$ in the expression of the function $F(s)$.

$$\begin{aligned}L\ \left[e^{-2t}\sin 2t\right]&=\frac{1}{2}\left(\frac{1}{\left(\frac{s}{2}+1\right)^2+1}\right)\\&=\frac{1}{2}\left(\frac{1}{\frac{(s+2)^2}{4}+1}\right)\\&=\frac{1}{2}\left(\frac{4}{(s+2)^2+4}\right)\\&=\frac{2}{(s+2)^2+4}\end{aligned}$$

Thus, the Laplace transform of $e^{-2t}\sin 2t$ is $\boxed{\frac{2}{(s+2)^2+4}}$.

Step 1 of 5

Consider the function.

$$F(s)=\frac{100}{s^3(s+5)}$$

Assume $\frac{100}{s^3(s+5)}$ to be $\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s^3}+\frac{D}{s+5}$.

$$\frac{100}{s^3(s+5)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s^3}+\frac{D}{s+5} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of C.

$$\begin{aligned}C&=s^3\left[\frac{100}{s^3(s+5)}\right]\Bigg|_{s=0}\\&=\left[\frac{100}{(s+5)}\right]\Bigg|_{s=0}\\&=\frac{100}{(0+5)}\\&=\frac{100}{5}\\C&=20\end{aligned}$$

Therefore, the value of C is 20.

Step 2 of 5

Calculate the value of B.

$$\begin{aligned}B&=\frac{d}{ds}s^3\left[\frac{100}{s^3(s+5)}\right]\Bigg|_{s=0}\\&=\frac{d}{ds}\left[\frac{100}{(s+5)}\right]\Bigg|_{s=0}\\&=\frac{(-1)100}{(s+5)^2}\Bigg|_{s=0}\\&=\frac{-100}{(0+5)^2}\\B&=\frac{-100}{25}\\&=-4\end{aligned}$$

Therefore, the value of B is -4.

Step 3 of 5

Calculate the value of A.

$$\begin{aligned}A&=\frac{d^2}{ds^2}s^3\left[\frac{100}{s^3(s+5)}\right]\Bigg|_{s=0}\\&=\frac{d}{ds}\left(\frac{d}{ds}\left[\frac{100}{(s+5)}\right]\right)\Bigg|_{s=0}\\&=\frac{d}{ds}\left(\frac{(-1)100}{(s+5)^5}\right)\Bigg|_{s=0}\\&=\frac{d}{ds}\left(\frac{-100}{(s+5)^5}\right)\Bigg|_{s=0}\\A&=\frac{(-100)(-2)}{(s+5)^3}\Bigg|_{s=0}\\&=\frac{200}{(0+5)^3}\\&=\frac{200}{125}\\&=1.6\end{aligned}$$

Therefore, the value of A is 1.6.

Step 4 of 5

Calculate the value of D.

$$\begin{aligned}D&=(s+5)\left[\frac{100}{s^3(s+5)}\right]\Bigg|_{s=-5}\\&=\left[\frac{100}{s^3}\right]\Bigg|_{s=0}\\&=\frac{100}{(-5)^5}\\&=-\frac{100}{125}\\D&=-0.8\end{aligned}$$

Therefore, the value of D is -0.8.

Step 5 of 5

Consider equation (1).

$$\frac{100}{s^3(s+5)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s^3}+\frac{D}{s+5}$$

Substitute $F(s)$ for $\frac{100}{s^3(s+5)}$, -4 for B, 1.6 for A, 20 for C and -0.8 for C

$$F(s)=\frac{1.6}{s}-\frac{4}{s^2}+\frac{20}{s^3}-\frac{0.8}{s+5}$$

Apply inverse Laplace transform.

$$L^{-1}[F(s)]=1.6L^{-1}\left[\frac{1}{s}\right]-4L^{-1}\left[\frac{1}{s^2}\right]+20L^{-1}\left[\frac{1}{s^3}\right]-0.8L^{-1}\left[\frac{1}{(s+5)}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$, $L^{-1}\left[\frac{1}{s^2}\right]=t$, $L^{-1}\left[\frac{1}{s^3}\right]=t^2$ and $L^{-1}\left[\frac{1}{(s+a)}\right]=e^{-at}$

$$\begin{aligned}f(t)&=\left((1.6)(1)-4t+20t^2+0.8e^{-5t}\right)u(t)\\&=\left(1.6-4t+20t^2-0.8e^{-5t}\right)u(t)\end{aligned}$$

Therefore, the inverse Laplace transform of $\frac{100}{s^3(s+5)}$ is $\boxed{\left(1.6-4t+20t^2-0.8e^{-5t}\right)u(t)}$.

Step 1 of 1

Write the expression of the Laplace transform of $f(t)$.

$$L\ \left[f(t)\right]=\int_0^\infty f(t)dt$$

Substitute $t^2e^{-at}u(t-2)$ for $f(t)$.

$$\begin{aligned}
L\ \left[f(t)\right]&=\int_0^\infty\left(t^2e^{-at}u(t-2)\right)e^{-st}dt\\
&=\int_2^\infty\left(t^2e^{-t(s+a)}\right)dt\\
&=\left(e^{-t(s+a)}\left(\frac{t^2}{(-(s+a))}-\frac{2t}{(-(s+a))^2}+\frac{2}{(-(s+a))^3}\right)\right)\Bigg|_2^\infty\\
&=\left[0-\left(e^{-2(s+a)}\left(-\frac{(2)^2}{(s+a)}-\frac{2(2)}{(s+a)^2}-\frac{2}{(s+a)^3}\right)\right)\right]
\end{aligned}$$

Simplify further.

$$L\ \left[f(t)\right]=\left(\frac{4}{(s+a)}+\frac{4}{(s+a)^2}+\frac{2}{(s+a)^3}\right)e^{-2(s+a)}$$

Thus, the Laplace transform of $f(t)$ is $\boxed{\left(\frac{4}{(s+a)}+\frac{4}{(s+a)^2}+\frac{2}{(s+a)^3}\right)e^{-2(s+a)}}$.

13.014

E

Step 1 of 2

Consider the function.

$$\mathbf{F}(s)=\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(0) &= \lim_{s\to\infty} s\left(\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}\right)\\
&= \lim_{s\to\infty}\left(\frac{s^3\left(1+\frac{1}{s}\right)^2}{s^4\left(1+\frac{2}{s}\right)\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}\right)\\
&= \lim_{s\to\infty}\left(\frac{\left(1+\frac{1}{s}\right)^2}{s\left(1+\frac{2}{s}\right)\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}\right)\\
&= \frac{\left(1+\frac{1}{\infty}\right)^2}{\infty\left(1+\frac{2}{\infty}\right)\left(1+\frac{2}{\infty}+\frac{2}{\infty}\right)}
\end{aligned}$$

Simplify further.

$$\begin{aligned}
f(0) &= (0)\frac{\left(1+\frac{1}{\infty}\right)^2}{\left(1+\frac{2}{\infty}\right)\left(1+\frac{2}{\infty}+\frac{2}{\infty}\right)}\\
&= 0
\end{aligned}$$

Therefore, the initial value for the function is $\boxed{0}$.

Step 2 of 2

Consider the function.

$$\mathbf{F}(s)=\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(\infty) &= \lim_{s\to 0} s\left(\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}\right)\\
&= \lim_{s\to 0}\left(\frac{(s+1)^2}{(s+2)(s^2+2s+2)}\right)\\
&= \frac{(0+1)^2}{(0+2)(0+0+2)}\\
&= \frac{1}{4}
\end{aligned}$$

$$f(\infty)=\frac{1}{4}$$

Therefore, the final value for the function is $\boxed{\frac{1}{4}}$.

Step 1 of 2

Consider the function.

$$f(t)=t\sin\omega t u(t-1)$$

Let $t\cos(\omega t)$ be $f_1(t)$.

$$f(t)=f_1(t)u(t-1)$$

Apply the property,

$$f(t)=g(t)u(t-t_0)$$
$$\Rightarrow L[f(t)]=e^{-t_0 s}L[g(t+t_0)]$$

$$F(s)=e^{-s}L\{(t+1)\sin(t+1)\}$$
$$=e^{-s}L\{(t\sin(\omega t+\omega)+\sin(\omega t+\omega))\}$$

$$F(s)=e^{-s}\{L(t\sin(\omega t+\omega))+L(\sin(\omega t+\omega))\} \quad \text{..... (1)}$$

Assume $\sin(\omega t+\omega)$ to be $g(t)$.

$$g(t)=\sin(\omega t+\omega)$$

Apply trigonometric expansion.

$$g(t)=\sin\omega t\cos\omega+\cos\omega t\sin\omega$$

Apply Laplace transform.

$$G(s)=\cos\omega L\{\sin\omega t\}+\sin\omega L\{\cos\omega t\}$$

Since $L\{\cos\omega t\}=\dfrac{s}{s^2+\omega^2}$ and $L\{\sin\omega t\}=\dfrac{\omega}{s^2+\omega^2}$.

$$G(s)=\cos\omega\left(\frac{\omega}{s^2+\omega^2}\right)+\sin\omega\left(\frac{s}{s^2+\omega^2}\right)$$
$$=\frac{\omega\cos\omega}{s^2+\omega^2}+\frac{s\sin\omega}{s^2+\omega^2}$$
$$=\frac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}$$

Therefore, the Laplace Transform of $\sin(\omega t+\omega)$ is $\dfrac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}$.

Step 2 of 2

Recall the expression (1).

$$F(s)=e^{-s}\{L(t\sin(\omega t+\omega))+L(\sin(\omega t+\omega))\}$$

Substitute $g(t)$ for $\sin(\omega t+\omega)$.

$$F(s)=e^{-s}\{L(tg(t))+L(g(t))\}$$
$$=e^{-s}\left\{-\frac{d}{ds}G(s)+G(s)\right\}$$

Substitute $\dfrac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}$ for $G(s)$ in the equation.

$$F(s)=e^{-s}\left\{-\frac{d}{ds}\left[\frac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}\right]+\frac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}\right\}$$
$$=e^{-s}\left\{\begin{array}{l}-\left[\dfrac{(s^2+\omega^2)\dfrac{d(\omega\cos\omega+s\sin\omega)}{ds}-(\omega\cos\omega+s\sin\omega)\dfrac{d(s^2+\omega^2)}{ds}}{(s^2+\omega^2)^2}\right]\\+\dfrac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}\end{array}\right\}$$
$$=e^{-s}\left\{-\left[\frac{(s^2+\omega^2)(\sin\omega)-(\omega\cos\omega+s\sin\omega)(2s)}{(s^2+\omega^2)^2}\right]+\frac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}\right\}$$

Therefore, the Laplace transform of $t\sin\omega t u(t-1)$ is

$$\boxed{e^{-s}\left\{-\left[\frac{(s^2+\omega^2)(\sin\omega)-(\omega\cos\omega+s\sin\omega)(2s)}{(s^2+\omega^2)^2}\right]+\frac{\omega\cos\omega+s\sin\omega}{s^2+\omega^2}\right\}}.$$

13.015

E

Step 1 of 2

Consider the function.

$$\mathbf{F}(s)=\frac{8s^2-20s+500}{s(s^2+4s+50)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{8s^2-20s+500}{s(s^2+4s+50)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(0)&=\lim_{s\to\infty} s\left(\frac{8s^2-20s+500}{s(s^2+4s+50)}\right)\\
&=\lim_{s\to\infty}\left(\frac{s^3\left(8-\frac{20}{s}+\frac{500}{s^2}\right)}{s^3\left(1+\frac{4}{s}+\frac{50}{s^2}\right)}\right)\\
&=\lim_{s\to\infty}\left(\frac{8-\frac{20}{s}+\frac{500}{s^2}}{1+\frac{4}{s}+\frac{50}{s^2}}\right)\\
&=\frac{8-\frac{20}{\infty}+\frac{500}{\infty}}{1+\frac{4}{\infty}+\frac{50}{\infty}}
\end{aligned}$$

$$\begin{aligned}
f(0)&=\frac{8}{1}\\
&=8
\end{aligned}$$

Therefore, the initial value for the function is $\boxed{8}$.

Step 2 of 2

Consider the function.

$$\mathbf{F}(s)=\frac{8s^2-20s+500}{s(s^2+4s+50)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{8s^2-20s+500}{s(s^2+4s+50)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\left(\frac{8s^2-20s+500}{s(s^2+4s+50)}\right)\\
&=\lim_{s\to 0}\left(\frac{8s^2-20s+500}{(s^2+4s+50)}\right)\\
&=\frac{8(0)-20(0)+500}{(0)+4(0)+50}\\
&=\frac{500}{50}
\end{aligned}$$

$$f(\infty)=10$$

Therefore, the final value for the function is $\boxed{10}$.

Step 1 of 4

Simplify the expression of $\mathbf{F}(s)$.

$$\begin{aligned}\mathbf{F}(s) &= \frac{(s^2+2s+1)(s^2+6s+9)}{(s^2+6s+8)}\\ &= \frac{s^4+8s^3+22s^2+9}{s^2+6s+8}\\ &= \frac{s^2(s^2+6s+8)+2s^3+14s^2+9}{s^2+6s+8}\\ &= \frac{s^2(s^2+6s+8)+2s(s^2+7s+4.5)}{s^2+6s+8}\end{aligned}$$

Simplify further.

$$\begin{aligned}\mathbf{F}(s) &= \frac{s^2(s^2+6s+8)+2s(s^2+6s+8)+2s^2-7s}{s^2+6s+8}\\ &= \frac{s^2(s^2+6s+8)+2s(s^2+6s+8)+2(s^2-3.5s)}{s^2+6s+8}\\ &= \frac{s^2(s^2+6s+8)+2s(s^2+6s+8)+2(s^2+6s+8)-19s-16}{s^2+6s+8}\\ &= s^2+2s+2-\left(\frac{19s+16}{s^2+6s+8}\right)\end{aligned}$$

Step 2 of 4

Express $\mathbf{F}(s)$ as a partial fraction expansion.

$$\begin{aligned}\mathbf{F}(s) &= s^2+2s+2-\left(\frac{19s+16}{(s+2)(s+4)}\right)\\ &= s^2+2s+2-\left[\frac{K_1}{s+2}+\frac{K_2}{s+4}\right]\end{aligned}$$

Find the value of K_1.

$$\begin{aligned}K_1 &= (s+2)\left(\frac{19s+16}{(s+2)(s+4)}\right)\Bigg|_{s=-2}\\ &= \frac{19(-2)+16}{(-2+4)}\\ &= \frac{-38+16}{2}\\ &= -11\end{aligned}$$

Step 3 of 4

Find the value of K_2.

$$\begin{aligned}K_2 &= (s+4)\left(\frac{19s+16}{(s+2)(s+4)}\right)\Bigg|_{s=-4}\\ &= \frac{19(-4)+16}{(-4+2)}\\ &= \frac{-76+16}{-2}\\ &= 30\end{aligned}$$

The partial fraction expansion of $\mathbf{F}(s)$ is,

$$\begin{aligned}\mathbf{F}(s) &= s^2+2s+2-\left[\frac{-11}{s+2}+\frac{30}{s+4}\right]\\ &= s^2+2s+2+\frac{11}{s+2}-\frac{30}{s+4}\end{aligned}$$

Step 4 of 4

Determine the inverse Laplace transform of $\mathbf{F}(s)$.

$$\begin{aligned}f(t) &= L^{-1}\left[s^2+2s+2+\frac{11}{s+2}-\frac{30}{s+4}\right]\\ &= \frac{d^2}{dt^2}(\delta(t))+2\frac{d}{dt}(\delta(t))+2\delta(t)+11e^{-2t}u(t)-30e^{-4t}u(t)\end{aligned}$$

Thus, the expression for $f(t)$ is $\boxed{\frac{d^2}{dt^2}(\delta(t))+2\frac{d}{dt}(\delta(t))+2\delta(t)+11e^{-2t}u(t)-30e^{-4t}u(t)}$.

13.016
E

Step 1 of 3

Consider the differential equation.

$$\frac{dy(t)}{dt}+4y(t)+4\int_0^t y(x)dx=10u(t)$$

Apply Laplace transform.

$$sY(s)-Y(0)+4Y(s)+\frac{4}{s}Y(s)=\frac{10}{s}$$

Substitute 10 for $Y(0)$.

$$sY(s)-10+4Y(s)+\frac{4}{s}Y(s)=\frac{10}{s}$$

$$sY(s)+4Y(s)+\frac{4}{s}Y(s)=\frac{10}{s}+10$$

$$\left(\frac{s^2+4s+4}{s}\right)Y(s)=\frac{10+10s}{s}$$

$$(s+2)^2Y(s)=10(s+1)$$

$$Y(s)=\frac{10(s+1)}{(s+2)^2} \quad \text{..... (1)}$$

Assume $\frac{10(s+1)}{(s+2)^2}$ to be $\frac{A}{s+2}+\frac{B}{(s+2)^2}$.

$$\frac{10(s+1)}{(s+2)^2}=\frac{A}{s+2}+\frac{B}{(s+2)^2} \quad \text{..... (2)}$$

Use residue's method to find the values of A and B.

Calculate the value of B.

$$\begin{aligned}B&=(s+2)^2\left[\frac{10(s+1)}{(s+2)^2}\right]\Bigg|_{s=-2}\\&=\left[\frac{10(s+1)}{1}\right]\Bigg|_{s=-2}\\&=10(-2+1)\\&=-10\end{aligned}$$

Therefore, the value of B is -10.

Step 2 of 3

Calculate the value of A.

$$\begin{aligned}A&=\frac{d}{ds}(s+2)^2\left[\frac{10(s+1)}{(s+2)^2}\right]\Bigg|_{s=-2}\\&=\frac{d}{ds}[10(s+1)]\Big|_{s=-1}\\&=10\end{aligned}$$

Therefore, the value of A is 10.

Step 3 of 3

Consider expression (2).

$$\frac{10(s+1)}{(s+2)^2}=\frac{A}{s+2}+\frac{B}{(s+2)^2}$$

Substitute $\frac{1}{(s+2)(s+1)}$ for $Y(s)$, 10 for A and -10 for B

$$Y(s)=\frac{10}{s+2}-\frac{10}{(s+2)^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{Y(s)\}=10\mathcal{L}\left\{\frac{1}{s+2}\right\}-10\mathcal{L}\left\{\frac{1}{(s+2)^2}\right\}$$

Apply the property's, $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and $\mathcal{L}^{-1}\left\{\frac{1}{(s+a)^2}\right\}=te^{-at}$.

$$y(t)=\left[10e^{-2t}-10te^{-2t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left[10e^{-2t}-10te^{-2t}\right]u(t)}$.

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Step 1 of 3

Simplify the expression of $\mathbf{F}(s)$.

$$\begin{aligned}\mathbf{F}(s) &= \frac{s^2+4s+3+1}{(s+1)(s+3)}\\ &= \frac{(s+1)(s+3)+1}{(s+1)(s+3)}\\ &= \frac{(s+1)(s+3)}{(s+1)(s+3)}+\frac{1}{(s+1)(s+3)}\\ &= 1+\frac{1}{(s+1)(s+3)}\end{aligned}$$

Step 2 of 3

Express $\mathbf{F}(s)$ as a partial fraction expansion.

$$\mathbf{F}(s)=1+\frac{K_1}{s+1}+\frac{K_2}{s+3}$$

Find the value of K_1.

$$\begin{aligned}K_1 &= (s+1)\frac{1}{(s+1)(s+3)}\bigg|_{s=-1}\\ &= \frac{1}{(-1+3)}\\ &= 0.5\end{aligned}$$

Find the value of K_2.

$$\begin{aligned}K_2 &= (s+3)\frac{1}{(s+1)(s+3)}\bigg|_{s=-1}\\ &= \frac{1}{(-3+1)}\\ &= -0.5\end{aligned}$$

The partial fraction expansion of $\mathbf{F}(s)$ is,

$$\mathbf{F}(s)=1+\frac{0.5}{s+1}+\frac{(-0.5)}{s+3}$$

Step 3 of 3

Determine the inverse Laplace transform of $\mathbf{F}(s)$.

$$\begin{aligned}f(t) &= L^{-1}\left[1+\frac{0.5}{s+1}+\frac{(-0.5)}{s+3}\right]\\ &= \delta(t)+0.5e^{-t}u(t)-0.5e^{-3t}u(t)\end{aligned}$$

Thus, the Laplace transform of $f(t)$ is $\boxed{\delta(t)+0.5e^{-t}u(t)-0.5e^{-3t}u(t)}$.

Step 1 of 2

Refer to Figure E13.17 in the textbook.

For $t<0$, the circuit is in steady state and the inductor acts as short circuit.

Find the current in the circuit using Ohm's law.

$$\begin{aligned} i(0^-) &= \frac{6\text{ V}}{2\,\Omega+1\,\Omega} \\ &= \frac{6\text{ V}}{3\,\Omega} \\ &= 2\text{ A} \end{aligned}$$

The current across the inductor does not change immediately. Therefore, $i(0^+)=2\text{ A}$.

Draw the s -domain equivalent circuit for $t>0$.

Figure 1

Step 2 of 2

The $1\,\Omega$ resistance in the circuit of Figure 1 vanishes due to the short circuit across it.

Apply Kirchhoff's voltage law to the circuit.

$$-\frac{6}{s}+2I(s)+\left[sI(s)-I(0^+)\right]=0$$

$$I(s)[2+s]=\frac{6}{s}+2$$

$$I(s)[2+s]=\frac{6+2s}{s}$$

$$I(s)=\frac{6+2s}{s(2+s)}$$

Simplify the function further using partial fractions method.

$$\frac{6+2s}{s(2+s)}=\frac{A}{s}+\frac{B}{2+s}$$

$$\frac{6+2s}{s(2+s)}=\frac{A(2+s)+Bs}{s(2+s)}$$

$$6+2s=2A+s(A+B)$$

Therefore,

$$\begin{aligned} A &= \frac{6}{2} \\ &= 3 \end{aligned}$$

And

$$\begin{aligned} B &= 2-A \\ &= 2-3 \\ &= -1 \end{aligned}$$

Therefore,

$$I(s)=\frac{3}{s}-\frac{1}{s+2}$$

Apply inverse Laplace transform.

$$\begin{aligned} i(t) &= 3u(t)-e^{-2t}u(t) \\ &= \left[3-e^{-2t}\right]u(t)\text{ V} \end{aligned}$$

Thus, the current $i(t)$ for $t>0$ is, $\boxed{i(t)=\left[3-e^{-2t}\right]u(t)\text{ V}}$.

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Step 1 of 16

(a)

Consider the following function:

$$\mathbf{F}(s)=\frac{2(s+1)}{(s+2)(s+3)}$$

The function $f(t)$ is

$$f(t)=L^{-1}\left[\mathbf{F}(s)\right]$$

Express $\mathbf{F}(s)$ in a partial fraction expansion.

$$\frac{2(s+1)}{(s+2)(s+3)}=\frac{K_0}{s+2}+\frac{K_1}{s+3}$$

Step 2 of 16

Calculate the value of K_0.

$$\begin{aligned}K_0&=(s+2)\mathbf{F}(s)\big|_{s=-2}\\&=(s+2)\frac{2(s+1)}{(s+2)(s+3)}\bigg|_{s=-2}\\&=\frac{2(-2+1)}{-2+3}\\&=-2\end{aligned}$$

Step 3 of 16

Calculate the value of K_1.

$$\begin{aligned}K_1&=(s+3)\mathbf{F}(s)\big|_{s=-3}\\&=(s+3)\frac{2(s+1)}{(s+2)(s+3)}\bigg|_{s=-3}\\&=\frac{2(-3+1)}{-3+2}\\&=4\end{aligned}$$

Step 4 of 16

The partial fraction expansion of $\mathbf{F}(s)$ is,

$$\mathbf{F}(s)=\frac{-2}{s+2}+\frac{4}{s+3}$$

Step 5 of 16

Now apply inverse Laplace transforms on both sides.

$$f(t)=\left(-2e^{-2t}+4e^{-3t}\right)u(t)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\left(-2e^{-2t}+4e^{-3t}\right)u(t)}$$

Step 6 of 16

(b)

Consider the following function:

$$\mathbf{F}(s)=\frac{10(s+2)}{(s+1)(s+4)}$$

The function $f(t)$ is

$$f(t)=L^{-1}\left[\mathbf{F}(s)\right]$$

Express $\mathbf{F}(s)$ in a partial fraction expansion.

$$\frac{10(s+2)}{(s+1)(s+4)}=\frac{K_0}{s+1}+\frac{K_1}{s+4}$$

Step 7 of 16

Calculate the value of K_0.

$$\begin{aligned}K_0&=(s+1)\mathbf{F}(s)\big|_{s=-1}\\&=(s+1)\frac{10(s+2)}{(s+1)(s+4)}\bigg|_{s=-1}\\&=\frac{10(-1+2)}{-1+4}\\&=\frac{10}{3}\end{aligned}$$

Step 8 of 16

Calculate the value of K_1.

$$\begin{aligned}K_1&=(s+4)\mathbf{F}(s)\big|_{s=-4}\\&=(s+4)\frac{10(s+2)}{(s+1)(s+4)}\bigg|_{s=-4}\\&=\frac{10(-4+2)}{-4+1}\\&=\frac{20}{3}\end{aligned}$$

Step 9 of 16

The partial fraction expansion of $\mathbf{F}(s)$ is,

$$\begin{aligned}\mathbf{F}(s)&=\frac{\frac{10}{3}}{s+1}+\frac{\frac{20}{3}}{s+4}\\&=\frac{10}{3}\frac{1}{s+1}+\frac{20}{3}\frac{1}{s+4}\end{aligned}$$

Step 10 of 16

Step 11 of 16

Now apply inverse Laplace transforms on both sides.

$$\begin{aligned}f(t)&=\left(\frac{10}{3}e^{-t}+\frac{20}{3}e^{-4t}\right)u(t)\\&=\frac{10}{3}\left(e^{-t}+2e^{-4t}\right)u(t)\end{aligned}$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\frac{10}{3}\left(e^{-t}+2e^{-4t}\right)u(t)}$$

Step 12 of 16

(c)

Consider the following function:

$$\mathbf{F}(s)=\frac{s^2+2s+3}{s(s+1)(s+2)}$$

The function $f(t)$ is

$$f(t)=L^{-1}\left[\mathbf{F}(s)\right]$$

Express $\mathbf{F}(s)$ in a partial fraction expansion.

$$\frac{s^2+2s+3}{s(s+1)(s+2)}=\frac{K_0}{s}+\frac{K_1}{s+1}+\frac{K_2}{s+2}$$

Step 13 of 16

Calculate the value of K_0.

$$\begin{aligned}K_0&=(s)\mathbf{F}(s)\big|_{s=0}\\&=(s)\frac{s^2+2s+3}{s(s+1)(s+2)}\bigg|_{s=0}\\&=\frac{0^2+2(0)+3}{(0+1)(0+2)}\\&=\frac{3}{2}\end{aligned}$$

Step 14 of 16

Calculate the value of K_1.

$$\begin{aligned}K_1&=(s+1)\mathbf{F}(s)\big|_{s=-1}\\&=(s+1)\frac{s^2+2s+3}{s(s+1)(s+2)}\bigg|_{s=-1}\\&=\frac{(-1)^2+2(-1)+3}{(-1)(-1+2)}\\&=-2\end{aligned}$$

Step 15 of 16

Calculate the value of K_2.

$$\begin{aligned}K_2&=(s+2)\mathbf{F}(s)\big|_{s=-2}\\&=(s+2)\frac{s^2+2s+3}{s(s+1)(s+2)}\bigg|_{s=-2}\\&=\frac{(-2)^2+2(-2)+3}{(-2)(-2+1)}\\&=\frac{3}{2}\end{aligned}$$

The partial fraction expansion of $\mathbf{F}(s)$ is,

$$\begin{aligned}\mathbf{F}(s)&=\frac{\left(\frac{3}{2}\right)}{s}+\frac{-2}{s+1}+\frac{\left(\frac{3}{2}\right)}{s+2}\\&=\frac{3}{2}\frac{1}{s}-2\frac{1}{s+1}+\frac{3}{2}\frac{1}{s+2}\end{aligned}$$

Step 16 of 16

Now apply inverse Laplace transforms on both sides.

$$f(t)=\left(\frac{3}{2}-2e^{-t}+\frac{3}{2}e^{-2t}\right)u(t)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\left(\frac{3}{2}-2e^{-t}+\frac{3}{2}e^{-2t}\right)u(t)}$$

Step 1 of 7

Consider the Figure E13.18 from the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

Step 2 of 7

Calculate Kirchhoff's current Law at node-1.

$$\frac{v_C(0^-)}{6\,\text{k}} + \frac{v_C(0^-)}{6\,\text{k}} + \frac{v_C(0^-) - 9}{6\,\text{k}} = 2\,\text{m}$$

$$v_C(0^-)\left(\frac{1}{6\,\text{k}} + \frac{1}{6\,\text{k}} + \frac{1}{6\,\text{k}}\right) - \frac{9}{6\,\text{k}} = 2\,\text{m}$$

$$v_C(0^-)\left(\frac{3}{6\,\text{k}}\right) = 2\,\text{m} + \frac{9}{6\,\text{k}}$$

$$v_C(0^-)(0.5\,\text{m}) = 2\,\text{m} + 1.5\,\text{m}$$

$$v_C(0^-)(0.5\,\text{m}) = 3.5\,\text{m}$$

$$v_C(0^-) = 7\,\text{V}$$

Therefore, the value of $v_C(0^-)$ is $7\,\text{V}$.

Step 3 of 7

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 7

Redraw the circuit diagram using source transformation technique.

Figure 3

Step 5 of 7

Consider the Kirchhoff's Voltage Law in loop-1.

$$i(t)(6\,\text{k}) + \left(\frac{1}{2.5\mu}\right)\int i(t)dt = 12$$

Apply Laplace transform.

$$I(s)(6\,\text{k}) + \frac{1}{(2.5\mu)s}I(s) + \frac{v(0^-)}{s} = \frac{12}{s}$$

$$I(s)\left(6\,\text{k} + \frac{1}{(2.5\mu)s}\right) + \frac{v(0^-)}{s} = \frac{12}{s}$$

Substitute $7\,\text{V}$ for $v_C(0^-)$.

$$I(s)\left(6\,\text{k} + \frac{1}{(2.5\mu)s}\right) + \frac{7}{s} = \frac{12}{s}$$

$$I(s)\left(6\,\text{k} + \frac{1}{(2.5\mu)s}\right) = \frac{12}{s} - \frac{7}{s}$$

$$I(s)\left(6\,\text{k} + \frac{1}{(2.5\mu)s}\right) = \frac{5}{s}$$

$$I(s)\left(\frac{(6\,\text{k})(2.5\mu)s + 1}{(2.5\mu)s}\right) = \frac{5}{s}$$

$$I(s)\left(\frac{(6\,\text{k})(2.5\mu)s + 1}{2.5\mu}\right) = 5$$

$$I(s)((6\,\text{k})(2.5\mu)s + 1) = 5(2.5\mu)$$

$$I(s)(6\,\text{k})(2.5\mu)\left(s + \frac{1}{(6\,\text{k})(2.5\mu)}\right) = 5(2.5\mu)$$

$$I(s)(6\,\text{k})\left(s + \frac{1}{(6\,\text{k})(2.5\mu)}\right) = 5$$

$$I(s)(6\,\text{k})(s + 66.67) = 5$$

$$I(s) = \frac{5}{(6\,\text{k})(s + 66.67)}$$

Step 6 of 7

Apply inverse Laplace transform.

$$\mathbf{L}\{I(s)\} = \left(\frac{5}{6\,\text{k}}\right)\mathbf{L}\left\{\frac{1}{s + 66.67}\right\}$$

Apply the property's, $\mathbf{L}\left\{\frac{1}{s+a}\right\} = e^{-at}$.

$$i(t) = \left(\frac{5}{6\,\text{k}}\right)\mathbf{L}\left\{\frac{1}{s + 66.67}\right\}$$

$$= \left(\frac{5}{6\,\text{k}}\right)e^{-66.67t}u(t)\,\text{A}$$

Therefore, the value of $i(t)$ is $\left(\frac{5}{6\,\text{k}}\right)e^{-66.67t}u(t)\,\text{A}$.

Step 7 of 7

Calculate the value of $v_O(t)$.

$$v_O(t) = 12 - i(t)(6\,\text{k})$$

Substitute $\left(\frac{5}{6\,\text{k}}\right)e^{-66.67t}u(t)\,\text{A}$ for $i(t)$.

$$v_O(t) = 12 - \left(\left(\frac{5}{6\,\text{k}}\right)e^{-66.67t}\right)(6\,\text{k})$$

$$= \left(12 - 5e^{-66.67t}\right)u(t)\,\text{V}$$

Therefore, the value of $v_O(t)$ is $\boxed{\left(12 - 5e^{-66.67t}\right)u(t)\,\text{V}}$.

Step 1 of 12

(a)

Consider the function.

$$F(s)=\frac{s+1}{(s+2)(s+6)}$$

Assume $\frac{s+1}{(s+2)(s+6)}$ to be $\frac{A}{s+2}+\frac{B}{s+6}$.

$$\frac{s+1}{(s+2)(s+6)}=\frac{A}{s+2}+\frac{B}{s+6} \text{ ..... (1)}$$

$$s+1=A(s+6)+B(s+2) \text{ ..... (2)}$$

Substitute -2 for s in the equation.

$$-2+1=A(-2+6)+B(-2+2)$$
$$-1=A(4)+B(0)$$
$$-1=A(4)$$
$$A=-\frac{1}{4}$$

Therefore, the value of A is $-\frac{1}{4}$.

Step 2 of 12

Recall equation (2).

$$s+1=A(s+6)+B(s+2)$$

Substitute -6 for s in the equation.

$$-6+1=A(-6+6)+B(-6+2)$$
$$-5=A(0)+B(-4)$$
$$-5=B(-4)$$
$$B=\frac{5}{4}$$

Therefore, the value of B is $\frac{5}{4}$.

Step 3 of 12

Recall equation (1).

$$\frac{s+1}{(s+2)(s+6)}=\frac{A}{s+2}+\frac{B}{s+6}$$

Substitute $F(s)$ for $\frac{s+1}{(s+2)(s+6)}$, $\frac{5}{4}$ for B and $-\frac{1}{4}$ for A in the equation.

$$F(s)=\frac{\left(-\frac{1}{4}\right)}{s+2}+\frac{\left(\frac{5}{4}\right)}{s+6}$$
$$=\left(\frac{1}{4}\right)\left(\frac{-1}{s+2}+\frac{5}{s+6}\right)$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\left(\frac{1}{4}\right)\left(-L^{-1}\left[\frac{1}{s+2}\right]+5L^{-1}\left[\frac{1}{s+6}\right]\right)$$

Apply the property, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(\frac{1}{4}\right)\left(-e^{-2t}+5e^{-6t}\right)u(t)$$
$$=\left(\frac{-e^{-2t}+5e^{-6t}}{4}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+1}{(s+2)(s+6)}$ is $\boxed{\left(\frac{-e^{-2t}+5e^{-6t}}{4}\right)u(t)}$.

Step 4 of 12

(b)

Consider the function.

$$F(s)=\frac{24}{(s+2)(s+3)}$$

Assume $\frac{24}{(s+2)(s+3)}$ to be $\frac{A}{s+2}+\frac{B}{s+3}$.

$$\frac{24}{(s+2)(s+3)}=\frac{A}{s+2}+\frac{B}{s+3} \text{ ..... (3)}$$

$$24=A(s+3)+B(s+2) \text{ ..... (4)}$$

Substitute -2 for s in the equation.

$$24=A(-2+3)+B(-2+2)$$
$$24=A(1)+B(0)$$
$$24=A(1)$$
$$A=24$$

Therefore, the value of A is 24.

Step 5 of 12

Recall equation (4).

$$24=A(s+3)+B(s+2)$$

Substitute -3 for s in the equation.

$$24=A(-3+3)+B(-3+2)$$
$$24=A(0)+B(-1)$$
$$24=B(-1)$$
$$B=-24$$

Therefore, the value of B is -24.

Step 6 of 12

Recall equation (3).

$$\frac{24}{(s+2)(s+3)}=\frac{A}{s+2}+\frac{B}{s+3}$$

Substitute $F(s)$ for $\frac{24}{(s+2)(s+3)}$, -24 for B and 24 for A in the equation.

$$F(s)=\frac{24}{s+2}+\frac{(-24)}{s+3}$$
$$=(24)\left(\frac{1}{s+2}-\frac{1}{s+3}\right)$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=(24)\left(L^{-1}\left[\frac{1}{s+2}\right]-L^{-1}\left[\frac{1}{s+3}\right]\right)$$

Apply the property, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=(24)\left(e^{-2t}-e^{-3t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{24}{(s+2)(s+3)}$ is $\boxed{(24)\left(e^{-2t}-e^{-3t}\right)u(t)}$.

Step 7 of 12

(c)

Consider the function.

$$F(s)=\frac{4}{(s+3)(s+4)}$$

Assume $\frac{4}{(s+3)(s+4)}$ to be $\frac{A}{s+3}+\frac{B}{s+4}$.

$$\frac{4}{(s+3)(s+4)}=\frac{A}{s+3}+\frac{B}{s+4} \text{ ..... (5)}$$

$$4=A(s+4)+B(s+3) \text{ ..... (6)}$$

Substitute -3 for s in the equation.

$$4=A(-3+4)+B(-3+3)$$
$$4=A(1)+B(0)$$
$$4=A(1)$$
$$A=4$$

Therefore, the value of A is 4.

Step 8 of 12

Recall equation (6).

$$4=A(s+4)+B(s+3)$$

Substitute -4 for s in the equation.

$$4=A(-4+4)+B(-4+3)$$
$$4=A(0)+B(-1)$$
$$4=B(-1)$$
$$B=-4$$

Therefore, the value of B is -4.

Step 9 of 12

Recall equation (5).

$$\frac{4}{(s+3)(s+4)}=\frac{A}{s+3}+\frac{B}{s+4}$$

Substitute $F(s)$ for $\frac{4}{(s+3)(s+4)}$, -4 for B and 4 for A in the equation.

$$F(s)=\frac{4}{s+3}+\frac{(-4)}{s+4}$$
$$=(4)\left(\frac{1}{s+3}-\frac{1}{s+4}\right)$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=(4)\left(L^{-1}\left[\frac{1}{s+3}\right]-L^{-1}\left[\frac{1}{s+4}\right]\right)$$

Apply the property, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=(4)\left(e^{-3t}-e^{-4t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{4}{(s+3)(s+4)}$ is $\boxed{(4)\left(e^{-3t}-e^{-4t}\right)u(t)}$.

Step 10 of 12

(d)

Consider the function.

$$F(s)=\frac{10s}{(s+1)(s+6)}$$

Assume $\frac{10s}{(s+1)(s+6)}$ to be $\frac{A}{s+1}+\frac{B}{s+6}$.

$$\frac{10s}{(s+1)(s+6)}=\frac{A}{s+1}+\frac{B}{s+6} \text{ ..... (7)}$$

$$10s=A(s+6)+B(s+1) \text{ ..... (8)}$$

Substitute -1 for s in the equation.

$$10(-1)=A(-1+6)+B(-1+1)$$
$$-10=A(5)+B(0)$$
$$-10=A(5)$$
$$A=-\frac{10}{5}$$
$$A=-2$$

Therefore, the value of A is -2.

Step 11 of 12

Recall equation (7).

$$10s=A(s+6)+B(s+1)$$

Substitute -6 for s in the equation.

$$10(-6)=A(-6+6)+B(-6+1)$$
$$-60=A(0)+B(-5)$$
$$-60=B(-5)$$
$$B=\frac{60}{5}$$
$$B=12$$

Therefore, the value of B is 12.

Step 12 of 12

Recall equation (8).

$$\frac{10s}{(s+1)(s+6)}=\frac{A}{s+1}+\frac{B}{s+6}$$

Substitute $F(s)$ for $\frac{10s}{(s+1)(s+6)}$, 12 for B and -2 for A in the equation.

$$F(s)=\frac{(-2)}{s+1}+\frac{(12)}{s+6}$$
$$=\frac{-2}{s+1}+\frac{12}{s+6}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=(-2)L^{-1}\left[\frac{1}{s+2}\right]+12L^{-1}\left[\frac{1}{s+6}\right]$$

Apply the property, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(-2e^{-2t}+12e^{-6t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{10s}{(s+1)(s+6)}$ is $\boxed{\left(-2e^{-2t}+12e^{-6t}\right)u(t)}$.

Step 1 of 8

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Consider the Figure E13.19 from the text book.

Consider the circuit diagram at $t < 0$.

Figure 1

Step 2 of 8

Calculate value of the current $i_L(0^-)$

$$i_L(0^-) = \frac{36}{4}$$
$$= 9 \text{ A}$$

Therefore, the value of the current $i_L(0^-)$ is 9 A .

Step 3 of 8

Calculate value of the voltage $v_C(0^-)$

$$v_C(0^-) = 12 \text{ V}$$

Therefore, the value of the voltage $v_C(0^-)$ is 12 V .

Step 4 of 8

Consider the circuit diagram at $t > 0$.

Figure 2

Step 5 of 8

Consider Kirchhoff's Voltage Law in Loop-1.

$$-12 + i(t)(2+4) + (1)\frac{di(t)}{dt} + \frac{1}{1}\int i(t)\,dt = 0$$

Apply Laplace transform.

$$\frac{-12}{s} + I(s)(6) + (1)sI(s) - i(0^-) + \frac{1}{1s}I(s) + \frac{v_C(0^-)}{s} = 0$$

Substitute 12 V for $v_C(0^-)$ and 9 A for $i_L(0^-)$.

$$\frac{-12}{s} + I(s)(6) + (1)sI(s) - 9 + \frac{1}{1s}I(s) + \frac{12}{s} = 0$$

$$I(s)\left[6 + s + \frac{1}{s}\right] - 9 = 0$$

$$I(s)\left[\frac{s^2+6s+1}{s}\right] - 9 = 0$$

$$I(s)\left[s^2+6s+1\right] - 9s = 0$$

$$I(s)\left[s^2+6s+1\right] = 9s$$

$$I(s) = \frac{9s}{s^2+6s+1}$$

$$I(s) = \frac{9s}{(s+0.172)(s+5.828)} \quad \text{..... (1)}$$

Therefore, the expression for $I(s)$ is $\frac{9s}{(s+0.172)(s+5.828)}$.

Step 6 of 8

Assume $\frac{9s}{(s+0.172)(s+5.828)}$ to be $\frac{A}{s+0.172} + \frac{B}{s+5.828}$.

Solve for the values of A and B using residue method.

Solve for A .

$$A = (s+0.172)\frac{9s}{(s+0.172)(s+5.828)}\Bigg|_{s=-0.172}$$
$$= \frac{9s}{(s+5.828)}\Bigg|_{s=-0.172}$$
$$= \frac{9(-0.172)}{(-0.172+5.828)}$$
$$= \frac{-1.548}{5.656}$$
$$A = -0.274$$

Therefore, the value of A is -0.274 .

Step 7 of 8

Solve for B .

$$B = (s+5.828)\frac{9s}{(s+0.172)(s+5.828)}\Bigg|_{s=-5.828}$$
$$= \frac{9s}{(s+0.172)}\Bigg|_{s=-5.828}$$
$$= \frac{9(-5.828)}{(-5.828+0.172)}$$
$$= \frac{-52.452}{-5.656}$$
$$B = 9.274$$

Therefore, the value of B is 9.274 .

Step 8 of 8

Recall equation (1).

$$I(s) = \frac{9s}{(s+0.172)(s+5.828)}$$

Substitute $\frac{-0.274}{s+0.172} + \frac{9.274}{s+5.828}$ for $\frac{9s}{(s+0.172)(s+5.828)}$.

$$I(s) = \frac{-0.274}{s+0.172} + \frac{9.274}{s+5.828}$$

Apply inverse Laplace transform.

$$i(t) = \left[-0.274e^{-0.172t} + 9.274e^{-5.828t}\right]u(t)$$

Therefore, the value of the current $i(t)$ is $\boxed{\left[-0.274e^{-0.172t} + 9.274e^{-5.828t}\right]u(t)}$.

Step 1 of 13

(a)

Consider the function.

$$F(s)=\frac{s^2+7s+12}{(s+2)(s+4)(s+6)}$$
$$=\frac{(s+3)(s+4)}{(s+2)(s+4)(s+6)}$$
$$=\frac{s+3}{(s+2)(s+6)}$$

Assume $\frac{s+3}{(s+2)(s+6)}$ to be $\frac{A}{s+2}+\frac{B}{s+6}$.

$$\frac{s+3}{(s+2)(s+6)}=\frac{A}{s+2}+\frac{B}{s+6} \text{ ..... (1)}$$

$$\frac{s+3}{(s+2)(s+6)}=\frac{A(s+6)+B(s+2)}{(s+2)(s+6)}$$

$$s+3=A(s+6)+B(s+2) \text{ ..... (2)}$$

Substitute -2 for s in the equation.

$$(-2)+3=A(-2+6)+B(-2+2)$$
$$1=A(4)+B(0)$$
$$1=A(4)$$
$$A=\frac{1}{4}$$

Therefore, the value of A is $\frac{1}{4}$.

Step 2 of 13

Recall equation (2).

$$s+3=A(s+6)+B(s+2)$$

Substitute -6 for s in the equation.

$$(-6)+3=A(-6+6)+B(-6+2)$$
$$-3=A(0)+B(-4)$$
$$-3=B(-4)$$
$$B=\frac{3}{4}$$

Therefore, the value of B is $\frac{3}{4}$.

Step 3 of 13

Recall equation (1).

$$\frac{s+3}{(s+2)(s+6)}=\frac{A}{s+2}+\frac{B}{s+6}$$

Substitute $F(s)$ for $\frac{s+3}{(s+2)(s+6)}$, $\frac{3}{4}$ for B and $\frac{1}{4}$ for A in the equation.

$$F(s)=\frac{1}{4(s+2)}+\frac{3}{4(s+6)}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{1}{4}L^{-1}\left[\frac{1}{s+2}\right]+\frac{3}{4}L^{-1}\left[\frac{1}{s+6}\right]$$

Apply the property's. $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(\frac{1}{4}e^{-2t}+\frac{3}{4}e^{-6t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s^2+7s+12}{(s+2)(s+4)(s+6)}$ is $\boxed{\left(\frac{1}{4}e^{-2t}+\frac{3}{4}e^{-6t}\right)u(t)}$.

Step 4 of 13

(b)

Consider the function.

$$F(s)=\frac{(s+3)(s+6)}{s(s^2+10s+24)}$$
$$=\frac{(s+3)(s+6)}{s(s+4)(s+6)}$$
$$=\frac{s+3}{s(s+4)}$$

Assume $\frac{s+3}{s(s+4)}$ to be $\frac{A}{s}+\frac{B}{s+4}$.

$$\frac{s+3}{s(s+4)}=\frac{A}{s}+\frac{B}{s+4} \text{ ..... (3)}$$

$$\frac{s+3}{s(s+4)}=\frac{A(s+4)+B(s)}{s(s+4)}$$

$$s+3=A(s+4)+Bs \text{ ..... (4)}$$

Substitute 0 for s in the equation.

$$0+3=A(0+4)+B(0)$$
$$3=A(4)+B(0)$$
$$3=A(4)$$
$$A=\frac{3}{4}$$

Therefore, the value of A is $\frac{3}{4}$.

Step 5 of 13

Recall equation (4).

$$s+3=A(s+4)+B(s)$$

Substitute -4 for s in the equation.

$$-4+3=A(-4+4)+B(-4)$$
$$-1=A(0)+B(-4)$$
$$-1=B(-4)$$
$$B=\frac{1}{4}$$

Therefore, the value of B is $\frac{1}{4}$.

Step 6 of 13

Recall equation (3).

$$\frac{s+3}{s(s+4)}=\frac{A}{s}+\frac{B}{s+4}$$

Substitute $F(s)$ for $\frac{s+3}{s(s+4)}$, $\frac{1}{4}$ for B and $\frac{3}{4}$ for A in the equation.

$$F(s)=\frac{3}{4s}+\frac{1}{4(s+4)}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{3}{4}L^{-1}\left[\frac{1}{s}\right]+\frac{1}{4}L^{-1}\left[\frac{1}{s+4}\right]$$

Apply the property's. $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{s}\right]=1$

$$f(t)=\left(\frac{3}{4}(1)+\frac{1}{4}e^{-4t}\right)u(t)$$
$$=\left(\frac{3}{4}+\frac{1}{4}e^{-4t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{(s+3)(s+6)}{s(s^2+10s+24)}$ is $\boxed{\left(\frac{3}{4}+\frac{1}{4}e^{-4t}\right)u(t)}$.

Step 7 of 13

(c)

Consider the function.

$$F(s)=\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}$$

Assume $\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}$ to be $\frac{A}{s+2}+\frac{B}{s+4}+\frac{C}{s+6}$.

$$\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}=\frac{A}{s+2}+\frac{B}{s+4}+\frac{C}{s+6} \text{ ..... (5)}$$

$$\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}=\frac{A(s+4)(s+6)+B(s+2)(s+6)+C(s+2)(s+4)}{(s+2)(s+4)(s+6)}$$

$$s^2+5s+12=A(s+4)(s+6)+B(s+2)(s+6)+C(s+2)(s+4) \text{ ..... (6)}$$

Substitute -2 for s in the equation.

$$(-2)^2+5(-2)+12=A(-2+4)(-2+6)+B(-2+2)(-2+6)+C(-2+2)(-2+4)$$
$$4-10+12=A(2)(4)+B(0)+C(0)$$
$$6=A(8)$$
$$A=\frac{6}{8}$$
$$A=\frac{3}{4}$$

Therefore, the value of A is $\frac{3}{4}$

Step 8 of 13

Recall equation (6).

$$s^2+5s+12=A(s+4)(s+6)+B(s+2)(s+6)+C(s+2)(s+4)$$

Substitute -4 for s in the equation.

$$(-4)^2+5(-4)+12=A(-4+4)(-4+6)+B(-4+2)(-4+6)+C(-4+2)(-4+4)$$
$$16-20+12=A(0)(2)+B(-2)(2)+C(-2)(0)$$
$$8=0+B(-4)+0$$
$$B=\frac{-8}{4}$$
$$B=-2$$

Therefore, the value of B is -2.

Step 9 of 13

Recall equation (6).

$$s^2+5s+12=A(s+4)(s+6)+B(s+2)(s+6)+C(s+2)(s+4)$$

Substitute -6 for s in the equation.

$$(-6)^2+5(-6)+12=A(-6+4)(-6+6)+B(-6+2)(-6+6)+C(-6+2)(-6+4)$$
$$36-30+12=A(-2)(0)+B(-4)(0)+C(-4)(-2)$$
$$18=0+0+C(8)$$
$$C=\frac{18}{8}$$
$$C=\frac{9}{4}$$

Therefore, the value of C is $\frac{9}{4}$

Step 10 of 13

Recall equation (5).

$$\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}=\frac{A}{s+2}+\frac{B}{s+4}+\frac{C}{s+6}$$

Substitute $F(s)$ for $\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}$, -2 for B, $\frac{9}{4}$ for C and $\frac{3}{4}$ for A in the equation.

$$F(s)=\frac{3}{4(s+2)}+\frac{9}{4(s+4)}-\frac{2}{s+6}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{3}{4}L^{-1}\left[\frac{1}{s+2}\right]-2L^{-1}\left[\frac{1}{s+4}\right]+\frac{9}{4}L^{-1}\left[\frac{1}{s+6}\right]$$

Apply the property's. $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(\frac{3}{4}e^{-2t}-2e^{-4t}+\frac{9}{4}e^{-6t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s^2+5s+12}{(s+2)(s+4)(s+6)}$ is

$$\boxed{\left(\frac{3}{4}e^{-2t}-2e^{-4t}+\frac{9}{4}e^{-6t}\right)u(t)}.$$

Step 11 of 13

(d)

Consider the function.

$$F(s)=\frac{(s+3)(s+6)}{s(s^2+8s+12)}$$
$$=\frac{(s+3)(s+6)}{s(s+2)(s+6)}$$
$$=\frac{s+3}{s(s+2)}$$

Assume $\frac{s+3}{s(s+2)}$ to be $\frac{A}{s}+\frac{B}{s+2}$.

$$\frac{s+3}{s(s+2)}=\frac{A}{s}+\frac{B}{s+2} \text{ ..... (7)}$$

$$\frac{s+3}{s(s+2)}=\frac{A(s+2)+B(s)}{s(s+2)}$$

$$s+3=A(s+2)+Bs \text{ ..... (8)}$$

Substitute 0 for s in the equation.

$$0+3=A(0+2)+B(0)$$
$$3=A(2)+B(0)$$
$$3=A(2)$$
$$A=\frac{3}{2}$$

Therefore, the value of A is $\frac{3}{2}$.

Step 12 of 13

Recall equation (8).

$$s+3=A(s+2)+B(s)$$

Substitute -2 for s in the equation.

$$-2+3=A(-2+2)+B(-2)$$
$$1=A(0)+B(-2)$$
$$1=B(-2)$$
$$B=-\frac{1}{2}$$

Therefore, the value of B is $-\frac{1}{2}$.

Step 13 of 13

Recall equation (7).

$$\frac{s+3}{s(s+2)}=\frac{A}{s}+\frac{B}{s+2}$$

Substitute $F(s)$ for $\frac{s+3}{s(s+2)}$, $-\frac{1}{2}$ for B and $\frac{3}{2}$ for A in the equation.

$$F(s)=\frac{3}{2s}-\frac{1}{2(s+2)}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{3}{2}L^{-1}\left[\frac{1}{s}\right]-\frac{1}{2}L^{-1}\left[\frac{1}{s+2}\right]$$

Apply the property's. $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{s}\right]=1$

$$f(t)=\left(\frac{3}{2}(1)-\frac{1}{2}e^{-2t}\right)u(t)$$
$$=\left(\frac{3}{2}-\frac{1}{2}e^{-2t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{(s+3)(s+6)}{s(s^2+8s+12)}$ is $\boxed{\left(\frac{3}{2}-\frac{1}{2}e^{-2t}\right)u(t)}$

Step 1 of 7

(a)

Consider the function.

$$F(s)=\frac{s+3}{s(s+2)^2}$$

Assume $\frac{s+3}{s(s+2)^2}$ to be $\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$.

$$\frac{s+3}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2} \quad \text{..... (1)}$$

$$\frac{s+3}{s(s+2)^2}=\frac{A(s+2)^2+Bs(s+2)+Cs}{s(s+2)^2}$$

$$s+3=A(s+2)^2+Bs(s+2)+Cs \quad \text{..... (2)}$$

Substitute -2 for s in the equation.

$$-2+3=A(-2+2)^2+B(-2)(-2+2)+C(-2)$$
$$1=A(0)+B(0)+C(-2)$$
$$1=C(-2)$$
$$C=-\frac{1}{2}$$

Therefore, the value of C is $-\frac{1}{2}$.

Step 2 of 7

Recall equation (2).

$$s+3=A(s+2)^2+Bs(s+2)+Cs$$

Substitute 0 for s in the equation.

$$0+3=A(0+2)^2+B(0)(0+2)+C(0)$$
$$3=A(4)+B(0)+C(0)$$
$$3=4A$$
$$A=\frac{3}{4}$$

Therefore, the value of A is $\frac{3}{4}$.

Step 3 of 7

Recall equation (2).

$$s+3=A(s+2)^2+Bs(s+2)+Cs$$

Substitute 1 for s, $-\frac{1}{2}$ for C and $\frac{3}{4}$ for A in the equation.

$$1+3=\left(\frac{3}{4}\right)(1+2)^2+B(1)(1+2)+\left(-\frac{1}{2}\right)(1)$$
$$4=\left(\frac{3}{4}\right)(9)+B(3)-\frac{1}{2}$$
$$4=\frac{27}{4}+B(3)-\frac{1}{2}$$
$$3B=4-\frac{27}{4}+\frac{1}{2}$$
$$3B=\frac{16-27+2}{4}$$
$$3B=\frac{-9}{4}$$
$$B=-\frac{3}{4}$$

Therefore, the value of B is $-\frac{3}{4}$.

Step 4 of 7

Recall equation (1).

$$\frac{s+3}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$$

Substitute $F(s)$ for $\frac{s+3}{s(s+2)^2}$, $-\frac{3}{4}$ for B, $\frac{3}{4}$ for A and $-\frac{1}{2}$ for C in the equation.

$$F(s)=\frac{3}{4s}-\frac{3}{4(s+2)}-\frac{1}{2(s+2)^2}$$

Apply inverse Laplace transform.

$$L^{-1}[F(s)]=\frac{3}{4}L^{-1}\left[\frac{1}{s}\right]-\frac{3}{4}L^{-1}\left[\frac{1}{s+2}\right]-\frac{1}{2}L^{-1}\left[\frac{1}{(s+2)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$f(t)=\left(\frac{3}{4}(1)-\frac{3}{4}e^{-2t}-\frac{1}{2}te^{-2t}\right)u(t)$$
$$=\left(\frac{3}{4}-\frac{3}{4}e^{-2t}-\frac{1}{2}te^{-2t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+3}{s(s+2)^2}$ is $\boxed{\left(\frac{3}{4}-\frac{3}{4}e^{-2t}-\frac{1}{2}te^{-2t}\right)u(t)}$.

(b)

Consider the function.

$$F(s)=\frac{s+6}{s(s+2)^2}$$

Assume $\frac{s+6}{s(s+2)^2}$ to be $\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$.

$$\frac{s+6}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2} \quad \text{..... (3)}$$

$$\frac{s+6}{s(s+2)^2}=\frac{A(s+2)^2+Bs(s+2)+Cs}{s(s+2)^2}$$

$$s+6=A(s+2)^2+Bs(s+2)+Cs \quad \text{..... (4)}$$

Substitute -2 for s in the equation.

$$-2+6=A(-2+2)^2+B(-2)(-2+2)+C(-2)$$
$$4=A(0)+B(0)+C(-2)$$
$$4=C(-2)$$
$$C=-2$$

Therefore, the value of C is -2.

Step 5 of 7

Recall equation (4).

$$s+6=A(s+2)^2+Bs(s+2)+Cs$$

Substitute 0 for s in the equation.

$$0+6=A(0+2)^2+B(0)(0+2)+C(0)$$
$$6=A(4)+B(0)+C(0)$$
$$6=4A$$
$$A=\frac{6}{4}$$
$$A=\frac{3}{2}$$

Therefore, the value of A is $\frac{3}{2}$.

Step 6 of 7

Recall equation (4).

$$s+6=A(s+2)^2+Bs(s+2)+Cs$$

Substitute 1 for s, -2 for C and $\frac{3}{2}$ for A in the equation.

$$1+6=\left(\frac{3}{2}\right)(1+2)^2+B(1)(1+2)+(-2)(1)$$
$$7=\left(\frac{3}{2}\right)(9)+B(3)-2$$
$$7=\frac{27}{2}+B(3)-2$$
$$3B=7-\frac{27}{2}+2$$
$$3B=\frac{14-27+4}{2}$$
$$3B=\frac{-9}{2}$$
$$B=-\frac{3}{2}$$

Therefore, the value of B is $-\frac{3}{2}$.

Step 7 of 7

Recall equation (3).

$$\frac{s+6}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$$

Substitute $F(s)$ for $\frac{s+6}{s(s+2)^2}$, $-\frac{3}{2}$ for B, $\frac{3}{2}$ for A and -2 for C in the equation.

$$F(s)=\frac{3}{2s}-\frac{3}{2(s+2)}-\frac{2}{(s+2)^2}$$

Apply inverse Laplace transform.

$$L^{-1}[F(s)]=\frac{3}{2}L^{-1}\left[\frac{1}{s}\right]-\frac{3}{2}L^{-1}\left[\frac{1}{s+2}\right]-2L^{-1}\left[\frac{1}{(s+2)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$f(t)=\left(\frac{3}{2}(1)-\frac{3}{2}e^{-1t}-2te^{-2t}\right)u(t)$$
$$=\left(\frac{3}{2}-\frac{3}{2}e^{-1t}-2te^{-2t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+6}{s(s+2)^2}$ is $\boxed{\left(\frac{3}{2}-\frac{3}{2}e^{-1t}-2te^{-2t}\right)u(t)}$.

Step 1 of 5

(a)

Consider the following function:

$$F(s)=\frac{s+6}{s^2(s+2)}$$

Assume $\frac{s+6}{s^2(s+2)}$ to be $\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+2}$.

$$\frac{s+6}{s^2(s+2)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+2} \text{ ..... (1)}$$

$$\frac{s+6}{s^2(s+2)}=\frac{As(s+2)+B(s+2)+Cs^2}{s^2(s+2)}$$

$$s+6=As(s+2)+B(s+2)+Cs^2 \text{ ..... (2)}$$

Substitute -2 for s.

$$-2+6=A(-2)(-2+2)+B(-2+2)+C(-2)^2$$
$$4=A(0)+B(0)+C(4)$$
$$4=C(4)$$
$$C=1$$

Therefore, the value of C is 1.

Step 2 of 5

Consider equation (2).

$$s+6=As(s+2)+B(s+2)+Cs^2$$

Substitute 0 for s.

$$0+6=A(0)(0+2)^2+B(0+2)+C(0)^2$$
$$6=A(0)+B(2)+C(0)$$
$$6=2B$$
$$B=3$$

Therefore, the value of B is 3.

Step 3 of 5

Consider equation (2).

$$s+6=As(s+2)+B(s+2)+Cs^2$$

Substitute 1 for s, 1 for C and 3 for B.

$$1+6=A(1)(1+2)+(3)(1+2)+(1)(1)^2$$
$$7=A(3)+9+1$$
$$A(3)=7-9-1$$
$$A(3)=-3$$
$$A=-1$$

Therefore, the value of A is -1.

Step 4 of 5

Consider equation (1).

$$\frac{s+6}{s^2(s+2)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{(s+2)}$$

Substitute $F(s)$ for $\frac{s+6}{s^2(s+2)}$, 3 for B, -1 for A and 1 for C.

$$F(s)=\frac{-1}{s}+\frac{3}{s^2}+\frac{1}{(s+2)}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=-\mathcal{L}^{-1}\left[\frac{1}{s}\right]+3\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]+\mathcal{L}^{-1}\left[\frac{1}{(s+2)}\right]$$

Apply the properties, $\mathcal{L}^{-1}\left[\frac{1}{s}\right]=1$, $\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]=t$ and $\mathcal{L}^{-1}\left[\frac{1}{(s+a)}\right]=e^{-at}$.

$$\begin{aligned} f(t)&=\left((-1)(1)+3t+e^{-2t}\right)u(t)\\ &=\left(-1+3t+e^{-2t}\right)u(t)\end{aligned}$$

Therefore, the inverse Laplace transform of $\frac{s+6}{s^2(s+2)}$ is $\boxed{\left(-1+3t+e^{-2t}\right)u(t)}$.

Step 5 of 5

(b)

Consider the following function:

$$\begin{aligned} F(s)&=\frac{s+3}{(s+1)^2(s+3)}\\ &=\frac{1}{(s+1)^2}\end{aligned}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=\mathcal{L}^{-1}\left[\frac{1}{(s+1)^2}\right]$$

Apply the property, $\mathcal{L}^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$.

$$f(t)=te^{-t}u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+3}{(s+1)^2(s+3)}$ is $\boxed{te^{-t}u(t)}$.

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Step 1 of 10

(a)

Consider the following function:

$$F(s)=\frac{s+8}{s^2(s+4)}$$

Assume $\frac{s+8}{s^2(s+4)}$ to be $\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+4}$.

$$\frac{s+8}{s^2(s+4)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+4} \quad \text{..... (1)}$$

$$\frac{s+8}{s^2(s+4)}=\frac{As(s+4)+B(s+4)+Cs^2}{s^2(s+4)}$$

$$s+8=As(s+4)+B(s+4)+Cs^2 \quad \text{..... (2)}$$

Substitute -4 for s.

$$-4+8=A(-4)(-4+4)+B(-4+4)+C(-4)^2$$
$$4=A(0)+B(0)+C(16)$$
$$4=C(16)$$
$$C=\frac{1}{4}$$

Therefore, the value of C is $\frac{1}{4}$.

Step 2 of 10

Consider equation (2).

$$s+8=As(s+4)+B(s+4)+Cs^2$$

Substitute 0 for s.

$$0+8=A(0)(0+4)^2+B(0+4)+C(0)^2$$
$$8=A(0)+B(4)+C(0)$$
$$8=2B$$
$$B=2$$

Therefore, the value of B is 2.

Step 3 of 10

Consider equation (2).

$$s+8=As(s+4)+B(s+4)+Cs^2$$

Substitute 1 for s, $\frac{1}{4}$ for C and 2 for B.

$$1+8=A(1)(1+4)+(2)(1+4)+\left(\frac{1}{4}\right)(1)^2$$
$$9=A(5)+10+\frac{1}{4}$$
$$A(5)=9-10-\frac{1}{4}$$
$$A(5)=-1-\frac{1}{4}$$
$$A(5)=-\frac{5}{4}$$
$$A=-\frac{1}{4}$$

Therefore, the value of A is $-\frac{1}{4}$.

Step 4 of 10

Consider equation (1).

$$\frac{s+8}{s^2(s+4)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{(s+4)}$$

Substitute $F(s)$ for $\frac{s+8}{s^2(s+4)}$, 2 for B, $-\frac{1}{4}$ for A and $\frac{1}{4}$ for C.

$$F(s)=\frac{-1}{4s}+\frac{2}{s^2}+\frac{1}{4(s+4)}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=-\frac{1}{4}\mathcal{L}^{-1}\left[\frac{1}{s}\right]+2\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]+\frac{1}{4}\mathcal{L}^{-1}\left[\frac{1}{(s+2)}\right]$$

Apply the properties, $\mathcal{L}^{-1}\left[\frac{1}{s}\right]=1$, $\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]=t$ and $\mathcal{L}^{-1}\left[\frac{1}{(s+a)}\right]=e^{-at}$.

$$f(t)=\left(\left(-\frac{1}{4}\right)(1)+2t+\frac{1}{4}e^{-4t}\right)u(t)$$
$$=\left(-\frac{1}{4}+2t+\frac{1}{4}e^{-4t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+8}{s^2(s+4)}$ is $\boxed{\left(-\frac{1}{4}+2t+\frac{1}{4}e^{-4t}\right)u(t)}$.

Step 5 of 10

(b)

Consider the following function:

$$F(s)=\frac{1}{s^2(s+1)^2}$$

Assume $\frac{1}{s^2(s+1)^2}$ to be $\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1}+\frac{D}{(s+1)^2}$.

$$\frac{1}{s^2(s+1)^2}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1}+\frac{D}{(s+1)^2} \quad \text{..... (3)}$$

$$\frac{1}{s^2(s+1)^2}=\frac{As(s+1)^2+B(s+1)^2+Cs^2(s+1)+Ds^2}{s^2(s+1)^2}$$

$$1=As(s+1)^2+B(s+1)^2+Cs^2(s+1)+Ds^2 \quad \text{..... (4)}$$

Substitute -1 for s.

$$1=A(-1)(-1+1)^2+B(-1+1)^2+C(-1)^2(-1+1)+D(-1)^2$$
$$1=A(0)+B(0)+C(0)+D(1)$$
$$1=D(1)$$
$$D=1$$

Therefore, the value of D is 1.

Step 6 of 10

Consider equation (4).

$$1=As(s+1)^2+B(s+1)^2+Cs^2(s+1)+Ds^2$$

Substitute 0 for s.

$$1=A(0)(0+1)^2+B(0+1)^2+C(0)^2(0+1)+D(0)^2$$
$$1=A(0)+B(1)+C(0)+D(0)$$
$$1=1B$$
$$B=1$$

Therefore, the value of B is 1.

Step 7 of 10

Consider equation (4).

$$1=As(s+1)^2+B(s+1)^2+Cs^2(s+1)+Ds^2$$

Substitute 1 for s, 1 for D and 1 for B.

$$1=A(1)(1+1)^2+B(1+1)^2+C(1)^2(1+1)+D(1)^2$$
$$1=A(4)+(1)(4)+C(2)+(1)(1)^2$$
$$1=4A+2C+5$$
$$2C=-4A-4$$
$$C=-2A-2$$

Therefore, the expression for C is $-2A-2$.

Step 8 of 10

Consider equation (4).

$$1=As(s+1)^2+B(s+1)^2+Cs^2(s+1)+Ds^2$$

Substitute 2 for s, $-2A-2$ for C, 1 for D and 1 for B.

$$1=A(2)(2+1)^2+(1)(2+1)^2+(-2A-2)(2^2)(2+1)+(1)(2)^2$$
$$1=A(2)(9)+(1)(3)^2+(-2A-2)(4)(3)+(1)(4)$$
$$1=A(18)+9+(-2A-2)(12)+4$$
$$1=A(18)+9-24A-24+4$$
$$1=A(-6)-11$$
$$A(-6)=12$$
$$A=\frac{-12}{6}$$
$$A=-2$$

Therefore, the value of A is -2.

Step 9 of 10

Consider the expression for C.

$$C=-2A-2$$

Substitute -2 for A.

$$C=-2(-2)-2$$
$$C=4-2$$
$$C=2$$

Therefore, the value of C is 2.

Step 10 of 10

Consider equation (3).

$$\frac{1}{s^2(s+1)^2}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{s+1}+\frac{D}{(s+1)^2}$$

Substitute $F(s)$ for $\frac{1}{s^2(s+1)^2}$, 1 for B, 1 for D, -2 for A and 2 for C.

$$F(s)=-\frac{2}{s}+\frac{1}{s^2}+\frac{2}{s+1}+\frac{1}{(s+1)^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=-2\mathcal{L}^{-1}\left[\frac{1}{s}\right]+\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]+2\mathcal{L}^{-1}\left[\frac{1}{(s+1)}\right]+\mathcal{L}^{-1}\left[\frac{1}{(s+1)^2}\right]$$

Apply the properties, $\mathcal{L}^{-1}\left[\frac{1}{s}\right]=1$, $\mathcal{L}^{-1}\left[\frac{1}{s^2}\right]=t$, $\mathcal{L}^{-1}\left[\frac{1}{(s+a)}\right]=e^{-at}$ and $\mathcal{L}^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$.

$$f(t)=\left((-2)(1)+t+2e^{-t}+te^{-t}\right)u(t)$$
$$=\left(-2+t+2e^{-t}+te^{-t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{1}{s^2(s+1)^2}$ is $\boxed{\left(-2+t+2e^{-t}+te^{-t}\right)u(t)}$.

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Step 1 of 5

(a)

Consider the following function:

$$\mathbf{F}(s)=\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}$$

The function $f(t)$ is

$$f(t)=L^{-1}[\mathbf{F}(s)]$$

Express $\mathbf{F}(s)$ in a partial fraction expansion.

$$\mathbf{F}(s)=\frac{K_0}{s}+\frac{K_1}{s+2}+\frac{K_2s+K_3}{s^2+2s+2} \quad \text{..... (1)}$$

$$\frac{(s+1)^2}{s(s+2)(s^2+2s+2)}=\frac{K_0}{s}+\frac{K_1}{s+2}+\frac{K_2s+K_3}{s^2+2s+2}$$

$$s^2+2s+1=K_0(s+2)(s^2+2s+2)+K_1s(s^2+2s+2)+(K_2s+K_3)s(s+2)$$

$$s^2+2s+1=K_0\begin{pmatrix}s^3+2s^2+2s+\\2s^2+4s+4\end{pmatrix}+K_1(s^3+2s^2+2s)+(K_2s+K_3)(s^2+2s)$$

$$s^2+2s+1=K_0(s^3+4s^2+6s+4)+K_1(s^3+2s^2+2s)+K_2(s^3+2s^2)+K_3(s^2+2s)$$

$$s^2+2s+1=(K_0+K_1+K_2)s^3+\begin{pmatrix}4K_0+2K_1+\\2K_2+K_3\end{pmatrix}s^2+(6K_0+2K_1+2K_3)s+4K_0 \quad \text{..... (2)}$$

Step 2 of 5

Compare constants terms on both sides

$$1=4K_0$$

$$K_0=\frac{1}{4}$$

Step 3 of 5

Compare coefficients of s^3 on both sides of equation (2).

$$K_0+K_1+K_2=0$$

Substitute $\frac{1}{4}$ for K_0 in the equation.

$$\frac{1}{4}+K_1+K_2=0$$

$$K_2=-K_1-\frac{1}{4} \quad \text{..... (3)}$$

Compare coefficients of s on both sides of equation (2).

$$6K_0+2K_1+2K_3=2$$

Substitute $\frac{1}{4}$ for K_0 in the equation.

$$6\left(\frac{1}{4}\right)+2K_1+2K_3=2$$

$$2K_3=2-2K_1-\frac{3}{2}$$

$$2K_3=\frac{1}{2}-2K_1$$

$$K_3=\frac{1}{4}-K_1 \quad \text{..... (4)}$$

Step 4 of 5

Compare coefficients of s^2 on both sides of equation (2).

$$4K_0+2K_1+2K_2+K_3=1$$

Substitute $\frac{1}{4}$ for K_0, $\frac{1}{4}-K_1$ for K_3, and $-K_1-\frac{1}{4}$ for K_2 in the equation.

$$4\left(\frac{1}{4}\right)+2K_1+2\left(-K_1-\frac{1}{4}\right)+\left(\frac{1}{4}-K_1\right)=1$$

$$1+2K_1-2K_1-\frac{1}{2}+\frac{1}{4}-K_1=1$$

$$-K_1=\frac{1}{4}$$

$$K_1=-\frac{1}{4}$$

Substitute $-\frac{1}{4}$ for K_1 in equation (3).

$$K_2=-\left(-\frac{1}{4}\right)-\frac{1}{4}$$

$$=0$$

Substitute $-\frac{1}{4}$ for K_1 in equation (4).

$$K_3=\frac{1}{4}-\left(-\frac{1}{4}\right)$$

$$=\frac{1}{2}$$

Step 5 of 5

Substitute $\frac{1}{4}$ for K_0, $-\frac{1}{4}$ for K_1, 0 for K_2, and $\frac{1}{2}$ for K_3 in equation (1).

$$\begin{aligned}\mathbf{F}(s)&=\frac{\frac{1}{4}}{s}+\frac{-\frac{1}{4}}{s+2}+\frac{(0)s+\frac{1}{2}}{s^2+2s+2}\\&=\frac{1}{4}\frac{1}{s}-\frac{1}{4}\frac{1}{s+2}+\frac{1}{2}\frac{1}{s^2+2s+2}\\&=\frac{1}{4}\frac{1}{s}-\frac{1}{4}\frac{1}{s+2}+\frac{1}{2}\frac{1}{s^2+2s+1+1}\\&=\frac{1}{4}\frac{1}{s}-\frac{1}{4}\frac{1}{s+2}+\frac{1}{2}\frac{1}{(s+1)^2+1^2}\end{aligned}$$

Now apply inverse Laplace transforms on both sides.

$$\begin{aligned}f(t)&=\left(\frac{1}{4}-\frac{1}{4}e^{-2t}+\frac{1}{2}e^{-t}\sin t\right)u(t)\\&=\frac{1}{4}\left(1-e^{-2t}+2e^{-t}\sin t\right)u(t)\end{aligned}$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\frac{1}{4}\left(1-e^{-2t}+2e^{-t}\sin t\right)u(t)}$$

Step 1 of 1

13.024 P

Consider the following function:

$$\begin{aligned}\mathbf{F}(s) &= \frac{e^{-s}}{s^2+2s+2}\\ &= \frac{e^{-s}}{s^2+2s+1+1}\\ &= \frac{e^{-s}}{(s+1)^2+1^2}\end{aligned}$$

The function $f(t)$ is,

$$f(t)=L^{-1}\left[\mathbf{F}(s)\right]$$

Consider the following relation.

$$L^{-1}\left\{\frac{b}{(s+a)^2+b^2}\right\}=e^{-at}\sin bt\,u(t)$$

Thus, the inverse Laplace of $\frac{1}{(s+1)^2+1^2}$ is

$$L^{-1}\left\{\frac{1}{(s+1)^2+1^2}\right\}=e^{-t}\sin(t)u(t)$$

From time shifting property of Laplace transform.

$$L^{-1}\left\{\frac{e^{-s}}{(s+1)^2+1^2}\right\}=e^{-(t-1)}\sin(t-1)u(t-1)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=e^{-(t-1)}\sin(t-1)u(t-1)}.$$

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Step 1 of 5

Consider the following function:

$$\mathbf{F}(s)=\frac{e^{-s}}{s^2\left(s^2+1\right)\left(s^2+4\right)}$$
$$=\frac{e^{-s}}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}$$

The function $f(t)$ is

$$f(t)=L^{-1}\left[\mathbf{F}(s)\right]$$

Express $\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}$ in a partial fraction expansion.

$$\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}=\frac{K_{11}}{s}+\frac{K_{12}}{s^2}+\frac{K_2}{s+j1}+\frac{K_3}{s-j1}+\frac{K_4}{s+j2}+\frac{K_5}{s-j2}$$

Step 2 of 5

Calculate the value of K_{12}.

$$K_{12}=s^2\,\mathbf{F}(s)\Big|_{s=0}$$
$$=s^2\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=0}$$
$$=\frac{1}{(0+j1)(0-j1)(0+j2)(0-j2)}$$
$$=\frac{1}{4}$$

Calculate the value of K_{11}.

$$K_{11}=\left[\frac{d}{ds}s^2\mathbf{F}(s)\right]\Bigg|_{s=0}$$
$$=\frac{d}{ds}\frac{1}{(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=0}$$
$$=\frac{d}{ds}\frac{1}{\left(s^2+1\right)\left(s^2+4\right)}\Bigg|_{s=0}$$
$$=\frac{d}{ds}\frac{1}{s^4+5s^2+4}\Bigg|_{s=0}$$
$$=\frac{\left(s^4+5s^2+4\right)(0)-1\left(4s^3+10s\right)}{\left(s^4+5s^2+4\right)^2}\Bigg|_{s=0}$$
$$=\frac{-\left(4(0)^3+10(0)\right)}{\left((0)^4+5(0)^2+4\right)^2}$$
$$=0$$

Step 3 of 5

Calculate the value of K_2.

$$K_2=(s+j1)\mathbf{F}(s)\Big|_{s=-j1}$$
$$=(s+j1)\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=-j1}$$
$$=\frac{1}{(-j1)^2(-j1-j1)(-j1+j2)(-j1-j2)}$$
$$=-\frac{j1}{6}$$

Calculate the value of K_3.

$$K_3=(s-j1)\mathbf{F}(s)\Big|_{s=j1}$$
$$=(s-j1)\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=j1}$$
$$=\frac{1}{(j1)^2(j1+j1)(j1+j2)(j1-j2)}$$
$$=\frac{j1}{6}$$

Calculate the value of K_4.

$$K_4=(s+j2)\mathbf{F}(s)\Big|_{s=-j2}$$
$$=(s+j2)\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=-j2}$$
$$=\frac{1}{(-j2)^2(-j2+j1)(-j2-j1)(-j2-j2)}$$
$$=\frac{j1}{48}$$

Step 4 of 5

Calculate the value of K_5.

$$K_5=(s-j2)\mathbf{F}(s)\Big|_{s=-j2}$$
$$=(s-j2)\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\Bigg|_{s=j2}$$
$$=\frac{1}{(j2)^2(j2+j1)(j2-j1)(j2+j2)}$$
$$=-\frac{j1}{48}$$

The partial fraction expansion of $\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}$ is,

$$\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}=\left[\begin{array}{l}\frac{(0)}{s}+\frac{\left(\frac{1}{4}\right)}{s^2}+\frac{\left(-\frac{j1}{6}\right)}{s+j1}+\\ \frac{\left(\frac{j1}{6}\right)}{s-j1}+\frac{\left(\frac{j1}{48}\right)}{s+j2}+\frac{\left(-\frac{j1}{48}\right)}{s-j2}\end{array}\right]$$
$$=\left[\begin{array}{l}\frac{1}{4}\frac{1}{s^2}-\frac{j1}{6}\frac{1}{s+j1}+\\ \frac{j1}{6}\frac{1}{s-j1}+\frac{j1}{48}\frac{1}{s+j2}-\frac{j1}{48}\frac{1}{s-j2}\end{array}\right]$$

Step 5 of 5

Now apply inverse Laplace transforms on both sides.

$$L^{-1}\left\{\frac{1}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\right\}=\left[\begin{array}{l}\frac{1}{4}tu(t)-\frac{j1}{6}e^{-j1t}u(t)+\\ \frac{j1}{6}e^{j1t}u(t)+\frac{j1}{48}e^{-j2t}u(t)-\frac{j1}{48}e^{j2t}u(t)\end{array}\right]$$
$$=\left[\begin{array}{l}\frac{1}{4}t+\frac{j1}{6}\left(e^{j1t}-e^{-j1t}\right)-\\ \frac{j1}{48}\left(e^{j2t}-e^{-j2t}\right)\end{array}\right]u(t)$$
$$=\left[\begin{array}{l}\frac{1}{4}t+\frac{j1}{6}(2j\sin t)-\\ \frac{j1}{48}(2j\sin 2t)\end{array}\right]u(t)$$
$$=\left[\frac{1}{4}t-\frac{1}{3}\sin t+\frac{1}{24}\sin 2t\right]u(t)$$

By time shifting property, the inverse Laplace of $\frac{e^{-s}}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}$ is,

$$L^{-1}\left\{\frac{e^{-s}}{s^2(s+j1)(s-j1)(s+j2)(s-j2)}\right\}=\left[\begin{array}{l}\frac{1}{4}(t-1)-\frac{1}{3}\sin(t-1)+\\ \frac{1}{24}\sin\left(2(t-1)\right)\end{array}\right]u(t-1)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\left[\frac{1}{4}(t-1)-\frac{1}{3}\sin(t-1)+\frac{1}{24}\sin\left(2(t-1)\right)\right]u(t-1)}.$$

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Step 1 of 8

(a)

Consider the function.

$$F(s)=\frac{s+1}{s(s+2)(s+3)}$$

Assume $\frac{s+1}{s(s+2)(s+3)}$ to be $\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+3}$.

$$\frac{s+1}{s(s+2)(s+3)}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+3}$$

$$\frac{s+1}{s(s+2)(s+3)}=\frac{A(s+2)(s+3)+Bs(s+3)+Cs(s+2)}{s(s+2)(s+3)}$$

$$s+1=A(s+2)(s+3)+Bs(s+3)+Cs(s+2) \text{ ..... (1)}$$

Substitute 0 for s in the equation.

$$0+1=A(0+2)(0+3)+B(0)(0+3)+C(0)(0+2)$$
$$1=A(6)+0+0$$
$$1=A(6)$$
$$A=\frac{1}{6}$$

Therefore, the value of A is $\frac{1}{6}$.

Step 2 of 8

Recall equation (1).

$$s+1=A(s+2)(s+3)+Bs(s+3)+Cs(s+2)$$

Substitute -3 for s in the equation.

$$-3+1=A(-3+2)(-3+3)+B(-3)(-3+3)+C(-3)(-3+2)$$
$$-2=A(0)+B(0)+C(-3)(-1)$$
$$-2=0+0+C(3)$$
$$3C=-2$$
$$C=\frac{-2}{3}$$

Therefore, the value of C is $\frac{-2}{3}$.

Step 3 of 8

Recall equation (1).

$$s+1=A(s+2)(s+3)+Bs(s+3)+Cs(s+2)$$

Substitute -2 for s in the equation.

$$-2+1=A(-2+2)(-2+3)+B(-2)(-2+3)+C(-2)(-2+2)$$
$$-1=A(0)+B(-2)+C(0)$$
$$-1=0+B(-2)+0$$
$$-2B=-1$$
$$B=\frac{1}{2}$$

Therefore, the value of B is $\frac{1}{2}$.

Step 4 of 8

Recall equation (1).

$$\frac{s+1}{s(s+2)(s+3)}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+3}$$

Substitute $F(s)$ for $\frac{s+1}{s(s+2)(s+3)}$, $\frac{1}{2}$ for B, $\frac{-2}{3}$ for C and $\frac{1}{6}$ for A

$$F(s)=\frac{1}{6s}+\frac{1}{2(s+2)}-\frac{2}{3(s+3)}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{1}{6}L^{-1}\left[\frac{1}{s}\right]+\frac{1}{2}L^{-1}\left[\frac{1}{s+2}\right]-\frac{2}{3}L^{-1}\left[\frac{1}{s+3}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$ and $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(\frac{1}{6}(1)+\frac{1}{2}e^{-2t}-\frac{2}{3}e^{-3t}\right)u(t)$$
$$=\left(\frac{1}{6}+\frac{1}{2}e^{-2t}-\frac{2}{3}e^{-3t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+1}{s(s+2)(s+3)}$ is $\boxed{\left(\frac{1}{6}+\frac{1}{2}e^{-2t}-\frac{2}{3}e^{-3t}\right)u(t)}$.

Step 5 of 8

(b)

Consider the function.

$$F(s)=\frac{s^2+s+1}{s(s+1)(s+2)}$$

Assume $\frac{s^2+s+1}{s(s+1)(s+2)}$ to be $\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2}$.

$$\frac{s^2+s+1}{s(s+1)(s+2)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2}$$

$$\frac{s^2+s+1}{s(s+1)(s+2)}=\frac{A(s+1)(s+2)+Bs(s+2)+Cs(s+1)}{s(s+1)(s+2)}$$

$$s^2+s+1=A(s+1)(s+2)+Bs(s+2)+Cs(s+1) \text{ ..... (2)}$$

Substitute 0 for s in the equation.

$$0+0+1=A(0+1)(0+2)+B(0)(0+2)+C(0)(0+1)$$
$$1=A(2)+0+0$$
$$1=A(2)$$
$$A=\frac{1}{2}$$

Therefore, the value of A is $\frac{1}{2}$.

Step 6 of 8

Recall equation (2).

$$s^2+s+1=A(s+1)(s+2)+Bs(s+2)+Cs(s+1)$$

Substitute -2 for s in the equation.

$$(-2)^2-2+1=A(-2+1)(-2+2)+B(-2)(-2+3)+C(-2)(-2+1)$$
$$3=A(0)+B(0)+C(-2)(-1)$$
$$3=0+0+C(2)$$
$$2C=3$$
$$C=\frac{3}{2}$$

Therefore, the value of C is $\frac{3}{2}$.

Step 7 of 8

Recall equation (2).

$$s^2+s+1=A(s+1)(s+2)+Bs(s+2)+Cs(s+1)$$

Substitute -1 for s in the equation.

$$(-1)^2-1+1=A(-1+1)(-1+2)+B(-1)(-1+2)+C(-1)(-1+1)$$
$$1=A(0)+B(-1)+C(0)$$
$$1=0+B(-1)+$$
$$B=-1$$

Therefore, the value of B is -1.

Step 8 of 8

Consider equation (2).

$$\frac{s^2+s+1}{s(s+1)(s+2)}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{s+2}$$

Substitute $F(s)$ for $\frac{s^2+s+1}{s(s+1)(s+2)}$, -1 for B, $\frac{3}{2}$ for C and $\frac{1}{2}$ for A

$$F(s)=\frac{1}{2s}-\frac{1}{s+2}+\frac{3}{2(s+3)}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{1}{2}L^{-1}\left[\frac{1}{s}\right]-L^{-1}\left[\frac{1}{s+1}\right]+\frac{3}{2}L^{-1}\left[\frac{1}{s+2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$ and $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$.

$$f(t)=\left(\frac{1}{2}(1)-e^{-t}+\frac{3}{2}e^{-2t}\right)u(t)$$
$$=\left(\frac{1}{2}-e^{-t}+\frac{3}{2}e^{-2t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s^2+s+1}{s(s+1)(s+2)}$ is $\boxed{\left(\frac{1}{2}-e^{-t}+\frac{3}{2}e^{-2t}\right)u(t)}$.

Step 1 of 7

(a)

Consider the function.

$$F(s)=\frac{s^2+4s+8}{(s+1)(s+4)^2}$$

Assume $\frac{s^2+4s+8}{(s+1)(s+4)^2}$ to be $\frac{A}{s+1}+\frac{B}{s+4}+\frac{C}{(s+4)^2}$.

$$\frac{s^2+4s+8}{(s+1)(s+4)^2}=\frac{A}{s+1}+\frac{B}{s+4}+\frac{C}{(s+4)^2} \text{ ..... (1)}$$

$$\frac{s^2+4s+8}{(s+1)(s+4)^2}=\frac{A(s+4)^2+B(s+1)(s+4)+C(s+1)}{(s+1)(s+4)^2}$$

$$s^2+4s+8=A(s+4)^2+B(s+1)(s+4)+C(s+1) \text{ ..... (2)}$$

Substitute -1 for s in the equation.

$$(-1)^2+4(-1)+8=A(-1+4)^2+B(-1+1)(-1+4)+C(-1+1)$$
$$1-4+8=A(3)^2+B(0)+C(0)$$
$$5=A(9)$$
$$A=\frac{5}{9}$$

Therefore, the value of A is $\frac{5}{9}$.

Step 2 of 7

Recall equation (2).

$$s^2+4s+8=A(s+4)^2+B(s+1)(s+4)+C(s+1)$$

Substitute -4 for s in the equation.

$$(-4)^2+4(-4)+8=A(-4+4)^2+B(-4+1)(-4+4)+C(-4+1)$$
$$16-16+8=A(0)+B(-3)(0)+C(-3)$$
$$8=0+0+C(-3)$$
$$C=\frac{-8}{3}$$

Therefore, the value of C is $\frac{-8}{3}$.

Step 3 of 7

Recall equation (2).

$$s^2+4s+8=A(s+4)^2+B(s+1)(s+4)+C(s+1)$$

Substitute 0 for s, $\frac{-8}{3}$ for C and $\frac{5}{9}$ for A in the equation.

$$(0)^2+4(0)+8=\left(\frac{5}{9}\right)(0+4)^2+B(0+1)(0+4)+\left(\frac{-8}{3}\right)(0+1)$$
$$8=\left(\frac{5}{9}\right)(16)+B(4)+\left(\frac{-8}{3}\right)$$
$$8=\frac{80}{9}+B(4)-\frac{8}{3}$$
$$B(4)=8-\frac{80}{9}+\frac{8}{3}$$
$$B(4)=\frac{72-80+24}{9}$$
$$B(4)=\frac{16}{9}$$
$$B=\frac{4}{9}$$

Therefore, the value of B is $\frac{4}{9}$.

Step 4 of 7

Recall equation (1).

$$\frac{s^2+4s+8}{(s+1)(s+4)^2}=\frac{A}{s+1}+\frac{B}{s+4}+\frac{C}{(s+4)^2}$$

Substitute $F(s)$ for $(s+4)^2$, $\frac{4}{9}$ for B, $-\frac{8}{3}$ for C and $\frac{5}{9}$ for A in the equation.

$$F(s)=\frac{5}{9(s+1)}+\frac{4}{9(s+4)}-\frac{8}{3(s+4)^2}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=\frac{5}{9}L^{-1}\left[\frac{1}{s+1}\right]+\frac{4}{9}L^{-1}\left[\frac{1}{s+4}\right]-\frac{8}{3}L^{-1}\left[\frac{1}{(s+4)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$f(t)=\left(\frac{5}{9}e^{-t}+\frac{4}{9}e^{-4t}-\frac{8}{3}te^{-4t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s^2+4s+8}{(s+1)(s+4)^2}$ is

$$\boxed{\left(\frac{5}{9}e^{-t}+\frac{4}{9}e^{-4t}-\frac{8}{3}te^{-4t}\right)u(t)}.$$

Step 5 of 7

(b)

Consider the function.

$$F(s)=\frac{s+4}{s^2}$$

Assume $\frac{s+4}{s^2}$ to be $\frac{A}{s}+\frac{B}{s^2}$.

$$\frac{s+4}{s^2}=\frac{A}{s}+\frac{B}{s^2} \text{ ..... (3)}$$

$$\frac{s+4}{s^2}=\frac{As+B}{s^2}$$

$$s+4=As+B \text{ ..... (4)}$$

Substitute 0 for s in the equation.

$$0+4=A(0)+B$$
$$4=0+B$$
$$B=4$$

Therefore, the value of B is 4.

Step 6 of 7

Recall equation (4).

$$s+4=As+B$$

Substitute 1 for s and 4 for B in the equation.

$$1+4=A+B$$
$$5=A+4$$
$$5-4=A$$
$$A=1$$

Therefore, the value of A is 1.

Step 7 of 7

Recall equation (3).

$$\frac{s+4}{s^2}=\frac{A}{s}+\frac{B}{s^2}$$

Substitute $F(s)$ for $\frac{s+4}{s^2}$, 4 for B and 1 for A in the equation.

$$F(s)=\frac{1}{s}+\frac{4}{s^2}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=L^{-1}\left[\frac{1}{s}\right]+4L^{-1}\left[\frac{1}{s^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s^2}\right]=t$ and $L^{-1}\left[\frac{1}{s}\right]=1$

$$f(t)=(1+4t)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+4}{s^2}$ is $\boxed{(1+4t)u(t)}$.

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Step 1 of 6

(a)

Consider the function.

$$F(s)=\frac{s+4}{(s+2)^2}$$

Assume $\frac{s+4}{(s+2)^2}$ to be $\frac{A}{s+2}+\frac{B}{(s+2)^2}$.

$$\frac{s+4}{(s+2)^2}=\frac{A}{s+2}+\frac{B}{(s+2)^2} \quad \text{..... (1)}$$

$$\frac{s+4}{(s+2)^2}=\frac{A(s+2)+B}{(s+2)^2}$$

$$s+4=A(s+2)+B \quad \text{..... (2)}$$

Substitute -2 for s in the equation.

$$-2+4=A(-2+2)+B$$
$$2=A(0)+B$$
$$2=0+B$$
$$B=2$$

Therefore, the value of B is 2.

Step 2 of 6

Recall equation (2).

$$s+4=A(s+2)+B$$

Substitute 0 for s and 2 for B in the equation.

$$0+4=A(0+2)+B$$
$$4=2A+2$$
$$4-2=2A$$
$$A=\frac{2}{2}$$
$$A=1$$

Therefore, the value of A is 1.

Step 3 of 6

Recall equation (3).

$$\frac{s+4}{(s+2)^2}=\frac{A}{s+2}+\frac{B}{(s+2)^2}$$

Substitute $F(s)$ for $\frac{s+4}{(s+2)^2}$, 2 for B and 1 for A in the equation.

$$F(s)=\frac{1}{s+2}+\frac{2}{(s+2)^2}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=L^{-1}\left[\frac{1}{s+2}\right]+2L^{-1}\left[\frac{1}{(s+2)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$f(t)=\left(e^{-2t}+2te^{-2t}\right)u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+4}{(s+2)^2}$ is $\boxed{\left(e^{-2t}+2te^{-2t}\right)u(t)}$.

Step 4 of 6

(b)

Consider the function.

$$F(s)=\frac{s+6}{s(s+1)^2}$$

Assume $\frac{s+6}{s(s+1)^2}$ to be $\frac{A}{s}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$.

$$\frac{s+6}{s(s+1)^2}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{(s+1)^2} \quad \text{..... (3)}$$

$$\frac{s+6}{s(s+1)^2}=\frac{A(s+1)^2+Bs(s+1)+Cs}{s(s+1)^2}$$

$$s+6=A(s+1)^2+Bs(s+1)+Cs \quad \text{..... (4)}$$

Substitute -1 for s in the equation.

$$-1+6=A(-1+1)^2+B(-1)(-1+1)+C(-1)$$
$$5=A(0)+B(0)+C(-1)$$
$$5=C(-1)$$
$$C=-5$$

Therefore, the value of C is -5.

Step 5 of 6

Recall equation (4).

$$s+6=A(s+1)^2+Bs(s+1)+Cs$$

Substitute 0 for s in the equation.

$$0+6=A(0+1)^2+B(0)(0+1)+C(0)$$
$$6=A(1)+B(0)+C(0)$$
$$6=A$$
$$A=6$$

Therefore, the value of A is 6.

Recall equation (4).

$$s+6=A(s+1)^2+Bs(s+1)+Cs$$

Substitute 1 for s, -5 for C and 6 for A in the equation.

$$1+6=(6)(1+1)^2+B(1)(1+1)+(-5)(1)$$
$$7=(6)(4)+B(2)-5$$
$$7=24+B(2)-5$$
$$2B=7-24+5$$
$$2B=-12$$
$$B=-6$$

Therefore, the value of B is -6.

Step 6 of 6

Recall equation (3).

$$\frac{s+6}{s(s+1)^2}=\frac{A}{s}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$$

Substitute $F(s)$ for $\frac{s+6}{s(s+1)^2}$, -6 for B, 6 for A and -5 for C in the equation.

$$F(s)=\frac{6}{s}-\frac{6}{s+1}-\frac{5}{(s+1)^2}$$

Apply inverse Laplace transform.

$$L^{-1}\left[F(s)\right]=6L^{-1}\left[\frac{1}{s}\right]-6L^{-1}\left[\frac{1}{s+1}\right]-5L^{-1}\left[\frac{1}{(s+1)^2}\right]$$

Apply the property's, $L^{-1}\left[\frac{1}{s}\right]=1$, $L^{-1}\left[\frac{1}{s+a}\right]=e^{-at}$ and $L^{-1}\left[\frac{1}{(s+a)^2}\right]=te^{-at}$

$$\begin{aligned} f(t)&=\left(6(1)-6e^{-t}-5te^{-t}\right)u(t)\\ &=\left(6-6e^{-t}-5te^{-t}\right)u(t)\end{aligned}$$

Therefore, the inverse Laplace transform of $\frac{s+6}{s(s+1)^2}$ is $\boxed{\left(6-6e^{-t}-5te^{-t}\right)u(t)}$.

Step 1 of 4

(a)

Consider the function.

$$F(s)=\frac{10}{s^2+2s+2}$$
$$=\frac{10}{(s+1-j1)(s+1+j1)}$$

Assume $\frac{10}{(s+1-j1)(s+1+j1)}$ to be $\frac{A}{s+1-j1}+\frac{A^*}{s+1+j1}$.

$$\frac{10}{(s+1-j1)(s+1+j1)}=\frac{A}{s+1-j1}+\frac{A^*}{s+1+j1} \quad \text{..... (1)}$$

Use residue's method to find the values of A and A^*.

Calculate the value of A.

$$A=(s+1-j1)\left[\frac{10}{(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1+j1}$$
$$=\left[\frac{10}{(-1+j1+1+j1)}\right]\Bigg|_{s=-1+j1}$$
$$=\frac{10}{(j2)}$$
$$=5\angle -90^\circ$$

Therefore, the value of A is $5\angle -90^\circ$.

As A^* is the conjugate value of A, the value of A^* is $5\angle 90^\circ$.

Step 2 of 4

Consider the function (1).

$$\frac{10}{(s+1-j1)(s+1+j1)}=\frac{A}{s+1-j1}+\frac{A^*}{s+1+j1}$$

Substitute $F(s)$ for $\frac{10}{(s+1-j1)(s+1+j1)}$, $5\angle 90^\circ$ for A^* and $5\angle -90^\circ$ for A.

$$F(s)=\frac{5\angle -90^\circ}{s+1-j1}+\frac{5\angle 90^\circ}{s+1+j1}$$

Apply inverse Laplace transform.

Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$f(t)=\left[2(5)e^{-t}\cos(t-90^\circ)\right]u(t)$$
$$=\left[10e^{-t}\cos(t-90^\circ)\right]u(t)$$
$$=\left[10e^{-t}\sin(t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{10}{s^2+2s+2}$ is $\boxed{\left[10e^{-t}\sin(t)\right]u(t)}$.

Step 3 of 4

b)

Consider the function.

$$F(s)=\frac{10(s+2)}{s^2+4s+5}$$
$$=\frac{10(s+2)}{(s+2-j1)(s+2+j1)}$$

Assume $\frac{10(s+2)}{(s+2-j1)(s+2+j1)}$ to be $\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}$.

$$\frac{10(s+2)}{(s+2-j1)(s+2+j1)}=\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1} \quad \text{..... (2)}$$

Use residue's method to find the values of A and A^*.

Calculate the value of A.

$$A=(s+2-j1)\left[\frac{10(s+2)}{(s+2-j1)(s+2+j1)}\right]\Bigg|_{s=-2+j1}$$
$$=\left[\frac{10(-2+j1+2)}{(-2+j1+2+j1)}\right]\Bigg|_{s=-2+j1}$$
$$=\frac{10(j1)}{(j2)}$$
$$=5\angle 0^\circ$$

Therefore, the value of A is $5\angle 0^\circ$.

As A^* is the conjugate value of A, the value of A^* is $5\angle 0^\circ$.

Step 4 of 4

Consider the function (2).

$$\frac{10(s+2)}{(s+2-j1)(s+2+j1)}=\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}$$

Substitute $F(s)$ for $\frac{10(s+2)}{(s+2-j1)(s+2+j1)}$, $5\angle 0^\circ$ for A^* and $5\angle 0^\circ$ for A.

$$F(s)=\frac{5\angle 0^\circ}{s+2-j1}+\frac{5\angle 0^\circ}{s+2+j1}$$

Apply inverse Laplace transform.

Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$f(t)=\left[2(5)e^{-2t}\cos(t-0^\circ)\right]u(t)$$
$$=\left[10e^{-2t}\cos(t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{10(s+2)}{s^2+4s+5}$ is $\boxed{\left[10e^{-2t}\cos(t)\right]u(t)}$.

Step 1 of 4

(a)

Consider the following function:

$$F(s)=\frac{10(s+1)}{s^2+2s+2}$$
$$=\frac{10(s+1)}{s^2+2s+1+1}$$
$$=\frac{10(s+1)}{(s+1)^2+1^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}^{-1}[F(s)]=10\mathcal{L}^{-1}\left[\frac{s+1}{(s+1)^2+1^2}\right]$$

Apply the property, $\mathcal{L}^{-1}\left[\frac{s+a}{(s+a)^2+\omega^2}\right]=e^{-at}\cos\omega t$.

$$f(t)=10e^{-t}\cos tu(t)$$

Therefore, the inverse Laplace transform of $\frac{10(s+1)}{s^2+2s+2}$ is $\boxed{10e^{-t}\cos tu(t)}$.

Step 2 of 4

(b)

Consider the following function:

$$F(s)=\frac{s+1}{s(s^2+4s+5)}$$
$$=\frac{s+1}{s(s+2-j1)(s+2+j1)}$$

Assume $\frac{s+1}{s(s+2-j1)(s+2+j1)}$ to be $\frac{A}{s}+\frac{B}{s+2-j1}+\frac{B^*}{s+2+j1}$.

$$\frac{s+1}{s(s+2-j1)(s+2+j1)}=\frac{A}{s}+\frac{B}{s+2-j1}+\frac{B^*}{s+2+j1} \quad \text{..... (1)}$$

$$\frac{s+1}{s(s+2-j1)(s+2+j1)}=\frac{A(s+2-j1)(s+2+j1)+Bs(s+2+j1)+B^*s(s+2-j1)}{s(s+2-j1)(s+2+j1)}$$

$$s+1=A(s+2-j1)(s+2+j1)+Bs(s+2+j1)+B^*s(s+2-j1) \quad \text{..... (2)}$$

Substitute 0 for s .

$$0+1=A(0+2-j1)(0+2+j1)+B(0)(0+2+j1)+B^*(0)(0+2-j1)$$
$$1=A(2-j1)(2+j1)+B(0)+B^*(0)$$
$$1=A(5)$$
$$A=\frac{1}{5}$$

Therefore, the value of A is $\frac{1}{5}$.

Step 3 of 4

Consider equation (2).

$$s+1=A(s+2-j1)(s+2+j1)+Bs(s+2+j1)+B^*s(s+2-j1)$$

Substitute $-2+j1$ for s .

$$-2+j1+1=\left[\begin{array}{l}A(-2+j1+2-1j)(-2+j1+2+1j)+B(-2+j1)(-2+j1+2+1j)\\+B^*(-2+j1)(-2+j1+2-1j)\end{array}\right]$$
$$-1+j1=A(0)(2j)+B(-2+j1)(j2)+B^*(-2+j1)(0)$$
$$-1+j1=B(-2-j4)$$
$$B=\frac{-1+j1}{-2-j4}$$

$$B=\frac{-1+j1}{-2-j4}$$
$$=-0.1-j0.3$$

Therefore, the value of B is $-0.1-j0.3$.

As B^* is the conjugate value of B , the value of B^* is $-0.1+j0.3$.

Step 4 of 4

Consider the function (1).

$$\frac{s+1}{s(s+2-j1)(s+2+j1)}=\frac{A}{s}+\frac{B}{s+2-j1}+\frac{B^*}{s+2+j1}$$

Substitute $F(s)$ for $\frac{s+1}{s(s+2-j1)(s+2+j1)}$, $-0.1+j0.3$ for B^* , $-0.1-j0.3$ for B and $\frac{1}{5}$ for A .

$$F(s)=\frac{1}{5s}+\frac{-0.1-j0.3}{s+2-j1}+\frac{-0.1+j0.3}{s+2+j1}$$
$$=\frac{1}{5s}+\frac{0.316\angle-108.44^\circ}{s+2-j1}+\frac{0.316\angle108.44^\circ}{s+2+j1}$$

Apply inverse Laplace transform.

Apply the property, $\mathcal{L}^{-1}\left\{\frac{1}{s}\right\}=1$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs

$$\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}.$$

$$f(t)=\left[\frac{1}{5}+2(0.316)e^{-2t}\cos(t-108.44^\circ)\right]u(t)$$
$$=\left[\frac{1}{5}+0.632e^{-2t}\cos(t-108.44^\circ)\right]u(t)$$

Therefore, the inverse Laplace transform of $\frac{s+1}{s(s^2+4s+5)}$ is,

$$\boxed{\left[\frac{1}{5}+0.632e^{-2t}\cos(t-108.44^\circ)\right]u(t)}.$$

Step 1 of 6

(a)

Consider the function.

$$F(s)=\frac{s(s+6)}{(s+3)(s^2+6s+18)}$$
$$=\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$$

Assume $\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$ to be $\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3}$.

$$\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}=\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of A.

$$A=(s+3)\left[\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3}$$
$$=\left[\frac{s(s+6)}{(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3}$$
$$=\frac{(-3)(-3+6)}{(-3+3-j3)(-3+3+j3)}$$
$$=\frac{(-3)(3)}{(-j3)(j3)}$$

$$A=\frac{(-9)}{(9)}$$
$$=-1$$

Therefore, the value of A is -1.

Step 2 of 6

Calculate the value of B.

$$B=(s+3-j3)\left[\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3+j3}$$
$$=\left[\frac{s(s+6)}{(s+3)(s+3+j3)}\right]\Bigg|_{s=-3+j3}$$
$$=\frac{(-3+j3)(-3+j3+6)}{(-3+j3+3)(-3+j3+3+j3)}$$
$$=\frac{(-3+j3)(3+j3)}{(j3)(j6)}$$

$$B=\frac{(-18)}{(-18)}$$
$$=1$$

Therefore, the value of B is 1.

As B^* is the conjugate value of B, the value of B^* is 1.

Step 3 of 6

Consider the function (1).

$$\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}=\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3}$$

Substitute $F(s)$ for $\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$, 1 for B^*, 1 for B and -1 for A.

$$F(s)=\frac{-1}{s+3}+\frac{1}{s+3-j3}+\frac{1}{s+3+j3}$$
$$=-\frac{1}{s+3}+\frac{1\angle 0^\circ}{s+3-j3}+\frac{1\angle 0^\circ}{s+3+j3}$$

Apply inverse Laplace transform.

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs

$$\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}.$$

$$f(t)=\left[-e^{-3t}+2(1)e^{-3t}\cos(3t-0^\circ)\right]u(t)$$
$$=\left[-e^{-3t}+2e^{-3t}\cos(3t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s(s+6)}{(s+3)(s^2+6s+18)}$ is

$$\boxed{\left[-e^{-3t}+2e^{-3t}\cos(3t)\right]u(t)}.$$

Step 4 of 6

b)

Consider the function.

$$F(s)=\frac{(s+4)(s+8)}{s(s^2+8s+32)}$$
$$=\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}$$

Assume $\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}$ to be $\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4}$.

$$\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}=\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4} \quad \text{..... (2)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of A.

$$A=(s)\left[\frac{(s+4)(s+8)}{(s)(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=0}$$
$$=\left[\frac{(s+4)(s+8)}{(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=0}$$
$$=\frac{(0+4)(0+8)}{(0+4-j4)(0+4+j4)}$$
$$=\frac{(4)(8)}{(4-j4)(4+j4)}$$

$$A=\frac{(32)}{(32)}$$
$$=1$$

Therefore, the value of A is 1.

Step 5 of 6

Calculate the value of B.

$$B=(s+4-j4)\left[\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=-4+j4}$$
$$=\left[\frac{(s+4)(s+8)}{s(s+4+j4)}\right]\Bigg|_{s=-4+j4}$$
$$=\frac{(-4+j4+4)(-4+j4+8)}{(-4+j4)(-4+j4+4+j4)}$$
$$=\frac{(j4)(4+j4)}{(-4+j4)(j8)}$$

$$B==\frac{(j4)(4+j4)}{(-4+j4)(j8)}$$
$$=-j0.5$$
$$=0.5\angle-90^\circ$$

Therefore, the value of B is $0.5\angle-90^\circ$.

As B^* is the conjugate value of B, the value of B^* is $0.5\angle 90^\circ$.

Step 6 of 6

Consider the function (2).

$$\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}=\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4}$$

Substitute $F(s)$ for $\frac{(s+4)(s+8)}{s(s+2-j2)(s+2+j2)}$, $0.5\angle 90^\circ$ for B^*, $0.5\angle-90^\circ$ for B and 1 for A.

$$F(s)=\frac{1}{s}+\frac{0.5\angle-90^\circ}{s+4-j4}+\frac{0.5\angle 90^\circ}{s+4+j4}$$

Apply inverse Laplace transform.

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s}\right\}=1$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs

$$\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}.$$

$$f(t)=\left[1+2(0.5)e^{-4t}\cos(4t-90^\circ)\right]u(t)$$
$$=\left[1+e^{-4t}\cos(4t-90^\circ)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{(s+4)(s+8)}{s(s^2+8s+32)}$ is

$$\boxed{\left[1+e^{-4t}\cos(4t-90^\circ)\right]u(t)}.$$

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Step 1 of 6

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Step 2 of 6

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 3 of 6

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 4 of 6

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 5 of 6

There was a problem loading this step. We have been notified and we will fix it shortly.

Step 6 of 6

There was a problem loading this step. We have been notified and we will fix it shortly.

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Step 1 of 6

(a)

Consider the function.

$$F(s)=\frac{s(s+6)}{(s+3)(s^2+6s+18)}$$
$$=\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$$

Assume $\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$ to be $\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3}$.

$$\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}=\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3} \quad \text{..... (1)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of A.

$$A=(s+3)\left[\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3}$$
$$=\left[\frac{s(s+6)}{(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3}$$
$$=\frac{(-3)(-3+6)}{(-3+3-j3)(-3+3+j3)}$$
$$=\frac{(-3)(3)}{(-j3)(j3)}$$

$$A=\frac{(-9)}{(9)}$$
$$=-1$$

Therefore, the value of A is -1.

Step 2 of 6

Calculate the value of B.

$$B=(s+3-j3)\left[\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}\right]\Bigg|_{s=-3+j3}$$
$$=\left[\frac{s(s+6)}{(s+3)(s+3+j3)}\right]\Bigg|_{s=-3+j3}$$
$$=\frac{(-3+j3)(-3+j3+6)}{(-3+j3+3)(-3+j3+3+j3)}$$
$$=\frac{(-3+j3)(3+j3)}{(j3)(j6)}$$

$$B=\frac{(-18)}{(-18)}$$
$$=1$$

Therefore, the value of B is 1.

As B^* is the conjugate value of B, the value of B^* is 1.

Step 3 of 6

Consider the function (1).

$$\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}=\frac{A}{s+3}+\frac{B}{s+3-j3}+\frac{B^*}{s+3+j3}$$

Substitute $F(s)$ for $\frac{s(s+6)}{(s+3)(s+3-j3)(s+3+j3)}$, 1 for B^*, 1 for B and -1 for A.

$$F(s)=\frac{-1}{s+3}+\frac{1}{s+3-j3}+\frac{1}{s+3+j3}$$
$$=-\frac{1}{s+3}+\frac{1\angle 0^\circ}{s+3-j3}+\frac{1\angle 0^\circ}{s+3+j3}$$

Apply inverse Laplace transform.

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs

$$\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}.$$

$$f(t)=\left[-e^{-3t}+2(1)e^{-3t}\cos(3t-0^\circ)\right]u(t)$$
$$=\left[-e^{-3t}+2e^{-3t}\cos(3t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s(s+6)}{(s+3)(s^2+6s+18)}$ is

$$\boxed{\left[-e^{-3t}+2e^{-3t}\cos(3t)\right]u(t)}.$$

Step 4 of 6

b)

Consider the function.

$$F(s)=\frac{(s+4)(s+8)}{s(s^2+8s+32)}$$
$$=\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}$$

Assume $\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}$ to be $\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4}$.

$$\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}=\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4} \quad \text{..... (2)}$$

Use residue's method to find the values of A, B and B^*.

Calculate the value of A.

$$A=(s)\left[\frac{(s+4)(s+8)}{(s)(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=0}$$
$$=\left[\frac{(s+4)(s+8)}{(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=0}$$
$$=\frac{(0+4)(0+8)}{(0+4-j4)(0+4+j4)}$$
$$=\frac{(4)(8)}{(4-j4)(4+j4)}$$

$$A=\frac{(32)}{(32)}$$
$$=1$$

Therefore, the value of A is 1.

Step 5 of 6

Calculate the value of B.

$$B=(s+4-j4)\left[\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}\right]\Bigg|_{s=-4+j4}$$
$$=\left[\frac{(s+4)(s+8)}{s(s+4+j4)}\right]\Bigg|_{s=-4+j4}$$
$$=\frac{(-4+j4+4)(-4+j4+8)}{(-4+j4)(-4+j4+4+j4)}$$
$$=\frac{(j4)(4+j4)}{(-4+j4)(j8)}$$

$$B==\frac{(j4)(4+j4)}{(-4+j4)(j8)}$$
$$=-j0.5$$
$$=0.5\angle-90^\circ$$

Therefore, the value of B is $0.5\angle-90^\circ$.

As B^* is the conjugate value of B, the value of B^* is $0.5\angle 90^\circ$.

Step 6 of 6

Consider the function (2).

$$\frac{(s+4)(s+8)}{s(s+4-j4)(s+4+j4)}=\frac{A}{s}+\frac{B}{s+4-j4}+\frac{B^*}{s+4+j4}$$

Substitute $F(s)$ for $\frac{(s+4)(s+8)}{s(s+2-j2)(s+2+j2)}$, $0.5\angle 90^\circ$ for B^*, $0.5\angle-90^\circ$ for B and 1 for A.

$$F(s)=\frac{1}{s}+\frac{0.5\angle-90^\circ}{s+4-j4}+\frac{0.5\angle 90^\circ}{s+4+j4}$$

Apply inverse Laplace transform.

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s}\right\}=1$ and the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs

$$\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}.$$

$$f(t)=\left[1+2(0.5)e^{-4t}\cos(4t-90^\circ)\right]u(t)$$
$$=\left[1+e^{-4t}\cos(4t-90^\circ)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{(s+4)(s+8)}{s(s^2+8s+32)}$ is

$$\boxed{\left[1+e^{-4t}\cos(4t-90^\circ)\right]u(t)}.$$

Step 1 of 5

(a)

Consider the function.

$$F(s)=\frac{6s+12}{(s^2+4s+5)(s^2+4s+8)}$$
$$=\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}$$

Assume $\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}$ to be

$$\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}+\frac{B}{s+2-j2}+\frac{B^*}{s+2+j2}.$$

$$\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}=\left[\begin{array}{l}\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}\\+\frac{B}{s+2-j2}+\frac{B^*}{s+2+j2}\end{array}\right] \quad \text{..... (1)}$$

Use residue's method to find the values of A, A^*, B and B^*.

Calculate the value of A.

$$A=(s+2-j1)\left[\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}\right]\Bigg|_{s=-2+j1}$$
$$=\left[\frac{6s+12}{(s+2+j1)(s+2-j2)(s+2+j2)}\right]\Bigg|_{s=-2+j1}$$
$$=\frac{6(-2+j1)+12}{(-2+j1+2+j1)(-2+j1+2-j2)(-2+j1+2+j2)}$$
$$=\frac{j6}{(j2)(-j1)(j3)}$$

$$A=\frac{j6}{(j6)}$$
$$=1\angle 0^\circ$$

Therefore, the value of A is $1\angle 0^\circ$.

As A^* is the conjugate value of A, the value of A^* is $1\angle 0^\circ$.

Step 2 of 5

Calculate the value of B.

$$B=(s+2-j2)\left[\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}\right]\Bigg|_{s=-2+j2}$$
$$=\left[\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2+j2)}\right]\Bigg|_{s=-2+j2}$$
$$=\frac{6(-2+j2)+12}{(-2+j2+2-j1)(-2+j2+2+j1)(-2+j2+2+j2)}$$
$$=\frac{j12}{(j1)(j3)(j4)}$$

$$B=\frac{j12}{(-j12)}$$
$$=-1\angle 0^\circ$$

Therefore, the value of B is $-1\angle 0^\circ$.

As B^* is the conjugate value of B, the value of B^* is $-1\angle 0^\circ$.

Step 3 of 5

Consider the function (1).

$$\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}=\left[\begin{array}{l}\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}\\+\frac{B}{s+2-j2}+\frac{B^*}{s+2+j2}\end{array}\right]$$

Substitute $F(s)$ for $\frac{6s+12}{(s+2-j1)(s+2+j1)(s+2-j2)(s+2+j2)}$, $-1\angle 0^\circ$ for B^*, $-1\angle 0^\circ$ for B, $1\angle 0^\circ$ for A and $1\angle 0^\circ$ for A^*.

$$F(s)=\frac{1\angle 0^\circ}{s+2-j1}+\frac{1\angle 0^\circ}{s+2+j1}-\frac{1\angle 0^\circ}{s+2-j2}-\frac{1\angle 0^\circ}{s+2+j2}$$

Apply inverse Laplace transform.

Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$f(t)=\left[2(1)e^{-2t}\cos(t-0^\circ)-2(1)e^{-2t}\cos(2t-0^\circ)\right]u(t)$$
$$=\left[2e^{-2t}\cos(t)-2e^{-2t}\cos(2t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{6s+12}{(s^2+4s+5)(s^2+4s+8)}$ is

$$\boxed{\left[2e^{-2t}\cos(t)-2e^{-2t}\cos(2t)\right]u(t)}.$$

Step 4 of 5

b)
Consider the function.

$$F(s)=\frac{s(s+2)}{s^2+2s+2}$$
$$=\frac{s^2+2s}{s^2+2s+2}$$
$$=1-\frac{2}{s^2+2s+2}$$
$$=1-\left(\frac{2}{(s+1-j1)(s+1+j1)}\right)$$

Assume $1-\frac{2}{(s+1-j1)(s+1+j1)}$ to be $1-\left(\frac{A}{s+1-j1}+\frac{A^*}{s+1+j1}\right)$.

$$1-\frac{2}{(s+1-j1)(s+1+j1)}=1-\left(\frac{A}{s+1-j1}+\frac{A^*}{s+1+j1}\right) \quad \text{..... (2)}$$

Use residue's method to find the values of A and A^*.

Calculate the value of A.

$$A=(s+1-j1)\left[\frac{2}{(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1+j1}$$
$$=\left[\frac{2}{(-1+j1+1+j1)}\right]$$
$$=\frac{2}{(j2)}$$
$$=1\angle -90^\circ$$

Therefore, the value of A is $1\angle -90^\circ$.

As A^* is the conjugate value of A, the value of A^* is $1\angle 90^\circ$.

Step 5 of 5

Consider the function (2).

$$1-\frac{2}{(s+2-j1)(s+2+j1)}=1-\left(\frac{A}{s+2-j1}+\frac{A^*}{s+2+j1}\right)$$

Substitute $F(s)$ for $1-\frac{2}{(s+1-j1)(s+1+j1)}$, $1\angle -90^\circ$ for A^* and $1\angle 90^\circ$ for A.

$$F(s)=1-\left(\frac{1\angle -90^\circ}{s+1-j1}+\frac{1\angle 90^\circ}{s+1+j1}\right)$$

Apply inverse Laplace transform.

Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$f(t)=\left[\delta(t)-2(1)e^{-t}\cos(t-90^\circ)\right]u(t)$$
$$=\left[\delta(t)-2e^{-t}\cos(t-90)\right]u(t)$$
$$=\left[\delta(t)-2e^{-t}\sin(t)\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s(s+2)}{s^2+2s+1}$ is $\boxed{\left[\delta(t)-2e^{-t}\sin(t)\right]u(t)}$.

Step 1 of 5

(a)

Consider the function.

$$F(s)=\frac{e^{-s}}{s+1} \quad \text{..... (1)}$$

Let $\frac{1}{s+1}$ be $G(s)$.

$$G(s)=\frac{1}{s+1}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{G(s)\}=\mathcal{L}\left\{\frac{1}{s+1}\right\}$$
$$g(t)=e^{-t}u(t)$$

Therefore, the inverse Laplace transform of $\frac{1}{s+1}$ is $e^{-t}u(t)$.

Step 2 of 5

Consider the function (1).

$$F(s)=\frac{e^{-s}}{s+1}$$

Substitute $G(s)$ for $\frac{1}{s+1}$.

$$F(s)=e^{-s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0 s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-1)u(t-1)$$

Substitute $e^{-(t-1)}u(t-1)$ for $g(t-1)$ since $g(t)=e^{-t}u(t)$.

$$f(t)=e^{-(t-1)}u(t-1)$$

Therefore, the inverse Laplace transform of $\frac{e^{-s}}{s+1}$ is $\boxed{e^{-(t-1)}u(t-1)}$.

Step 3 of 5

(b)

Consider the function.

$$F(s)=\frac{1-e^{-2s}}{s}$$
$$=\frac{1}{s}-\frac{e^{-2s}}{s}$$

Apply inverse Laplace transform and use the property, $e^{-t_0 s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=u(t)-u(t-2)$$

Therefore, the inverse Laplace transform of $\frac{1-e^{-2s}}{s}$ is $\boxed{u(t)-u(t-2)}$.

Step 4 of 5

(c)

Consider the function.

$$F(s)=\frac{1-e^{-s}}{s+2}$$

$$F(s)=\frac{1}{s+2}-\frac{e^{-s}}{s+2} \quad \text{..... (2)}$$

Let $\frac{1}{s+2}$ be $G(s)$.

$$G(s)=\frac{1}{s+2}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{G(s)\}=\mathcal{L}\left\{\frac{1}{s+2}\right\}$$
$$g(t)=e^{-2t}$$

Therefore, the inverse Laplace transform of $\frac{1}{s+1}$ is $e^{-2t}u(t)$.

Step 5 of 5

Consider the function (2).

$$F(s)=\frac{1}{s+2}-\frac{e^{-s}}{s+2}$$

Substitute $G(s)$ for $\frac{1}{s+1}$.

$$F(s)=G(s)-e^{-s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0 s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t)-g(t-1)u(t-1)$$

Substitute $e^{-(t-1)}$ for $g(t-1)$ since $g(t)=e^{-2t}$ and e^{-2t} for $g(t)$.

$$f(t)=e^{-2t}u(t)-e^{-2(t-1)}u(t-1)$$

Therefore, the inverse Laplace transform of $\frac{1-e^{-s}}{s+2}$ is $\boxed{e^{-2t}u(t)-e^{-2(t-1)}u(t-1)}$.

Step 1 of 15

(a)

Consider the function.

$$F(s)=\frac{2(s+1)e^{-s}}{(s+2)(s+4)} \quad \text{..... (1)}$$

Let $\frac{2(s+1)}{(s+2)(s+4)}$ for $G(s)$.

$$G(s)=\frac{2(s+1)}{(s+2)(s+4)} \quad \text{..... (2)}$$

Assume $\frac{2(s+1)}{(s+2)(s+4)}$ to be $\frac{A}{s+2}+\frac{B}{s+4}$.

$$\frac{2(s+1)}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+4}$$

Step 2 of 15

Use residue's method to find the values of A and B.

Calculate the value of A.

$$\begin{aligned}A&=(s+2)\left[\frac{2(s+1)}{(s+2)(s+4)}\right]\Bigg|_{s=-2}\\&=\left[\frac{2(s+1)}{(s+4)}\right]\Bigg|_{s=-2}\\&=\frac{2(-2+1)}{(-2+4)}\\&=\frac{-2}{2}\\A&=-1\end{aligned}$$

Therefore, the value of A is -1.

Step 3 of 15

Calculate the value of B.

$$\begin{aligned}B&=(s+4)\left[\frac{2(s+1)}{(s+2)(s+4)}\right]\Bigg|_{s=-4}\\&=\left[\frac{2(s+1)}{(s+2)}\right]\Bigg|_{s=-4}\\&=\frac{2(-4+1)}{(-4+2)}\\&=\frac{(2)(-3)}{(-2)}\\B&=3\end{aligned}$$

Therefore, the value of B is 3.

Step 4 of 15

Consider the function (2).

$$\frac{2(s+1)}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+4}$$

Substitute $G(s)$ for $\frac{2(s+1)}{(s+2)(s+4)}$, 3 for B and -1 for A.

$$G(s)=\frac{-1}{s+2}+\frac{3}{s+4}$$

Apply inverse Laplace transform.

Apply the property $L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$g(t)=\left[-e^{-2t}+3e^{-4t}\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{2(s+1)}{(s+2)(s+4)}$ is $\left[-e^{-2t}+3e^{-4t}\right]u(t)$.

Step 5 of 15

Consider function (1).

$$F(s)=\frac{2(s+1)e^{-s}}{(s+2)(s+4)}$$

Substitute $G(s)$ for $\frac{2(s+1)}{(s+2)(s+4)}$.

$$F(s)=e^{-s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-1)u(t-1)$$

Substitute $\left[-e^{-2(t-1)}+3e^{-4(t-1)}\right]u(t-1)$ for $g(t-1)$ since $g(t)=\left[-e^{-2t}+3e^{-4t}\right]u(t)$.

$$f(t)=\left[-e^{-2(t-1)}+3e^{-4(t-1)}\right]u(t-1)$$

Therefore, the inverse Laplace transform of $\frac{2(s+1)e^{-s}}{(s+2)(s+4)}$ is

$$\boxed{\left[-e^{-2(t-1)}+3e^{-4(t-1)}\right]u(t-1)}.$$

Step 6 of 15

(b)

Consider the function.

$$F(s)=\frac{10(s+2)e^{-2s}}{(s+1)(s+4)} \quad \text{..... (3)}$$

Let $\frac{10(s+2)}{(s+1)(s+4)}$ for $G(s)$.

$$G(s)=\frac{10(s+2)}{(s+1)(s+4)} \quad \text{..... (4)}$$

Assume $\frac{10(s+2)}{(s+1)(s+4)}$ to be $\frac{A}{s+1}+\frac{B}{s+4}$.

$$\frac{10(s+2)}{(s+1)(s+4)}=\frac{A}{s+1}+\frac{B}{s+4}$$

Step 7 of 15

Use residue's method to find the values of A and B.

Calculate the value of A.

$$\begin{aligned}A&=(s+1)\left[\frac{10(s+2)}{(s+1)(s+4)}\right]\Bigg|_{s=-1}\\&=\left[\frac{10(s+2)}{(s+4)}\right]\Bigg|_{s=-1}\\&=\frac{10(-1+2)}{(-1+4)}\\&=\frac{10}{3}\end{aligned}$$

Therefore, the value of A is $\frac{10}{3}$.

Step 8 of 15

Calculate the value of B.

$$\begin{aligned}B&=(s+4)\left[\frac{10(s+2)}{(s+1)(s+4)}\right]\Bigg|_{s=-4}\\&=\left[\frac{10(s+2)}{(s+1)}\right]\Bigg|_{s=-4}\\&=\frac{10(-4+2)}{(-4+1)}\\&=\frac{-20}{(-3)}\\B&=\frac{20}{3}\end{aligned}$$

Therefore, the value of B is $\frac{20}{3}$.

Step 9 of 15

Consider the function (4).

$$\frac{10(s+2)}{(s+1)(s+4)}=\frac{A}{s+1}+\frac{B}{s+4}$$

Substitute $G(s)$ for $\frac{10(s+2)}{(s+1)(s+4)}$, $\frac{20}{3}$ for B and $\frac{10}{3}$ for A.

$$G(s)=\frac{10}{3(s+1)}+\frac{20}{3(s+4)}$$

Apply inverse Laplace transform.

Apply the property $L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$g(t)=\left[\frac{10}{3}e^{-t}+\frac{20}{3}e^{-4t}\right]u(t)$$

Therefore, the inverse Laplace transform of $\frac{10(s+2)}{(s+1)(s+4)}$ is $\left[\frac{10}{3}e^{-t}+\frac{20}{3}e^{-4t}\right]u(t)$.

Step 10 of 15

Consider function (3).

$$F(s)=\frac{10(s+2)e^{-2s}}{(s+1)(s+4)}$$

Substitute $G(s)$ for $\frac{10(s+2)}{(s+1)(s+4)}$.

$$F(s)=e^{-2s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-2)u(t-2)$$

Substitute $\left[\frac{10}{3}e^{-(t-2)}+\frac{20}{3}e^{-4(t-2)}\right]u(t)$ for $g(t-2)$ since $g(t)=\left[-e^{-2t}+3e^{-4t}\right]u(t)$.

$$f(t)=\left[\frac{10}{3}e^{-(t-2)}+\frac{20}{3}e^{-4(t-2)}\right]u(t-2)$$

Therefore, the inverse Laplace transform of $\frac{10(s+2)e^{-2s}}{(s+1)(s+4)}$ is

$$\boxed{\left[\frac{10}{3}e^{-(t-2)}+\frac{20}{3}e^{-4(t-2)}\right]u(t-2)}.$$

Step 11 of 15

(c)

Consider the function.

$$F(s)=\frac{se^{-s}}{(s+4)(s+8)} \quad \text{..... (5)}$$

Let $\frac{s}{(s+4)(s+8)}$ for $G(s)$.

$$G(s)=\frac{s}{(s+4)(s+8)} \quad \text{..... (6)}$$

Assume $\frac{s}{(s+4)(s+8)}$ to be $\frac{A}{s+4}+\frac{B}{s+8}$.

$$\frac{s}{(s+4)(s+8)}=\frac{A}{s+4}+\frac{B}{s+8}$$

Step 12 of 15

Use residue's method to find the values of A and B.

Calculate the value of A.

$$\begin{aligned}A&=(s+4)\left[\frac{s}{(s+4)(s+8)}\right]\Bigg|_{s=-4}\\&=\left[\frac{s}{(s+8)}\right]\Bigg|_{s=-4}\\&=\frac{(-4)}{(-4+8)}\\&=\frac{-4}{4}\\A&=-1\end{aligned}$$

Therefore, the value of A is -1.

Step 13 of 15

Calculate the value of B.

$$\begin{aligned}B&=(s+8)\left[\frac{s}{(s+4)(s+8)}\right]\Bigg|_{s=-8}\\&=\left[\frac{s}{(s+4)}\right]\Bigg|_{s=-8}\\&=\frac{(-8)}{(-8+4)}\\&=\frac{-8}{-4}\\B&=2\end{aligned}$$

Therefore, the value of B is 2.

Step 14 of 15

Consider the function (6).

$$\frac{s}{(s+4)(s+8)}=\frac{A}{s+4}+\frac{B}{s+8}$$

Substitute $G(s)$ for $\frac{s}{(s+4)(s+8)}$, 2 for B and -1 for A.

$$G(s)=\frac{2}{s+8}-\frac{1}{s+4}$$

Apply inverse Laplace transform.

Apply the property $L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$g(t)=\left[2e^{-8t}-e^{-4t}\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s}{(s+4)(s+8)}$ is $\left[2e^{-8t}-e^{-4t}\right]u(t)$.

Step 15 of 15

Consider function (5).

$$F(s)=\frac{se^{-s}}{(s+4)(s+8)}$$

Substitute $G(s)$ for $\frac{s}{(s+4)(s+8)}$.

$$F(s)=e^{-s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-1)u(t-1)$$

Substitute $\left[2e^{-8(t-1)}-e^{-4(t-1)}\right]u(t-1)$ for $g(t-1)$ since $g(t)=\left[2e^{-8t}-e^{-4t}\right]u(t)$.

$$f(t)=\left[2e^{-8(t-1)}-e^{-4(t-1)}\right]u(t-1)$$

Therefore, the inverse Laplace transform of $\frac{se^{-s}}{(s+4)(s+8)}$ is

$$\boxed{\left[2e^{-8(t-1)}-e^{-4(t-1)}\right]u(t-1)}$$

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Step 1 of 5

(a)

Consider the following function:

$$F(s)=\frac{(s+3)e^{-s}}{s(s+2)}$$
$$=e^{-s}\frac{(s+3)}{s(s+2)}$$

Express $\frac{(s+3)}{s(s+2)}$ in a partial fraction expansion.

$$\frac{(s+3)}{s(s+2)}=\frac{K_0}{s}+\frac{K_1}{s+2}$$

Calculate the value of K_0

$$K_0=\left.\frac{s+3}{s+2}\right|_{s=0}$$
$$=\frac{3}{2}$$

Calculate the value of K_1

$$K_0=\left.\frac{s+3}{s}\right|_{s=-2}$$
$$=\frac{-2+3}{-2}$$
$$=-\frac{1}{2}$$

The function $F(s)$ is,

$$F(s)=e^{-s}\left[\frac{3}{2}\frac{1}{s}-\frac{1}{2}\frac{1}{s+2}\right]$$

Apply inverse Laplace transforms on both sides and frequency shifting property of Laplace transforms.

$$L^{-1}\{F(s)\}=L^{-1}\left[\frac{3}{2}\frac{e^{-s}}{s}-\frac{1}{2}\frac{e^{-s}}{s+2}\right]$$

$$f(t)=\frac{3}{2}u(t-1)-\frac{1}{2}e^{-2(t-1)}u(t-1)$$
$$=\frac{1}{2}\left[3-e^{-2(t-1)}\right]u(t-1)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\frac{1}{2}\left[3-e^{-2(t-1)}\right]u(t-1)}$$

Step 2 of 5

(b)

Consider the following function:

$$F(s)=\frac{e^{-10s}}{(s+2)(s+3)}$$
$$=e^{-10s}\left[\frac{1}{(s+2)(s+3)}\right]$$

Express $\frac{1}{(s+2)(s+3)}$ in a partial fraction expansion.

$$\frac{1}{(s+2)(s+3)}=\frac{K_0}{s+2}+\frac{K_1}{s+3}$$

Calculate the value of K_0

$$K_0=\left.\frac{1}{s+3}\right|_{s=-2}$$
$$=\frac{1}{-2+3}$$
$$=1$$

Calculate the value of K_1

$$K_1=\left.\frac{1}{s+2}\right|_{s=-3}$$
$$=\frac{1}{-3+2}$$
$$=-1$$

The function $F(s)$ is,

$$F(s)=e^{-10s}\left[\frac{1}{s+2}-\frac{1}{s+3}\right]$$

Step 3 of 5

Apply inverse Laplace transforms on both sides and frequency shifting property of Laplace transforms.

$$L^{-1}\{F(s)\}=L^{-1}\left[\frac{e^{-10s}}{s+2}-\frac{e^{-10s}}{s+3}\right]$$

$$f(t)=e^{-2(t-10)}u(t-10)-e^{-3(t-10)}u(t-10)$$
$$=\left[e^{-2(t-10)}-e^{-3(t-10)}\right]u(t-10)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\left[e^{-2(t-10)}-e^{-3(t-10)}\right]u(t-10)}$$

Step 4 of 5

(c)

Consider the following function:

$$F(s)=\frac{(s^2+2s+1)e^{-2s}}{s(s+1)(s+2)}$$
$$=\frac{(s+1)^2e^{-2s}}{s(s+1)(s+2)}$$
$$=\frac{(s+1)e^{-2s}}{s(s+2)}$$

Express $\frac{(s+1)}{s(s+2)}$ in a partial fraction expansion.

$$\frac{s+1}{s(s+2)}=\frac{K_0}{s}+\frac{K_1}{s+2}$$

Calculate the value of K_0

$$K_0=\left.\frac{s+1}{s+2}\right|_{s=0}$$
$$=\frac{1}{2}$$

Calculate the value of K_1

$$K_1=\left.\frac{s+1}{s}\right|_{s=-2}$$
$$=\frac{-2+1}{-2}$$
$$=\frac{1}{2}$$

The function $F(s)$ is,

$$F(s)=e^{-2s}\left[\frac{\left(\frac{1}{2}\right)}{s}+\frac{\left(\frac{1}{2}\right)}{s+2}\right]$$
$$=\frac{1}{2}\left[\frac{e^{-2s}}{s}+\frac{e^{-2s}}{s+2}\right]$$

Apply inverse Laplace transforms on both sides and frequency shifting property of Laplace transforms.

$$L^{-1}[F(s)]=\frac{1}{2}\left\{L^{-1}\left[\frac{e^{-2s}}{s}\right]+L^{-1}\left[\frac{e^{-2s}}{s+2}\right]\right\}$$

$$f(t)=\frac{1}{2}\left\{u(t-2)+e^{-2(t-2)}u(t-2)\right\}$$
$$=\frac{1}{2}\left[1+e^{-2(t-2)}\right]u(t-2)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\frac{1}{2}\left[1+e^{-2(t-2)}\right]u(t-2)}$$

Step 5 of 5

(d)

Consider the following function:

$$F(s)=\frac{(s+1)e^{-4s}}{s^2(s+2)}$$

Express $\frac{(s+1)}{s^2(s+2)}$ in a partial fraction expansion.

$$\frac{s+1}{s^2(s+2)}=\frac{K_{11}}{s}+\frac{K_{12}}{s^2}+\frac{K_2}{s+2}$$

Calculate the value of K_{12}

$$K_{12}=\left.\frac{s+1}{s+2}\right|_{s=0}$$
$$=\frac{1}{2}$$

Calculate the value of K_2

$$K_2=\left.\frac{(s+1)}{s^2}\right|_{s=-2}$$
$$=\frac{-1}{4}$$

Calculate the value of K_{11}

$$K_{11}=\frac{d}{ds}\left[\frac{s+1}{s+2}\right]_{s=0}$$
$$=\left[\frac{(s+2)-(s+1)}{(s+2)^2}\right]_{s=0}$$
$$=\frac{1}{4}$$

The function $F(s)$ is,

$$F(s)=e^{-4s}\left[\frac{\left(\frac{1}{4}\right)}{s}+\frac{\left(\frac{1}{2}\right)}{s^2}-\frac{\left(\frac{1}{4}\right)}{s+2}\right]$$

Apply inverse Laplace transforms on both sides and frequency shifting property of Laplace transforms.

$$L^{-1}[F(s)]=\frac{1}{4}L^{-1}\left[\frac{e^{-4s}}{s}\right]+\frac{1}{2}L^{-1}\left[\frac{e^{-4s}}{s^2}\right]+\frac{1}{4}L^{-1}\left[\frac{e^{-4s}}{s+2}\right]$$

$$f(t)=\frac{1}{4}u(t-4)+\frac{1}{2}(t-4)u(t-4)-\frac{1}{4}e^{-2(t-4)}u(t-4)$$
$$=\left[-\frac{7}{4}+\frac{1}{2}t-\frac{1}{4}e^{-2(t-4)}\right]u(t-4)$$

Therefore, the function $f(t)$ is,

$$\boxed{f(t)=\left[-\frac{7}{4}+\frac{1}{2}t-\frac{1}{4}e^{-2(t-4)}\right]u(t-4)}$$

Step 1 of 6

Consider the function.

$$F(s)=\frac{(s+1)e^{-s}}{s(s+2)(s^2+2s+2)} \quad \text{..... (1)}$$

Let $\frac{s+1}{s(s+2)(s^2+2s+2)}$ for $G(s)$.

$$G(s)=\frac{s+1}{s(s+2)(s^2+2s+2)}$$

$$G(s)=\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}$$

Assume $\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}$ to be $\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1}$.

$$\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1} \quad \text{..... (2)}$$

Step 2 of 6

Use residue's method to find the values of A, B, C and C^*.

Calculate the value of B.

$$\begin{aligned}B&=(s+2)\left[\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-2}\\&=\left[\frac{s+1}{s(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-2}\\&=\frac{-2+1}{(-2)(-2+1-j1)(-2+1+j1)}\\&=\frac{-1}{(-2)(-1-j1)(-1+j1)}\end{aligned}$$

$$\begin{aligned}B&=\frac{-1}{(-2)(2)}\\&=\frac{1}{4}\end{aligned}$$

Therefore, the value of B is $\frac{1}{4}$.

Step 3 of 6

Calculate the value of A.

$$\begin{aligned}A&=s\left[\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=0}\\&=\left[\frac{s+1}{(s+2)(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-2}\\&=\frac{0+1}{(0+2)(0+1-j1)(0+1+j1)}\\&=\frac{1}{(2)(1-j1)(1+j1)}\end{aligned}$$

$$\begin{aligned}A&=\frac{1}{(2)(2)}\\&=\frac{1}{4}\end{aligned}$$

Therefore, the value of A is $\frac{1}{4}$.

Step 4 of 6

Calculate the value of C.

$$\begin{aligned}C&=(s+1-j1)\left[\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1+j1}\\&=\left[\frac{s+1}{s(s+2)(s+1+j1)}\right]\Bigg|_{s=-1+j1}\\&=\frac{-1+j1+1}{(-1+j1)(-1+j1+2)(-1+j1+1+j1)}\\&=\frac{j1}{(-1+j1)(1+j1)(j2)}\end{aligned}$$

$$\begin{aligned}C&=\frac{1}{(-2)(2)}\\&=-\frac{1}{4}\end{aligned}$$

Therefore, the value of C is $-\frac{1}{4}$.

As C^* is the conjugate value of C, the value of C^* is $-\frac{1}{4}$.

Step 5 of 6

Consider the function (2).

$$\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1}$$

Substitute $G(s)$ for $\frac{s+1}{s(s+2)(s+1-j1)(s+1+j1)}$, $\frac{1}{4}$ for B and A and $-\frac{1}{4}$ for D and C in the equation.

$$\begin{aligned}G(s)&=\frac{1}{4s}+\frac{1}{4(s+2)}-\frac{1}{4(s+1-j1)}-\frac{1}{4(s+1+j1)}\\&=\frac{1}{4s}+\frac{1}{4(s+2)}-\frac{1}{4}\left(\frac{1}{s+1-j1}+\frac{1}{s+1+j1}\right)\end{aligned}$$

Apply inverse Laplace transform.

Apply the property's $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$\begin{aligned}g(t)&=\left[\frac{1}{4}+\frac{1}{4}e^{-2t}-\frac{1}{4}2(1)e^{-t}\cos(t)\right]u(t)\\&=\left[\frac{1}{4}+\frac{1}{4}e^{-2t}-\frac{1}{2}e^{-t}\cos(t)\right]u(t)\end{aligned}$$

Therefore, the Inverse Laplace transform of $\frac{s+1}{s(s+2)(s^2+2s+2)}$ is $\left[\frac{1}{4}+\frac{1}{4}e^{-2t}-\frac{1}{2}e^{-t}\cos(t)\right]u(t)$.

Step 6 of 6

Consider function (1).

$$F(s)=\frac{(s+1)e^{-s}}{s(s+2)(s^2+2s+2)}$$

Substitute $G(s)$ for $\frac{s+1}{s^2(s+2)}$.

$$F(s)=e^{-s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-1)u(t-1)$$

Substitute $\left[\frac{1}{4}+\frac{1}{4}e^{-2(t-1)}-\frac{1}{2}e^{-(t-1)}\cos(t-1)\right]u(t-1)$ for $g(t-1)$ since $g(t)=\left[\frac{1}{4}+\frac{1}{4}e^{-2t}-\frac{1}{2}e^{-t}\cos(t)\right]u(t)$.

$$f(t)=\left[\frac{1}{4}+\frac{1}{4}e^{-2(t-1)}-\frac{1}{2}e^{-(t-1)}\cos(t-1)\right]u(t-1)$$

Therefore, the inverse Laplace transform of $\frac{(s+1)e^{-s}}{s(s+2)(s^2+2s+2)}$ is

$$\boxed{\left[\frac{1}{4}+\frac{1}{4}e^{-2(t-1)}-\frac{1}{2}e^{-(t-1)}\cos(t-1)\right]u(t-1)}.$$

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Step 1 of 4

Consider the function.

$$F(s)=\frac{10s(s+2)e^{-4s}}{(s+1)^2(s^2+2s+2)} \quad \text{..... (1)}$$

Let $\frac{10s(s+2)}{(s+1)^2(s^2+2s+2)}$ for $G(s)$.

$$G(s)=\frac{10s(s+2)}{(s+1)^2(s^2+2s+2)}$$

$$G(s)=\frac{10s(s+2)}{(s+1)^2(s+1-j1)(s+1+j1)}$$

Assume $\frac{10s(s+2)}{(s+1)^2(s+1+1j)(s+1-1j)}$ to be $\frac{A}{s+1}+\frac{B}{(s+1)^2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1}$.

$$\frac{10s(s+2)}{(s+1)^2(s+1-1j)(s+1+1j)}=\frac{A}{s+1}+\frac{B}{(s+1)^2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1} \quad \text{..... (2)}$$

Use residue's method to find the values of A, B, C and C^*.

Calculate the value of B.

$$\begin{aligned}B&=(s+1)^2\left[\frac{10s(s+2)}{(s+1)^2(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1}\\&=\left[\frac{10s(s+2)}{(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1}\\&=\frac{10(-1)(-1+2)}{(-1+1-j1)(-1+1+j1)}\\&=\frac{10(-1)(1)}{(-j1)(+j1)}\end{aligned}$$

$$\begin{aligned}B&=\frac{-10}{1}\\&=-10\end{aligned}$$

Therefore, the value of B is -10.

Step 2 of 4

Calculate the value of A.

$$\begin{aligned}A&=\frac{d}{ds}(s+1)^2\left[\frac{10s(s+2)}{(s+1)^2(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1}\\&=\left[\frac{d}{ds}\frac{10s(s+2)}{(s^2+2s+2)}\right]\Bigg|_{s=-1}\\&=\frac{(s^2+2s+2)(20s+20)-10s(s+2)(2s+2)}{(s^2+2s+2)^2}\Bigg|_{s=-1}\\&=\frac{(1-2+2)(-20+20)-10(-1)(-1+2)(-2+2)}{(1-2+2)^2}\end{aligned}$$

$$\begin{aligned}A&=\frac{0-0}{1}\\&=0\end{aligned}$$

Therefore, the value of A is 0.

Step 3 of 4

Calculate the value of C.

$$\begin{aligned}C&=(s+1-j1)\left[\frac{10s(s+2)}{(s+1)^2(s+1-j1)(s+1+j1)}\right]\Bigg|_{s=-1+1j}\\&=\left[\frac{10s(s+2)}{(s+1)^2(s+1+j1)}\right]\Bigg|_{s=-1+1j}\\&=\frac{10(-1+1j)(-1+1j+2)}{(-1+j1+1)^2(-1+1j+1+j1)}\\&=\frac{-20}{-j2}\end{aligned}$$

$$\begin{aligned}C&=-j10\\&=10\angle-90^\circ\end{aligned}$$

Therefore, the value of C is $10\angle-90^\circ$.

As C^* is the conjugate value of C, the value of C^* is $10\angle 90^\circ$.

Consider the function (2).

$$\frac{10s(s+2)}{(s+1)^2(s+1+1j)(s+1-1j)}=\frac{A}{s+1}+\frac{B}{(s+1)^2}+\frac{C}{s+1-j1}+\frac{C^*}{s+1+j1}$$

Substitute $G(s)$ for $\frac{10s(s+2)}{(s+1)^2(s+1+1j)(s+1-1j)}$, -10 for B, 0 for A and $10\angle-90^\circ$ for C and $10\angle 90^\circ$ C^*.

$$\begin{aligned}G(s)&=\frac{0}{s+1}+\frac{-10}{(s+1)^2}+\frac{10\angle-90^\circ}{s+1-j1}+\frac{10\angle 90^\circ}{s+1+j1}\\&=\frac{-10}{(s+1)^2}+\frac{10\angle-90^\circ}{s+1-j1}+\frac{10\angle 90^\circ}{s+1+j1}\end{aligned}$$

Apply inverse Laplace transform.

Apply the property's $L^{-1}\left\{\frac{1}{(s+a)^2}\right\}=te^{-at}$ and Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta^\circ}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta^\circ}{s+\alpha+j\beta}$.

$$\begin{aligned}g(t)&=\left[-10te^{-t}+2(10)e^{-t}\cos(t-90^\circ)\right]u(t)\\&=\left[-10te^{-t}+20e^{-t}\sin(t)\right]u(t)\end{aligned}$$

Therefore, the Inverse Laplace transform of $\frac{10s(s+2)}{(s+1)^2(s+1+1j)(s+1-1j)}$ is

$\left[-10te^{-t}+20e^{-t}\sin(t)\right]u(t)$.

Step 4 of 4

Consider function (1).

$$F(s)=\frac{10s(s+2)e^{-4s}}{(s+1)^2(s^2+2s+2)}$$

Substitute $G(s)$ for $F(s)=\frac{10s(s+2)}{(s+1)^2(s^2+2s+2)}$.

$$F(s)=e^{-4s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-4)u(t-4)$$

Substitute $\left[-10(t-4)e^{-(t-4)}+20e^{-(t-4)}\sin(t-4)\right]u(t-4)$ for $g(t-1)$ since \

$g(t)=\left[-10te^{-t}+20e^{-t}\sin(t)\right]u(t)$.

$$f(t)=\left[-10(t-4)e^{-(t-4)}+20e^{-(t-4)}\sin(t-4)\right]u(t-4)$$

Therefore, the inverse Laplace transform of $\frac{10s(s+2)e^{-4s}}{(s+1)^2(s^2+2s+2)}$ is

$$\boxed{\left[-10(t-4)e^{-(t-4)}+20e^{-(t-4)}\sin(t-4)\right]u(t-4)}.$$

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Step 1 of 6

Consider the function.

$$F(s)=\frac{s^2e^{-2s}}{(s^2+1)(s+1)(s^2+2s-2)} \quad \text{..... (1)}$$

Let $\frac{s^2e^{-2s}}{(s^2+1)(s+1)(s^2+2s-2)}$ for $G(s)$.

$$G(s)=\frac{s^2e^{-2s}}{(s^2+1)(s+1)(s^2+2s-2)}$$
$$=\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}$$

Assume $\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}$ to be

$\frac{A}{s-j1}+\frac{A^*}{s+j1}+\frac{B}{s+1}+\frac{C}{s-0.732}+\frac{D}{s+2.732}$.

$$\frac{s^2}{\begin{bmatrix}(s-j1)(s+j1)(s+1)\\(s-0.732)(s+2.732)\end{bmatrix}}=\frac{A}{s-j1}+\frac{A^*}{s+j1}+\frac{B}{s+1}+\frac{C}{s-0.732}+\frac{D}{s+2.732} \quad \text{..... (2)}$$

Use residue's method to find the values of A, A^*, B, C and D.

Calculate the value of B.

$$A=(s-j1)\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}\Bigg|_{s=j1}$$
$$=\frac{s^2}{(s+j1)(s+1)(s-0.732)(s+2.732)}\Bigg|_{s=j1}$$
$$=\frac{(j1)^2}{(j1+j1)(j1+1)(j1-0.732)(j1+2.732)}$$
$$=\frac{-1}{2-10j}$$

$$A=0.098\angle-101.31°$$

Therefore, the value of A is $0.098\angle-101.31°$.

As A^* is the conjugate value of A, the value of A^* is $0.098\angle101.31°$.

Step 2 of 6

Calculate the value of B.

$$B=(s+1)\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}\Bigg|_{s=-1}$$
$$=\frac{s^2}{(s-j1)(s+j1)(s-0.732)(s+2.732)}\Bigg|_{s=-1}$$
$$=\frac{(-1)^2}{(-1-j1)(-1+j1)(-1-0.732)(-1+2.732)}$$
$$=-\frac{1}{6}$$

Therefore, the value of B is $-\frac{1}{6}$.

Step 3 of 6

Calculate the value of C.

$$C=(s-0.732)\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}\Bigg|_{s=0.732}$$
$$=\frac{s^2}{(s-j1)(s+j1)(s+1)(s+2.732)}\Bigg|_{s=0.732}$$
$$=\frac{(0.732)^2}{(0.732-j1)(0.732+j1)(0.732+1)(0.732+2.732)}$$
$$=\frac{0.535824}{9.214403}$$

$$C=0.058$$

Therefore, the value of C is 0.058.

Step 4 of 6

Calculate the value of D.

$$D=(s+2.732)\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}\Bigg|_{s=-2.732}$$
$$=\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)}\Bigg|_{s=-2.732}$$
$$=\frac{(-2.732)^2}{(-2.732-j1)(-2.732+j1)(-2.732+1)(-2.732-0.732)}$$
$$=\frac{7.463824}{50.779965}$$

$$D=0.147$$

Therefore, the value of D is 0.147.

Step 5 of 6

Consider the function (2).

$$\frac{s^2}{\begin{bmatrix}(s-j1)(s+j1)(s+1)\\(s-0.732)(s+2.732)\end{bmatrix}}=\frac{A}{s-j1}+\frac{A^*}{s+j1}+\frac{B}{s+1}+\frac{C}{s-0.732}+\frac{D}{s+2.732}$$

Substitute $G(s)$ for $\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}$, $-\frac{1}{6}$ for B, $0.098\angle-101.31°$ for A, $0.098\angle101.31°$ for A^*, 0.058 for C and 0.147 D.

$$G(s)=\frac{0.098\angle-101.31°}{s-j1}+\frac{0.098\angle101.31°}{s+j1}+\frac{-1}{6(s+1)}+\frac{0.058}{s-0.732}+\frac{0.147}{s+2.732}$$

Apply inverse Laplace transform.

Apply the property's $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and Apply the form $2|K_1|e^{-\alpha t}\cos(\beta t+\theta)$ for conjugate pairs $\frac{|K_1|\angle\theta°}{s+\alpha-j\beta}+\frac{|K_1|\angle-\theta°}{s+\alpha+j\beta}$.

$$g(t)=\left[2(0.098)e^{-(0)t}\cos(t-101.31°)-\frac{1}{6}e^{-t}+0.058e^{0.732t}+0.147e^{-2.732t}\right]u(t)$$
$$=\left[0.196\cos(t-101.31°)-\frac{1}{6}e^{-t}+0.058e^{0.732t}+0.147e^{-2.732t}\right]u(t)$$

Therefore, the Inverse Laplace transform of $\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}$ is $\left[0.196\cos(t-101.31°)-\frac{1}{6}e^{-t}+0.058e^{0.732t}+0.147e^{-2.732t}\right]u(t)$.

Step 6 of 6

Consider function (1).

$$F(s)=\frac{s^2e^{-2s}}{(s^2+1)(s+1)(s^2+2s-2)}$$

Substitute $G(s)$ for $F(s)=\frac{s^2}{(s^2+1)(s+1)(s^2+2s-2)}$.

$$F(s)=e^{-2s}G(s)$$

Apply inverse Laplace transform and use the property, $e^{-t_0s}G(s)\Rightarrow f(t-t_0)u(t-t_0)$.

$$f(t)=g(t-2)u(t-2)$$

Substitute $\left[0.196\cos(t-2-101.31°)-\frac{1}{6}e^{-(t-2)}+0.058e^{0.732(t-2)}+0.147e^{-2.732(t-2)}\right]u(t-2)$ for $g(t-1)$ since $g(t)=\left[0.196\cos(t-101.31°)-\frac{1}{6}e^{-t}+0.058e^{0.732t}+0.147e^{-2.732t}\right]u(t)$.

$$f(t)=\left[0.196\cos(t-2-101.31°)-\frac{1}{6}e^{-(t-2)}+0.058e^{0.732(t-2)}+0.147e^{-2.732(t-2)}\right]u(t-2)$$

Therefore, the inverse Laplace transform of $\frac{s^2}{(s-j1)(s+j1)(s+1)(s-0.732)(s+2.732)}$ is

$$\boxed{\left[0.196\cos((t-2)-101.31°)-\frac{1}{6}e^{-(t-2)}+0.058e^{0.732(t-2)}+0.147e^{-2.732(t-2)}\right]u(t-2)}.$$

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Step 1 of 6

(a)

Consider the differential expression.

$$\frac{dy(t)}{dt}+3y(t)=e^{-t}$$

Apply Laplace transform on both sides of the differential expression.

$$\left[sY(s)-y(0)\right]+3Y(s)=\frac{1}{s+1}$$

The initial condition is $y(0)=1$

$$\left[sY(s)-1\right]+3Y(s)=\frac{1}{s+1}$$
$$(s+3)Y(s)=\frac{1}{s+1}+1$$
$$(s+3)Y(s)=\frac{s+2}{s+1}$$
$$Y(s)=\frac{s+2}{(s+1)(s+3)}$$

Step 2 of 6

Apply the partial fraction method to $Y(s)$.

$$Y(s)=\frac{s+2}{(s+1)(s+3)}$$
$$=\frac{A}{s+1}+\frac{B}{s+3}$$

Use the residue theorem to calculate the value of A

$$A=\frac{s+2}{(s+1)(s+3)}(s+1)\Big|_{s=-1}$$
$$=\frac{s+2}{(s+3)}\Big|_{s=-1}$$
$$=\frac{-1+2}{-1+3}$$
$$=\frac{1}{2}$$

Use the residue theorem to calculate the value of B

$$B=\frac{s+2}{(s+1)(s+3)}(s+3)\Big|_{s=-3}$$
$$=\frac{s+2}{(s+1)}\Big|_{s=-3}$$
$$=\frac{-3+2}{-3+1}$$
$$=\frac{1}{2}$$

Step 3 of 6

The partial fraction form of the expression $Y(s)$ is,

$$Y(s)=\frac{1}{2(s+1)}+\frac{1}{2(s+3)}$$

Apply inverse Laplace transform on both sides.

$$y(t)=\frac{1}{2}e^{-t}u(t)+\frac{1}{2}e^{-3t}u(t)$$
$$=\frac{1}{2}\left\{e^{-t}+e^{-3t}\right\}u(t)$$

Therefore, the solution to the differential expression is $\boxed{y(t)=\frac{1}{2}\left\{e^{-t}+e^{-3t}\right\}u(t)}$.

Step 4 of 6

(b)

Consider the differential expression.

$$\frac{dy(t)}{dt}+4y(t)=2u(t)$$

Apply Laplace transform on both sides of the differential expression.

$$\left[sY(s)-y(0)\right]+4Y(s)=\frac{2}{s}$$

The initial condition is $y(0)=2$

$$\left[sY(s)-2\right]+4Y(s)=\frac{2}{s}$$
$$(s+4)Y(s)=\frac{2}{s}+2$$
$$(s+4)Y(s)=\frac{2s+2}{s}$$
$$Y(s)=\frac{(2s+2)}{s(s+4)}$$

Step 5 of 6

Apply the partial fraction method to $Y(s)$.

$$Y(s)=\frac{(2s+2)}{s(s+4)}$$
$$=\frac{A}{s}+\frac{B}{s+4}$$

Use the residue theorem to calculate the value of A

$$A=\frac{(2s+2)}{s(s+4)}s\Big|_{s=0}$$
$$=\frac{(2s+2)}{(s+4)}\Big|_{s=0}$$
$$=\frac{2(0)+2}{0+4}$$
$$=\frac{1}{2}$$

Use the residue theorem to calculate the value of B

$$B=\frac{(2s+2)}{s(s+4)}(s+4)\Big|_{s=-4}$$
$$=\frac{(2s+2)}{s}\Big|_{s=-4}$$
$$=\frac{2(-4)+2}{-4}$$
$$=\frac{3}{2}$$

Step 6 of 6

The partial fraction form of the expression $Y(s)$ is,

$$Y(s)=\frac{1}{2}\frac{1}{s}+\frac{3}{2}\frac{1}{(s+4)}$$

Apply inverse Laplace transform on both sides.

$$y(t)=\frac{1}{2}u(t)+\frac{3}{2}e^{-4t}u(t)$$
$$=\frac{1}{2}\left\{1+3e^{-4t}\right\}u(t)$$

Therefore, the solution to the differential expression is $\boxed{y(t)=\frac{1}{2}\left\{1+3e^{-4t}\right\}u(t)}$.

Step 1 of 4

Consider the following integrodifferential equation.

$$y(t)+4\int_0^t y(\lambda)e^{-4(t-\lambda)}d\lambda = 2e^{-t} \qquad t>0$$

Convolution property:

The convolution in the time domain results to multiplication in the frequency domain.

That is,

$$\begin{aligned} y_1(t)\otimes y_2(t) &= \int_0^t y_1(\lambda)y_2(t-\lambda)\,d\lambda \\ &= \int_0^t y_1(t-\lambda)y_2(\lambda)\,d\lambda \\ &= \mathbf{Y}_1(s)\mathbf{Y}_2(s) \end{aligned}$$

Consider the middle term in the integrodifferential equation, $\int_0^t y(\lambda)e^{-4(t-\lambda)}d\lambda$

The two functions are,

$$y_1(t)=y(t)$$
$$y_2(t)=e^{-4t}$$

Step 2 of 4

The Laplace transform of $y_1(t)$ is,

$$\mathbf{Y}_1(s)=\mathbf{Y}(s)$$

The Laplace transform of $y_2(t)$ is,

$$\mathbf{Y}_2(s)=\frac{1}{s+4}$$

Therefore, the integrodifferential equation is,

$$y(t)+4\left\{y(t)\otimes e^{-4t}\right\}=2e^{-t}$$

Apply Laplace transform on both sides.

$$\begin{aligned} \mathbf{Y}(s)+4\left\{\mathbf{Y}(s)\frac{1}{s+4}\right\} &= \frac{2}{s+1} \\ \left\{1+\frac{4}{s+4}\right\}\mathbf{Y}(s) &= \frac{2}{s+1} \\ \left\{\frac{s+8}{s+4}\right\}\mathbf{Y}(s) &= \frac{2}{s+1} \\ \mathbf{Y}(s) &= \frac{2(s+4)}{(s+1)(s+8)} \end{aligned}$$

Step 3 of 4

Apply the partial fraction method to $\mathbf{Y}(s)$.

$$\begin{aligned} \mathbf{Y}(s) &= \frac{2(s+4)}{(s+1)(s+8)} \\ &= \frac{A}{s+1}+\frac{B}{s+8} \end{aligned}$$

Use the residue theorem to calculate the value of A

$$\begin{aligned} A &= \frac{2(s+4)}{(s+1)(s+8)}(s+1)\bigg|_{s=-1} \\ &= \frac{2(s+4)}{(s+8)}\bigg|_{s=-1} \\ &= \frac{2(-1+4)}{(-1+8)} \\ &= \frac{6}{7} \end{aligned}$$

Use the residue theorem to calculate the value of B

$$\begin{aligned} B &= \frac{2(s+4)}{(s+1)(s+8)}(s+8)\bigg|_{s=-8} \\ &= \frac{2(s+4)}{(s+1)}\bigg|_{s=-8} \\ &= \frac{2(-8+4)}{(-8+1)} \\ &= \frac{8}{7} \end{aligned}$$

Step 4 of 4

The partial fraction form of the expression $Y(s)$ is,

$$\mathbf{Y}(s)=\frac{6}{7(s+1)}+\frac{8}{7(s+8)}$$

Apply inverse Laplace transform on both sides.

$$\begin{aligned} y(t) &= \frac{6}{7}e^{-t}u(t)+\frac{8}{7}e^{-8t}u(t) \\ &= \frac{1}{7}\left\{6e^{-t}+8e^{-8t}\right\}u(t) \end{aligned}$$

Hence, the solution to the integrodifferential expression is, $\boxed{y(t)=\frac{1}{7}\left\{6e^{-t}+8e^{-8t}\right\}u(t)}$.

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Step 1 of 5

Consider the differential equation.

$$\frac{dy(t)}{dt}+2y(t)+\int_0^t y(\lambda)\,d\lambda=1-e^{-2t}$$

Apply Laplace transform.

$$sY(s)-Y(0)+2Y(s)+\frac{1}{s}Y(s)=\frac{1}{s}-\frac{1}{s+2}$$

Substitute 0 for $Y(0)$.

$$sY(s)-0+2Y(s)+\frac{1}{s}Y(s)=\frac{s+2-s}{s(s+2)}$$

$$sY(s)+2Y(s)+\frac{1}{s}Y(s)=\frac{2}{s(s+2)}$$

$$\left(\frac{s^2+2s+1}{s}\right)Y(s)=\frac{2}{s(s+2)}$$

$$(s+1)^2Y(s)=\frac{2}{s+2}$$

$$Y(s)=\frac{2}{(s+2)(s+1)^2}\quad\text{..... (1)}$$

Step 2 of 5

Assume $\frac{2}{(s+2)(s+1)^2}$ to be $\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$.

$$\frac{s+1}{(s+2)(s+1)^2}=\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2}\quad\text{..... (2)}$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$\begin{aligned}A&=(s+2)\left[\frac{2}{(s+2)(s+1)^2}\right]\Bigg|_{s=-2}\\&=\left[\frac{2}{(s+1)^2}\right]\Bigg|_{s=-2}\\&=\frac{2}{(-2+1)^2}\\&=2\end{aligned}$$

Therefore, the value of A is 2.

Step 3 of 5

Calculate the value of C.

$$\begin{aligned}C&=(s+1)^2\left[\frac{2}{(s+2)(s+1)^2}\right]\Bigg|_{s=-1}\\&=\left[\frac{2}{(s+2)}\right]\Bigg|_{s=-1}\\&=\frac{2}{-1+2}\\&=2\end{aligned}$$

Therefore, the value of C is 2.

Step 4 of 5

Calculate the value of B.

$$\begin{aligned}B&=\frac{d}{ds}(s+1)^2\left[\frac{1}{(s+2)(s+1)^2}\right]\Bigg|_{s=-1}\\&=\left[\frac{d}{ds}\frac{2}{(s+2)}\right]\Bigg|_{s=-1}\\&=\frac{-2}{(s+2)^2}\Bigg|_{s=-1}\\&=\frac{-2}{(-1+2)^2}\Bigg|\end{aligned}$$

$$B=-2$$

Therefore, the value of B is -2.

Step 5 of 5

Consider expression (2).

$$\frac{2}{(s+2)(s+1)^2}=\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$$

Substitute $\frac{2}{(s+2)(s+1)^2}$ for $Y(s)$, 2 for A and C and -2 for B

$$Y(s)=\frac{2}{s+2}-\frac{2}{s+1}+\frac{2}{(s+1)^2}$$

Apply inverse Laplace transform.

$$\mathrm{L}\{Y(s)\}=\mathrm{L}\left\{\frac{2}{s+2}\right\}+\mathrm{L}\left\{\frac{2}{s+1}\right\}+\mathrm{L}\left\{\frac{2}{(s+1)^2}\right\}$$

Apply the property $\mathrm{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$y(t)=\left[2e^{-2t}-2e^{-t}+2te^{-t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left[2e^{-2t}-2e^{-t}+2te^{-t}\right]u(t)}$.

Step 1 of 8

(a)

Consider the differential equation.

$$\frac{dx(t)}{dt}+4x(t)=e^{-2t}$$

Apply Laplace transform.

$$sX(s)-X(0)+4X(s)=\frac{1}{s+2}$$

Substitute 1 for $X(0)$ in the equation.

$$sX(s)-1+4X(s)=\frac{1}{s+2}$$
$$sX(s)+4X(s)=\frac{1}{s+2}+1$$
$$sX(s)+4X(s)=\frac{1+s+2}{s+2}$$
$$(s+4)X(s)=\frac{s+3}{s+2}$$
$$X(s)=\frac{s+3}{(s+2)(s+4)} \quad \text{..... (1)}$$

Step 2 of 8

Assume $\frac{s+3}{(s+2)(s+4)}$ to be $\frac{A}{s+2}+\frac{B}{s+3}$.

$$\frac{s+3}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+3} \quad \text{..... (2)}$$

Use residue's method to find the values of A and B.

Calculate the value of A.

$$A=(s+2)\left[\frac{s+3}{(s+2)(s+4)}\right]\Bigg|_{s=-2}$$
$$=\left[\frac{s+3}{(s+4)}\right]\Bigg|_{s=-2}$$
$$=\frac{-2+3}{-2+4}$$
$$=\frac{1}{2}$$

Therefore, the value of A is $\frac{1}{2}$.

Step 3 of 8

Calculate the value of B.

$$B=(s+4)\left[\frac{s+3}{(s+2)(s+4)}\right]\Bigg|_{s=-4}$$
$$=\left[\frac{s+3}{(s+2)}\right]\Bigg|_{s=-2}$$
$$=\frac{-4+3}{-4+2}$$
$$=\frac{-1}{-2}$$
$$B=\frac{1}{2}$$

Therefore, the value of B is $\frac{1}{2}$.

Step 4 of 8

Consider expression (2).

$$\frac{s+3}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+4}$$

Substitute $\frac{s+3}{(s+2)(s+4)}$ for $X(s)$ $\frac{1}{2}$ for A and B in the equation.

$$X(s)=\frac{1}{2(s+2)}+\frac{1}{2(s+4)}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{X(s)\}=\frac{1}{2}\left[\mathcal{L}\left\{\frac{1}{s+2}\right\}+\mathcal{L}\left\{\frac{1}{s+4}\right\}\right]$$

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$x(t)=\frac{1}{2}\left[e^{-2t}+e^{-4t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\frac{1}{2}\left[e^{-2t}+e^{-4t}\right]u(t)}$.

Step 5 of 8

(b)

Consider the differential equation.

$$\frac{dx(t)}{dt}+6x(t)=4u(t)$$

Apply Laplace transform.

$$sX(s)-X(0)+6X(s)=\frac{4}{s}$$

Substitute 2 for $X(0)$ in the equation.

$$sX(s)-2+6X(s)=\frac{4}{s}$$
$$sX(s)+6X(s)=\frac{4}{s}+2$$
$$sX(s)+6X(s)=\frac{4+2s}{s}$$
$$(s+6)X(s)=\frac{2(s+2)}{s}$$
$$X(s)=\frac{2(s+2)}{s(s+6)} \quad \text{..... (3)}$$

Assume $\frac{2(s+2)}{s(s+6)}$ to be $\frac{A}{s}+\frac{B}{s+6}$.

$$\frac{2(s+2)}{s(s+6)}=\frac{A}{s}+\frac{B}{s+6} \quad \text{..... (4)}$$

Step 6 of 8

Use residue's method to find the values of A and B.

Calculate the value of A.

$$A=s\left[\frac{2(s+2)}{s(s+6)}\right]\Bigg|_{s=0}$$
$$=\left[=\frac{2(s+2)}{(s+6)}\right]\Bigg|_{s=0}$$
$$=\frac{2(0+2)}{0+6}$$
$$=\frac{2}{3}$$

Therefore, the value of A is $\frac{2}{3}$.

Step 7 of 8

Calculate the value of B.

$$B=(s+6)\left[\frac{2(s+2)}{s(s+6)}\right]\Bigg|_{s=-6}$$
$$=\left[\frac{2(s+2)}{s}\right]\Bigg|_{s=-6}$$
$$=\frac{2(-6+2)}{-6}$$
$$=\frac{-4}{-3}$$
$$B=\frac{4}{3}$$

Therefore, the value of B is $\frac{4}{3}$.

Step 8 of 8

Consider expression (4).

$$\frac{2(s+2)}{s(s+6)}=\frac{A}{s}+\frac{B}{s+6}$$

Substitute $\frac{2(s+2)}{s(s+6)}$ for $X(s)$, $\frac{2}{3}$ for A and $\frac{4}{3}$ for B in the equation.

$$X(s)=\frac{2}{3s}+\frac{4}{3(s+6)}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{X(s)\}=\frac{2}{3}\mathcal{L}\left\{\frac{1}{s}\right\}+\frac{4}{3}\mathcal{L}\left\{\frac{1}{s+6}\right\}$$

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$x(t)=\left(\frac{2}{3}(1)+\frac{4}{3}e^{-6t}\right)u(t)$$
$$=\left(\frac{2}{3}+\frac{4}{3}e^{-6t}\right)u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left(\frac{2}{3}+\frac{4}{3}e^{-6t}\right)u(t)}$.

Step 1 of 10

(a)

Consider the differential equation.

$$\frac{d^2y(t)}{dt^2}+\frac{2dy(t)}{dt}+y(t)=e^{-2t}$$

Apply Laplace transform.

$$s^2Y(s)-sY(0)-Y'(0)+2\left[sY(s)-Y(0)\right]+Y(s)=\frac{1}{s+2}$$

Substitute 0 for $Y(0)$ and 0 for $Y'(0)$ in the equation.

$$s^2Y(s)-0-0+2\left[sY(s)-0\right]+Y(s)=\frac{1}{s+2}$$

$$s^2Y(s)+2sY(s)+Y(s)=\frac{1}{s+2}$$

$$\left(s^2+2s+1\right)Y(s)=\frac{1}{s+2}$$

$$(s+1)^2Y(s)=\frac{1}{s+2}$$

$$Y(s)=\frac{1}{(s+2)(s+1)^2} \quad \text{..... (1)}$$

Step 2 of 10

Assume $\frac{1}{(s+2)(s+1)^2}$ to be $\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$.

$$\frac{1}{(s+2)(s+1)^2}=\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2} \quad \text{..... (2)}$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$A=(s+2)\left[\frac{1}{(s+2)(s+1)^2}\right]\Bigg|_{s=-2}$$

$$=\left[\frac{1}{(s+1)^2}\right]\Bigg|_{s=-2}$$

$$=\frac{1}{(-2+1)^2}$$

$$=1$$

Therefore, the value of A is 1.

Step 3 of 10

Calculate the value of C.

$$C=(s+1)^2\left[\frac{1}{(s+2)(s+1)^2}\right]\Bigg|_{s=-1}$$

$$=\left[\frac{1}{(s+2)}\right]\Bigg|_{s=-1}$$

$$=\frac{1}{-1+2}$$

$$=1$$

Therefore, the value of C is 1.

Step 4 of 10

Calculate the value of B.

$$B=\frac{d}{ds}(s+1)^2\left[\frac{1}{(s+2)(s+1)^2}\right]\Bigg|_{s=-1}$$

$$=\left[\frac{d}{ds}\frac{1}{(s+2)}\right]\Bigg|_{s=-1}$$

$$=\frac{-1}{(s+2)^2}\Bigg|_{s=-1}$$

$$=\frac{-1}{(-1+2)^2}\Bigg|$$

$$B=-1$$

Therefore, the value of B is -1.

Step 5 of 10

Consider expression (2).

$$\frac{1}{(s+2)(s+1)^2}=\frac{A}{s+2}+\frac{B}{s+1}+\frac{C}{(s+1)^2}$$

Substitute $\frac{1}{(s+2)(s+1)^2}$ for $Y(s)$, 1 for A and C and -1 for B in the equation.

$$Y(s)=\frac{1}{s+2}-\frac{1}{s+1}+\frac{1}{(s+1)^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{Y(s)\}=\mathcal{L}\left\{\frac{1}{s+2}\right\}-\mathcal{L}\left\{\frac{1}{s+1}\right\}+\mathcal{L}\left\{\frac{1}{(s+1)^2}\right\}$$

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$y(t)=\left[e^{-2t}-e^{-t}+te^{-t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left[e^{-2t}-e^{-t}+te^{-t}\right]u(t)}$.

Step 6 of 10

(b)

Consider the differential equation.

$$\frac{d^2y(t)}{dt^2}+\frac{4dy(t)}{dt}+4y(t)=u(t)$$

Apply Laplace transform.

$$s^2Y(s)-sY(0)-Y'(0)+4\left[sY(s)-Y(0)\right]+4Y(s)=\frac{1}{s}$$

Substitute 0 for $Y(0)$ and 1 for $Y'(0)$ in the equation.

$$s^2Y(s)-0-1+4\left[sY(s)-0\right]+4Y(s)=\frac{1}{s}$$

$$s^2Y(s)-1+4sY(s)+4Y(s)=\frac{1}{s}$$

$$\left(s^2+4s+4\right)Y(s)=\frac{1}{s}+1$$

$$(s+2)^2Y(s)=\frac{s+1}{s}$$

$$Y(s)=\frac{s+1}{s(s+2)^2} \quad \text{..... (3)}$$

Step 7 of 10

Assume $\frac{s+1}{s(s+2)^2}$ to be $\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$.

$$\frac{1}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2} \quad \text{..... (4)}$$

Use residue's method to find the values of A, B and C.

Calculate the value of A.

$$A=s\left[\frac{s+1}{s(s+2)^2}\right]\Bigg|_{s=0}$$

$$=\left[\frac{s+1}{(s+2)^2}\right]\Bigg|_{s=-2}$$

$$=\frac{0+1}{(0+2)^2}$$

$$=\frac{1}{4}$$

Therefore, the value of A is $\frac{1}{4}$.

Step 8 of 10

Calculate the value of C.

$$C=(s+2)^2\left[\frac{s+1}{s(s+2)^2}\right]\Bigg|_{s=-1}$$

$$=\left[\frac{s+1}{s}\right]\Bigg|_{s=-2}$$

$$=\frac{-2+1}{-2}$$

$$=\frac{1}{2}$$

Therefore, the value of C is $\frac{1}{2}$.

Step 9 of 10

Calculate the value of B.

$$B=\frac{d}{ds}(s+2)^2\left[\frac{s+1}{s(s+2)^2}\right]\Bigg|_{s=-2}$$

$$=\left[\frac{d}{ds}\left(\frac{s+1}{s}\right)\right]\Bigg|_{s=-2}$$

$$=\left[\frac{d}{ds}\left(1+\frac{1}{s}\right)\right]\Bigg|_{s=-2}$$

$$=0-\frac{1}{s^2}\Bigg|_{s=-2}$$

$$B=-\frac{1}{(-2)^2}$$

$$=-\frac{1}{4}$$

Therefore, the value of B is $-\frac{1}{4}$.

Step 10 of 10

Consider expression (4).

$$\frac{s+1}{s(s+2)^2}=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{(s+2)^2}$$

Substitute $\frac{s+1}{s(s+2)^2}$ for $Y(s)$, $\frac{1}{4}$ for A, $-\frac{1}{4}$ for C and $\frac{1}{2}$ for B

$$Y(s)=\frac{1}{4s}-\frac{1}{4(s+2)}+\frac{1}{2(s+2)^2}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{Y(s)\}=\frac{1}{4}\mathcal{L}\left\{\frac{1}{s}\right\}-\frac{1}{4}\mathcal{L}\left\{\frac{1}{s+2}\right\}+\frac{1}{2}\mathcal{L}\left\{\frac{1}{(s+2)^2}\right\}$$

Apply the property $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$y(t)=\left[\frac{1}{4}-\frac{1}{4}e^{-2t}+\frac{1}{2}te^{-2t}\right]u(t)$$

Therefore, the solution of the differential equation is $\boxed{\left[\frac{1}{4}-\frac{1}{4}e^{-2t}+\frac{1}{2}te^{-2t}\right]u(t)}$.

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Step 1 of 4

Consider the integro-differential equation.

$$\frac{dy(t)}{dt}+2y(t)+\int_0^t y(\lambda)e^{-2(t-\lambda)}d\lambda=4u(t)$$

Use property 6 to 10 of Table 13.2 to find the Laplace transform of integro- differential equation.

Apply Laplace transform.

$$s\mathbf{Y}(s)-y(0)+2\mathbf{Y}(s)+\frac{\mathbf{Y}(s)}{s+2}=\frac{4}{s}$$

Substitute 1 for $y(0)$.

$$s\mathbf{Y}(s)-1+2\mathbf{Y}(s)+\frac{\mathbf{Y}(s)}{s+2}=\frac{4}{s}$$

$$\mathbf{Y}(s)\left[s+2+\frac{1}{s+2}\right]=\frac{4}{s}+1$$

$$\mathbf{Y}(s)\left[\frac{(s+2)^2+1}{s+2}\right]=\frac{s+4}{s}$$

$$\mathbf{Y}(s)=\frac{s^2+6s+8}{s(s^2+4s+5)}$$

Step 2 of 4

Resolve $Y(s)$ into partial fractions.

$$\mathbf{Y}(s)=\frac{A}{s}+\frac{Bs+C}{s^2+4s+5}$$

$$\frac{s^2+6s+8}{s(s^2+4s+5)}=\frac{A}{s}+\frac{Bs+C}{s^2+4s+5} \quad \text{..... (1)}$$

Use residue method in partial fraction expansion to find coefficient *A*

$$\begin{aligned}A&=\underset{s\to 0}{\mathrm{Lt}}\, sY(s)\\&=s\left[\frac{s^2+6s+8}{s(s^2+4s+5)}\right]\\&=\frac{8}{5}\end{aligned}$$

Step 3 of 4

To find *B* and *C*, equate coefficients of numerators of equation (1).

$$s^2+6s+8=A(s^2+4s+5)+Bs^2+Cs$$

$$s^2+6s+8=s^2(A+B)+s(4A+C)+5A$$

Equate s^2 coefficient on both sides of equation.

$$A+B=1$$

Substitute $\frac{8}{5}$ for *A* to find *B*.

$$B=-\frac{3}{5}$$

Equate s coefficient on both sides of equation.

$$4A+C=6$$

Substitute $\frac{8}{5}$ for *A* to find *C*.

$$C=-\frac{2}{5}$$

Step 4 of 4

Thus, the partial fraction expansion of $\mathbf{Y}(s)$ is,

$$\begin{aligned}\mathbf{Y}(s)&=\frac{8}{5s}-\frac{1}{5}\left[\frac{3s+2}{s^2+4s+5}\right]\\&=\frac{8}{5s}-\frac{1}{5}\left[\frac{3(s+2)-6+2}{s^2+4s+5}\right]\\&=\frac{8}{5s}-\frac{1}{5}\left[\frac{3(s+2)}{(s+2)^2+1}\right]+\frac{4}{5}\left[\frac{1}{(s+2)^2+1}\right]\end{aligned}$$

Apply inverse Laplace transform to find solution, $y(t)$.

$$y(t)=\frac{8}{5}-\frac{3}{5}e^{-2t}\cos t+\frac{4}{5}e^{-2t}\sin t$$

Therefore, the expression $y(t)$ is, $\boxed{\frac{8}{5}-\frac{3}{5}e^{-2t}\cos t+\frac{4}{5}e^{-2t}\sin t}$.

Step 1 of 2

Convolution property:

The convolution in the time domain results to multiplication in the frequency domain.

That is,

$$f_1(t) \otimes f_2(t) = \mathbf{F}_1(s)\mathbf{F}_2(s)$$

Consider the following Laplace transform function.

$$\mathbf{F}(s) = \frac{1}{s(s+2)}$$

Split $\mathbf{F}(s)$ into multiplication of two frequency domain functions. That is,

$$\mathbf{F}(s) = \mathbf{F}_1(s)\mathbf{F}_2(s)$$

Here,

$$\mathbf{F}_1(s) = \frac{1}{s}$$

$$\mathbf{F}_2(s) = \frac{1}{s+2}$$

Step 2 of 2

The inverse Laplace transform of $\mathbf{F}_1(s)$ is,

$$f_1(t) = \mathrm{L}^{-1}\left[\mathbf{F}_1(s)\right]$$
$$= u(t)$$

The inverse L

$$f_2(t) = \mathrm{L}^{-1}$$
$$= e^{-2t}$$

Use the conv

$$f(t) = \mathrm{L}^{-1}$$
$$= \int_0^t f_1$$

Substitute the

$$f(t) = \int_0^t e^{-2}$$
$$= \int_0^t e^{-2}$$
$$= e^{-2t}\int$$
$$= e^{-2t}\frac{e}{2}\Big|_0$$

is,

er.

$$e^{2t} - e^{2(0)}\Big]$$

$$-e^{-2t}\Big]u(t)$$

The inverse Laplace transform of $\mathbf{F}_2(s)$ is,

$$f_2(t) = \mathrm{L}^{-1}\left[\mathbf{F}_2(s)\right]$$
$$= e^{-2t}u(t)$$

Use the convolution integral formula.

$$f(t) = \mathrm{L}^{-1}\left[F_1(s).F_2(s)\right]$$
$$= \int_0^t f_1(\lambda) f_2(t-\lambda) d\lambda$$

Substitute the corresponding expressions.

$$f(t) = \int_0^t e^{-2(t-\lambda)} d\lambda$$
$$= \int_0^t e^{-2t} e^{2\lambda} d\lambda$$
$$= e^{-2t}\int_0^t e^{2\lambda} d\lambda$$
$$= e^{-2t}\frac{e^{2\lambda}}{}\Big|^t$$

Therefore, the inverse Laplace transform $f(t)$ of the function $\mathbf{F}(s)$ is $\boxed{\frac{1}{2}\left[1-e^{-2t}\right]u(t)}$.

Step 1 of 3

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Convolution property:

The convolution in the time domain results to multiplication in the frequency domain.

That is,

$$f_1(t) \otimes f_2(t) = \mathbf{F}_1(s)\mathbf{F}_2(s)$$

Consider the following Laplace transform function.

$$\mathbf{F}(s) = \frac{s+2}{s^2(s+1)}$$

Split $\mathbf{F}(s)$ into multiplication of two frequency domain functions. That is,

$$\mathbf{F}(s) = \mathbf{F}_1(s)\mathbf{F}_2(s)$$

Here,

$$\mathbf{F}_1(s) = \frac{s+2}{s^2}$$

$$\mathbf{F}_2(s) = \frac{1}{s+1}$$

Step 2 of 3

The inverse Laplace transform of $\mathbf{F}_1(s)$ is,

$$\begin{aligned} f_1(t) &= \mathcal{L}^{-1}\left[\mathbf{F}_1(s)\right] \\ &= \mathcal{L}^{-1}\left[\frac{1}{s} + \frac{2}{s^2}\right] \\ &= (1+2t)u(t) \end{aligned}$$

The inverse Laplace transform of $\mathbf{F}_2(s)$ is,

$$\begin{aligned} f_2(t) &= \mathcal{L}^{-1}\left[\mathbf{F}_2(s)\right] \\ &= \mathcal{L}^{-1}\left[\frac{1}{s+1}\right] \\ &= e^{-t}u(t) \end{aligned}$$

Use the convolution integral formula.

$$\begin{aligned} f(t) &= \mathcal{L}^{-1}\left[F_1(s).F_2(s)\right] \\ &= \int_0^t f_1(\lambda) f_2(t-\lambda) d\lambda \end{aligned}$$

Substitute the corresponding expressions.

$$\begin{aligned} f(t) &= \int_0^t (1+2\lambda)e^{-(t-\lambda)} d\lambda \\ &= \int_0^t e^{-(t-\lambda)} d\lambda + \int_0^t 2\lambda e^{-(t-\lambda)} d\lambda \\ &= \int_0^t e^{-t} e^{\lambda} d\lambda + 2\int_0^t \lambda e^{-t} e^{\lambda} d\lambda \\ &= e^{-t}\left\{\int_0^t e^{\lambda} d\lambda + 2\int_0^t \lambda e^{\lambda} d\lambda\right\} \end{aligned}$$

Step 3 of 3

Simplify further.

$$\begin{aligned} f(t) &= e^{-t}\left\{\left.\frac{e^{\lambda}}{1}\right|_0^t + 2\int_0^t \lambda d\left(e^{\lambda}\right) d\lambda\right\} \qquad \left\{\text{since } \int u dv = uv - \int v du\right\} \\ &= e^{-t}\left\{\left(e^t - 1\right) + 2\left[\left.\lambda e^{\lambda}\right|_0^t - \int_0^t e^{\lambda} d\lambda\right]\right\} \\ &= e^{-t}\left\{\left(e^t - 1\right) + 2\left[\left.\lambda e^{\lambda}\right|_0^t - \left.e^{\lambda}\right|_0^t\right]\right\} \end{aligned}$$

$$\begin{aligned} &= e^{-t}\left\{\left(e^t - 1\right) + \left[2te^t - 2e^t + 2\right]\right\} \\ &= 1 - e^{-t} + 2t - 2 + 2e^{-t} \\ &= \left[e^{-t} + 2t - 1\right]u(t) \end{aligned}$$

Therefore, the inverse Laplace transform $f(t)$ is $\boxed{\left[e^{-t} + 2t - 1\right]u(t)}$.

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Step 1 of 2

Consider the function.

$$\mathbf{F}(s)=\frac{1}{(s+1)(s+2)}$$

Let $\frac{1}{s+1}$ to be $\mathbf{F}_1(s)$.

$$\mathbf{F}_1(s)=\frac{1}{s+1}$$

Apply inverse Laplace transform.

$$f_1(t)=e^{-t}$$

Therefore, the inverse Laplace transform of $\frac{1}{s+1}$ is e^{-t}.

Let $\frac{1}{s+2}$ to be $\mathbf{F}_2(s)$.

$$\mathbf{F}_2(s)=\frac{1}{s+2}$$

Apply inverse Laplace transform.

$$f_2(t)=e^{-2t}$$

Therefore, the inverse Laplace transform of $\frac{1}{s+2}$ is e^{-2t}.

Step 2 of 2

Consider the formula for the convolution integral.

$$f_1(t)\otimes f_2(t)=\int_0^t f_1(\lambda)f_2(t-\lambda)d\lambda$$

Substitute $f_1(t)\otimes f_2(t)$ for $f(t)$, $e^{-\lambda}$ for $f_1(\lambda)$ and $e^{-2(t-\lambda)}$ for $f_2(t-\lambda)$ in the equation.

$$\begin{aligned}
f(t)&=\int_0^t e^{-\lambda}\cdot e^{-2(t-\lambda)}d\lambda\\
&=\int_0^t e^{-\lambda}\cdot e^{-2t}\cdot e^{2\lambda}d\lambda\\
&=e^{-2t}\int_0^t e^{-\lambda+2\lambda}d\lambda\\
&=e^{-2t}\int_0^t e^{\lambda}d\lambda
\end{aligned}$$

$$\begin{aligned}
f(t)&=e^{-2t}\left(e^{\lambda}\right)_0^t\\
&=e^{-2t}\left(e^{t}-e^{0}\right)\\
&=e^{-2t}\left(e^{t}-1\right)\\
&=\left[e^{-t}-e^{-2t}\right]u(t)
\end{aligned}$$

Therefore, the function $f(t)$ is $\boxed{\left[e^{-t}-e^{-2t}\right]u(t)}$.

Step 1 of 4

(a)

Consider the function.

$$\mathbf{F}(s)=\frac{1}{(s+1)(s+4)}$$

Let $\frac{1}{s+1}$ to be $\mathbf{F}_1(s)$.

$$\mathbf{F}_1(s)=\frac{1}{s+1}$$

Apply inverse Laplace transform.

$$f_1(t)=e^{-t}$$

Therefore, the inverse Laplace transform of $\frac{1}{s+1}$ is e^{-t}.

Let $\frac{1}{s+4}$ to be $\mathbf{F}_2(s)$.

$$\mathbf{F}_2(s)=\frac{1}{s+4}$$

Apply inverse Laplace transform.

$$f_2(t)=e^{-4t}$$

Therefore, the inverse Laplace transform of $\frac{1}{s+4}$ is e^{-4t}.

Step 2 of 4

Consider the formula for the convolution integral.

$$f_1(t)\otimes f_2(t)=\int_0^t f_1(\lambda)f_2(t-\lambda)d\lambda$$

Substitute $f_1(t)\otimes f_2(t)$ for $f(t)$ $e^{-\lambda}$ for $f_1(\lambda)$ and $e^{-4(t-\lambda)}$ for $f_2(t-\lambda)$.

$$\begin{aligned}f(t)&=\int_0^t e^{-\lambda}\cdot e^{-4(t-\lambda)}d\lambda\\&=\int_0^t e^{-\lambda}\cdot e^{-4t}\cdot e^{4\lambda}d\lambda\\&=e^{-4t}\int_0^t e^{-\lambda+4\lambda}d\lambda\\&=e^{-4t}\int_0^t e^{3\lambda}d\lambda\end{aligned}$$

$$\begin{aligned}f(t)&=e^{-4t}\left(\frac{e^{3\lambda}}{3}\right)_0^t\\&=\frac{e^{-4t}}{3}\left(e^{3t}-e^0\right)\\&=\frac{e^{-4t}}{3}\left(e^{3t}-1\right)\\&=\left[\frac{e^{-t}-e^{-4t}}{3}\right]u(t)\end{aligned}$$

Therefore, the function $f(t)$ is $\boxed{\left[\frac{e^{-t}-e^{-4t}}{3}\right]u(t)}$.

Step 3 of 4

(b)

Consider the function.

$$\mathbf{F}(s)=\frac{10}{(s+1)(s+3)^2}$$

Let $\frac{10}{s+1}$ to be $\mathbf{F}_1(s)$.

$$\mathbf{F}_1(s)=\frac{10}{s+1}$$

Apply inverse Laplace transform.

$$f_1(t)=10e^{-t}$$

Therefore, the inverse Laplace transform of $\frac{10}{s+1}$ is $10e^{-t}$.

Let $\frac{1}{(s+3)^2}$ to be $\mathbf{F}_2(s)$.

$$\mathbf{F}_2(s)=\frac{1}{(s+3)^2}$$

Apply inverse Laplace transform.

$$f_2(t)=te^{-3t}$$

Therefore, the inverse Laplace transform of $\frac{1}{(s+3)^2}$ is te^{-3t}.

Step 4 of 4

Consider the formula for the convolution integral.

$$f_1(t)\otimes f_2(t)=\int_0^t f_1(\lambda)f_2(t-\lambda)d\lambda$$

Substitute $f_1(t)\otimes f_2(t)$ for $f(t)$, $10e^{-\lambda}$ for $f_1(\lambda)$ and $(t-\lambda)e^{-3(t-\lambda)}$ for $f_2(t-\lambda)$.

$$\begin{aligned}f(t)&=\int_0^t 10e^{-\lambda}\cdot(t-\lambda)e^{-3(t-\lambda)}d\lambda\\&=\int_0^t 10e^{-\lambda}\cdot(t-\lambda)e^{-3t}e^{3\lambda}d\lambda\\&=10e^{-3t}\int_0^t e^{-\lambda+3\lambda}(t-\lambda)d\lambda\\&=10e^{-3t}\left(\int_0^t te^{2\lambda}d\lambda-\int_0^t \lambda e^{2\lambda}d\lambda\right)\end{aligned}$$

$$\begin{aligned}f(t)&=10e^{-3t}\left(t\int_0^t e^{2\lambda}d\lambda-\int_0^t \lambda e^{2\lambda}d\lambda\right)\\&=10e^{-3t}\left(t\left[\frac{e^{2\lambda}}{2}\right]_0^t-\left(\lambda\int_0^t e^{2\lambda}d\lambda-\int_0^t(\lambda)'\int e^{2\lambda}d\lambda\,d\lambda\right)\right)\\&=10e^{-3t}\left(\frac{t}{2}\left(e^{2t}-e^0\right)-\left(\frac{\lambda e^{2\lambda}}{2}\right)_0^t+\int_0^t\frac{e^{2\lambda}}{2}d\lambda\right)\\&=10e^{-3t}\left(\frac{t}{2}\left(e^{2t}-1\right)-\left(\frac{te^{2t}}{2}-0\right)+\frac{1}{2}\left[\frac{e^{2\lambda}}{2}\right]_0^t\right)\end{aligned}$$

$$\begin{aligned}f(t)&=10e^{-3t}\left(\frac{t}{2}\left(e^{2t}-1\right)-\frac{t}{2}e^{2t}+\left[\frac{e^{2t}-e^0}{4}\right]\right)\\&=\frac{10e^{-3t}}{2}\left(te^{2t}-t-te^{2t}+\frac{e^{2t}-1}{2}\right)\\&=5e^{-3t}\left(-t+\frac{e^{2t}-1}{2}\right)\\&=\left[-5te^{-3t}+2.5e^{-t}-2.5e^{-3t}\right]u(t)\end{aligned}$$

Therefore, the function $f(t)$ is $\boxed{\left[-5te^{-3t}+2.5e^{-t}-2.5e^{-3t}\right]u(t)}$.

Step 1 of 6

(a)

Consider the following Laplace transform, $\mathbf{F}(s)$ of the time function $f(t)$.

$$\mathbf{F}(s)=\frac{s+3}{s(s+2)}$$

The initial value theorem:

$$\begin{aligned} f(0) &= \lim_{t\to 0} f(t) \\ &= \lim_{s\to\infty} s\mathbf{F}(s) \end{aligned}$$

Apply the initial value theorem to find the initial value of $\mathbf{F}(s)$.

$$\begin{aligned} f(0) &= \lim_{s\to\infty} s\frac{s+3}{s(s+2)} \\ &= \lim_{s\to\infty}\frac{s+3}{(s+2)} \\ &= \lim_{s\to\infty}\frac{1+\frac{3}{s}}{1+\frac{2}{s}} \qquad \left\{\text{since } s\to\infty, \text{ then } \frac{1}{s}\to 0\right\} \\ &= \frac{1+0}{1+0} \\ &= 1 \end{aligned}$$

Therefore, the initial value $f(0)$ of $\mathbf{F}(s)$ is $\boxed{1}$.

Step 2 of 6

The final value theorem:

$$\begin{aligned} f(\infty) &= \lim_{t\to\infty} f(t) \\ &= \lim_{s\to 0} s\mathbf{F}(s) \end{aligned}$$

Obtain the poles from the transfer function.

$$s(s+2)=0$$
$$s=0, s=-2$$

The final value theorem is applicable if the poles of the transfer function $\mathbf{F}(s)$ must have negative real parts with the exception that there can be a simple pole at $s=0$.

Here, the poles are negative real parts. So, it is concluded that the final value theorem is applicable.

Apply the final value theorem to find the final value of $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\frac{s+3}{s(s+2)} \\ &= \lim_{s\to 0}\frac{s+3}{(s+2)} \\ &= \frac{0+3}{0+2} \\ &= \frac{3}{2} \end{aligned}$$

Therefore, the final value $f(\infty)$ of $\mathbf{F}(s)$ is $\boxed{\frac{3}{2}}$.

Step 3 of 6

(b)

Consider the following Laplace transform, $\mathbf{F}(s)$ of the time function $f(t)$.

$$\mathbf{F}(s)=\frac{2(s^2+2s+2)}{(s+1)(s^2+2s+6)}$$

Apply the initial value theorem to find the initial value of $\mathbf{F}(s)$.

$$\begin{aligned} f(0) &= \lim_{s\to\infty} s\frac{2(s^2+2s+2)}{(s+1)(s^2+2s+6)} \\ &= \lim_{s\to\infty}\frac{2(s^3+2s^2+2s)}{s^3+3s^2+8s+6} \\ &= \lim_{s\to\infty}\frac{2\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}{1+\frac{3}{s}+\frac{8}{s^2}+\frac{6}{s^3}} \qquad \left\{\text{since } s\to\infty, \text{ then } \frac{1}{s}\to 0\right\} \\ &= \frac{2(1+0+0)}{1+0+0+0} \\ &= 2 \end{aligned}$$

Therefore, the initial value $f(0)$ of $\mathbf{F}(s)$ is $\boxed{2}$.

Step 4 of 6

Obtain the poles from the transfer function.

$$(s+1)(s^2+2s+6)=0$$
$$s=-1, s=-1\pm j\sqrt{5}$$

The final value theorem is applicable if the poles of the transfer function $\mathbf{F}(s)$ must have negative real parts with the exception that there can be a simple pole at $s=0$.

Here, the poles are negative real parts. So, it is concluded that the final value theorem is applicable.

Apply the final value theorem to find the final value of $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\frac{2(s^2+2s+2)}{(s+1)(s^2+2s+6)} \\ &= \lim_{s\to 0}\frac{2(s^3+2s^2+2s)}{s^3+3s^2+8s+6} \\ &= \frac{2[(0)^3+2(0)^2+2(0)]}{(0)^3+3(0)^2+8(0)+6} \\ &= 0 \end{aligned}$$

Therefore, the final value $f(\infty)$ of $\mathbf{F}(s)$ is $\boxed{0}$.

Step 5 of 6

(c)

Consider the following Laplace transform, $\mathbf{F}(s)$ of the time function $f(t)$.

$$\mathbf{F}(s)=\frac{s^2+2s+1}{(s+4)(s+2)(s+6)}$$

Apply the initial value theorem to find the initial value of $\mathbf{F}(s)$.

$$\begin{aligned} f(0) &= \lim_{s\to\infty} s\frac{s^2+2s+1}{(s+4)(s+2)(s+6)} \\ &= \lim_{s\to\infty}\frac{s^3+2s^2+s}{(s+4)(s+2)(s+6)} \\ &= \lim_{s\to\infty}\frac{1+\frac{2}{s}+\frac{1}{s^2}}{\left(1+\frac{4}{s}\right)\left(1+\frac{2}{s}\right)\left(1+\frac{6}{s}\right)} \qquad \left\{\text{since } s\to\infty, \text{ then } \frac{1}{s}\to 0\right\} \\ &= \frac{1+0+0}{(1+0)(1+0)(1+0)} \\ &= 1 \end{aligned}$$

Therefore, the initial value $f(0)$ of $\mathbf{F}(s)$ is $\boxed{1}$.

Step 6 of 6

Obtain the poles from the transfer function.

$$(s+4)(s+2)(s+6)=0$$
$$s=-4, s=-2, s=-6$$

The final value theorem is applicable if the poles of the transfer function $\mathbf{F}(s)$ must have negative real parts.

Here, the poles are negative real parts. So, it is concluded that the final value theorem is applicable.

Apply the final value theorem to find the final value of $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\frac{s^2+2s+1}{(s+4)(s+2)(s+6)} \\ &= \lim_{s\to 0}\frac{s^3+2s^2+s}{(s+4)(s+2)(s+6)} \\ &= \frac{(0)^3+2(0)^2+0}{(0+4)(0+2)(0+6)} \\ &= 0 \end{aligned}$$

Therefore, the final value $f(\infty)$ of $\mathbf{F}(s)$ is $\boxed{0}$.

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Step 1 of 6

(a)

Consider the function.

$$\mathbf{F}(s)=\frac{2(s+2)}{s(s+1)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{2(s+2)}{s(s+1)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(0)&=\lim_{s\to\infty} s\left(\frac{2(s+2)}{s(s+1)}\right)\\&=\lim_{s\to\infty}\left(\frac{2s^2\left(1+\frac{2}{s}\right)}{s^s\left(1+\frac{1}{s}\right)}\right)\\&=\lim_{s\to\infty}\left(\frac{2\left(1+\frac{2}{s}\right)}{\left(1+\frac{1}{s}\right)}\right)\\&=\frac{2\left(1+\frac{2}{\infty}\right)}{\left(1+\frac{1}{\infty}\right)}\end{aligned}$$

$$\begin{aligned}f(0)&=\frac{2(1+0)}{(1+0)}\\&=\frac{2}{1}\\&=2\end{aligned}$$

Therefore, the initial value for the function is $\boxed{2}$.

Step 2 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{2(s+2)}{s(s+1)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{2(s+2)}{s(s+1)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(\infty)&=\lim_{s\to 0} s\left(\frac{2(s+2)}{s(s+1)}\right)\\&=\lim_{s\to 0}\left(\frac{2(s+2)}{(s+1)}\right)\\&=\frac{2(0+2)}{(0+1)}\\&=\frac{2(2)}{1}\end{aligned}$$

$$f(\infty)=4$$

Therefore, the final value for the function is $\boxed{4}$.

Step 3 of 6

(b)

Consider the function.

$$\mathbf{F}(s)=\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(0)&=\lim_{s\to\infty} s\left(\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}\right)\\&=\lim_{s\to\infty}\left(\frac{2s^3\left(1+\frac{2}{s}+\frac{6}{s^2}\right)}{s^3\left(1+\frac{1}{s}\right)\left(1+\frac{2}{s}\right)\left(1+\frac{3}{s}\right)}\right)\\&=\lim_{s\to\infty}\left(\frac{2\left(1+\frac{2}{s}+\frac{6}{s^2}\right)}{\left(1+\frac{1}{s}\right)\left(1+\frac{2}{s}\right)\left(1+\frac{3}{s}\right)}\right)\\&=\frac{2\left(1+\frac{2}{\infty}+\frac{6}{\infty}\right)}{\left(1+\frac{1}{\infty}\right)\left(1+\frac{2}{\infty}\right)\left(1+\frac{3}{\infty}\right)}\end{aligned}$$

$$\begin{aligned}f(0)&=\frac{2(1+0+0)}{(1+0)(1+0)(1+0)}\\&=\frac{2(1)}{(1)(1)(1)}\\&=\frac{2}{1}\\&=2\end{aligned}$$

Therefore, the initial value for the function is $\boxed{2}$.

Step 4 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(\infty)&=\lim_{s\to 0} s\left(\frac{2(s^2+2s+6)}{(s+1)(s+2)(s+3)}\right)\\&=(0)\left(\frac{2(0+2(0)+6)}{(0+1)(0+2)(0+3)}\right)\\&=0\end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

Step 5 of 6

(c)

Consider the function.

$$\mathbf{F}(s)=\frac{2s^2}{(s+1)(s^2+2s+2)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{2s^2}{(s+1)(s^2+2s+2)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(0)&=\lim_{s\to\infty} s\left(\frac{2s^2}{(s+1)(s^2+2s+2)}\right)\\&=\lim_{s\to\infty}\left(\frac{2s^3}{s^3\left(1+\frac{1}{s}\right)\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}\right)\\&=\lim_{s\to\infty}\left(\frac{2}{\left(1+\frac{1}{s}\right)\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}\right)\\&=\frac{2}{\left(1+\frac{1}{\infty}\right)\left(1+\frac{2}{\infty}+\frac{2}{\infty}\right)}\end{aligned}$$

$$\begin{aligned}f(0)&=\frac{2}{(1+0)(1+0+0)}\\&=\frac{2}{(1)(1)}\\&=\frac{2}{1}\\&=2\end{aligned}$$

Therefore, the initial value for the function is $\boxed{2}$.

Step 6 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{2s^2}{(s+1)(s^2+2s+2)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{2s^2}{(s+1)(s^2+2s+2)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}f(\infty)&=\lim_{s\to 0} s\left(\frac{2s^2}{(s+1)(s^2+2s+2)}\right)\\&=(0)\left(\frac{2(0)}{(0+1)(0+2(0)+2)}\right)\\&=0\end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

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Step 1 of 2

(a)

Consider the function.

$$\mathbf{F}(s)=\frac{10(s+1)}{(s+2)(s-3)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{10(s+1)}{(s+2)(s-3)}$ for $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\left(\frac{10(s+1)}{(s+2)(s-3)}\right) \\ &= \lim_{s\to 0}\left(\frac{10s(s+1)}{(s+2)(s-3)}\right) \\ &= \frac{10(0)(0+1)}{(0+1)(0-3)} \\ &= 0 \end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

Step 2 of 2

(b)

Consider the function.

$$\mathbf{F}(s)=\frac{10}{s^2+4}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{10}{s^2+4}$ for $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\left(\frac{10}{s^2+4}\right) \\ &= \lim_{s\to 0}\left(\frac{10s}{s^2+4}\right) \\ &= \frac{10(0)}{(0+4)} \\ &= 0 \end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

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Step 1 of 2

(a)

Consider the function.

$$\mathbf{F}(s)=\frac{10(s+6)}{(s+2)(s-3)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{10(s+6)}{(s+2)(s-3)}$ for $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\left(\frac{10(s+6)}{(s+2)(s-3)}\right) \\ &= \lim_{s\to 0}\left(\frac{10s(s+6)}{(s+2)(s-3)}\right) \\ &= \frac{10(0)(0+6)}{(0+1)(0-3)} \\ &= 0 \end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

Step 2 of 2

(b)

Consider the function.

$$\mathbf{F}(s)=\frac{2}{s^2+4s+8}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{2}{s^2+4s+8}$ for $\mathbf{F}(s)$.

$$\begin{aligned} f(\infty) &= \lim_{s\to 0} s\left(\frac{2}{s^2+4s+8}\right) \\ &= \lim_{s\to 0}\left(\frac{2s}{s^2+4s+8}\right) \\ &= \frac{2(0)}{0+4(0)+8} \\ &= 0 \end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

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Step 1 of 6

(a)

Consider the function.

$$\mathbf{F}(s)=\frac{10(s+2)}{(s+1)(s+4)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{10(s+2)}{(s+1)(s+4)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(0)&=\lim_{s\to\infty} s\left(\frac{10(s+2)}{(s+1)(s+4)}\right)\\
&=\lim_{s\to\infty}\left(\frac{10s^2\left(1+\frac{2}{s}\right)}{s^5\left(1+\frac{1}{s}\right)\left(1+\frac{4}{s}\right)}\right)\\
&=\lim_{s\to\infty}\left(\frac{10\left(1+\frac{2}{s}\right)}{\left(1+\frac{1}{s}\right)\left(1+\frac{4}{s}\right)}\right)\\
&=\frac{10\left(1+\frac{2}{\infty}\right)}{\left(1+\frac{1}{\infty}\right)\left(1+\frac{4}{\infty}\right)}
\end{aligned}$$

$$\begin{aligned}
f(0)&=\frac{10(1+0)}{(1+0)(1+0)}\\
&=\frac{10}{1}\\
&=10
\end{aligned}$$

Therefore, the initial value for the function is $\boxed{10}$.

Step 2 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{10(s+2)}{(s+1)(s+4)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{10(s+2)}{(s+1)(s+4)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\left(\frac{10(s+2)}{(s+1)(s+4)}\right)\\
&=\lim_{s\to 0}\left(\frac{10(s)(s+2)}{(s+1)(s+4)}\right)\\
&=\frac{10(0)(0+2)}{(0+1)(0+4)}\\
&=0
\end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

Step 3 of 6

(b)

Consider the function.

$$\mathbf{F}(s)=\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(0)&=\lim_{s\to\infty} s\left(\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}\right)\\
&=\lim_{s\to\infty}\left(\frac{2s^3\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}{s^4\left(1+\frac{6}{s}\right)\left(1+\frac{4}{s}+\frac{8}{s^2}+\frac{4}{s^3}\right)}\right)\\
&=\lim_{s\to\infty}\left(\frac{2\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}{s\left(1+\frac{6}{s}\right)\left(1+\frac{4}{s}+\frac{8}{s^2}+\frac{4}{s^3}\right)}\right)\\
&=\frac{2\left(1+\frac{2}{\infty}+\frac{2}{\infty}\right)}{\infty\left(1+\frac{6}{\infty}\right)\left(1+\frac{4}{\infty}+\frac{8}{\infty}+\frac{4}{\infty}\right)}
\end{aligned}$$

$$\begin{aligned}
f(0)&=\frac{(0)\left(1+\frac{2}{\infty}+\frac{2}{\infty}\right)}{\left(1+\frac{6}{\infty}\right)\left(1+\frac{4}{\infty}+\frac{8}{\infty}+\frac{4}{\infty}\right)}\\
&=0
\end{aligned}$$

Therefore, the initial value for the function is $\boxed{0}$.

Step 4 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\left(\frac{s^2+2s+2}{(s+6)(s^3+4s^2+8s+4)}\right)\\
&=(0)\left(\frac{0+2(0)+2}{(0+6)(0+4(0)+8(0)+4)}\right)\\
&=0
\end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

Step 5 of 6

(c)

Consider the function.

$$\mathbf{F}(s)=\frac{2s}{s^2+2s+3}$$

Consider the expression for initial value of $f(t)$.

$$f(0)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{2s}{s^2+2s+3}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(0)&=\lim_{s\to\infty} s\left(\frac{2s}{s^2+2s+3}\right)\\
&=\lim_{s\to\infty}\left(\frac{2s^2}{s^2\left(1+\frac{2}{s}+\frac{3}{s^2}\right)}\right)\\
&=\lim_{s\to\infty}\left(\frac{2}{\left(1+\frac{2}{s}+\frac{3}{s^2}\right)}\right)\\
&=\frac{2}{\left(1+\frac{2}{\infty}+\frac{3}{\infty}\right)}
\end{aligned}$$

$$\begin{aligned}
f(0)&=\frac{2}{(1+0+0)}\\
&=\frac{2}{(1)(1)}\\
&=\frac{2}{1}\\
&=2
\end{aligned}$$

Therefore, the initial value for the function is $\boxed{2}$.

Step 6 of 6

Consider the function.

$$\mathbf{F}(s)=\frac{2s}{s^2+2s+3}$$

Consider the expression for initial value of $f(t)$.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{2s}{s^2+2s+3}$ for $\mathbf{F}(s)$.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\left(\frac{2s}{s^2+2s+3}\right)\\
&=(0)\left(\frac{2(0)}{(0+1)(0+2(0)+3)}\right)\\
&=0
\end{aligned}$$

Therefore, the final value for the function is $\boxed{0}$.

13.056
P

Step 1 of 7

(a)

Consider the equation is,

$$\mathbf{F}(s)=\frac{s+4}{s(s+12)(s+3)}$$

Calculate the initial value.

$$f(0^+)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{s+4}{s(s+12)(s+3)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(0^+)&=\lim_{s\to\infty} s\frac{s+4}{s(s+12)(s+3)}\\
&=\lim_{s\to\infty}\frac{s+4}{(s+12)(s+3)}\\
&=\lim_{s\to\infty}\frac{s\left(1+\frac{4}{s}\right)}{s^2\left(1+\frac{12}{s}\right)\left(1+\frac{3}{s}\right)}\\
&=\frac{\left(1+\frac{4}{\infty}\right)}{\infty\left(1+\frac{12}{\infty}\right)\left(1+\frac{3}{\infty}\right)}\\
&=0
\end{aligned}$$

Step 2 of 7

Thus, the initial value is $\boxed{0}$.

Step 3 of 7

Calculate the final value.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{s+4}{s(s+12)(s+3)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\frac{s+4}{s(s+12)(s+3)}\\
&=\lim_{s\to 0}\frac{s+4}{(s+12)(s+3)}\\
&=\lim_{s\to 0}\frac{(0+4)}{(0+12)(0+3)}\\
&=\frac{4}{36}\\
&=0.1111
\end{aligned}$$

Thus, the final value is $\boxed{0.1111}$.

Step 4 of 7

(b)

Consider the equation is,

$$\mathbf{F}(s)=\frac{s+3}{s(s^2+5s+4)}$$

Calculate the initial value.

$$f(0^+)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{s+3}{s(s^2+5s+4)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(0^+)&=\lim_{s\to\infty} s\frac{s+3}{s(s^2+5s+4)}\\
&=\lim_{s\to\infty}\frac{s+3}{(s^2+5s+4)}\\
&=\lim_{s\to\infty}\frac{s\left(1+\frac{3}{s}\right)}{s^2\left(1+\frac{5}{s}+\frac{4}{s^2}\right)}\\
&=\frac{\left(1+\frac{3}{\infty}\right)}{(\infty)\left(1+\frac{5}{\infty}+\frac{4}{\infty^2}\right)}\\
&=0
\end{aligned}$$

Thus, the initial value is $\boxed{0}$.

Step 5 of 7

Calculate the final value.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{s+3}{s(s^2+5s+4)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\frac{s+3}{s(s^2+5s+4)}\\
&=\lim_{s\to 0}\frac{s+3}{(s^2+5s+4)}\\
&=\lim_{s\to 0}\frac{0+3}{(0^2+0(s)+4)}\\
&=\frac{3}{4}
\end{aligned}$$

Thus, the final value is $\boxed{\frac{3}{4}}$.

Step 6 of 7

(c)

Consider the equation is,

$$\mathbf{F}(s)=\frac{(s^2+2s+2)}{(s+3)(s^2+4s+5)}$$

Calculate the initial value.

$$f(0^+)=\lim_{s\to\infty} s\mathbf{F}(s)$$

Substitute $\frac{(s^2+2s+2)}{(s+3)(s^2+4s+5)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(0^+)&=\lim_{s\to\infty} s\frac{(s^2+2s+2)}{(s+3)(s^2+4s+5)}\\
&=\lim_{s\to\infty}\frac{s^3\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}{s^3\left(1+\frac{3}{s}\right)\left(1+\frac{4}{s}+\frac{5}{s^2}\right)}\\
&=\lim_{s\to\infty}\frac{\left(1+\frac{2}{s}+\frac{2}{s^2}\right)}{\left(1+\frac{3}{s}\right)\left(1+\frac{4}{s}+\frac{5}{s^2}\right)}\\
&=\frac{\left(1+\frac{2}{\infty}+\frac{2}{\infty^2}\right)}{\left(1+\frac{3}{\infty}\right)\left(1+\frac{4}{\infty}+\frac{5}{\infty^2}\right)}\\
&=1
\end{aligned}$$

Thus, the initial value is $\boxed{1}$.

Step 7 of 7

Calculate the final value.

$$f(\infty)=\lim_{s\to 0} s\mathbf{F}(s)$$

Substitute $\frac{(s^2+2s+2)}{(s+3)(s^2+4s+5)}$ for $\mathbf{F}(s)$ in equation.

$$\begin{aligned}
f(\infty)&=\lim_{s\to 0} s\frac{(s^2+2s+2)}{(s+3)(s^2+4s+5)}\\
&=\lim_{s\to 0}\frac{(s^3+2s^2+2s)}{(s+3)(s^2+4s+5)}\\
&=\frac{(0^3+2(0)^2+2(0))}{(0+3)((0)^2+4(0)+5)}\\
&=0
\end{aligned}$$

Thus, the final value is $\boxed{0}$.

Step 1 of 6

Consider the Figure P13.53 from the text book.

Draw the circuit diagram at $t<0$.

Figure 1

Step 2 of 6

Calculate the value of $v_C(0^-)$ using voltage division rule.

$$\begin{aligned} v_C(0^-) &= 12\left(\frac{4\text{ k}+2\text{ k}}{4\text{ k}+2\text{ k}+3\text{ k}}\right) \\ &= 12\left(\frac{6\text{ k}}{9\text{ k}}\right) \\ &= 12\left(\frac{2}{3}\right) \\ &= 8\text{ V} \end{aligned}$$

Therefore, the value of $v_C(0^-)$ is 8 V .

Step 3 of 6

Draw the circuit diagram at $t>0$.

Figure 2

Step 4 of 6

Consider Kirchhoff's voltage law in loop-1.

$$v_C(t)-i(t)(4\text{ k}+2\text{ k})=0$$
$$v_C(t)-i(t)(6\text{ k})=0$$

Substitute $-(100\,\mu)\dfrac{dv_C(t)}{dt}$ for $i(t)$.

$$v_C(t)-\left(-(100\,\mu)\frac{dv_C(t)}{dt}\right)(6\text{ k})=0$$
$$v_C(t)+(100\,\mu)\frac{dv_C(t)}{dt}(6\text{ k})=0$$
$$v_C(t)+(0.6)\frac{dv_C(t)}{dt}=0$$

Step 5 of 6

Apply Laplace transform.

$$V_C(s)+(0.6)\left[sV_C(s)-V_C(0^-)\right]=0$$
$$V_C(s)+(0.6)sV_C(s)-(0.6)V_C(0^-)=0$$
$$V_C(s)(1+0.6s)=(0.6)V_C(0^-)$$

Substitute 8 V for $V_C(0^-)$.

$$V_C(s)\left(1+\frac{6}{10}s\right)=(0.6)(8)$$
$$V_C(s)\left(1+\frac{3}{5}s\right)=4.8$$
$$V_C(s)\frac{3}{5}\left(\frac{5}{3}+s\right)=4.8$$
$$V_C(s)=\frac{4.8}{\frac{3}{5}\left(\frac{5}{3}+s\right)}$$
$$V_C(s)=\frac{4.8(5)}{3}\left(\frac{1}{s+\frac{5}{3}}\right)$$
$$V_C(s)=8\left(\frac{1}{s+\frac{5}{3}}\right)$$

Apply inverse Laplace transform.

$$v_C(t)=8e^{-\frac{5}{3}t}u(t)$$

Therefore, the value of $v_C(t)$ at $t>0$ is $8e^{-\frac{5}{3}t}u(t)$.

Step 6 of 6

Consider the expression for $v_O(t)$ using voltage division rule.

$$\begin{aligned} v_O(t) &= v_C(t)\left(\frac{2\text{ k}}{2\text{ k}+4\text{ k}}\right) \\ &= v_C(t)\left(\frac{2\text{ k}}{6\text{ k}}\right) \\ &= v_C(t)\left(\frac{1}{3}\right) \end{aligned}$$

Substitute $8e^{-\frac{5}{3}t}u(t)$ for $v_C(t)$.

$$\begin{aligned} v_O(t) &= \left(8e^{-\frac{5}{3}t}u(t)\right)\left(\frac{1}{3}\right) \\ &= \frac{8}{3}e^{-\frac{5}{3}t}u(t)\text{ V} \end{aligned}$$

Therefore, the value of $v_O(t)$ is $\boxed{\frac{8}{3}e^{-\frac{5}{3}t}u(t)\text{ V}}$.

Step 1 of 4

Consider the Figure P13.51 from the text book.

Draw the circuit diagram at $t < 0$.

Figure 1

Step 2 of 4

Calculate the value of $v(0^-)$ using voltage division rule.

$$\begin{aligned} v(0^-) &= 12\left(\frac{6\text{ k}}{6\text{ k}+6\text{ k}}\right) \\ &= 12\left(\frac{6\text{ k}}{2(6\text{ k})}\right) \\ &= 12\left(\frac{1}{2}\right) \\ &= 6\text{ V} \end{aligned}$$

Therefore, the value of $v(0^-)$ is 6 V .

Step 3 of 4

Draw the circuit diagram at $t > 0$.

Figure 2

Step 4 of 4

Consider Kirchhoff's current law at node-1.

$$\frac{v(t)}{6\text{ k}} + (100\ \mu)\frac{dv(t)}{dt} + \frac{v(t)}{6\text{ k}} = 0$$

Apply Laplace transform.

$$\frac{V(s)}{6\text{ k}} + (100\ \mu)\left[sV(s) - V(0^-)\right] + \frac{V(s)}{6\text{ k}} = 0$$

$$\frac{V(s)}{6\text{ k}} + (100\ \mu)sV(s) - (100\ \mu)V(0^-) + \frac{V(s)}{6\text{ k}} = 0$$

$$V(s)\left(\frac{1}{6\text{ k}} + \frac{1}{6\text{ k}} + (100\mu)s\right) = (100\ \mu)V(0^-)$$

$$V(s)\left(\frac{1}{3\text{ k}} + (100\mu)s\right) = (100\ \mu)V(0^-)$$

Substitute 6 V for $V(0^-)$.

$$V(s)(100\mu)\left(\frac{1}{3(100\mu)\text{ k}} + s\right) = (100\ \mu)(6)$$

$$V(s)\left(\frac{1}{0.3} + s\right) = 6$$

$$V(s) = \frac{6}{s + \frac{1}{0.3}}$$

$$V(s) = \frac{6}{s + \frac{10}{3}}$$

Apply inverse Laplace transform.

$$v(t) = 6e^{-\frac{10}{3}t}u(t)$$

Therefore, the value of $v(t)$ at $t > 0$ is $\boxed{6e^{-\frac{10}{3}t}u(t)}$.

Step 1 of 4

Consider the Figure P13.52 from the text book.

Draw the circuit diagram at $t < 0$.

Figure 1

Step 2 of 4

Calculate the value of $i(0^-)$.

$$i(0^-) = \frac{12}{3}$$
$$= 4\text{ A}$$

Therefore, the value of $i(0^-)$ is 4 V .

Step 3 of 4

Draw the circuit diagram at $t > 0$.

Figure 1

Step 4 of 4

Consider Kirchhoff's voltage law in loop-1.

$$i(t)(6+3) + 3\frac{di(t)}{dt} = 0$$
$$i(t)(9) + 3\frac{di(t)}{dt} = 0$$

Apply Laplace transform.

$$I(s)(9) + 3\left[sI(s) - I(0^-)\right] = 0$$
$$I(s)(9) + 3sI(s) - 3I(0^-) = 0$$
$$I(s)(3) + sI(s) - I(0^-) = 0$$
$$I(s)(s+3) = I(0^-)$$

Substitute 4 A for $I(0^-)$.

$$I(s)(s+3) = 4$$
$$I(s) = \frac{4}{s+3}$$

Apply inverse Laplace transform.

$$i(t) = 4e^{-3t}u(t)$$

Therefore, the value of $i(t)$ at $t > 0$ is $\boxed{4e^{-3t}u(t)}$.

Step 1 of 10

13.060 P

Refer to the Figure 13.56 in the text book.

For $t < 0$, the switch in the circuit is closed for long time and circuit reaches steady state. Under steady state capacitor acts as open circuit and inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 10

Calculate the value of $i_L(0^-)$.

Since the current flows through the shorted switch, no current flows to the shorted inductor. Hence, $i_L(0^-) = 0\ \text{A}$.

Calculate the value of $v_C(0^-)$.

Since the terminals of the opened capacitor are shorted, the value of voltage across the capacitor is $0\ \text{V}$.

Step 3 of 10

Consider the circuit diagram at $t > 0$.

Figure 2

Step 4 of 10

Consider the Kirchhoff's current Law at node-1.

$$i_2(t) = i_1(t) - i_L(t)$$

Substitute $1\ \text{A}$ for $i_1(t)$ in the equation.

$$i_2(t) = 1 - i_L(t)$$

Apply Laplace transform.

$$\mathbf{I}_2(s) = \frac{1}{s} - \mathbf{I}_L(s)$$

Therefore, the expression for $\mathbf{I}_2(s)$ is $\frac{1}{s} - \mathbf{I}_L(s)$.

Step 5 of 10

Consider Kirchhoff's Voltage Law in loop-1.

$$3i_2(t) + \frac{1}{0.5}\int i_2(t)\,dt + (1)\frac{di_L(t)}{dt} = 0$$

Apply Laplace transform.

$$3\mathbf{I}_2(s) + \left(\frac{1}{0.5s}\right)\mathbf{I}_2(s) + \frac{v_C(0^-)}{s} + s\mathbf{I}_L(s) - \mathbf{I}_L(0^-) = 0$$

Substitute $0\ \text{V}$ for $v_C(0^-)$ and $0\ \text{A}$ for $i_L(0^-)$ in the equation.

$$3\mathbf{I}_2(s) + \left(\frac{2}{s}\right)\mathbf{I}_2(s) + \frac{0}{s} + s\mathbf{I}_L(s) - 0 = 0$$

$$3\mathbf{I}_2(s) + \left(\frac{2}{s}\right)\mathbf{I}_2(s) + s\mathbf{I}_L(s) = 0$$

$$\left(3 + \frac{2}{s}\right)\mathbf{I}_2(s) + s\mathbf{I}_L(s) = 0$$

Step 6 of 10

Substitute $\frac{1}{s} - \mathbf{I}_L(s)$ for $\mathbf{I}_2(s)$ in the equation.

$$\left(3 + \frac{2}{s}\right)\left(\frac{1}{s} - \mathbf{I}_L(s)\right) + s\mathbf{I}_L(s) = 0$$

$$\left(3 + \frac{2}{s}\right)\frac{1}{s} - \left(3 + \frac{2}{s}\right)\mathbf{I}_L(s) + s\mathbf{I}_L(s) = 0$$

$$\left(\frac{3s+2}{s}\right)\frac{1}{s} - \left(\frac{3s+2+s^2}{s}\right)\mathbf{I}_L(s) = 0$$

$$\left(\frac{3s+2}{s}\right) - \left(s^2 + 3s + 2\right)\mathbf{I}_L(s) = 0$$

$$\left(s^2 + 3s + 2\right)\mathbf{I}_L(s) = \frac{3s+2}{s}$$

$$\mathbf{I}_L(s) = \frac{3s+2}{s\left(s^2 + 3s + 2\right)}$$

$$\mathbf{I}_L(s) = \frac{3s+2}{s(s+1)(s+2)} \quad \text{..... (1)}$$

Step 7 of 10

Assume $\frac{3s+2}{s(s+1)(s+2)}$ to be $\frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+2}$.

$$\frac{3s+2}{s(s+1)(s+2)} = \frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+2} \quad \text{..... (2)}$$

Use residue's method to calculate the values of A, B and C.

Calculate the value of A

$$A = s\left(\frac{3s+2}{s(s+1)(s+2)}\right)\Bigg|_{s=0}$$

$$= \frac{3s+2}{(s+1)(s+2)}\Bigg|_{s=0}$$

$$= \frac{3(0)+2}{(0+1)(0+2)}$$

$$= \frac{2}{2}$$

$$A = 1$$

Therefore, the value of A is 1.

Step 8 of 10

Calculate the value of B.

$$B = (s+1)\left(\frac{3s+2}{s(s+1)(s+2)}\right)\Bigg|_{s=-1}$$

$$= \frac{3s+2}{s(s+2)}\Bigg|_{s=-1}$$

$$= \frac{3(-1)+2}{(-1)(-1+2)}$$

$$= \frac{-3+2}{(-1)(1)}$$

$$B = \frac{-1}{-1}$$

$$= 1$$

Therefore, the value of B is 1.

Step 9 of 10

Calculate the value of C.

$$C = (s+2)\left(\frac{3s+2}{s(s+1)(s+2)}\right)\Bigg|_{s=-2}$$

$$= \frac{3s+2}{s(s+1)}\Bigg|_{s=-2}$$

$$= \frac{3(-2)+2}{(-2)(-2+1)}$$

$$= \frac{-6+2}{(-2)(-1)}$$

$$C = \frac{-4}{2}$$

$$= -2$$

Therefore, the value of C is -2.

Therefore, the expression $\frac{3s+2}{s(s+1)(s+2)}$ is $\frac{1}{s} + \frac{1}{s+1} - \frac{2}{s+2}$

Step 10 of 10

Consider expression (1).

$$\mathbf{I}_L(s) = \frac{3s+2}{s(s+1)(s+2)}$$

Substitute $\frac{1}{s} + \frac{1}{s+1} - \frac{2}{s+2}$ for $\frac{3s+2}{s(s+1)(s+2)}$ in the equation.

$$\mathbf{I}_L(s) = \frac{1}{s} + \frac{1}{s+1} - \frac{2}{s+2}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{\mathbf{I}_L(s)\} = \mathcal{L}\left\{\frac{1}{s}\right\} + \mathcal{L}\left\{\frac{1}{s+1}\right\} - 2\mathcal{L}\left\{\frac{1}{s+2}\right\}$$

Apply the property's, $\mathcal{L}^{-1}\left\{\frac{1}{s}\right\} = 1$ and $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\} = e^{-at}$.

$$i_L(t) = \left(1 + e^{-t} - 2e^{-2t}\right)u(t)\ \text{A}$$

Therefore, the value of $i_L(t)$ is $\boxed{\left(1 + e^{-t} - 2e^{-2t}\right)u(t)\ \text{A}}$.

Step 1 of 4

Refer to Figure P13.61 in the text book.

Redraw the circuit prior to switch opened.

Figure 1

Step 2 of 4

For dc Inductor acts as a short circuit and capacitor acts as an open circuit.

The initial current passing through the inductor is,

$$i(0)=\frac{12}{1+5}$$
$$=2\text{ A}$$

The initial voltage across the capacitor is,

$$v_C(0)=5i(0)$$

Substitute 2 A for $i(0)$ in equation.

$$v_C(0)=5(2)$$
$$=10\text{ V}$$

Step 3 of 4

For $t>0$. Redraw the circuit as shown in Figure 2.

Figure 2

Step 4 of 4

Apply Kirchhoff's voltage law.

$$12u(t)=1(i(t))+0.5\frac{di(t)}{dt}+\frac{1}{2}\int_0^t i(t)+v_C(0)$$

Apply Laplace transform on both sides.

$$\frac{12}{s}=\mathbf{I}(s)+0.5s\mathbf{I}(s)-0.5i(0)+\frac{1}{2}\frac{\mathbf{I}(s)}{s}+\frac{v_C(0)}{s}$$

Substitute 10 V for $v_C(0)$ and 2 A for $i(0)$ in equation.

$$\frac{12}{s}=\mathbf{I}(s)+0.5s\mathbf{I}(s)-0.5(2)+\frac{1}{2}\frac{\mathbf{I}(s)}{s}+\frac{10}{s}$$
$$\frac{12}{s}=\mathbf{I}(s)\left(1+0.5s+\frac{1}{2s}\right)-0.5(2)+\frac{10}{s}$$
$$\mathbf{I}(s)\left(1+0.5s+\frac{1}{2s}\right)=\frac{2}{s}+1$$
$$\mathbf{I}(s)\left(\frac{2s+s^2+1}{2s}\right)=\frac{s+2}{s}$$

$$\mathbf{I}(s)=\frac{2(s+2)}{(s+1)^2}$$
$$=\frac{2(s+1)}{(s+1)^2}+\frac{(2)}{(s+1)^2}$$
$$=\frac{2}{(s+1)}+\frac{2}{(s+1)^2}$$

Apply Inverse Laplace transform on both sides.

$$i(t)=2e^{-t}+2te^{-t}$$
$$=2e^{-t}(1+t)u(t)\text{ A}$$

Therefore, the output current $i(t)$ is $\boxed{2e^{-t}(1+t)u(t)\text{ A}}$.

Step 1 of 4

Refer to Figure P13.54 in the text book for the circuit.

For $t < 0$ the switch is closed. Under steady state, inductor acts as a short circuit. Redraw the circuit by replacing the inductor with a short circuit.

Figure 1

Step 2 of 4

Determine the equivalent resistance of the network.

$$\begin{aligned} R_{eq} &= 2 + [3 \| (4+2)] \\ &= 2 + [3 \| 6] \\ &= 2 + \frac{3 \times 6}{3+6} \\ &= 4\ \Omega \end{aligned}$$

Determine the current from the source.

$$\begin{aligned} I &= \frac{12}{4} \\ &= 3\ \text{A} \end{aligned}$$

Apply current division rule to find the current, $I(0)$.

$$\begin{aligned} I(0) &= -I\left(\frac{3}{3+4+2}\right) \\ &= -(3)\left(\frac{3}{3+4+2}\right) \\ &= -1\ \text{A} \end{aligned}$$

Step 3 of 4

Redraw the circuit when the switch is open in *s*-domain.. It is a series RL circuit.

Figure 2

Step 4 of 4

Write the differential equation describing the circuit.

$$2\frac{di}{dt} + (3+4+2)i(t) = 0$$

$$2\frac{di}{dt} + 9i(t) = 0$$

Apply Laplace transform to the equation.

$$2[sI(s) - I(0)] + 9I(s) = 0$$

$$2(sI(s) + 1) + 9I(s) = 0$$

$$\begin{aligned} I(s) &= -\frac{2}{2s+9} \\ &= -\frac{1}{s+4.5} \end{aligned}$$

Consider the following inverse Laplace transform.

$$\mathcal{L}^{-1}\left(\frac{1}{s+1}\right) = e^{-at}$$

Thus, the current is $\boxed{i(t) = -e^{-4.5t}\ \text{A}}$.

Step 1 of 8

13.063 P

Consider the Figure 13.57 form the text book.

For $t<0$, the switch in the circuit is closed for long time and circuit reaches steady state. Under steady state capacitor acts as open circuit and inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Calculate the value of $i_L(0^-)$.

$$\begin{aligned} i_L(0^-) &= \frac{-24}{4+4} \\ &= \frac{-24}{8} \\ &= -3\text{ A} \end{aligned}$$

Therefore, the value of $i_L(0^-)$ is -3 A.

Calculate the value of $v_C(0^-)$.

$$v_C(0^-) = 6+24+4i_L(0^-)$$

Substitute -3 A for $i_L(0^-)$ in the equation.

$$\begin{aligned} v_C(0^-) &= 6+24+4(-3) \\ &= 30-12 \\ &= 18\text{ V} \end{aligned}$$

Therefore, the value of $v_C(0^-)$ is 18 V.

Step 3 of 8

Consider the circuit diagram at $t>0$.

Figure 2

Step 4 of 8

Consider Kirchhoff's Voltage Law in loop.

$$4i(t)+\frac{1}{\left(3/16\right)}\int i(t)\,dt+\left(\frac{2}{3}\right)\frac{di(t)}{dt}=6$$

Apply Laplace transform.

$$4\mathbf{I}(s)+\left(\frac{16}{3s}\right)\mathbf{I}(s)+\frac{v_C(0^-)}{s}+\frac{2}{3}s\mathbf{I}(s)-\frac{2}{3}\mathbf{I}(0^-)=\frac{6}{s}$$

Substitute 18 V for $v_C(0^-)$ and -3 A for $i_L(0^-)$ in the equation.

$$4\mathbf{I}(s)+\left(\frac{16}{3s}\right)\mathbf{I}(s)+\frac{18}{s}+\frac{2}{3}s\mathbf{I}(s)-\frac{2}{3}(-3)=\frac{16}{s}$$

$$4\mathbf{I}(s)+\left(\frac{16}{3s}\right)\mathbf{I}(s)+\frac{18}{s}+\frac{2}{3}s\mathbf{I}(s)+2=\frac{6}{s}$$

$$\mathbf{I}(s)\left(4+\frac{16}{3s}+\frac{2}{3}s\right)=\frac{6}{s}-\frac{18}{s}-2$$

Step 5 of 8

On further simplification:

$$\mathbf{I}(s)\left(\frac{12s+16+2s^2}{3s}\right)=\frac{-12-2s}{s}$$

$$\mathbf{I}(s)\left(\frac{12s+16+2s^2}{3}\right)=(-2)(s+6)$$

$$\mathbf{I}(s)\left(\frac{s^2+6s+8}{3}\right)=(-1)(s+6)$$

$$\mathbf{I}(s)\left(s^2+6s+8\right)=(-3)(s+6)$$

$$\begin{aligned} \mathbf{I}(s) &= \frac{(-3)(s+6)}{s^2+6s+8} \\ &= \frac{(-3)(s+6)}{(s+2)(s+4)} \end{aligned}$$

$$\mathbf{I}(s)=\frac{(-3)(s+6)}{(s+2)(s+4)} \quad \text{..... (1)}$$

Assume $\frac{(-3)(s+6)}{(s+2)(s+4)}$ to be $\frac{A}{s+2}+\frac{B}{s+4}$.

$$\frac{(-3)(s+6)}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+4} \quad \text{..... (2)}$$

Step 6 of 8

Use residue's method to calculate the values of A and B.

Calculate the value of A

$$\begin{aligned} A &= (s+2)\left(\frac{(-3)(s+6)}{(s+2)(s+4)}\right)\Bigg|_{s=-2} \\ &= \frac{(-3)(s+6)}{(s+4)}\Bigg|_{s=-2} \\ &= \frac{(-3)(-2+6)}{(-2+4)} \\ &= \frac{(-3)(4)}{(2)} \end{aligned}$$

$$\begin{aligned} A &= \frac{(-3)(2)}{1} \\ &= -6 \end{aligned}$$

Therefore, the value of A is -6.

Step 7 of 8

Calculate the value of B.

$$\begin{aligned} B &= (s+4)\left(\frac{(-3)(s+6)}{(s+2)(s+4)}\right)\Bigg|_{s=-4} \\ &= \frac{(-3)(-4+6)}{(-4+2)}\Bigg|_{s=-4} \\ &= \frac{(-3)(2)}{(-2)} \\ &= \frac{-3}{-1} \end{aligned}$$

$$B=3$$

Therefore, the value of B is 3.

Therefore, the expression $\frac{(-3)(s+6)}{(s+2)(s+4)}$ is $-\frac{6}{s+2}+\frac{3}{s+4}$

Step 8 of 8

Consider expression (1).

$$\mathbf{I}(s)=\frac{(-3)(s+6)}{(s+2)(s+4)}$$

Substitute $-\frac{6}{s+2}+\frac{3}{s+4}$ for $\frac{(-3)(s+6)}{(s+2)(s+4)}$ in the equation.

$$\mathbf{I}(s)=-\frac{6}{s+2}+\frac{3}{s+4}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{\mathbf{I}(s)\}=-6\mathcal{L}\left\{\frac{1}{s+2}\right\}+3\mathcal{L}\left\{\frac{1}{s+4}\right\}$$

Apply the property, $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$i(t)=\left(-6e^{-2t}+3e^{-4t}\right)u(t)\text{ A}$$

Therefore, the value of $i(t)$ is $\boxed{\left(-6e^{-2t}+3e^{-4t}\right)u(t)\text{ A}}$.

Step 1 of 8

13.064
P

Refer to the Figure 13.58 in the text book.

For $t<0$, the switch in the circuit is closed for long time and circuit reaches steady state. Under steady state capacitor acts as open circuit and inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 8

Calculate the value of $i_L(0^-)$.

$$i_L(0^-)=\frac{-12}{4}$$
$$=-3\text{ A}$$

Therefore, the value of $i_L(0^-)$ is -3 A.

Calculate the value of $v_C(0^-)$.

$$v_C(0^-)=12+12$$
$$=24\text{ V}$$

Therefore, the value of $v_C(0^-)$ is 24 V.

Step 3 of 8

Consider the circuit diagram at $t>0$.

Figure 2

Step 4 of 8

Consider Kirchhoff's Voltage Law in loop.

$$(4+2+4)i(t)+\frac{1}{1}\int i(t)dt+2\frac{di(t)}{dt}=12$$

Apply Laplace transform.

$$10\mathbf{I}(s)+\frac{1}{s}\mathbf{I}(s)+\frac{v_C(0^-)}{s}+2s\mathbf{I}(s)-2\mathbf{I}(0^-)=\frac{12}{s}$$

Substitute 24 V for $v_C(0^-)$ and -3 A for $i_L(0^-)$ in the equation.

$$10\mathbf{I}(s)+\frac{1}{s}\mathbf{I}(s)+\frac{24}{s}+2s\mathbf{I}(s)-2(-3)=\frac{12}{s}$$
$$\mathbf{I}(s)\left(10+\frac{1}{s}+2s\right)=\frac{12}{s}-\frac{24}{s}-6$$
$$\mathbf{I}(s)\left(\frac{10s+1+2s^2}{s}\right)=\frac{-12-6s}{s}$$
$$\mathbf{I}(s)\left(10s+1+2s^2\right)=-12-6s$$

Step 5 of 8

On further simplification:

$$\mathbf{I}(s)(2)\left(s^2+5s+0.5\right)=(-6)(s+2)$$
$$\mathbf{I}(s)\left(s^2+5s+0.5\right)=(-3)(s+2)$$
$$\mathbf{I}(s)=\frac{(-3)(s+2)}{s^2+5s+0.5}$$
$$\mathbf{I}(s)=\frac{(-3)(s+2)}{(s+0.1)(s+4.9)}\quad\text{..... (1)}$$

Assume $\frac{(-3)(s+2)}{(s+0.102)(s+4.898)}$ to be $\frac{A}{s+0.102}+\frac{B}{s+4.898}$.

$$\frac{(-3)(s+2)}{(s+0.102)(s+4.898)}=\frac{A}{s+0.102}+\frac{B}{s+4.898}\quad\text{..... (2)}$$

Step 6 of 8

Use residue's method to calculate the values of A and B.
Calculate the value of A

$$A=(s+0.102)\left(\frac{(-3)(s+2)}{(s+0.102)(s+4.898)}\right)\Bigg|_{s=-0.102}$$
$$=\frac{(-3)(s+2)}{(s+4.898)}\Bigg|_{s=-0.102}$$
$$=\frac{(-3)(-0.102+2)}{(-0.102+4.898)}$$
$$=\frac{(-3)(1.898)}{(4.798)}$$
$$A=\frac{-5.694}{4.789}$$
$$=-1.189$$

Therefore, the value of A is -1.189.

Step 7 of 8

Calculate the value of B.

$$B=(s+4.898)\left(\frac{(-3)(s+2)}{(s+0.102)(s+4.898)}\right)\Bigg|_{s=-4.898}$$
$$=\frac{(-3)(-4.898+2)}{(-4.898+0.102)}\Bigg|_{s=-4.9}$$
$$=\frac{(-3)(-2.898)}{(-4.798)}$$
$$=\frac{8.698}{-4.798}$$
$$B=-1.812$$

Therefore, the value of B is -1.812.

Therefore, the expression $\frac{(-3)(s+2)}{(s+0.1)(s+4.9)}$ is $-\frac{1.189}{s+0.1}-\frac{1.812}{s+4.9}$

Step 8 of 8

Consider expression (1).

$$\mathbf{I}(s)=\frac{(-3)(s+2)}{(s+0.1)(s+4.9)}$$

Substitute $-\frac{1.189}{s+0.102}-\frac{1.812}{s+4.898}$ for $\frac{(-3)(s+2)}{(s+0.102)(s+4.898)}$ in the equation.

$$\mathbf{I}(s)=-\frac{1.189}{s+0.102}-\frac{1.812}{s+4.898}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{\mathbf{I}(s)\}=-1.189\mathcal{L}\left\{\frac{1}{s+0.102}\right\}-1.812\mathcal{L}\left\{\frac{1}{s+4.898}\right\}$$

Apply the property, $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$i(t)=\left(-1.189e^{-0.102t}-1.812e^{-4.898t}\right)u(t)\text{ A}$$

Therefore, the value of $i(t)$ is $\boxed{\left(-1.189e^{-0.102t}-1.812e^{-4.898t}\right)u(t)\text{ A}}$.

Step 1 of 7

13.065 P

Refer to the Figure 13.59 in the text book.

For $t<0$, the switch in the circuit is closed for long time and circuit reaches steady state. Under steady state capacitor acts as open circuit and inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 7

Calculate the value of $i_L(0^-)$.

$$i_L(0^-)(5+5)-10-20=0$$
$$i_L(0^-)(10)-30=0$$
$$i_L(0^-)-3=0$$
$$i_L(0^-)=3\text{ A}$$

Therefore, the value of $i_L(0^-)$ is 3 A.

Calculate the value of $v_C(0^-)$.

$$v_C(0^-)=5i_L(0^-)-10$$

Substitute 3 A for $i_L(0^-)$.

$$\begin{aligned} v_C(0^-)&=5(3)-10\\ &=15-10\\ &=5\text{ V}\end{aligned}$$

Therefore, the value of $v_C(0^-)$ is 5 V.

Step 3 of 7

Consider the circuit diagram at $t>0$.

Figure 2

Step 4 of 7

Consider Kirchhoff's Voltage Law in loop.

$$(5+5)i(t)+\frac{1}{0.04}\int i(t)dt+\frac{di(t)}{dt}=10$$

Apply Laplace transform.

$$10\mathbf{I}(s)+\frac{25}{s}\mathbf{I}(s)+\frac{v_C(0^-)}{s}+s\mathbf{I}(s)-\mathbf{I}(0^-)=\frac{10}{s}$$

Substitute 5 V for $v_C(0^-)$ and 3 A for $i_L(0^-)$ in the equation.

$$10\mathbf{I}(s)+\frac{25}{s}\mathbf{I}(s)+\frac{5}{s}+s\mathbf{I}(s)-3=\frac{10}{s}$$
$$\mathbf{I}(s)\left(10+\frac{25}{s}+s\right)+\frac{5}{s}-3=\frac{10}{s}$$
$$\mathbf{I}(s)\left(\frac{s^2+10s+25}{s}\right)=\frac{10}{s}-\frac{5}{s}+3$$
$$\mathbf{I}(s)\left(\frac{s^2+10s+25}{s}\right)=\frac{5+3s}{s}$$
$$\mathbf{I}(s)=\frac{3s+5}{(s+5)^2}\quad\text{..... (1)}$$

Step 5 of 7

Assume $\frac{3s+5}{(s+5)^2}$ to be $\frac{A}{s+5}+\frac{B}{(s+5)^2}$.

$$\frac{3s+5}{(s+5)^2}=\frac{A}{s+5}+\frac{B}{(s+5)^2}\quad\text{..... (2)}$$

Use residue's method to calculate the values of A and B.

Calculate the value of A

$$\begin{aligned} A&=(s+5)^2\left(\frac{3s+5}{(s+5)^2}\right)\Bigg|_{s=-5}\\ &=3s+5\big|_{s=-5}\\ &=3(-5)+5\\ &=-15+5\end{aligned}$$
$$A=-10$$

Therefore, the value of A is -10.

Step 6 of 7

Calculate the value of B.

$$\begin{aligned} B&=\frac{d}{ds}(s+5)^2\left(\frac{3s+5}{(s+5)^2}\right)\Bigg|_{s=-5}\\ &=\frac{d}{ds}3s+5\big|_{s=-5}\\ &=3\end{aligned}$$

Therefore, the value of B is 3.

Therefore, the expression $\frac{3s+5}{(s+5)^2}$ is $-\frac{10}{s+5}+\frac{3}{(s+5)^2}$

Step 7 of 7

Consider expression (1).

$$\mathbf{I}(s)=\frac{3s+5}{(s+5)^2}$$

Substitute $-\frac{10}{s+5}+\frac{3}{(s+5)^2}$ for $\frac{3s+5}{(s+5)^2}$ in the equation.

$$\mathbf{I}(s)=-\frac{10}{s+5}+\frac{3}{(s+5)^2}$$

Apply inverse Laplace transform.

$$\mathbf{L}\{\mathbf{I}(s)\}=-10\mathbf{L}\left\{\frac{1}{s+5}\right\}+3\mathbf{L}\left\{\frac{1}{(s+5)^2}\right\}$$

Apply the property's, $\mathbf{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$ and $\mathbf{L}^{-1}\left\{\frac{1}{(s+a)^2}\right\}=te^{-at}$.

$$i(t)=\left(-10e^{-5t}+3te^{-5t}\right)u(t)\text{ A}$$

Therefore, the value of $i(t)$ is $\boxed{\left(-10e^{-5t}+3te^{-5t}\right)u(t)\text{ A}}$.

Step 1 of 9

13.066
P

Refer to the Figure 13.60 in the text book.

For $t<0$, the left side switch in the circuit is closed for long time and right side is open circuit, circuit reaches steady state. Under steady state capacitor acts as open circuit and inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 9

Calculate the value of $i_L(0^-)$.

$$i_L(0^-)=\frac{12}{8}$$
$$=1.5\text{ A}$$

Therefore, the value of $i_L(0^-)$ is 1.5 A .

The value of the voltage $v_C(0^-)$ is 0 V since, the terminals of switch are opened.

Step 3 of 9

Consider the circuit diagram at $t>0$.

Figure 2

Step 4 of 9

Consider Kirchhoff's Voltage Law in loop.

$$3i(t)+\frac{1}{\left(\frac{1}{4}\right)}\int i(t)\,dt+\frac{1}{2}\frac{di(t)}{dt}=6$$

Apply Laplace transform.

$$3\mathbf{I}(s)+\frac{4}{s}\mathbf{I}(s)+\frac{v_C(0^-)}{s}+\frac{1}{2}s\mathbf{I}(s)-\frac{1}{2}\mathbf{I}(0^-)=\frac{6}{s}$$

Substitute 0 V for $v_C(0^-)$ and 1.5 A for $i_L(0^-)$ in the equation.

$$3\mathbf{I}(s)+\frac{4}{s}\mathbf{I}(s)+\frac{0}{s}+\frac{1}{2}s\mathbf{I}(s)-\frac{1}{2}(1.5)=\frac{6}{s}$$
$$\mathbf{I}(s)\left(3+\frac{4}{s}+\frac{s}{2}\right)-\frac{1.5}{2}=\frac{6}{s}$$
$$\mathbf{I}(s)\left(\frac{s^2+6s+8}{2s}\right)=\frac{6}{s}+\frac{1.5}{2}$$
$$\mathbf{I}(s)\left(\frac{s^2+6s+8}{2s}\right)=\frac{12+1.5s}{2s}$$

Step 5 of 9

On further simplification:

$$\mathbf{I}(s)\left(s^2+6s+8\right)=12+1.5s$$
$$\mathbf{I}(s)=\frac{1.5(s+8)}{s^2+6s+8}$$
$$\mathbf{I}(s)=\frac{1.5(s+8)}{(s+2)(s+4)}\quad\text{..... (1)}$$

Assume $\frac{1.5(s+8)}{(s+2)(s+4)}$ to be $\frac{A}{s+2}+\frac{B}{s+4}$.

$$\frac{1.5(s+8)}{(s+2)(s+4)}=\frac{A}{s+2}+\frac{B}{s+4}\quad\text{..... (2)}$$

Step 6 of 9

Use residue's method to calculate the values of A and B .
Calculate the value of A .

$$A=(s+2)\left(\frac{1.5(s+8)}{(s+2)(s+4)}\right)\Bigg|_{s=-2}$$
$$=\frac{1.5(s+8)}{(s+4)}\Bigg|_{s=-2}$$
$$=\frac{1.5(-2+8)}{(-2+4)}$$
$$=\frac{1.5(6)}{(2)}$$
$$A=1.5(3)$$
$$=4.5$$

Therefore, the value of A is 4.5 .

Step 7 of 9

Calculate the value of B .

$$B=(s+4)\left(\frac{1.5(s+8)}{(s+2)(s+4)}\right)\Bigg|_{s=-4}$$
$$=\frac{1.5(s+8)}{(s+2)}\Bigg|_{s=-4}$$
$$=\frac{1.5(-4+8)}{(-4+2)}$$
$$=\frac{1.5(4)}{(-2)}$$
$$B=1.5(-2)$$
$$=-3$$

Therefore, the value of B is -3 .

Therefore, the expression $\frac{1.5(s+8)}{s^2+6s+8}$ is $\frac{4.5}{s+2}-\frac{3}{s+4}$

Step 8 of 9

Consider expression (1).

$$\mathbf{I}(s)=\frac{1.5(s+8)}{s^2+6s+8}$$

Substitute $\frac{4.5}{s+2}-\frac{3}{s+4}$ for $\frac{1.5(s+8)}{s^2+6s+8}$ in the equation.

$$\mathbf{I}(s)=\frac{4.5}{s+2}-\frac{3}{s+4}$$

Apply inverse Laplace transform.

$$\mathcal{L}\{\mathbf{I}(s)\}=4.5\mathcal{L}\left\{\frac{1}{s+2}\right\}-3\mathcal{L}\left\{\frac{1}{s+4}\right\}$$

Apply the property, $\mathcal{L}^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$.

$$i(t)=\left(4.5e^{-2t}-3e^{-4t}\right)u(t)\text{ A}$$

Therefore, the value of $i(t)$ is $\left(4.5e^{-2t}-3e^{-4t}\right)u(t)\text{ A}$.

Step 9 of 9

Calculate the value of $v_O(t)$.

$$v_O(t)=3i(t)$$

Substitute $\left(4.5e^{-2t}-3e^{-4t}\right)u(t)\text{ A}$ for $i(t)$.

$$v_O(t)=3\left(4.5e^{-2t}-3e^{-4t}\right)u(t)$$
$$=\left(13.5e^{-2t}-9e^{-4t}\right)u(t)\text{ V}$$

Therefore, the value of $v_O(t)$ is $\boxed{\left(13.5e^{-2t}-9e^{-4t}\right)u(t)\text{ V}}$.

Step 1 of 2

14.001 E

Refer to the waveform in textbook Figure E15.1.

The time period (T_0) of the waveform is,

$$\begin{aligned} T_0 &= \frac{2\pi}{\omega_0} \\ &= \frac{2\pi}{2\pi(f)} \\ &= \frac{2\pi}{2\pi(0.5)} \\ &= 2 \end{aligned}$$

Find the Fourier coefficients of the waveform.

$$\begin{aligned} c_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)\,dt \\ &= \frac{1}{2}\int_{-1}^{0} 0\,dt + \frac{1}{2}\int_{0}^{1} 1\,dt \\ &= \frac{1}{2}t\Big|_0^1 \\ &= \frac{1}{2} \end{aligned}$$

Therefore we have $c_0 = \frac{1}{2}$.

Step 2 of 2

Find the Fourier coefficient c_n.

$$\begin{aligned} c_n &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{2}\int_{-1}^{0}(0)e^{-jn\omega_0 t}\,dt + \frac{1}{2}\int_{0}^{1}(1)e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{2}\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Bigg|_0^1 \end{aligned}$$

Angular frequency is,

$$\begin{aligned} \omega_0 &= 2\pi f \\ &= 2\pi(0.5) \\ &= \pi \end{aligned}$$

Substitute π for ω_0 in the equation.

$$\begin{aligned} c_n &= \left(\frac{1}{2}\right)\frac{e^{-jn\pi t}}{-jn\pi}\Bigg|_0^1 \\ &= \frac{1-e^{-jn\pi}}{2j\pi n} \end{aligned}$$

Therefore Fourier coefficient c_n is $\frac{1-e^{-jn\pi}}{2j\pi n}$.

Therefore the Fourier coefficients for the waveform are $\boxed{c_0 = \frac{1}{2}}$ and $\boxed{c_n = \frac{1-e^{-jn\pi}}{j2\pi n}}$.

14.002
E

Step 1 of 3

Consider the differential equation.

$$2\frac{d^2v(t)}{dt^2}+4\frac{dv(t)}{dt}+4v(t)=12u(t) \quad t>0$$

Apply Laplace transform on both sides of the differential equation.

$$2s^2\mathbf{V}(s)+4s\mathbf{V}(s)+4\mathbf{V}(s)=\frac{12}{s}$$

$$\mathbf{V}(s)\left[2s^2+4s+4\right]=\frac{12}{s}$$

$$\mathbf{V}(s)\left[s^2+2s+2\right]=\frac{6}{s}$$

$$\mathbf{V}(s)=\frac{6}{s\left(s^2+2s+2\right)}$$

Simplify the expression further.

$$\mathbf{V}(s)=\frac{6}{s(s+1-j)(s+1+j)}$$

Step 2 of 3

Apply partial fraction rule.

$$\frac{6}{s(s+1-j)(s+1+j)}=\frac{A}{s}+\frac{B}{s+1-j}+\frac{B^*}{s+1+j}$$

Calculate the value of A.

$$\begin{aligned}A&=\frac{6}{s(s+1-j)(s+1+j)}s\Big|_{s=0}\\&=\frac{6}{(0+1-j)(0+1+j)}\\&=\frac{6}{2}\\&=3\end{aligned}$$

Calculate the value of B.

$$\begin{aligned}B&=\frac{6}{s(s+1-j)(s+1+j)}(s+1-j)\Big|_{s=-1+j}\\&=\frac{6}{(-1+j)(-1+j+1+j)}\\&=\frac{6}{-2j-2}\\&=2.12\angle 135^\circ\end{aligned}$$

Calculate the value of B^*.

$$\begin{aligned}B^*&=\frac{6}{s(s+1-j)(s+1+j)}(s+1+j)\Big|_{s=-1-j}\\&=\frac{6}{(-1-j)(-1-j+1-j)}\\&=\frac{6}{2j-2}\\&=2.12\angle -135^\circ\end{aligned}$$

Step 3 of 3

Therefore, the transfer function is,

$$\mathbf{V}(s)=\frac{3}{s}+\frac{2.12\angle 135^\circ}{s+1-j}+\frac{2.12\angle -135^\circ}{s+1+j}$$

Apply inverse Laplace transform.

$$L^{-1}\left[\mathbf{V}(s)\right]=L^{-1}\left[\frac{3}{s}\right]+L^{-1}\left\{\frac{2.12\angle 135^\circ}{s+1-j}+\frac{2.12\angle -135^\circ}{s+1+j}\right\}$$

$$\begin{aligned}v(t)&=3u(t)+2|2.12|e^{-t}\cos(t+135^\circ)u(t)\\&=\left\{3+4.24e^{-t}\cos(t+135^\circ)\right\}u(t)\end{aligned}$$

Simplify the expression further.

$$\begin{aligned}v(t)&=3+4.24e^{-t}\left\{\cos t\cos 135^\circ-\sin t\sin 135^\circ\right\}\\&=3+4.24e^{-t}\left\{\cos t\left[-\frac{1}{\sqrt{2}}\right]-\sin t\left[\frac{1}{\sqrt{2}}\right]\right\}\\&=3-\frac{4.24}{\sqrt{2}}e^{-t}\cos t-\frac{4.24}{\sqrt{2}}e^{-t}\sin t\\&=K_1+K_2e^{-t}\cos t+K_3e^{-t}\sin t\end{aligned}$$

Therefore, the correct option is, $\boxed{\text{d}}$.

Step 1 of 5

Refer to Figure P14.1 in the textbook for the circuit diagram.

The *s*-domain representation of the capacitor C is, $\frac{1}{sC}$ and the *s*-domain representation of the capacitor L is, sL .

The *s*-domain equivalent of the circuit is shown in Figure 1.

Figure 1

Step 2 of 5

The modified circuit of the Figure 1 with the indication of impedances $\mathbf{Z}_1$ and $\mathbf{Z}_2$ is shown in Figure 2.

Figure 2

Step 3 of 5

Calculate the equivalent impedance, $\mathbf{Z}_1$.

$$\begin{aligned}\mathbf{Z}_1 &= 2+\left[1\|(2+2s)\right]\\ &= 2+\left[\frac{(1)(2+2s)}{1+2+2s}\right]\\ &= 2+\frac{2+2s}{3+2s}\end{aligned}$$

Simplify further.

$$\begin{aligned}\mathbf{Z}_1 &= \frac{2(3+2s)+2+2s}{3+2s}\\ &= \frac{6+4s+2+2s}{3+2s}\\ &= \frac{8+6s}{3+2s}\end{aligned}$$

Step 4 of 5

Calculate the equivalent impedance, $\mathbf{Z}_2$.

$$\begin{aligned}\mathbf{Z}_2 &= 1\|\frac{1}{s}\\ &= \frac{1\frac{1}{s}}{1+\frac{1}{s}}\\ &= \frac{\frac{1}{s}}{\frac{s+1}{s}}\\ &= \frac{1}{s+1}\end{aligned}$$

Step 5 of 5

Now the total equivalent impedance or input impedance is,

$$\mathbf{Z}(s) = \mathbf{Z}_1 \| \mathbf{Z}_2$$

Substitute $\frac{8+6s}{3+2s}$ for $\mathbf{Z}_1$ and $\frac{1}{s+1}$ for $\mathbf{Z}_2$.

$$\begin{aligned}\mathbf{Z}(s) &= \left(\frac{8+6s}{3+2s}\right)\|\left(\frac{1}{s+1}\right)\\ &= \frac{\left(\frac{8+6s}{3+2s}\right)\left(\frac{1}{s+1}\right)}{\left(\frac{8+6s}{3+2s}\right)+\left(\frac{1}{s+1}\right)}\\ &= \frac{8+6s}{(8+6s)(s+1)+(3+2s)}\\ &= \frac{8+6s}{6s^2+16s+11}\end{aligned}$$

Therefore, the input impedance $\mathbf{Z}(s)$ of the circuit is, $\boxed{\frac{8+6s}{6s^2+16s+11}}$.

Step 1 of 2

Refer to Figure 14PFE-2 in the textbook for the circuit diagram.

The *s*-domain representation of the circuit is shown in Figure 1.

Figure 1

Step 2 of 2

Calculate the output voltage by using the voltage division rule.

$$\mathbf{V}_o(s)=\left(\frac{2}{2+2s+\frac{4}{s}}\right)\mathbf{V}_s(s)$$

Now, the transfer function is,

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_s(s)}=\frac{2s}{2s+2s^2+4}$$

$$=\frac{s}{s^2+s+2}$$

Therefore, the correct option is, $\boxed{\text{c}}$.

Step 1 of 3

14.003 E

Refer to Figure E14.3 in the textbook.

There exists a current source between the two loops forming a super mesh

Apply Kirchhoff's current law to the super mesh.

$$I_1(s)\left(\frac{1}{s}\right)+I_1(s)(2)+I_2(s)(s)-\frac{12}{s}+I_2(s)(2)=0$$

$$(1+2s)I_1(s)+\left(s^2+2s\right)I_2(s)=12 \quad \text{..... (1)}$$

The equation for currents inside the super mesh is,

$$I_1(s)-I_2(s)=-\frac{2}{s} \quad \text{..... (2)}$$

Multiply equation (2) by $(1+2s)$ and subtract from equation (1) to find the value of $I_2(s)$.

$$I_2(s)\left(\left(s^2+2s\right)+(1+2s)\right)=12+\frac{2}{s}(1+2s)$$

$$I_2(s)=\frac{12s+2+4s}{s\left(s^2+4s+1\right)}$$

$$I_2(s)=\frac{16s+2}{s\left(s^2+4s+1\right)} \quad \text{..... (3)}$$

Step 2 of 3

Resolve equation (3) into partial fractions.

$$\begin{aligned} I_2(s) &= \frac{16s+2}{s(s+3.732)(s+0.268)} \\ &= \frac{K_1}{s}+\frac{K_2}{s+3.732}+\frac{K_3}{0.268} \end{aligned}$$

The value of K_1 is,

$$\begin{aligned} K_1 &= \left.\frac{16s+2}{(s+3.732)(s+0.268)}\right|_{s=0} \\ &= 2 \end{aligned}$$

The value of K_2 is,

$$\begin{aligned} K_2 &= \left.\frac{16s+2}{s(s+3.732)(s+0.268)}\right|_{s=-3.732} \\ &= -4.46 \end{aligned}$$

The value of K_3 is,

$$\begin{aligned} K_3 &= \left.\frac{16s+2}{s(s+3.732)(s+0.268)}\right|_{s=-0.268} \\ &= 2.46 \end{aligned}$$

The expression for $I_2(s)$ is,

$$I_2(s)=\frac{2}{s}-\frac{4.46}{s+3.732}+\frac{2.46}{0.268} \quad \text{..... (4)}$$

Step 3 of 3

Apply inverse Laplace transform to equation (4).

$$i_2(t)=2-4.464e^{-3.732t}+2.46e^{-0.268t}\ \text{A} \qquad ,t>0$$

The voltage across the 2Ω, $V_0(t)$, is,

$$\begin{aligned} V_0(t) &= 2i_2(t) \\ &= 2\left(2-4.464e^{-3.732t}+2.46e^{-0.268t}\right) \\ &= \left(4-8.93e^{-3.73t}+4.93e^{-0.27t}\right)u(t)\ \text{V} \end{aligned}$$

Therefore, the voltage, $V_0(t)$, is $\boxed{\left(4-8.93e^{-3.73t}+4.93e^{-0.27t}\right)u(t)\ \text{V}}$.

Step 1 of 5

(a)

Refer to Figure P14.2 in the textbook for the circuit diagram.

When terminals B and B' are open circuited, the equivalent circuit diagram is shown in Figure 1.

Figure 1

Step 2 of 5

The s-domain representation of the inductor is, Ls and for capacitor it is $\frac{1}{sC}$. From the Figure 1, observe that the resistance R_2 and inductive impedance are in series. The resistance R_1 and capacitive impedance are in series. Therefore, the total impedance is,

$$\begin{aligned}\mathbf{Z}(s) &= \left(\frac{1}{sC}+R_1\right)\|(sL+R_2)\\ &= \frac{\left(\frac{1}{sC}+R_1\right)(sL+R_2)}{R_1+R_2+sL+\frac{1}{sC}}\\ &= \frac{\left(\frac{1}{s(1)}+2\right)(s(2)+1)}{2+1+s(2)+\frac{1}{s(1)}}\end{aligned}$$

Simplify further.

$$\begin{aligned}\mathbf{Z}(s) &= \frac{\left(\frac{1}{s}+2\right)(2s+1)}{3+2s+\frac{1}{s}}\\ &= \frac{4s^2+4s+1}{2s^2+3s+1}\end{aligned}$$

Therefore, the input impedance $\mathbf{Z}(s)$ of the network is, $\boxed{\frac{4s^2+4s+1}{2s^2+3s+1}}$.

Step 3 of 5

(b)

When terminals B and B' are short circuited, the equivalent circuit diagram is shown in Figure 2.

Figure 2

Step 4 of 5

The s-domain representation of the inductor is, Ls and for capacitor it is $\frac{1}{sC}$. From the Figure 2, observe that the resistance R_2 and capacitive impedance are in parallel. The resistance R_1 and inductive impedance are in parallel.

Step 5 of 5

Calculate the total impedance.

$$\begin{aligned}\mathbf{Z}(s) &= \left(R_2\|\frac{1}{sC}\right)+(R_1\|sL)\\ &= \frac{R_2}{1+sR_2C}+\frac{sR_1L}{R_1+sL}\\ &= \frac{1}{1+s}+\frac{4s}{2+2s}\\ &= \frac{2s+1}{s+1}\end{aligned}$$

Therefore, the input impedance $\mathbf{Z}(s)$ of the network is, $\boxed{\frac{2s+1}{s+1}}$.

Step 1 of 2

14.03FE

Refer to Figure 14PFE-3 in the textbook for the circuit diagram.

The *s*-domain representation of the circuit is shown in Figure 1.

Figure 1

Step 2 of 2

Calculate the output current by using current divider rule.

$$\mathbf{I}_o(s)=\left(\frac{s+4}{s+4+\frac{3}{s}}\right)\mathbf{I}_s(s)$$

$$\frac{\mathbf{I}_o(s)}{\mathbf{I}_s(s)}=\left(\frac{s+4}{s+4+\frac{3}{s}}\right)$$

$$=\frac{s(s+4)}{s^2+4s+3}$$

Therefore, the correct option is, $\boxed{\text{a}}$.

Step 1 of 6

Refer to Figure E14.2 in the textbook.

The Laplace transformed network is,

The value of the current circulating in loop1 is,

$$\mathbf{I}_1(s)=\frac{3}{s}$$

Apply Kirchhoff's Voltage Law to loop 2.

$$\mathbf{I}_2(s)+\frac{1}{0.5s}\left[\mathbf{I}_2(s)-\mathbf{I}_3(s)\right]+\frac{10}{s}+2s\left[\mathbf{I}_2(s)-\mathbf{I}_1(s)\right]=0$$

$$\mathbf{I}_2(s)\left[1+\frac{1}{0.5s}+2s\right]-\mathbf{I}_3(s)\left[\frac{1}{0.5s}\right]-\mathbf{I}_1(s)(2s)+\frac{10}{s}=0$$

$$\mathbf{I}_2(s)\left[1+\frac{1}{0.5s}+2s\right]-\mathbf{I}_3(s)\left[\frac{1}{0.5s}\right]-2s\left(\frac{3}{s}\right)+\frac{10}{s}=0$$

$$\mathbf{I}_2(s)\left[\frac{s+2+2s^2}{s}\right]-\mathbf{I}_3(s)\left[\frac{2}{s}\right]-6+\frac{10}{s}=0$$

$$\mathbf{I}_2(s)\left[\frac{2s^2+s+2}{s}\right]-\mathbf{I}_3(s)\left[\frac{2}{s}\right]=\frac{6s-10}{s}$$

$$\mathbf{I}_2(s)\left(2s^2+s+2\right)-\mathbf{I}_3(s)(2)=6s-10 \quad \text{..... (1)}$$

Step 2 of 6

Apply Kirchhoff's Voltage Law to loop 3.

$$2\mathbf{I}_3(s)-\frac{10}{s}+\frac{1}{0.5s}\left[\mathbf{I}_3(s)-\mathbf{I}_2(s)\right]=0$$

$$\mathbf{I}_3(s)\left[2+\frac{1}{0.5s}\right]-\mathbf{I}_2(s)\left[\frac{1}{0.5s}\right]-\frac{10}{s}=0$$

$$\mathbf{I}_3(s)\left[\frac{2s+2}{s}\right]-\mathbf{I}_2(s)\left[\frac{2}{s}\right]=\frac{10}{s}$$

$$\mathbf{I}_2(s)\left[\frac{2}{s}\right]=\mathbf{I}_3(s)\left[\frac{2s+2}{s}\right]-\frac{10}{s}$$

$$\mathbf{I}_2(s)=\mathbf{I}_3(s)\left[\frac{2s+2}{s}\right]\left(\frac{s}{2}\right)-\frac{10}{s}\left(\frac{s}{2}\right)$$

$$\mathbf{I}_2(s)=\mathbf{I}_3(s)[s+1]-5 \quad \text{..... (2)}$$

Step 3 of 6

Substitute equation (2) in equation (1).

$$\left[\mathbf{I}_3(s)(s+1)-5\right]\left(2s^2+s+2\right)-\mathbf{I}_3(s)(2)=6s-10$$

$$\mathbf{I}_3(s)\left[(s+1)\left(2s^2+s+2\right)\right]-5\left(2s^2+s+2\right)-\mathbf{I}_3(s)(2)=6s-10$$

$$\mathbf{I}_3(s)\left(2s^3+s^2+2s+2s^2+s+2-2\right)-\left(10s^2+5s+10\right)=6s-10$$

$$\mathbf{I}_3(s)\left(2s^3+3s^2+3s\right)=10s^2+5s+10+6s-10$$

$$\mathbf{I}_3(s)=\frac{10s^2+11s}{2s^3+3s^2+3s}$$

$$\mathbf{I}_3(s)=\frac{10s+11}{2s^2+3s+3}$$

Step 4 of 6

The output voltage, $\mathbf{V}_o(s)$, is,

$$\mathbf{V}_o(s)=2\mathbf{I}_3(s)$$

Substitute $\mathbf{I}_3(s)$.

$$\mathbf{V}_o(s)=\frac{2(10s+11)}{\left(2s^2+3s+3\right)}$$

$$=\frac{2(10s+11)}{2\left(s^2+1.5s+1.5\right)}$$

$$=\frac{10s+11}{s^2+1.5s+1.5}$$

Simplify the quadratic equation ' $s^2+1.5s+1.5$ 'we get,

$$s=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

$$=\frac{-1.5\pm\sqrt{1.5^2-4\times1\times1.5}}{2\times1}$$

$$=\frac{-1.5\pm\sqrt{2.25-6}}{2}$$

$$=\frac{-1.5\pm\sqrt{-3.75}}{2}$$

$$=\frac{-1.5\pm j1.94}{2}$$

$$s=-0.75\pm0.97$$

Step 5 of 6

The equation of $\mathbf{V}_o(s)$ is,

$$\mathbf{V}_o(s)=\frac{10s+11}{(s+0.75-j0.97)(s+0.75+j0.97)}$$

Resolve into partial fractions.

$$\mathbf{V}_o(s)=\frac{K_1}{(s+0.75-j0.97)}+\frac{K_1^*}{(s+0.75+j0.97)}$$

The value of K_1 is,

$$K_1=\left.\frac{10s+11}{(s+0.75+j0.97)}\right|_{s=-0.75+j0.97}$$

$$=\frac{10(-0.75+j0.97)+11}{(-0.75+j0.97+0.75+j0.97)}$$

$$=5-j1.804$$

$$=5.315\angle-19.84^\circ$$

The value of K_1^* is,

$$K_1^*=5.315\angle19.84^\circ$$

Step 6 of 6

The partial fraction expansion of $\mathbf{V}_o(s)$ is,

$$\mathbf{V}_o(s)=\frac{5.315\angle-19.84^\circ}{(s+0.75-j0.97)}+\frac{5.315\angle19.84^\circ}{(s+0.75+j0.97)}$$

$$\mathbf{V}_o(s)=\frac{5.315e^{-j19.84^\circ}}{(s+0.75-j0.97)}+\frac{5.315e^{j19.84^\circ}}{(s+0.75+j0.97)}$$

Apply inverse Laplace transform.

$$v_o(t)=\left[5.315e^{-j19.84^\circ}e^{-(0.75-j0.97)t}+5.315e^{j19.84^\circ}e^{-(0.75+j0.97)t}\right]u(t)$$

$$=\left[5.315e^{-j19.84^\circ}e^{-0.75t}e^{j0.97t}+5.315e^{j19.84^\circ}e^{-0.75t}e^{-j0.97t}\right]u(t)$$

$$=\left[5.315e^{-0.75t}\left(e^{j(0.97t-19.84^\circ)}+e^{-j(0.97t-19.84^\circ)}\right)\right]u(t)$$

$$=5.315e^{-0.75t}\left[2\cos\left(0.97t-19.84^\circ\right)\right]u(t)$$

The value of the output voltage, $\mathbf{V}_o(s)$, is

$$\boxed{v_o(t)=\left[10.63e^{-0.75t}\cos\left(0.97t-19.84^\circ\right)\right]u(t)\ \text{V}}$$

Step 1 of 6

14.004
P

Refer to Figure P14.4 in the text book for the circuit diagram.

Draw the Figure P14.4 in *s*-domain.

Figure 1

Step 2 of 6

Apply nodal analysis at node 1.

$$\frac{V_1}{6}-\frac{12}{s}+\frac{V_1-V_2}{s}=0$$

$$V_1\left(\frac{1}{6}+\frac{1}{s}\right)-V_2\left(\frac{1}{s}\right)=\frac{12}{s} \quad \text{..... (1)}$$

Apply nodal analysis at node 2.

$$\frac{V_2-V_1}{s}+V_2s+\frac{V_2}{3}=0$$

$$\frac{V_2}{s}+V_2s+\frac{V_2}{3}=\frac{V_1}{s}$$

$$V_2\left(\frac{1}{s}+s+\frac{1}{3}\right)=\frac{V_1}{s}$$

$$V_2\left(\frac{3+3s^2+s}{3s}\right)=\frac{V_1}{s}$$

$$V_1=V_2\left(\frac{3s^2+s+3}{3}\right) \quad \text{..... (2)}$$

Step 3 of 6

Substitute $V_2\left(\frac{3s^2+s+3}{3}\right)$ for V_1 in equation (1).

$$V_2\left(\frac{3s^2+s+3}{3}\right)\left(\frac{1}{6}+\frac{1}{s}\right)-V_2\left(\frac{1}{s}\right)=\frac{12}{s}$$

$$V_2\left(\frac{3s^2+s+3}{3}\right)\left(\frac{6+s}{6s}\right)-V_2\left(\frac{1}{s}\right)=\frac{12}{s}$$

$$V_2\left(\frac{(3s^2+s+3)(s+6)}{18s}-\frac{1}{s}\right)=\frac{12}{s}$$

$$V_2\left(\frac{(3s^2+s+3)(s+6)-18}{18s}\right)=\frac{12}{s}$$

$$V_2\left((3s^3+18s^2+s^2+6s+3s+18)-18\right)=216$$

$$V_2\left(3s^3+19s^2+9s\right)=216$$

$$V_2=\frac{216}{(3s^2+19s+9)s} \quad \text{..... (3)}$$

Step 4 of 6

From the Figure 1, Calculate the output voltage, $V_o(s)$.

$$V_o(s)=\left(\frac{1}{1+2}\right)V_2(s) \quad \text{..... (4)}$$

Substitute $\frac{216}{(3s^2+19s+9)s}$ for V_2 in equation (4).

$$V_o(s)=\left(\frac{1}{3}\right)\left(\frac{216}{(3s^2+19s+9)s}\right)$$

$$V_o(s)=\frac{24}{s(s^2+6.33s+3)} \quad \text{..... (5)}$$

Step 5 of 6

Use partial fractions to the output equation.

$$\frac{24}{s(s^2+6.33s+3)}=\frac{A}{s}+\frac{B}{s+0.52}+\frac{C}{s+5.82}$$

Step 6 of 6

Calculate the value of A.

$$A=\left.\frac{24}{s(s^2+6.33s+3)}s\right|_{s=0}$$

$$=\frac{24}{\left((0)^2+6.33(0)+3\right)}$$

$$=8$$

Calculate the value of B.

$$B=\left.\frac{24}{s(s+0.52)(s+5.82)}(s+0.52)\right|_{s=-0.52}$$

$$=\frac{24}{(-0.52)(-0.52+5.82)}$$

$$=-8.71$$

Calculate the value of C.

$$B=\left.\frac{24}{s(s+0.52)(s+5.82)}(s+5.82)\right|_{s=-5.82}$$

$$=\frac{24}{(-5.82)(-5.82+0.52)}$$

$$=0.77$$

Therefore, the output voltage expression is,

$$V_o(s)=\frac{8}{s}-\frac{8.71}{s+0.52}+\frac{0.77}{s+5.82} \quad \text{..... (6)}$$

Apply inverse Laplace transform.

$$v_o(s)=\left(8-8.71e^{-0.52t}+0.77e^{-5.82t}\right)u(t)$$

Therefore, the value of the output voltage is, $\boxed{\left(8-8.71e^{-0.52t}+0.77e^{-5.82t}\right)u(t)\ \text{V}}$.

Step 1 of 2

14.04E

E

Refer to Figure 14PFE-4 in the textbook for the circuit diagram.

The *s*-domain representation of the circuit is shown in Figure 1.

Figure 1

Step 2 of 2

Apply Kirchhoff's voltage law to the circuit.

$$-\mathbf{V}_s(s)+s\mathbf{I}(s)+\frac{4}{s}\mathbf{I}(s)+2\mathbf{I}(s)=0$$

$$\left(s+\frac{4}{s}+2\right)\mathbf{I}(s)=\mathbf{V}_s(s)$$

$$\mathbf{I}(s)=\frac{\mathbf{V}_s(s)}{s+\frac{4}{s}+2}$$

$$\mathbf{I}(s)=\left(\frac{s}{s^2+2s+4}\right)\mathbf{V}_s(s)$$

Now the input source voltage is, $v_s(t)=4\cos tu(t)$

The Laplace transform pf the input voltage is,

$$\mathbf{V}_s(s)=\frac{4s}{s^2+1}$$

Substitute $\frac{4s}{s^2+1}$ for $\mathbf{V}_s(s)$ in the current expression, $\mathbf{I}(s)$.

$$\mathbf{I}(s)=\left(\frac{s}{s^2+2s+4}\right)\left(\frac{4s}{s^2+1}\right)$$

$$=\frac{4s^2}{(s^2+1)(s^2+2s+4)}$$

Therefore, the correct option is, $\boxed{\text{b}}$.

Step 1 of 18

Refer to Figure E14.2 in the textbook.

The Laplace transformed circuit is,

Step 2 of 18

Step 3 of 18

Figure 1

Step 4 of 18

The output voltage is the voltage across the $2\,\Omega$ resistance.

The Thevenin's equivalent for the circuit can be calculated by removing the $2\,\Omega$ resistance.

The resulting circuit is,

Step 5 of 18

Figure 2

Step 6 of 18

From Figure 2 the current in the first loop is,

$$\mathbf{I_1}(s)=\frac{3}{s}$$

Apply Kirchhoff's Voltage Law to loop 2.

$$\mathbf{I_2}(s)+\frac{1}{0.5s}\mathbf{I_2}(s)+\frac{10}{s}+2s\left[\mathbf{I_2}(s)-\mathbf{I_1}(s)\right]=0$$

$$\mathbf{I_2}(s)\left[1+\frac{1}{0.5s}+2s\right]-\mathbf{I_1}(s)(2s)+\frac{10}{s}=0$$

$$\mathbf{I_2}(s)\left[1+\frac{1}{0.5s}+2s\right]-2s\left(\frac{3}{s}\right)+\frac{10}{s}=0$$

$$\mathbf{I_2}(s)\left[\frac{s+2+2s^2}{s}\right]-6+\frac{10}{s}=0$$

$$\mathbf{I_2}(s)\left[\frac{2s^2+s+2}{s}\right]=\frac{6s-10}{s}$$

$$\mathbf{I_2}(s)=\frac{6s-10}{2s^2+s+2}$$

Step 7 of 18

The Thevenin's equivalent voltage can be calculated as,

$$\begin{aligned}\mathbf{V_{Th}}(s)&=\frac{1}{0.5s}\mathbf{I_2}(s)+\frac{10}{s}\\&=\frac{2}{s}\left[\frac{6s-10}{2s^2+s+2}\right]+\frac{10}{s}\\&=\frac{12s-20+10\left(2s^2+s+2\right)}{s\left(2s^2+s+2\right)}\\&=\frac{12s-20+20s^2+10s+20}{s\left(2s^2+s+2\right)}\\&=\frac{20s^2+22s}{s\left(2s^2+s+2\right)}\\&=\frac{2s(10s+11)}{2s\left(s^2+0.5s+1\right)}\end{aligned}$$

$$\mathbf{V_{Th}}(s)=\frac{10s+11}{s^2+0.5s+1}$$

Step 8 of 18

The Thevenin equivalent resistance is calculated by replacing the sources in the network with their internal impedances.

Step 8 of 18

Step 10 of 18

Figure 3

Step 11 of 18

Step 12 of 18

Step 13 of 18

The equivalent impedance is,

$$\begin{aligned}\mathbf{Z_{Th}}(s)&=(1+2s)\,||\left(\frac{1}{0.5s}\right)\\&=\frac{(1+2s)\left(\frac{2}{s}\right)}{(1+2s)+\left(\frac{2}{s}\right)}\\&=\frac{\frac{2+4s}{s}}{\frac{s+2s^2+2}{s}}\\&=\frac{1+2s}{s^2+0.5s+1}\end{aligned}$$

Step 14 of 18

The Thevenin equivalent circuit is,

Figure 4

Apply voltage division rule at output.

$$\begin{aligned}\mathbf{V_o}(s)&=\mathbf{V_{Th}}(s)\times\frac{2}{2+\mathbf{Z_{Th}}(s)}\\&=\frac{10s+11}{s^2+0.5s+1}\times\frac{2}{2+\frac{1+2s}{s^2+0.5s+1}}\\&=\frac{10s+11}{s^2+0.5s+1}\times\frac{2\left(s^2+0.5s+1\right)}{2\left(s^2+0.5s+1\right)+1+2s}\\&=\frac{2(10s+11)}{2\left(s^2+0.5s+1\right)+1+2s}\\&=\frac{2(10s+11)}{2\left(s^2+0.5s+1+0.5+s\right)}\end{aligned}$$

$$\mathbf{V_o}(s)=\frac{10s+11}{s^2+1.5s+1.5}$$

Step 15 of 18

Simplify the quadratic equation ' $s^2+1.5s+1.5$ we get,

$$\begin{aligned}s&=\frac{-b\pm\sqrt{b^2-4ac}}{2a}\\&=\frac{-1.5\pm\sqrt{1.5^2-4\times1\times1.5}}{2\times1}\\&=\frac{-1.5\pm\sqrt{2.25-6}}{2}\\&=\frac{-1.5\pm\sqrt{-3.75}}{2}\\&=\frac{-1.5\pm j1.94}{2}\\s&=-0.75\pm0.97\end{aligned}$$

Step 16 of 18

The equation $\mathbf{V_o}(s)$ is,

$$\mathbf{V_o}(s)=\frac{10s+11}{(s+0.75-j0.97)(s+0.75+j0.97)}$$

Express $\mathbf{V_o}(s)$ in a partial fraction expansion.

$$\mathbf{V_o}(s)=\frac{K_1}{(s+0.75-j0.97)}+\frac{K_1^*}{(s+0.75+j0.97)}$$

The value of K_1 is.

$$\begin{aligned}K_1&=(s+0.75-j0.97)\mathbf{F}(s)\big|_{s=-0.75+j0.97}\\&=(s+0.75-j0.97)\frac{10s+11}{(s+0.75-j0.97)(s+0.75+j0.97)}\Bigg|_{s=-0.75+j0.97}\\&=\frac{10s+11}{(s+0.75+j0.97)}\Bigg|_{s=-0.75+j0.97}\\&=\frac{10(-0.75+j0.97)+11}{(-0.75+j0.97+0.75+j0.97)}\\&=\frac{-7.5+j9.7+11}{j1.94}\\&=\frac{3.5+j9.7}{j1.94}\\&=-j1.804+5\\K_1&=5-j1.804\\K_1&=5.315\angle-19.84^\circ\end{aligned}$$

Step 17 of 18

The value of K_1^* is.

$$K_1^*=5.315\angle19.84^\circ$$

The partial fraction expansion of $\mathbf{V_o}(s)$ is then

$$\mathbf{V_o}(s)=\frac{5.315\angle-19.84^\circ}{(s+0.75-j0.97)}+\frac{5.315\angle19.84^\circ}{(s+0.75+j0.97)}$$

$$\mathbf{V_o}(s)=\frac{5.315e^{-j19.84^\circ}}{(s+0.75-j0.97)}+\frac{5.315e^{j19.84^\circ}}{(s+0.75+j0.97)}$$

Step 10 of 18

Apply inverse Laplace transform.

$$\begin{aligned}v_o(t)&=\left[5.315e^{-j19.84^\circ}e^{-(0.75-j0.97)t}+5.315e^{j19.84^\circ}e^{-(0.75+j0.97)t}\right]u(t)\\&=\left[5.315e^{-j19.84^\circ}e^{-0.75t}e^{j0.97t}+5.315e^{j19.84^\circ}e^{-0.75t}e^{-j0.97t}\right]u(t)\\&=\left[5.315e^{-0.75t}\left(e^{j(0.97t-19.84^\circ)}+e^{-j(0.97t-19.84^\circ)}\right)\right]u(t)\\&=5.315e^{-0.75t}\left[2\cos\left(0.97t-19.84^\circ\right)\right]u(t)\end{aligned}$$

Thus, the value of the output voltage is,

$$\boxed{v_o(t)=\left[10.63e^{-0.75t}\cos\left(0.97t-19.84^\circ\right)\right]u(t)\ \text{V}}$$

Step 1 of 3

14.006 P

Refer to the circuit diagram in Figure E14.6 in the textbook.

Transform the circuit from the time domain to the $s-$ domain.

$$50u(t) \Rightarrow \frac{50}{s}$$

$$1\text{ F} \Rightarrow \frac{1}{sC} = \frac{1}{s}$$

The resulting $s-$ domain circuit is shown in Figure 1

Figure 1

Step 2 of 3

From the figure 1, it is clear that the current, $\mathbf{I}(s)$ flowing through the independent voltage source, $\frac{50}{s}$ is zero.

So,

$$-\frac{50}{s} + \mathbf{I} + \mathbf{V}_x = 0$$

$$\mathbf{V}_x = \frac{50}{s} \qquad \text{since } \mathbf{I} = 0$$

Apply Kirchhoff's voltage law around the loop 1.

$$0.2\mathbf{V}_x + \mathbf{I}_1 + \frac{1}{s}\mathbf{I}_1 = 0$$

Substitute $\frac{50}{s}$ for $\mathbf{V}_x$ in the equation.

$$0.2\left(\frac{50}{s}\right) + \mathbf{I}_1 + \frac{1}{s}\mathbf{I}_1 = 0$$

$$\frac{10}{s} + \mathbf{I}_1\left(1 + \frac{1}{s}\right) = 0$$

$$\mathbf{I}_1\left(1 + \frac{1}{s}\right) = -\frac{10}{s}$$

$$\mathbf{I}_1 = -\frac{10}{s+1}$$

Step 3 of 3

Apply Kirchhoff's voltage law around $\mathbf{V}_x(s)$ to $\mathbf{V}_o(s)$ through capacitor $\frac{1}{s}$.

$$-\mathbf{V}_x + \frac{1}{s}(\mathbf{I}_1) + \mathbf{V}_o = 0$$

Substitute $-\frac{10}{s+1}$ for $\mathbf{I}_1$ and $\frac{50}{s}$ for $\mathbf{V}_x$ in the equation.

$$-\frac{50}{s} + \frac{1}{s}\left(-\frac{10}{s+1}\right) + \mathbf{V}_o = 0$$

$$-\frac{50}{s} - \frac{10}{s(s+1)} + \mathbf{V}_o = 0$$

Rewrite the equation.

$$\begin{aligned}\mathbf{V}_o(s) &= \frac{50}{s} + \frac{10}{s(s+1)} \\ &= \frac{50(s+1)+10}{s(s+1)} \\ &= \frac{50s+60}{s(s+1)} \\ &= \frac{50}{s+1} + \frac{60}{s} - \frac{60}{s+1}\end{aligned}$$

Apply inverse transform.

$$v_o(t) = \left(50e^{-t} + 60 - 60e^{-t}\right)u(t) \quad t > 0$$

Step 1 of 7

Given circuit diagram:

Step 2 of 7

For $t < 0$ the switch is closed. Initially the inductor acts like a short circuit and capacitor acts like an open circuit.

Step 3 of 7

Modified circuit diagram is as follows:

Step 4 of 7

Finding the initial current $I_L(0^-)$:

$$I_L(0^-) = \frac{12}{12}$$
$$I_L(0^-) = 1 \text{ A}$$

Step 5 of 7

At $t = 0$ the switch is opened. Modified circuit diagram is as follows:

Step 6 of 7

Applying the transformation to above circuit as:

Step 7 of 7

Writing the loop equation we find the value of $I_1(t)$:

$$6I_1(s) + 12I_1(s) + 2sI_1(s) - LI_1(0^-) = 0$$
$$I_1(s)(6 + 12 + 2s) - 2(1) = 0$$
$$I_1(s)(18 + 2s) = 2$$
$$I_1(s) = \frac{2}{(18 + 2s)}$$
$$I_1(s) = \frac{1}{(s + 9)}$$

Applying the inverse Laplace transformation we get

$$\boxed{i_1(t) = 1e^{-9t}u(t)}.$$

Step 1 of 4

14.007 P

Refer to Figure P14.7 in the textbook for the circuit diagram.

Frequency domain equivalent of the circuit is shown in Figure 1.

Figure 1

Step 2 of 4

Apply Kirchhoff's voltage law to loop 1.

$$\frac{5}{s}=(1)I_1(s)+\left[\frac{1}{s}\right]\left[I_1(s)-I_2(s)\right]$$

$$I_1(s)\left[1+\frac{1}{s}\right]-I_2(s)\left[\frac{1}{s}\right]=\frac{5}{s}$$

Apply Kirchhoff's voltage law to loop 2.

$$\left[I_2(s)-I_1(s)\right]\left[\frac{1}{s}\right]+I_2(s)[2]=\frac{10}{s}$$

$$-I_1(s)\left[\frac{1}{s}\right]+I_2(s)\left[2+\frac{1}{s}\right]=\frac{10}{s}$$

Write the equations in matrices form.

$$\begin{bmatrix}1+\frac{1}{s} & -\frac{1}{s}\\ -\frac{1}{s} & 2+\frac{1}{s}\end{bmatrix}\begin{bmatrix}I_1(s)\\ I_2(s)\end{bmatrix}=\begin{bmatrix}\frac{5}{s}\\ \frac{10}{s}\end{bmatrix}$$

Step 3 of 4

Use the Cramer's rule to calculate the currents.

$$\begin{aligned}
\mathbf{I}_2(s)&=\frac{\begin{bmatrix}1+\frac{1}{s} & \frac{5}{s}\\ -\frac{1}{s} & \frac{10}{s}\end{bmatrix}}{\left(1+\frac{1}{s}\right)\left(2+\frac{1}{s}\right)-\frac{1}{s^2}}\\
&=\frac{\left[\frac{10}{s}+\frac{10}{s^2}+\frac{5}{s^2}\right]}{2+\frac{1}{s}+\frac{2}{s}+\frac{1}{s^2}-\frac{1}{s^2}}\\
&=\frac{\frac{10}{s}+\frac{15}{s^2}}{2+\frac{3}{s}}\\
&=\frac{\frac{10s+15}{s^2}}{\frac{2s+3}{s}}
\end{aligned}$$

$$\begin{aligned}
\mathbf{I}_2(s)&=\frac{5(2s+3)}{s^2}\frac{s}{2s+3}\\
&=\frac{5}{s}
\end{aligned}$$

Step 4 of 4

Calculate the voltage across the $2\,\Omega$ resistor, $\mathbf{V}(s)$.

$$\mathbf{V}(s)=2\mathbf{I}_2(s)$$

Substitute $\frac{5}{s}$ for $\mathbf{I}_2(s)$.

$$\begin{aligned}
\mathbf{V}(s)&=2\left(\frac{5}{s}\right)\\
&=\frac{10}{s}
\end{aligned}$$

Apply inverse Laplace transform.

$$v(t)=10u(t)$$

Therefore, the voltage $v(t)$ is, $\boxed{10u(t)\ \text{V}}$.

Step 1 of 3

14.008
E

Refer to Figure E7.3 in the textbook.

The circuit before the switch is opened, at $t=0^-$, in steady state is,

Apply Kirchhoff's Current Law at the output node.

$$\frac{V_0-12}{2}+\frac{V_0+4}{2}+\frac{V_0}{2}=0$$

$$V_0=\frac{8}{3}\text{ V}$$

The current $i_L(0)$ is,

$$\begin{aligned} i_L(0) &= \frac{V_o}{2} \\ &= \frac{8}{3(2)} \\ &= 1.33\text{ A} \end{aligned}$$

The current through the inductor does not change instantaneously.

The voltage developed across the 2H inductor is 2.66 volts.

Step 2 of 3

When the switch is closed, the following is the circuit for $t>0$:

Apply Kirchhoff's Voltage Law to the loop.

$$4I_L(s)+2\left[sI_L(s)-i_L(0)\right]=\frac{12}{s}$$

$$I_L(s)[2s+4]=\frac{12}{s}+2.66$$

$$I_L(s)=\frac{6+1.33s}{s(s+2)}$$

Resolve into partial fractions.

$$I_L(s)=\frac{3}{s}-\frac{1.67}{s+2}$$

Step 3 of 3

Apply inverse Laplace transform.

$$i_L(t)=\left[3-1.67e^{-2t}\right]u(t)\text{ A}$$

The output voltage is,

$$\begin{aligned} V_0(t) &= 2i_L(t) \\ &= 2\left[3-1.67e^{-2t}\right]u(t) \\ &= \left[6-3.3e^{-2t}\right]u(t)\text{ V} \end{aligned}$$

Therefore, the output voltage is $\boxed{\left[6-3.3e^{-2t}\right]u(t)\text{ V}}$.

Step 1 of 7

Refer to Figure P14.18 in the textbook.

The Laplace transformed circuit is,

Figure 1

Use source transformation in the highlighted box part of the circuit.

'Z' is the impedance in series with the voltage source transformed.

$$Z=\left(1+\frac{1}{s}\right)\Omega$$

The transformed voltage source value is,

$$V=\left(\frac{2}{s}\right)\left(1+\frac{1}{s}\right)$$

Step 2 of 7

The resulting circuit is as follows:

Figure 2

The output voltage is expressed as,

$$V_o(s)=[1][I_1(s)]\quad V_o(s)=I_1(s)\ \text{..... (1)}$$

The current is expressed as,

$$I_1(s)=\left(\frac{s}{s+2}\right)I_o(s)\ \text{..... (2)}$$

Step 3 of 7

Apply Kirchhoff's voltage law to the first loop in Figure 2.

$$I_o(s)\left[(s\|2)+Z\right]=\frac{1}{s+2}+\frac{2}{s}\left(1+\frac{1}{s}\right)$$

$$I_o(s)\left[\frac{2s}{s+2}+\left(1+\frac{1}{s}\right)\right]=\frac{1}{s+2}+\frac{2}{s}\left(1+\frac{1}{s}\right)$$

$$I_o(s)\left[\frac{2s}{s+2}+\frac{s+1}{s}\right]=\frac{1}{s+2}+\frac{2(s+1)}{s^2}$$

$$I_o(s)\left[\frac{2s^2+(s+2)(s+1)}{s(s+2)}\right]=\frac{s^2+2(s+1)(s+2)}{s^2(s+2)}$$

$$I_o(s)=\frac{s^2+2s^2+6s+4}{s\left(2s^2+s^2+3s+2\right)}$$

$$I_o(s)=\frac{3s^2+6s+4}{s\left(3s^2+3s+2\right)}\ \text{..... (3)}$$

Step 4 of 7

From equation (1), (2) and (3), the output voltage is,

$$V_o(s)=\frac{s}{s+2}\left(\frac{3s^2+6s+4}{s\left(3s^2+3s+2\right)}\right)$$

$$=\frac{3s^2+6s+4}{(s+2)\left(3s^2+3s+2\right)}$$

$$=\frac{s^2+2s+\frac{4}{3}}{(s+2)\left(s^2+s+\frac{2}{3}\right)}$$

Resolve into partial fractions.

$$\frac{s^2+2s+\frac{4}{3}}{(s+2)\left(s^2+s+\frac{2}{3}\right)}=\frac{A}{s+2}+\frac{Bs+C}{s^2+s+\frac{2}{3}}$$

$$s^2+2s+\frac{4}{3}=A\left(s^2+s+\frac{2}{3}\right)+Bs(s+2)+C(s+2)$$

Step 5 of 7

The values of the coefficients are calculated as,

Consider $s=-2$ then,

$$(-2)^2+2(-2)+\frac{4}{3}=A\left((-2)^2-2+\frac{2}{3}\right)$$

$$A=\frac{4-4+\frac{4}{3}}{4-2+\frac{2}{3}}$$

$$A=\frac{1}{2}$$

Compare s^2 coefficients.

$$1=A+B$$

$$B=1-\frac{1}{2}$$

$$B=\frac{1}{2}$$

Compare constant terms.

$$\frac{4}{3}=\frac{2}{3}A+2C$$

$$2C=\frac{4}{3}-\left(\frac{2}{3}\right)\left(\frac{1}{2}\right)$$

$$C=\frac{4-1}{3(2)}$$

$$C=\frac{1}{2}$$

Step 6 of 7

The partial fraction expansion of the output voltage equation is,

$$V_o(s)=\frac{1}{2(s+2)}+\frac{s+1}{2\left(s^2+s+\frac{2}{3}\right)}$$

$$=\frac{1}{2(s+2)}+\frac{s+1}{2\left(s^2+s+\frac{1}{4}-\frac{1}{4}+\frac{2}{3}\right)}$$

$$=\frac{1}{2(s+2)}+\frac{s+\frac{1}{2}-\frac{1}{2}}{2\left(s^2+2.\frac{1}{2}s+\frac{1}{2^2}+\sqrt{\left(\frac{5}{12}\right)^2}\right)}$$

$$=\frac{1}{2(s+2)}+\frac{s+\frac{1}{2}}{2\left(\left(s+\frac{1}{2}\right)^2+\sqrt{\left(\frac{5}{12}\right)^2}\right)}-\frac{\sqrt{\frac{5}{12}}}{4\sqrt{\frac{5}{12}}\left(\left(s+\frac{1}{2}\right)^2+\sqrt{\left(\frac{5}{12}\right)^2}\right)}$$

$$=\frac{1}{2(s+2)}+\frac{s+\frac{1}{2}}{2\left(\left(s+\frac{1}{2}\right)^2+\sqrt{\left(\frac{5}{12}\right)^2}\right)}-\frac{1}{4\sqrt{\frac{5}{12}}}\frac{\sqrt{\frac{5}{12}}}{\left(\left(s+\frac{1}{2}\right)^2+\sqrt{\left(\frac{5}{12}\right)^2}\right)}$$

Step 7 of 7

Apply Inverse Laplace transform.

$$v_o(t)=\left[\frac{1}{2}e^{-2t}+\frac{1}{2}e^{-t/2}\cos\left(\sqrt{\frac{5}{12}}t\right)-\frac{1}{4\sqrt{\frac{5}{12}}}e^{-t/2}\sin\left(\sqrt{\frac{5}{12}}t\right)\right]u(t)$$

$$=\left[\frac{1}{2}e^{-2t}+\frac{1}{2}e^{-t/2}\cos\left(\sqrt{\frac{5}{12}}t\right)-\frac{1}{2}\sqrt{\frac{3}{5}}e^{-t/2}\sin\left(\sqrt{\frac{5}{12}}t\right)\right]u(t)$$

Hence, the output voltage, $v_0(t)$, of the circuit is

$$\boxed{\left[\frac{1}{2}e^{-2t}+\frac{1}{2}e^{-t/2}\cos\left(\sqrt{\frac{5}{12}}t\right)-\frac{1}{2}\sqrt{\frac{3}{5}}e^{-t/2}\sin\left(\sqrt{\frac{5}{12}}t\right)\right]u(t)}$$

Step 1 of 5

14.009 E

Refer to Figure E14.9 in the textbook.

At steady state the inductor will be short circuited and the capacitor will be open circuited so the circuit before the switch opened will be

Apply Kirchhoff's Voltage Law to the mesh.

$$-10+8i_L(0)+2i_L(0)+20=0$$
$$10i_L(0)=-10$$
$$i_L(0)=-1\text{ A}$$

The voltage across the capacitor can be calculated as follows:

$$\begin{aligned}\mathbf{V}_C(0)&=10-\left[8i_o(0)\right]\\&=10-\left[8(-1)\right]\\&=10+8\\&=18\text{ V}\end{aligned}$$

Step 2 of 5

The following circuit in Laplace domain after the switch opened:

Apply Kirchhoff's Voltage Law to the mesh.

$$-\frac{18}{s}+\frac{8}{3s}\left[\mathbf{I}_o(s)\right]+2\left[\mathbf{I}_o(s)\right]+\frac{1}{3}s\left[\mathbf{I}_o(s)\right]+\frac{1}{3}+\frac{20}{s}=0$$
$$\mathbf{I}_o(s)\left[\frac{8}{3s}+2+\frac{s}{3}\right]=\frac{18}{s}-\frac{1}{3}-\frac{20}{s}$$
$$\mathbf{I}_o(s)\left[\frac{8+2(3s)+s^2}{3s}\right]=\frac{54-s-60}{3s}$$
$$\mathbf{I}_o(s)\left(8+6s+s^2\right)=-s-6$$

$$\begin{aligned}\mathbf{I}_o(s)&=\frac{-(s+6)}{s^2+6s+8}\\&=\frac{-(s+6)}{s^2+2s+4s+8}\\&=\frac{-(s+6)}{s(s+2)+4(s+2)}\end{aligned}$$
$$\mathbf{I}_o(s)=\frac{-(s+6)}{(s+2)(s+4)}$$

Step 3 of 5

Resolve the expression of $\mathbf{I}_o(s)$ into partial fractions.

$$\mathbf{I}_o(s)=\frac{K_1}{(s+2)}+\frac{K_2}{(s+4)}$$

The value of K_1 is,

$$\begin{aligned}K_1&=(s+2)\mathbf{I}_o(s)\big|_{s=-2}\\&=(s+2)\frac{-(s+6)}{(s+2)(s+4)}\bigg|_{s=-2}\\&=\frac{-(s+6)}{(s+4)}\bigg|_{s=-2}\end{aligned}$$
$$K_1=\frac{-(-2+6)}{(-2+4)}$$
$$=\frac{-4}{2}$$
$$K_1=-2$$

Step 4 of 5

The value of K_2 is,

$$\begin{aligned}K_2&=(s+4)\mathbf{I}_o(s)\big|_{s=-4}\\&=(s+4)\frac{-(s+6)}{(s+2)(s+4)}\bigg|_{s=-4}\\&=\frac{-(s+6)}{(s+2)}\bigg|_{s=-2}\\&=\frac{-(-4+6)}{(-4+2)}\\&=\frac{-2}{-2}\end{aligned}$$
$$K_2=1$$

Step 5 of 5

The partial fraction expansion of $\mathbf{V}_o(s)$ is then

$$\mathbf{I}_o(s)=\frac{-2}{(s+2)}+\frac{1}{(s+4)}$$

Apply inverse Laplace transform.

$$i_o(t)=\left[-2e^{-2t}+e^{-4t}\right]u(t)\text{ A}$$

Therefore, the value of the current, $i_0(t)$, is $\boxed{\left[-2e^{-2t}+e^{-4t}\right]u(t)\text{ A}}$.

Step 1 of 4

Draw the frequency domain representation of the circuit.

Figure 1

Step 2 of 4

From the Figure 1, observe that the voltage $\mathbf{V}_1$ is, $\frac{4}{s}$ and the voltage $\mathbf{V}_2$ is, $-\frac{1}{s+1}$

Write nodal equation at node, $\mathbf{V}_3$.

$$\frac{\mathbf{V}_3-\mathbf{V}_1}{s}+\frac{\mathbf{V}_3}{2}+\frac{\mathbf{V}_3-\mathbf{V}_2}{1}=0$$

$$2\mathbf{V}_3-2\mathbf{V}_1+s\mathbf{V}_3+2s\mathbf{V}_3-2s\mathbf{V}_2=0$$

$$-2\mathbf{V}_1-2s\mathbf{V}_2+(3s+2)\mathbf{V}_3=0$$

Substitute $\frac{4}{s}$ for $\mathbf{V}_1$ and $-\frac{1}{s+1}$ for $\mathbf{V}_2$.

$$-2\left(\frac{4}{s}\right)-2s\left(\frac{-1}{s+1}\right)+(3s+2)\mathbf{V}_3=0$$

$$(3s+2)\mathbf{V}_3=\frac{8}{s}-\frac{2s}{s+1}$$

$$(3s+2)\mathbf{V}_3=\frac{8(s+1)-2s^2}{s(s+1)}$$

$$\mathbf{V}_3=\frac{8s+8-2s^2}{s(s+1)(3s+2)}$$

$$=\frac{-2s^2+8s+8}{s(s+1)(3s+2)}$$

Step 3 of 4

Now the current through the $2\,\Omega$ resistor is,

$$\mathbf{I}_o(s)=\frac{\mathbf{V}_3}{2}$$

Substitute $\frac{-2s^2+8s+8}{s(s+1)(3s+2)}$ for $\mathbf{V}_3$.

$$\mathbf{I}_o(s)=\frac{\left(\frac{-2s^2+8s+8}{s(s+1)(3s+2)}\right)}{2}$$

$$=\frac{-s^2+4s+4}{s(s+1)(3s+2)}$$

Now apply partial fraction rule.

$$\frac{-s^2+4s+4}{s(s+1)(3s+2)}=\frac{K_1}{s}+\frac{K_2}{s+1}+\frac{K_3}{3s+2}$$

Calculate the value of K_1.

$$K_1=\left.\frac{-s^2+4s+4}{(s+1)(3s+2)}\right|_{s=0}$$

$$=\frac{-(0)^2+4(0)+4}{(0+1)(3(0)+2)}$$

$$=2$$

Calculate the value of K_2.

$$K_2=\left.\frac{-s^2+4s+4}{s(3s+2)}\right|_{s=-1}$$

$$=\frac{-(-1)^2+4(-1)+4}{(-1)(3(-1)+2)}$$

$$=\frac{-1-4+4}{(-1)(-3+2)}$$

$$=-1$$

Step 4 of 4

Calculate the value of K_3.

$$K_3=\left.\frac{-s^2+4s+4}{s(s+1)}\right|_{s=-\frac{2}{3}}$$

$$=\frac{-\frac{4}{9}-\frac{8}{3}+4}{\left(-\frac{2}{3}\right)\left(\frac{1}{3}\right)}$$

$$=-4$$

Therefore, the expression for $\mathbf{I}_o(s)$ is,

$$\mathbf{I}_o(s)=\frac{2}{s}-\frac{1}{s+1}-\frac{4}{3\left(s+\frac{2}{3}\right)}$$

Apply inverse Laplace transform on both sides.

$$L^{-1}[\mathbf{I}_o(s)]=L^{-1}\left[\frac{2}{s}-\frac{1}{s+1}-\frac{4}{3\left(s+\frac{2}{3}\right)}\right]$$

$$=2L^{-1}\left(\frac{1}{s}\right)-L^{-1}\left(\frac{1}{s+1}\right)-\frac{4}{3}L^{-1}\left(\frac{1}{s+\frac{2}{3}}\right)$$

$$i_o(t)=\left(2-e^{-t}-\frac{4}{3}e^{-\frac{2}{3}t}\right)u(t)\text{ A}$$

Therefore, the expression for the current $i_o(t)$ is, $\boxed{\left(2-e^{-t}-\frac{4}{3}e^{-\frac{2}{3}t}\right)u(t)\text{ A}}$.

Step 1 of 3

14.010
P

Refer to Figure P14.10 in the textbook.

The circuit in frequency domain is,

Figure 1

Write the nodal equation for node with voltage *V*.

$$\frac{V-\frac{4}{s}}{(1+s)}+\frac{V}{(1+2)}+\frac{2}{s}=0$$

$$\frac{sV-4}{s(1+s)}+\frac{V}{3}+\frac{2}{s}=0$$

$$3sV-12+V(s)(s+1)+2(3)(1+s)=0$$

$$V\left(3s+s^2+s\right)+6+6s-12=0$$

$$V\left(s^2+4s\right)=6-6s$$

$$V=\frac{6-6s}{s^2+4s}$$

$$V=\frac{6-6s}{s(s+4)}\text{ V}$$

Step 2 of 3

Use voltage division rule to find the output voltage.

$$\begin{aligned}V_0(s)&=V\left[\frac{2}{2+1}\right]\\&=\frac{2}{3}\left[\frac{6-6s}{s(s+4)}\right]\\&=\frac{4(1-s)}{s(s+4)}\end{aligned}$$

Resolve into partial fractions.

$$\frac{4(1-s)}{s(s+4)}=\frac{k_0}{s}+\frac{k_1}{s+4}$$

The value of k_0 is,

$$\begin{aligned}k_0&=\left.\frac{4(1-s)}{s+4}\right|_{s=0}\\&=1\end{aligned}$$

The value of k_0 is,

$$\begin{aligned}k_1&=\left.\frac{4(1-s)}{s}\right|_{s=-4}\\&=-5\end{aligned}$$

Step 3 of 3

The output voltage is,

$$V_0(s)=\frac{1}{s}-\frac{5}{s+4}$$

Apply inverse Laplace transform.

$$v_0(t)=\left(1-5e^{-4t}\right)u(t)$$

Hence the output voltage, $v_0(t)$, is $\boxed{\left(1-5e^{-4t}\right)}$, $t>0$ for the network.

Step 1 of 7

14.011 P

Refer to Figure E14.11 from the textbook.

From the input waveform, write the voltage equation $v_i(t)$.

$$v_i(t) = 12\left(u(t) - u(t-1)\right) \text{ ..... (1)}$$

Apply Laplace transform to the equation (1).

$$V_i(s) = 12\left(\frac{1}{s} - \frac{e^{-s}}{s}\right)$$
$$= \frac{12\left(1 - e^{-s}\right)}{s}$$

Step 2 of 7

Draw the Figure E4.11 in s-domain.

Figure 1

Step 3 of 7

Calculate the current $I_i(s)$ in the Figure 1.

$$I_i(s) = \frac{V_i(s)}{\left((2+2s)\|2\right)+2}$$
$$= \frac{V_i(s)}{\left(\frac{(2+2s)(2)}{(2+2s+2)}\right)+2}$$
$$= \frac{V_i(s)}{\left(\frac{(2+2s)(2)}{(2s+4)}\right)+2}$$
$$= \frac{V_i(s)}{\left(\frac{2+2s}{(s+2)}\right)+2}$$
$$= \frac{V_i(s)}{\left(\frac{2+2s+2s+4}{(s+2)}\right)}$$
$$= \frac{V_i(s)(s+2)}{4s+6}$$

Step 4 of 7

Calculate the current $I_o(s)$ using current divider rule.

$$I_o(s) = I_i(s)\left(\frac{2}{4+2s}\right) \text{ ..... (2)}$$

Substitute $\frac{V_i(s)(s+2)}{6+4s}$ for $I_i(s)$ in equation (2).

$$I_o(s) = \frac{V_i(s)(s+2)}{6+4s}\left(\frac{2}{4+2s}\right)$$
$$= \frac{V_i(s)}{6+4s}$$

Step 5 of 7

From the Figure 1, write the output voltage equation.

$$V_o(s) = I_o(s)(2) \text{ ..... (3)}$$

Substitute $\frac{V_i(s)}{6+4s}$ for $I_o(s)$ in equation (3).

$$V_o(s) = \frac{V_i(s)(2)}{6+4s}$$

$$V_o(s) = \frac{V_i(s)}{3+2s} \text{ ..... (4)}$$

Substitute $\frac{12\left(1-e^{-s}\right)}{s}$ for $V_i(s)$ in equation (4).

$$V_O(s) = \frac{12}{s}\frac{\left(1-e^{-s}\right)}{3+2s} \text{ ..... (5)}$$

Step 6 of 7

Resolve equation (6) into partial fractions.

$$V_o(s) = \left(\frac{4}{s} - \frac{8}{3+2s}\right)\left(1-e^{-s}\right)$$
$$= \frac{4}{s} - \frac{8}{3+2s} - \frac{4e^{-s}}{s} + \frac{8e^{-s}}{3+2s}$$

$$V_o(s) = \frac{4}{s} - \frac{4}{s+1.5} - \frac{4e^{-s}}{s} + \frac{4e^{-s}}{s+1.5} \text{ ..... (6)}$$

Step 7 of 7

Apply inverse Laplace transform to equation (6).

$$v_o(t) = \frac{4}{s} - \frac{4}{s+1.5} - \frac{4e^{-s}}{s} + \frac{4e^{-s}}{s+1.5}$$
$$= 4u(t) - 4e^{-1.5t}u(t) - 4u(t-1) + 4e^{-1.5(t-1)}u(t-1)$$
$$= \left[\left(4-4e^{-1.5t}\right)u(t) - \left(4-4e^{-1.5(t-1)}\right)u(t-1)\right] \text{ V}$$

Therefore, the output voltage $v_o(t)$ is $\boxed{\left[\left(4-4e^{-1.5t}\right)u(t) - \left(4-4e^{-1.5(t-1)}\right)u(t-1)\right] \text{ V}}$.

Step 1 of 3

14.012

E

The unit impulse response of the network, $x_0(t)$, is,

$$x_0(t)=\frac{10}{9}\left(e^{-t}-e^{-10t}\right)$$

Apply Laplace transform.

$$\mathbf{X}_o(s)=\frac{10}{9}\left(\frac{1}{s+1}-\frac{1}{s+10}\right)$$

The transfer function of a network is,

$$\mathbf{H}(s)=\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}$$

Here, $\mathbf{V}_o(s)$ is the Laplace transform of the output signal

$\mathbf{V}_i(s)$ is the Laplace transform of the input signal.

The Laplace transform of a unit impulse function is 1.

The transfer function of the network will be equal to the Laplace transform of the output signal.

$$\begin{aligned}\mathbf{H}(s)&=\mathbf{X}_o(s)\\&=\frac{10}{9}\left(\frac{1}{s+1}-\frac{1}{s+10}\right)\end{aligned}$$

Step 2 of 3

Consider a unit step input to the network.

The Laplace transform of the unit step as input signal is,

$$\mathbf{X}_i(s)=\frac{1}{s}$$

Consider the step response as $x(t)$.

The output signal expression involving the transfer function of the network is,

$$\begin{aligned}\mathbf{X}(s)&=\mathbf{H}(s)\mathbf{X}_i(s)\\&=\frac{10}{9}\left(\frac{1}{s+1}-\frac{1}{s+10}\right)\left(\frac{1}{s}\right)\\&=\frac{10}{9}\left[\frac{1}{s(s+1)}-\frac{1}{s(s+10)}\right]\end{aligned}$$

Resolve into partial functions.

$$\begin{aligned}\mathbf{X}(s)&=\frac{10}{9}\left[\frac{1}{s}-\frac{1}{s+1}-\frac{1}{10s}+\frac{1}{10(s+10)}\right]\\&=\frac{10}{9s}-\frac{10}{9(s+1)}-\frac{1}{9s}+\frac{1}{9(s+10)}\\&=\frac{1}{s}-\frac{10}{9(s+1)}+\frac{1}{9(s+10)}\end{aligned}$$

Step 3 of 3

Apply inverse Laplace transform.

$$\begin{aligned}x(t)&=u(t)-\frac{10}{9}e^{-t}u(t)+\frac{1}{9}e^{-10t}u(t)\\&=\left(1-\frac{10}{9}e^{-t}+\frac{1}{9}e^{-10t}\right)u(t)\ \text{V}\end{aligned}$$

The unit step response of the network, $x(t)$, is $\boxed{\left(1-\frac{10}{9}e^{-t}+\frac{1}{9}e^{-10t}\right)u(t)\ \text{V}}$.

Step 1 of 4

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Refer to Figure P14.11 in the textbook.

The transformed circuit is,

Figure 1

From Figure1,

$$V_0(s) = V_4(s)$$

$$V_2(s) = \frac{6}{s}\text{V}$$

$$V_3(s) = \frac{6}{s} - \frac{4}{s+1}$$

$$V_1(s) = \frac{12}{s} - \frac{4}{s+1} + \frac{6}{s}$$

Step 2 of 4

Apply nodal analysis at node 1.

$$\frac{V_0(s) - V_1(s)}{1} + \frac{V_0(s)}{1} + \frac{V_0(s) - V_3(s)}{s} = 0$$

$$V_0(s)[2+s] - \frac{12}{s} + \frac{4}{s+} - \frac{6}{s} - s\left[\frac{6}{s} - \frac{4}{s+1}\right] = 0$$

$$\begin{aligned} V_0(s) &= \frac{12(s+1) - 4s + 6(s+1) - 6s(s+1) + 4s^2}{s(s+1)} \\ &= \frac{12s + 12 - 4s + 6s + 6 - 6s^2 - 6s + 4s^2}{s(s+1)} \\ &= \frac{-2s^2 + 8s + 18}{s(s+1)} \\ &= \frac{-2s^2 + 8s + 10}{s(s+1)(s+2)} \end{aligned}$$

Step 3 of 4

Resolve into partial fractions.

$$V_0(s) = \frac{K_1}{s} + \frac{K_2}{s+1} + \frac{K_3}{s+2}$$

The value of K_1 is,

$$\begin{aligned} K_1 &= \left.\frac{-2s^2 + 8s + 10}{(s+1)(s+2)}\right|_{s=0} \\ &= 9 \end{aligned}$$

The value of K_2 is,

$$\begin{aligned} K_2 &= \left.\frac{-2s^2 + 8s + 10}{s(s+2)}\right|_{s=-1} \\ &= -8 \end{aligned}$$

The value of K_3 is,

$$\begin{aligned} K_3 &= \left.\frac{-2s^2 + 8s + 10}{s(s+1)}\right|_{s=-2} \\ &= -3 \end{aligned}$$

Step 4 of 4

The partial fraction expansion of $V_0(s)$ is,

$$V_0(s) = \frac{9}{s} - \frac{8}{s+1} - \frac{3}{s+2}$$

Apply inverse Laplace transform.

$$v_o(t) = \left(9 - 8e^{-t} - 3e^{-2t}\right)u(t)$$

Therefore, the output voltage is $\boxed{9 - 8e^{-t} - 3e^{-2t}\text{ V}}$.

Step 1 of 11

The given circuit is,

(a)

Step 2 of 11

The circuit represented in s-domain,

Step 3 of 11

We take node 4 as the reference node.

Writing nodal equation at node (1)

$$\frac{V_1(s)}{\left(\frac{1}{s}\right)}+\frac{V_1(s)-V_0(s)}{1}+\frac{V_1(s)-V_3(s)}{1}-I_x(s)=0$$

$$(s+2)V_1(s)-V_0(s)-V_3(s)-I_x(s)=0 \qquad .....(i)$$

Step 4 of 11

Writing nodal equation at node (2)

$$\frac{V_0(s)}{1}+\frac{V_0(s)-V_1(s)}{1}-\frac{1}{s}=0$$

$$2sV_0(s)-sV_1(s)-1=0 \qquad .....(ii)$$

Writing nodal equation at node (3)

$$\frac{V_3(s)}{s}+\frac{V_3(s)-V_1(s)}{1}+\frac{2}{s}=0$$

$$-sV_1(s)+(s+1)V_3(s)+2=0 \qquad .....(iii)$$

Step 5 of 11

Writing nodal equation at node (5)

$$-I_x(s)+\frac{2}{s}-\frac{1}{s}=0$$

$$I_x(s)=\frac{1}{s} \qquad .....(iv)$$

Substituting (iv) in (i) we get

$$-V_0(s)+(s+2)V_1(s)-V_3(s)-\frac{1}{s}=0 \qquad .....(v)$$

Step 6 of 11

From (ii)

$$sV_1(s)=2sV_0(s)-1$$

$$V_1(s)=2V_0(s)-\frac{1}{s} \qquad .....(vi)$$

From (iii)

$$(s+1)V_3(s)=sV_1(s)-2$$

$$V_3(s)=\frac{sV_1(s)-2}{(s+1)}$$

$$V_3(s)=\frac{sV_1(s)}{s+1}-\frac{2}{s+1}$$

$$V_3(s)=\frac{s}{s+1}\left[2V_0(s)-\frac{1}{s}\right]-\frac{2}{s+1}$$

$$V_3(s)=\frac{2sV_0(s)}{s+1}-\frac{3}{s+1} \qquad .....(vii)$$

Step 7 of 11

Substituting (vi) and (vii) in (v) we get,

$$-V_0(s)+(s+2)\left[2V_0(s)-\frac{1}{s}\right]-\left[\frac{2sV_0(s)}{s+1}-\frac{3}{s+1}\right]-\frac{1}{s}=0$$

$$V_0(s)\left[-1+2(s+2)-\frac{2s}{s+1}\right]=\frac{s+2}{s}+\frac{1}{s}-\frac{3}{s+1}$$

$$V_0(s)\left[\frac{-(s+1)+2(s+2)(s+1)-2s}{s+1}\right]=\frac{(s+2)(s+1)+(s+1)-3s}{s(s+1)}$$

$$V_0(s)\left[-s-1+2s^2+6s+4-2s\right]=\frac{s^2+3s+2+s+1-3s}{s}$$

$$V_0(s)=\frac{s^2+s+3}{s\left(2s^2+3s+3\right)}$$

Step 8 of 11

By partial fractions,

$$\frac{s^2+s+3}{s\left(2s^2+3s+3\right)}=\frac{A}{s}+\frac{Bs+C}{2s^2+3s+3}$$

$$s^2+s+3=A\left(2s^2+3s+3\right)+Bs^2+Cs$$

Comparing coefficients of 's' on both sides,

$3A=3$

$A=1$

$2A+B=1$

$B=1-2$

$B=-1$

$3A+C=1$

$C=1-3$

$C=-2$

Step 9 of 11

$$\therefore V_0(s)=\frac{1}{s}+\frac{-s-2}{2s^2+3s+3}$$

$$V_0(s)=\frac{1}{s}+\frac{-s-2}{2\left(s^2+1.5s+1.5\right)}$$

$$V_0(s)=\frac{1}{s}+\frac{-s-2}{2\left(s^2+1.5s+0.5625-0.5625+1.5\right)}$$

$$V_0(s)=\frac{1}{s}+\frac{-s-2}{2\left(s^2+1.5s+0.5625+0.9375\right)}$$

$$V_0(s)=\frac{1}{s}+\frac{-s-2}{2\left[(s+0.75)^2+(0.96825)^2\right]}$$

Step 10 of 11

$$V_0(s)=\frac{1}{s}+\frac{-s-0.75-1.25}{2\left[(s+0.75)^2+(0.96825)^2\right]}$$

$$V_0(s)=\frac{1}{s}-\frac{(s+0.75)}{2\left[(s+0.75)^2+(0.96825)^2\right]}-\frac{1.25}{2\left[(s+0.75)^2+(0.96825)^2\right]}$$

$$V_0(s)=\frac{1}{s}-\frac{(s+0.75)}{2\left[(s+0.75)^2+(0.96825)^2\right]}-\left(\frac{1.25}{2\times0.96825}\right)\frac{0.96825}{\left[(s+0.75)^2+(0.96825)^2\right]}$$

$$V_0(s)=\frac{1}{s}-0.5\left[\frac{(s+0.75)}{(s+0.75)^2+(0.96825)^2}\right]-0.6455\left[\frac{0.96825}{(s+0.75)^2+(0.96825)^2}\right]$$

Step 11 of 11

Taking inverse Laplace transforms on both sides,

$$L^{-1}\left[V_0(s)\right]=L^{-1}\left(\frac{1}{s}\right)-0.5\,L^{-1}\left[\frac{(s+0.75)}{(s+0.75)^2+(0.96825)^2}\right]-0.6455\,L^{-1}\left[\frac{0.96825}{(s+0.75)^2+(0.96825)^2}\right]$$

$$v_0(t)=\left(1-0.5e^{-0.75t}\cos 0.96825t-0.6455e^{-0.75t}\sin 0.96825t\right)u(t)$$

$$\boxed{v_0(t)=\left[1-e^{-0.75t}\left(0.5\cos 0.96825t-0.6455\sin 0.96825t\right)\right]u(t)\ \text{V}}$$

Step 1 of 4

Refer to Figure E14.15 in the text book for the circuit.

Redraw the circuit with mesh currents as shown in Figure 1.

Figure 1

Step 2 of 4

As the initial conditions in the network are zeroes,

$$v_c(0^-) = i_L(0^-) = 0$$

Apply Kirchhoff's voltage law to the two loops.

$$\mathbf{I}_1\left(1+\frac{1}{s}\right)-\mathbf{I}_2\left(\frac{1}{s}\right)=\frac{12s}{s^2+4} \quad \text{..... (1)}$$

$$-\mathbf{I}_1\left(\frac{1}{s}\right)+\mathbf{I}_2\left(\frac{1}{s}+s+2\right)=0 \quad \text{..... (2)}$$

Write the equations (1) and (2) in matrix form.

$$\begin{bmatrix} 1+\frac{1}{s} & -\frac{1}{s} \\ -\frac{1}{s} & s+\frac{1}{s}+2 \end{bmatrix}\begin{bmatrix} \mathbf{I}_1(s) \\ \mathbf{I}_2(s) \end{bmatrix}=\begin{bmatrix} \frac{12s}{s^2+4} \\ 0 \end{bmatrix}$$

The current, $\mathbf{I}_2(s)$ is,

$$\mathbf{I}_2(s)=\frac{\begin{vmatrix} 1+\frac{1}{s} & \frac{12s}{s^2+4} \\ -\frac{1}{s} & 0 \end{vmatrix}}{\begin{vmatrix} 1+\frac{1}{s} & -\frac{1}{s} \\ -\frac{1}{s} & s+\frac{1}{s}+2 \end{vmatrix}}$$

$$=\frac{\frac{12}{s^2+4}}{\left(1+\frac{1}{s}\right)\left(s+\frac{1}{s}+2\right)-\frac{1}{s^2}}$$

$$=\frac{\frac{12}{s^2+4}}{\left(\frac{s+1}{s}\right)\left(\frac{s^2+2s+1}{s}\right)-\frac{1}{s^2}}$$

$$=\frac{12s^2}{(s^2+4)\left[(s^2+2s+1)(s+1)-1\right]}$$

$$=\frac{12s^2}{(s^2+4)(s^3+3s^2+3s)}$$

$$=\frac{12s}{(s^2+4)(s^2+3s+3)}$$

Step 3 of 4

The output voltage is,

$$\mathbf{V}_o(s)=2\mathbf{I}_2(s)$$

$$=\frac{24s}{(s^2+4)(s^2+3s+3)}$$

Apply inverse Laplace transform to get the output voltage in time domain.

$$\mathbf{V}_o(s)=\frac{24s}{(s^2+4)(s^2+3s+3)}=\frac{As+B}{s^2+4}+\frac{Cs+D}{s^2+3s+3}$$

$$\frac{24s}{(s^2+4)(s^2+3s+3)}=\frac{(As+B)(s^2+3s+3)+(Cs+D)(s^2+4)}{(s^2+4)(s^2+3s+3)}$$

$$\frac{24s}{(s^2+4)(s^2+3s+3)}=\frac{(A+C)s^3+(B+3A+D)s^2+(3B+3A+4C)s+3B+4D}{(s^2+4)(s^2+3s+3)}$$

Equate the coefficients.

$$A+C=0$$
$$3A+B+D=0$$
$$3A+3B+4C=24$$
$$3B+4D=0$$

Solve the four equations to get *A*, *B*, *C* and *D* values.

$$A=-0.65$$
$$B=7.78$$
$$C=0.65$$
$$D=-5.84$$

Step 4 of 4

The output voltage is,

$$\mathbf{V}_o(s)=\frac{-0.65s+7.78}{s^2+4}+\frac{0.65s-5.84}{s^2+3s+3}$$

$$=\frac{7.78}{s^2+2^2}-\frac{0.65s}{s^2+2^2}+\frac{0.65s}{(s+1.5)^2+0.75}-\frac{5.84}{(s+1.5)^2+0.75}$$

$$=(3.89)\frac{2}{s^2+2^2}-(0.65)\frac{s}{s^2+2^2}+\frac{0.65(s+0.866)}{(s+1.5)^2+(0.866)^2}-\frac{6.4}{(s+1.5)^2+(0.866)^2}$$

$$=(3.89)\frac{2}{s^2+2^2}-(0.65)\frac{s}{s^2+2^2}+\frac{0.65(s+1.5)}{(s+1.5)^2+(0.866)^2}-\frac{6.81}{(s+1.5)^2+(0.866)^2}$$

$$=(3.89)\frac{2}{s^2+2^2}-(0.65)\frac{s}{s^2+2^2}+\frac{0.65(s+1.5)}{(s+1.5)^2+(0.866)^2}-$$

$$(7.87)\frac{0.866}{(s+1.5)^2+(0.866)^2}$$

Consider the following inverse Laplace transforms:

$$\mathrm{L}^{-1}\left[\frac{b}{s^2+b^2}\right]=\sin bt$$

$$\mathrm{L}^{-1}\left[\frac{s}{s^2+b^2}\right]=\cos bt$$

$$\mathrm{L}^{-1}\left[\frac{b}{(s+a)^2+b^2}\right]=e^{-at}\sin bt$$

$$\mathrm{L}^{-1}\left[\frac{s+a}{(s+a)^2+b^2}\right]=e^{-at}\cos bt$$

Take inverse Laplace transform to get $v_o(t)$.

$$v_o(t)=3.89\sin 2t-0.65\cos 2t+0.65e^{-1.5t}\cos 0.866t-7.87e^{-1.5t}\sin 0.866t$$
$$=3.89\sin 2t-0.65\cos 2t+e^{-1.5t}(0.65\cos 0.866t-7.87\sin 0.866t)$$

Determine the steady state value, that is, the value of output voltage as $t\to\infty$.

As $t\to\infty$, the second term approaches to zero.

The steady state value is,

$$v_{oss}(t)=3.89\sin 2t-0.65\cos 2t$$
$$=3.89\sin(2t-9.48^\circ)$$
$$=3.89\cos(2t-99.48^\circ)\ \text{V}$$

Thus, the steady state output voltage is $\boxed{v_{oss}(t)=3.89\cos(2t-99.48^\circ)\ \text{V}}$.

Step 1 of 5

14.014 P

Refer to the circuit diagram in Figure P14.14 in the textbook.

Transform the circuit from the time domain to the $s-$ domain.

For step input, $u(t) \Rightarrow \frac{1}{s}$

Inductor $2\text{ H} \Rightarrow sL = 2s$

Capacitor $\frac{1}{2}\text{F} \Rightarrow \frac{1}{sC} = \frac{2}{s}$

The resulting $s-$ domain circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's voltage law around loop 1.

$$\frac{12}{s} = 2s\mathbf{I}_1 + 1(\mathbf{I}_1 - \mathbf{I}_2)$$

$$\frac{12}{s} = (2s+1)\mathbf{I}_1 - \mathbf{I}_2 \text{ ..... (1)}$$

Apply Kirchhoff's voltage law around loop 2.

$$1(\mathbf{I}_2 - \mathbf{I}_1) + \frac{1}{2s}(\mathbf{I}_2) + 4(\mathbf{I}_2) = 0$$

$$\mathbf{I}_2\left(1 + \frac{1}{2s} + 4\right) - \mathbf{I}_1 = 0$$

Rewrite the equation.

$$\mathbf{I}_1 = 1 + \frac{1}{2s} + 4$$
$$= \left(\frac{1+10s}{2s}\right)\mathbf{I}_2$$

Step 3 of 5

Substitute $\left(\frac{1+10s}{2s}\right)\mathbf{I}_2$ for $\mathbf{I}_1$ in equation (1).

$$\frac{12}{s} = (2s+1)\left(\frac{1+10s}{2s}\right)\mathbf{I}_2 - \mathbf{I}_2$$

Rewrite the equation.

$$\left((2s+1)\left(\frac{1+10s}{2s}\right) - 1\right)\mathbf{I}_2 = \frac{12}{s}$$
$$\left(\frac{2s+20s^2+1+10s-2s}{2s}\right)\mathbf{I}_2 = \frac{12}{s}$$
$$\left(\frac{20s^2+10s+1}{2s}\right)\mathbf{I}_2 = \frac{12}{s}$$

Step 4 of 5

Simplify the expression.

$$\mathbf{I}_2 = \frac{24}{20s^2+10s+1}$$
$$= \frac{24}{20}\left(\frac{1}{s^2 + \frac{10}{20}s + \frac{1}{20}}\right)$$
$$= \frac{24}{20}\left(\frac{1}{\left(s+\frac{1}{4}\right)^2 - \left(\frac{1}{4}\right)^2 + \frac{1}{20}}\right)$$
$$= \frac{24\sqrt{80}}{20}\left(\frac{\frac{1}{\sqrt{80}}}{\left(s+\frac{1}{4}\right)^2 - \left(\frac{1}{\sqrt{80}}\right)^2}\right)$$

Apply inverse Laplace transform.

$$i_2(t) = \frac{24\sqrt{80}}{20}e^{-\frac{1}{4}t}\sinh\left(\frac{1}{\sqrt{80}}t\right)u(t)$$

Step 5 of 5

Find the output voltage using ohm's law.

$$v_o(t) = 4i_2(t)$$
$$= 4\left(\frac{24\sqrt{80}}{20}e^{-\frac{1}{4}t}\sinh\left(\frac{1}{\sqrt{80}}t\right)u(t)\right)$$
$$= \frac{24}{5}\sqrt{80}e^{-\frac{1}{4}t}\sinh\left(\frac{1}{\sqrt{80}}t\right)u(t)$$

Therefore, the output voltage of the circuit is $\boxed{\frac{24}{5}\sqrt{80}e^{-\frac{1}{4}t}\sinh\left(\frac{1}{\sqrt{80}}t\right)u(t)}$.

Step 1 of 7

Refer to Figure E14.16 in the text book.

Draw the Figure E14.16 in frequency domain.

Figure 1

Step 2 of 7

Apply nodal analysis at node 1.

$$\frac{\mathbf{V}_1(s)}{4+\frac{4}{s}}+\frac{\mathbf{V}_1(s)}{s}+\frac{\mathbf{V}_1(s)}{2+\frac{4}{s}}+\mathbf{I}(s)=0$$

$$\mathbf{V}_1(s)\left(\frac{s}{4s+4}+\frac{1}{s}+\frac{s}{2s+4}\right)=-\mathbf{I}(s)$$

$$\mathbf{V}_1(s)\left\{\frac{s(2s+4)+s(4s+4)}{(4s+4)(2s+4)}+\frac{1}{s}\right\}=-\mathbf{I}(s)$$

$$\mathbf{V}_1(s)\left\{\frac{(6s^3+8s^2)+(4s+4)(2s+4)}{s(4s+4)(2s+4)}\right\}=-\mathbf{I}(s)$$

$$\mathbf{V}_1(s)\left(\frac{6s^3+16s^2+24s+16}{s(8s^2+24s+16)}\right)=-\mathbf{I}(s) \text{ ..... (1)}$$

Step 3 of 7

Apply nodal analysis at node $\mathbf{V}_o(s)$.

$$\left(\frac{\mathbf{V}_o(s)-\mathbf{V}_1(s)}{2}\right)+\frac{\mathbf{V}_o(s)}{\left(\frac{4}{s}\right)}=0$$

$$\mathbf{V}_o(s)\left(\frac{1}{2}+\frac{s}{4}\right)-\left(\frac{1}{2}\right)\mathbf{V}_1(s)=0$$

$$\mathbf{V}_o(s)\left(\frac{2+s}{4}\right)=\left(\frac{1}{2}\right)\mathbf{V}_1(s)$$

$$\mathbf{V}_1(s)=\left(\frac{2+s}{2}\right)\mathbf{V}_o(s) \text{ ..... (2)}$$

Step 4 of 7

Substitute $\frac{(2+s)}{2}\mathbf{V}_o(s)$ for $\mathbf{V}_1(s)$ in equation (1).

$$\frac{(2+s)}{2}\mathbf{V}_o(s)\left(\frac{6s^3+16s^2+24s+16}{s(8s^2+24s+16)}\right)=-\mathbf{I}(s)$$

$$\frac{\mathbf{V}_o(s)}{\mathbf{I}(s)}=-\left(\frac{2s(8s^2+24s+16)}{(s+2)(6s^3+16s^2+24s+16)}\right)$$

$$\frac{\mathbf{V}_o(s)}{\mathbf{I}(s)}=-\frac{s(8s^2+24s+16)}{(3s^3+8s^2+12s+8)(s+2)}$$

It is known that the transfer function is, $\frac{\mathbf{V}_o(s)}{\mathbf{I}(s)}=\mathbf{H}(s)$

Therefore,

$$\mathbf{H}(s)=-\frac{s(8s^2+24s+16)}{(3s^3+8s^2+12s+8)(s+2)} \text{ ..... (3)}$$

Step 5 of 7

Substitute $j\omega$ for s in the equation (3).

$$\mathbf{H}(j\omega)=-\frac{j\omega(8(j\omega)^2+24(j\omega)+16)}{(3(j\omega)^3+8(j\omega)^2+12(j\omega)+8)(j\omega+2)} \text{ ..... (4)}$$

Since the forcing function of the given circuit is $2\cos 2t\,\mathrm{u}(t)$.

Compare the forcing function with $I_M\cos\omega_o t\,\mathrm{u}(t)$.

$I_M = 2$ and $\omega_o = 2$

Step 6 of 7

Substitute 2 for ω_o in equation (4).

$$\begin{aligned}\mathbf{H}(j2)&=-\frac{j(2)(8(j2)^2+24(j2)+16)}{(3(j2)^3+8(j2)^2+12(j2)+8)(j2+2)}\\&=-\frac{j(2)(-32+j48+16)}{(-j24-32+j24+8)(j2+2)}\\&=-\frac{j(2)(-16+j48)}{(-24)(j2+2)}\\&=-\frac{(-j32-96)}{(-48-j48)}\end{aligned}$$

Simplify further.

$$\begin{aligned}\mathbf{H}(j2)&=-\frac{(96+j32)}{(48+j48)}\\&=-(1.333-j0.666)\\&=-(1.333-j0.666)\\&=1.49\angle 153.45^\circ\end{aligned}$$

Therefore, the value of $\mathbf{H}(j2)$ is $1.49\angle 153.45^\circ$.

Step 7 of 7

Write the formula for the steady state response.

$$v_{ss}(t)=I_M|\mathbf{H}(j2)|\cos(2t+\phi(j2)) \text{ ..... (5)}$$

Substitute 2 for I_M, 1.49 for $|\mathbf{H}(j2)|$ and 153.45° for $\phi(j2)$ in equation (5).

$$\begin{aligned}v_{ss}(t)&=(2)(1.49)\cos(2t+153.45^\circ)\\&=2.98\cos(2t+153.45^\circ)\ \mathbf{V}\end{aligned}$$

Therefore, the steady state response, $v_{ss}(t)$ is, $\boxed{2.98\cos(2t+153.45^\circ)\ \mathbf{V}}$.

14.016

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14.017

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Step 1 of 4

Refer to Figure P14.13 in the textbook.

The Laplace transformed circuit with loop currents is,

Figure 1

Write the loop current equations.

$$I_1(s)=\frac{2}{s}\text{A}$$

$$\left(I_2(s)-I_1(s)\right)+2I_2(s)+\left(I_2(s)-I_3(s)\right)=\frac{4}{s}$$

$$-I_1(s)+4I_2(s)-I_3(s)=\frac{4}{s}$$

$$4I_2(s)-I_3(s)=\frac{4}{s}+\frac{2}{s}$$

$$4I_2(s)-I_3(s)=\frac{6}{s}\ \text{.....}\ (1)$$

$$\left(I_3(s)-I_2(s)\right)+sI_3(s)+I_3(s)=0$$

$$-I_2(s)+(s+2)I_3(s)=0\ \text{.....}\ (2)$$

Step 2 of 4

Multiply equation (2) with '4' and add it to equation (1).

$$I_3(s)(-1+4s+8)=\frac{6}{s}$$

$$I_3(s)=\frac{6}{s(4s+7)}$$

$$I_3(s)=\frac{\frac{3}{2}}{s\left(s+\frac{7}{4}\right)}$$

Resolve into partial fractions.

$$I_3(s)=\frac{k_1}{s}+\frac{k_2}{\left(s+\frac{7}{4}\right)}$$

Step 3 of 4

The value of k_1 is,

$$k_1=\left.\frac{\frac{3}{2}}{\left(s+\frac{7}{4}\right)}\right|_{s=0}$$

$$=\frac{6}{7}$$

The value of k_2 is,

$$k_2=\left.\frac{\left(\frac{3}{2}\right)}{s}\right|_{s=-\frac{7}{4}}$$

$$=\frac{-6}{7}$$

Step 4 of 4

The expression for $I_3(s)$ is,

$$I_3(s)=\left(\frac{6}{7}\right)\left(\frac{1}{s}-\frac{1}{\left(s+\frac{7}{4}\right)}\right)$$

The expression for output voltage is,

$$V_0(s)=1\left(I_3(s)\right)$$

$$=\left(\frac{6}{7}\right)\left(\frac{1}{s}-\frac{1}{\left(s+\frac{7}{4}\right)}\right)$$

Apply inverse Laplace transform.

$$v_0(t)=\frac{6}{7}\left(1-e^{-\frac{7}{4}t}\right)u(t)$$

Therefore, the output voltage is $\boxed{\frac{6}{7}\left(1-e^{-\frac{7}{4}t}\right)u(t)}$.

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Step 1 of 5

14.020 P

Refer to Figure P14.17 in the textbook.

The Laplace transformed circuit is,

Figure 1

From Figure 1, the loop currents can be written as follows:

$$I_1(s)=\frac{4}{s+1}$$

$$I_2(s)=\frac{6}{s}$$

$$I_3(s)+I_4(s)=\frac{2}{s} \text{ ..... (1)}$$

Step 2 of 5

The loops 3 and 4 together form a super mesh.

Apply Kirchhoff's Voltage Law to the super mesh.

$$I_3(s)[2]-I_1(s)-I_4(s)[s+1]+sI_2(s)=0$$

$$2I_3(s)-(s+1)I_4(s)=\frac{4}{s+1}-6$$

$$2I_3(s)-(s+1)I_4(s)=\frac{4-6s-6}{s+1}$$

$$2I_3(s)-(s+1)I_4(s)=\frac{-6s-2}{s+1} \text{ ..... (2)}$$

Step 3 of 5

Multiply equation (1) with '2' and subtract it from equation (2).

$$(-s-1-2)I_4(s)=\frac{-(6s+2)}{s+1}-\frac{4}{s}$$

$$I_4(s)=\frac{6s^2+6s+4}{s(s+3)(s+1)}$$

Resolve into partial fractions.

$$I_4(s)=\frac{K_1}{s}+\frac{K_2}{s+1}+\frac{K_3}{s+3}$$

Step 4 of 5

The coefficients are calculated as follows:

$$K_1=\left.\frac{6s^2+6s+4}{(s+3)(s+1)}\right|_{s=0}$$

$$=\frac{4}{3}$$

$$K_2=\left.\frac{6s^2+6s+4}{s(s+3)}\right|_{s=-1}$$

$$=-2$$

$$K_3=\left.\frac{6s^2+6s+4}{s(s+1)}\right|_{s=-3}$$

$$=\frac{20}{3}$$

Step 5 of 5

The partial fraction expansion is,

$$I_4(s)=\frac{1}{3}\left(\frac{4}{s}-\frac{6}{s+1}+\frac{20}{s+3}\right)$$

The output voltage is expressed as,

$$V_0(s)=(-I_4(s))(1)$$

$$=\frac{-1}{3}\left(\frac{4}{s}-\frac{6}{s+1}+\frac{20}{s+3}\right)$$

Apply inverse Laplace transform.

$$v_0(t)=\frac{-1}{3}\left(4-6e^{-t}+20e^{-3t}\right)u(t)$$

Hence, the output voltage is $\boxed{\frac{-1}{3}\left(4-6e^{-t}+20e^{-3t}\right)u(t)\ \text{V}}$.

Step 1 of 4

14.021 P

Refer to Figure P14.12 from the text book.

Draw the Figure P14.12 in s-domain.

Figure 1

Step 2 of 4

Apply super mesh analysis to Figure 1.

$$-\frac{4}{s}+(1s)I_1(s)+(1)I_2(s)+\left(\frac{2}{s}\right)I_2(s)+(1)I_2(s)=0$$

$$sI_1(s)+\left(\frac{2}{s}+2\right)I_2(s)=\frac{4}{s} \quad \text{..... (1)}$$

From the Figure 1, write the super mesh equation.

$$I_2(s)-I_1(s)=\frac{2}{s}$$

$$I_1(s)=I_2(s)-\frac{2}{s} \quad \text{..... (2)}$$

Step 3 of 4

Substitute $\left(I_2(s)-\frac{2}{s}\right)$ for $I_1(s)$ in equation (1).

$$s\left(I_2(s)-\frac{2}{s}\right)+\left(\frac{2}{s}+2\right)I_2(s)=\frac{4}{s}$$

$$I_2(s)\left(s+2+\frac{2}{s}\right)=\frac{4}{s}+2$$

$$I_2(s)\left(s^2+2s+2\right)=4+2s$$

$$I_2(s)=\frac{4+2s}{\left(s^2+2s+2\right)} \quad \text{..... (3)}$$

Calculate the output voltage of the circuit.

$$V_o(s)=I_2(s)(1) \quad \text{..... (4)}$$

Substitute $\frac{4+2s}{\left(s^2+2s+2\right)}$ for $I_2(s)$ in equation (4).

$$V_o(s)=\frac{4+2s}{\left(s^2+2s+2\right)} \quad \text{..... (5)}$$

Step 4 of 4

Using partial fractions, the output voltage can be written as

$$V_o(s)=\frac{1-j1}{\left((s+1)-j1\right)}+\frac{1+j1}{\left((s+1)+j1\right)}$$

$$V_o(s)=\frac{\sqrt{2}(s+1)}{\left((s+1)^2+1^2\right)}\angle -45^\circ \quad \text{..... (6)}$$

Apply inverse Laplace transform on both sides of equation (6).

$$v_o(t)=\sqrt{2}e^{-t}\cos(t-45^\circ)u(t)\ \text{V}$$

Therefore, the value of the output voltage, $v_o(t)$ is $\boxed{\sqrt{2}e^{-t}\cos(t-45^\circ)u(t)\ \text{V}}$.

Step 1 of 9

Refer to Figure P14.20 in the textbook.

Draw the following circuit in s-domain.

Figure 1

Step 2 of 9

Use Superposition Theorem to find $v_o(t)$ for $t > 0$.

To use superposition theorem, first consider the voltage source acting alone and find the output. In this case, replace the current source with open circuit.

Re-draw the circuit in Figure 1 with the voltage source acting alone as shown in Figure 2.

Figure 2

Step 3 of 9

Apply Kirchhoff's Voltage Law in the circuit in Figure 2.

$$-\frac{4}{s}+s\mathbf{I}(s)+(1)\mathbf{I}(s)+\left(\frac{2}{s}\right)\mathbf{I}(s)+(1)\mathbf{I}(s)=0$$

$$-\frac{4}{s}+\left(s+1+\frac{2}{s}+1\right)\mathbf{I}(s)=0$$

$$\left(s+2+\frac{2}{s}\right)\mathbf{I}(s)=\frac{4}{s}$$

$$\mathbf{I}(s)=\frac{4}{s\left(s+2+\frac{2}{s}\right)}$$

Step 4 of 9

The output voltage from Figure 3 can be expressed as,

$$\mathbf{V}_o'(s)=(1)\mathbf{I}(s)$$

Substitute $\frac{4}{s\left(s+2+\frac{2}{s}\right)}$ for $\mathbf{I}(s)$.

$$\mathbf{V}_o'(s)=(1)\left[\frac{4}{s\left(s+2+\frac{2}{s}\right)}\right]$$

$$=\frac{4}{s^2+2s+2}$$

The output due to voltage source acting alone is $\mathbf{V}_o'(s)=\frac{4}{s^2+2s+2}$.

Step 5 of 9

Consider the current source is acting alone and find the output. In this case, replace the voltage source with short circuit.

Re-draw the circuit in Figure 2 with the current source acting alone as shown in Figure 3.

Figure 3

Step 6 of 9

Apply current division rule in the circuit in Figure 3.

$$\mathbf{I}_2(s)=\left(\frac{2}{s}\right)\left(\frac{s}{s+1+\frac{2}{s}+1}\right)$$

$$=\frac{2}{s+2+\frac{2}{s}}$$

$$=\frac{2s}{s^2+2s+2}$$

Step 7 of 9

Use Ohm's Law in the circuit in Figure 3.

$$\mathbf{V}_o''(s)=(1)\mathbf{I}_2(s)$$

Substitute $\frac{2s}{s^2+2s+2}$ for $\mathbf{I}_2(s)$ in this expression.

$$\mathbf{V}_o''(s)=(1)\left(\frac{2s}{s^2+2s+2}\right)$$

$$=\frac{2s}{s^2+2s+2}$$

The output due to voltage source acting alone is $\mathbf{V}_o''(s)=\frac{2s}{s^2+2s+2}$

Step 8 of 9

Use superposition theorem and write the expression for the total output voltage.

$$\mathbf{V}_o(s)=\mathbf{V}_o'(s)+\mathbf{V}_o''(s)$$

Substitute $\frac{4}{s^2+2s+2}$ for $\mathbf{V}_o'(s)$, and $\frac{2s}{s^2+2s+2}$ for $\mathbf{V}_o''(s)$ in this expression.

$$\mathbf{V}_o(s)=\frac{4}{s^2+2s+2}+\frac{2s}{s^2+2s+2}$$

The output voltage is,

$$\mathbf{V}_o(s)=\frac{2s+4}{s^2+2s+2}$$

$$\mathbf{V}_o(s)=\frac{2(s+1)+2}{(s+1)^2+1^2}$$

$$=\frac{2(s+1)}{(s+1)^2+1^2}+\frac{2}{(s+1)^2+1^2}$$

Apply inverse Laplace transform.

$$v_o(t)=\left(2e^{-t}\cos t\right)u(t)+\left(2e^{-t}\sin t\right)u(t)$$

Step 9 of 9

The output voltage expression can be simplified as,

$$v_o(t)=2e^{-t}\left(\cos t+\sin t\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\frac{\cos t+\sin t}{\sqrt{2}}\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\frac{1}{\sqrt{2}}\cos t+\frac{1}{\sqrt{2}}\sin t\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\cos 45^\circ\cos t+\sin 45^\circ\sin t\right)u(t)$$

$$v_o(t)=2\sqrt{2}e^{-t}\cos(45^\circ-t)u(t)$$

$$=2.828e^{-t}\cos(t-45^\circ)u(t)$$

Thus, the output voltage, $v_o(t)$ for $t>0$ is $\boxed{2.828e^{-t}\cos(t-45^\circ)u(t)\ \text{V}}$.

Step 1 of 4

Refer to Figure P14.24 in the textbook.

The Laplace transformed circuit with loop currents labelling is,

Figure 1

Perform mesh analysis and write the loop current equations.

$$I_3(s)=\frac{2}{s}$$

$$I_2(s)=\frac{1}{s+1}$$

$$\left(3+s+\frac{1}{s}\right)I_1(s)+I_2(s)\left[s+\frac{1}{s}\right]-I_3(s)=0$$

Step 2 of 4

Substitute the values of $I_2(s)$ and $I_3(s)$.

$$\begin{aligned}\left[\frac{s^2+3s+1}{s}\right]I_1(s)&=\frac{2}{s}-\left(\frac{1}{s+1}\right)\left(\frac{s^2+1}{s}\right)\\&=\frac{2}{s}-\frac{(s^2+1)}{s(s+1)}\\&=\frac{2(s+1)-s^2-1}{s(s+1)}\\&=\frac{2s+2-s^2-1}{s(s+1)}\end{aligned}$$

$$\begin{aligned}I_1(s)&=\frac{-s^2+2s+1}{s(s+1)}\times\frac{s}{s^2+3s+1}\\&=\frac{-s^2+2s+1}{(s+1)(s^2+3s+1)}\end{aligned}$$

Step 3 of 4

The output current $I_0(s)$ is,

$$\begin{aligned}I_0(s)&=I_1(s)-I_3(s)\\&=\frac{-s^2+2s+1}{(s+1)(s^2+3s+1)}-\frac{2}{s}\\&=\frac{-(3s^3+6s^2+7s+2)}{s(s+1)(s^2+3s+1)}\end{aligned}$$

Resolve into partial fractions.

$$I_0(s)=\frac{K_1}{s}+\frac{K_2}{s+1}+\frac{K_3}{(s+2.618)}+\frac{K_4}{s+0.38}$$

The values of the coefficients are calculated as follows:

$$\begin{aligned}K_1&=sI_0(s)\big|_{s=0}\\&=-2\end{aligned}$$

$$\begin{aligned}K_2&=(s+1)I_0(s)\big|_{s=-1}\\&=2\end{aligned}$$

$$\begin{aligned}K_3&=(s+2.618)I_0(s)\big|_{s=-2.618}\\&=-3\end{aligned}$$

$$\begin{aligned}K_4&=(s+0.38)I_0(s)\big|_{s=-0.8}\\&=0.0796\end{aligned}$$

Step 4 of 4

The partial fraction expansion of the output current is,

$$I_0(s)=\frac{-2}{s}+\frac{2}{s+1}-\frac{3}{s+2.618}+\frac{0.0796}{s+0.38}$$

Apply inverse Laplace Transform.

$$i_0(t)=-2+2e^{-t}-3e^{-2.618t}+0.0796e^{-0.38t}$$

Hence, the output current is $\boxed{-2+2e^{-t}-3e^{-2.618t}+0.0796e^{-0.38t}}$.

Step 1 of 4

14.025 P

Refer to Figure P14.16 in the textbook.

The Laplace transformed circuit is,

Figure 1

From Figure 1,

$$I_1(s)=\frac{I_x(s)}{2}$$
$$I_x(s)=I_2(s)-I_3(s)$$
$$I_1(s)=\frac{I_2(s)-I_3(s)}{2}$$
$$I_3(s)=\frac{4}{s}$$

Step 2 of 4

Apply Kirchhoff's Voltage Law to second mesh.

$$s\left[I_2(s)-I_1(s)\right]+1\left[I_2(s)-I_3(s)\right]+I_2(s)=0$$
$$-sI_1(s)+I_2(s)\left[s+2\right]-I_3(s)=0$$
$$-s\left[\frac{I_2(s)-I_3(s)}{2}\right]+I_2(s)\left[s+2\right]-I_3(s)=0$$
$$-\frac{s}{2}I_2(s)+\frac{s}{2}I_3(s)+I_2(s)\left[s+2\right]-I_3(s)=0$$
$$I_2(s)\left[s+2-\frac{s}{2}\right]+I_3(s)\left[\frac{s}{2}-1\right]=0$$
$$I_2(s)\left[s+4\right]+\frac{4}{s}(s-2)=0$$
$$I_2(s)\left[s+4\right]+\frac{4}{s}(s-2)=0$$
$$I_2(s)=\frac{-4(s-2)}{s(s+4)}$$

Step 3 of 4

The output voltage is expressed as,

$$V_0(s)=1\times\left(i_2(s)\right)$$
$$V_0(s)=\frac{4(2-s)}{s(s+4)}$$

Resolve into partial fractions.

$$\frac{4(2-s)}{s(s+4)}=\frac{k_0}{s}+\frac{k_1}{s+4}$$

The value of k_0 is,

$$k_0=\left.\frac{4(2-s)}{s+4}\right|_{s=0}$$
$$=2$$

The value of k_0 is,

$$k_1=\left.\frac{4(2-s)}{s}\right|_{s=-4}$$
$$=-6$$

Step 4 of 4

The partial fraction expansion is,

$$V_0(s)=\frac{2}{s}-\frac{6}{s+4}$$

Apply inverse Laplace transform.

$$v_0(t)=\left(2-6e^{-4t}\right)u(t)\ \text{V}$$

Therefore, the output voltage is $\boxed{\left(2-6e^{-4t}\right)u(t)\ \text{V}}$.

14.026

P

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Step 1 of 9

Refer to Figure P14.20 in the textbook.

Draw the following circuit in s-domain.

Figure 1

Step 2 of 9

Use Superposition Theorem to find $v_o(t)$ for $t > 0$.

To use superposition theorem, first consider the voltage source acting alone and find the output. In this case, replace the current source with open circuit.

Re-draw the circuit in Figure 1 with the voltage source acting alone as shown in Figure 2.

Figure 2

Step 3 of 9

Apply Kirchhoff's Voltage Law in the circuit in Figure 2.

$$-\frac{4}{s}+s\mathbf{I}(s)+(1)\mathbf{I}(s)+\left(\frac{2}{s}\right)\mathbf{I}(s)+(1)\mathbf{I}(s)=0$$

$$-\frac{4}{s}+\left(s+1+\frac{2}{s}+1\right)\mathbf{I}(s)=0$$

$$\left(s+2+\frac{2}{s}\right)\mathbf{I}(s)=\frac{4}{s}$$

$$\mathbf{I}(s)=\frac{4}{s\left(s+2+\frac{2}{s}\right)}$$

Step 4 of 9

The output voltage from Figure 3 can be expressed as,

$$\mathbf{V}_o'(s)=(1)\mathbf{I}(s)$$

Substitute $\frac{4}{s\left(s+2+\frac{2}{s}\right)}$ for $\mathbf{I}(s)$.

$$\mathbf{V}_o'(s)=(1)\left[\frac{4}{s\left(s+2+\frac{2}{s}\right)}\right]$$

$$=\frac{4}{s^2+2s+2}$$

The output due to voltage source acting alone is $\mathbf{V}_o'(s)=\frac{4}{s^2+2s+2}$

Step 5 of 9

Consider the current source is acting alone and find the output. In this case, replace the voltage source with short circuit.

Re-draw the circuit in Figure 2 with the current source acting alone as shown in Figure 3.

Figure 3

Step 6 of 9

Apply current division rule in the circuit in Figure 3.

$$\mathbf{I}_2(s)=\left(\frac{2}{s}\right)\left(\frac{s}{s+1+\frac{2}{s}+1}\right)$$

$$=\frac{2}{s+2+\frac{2}{s}}$$

$$=\frac{2s}{s^2+2s+2}$$

Step 7 of 9

Use Ohm's Law in the circuit in Figure 3.

$$\mathbf{V}_o''(s)=(1)\mathbf{I}_2(s)$$

Substitute $\frac{2s}{s^2+2s+2}$ for $\mathbf{I}_2(s)$ in this expression.

$$\mathbf{V}_o''(s)=(1)\left(\frac{2s}{s^2+2s+2}\right)$$

$$=\frac{2s}{s^2+2s+2}$$

The output due to voltage source acting alone is $\mathbf{V}_o''(s)=\frac{2s}{s^2+2s+2}$

Step 8 of 9

Use superposition theorem and write the expression for the total output voltage.

$$\mathbf{V}_o(s)=\mathbf{V}_o'(s)+\mathbf{V}_o''(s)$$

Substitute $\frac{4}{s^2+2s+2}$ for $\mathbf{V}_o'(s)$, and $\frac{2s}{s^2+2s+2}$ for $\mathbf{V}_o''(s)$ in this expression.

$$\mathbf{V}_o(s)=\frac{4}{s^2+2s+2}+\frac{2s}{s^2+2s+2}$$

The output voltage is,

$$\mathbf{V}_o(s)=\frac{2s+4}{s^2+2s+2}$$

$$\mathbf{V}_o(s)=\frac{2(s+1)+2}{(s+1)^2+1^2}$$

$$=\frac{2(s+1)}{(s+1)^2+1^2}+\frac{2}{(s+1)^2+1^2}$$

Apply inverse Laplace transform.

$$v_o(t)=\left(2e^{-t}\cos t\right)u(t)+\left(2e^{-t}\sin t\right)u(t)$$

Step 9 of 9

The output voltage expression can be simplified as,

$$v_o(t)=2e^{-t}\left(\cos t+\sin t\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\frac{\cos t+\sin t}{\sqrt{2}}\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\frac{1}{\sqrt{2}}\cos t+\frac{1}{\sqrt{2}}\sin t\right)u(t)$$

$$=2\sqrt{2}e^{-t}\left(\cos 45^\circ\cos t+\sin 45^\circ\sin t\right)u(t)$$

$$v_o(t)=2\sqrt{2}e^{-t}\cos\left(45^\circ-t\right)u(t)$$

$$=2.828e^{-t}\cos\left(t-45^\circ\right)u(t)$$

Thus, the output voltage, $v_o(t)$ for $t>0$ is $\boxed{2.828e^{-t}\cos\left(t-45^\circ\right)u(t)\ \text{V}}$.

Step 1 of 8

14.028 P

Refer to Figure P14.22 from the text book.

Draw the Figure P14.22 in s-domain.

Figure 1

Step 2 of 8

Consider only the voltage source to be present in the circuit and the current source is open circuited as shown in the Figure 2.

Figure 2

Step 3 of 8

Apply Kirchhoff's voltage law for loop in Figure 2.

$$-\frac{4}{s}+I_1(s)(s+1+1+2)=0$$

$$I_1(s)(s+4)=\frac{4}{s}$$

$$I_1(s)=\frac{4}{s(s+4)}$$

Step 4 of 8

From the Figure 2, calculate the output voltage.

$$V_o'(s)=2I_1(s)$$

$$=2\left(\frac{4}{s(s+4)}\right)$$

$$V_o'(s)=\frac{8}{s(s+4)} \quad \text{..... (1)}$$

Step 5 of 8

Consider only the current source to be present in the circuit and the voltage source is short circuited as shown in the Figure 3.

Figure 3

Step 6 of 8

Calculate the current through middle branch using current divider rule.

$$I_2(s)=-\frac{2}{s}\left(\frac{1+s}{1+2+1+s}\right)$$

$$=-\frac{2}{s}\left(\frac{1+s}{4+s}\right)$$

From the Figure 3, calculate the output voltage.

$$V_o''(s)=2I_2(s)$$

$$=-\frac{2}{s}\left(\frac{1+s}{4+s}\right)(2)$$

$$V_o''(s)=-\frac{4}{s}\left(\frac{1+s}{4+s}\right) \quad \text{..... (2)}$$

Step 7 of 8

Using super position theorem, the total voltage of the initial circuit is the sum of the output voltages using each source.

The output voltage of the circuit is,

$$V_o(s)=V_o'(s)+V_o''(s) \quad \text{..... (3)}$$

Substitute $\frac{8}{s(s+4)}$ for $V_o'(s)$ and $-\frac{4}{s}\left(\frac{1+s}{4+s}\right)$ for $V_o''(s)$ in equation (3).

$$V_o(s)=\frac{8}{s(s+4)}-\frac{4}{s}\left(\frac{1+s}{4+s}\right)$$

$$V_o(s)=\frac{-4s+4}{s(s+4)} \quad \text{..... (4)}$$

Step 8 of 8

Apply partial fractions to equation (4).

$$V_o(s)=\frac{1}{s}-\frac{5}{s+4} \quad \text{..... (5)}$$

Apply inverse Laplace transform to equation (5).

$$v_o(t)=\left(1-5e^{-4t}\right)u(t)\ \text{V}$$

Therefore, the output voltage in time domain, $v_o(t)$ is $\boxed{\left(1-5e^{-4t}\right)u(t)\ \text{V}}$.

14.029
P

Step 1 of 6

Refer to Figure P14.14 in the text book.

All initial conditions are zero.

Therefore the initial voltage across capacitor is,

$v_C(0) = 0\ \text{V}$.

The initial current passing through the inductor is,

$i_L(0) = 0\ \text{A}$

Step 2 of 6

The s- domain circuit is shown in Figure 1.

Figure 1

Step 3 of 6

Apply source transformation.

Transform the voltage source and series inductor in to a current source in parallel with the inductor as shown in Figure 2.

Figure 2

Step 4 of 6

Transform the current source and parallel impedance in to a current source in parallel with the impedance.

Calculate the equivalent impedance.

$$Z_1(s) = \frac{2s}{1+2s}$$

Calculate the source voltage.

$$V(s) = Z_1(s)\left(\frac{6}{s^2}\right)$$

Substitute $\frac{2s}{1+2s}$ for $Z_1(s)$ in equation.

$$\begin{aligned} V(s) &= \frac{2s}{1+2s}\left(\frac{6}{s^2}\right) \\ &= \frac{12}{s(1+2s)} \end{aligned}$$

The resultant circuit is shown in Figure 3.

Figure 3

Step 5 of 6

Apply voltage division rule.

$$\begin{aligned} \mathbf{V}_o(s) &= \left(\frac{4}{\frac{2s}{1+2s}+4+\frac{2}{s}}\right)\left(\frac{12}{s(1+2s)}\right) \\ &= \frac{4s(1+2s)}{2s^2+4s(1+2s)+2(1+2s)}\left(\frac{12}{s(1+2s)}\right) \\ &= \frac{48}{2s^2+4s+8s^2+2+4s} \\ &= \frac{24}{5s^2+4s+1} \end{aligned}$$

Step 6 of 6

Simplify the output voltage further:

$$\begin{aligned} \mathbf{V}_o(s) &= \frac{24}{5\left(s^2+\frac{4}{5}s+\frac{1}{5}\right)} \\ &= \frac{4.8}{\left(s^2+\frac{4}{5}s+\frac{1}{5}\right)} \\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{2}{5}\right)^2+\frac{1}{5}\right)} \\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{4}{25}-\frac{1}{5}\right)\right)} \\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{4-5}{25}\right)\right)} \\ &= (4.8)(5)\frac{\left(\frac{1}{5}\right)}{\left(\left(s+\frac{2}{5}\right)^2+\left(\frac{1}{5}\right)^2\right)} \end{aligned}$$

Apply inverse Laplace transform on both sides.

$$v_o(t) = 24e^{-\frac{2t}{5}}\sin\left(\frac{t}{5}\right)u(t)\ \text{V}$$

Therefore, the output voltage is $\boxed{24e^{-\frac{2t}{5}}\sin\left(\frac{t}{5}\right)u(t)\ \text{V}}$.

14.031

P

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Step 1 of 9

Refer to Figure P14.14 in the text book.

All initial conditions are zero.

Therefore the initial voltage across capacitor is,

$v_C(0) = 0\ \text{V}$.

The initial current passing through the inductor is,

$i_L(0) = 0\ \text{A}$

Step 2 of 9

The s- domain circuit is shown in Figure 1.

Figure 1

Step 3 of 9

Remove the $4\ \Omega$ resistor and draw the equivalent circuit as shown in Figure 2.

Figure 2

Step 4 of 9

Calculate the Thevenin's equivalent voltage.

Apply voltage division rule.

$$\begin{aligned}\mathbf{V}_{th}(s) &= \left(\frac{1}{1+2s}\right)\frac{12}{s}\\ &= \frac{12}{s(1+2s)}\ \text{V}\end{aligned}$$

Step 5 of 9

Short the voltage source and the resultant circuit is shown in Figure 3.

Figure 3

Step 6 of 9

Calculate the Thevenin's impedance.

$$\begin{aligned}\mathbf{Z}_{th}(s) &= \left(\frac{2s}{1+2s}\right)+\frac{2}{s}\\ &= \frac{2s^2+4s+2}{s(1+2s)}\end{aligned}$$

Step 7 of 9

The Thevenin's equivalent circuit is shown in Figure 4.

Figure 4

Step 8 of 9

Apply voltage division rule.

$$\mathbf{V}_o(s) = \left(\frac{4}{4+\mathbf{Z}_{th}(s)}\right)\mathbf{V}_{th}(s)$$

Substitute $\frac{2s^2+4s+2}{s(1+2s)}$ for $\mathbf{Z}_{th}(s)$ and $\frac{12}{s(1+2s)}$ V for $\mathbf{V}_{th}(s)$ in equation.

$$\begin{aligned}\mathbf{V}_o(s) &= \left(\frac{4}{4+\frac{2s^2+4s+2}{s(1+2s)}}\right)\frac{12}{s(1+2s)}\\ &= \frac{48}{4s(1+2s)+2s^2+4s+2}\\ &= \frac{48}{10s^2+8s+2}\\ &= \frac{24}{(5s^2+4s+1)}\end{aligned}$$

Step 9 of 9

Simplify the output voltage further:

$$\begin{aligned}\mathbf{V}_o(s) &= \frac{24}{5\left(s^2+\frac{4}{5}s+\frac{1}{5}\right)}\\ &= \frac{4.8}{\left(s^2+\frac{4}{5}s+\frac{1}{5}\right)}\\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{2}{5}\right)^2+\frac{1}{5}\right)}\\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{4}{25}-\frac{1}{5}\right)\right)}\\ &= \frac{4.8}{\left(\left(s+\frac{2}{5}\right)^2-\left(\frac{4-5}{25}\right)\right)}\\ &= (4.8)(5)\frac{\left(\frac{1}{5}\right)}{\left(\left(s+\frac{2}{5}\right)^2+\left(\frac{1}{5}\right)^2\right)}\end{aligned}$$

Apply inverse Laplace transform on both sides.

$$v_o(t) = 24e^{-\frac{2t}{5}}\sin\left(\frac{t}{5}\right)u(t)\ \text{V}$$

Therefore, the output voltage is $\boxed{24e^{-\frac{2t}{5}}\sin\left(\frac{t}{5}\right)u(t)\ \text{V}}$.

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14.035

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Step 1 of 9

Refer to Figure P14.30 in the textbook for the circuit diagram.

The circuit represented in s-domain is shown in Figure 1.

Figure 1

Step 2 of 9

The circuit to find the open circuit voltage across output terminals is shown in Figure 2.

Figure 2

Step 3 of 9

Apply super position principle to the open circuit voltage. First open the current source while keeping voltage source alone. The modified circuit is shown in Figure 3.

Figure 3

Step 4 of 9

From Figure 3, observe that there is no current flows through the any element. So, the input voltage is directly appeared across the output terminals.

$$\mathbf{V}_{oc1}(s) = \frac{1}{s}$$

First short the voltage source while keeping current source alone. The modified circuit is shown in Figure 4.

Figure 4

Step 5 of 9

From Figure 4, observe that the current flows through the circuit is, $\frac{2}{s}$. Therefore, the output volatge is,

$$\begin{aligned}\mathbf{V}_{oc2}(s) &= \left(-\frac{2}{s}\right)(1+s)\\ &= -\frac{2}{s}(s+1)\end{aligned}$$

Therefore, the total open circuit voltage is,

$$\begin{aligned}\mathbf{V}_{oc} &= \mathbf{V}_{oc1} + \mathbf{V}_{oc2}\\ &= \frac{1}{s} - \frac{2}{s}(s+1)\\ &= \frac{-(2s+1)}{s}\end{aligned}$$

Step 6 of 9

The circuit to find tc he thevenin impedance across the open circuit output terminals is shown in Figure 5.

Figure 5

Step 7 of 9

From the Figure 5, the thevenin's resistance is,

$$\mathbf{Z}_{th} = (s+2)$$

The thevenin's equivalent circuit is shown in Figure 6.

Figure 6

Step 8 of 9

Calculate the output voltage by using voltage division rule.

$$\begin{aligned}\mathbf{V}_o(s) &= \left(\frac{1}{1+s+2}\right)\left(\frac{-(2s+1)}{s}\right)\\ &= -\frac{(2s+1)}{s(s+3)}\end{aligned}$$

Apply the partial fraction rule.

$$\frac{(2s+1)}{s(s+3)} = \frac{A}{s} + \frac{B}{s+3}$$

Calculate the value of A

$$\begin{aligned}A &= \left.\frac{(2s+1)}{(s+3)}\right|_{s=0}\\ &= \frac{(2(0)+1)}{(0+3)}\\ &= \frac{1}{3}\end{aligned}$$

Calculate the value of B

$$\begin{aligned}B &= \left.\frac{(2s+1)}{s}\right|_{s=-3}\\ &= \frac{(2(-3)+1)}{-3}\\ &= \frac{5}{3}\end{aligned}$$

Step 9 of 9

Therefore, the output voltage is,

$$\mathbf{V}_o(s) = -\frac{1}{3s} - \frac{5}{3(s+3)}$$

Apply inverse Laplace transform on both sides.

$$\begin{aligned}v_o(t) &= -\frac{1}{3}u(t) - \frac{5}{3}e^{-3t}u(t)\\ &= \left[-\frac{1}{3} - \frac{5}{3}e^{-3t}\right]u(t)\ \mathbf{V}\end{aligned}$$

Therefore, the output voltage $v_o(t)$ is, $\boxed{\left[-\frac{1}{3} - \frac{5}{3}e^{-3t}\right]u(t)\ \mathbf{V}}$.

Step 1 of 11

Refer to the circuit in Figure P14.31 in the text book.

Redraw the circuit in the frequency domain

Figure 1

Step 2 of 11

To calculate the voltage $v_o(t)$ by the application of Thevenin's theorem, remove the $1\,\Omega$ resistance and calculate the voltage across its terminals.

To make the calculations simpler, apply superposition principle to calculate the voltage.

Assume only the voltage source is operating, the modified diagram is shown in Figure 2.

Figure 2

Step 3 of 11

Apply Voltage division principle and calculate the Thevenin's voltage $\mathbf{V}_{TH1}$.

$$\mathbf{V}_{TH1} = \frac{\frac{4}{s}\left(s+\frac{2}{s}\right)}{2+\frac{2}{s}+s}$$
$$= \frac{\frac{4}{s}\left(\frac{s^2+2}{8}\right)}{\frac{s^3+2s+2}{s}}$$
$$= \frac{4\left(s^3+2\right)}{s\left(s^3+2s+2\right)}$$

Assume only the current source is operating, the modified diagram is shown in Figure 3.

Figure 3

Step 4 of 11

Apply current division principle and calculate the Thevenin's voltage $\mathbf{V}_{TH2}$

$$\mathbf{V}_{TH2} = \left(\frac{s}{2+\frac{2}{s}+s}\right)\left(\frac{2}{s}\right)(2)$$
$$= \frac{\frac{2}{s}}{\frac{s^2+2s+2}{s}}(2)$$
$$= \frac{4s}{s^2+2s+2}$$

Step 5 of 11

Now, from the superposition theorem calculate the voltage V_{TH}.

$$\mathbf{V}_{TH} = \mathbf{V}_{TH1} + \mathbf{V}_{TH2}$$
$$= \frac{4\left(s^2+2\right)}{s\left(s^3+2s+2\right)} + \frac{4s}{s^2+2s+2}$$
$$= \frac{4\left(s^2+2\right)+4s^2}{s\left(s^2+2s+2\right)}$$

$$\mathbf{V}_{TH} = \frac{8\left(s^2+1\right)}{s\left(s^2+2s+2\right)} \quad \text{.....(1)}$$

Step 6 of 11

Calculate the Thevenin's impedance as seen by the $1\,\Omega$ resistance.

Figure 4

Step 7 of 11

Calculate the Thevenin's impedance of the circuit.

$$\mathbf{Z}_{TH} = (2)\,\|\left(s+\frac{2}{s}\right)$$
$$= \frac{2\left(s+\frac{2}{s}\right)}{2+\left(s+\frac{2}{s}\right)}$$
$$= \frac{2s^2+4}{s^2+2s+2}$$
$$= \frac{2\left(s^2+2\right)}{\left(s^2+2s+2\right)}$$

Step 0 of 11

Now, replace the circuit by its Thevenin's equivalent circuit as shown in Figure 5.

Figure 5

Step 9 of 11

In Figure 6, apply voltage division principle and calculate the output voltage in the frequency domain.

$$\mathbf{V}_o(s) = \frac{1}{\left[\frac{2\left(s^2+2\right)}{\left(s^3+2s+2\right)}+1\right]}\left[\frac{8\left(s^2+1\right)}{s\left(s^2+2s+2\right)}\right]$$
$$= \frac{8\left(s^2+1\right)}{\frac{2\left(s^2+2\right)}{s^2+2s+2}+1}$$
$$= \frac{8\left(s^2+1\right)}{s\left[2s^2+4+s^2+2s+2\right]}$$
$$= \frac{8\left(s^2+1\right)}{s\left(3s^2+2s+6\right)}$$

Step 10 of 11

Apply inverse Laplace transform to calculate the output voltage in time domain.

$$v_o(t) = L^{-1}\left[\mathbf{V}_o(s)\right]$$
$$= L^{-1}\left[\frac{8\left(s^2+1\right)}{s\left(3s^2+2s+6\right)}\right]$$

$$v_o(t) = L^{-1}\left[\frac{K_1}{s}+\frac{K_2}{(s+0.33-j1.37)}+\frac{K_2^*}{(s+0.33+j1.37)}\right] \quad \text{.....(2)}$$

Use residue theorem can calculate the value of the constants K_1, K_2 and K_2^*

$$K_1 = s\mathbf{V}_o(s)\big|_{s=0}$$
$$= \frac{8\left(s^2+1\right)}{\left(3s^2+2s+6\right)}\Bigg|_{s=0}$$
$$= \frac{8(0+1)}{(3(0)+2(0)+6)}$$
$$= \frac{4}{3}$$

$$K_2 = (s+0.33-j1.37)\mathbf{V}_o(s)\big|_{s=-0.33+j1.374}$$
$$= \frac{8\left(s^2+1\right)}{s(s-0.33+j1.374)}\Bigg|_{s=-0.33+j1.374}$$
$$= 8\left[\frac{(-0.33+j1.374)^2+1}{(-0.33+j1.374)(-0.33+j1.374-0.33+j1.374)}\right]$$
$$= 2.47\angle 36^\circ$$

$$K_2^* = (2.47\angle 36^\circ)^*$$
$$= 2.47\angle(-36)^\circ$$

Step 11 of 11

Substitute the calculated values of K_1, K_2 and K_2^* in equation (2).

$$v_o(t) = L^{-1}\left[\frac{1.33}{s}+\frac{2.47\angle 36^\circ}{(s+0.33-j1.37)}+\frac{2.47\angle(-36)^\circ}{(s+0.33+j1.37)}\right]$$
$$= 1.33u(t)+\left(2.47e^{j36^\circ}\right)\left(e^{(-0.33-j1.37)t}\right)u(t)+\left(2.47e^{(-36^\circ)}\right)\left(e^{(0.33+j1.37)t}\right)u(t)$$
$$= 1.33u(t)+4.94e^{-0.33t}\left[\frac{e^{j(1.37t+36^\circ)}+e^{-j(1.37t+36^\circ)}}{2}\right]u(t)$$
$$= 1.33u(t)+4.94e^{-0.33t}\cos(1.37t+36^\circ)u(t)$$

Thus, the output voltage in time domain is $\boxed{\left[1.33+4.94e^{-0.33t}\cos(1.37t+36^\circ)\right]u(t)}$

Step 1 of 7

The frequency domain circuit is

Step 2 of 7

Now to find $V_0(s)$ by thevenin theorem, we remove the 2Ω resistor and find the $V_{th}(s)$ across it.

Step 3 of 7

Since no current flows through 1Ω

$$V_{th}(s) = \frac{4}{s} - 1\left(\frac{2}{s}\right) - s\left(\frac{2}{s}\right)$$

$$= \frac{4}{s} - \frac{2}{s} - 2$$

$$= \frac{2}{s} - 2$$

$$V_{th}(s) = \frac{2(1-s)}{s}$$

Step 4 of 7

$\therefore$ Now thevenin impedance is found from the circuit.

$$Z_{th} = 2 + s$$

Step 5 of 7

$\therefore$ The thevenin equivalent circuit is

Step 6 of 7

$$\therefore V_0(s) = V_{th}(s) \cdot \frac{2}{2 + Z_{th}}$$

$$= \frac{2(1-s)}{s} \cdot \frac{2}{2+2+s}$$

$$V_0(s) = \frac{4(1-s)}{s(s+4)}$$

Step 7 of 7

$\therefore$ By partial fraction method

$$\frac{4(1-s)}{s(s+4)} = \frac{k_0}{s} + \frac{k_1}{s+4}$$

$$k_0 = \left.\frac{4(1-s)}{s+4}\right|_{s=0}$$

$$= 1$$

$$k_1 = \left.\frac{4(1-s)}{s}\right|_{s=-4}$$

$$k_1 = \frac{4(5)}{-4}$$

$$k_1 = -5$$

$$\therefore V_0(s) = \frac{1}{s} - \frac{5}{s+4}$$

$\therefore$ Applying inverse Laplace transform

$$\boxed{v_0(t) = \left(1 - 5e^{-4t}\right)u(t)}$$

Step 1 of 8

To calculate Thevenin's voltage, open the load resistor, the modified s-domain circuit is shown below.

Figure 1

Step 2 of 8

Calculate the Thevenin's voltage.

$$\begin{aligned}\mathbf{V}_{\text{Th}} &= (1\,\Omega)\left(-\frac{2}{s}\right)+\left(\frac{1}{s}\right)\left(\frac{1}{s+1}\right)\\ &= -\frac{2}{s}+\frac{1}{s(s+1)}\\ &= \frac{-2(s+1)+1}{s(s+1)}\\ &= \frac{-2s-1}{s(s+1)}\end{aligned}$$

Step 3 of 8

To calculate the Thevenin's resistance, open circuit the current source and capacitor. The modified circuit is shown in Figure 2.

Figure 2

Step 4 of 8

Calculate the Thevenin's resistance.

$$\begin{aligned}R_{\text{Th}} &= 1+\frac{1}{s}\\ &= \frac{s+1}{s}\end{aligned}$$

Step 5 of 8

The Thevenin's equivalent circuit is shown in Figure 3.

Figure 3

Step 6 of 8

Calculate the current $I_o(s)$.

$$\begin{aligned}I_o(s) &= \frac{\dfrac{-2s-1}{s(s+1)}}{1+s+\dfrac{s+1}{s}}\\ &= \frac{\dfrac{-2s-1}{s(s+1)}}{\dfrac{s+s^2+s+1}{s}}\\ &= \frac{-2s-1}{(s+1)^2}\end{aligned}$$

Step 7 of 8

Simplify the equation using partial fractions.

$$I_o(s)=\frac{A}{s+1}+\frac{B}{(s+1)^2}+\frac{C}{(s+1)^3} \quad \text{..... (1)}$$

$$\frac{-2s-1}{(s+1)^2}=\frac{A}{s+1}+\frac{B}{(s+1)^2}+\frac{C}{(s+1)^3}$$

$$-2s-1=A(s+1)^2+B(s+1)+C \quad \text{..... (2)}$$

Substitute -1 for s in the equation (2).

$$\begin{aligned}&-2(-1)-1=A(-1+1)^2+B(-1+1)^2+C\\ &2-1=0+0+C\\ &C=1\end{aligned}$$

Equate s^2 terms from equation (2).

$$A=0$$

Equate s terms from equation (2).

$$\begin{aligned}&-2=2A+B\\ &B=-2(0)-2\\ &B=-2\end{aligned}$$

Step 8 of 8

Substitute -1 for A, and 1 for B -1 for C in equation (1).

$$\begin{aligned}I_o(s) &= \frac{0}{s+1}+\frac{-2}{(s+1)^2}+\frac{1}{(s+1)^3}\\ &= -\frac{2}{(s+1)^2}+\frac{1}{(s+1)^3}\end{aligned}$$

Apply inverse Laplace transform.

$$\begin{aligned}i_o(t) &= -2te^{-t}u(t)+t^2e^{-t}u(t)\\ &= te^{-t}(t-2)u(t)\ \text{A}\end{aligned}$$

Therefore, the output current, $i_o(t)$ is $\boxed{te^{-t}(t-2)u(t)\ \text{A}}$.

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Step 1 of 9

Refer to Figure P14.34 in the text book.

Draw the Laplace domain of the circuit.

Figure 1

Step 2 of 9

Remove the $1\ \Omega$ resistor from the circuit and draw the circuit to determine the value for Thevenin's voltage.

Figure 2

Step 3 of 9

Determine the voltage $V_A(s)$.

$$V_A(s) = \left(\frac{2}{s}\right)(1)$$
$$= \frac{2}{s}\ \text{V}$$

Determine the value for Thevenin's voltage V_{Th}.

$$V_{Th} = V_A(s) + 2V_A(s)$$
$$= \frac{2}{s} + 2\left(\frac{2}{s}\right)$$
$$= \frac{6}{s}$$

Step 4 of 9

Replace the $1\ \Omega$ resistor in Figure P14.34P in the text book with short circuit.

Draw the modified circuit.

Figure 3

Step 5 of 9

The node voltage is,

$$V = V_A + 2V_A$$
$$= 3V_A$$

Apply Kirchhoff's current law to determine the voltage $V_A(s)$.

$$\frac{2}{s} = \frac{3V_A}{s} + V_A$$
$$= V_A\left(\frac{s+3}{s}\right)$$
$$V_A = \frac{2}{s+3}$$

Determine the short circuit current I_{SC}.

$$I_{SC} = \frac{3V_A}{s}$$
$$= 3\left(\frac{2}{s+3}\right)\left(\frac{1}{s}\right)$$

Step 6 of 9

Determine the expression for the Thevenin's impedance Z_{Th}.

$$Z_{Th} = \frac{V_{Th}}{I_{SC}}$$
$$= \frac{6/s}{6/s(s+3)}$$
$$= s+3$$

Draw the THevenin's equivalent circuit.

Figure 4

Step 7 of 9

Determine the output voltage.

$$V_o(s) = \frac{\frac{6}{s}}{(s+3)+1}$$
$$= \frac{6}{s(s+4)}$$

Split the expression of $V_o(s)$ into partial fractions.

$$V_o(s) = \frac{K_1}{s} + \frac{K_2}{s+4}$$

Step 8 of 9

Determine the values of K_1 and K_2.

$$K_1 = \lim_{s\to 0} sV_o(s)$$
$$= \lim_{s\to 0} s\left(\frac{6}{s(s+4)}\right)$$
$$= \lim_{s\to 0}\left(\frac{6}{(s+4)}\right)$$
$$= 1.5$$

$$K_2 = \lim_{s\to -4}(s+4)\frac{6}{s(s+4)}$$
$$= \lim_{s\to -4}\frac{6}{s}$$
$$= -1.5$$

The expression of $V_o(s)$ is,

$$V_o(s) = \frac{1.5}{s} - \frac{1.5}{s+4}$$

Step 9 of 9

Apply inverse Laplace transform.

$$v_o(t) = 1.5u(t) - 1.5e^{-4t}u(t)$$
$$= 1.5\left(1-e^{-4t}\right)u(t)$$

Thus, the expression of $v_o(t)$ is $\boxed{1.5\left(1-e^{-4t}\right)u(t)}$.

Step 1 of 8

Refer to the circuit in Figure P14.35 in the text book.

Draw the circuit in s-domain to calculate the open circuit voltage across the 10Ω resistor.

Figure 1

Step 2 of 8

Write nodal equation at node 2.

$$\frac{V_2(s)-V_1(s)}{\left(\frac{1}{2s}\right)}+\frac{V_2(s)}{10}+I_x(s)=0$$

Where, $I_x(s)=\dfrac{\frac{10}{s}-V_1(s)}{10}$ and $V_1(s)=4V_2(s)$

$$\frac{V_2(s)-4V_2(s)}{\left(\frac{1}{2s}\right)}+\frac{V_2(s)}{10}+\frac{\frac{10}{s}-4V_2(s)}{10}=0$$

$$-6sV_2(s)+\frac{V_2(s)}{10}+\frac{10-4sV_2(s)}{10s}=0$$

$$-60s^2V_2(s)+sV_2(s)+10-4sV_2(s)=0$$

$$-60s^2V_2(s)+sV_2(s)+10-4sV_2(s)=0$$

Simplify further.

$$\left(60s^2+3s\right)V_2(s)=10$$

$$V_2(s)=\frac{10}{60s^2+3s}$$

$$V_2(s)=\frac{10}{3s(1+20s)}$$

Since $V_{oc}=V_2(s)$

$$V_{oc}(s)=\frac{10}{3s(1+20s)}$$

Step 3 of 8

Draw the circuit in s-domain to calculate the short circuit current through the 10Ω resistor

Figure 2

Step 4 of 8

Due to the short circuit, the voltage $V_2(s)$ is,

$$V_2(s)=0\text{ V}$$

Therefore the dependent voltage source $4V_2(s)$ will also be a short circuit.

Hence, $I'_x(s)=\dfrac{\frac{10}{s}-0}{10}$

$$I'_x(s)=\frac{1}{s}$$

$$I_{sc}=-I'_x(s)$$

$$I_{sc}=-\frac{1}{s}\text{ A}$$

Step 5 of 8

Determine the Thevenin's impedance Z_{Th}.

$$\begin{aligned}Z_{Th}&=\frac{V_{oc}(s)}{I_{sc}(s)}\\&=\frac{\frac{10}{3s(1+20s)}}{-\frac{1}{s}}\\&=\frac{-10}{3(1+20s)}\end{aligned}$$

Step 6 of 8

Determine the output current $I_o(s)$.

$$\begin{aligned}I_o(s)&=\frac{V_{oc}(s)}{Z_L+Z_{th}}\\&=\frac{\frac{10}{3s(1+20s)}}{\left(10-\frac{10}{3(1+20s)}\right)}\\&=\frac{10}{s\left[30(1+20s)-10\right]}\\&=\frac{1}{60s\left(s+\frac{1}{30}\right)}\end{aligned}$$

Step 7 of 8

Express $I_o(s)$ in partial fractions.

$$\frac{1}{60s\left(s+\frac{1}{30}\right)}=\frac{A}{s}+\frac{B}{s+\frac{1}{30}}$$

The value of A is,

$$\begin{aligned}A&=\left.\frac{1}{60\left(s+\frac{1}{30}\right)}\right|_{s=0}\\&=\frac{1}{2}\end{aligned}$$

The value of B is,

$$\begin{aligned}B&=\left.\frac{1}{60s}\right|_{s=-\frac{1}{30}}\\&=-\frac{1}{2}\end{aligned}$$

Step 8 of 8

The expression of $I_o(s)$ is,

$$I_o(s)=\frac{\frac{1}{2}}{s}-\left(\frac{\frac{1}{2}}{s+\frac{1}{30}}\right)$$

Apply inverse Laplace transform.

$$i_o(t)=\frac{1}{2}u(t)-\frac{1}{2}e^{-\frac{1}{30}t}u(t)$$

Thus, the expression of $i_o(t)$ is $\boxed{\frac{1}{2}\left(1-e^{-\frac{1}{30}t}\right)u(t)\text{ A}}$.

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Step 1 of 9

The given circuit is,

Step 2 of 9

For $t < 0$, the switch is closed for a long time therefore the circuit is in steady state, hence the capacitor acts as open circuit and the inductor acts as short circuit.

Step 3 of 9

By voltage division,

$$V(0) = 12\left(\frac{4}{4+2}\right)$$

$$V(0) = 8\text{V}$$

$$I(0) = 0\text{A}$$

Step 4 of 9

Circuit represented in s-domain,

Step 5 of 9

Using mesh analysis,

KVL across mesh 1,

$$4I_1(s) + \frac{1}{sC}I_1(s) + \frac{V(0)}{s} + sL\left[I_1(s) - I_0(s)\right] - LI(0) = 0$$

$$4I_1(s) + \frac{1}{s}I_1(s) + \frac{8}{s} + 2s\left[I_1(s) - I_0(s)\right] = 0$$

$$\left(4 + \frac{1}{s} + 2s\right)I_1(s) + \frac{8}{s} = 2sI_0(s)$$

$$\left(2s^2 + 4s + 1\right)I_1(s) + 8 = 2s^2 I_0(s)$$

$$I_0(s) = \frac{2s^2 + 4s + 1}{2s^2}I_1(s) + \frac{8}{2s^2}$$

$$I_0(s) = \frac{2s^2 + 4s + 1}{2s^2}I_1(s) + \frac{4}{s^2} \quad \text{.....(1)}$$

Step 6 of 9

KVL across mesh 2,

$$LI(0) + sL\left[I_0(s) - I_1(s)\right] + I_0(s) + 3I_0(s) = 0$$

$$2s\left[I_0(s) - I_1(s)\right] + 4I_0(s) = 0$$

$$\left(2s + 4\right)I_0(s) = 2sI_1(s)$$

$$I_1(s) = \frac{2s+4}{2s}I_0(s)$$

$$I_1(s) = \frac{s+2}{s}I_0(s) \quad \text{.....(2)}$$

Step 7 of 9

Substituting (2) in (1) we get,

$$I_0(s) = \frac{2s^2 + 4s + 1}{2s^2}\left(\frac{s+2}{s}\right)I_0(s) + \frac{4}{s^2}$$

$$I_0(s)\left[1 - \frac{2s^3 + 8s^2 + 9s + 2}{2s^3}\right] = \frac{4}{s^2}$$

$$I_0(s)\left[\frac{2s^3 - 2s^3 - 8s^2 - 9s - 2}{2s^3}\right] = \frac{4}{s^2}$$

$$I_0(s) = \frac{-8s}{8s^2 + 9s + 2}$$

Step 8 of 9

$$I_0(s) = \frac{-s}{s^2 + \frac{9}{8}s + \frac{1}{4}}$$

$$I_0(s) = \frac{-s}{(s + 0.3048)(s + 0.8202)}$$

By partial fractions,

$$\frac{-s}{(s+0.3048)(s+0.8202)} = \frac{A}{s+0.3048} + \frac{B}{s+0.8202}$$

$$A = \left.\frac{-s}{(s+0.8202)}\right|_{s=-0.3048}$$

$$A = \frac{-(-0.3048)}{(-0.3048+0.8202)}$$

$$A = \frac{0.3048}{0.5154}$$

$$A = 0.5914$$

Step 9 of 9

$$B = \left.\frac{-s}{(s+0.3048)}\right|_{s=-0.8202}$$

$$B = \frac{-(-0.8202)}{(-0.8202+0.3048)}$$

$$B = \frac{0.8202}{-0.5154}$$

$$B = -1.5914$$

$$\therefore I_0(s) = \frac{0.5919}{(s+0.3048)} - \frac{1.5914}{(s+0.8202)}$$

Now taking inverse Laplace transforms,

$$i_0(t) = 0.5914e^{-0.3048t}u(t) - 1.5914e^{-0.8202t}u(t)$$

$$\boxed{i_0(t) = \left(0.5914e^{-0.3048t} - 1.5914e^{-0.8202t}\right)u(t)\ \text{A}}$$

Step 1 of 7

Step 2 of 7

At t = 0⁻, when the switch is closed, assuming that the circuit has reached steady state. The given circuit is as shown below:

Step 3 of 7

$$\therefore\ i_L(0^-) = \frac{14\times 0.5}{3.5} = 2\text{A}$$

Step 4 of 7

Now, for t > 0, when the switch is opened ,

Step 5 of 7

Applying KVL to the circuit,

$$2I_1(s) + 2\left[sI_1(s) - i_L(0^-)\right] - 2sI_2(s) = \frac{12}{s} \quad \text{.....(1)}$$

$$2I_2(s) + 2\left[sI_2(s) - i_L(0^-)\right] - 2sI_1(s) = 0 \quad \text{.....(2)}$$

$$\begin{bmatrix} (2s+2) & -2s \\ -2s & 2+2s \end{bmatrix}\begin{bmatrix} 2s+2 & 2s \\ 2s & 2s+2 \end{bmatrix}\begin{bmatrix} \frac{4s+12}{s} \\ 4 \end{bmatrix}$$

$$\therefore\ I_2(s) = \frac{16s+32}{4(2s+1)}$$

$$= \frac{16(s+2)}{4(2s+1)} = \frac{4(s+2)}{(2s+1)}$$

$$= \frac{2(s+2)}{\left(s+\frac{1}{2}\right)}$$

Step 6 of 7

$$\therefore\ i_0(t) = L^{-1}\left[I_0(s)\right]$$

$$= L^{-1}\left[I_2(s)\right]$$

$$= L^{-1}\left[\frac{2s}{s+\frac{1}{2}} + \frac{4}{s+\frac{1}{2}}\right]$$

$$= L^{-1}\left[\frac{2\left(s+\frac{1}{2}-\frac{1}{2}\right)}{s+\frac{1}{2}} + \frac{4}{s+\frac{1}{2}}\right]$$

$$= L^{-1}\left\{2\left[\frac{s+\frac{1}{2}}{s+\frac{1}{2}} - \frac{\frac{1}{2}}{s+\frac{1}{2}}\right] + \frac{4}{s+\frac{1}{2}}\right\}$$

Step 7 of 7

$$= 2L^{-1}\left[1 - \frac{\frac{1}{2}}{s+\frac{1}{2}}\right] + L^{-1}\left[\frac{4}{s+\frac{1}{2}}\right]$$

$$= \left\{2\left[\delta(t) - \frac{1}{2}e^{-0.5t}\right] + 4e^{-0.5t}\right\}$$

$$= 2\delta(t) - e^{-0.5t} + 4e^{-0.5t}$$

$$= 2\delta(t) + 3e^{-0.5t}$$

$$\boxed{\therefore\ i_0(t) = 2\delta(t) + 3e^{-0.5t}}$$

Step 1 of 6

14.046 P

The given circuit is.

Step 2 of 6

For $t < 0$, the switch is closed for a long time therefore the circuit is in steady state, hence the inductor acts as short circuit

Step 3 of 6

$$I(0) = \frac{12}{2+[6\|4\|(7+5)]}\left(\frac{6}{6+(4\|(7+5))}\right)$$

$$I(0) = \frac{12}{2+[6\|4\|12]}\left(\frac{6}{6+(4\|12)}\right)$$

$$I(0) = \frac{12}{2+[6\|3]}\left(\frac{6}{6+3}\right)$$

$$I(0) = \frac{12}{2+2}\left(\frac{6}{9}\right)$$

$$I(0) = 2\text{A}$$

Step 4 of 6

Circuit represented in s-domain,

Step 5 of 6

By mesh analysis,

KVL across mesh 1,

$$6I_L(s) + sLI_L(s) - LI(0) + 4[I_L(s) - I_2(s)] = 0$$

$$6I_L(s) + 2sI_L(s) - 4 + 4[I_L(s) - I_2(s)] = 0$$

$$(10+2s)I_L(s) - 4I_2(s) = 4 \quad \text{.....(1)}$$

KVL across mesh 2,

$$4[I_2(s) - I_L(s)] + 12I_2(s) = 0$$

$$-4I_L(s) + 16I_2(s) = 0$$

$$I_2(s) = \frac{1}{4}I_L(s) \quad \text{.....(2)}$$

Step 6 of 6

Adding (1) and (2),

$$(9+2s)I_L(s) = 4$$

$$I_L(s) = \frac{4}{9+2s}$$

Now

$$I_0(s) = I_L(s) - I_2(s)$$

$$I_0(s) = I_L(s) - \frac{1}{4}I_L(s)$$

$$I_0(s) = \frac{3}{4}I_L(s)$$

$$I_0(s) = \frac{3}{2s+9}$$

$$I_0(s) = \frac{1.5}{s+4.5}$$

Now taking inverse Laplace transforms gives:

$$\boxed{i_0(t) = 1.5e^{-4.5t}u(t) \text{ A}}$$

Step 1 of 5

14.047 P

Refer to circuit diagram in Figure P14.47 in the textbook.

For $t = 0^-$, the switch in the circuit is closed for long time, so circuit reaches steady state. At steady state condition, capacitor as open circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Apply Kirchhoff's current law at node $v_C(0^-)$.

$$\frac{v_C(0^-) - 6\text{ V}}{3\text{ k}\Omega} + \frac{v_C(0^-)}{4\text{ k}\Omega + 2\text{ k}\Omega} = 0$$

$$\frac{v_C(0^-)}{3\text{ k}\Omega} + \frac{v_C(0^-)}{6\text{ k}\Omega} = \frac{6\text{ V}}{3\text{ k}\Omega}$$

$$\left(\frac{1}{3\text{ k}\Omega} + \frac{1}{6\text{ k}\Omega}\right) v_C(0^-) = \frac{6\text{ V}}{3\text{ k}\Omega}$$

$$1.5 v_C(0^-) = 6\text{ V}$$

$$v_C(0^-) = 4\text{ V}$$

Step 3 of 5

For $t > 0$, the switch in the circuit is open and the s-domain circuit is shown in Figure 2.

Figure 2

Step 4 of 5

Apply Kirchhoff's current law at node $V_o(s)$.

$$\frac{V(s) - \frac{4}{s}}{\frac{10^4}{s}} + \frac{V(s)}{4\text{ k}\Omega + 2\text{ k}\Omega} = 0$$

$$\frac{sV(s) - 4}{10^4} + \frac{V(s)}{6000} = 0$$

$$\left(\frac{s}{10} + \frac{1}{6}\right) V(s) = \frac{4}{10}$$

$$\left(\frac{6s + 10}{60}\right) V(s) = \frac{4}{10}$$

$$V(s) = \frac{4}{s + 1.67} \quad \text{..... (1)}$$

Step 5 of 5

Calculate the output voltage using voltage division rule.

$$\begin{aligned} V_o(s) &= \left(\frac{2\text{ k}\Omega}{4\text{ k}\Omega + 2\text{ k}\Omega}\right) V(s) \\ &= \left(\frac{2\text{ k}\Omega}{6\text{ k}\Omega}\right)\left(\frac{4}{s + 1.67}\right) \\ &= (0.333)\left(\frac{4}{s + 1.67}\right) \\ &= \frac{1.33}{s + 1.67} \end{aligned}$$

Apply inverse Laplace transform.

$$v_o(t) = 1.33 e^{-1.67t}\text{ V}$$

Therefore, the output voltage, $v_o(t)$ for $t > 0$ is $\boxed{1.33 e^{-1.67t}\text{ V}}$.

Step **1** of 6

Refer to circuit diagram in Figure P14.48 in the textbook.

For $t = 0^-$, the switch in the circuit is open for long time and circuit reaches steady state. At steady state, capacitor acts as open circuit. The modified circuit is shown in Figure 1.

Figure 1

Step **2** of 6

Calculate the initial voltage across the capacitor.

$$\begin{aligned} v_C(0^-) &= \left(\frac{6\text{ k}\Omega}{3\text{ k}\Omega + 3\text{ k}\Omega + 6\text{ k}\Omega}\right)(4\text{ V}) \\ &= \left(\frac{6\text{ k}\Omega}{12\text{ k}\Omega}\right)(4\text{ V}) \\ &= (0.5)(4\text{ V}) \\ &= 2\text{ V} \end{aligned}$$

Step **3** of 6

For $t > 0$, the switch in the circuit is closed, the s-domain circuit is shown in Figure 2.

Figure 2

Step **4** of 6

Apply Kirchhoff's current law at node $V(s)$.

$$\frac{V(s)}{3\text{ k}\Omega} + \frac{V(s)}{6\text{ k}\Omega} + \frac{V(s) - V_o(s) - \frac{2}{s}}{\frac{5000}{s}} = 0$$

$$\frac{V(s)}{3} + \frac{V(s)}{6} + \frac{sV(s) - sV_o(s) - 2}{5} = 0$$

$$\left(\frac{1}{3} + \frac{1}{6} + \frac{s}{5}\right)V(s) - \frac{sV_o(s)}{5} = \frac{2}{5}$$

$$\left(\frac{10 + 5 + 6s}{30}\right)V(s) - \frac{6sV_o(s)}{30} = \frac{2}{5}$$

$$(15 + 6s)V(s) = 6sV_o(s) + 12$$

$$(s + 2.5)V(s) = sV_o(s) + 2$$

$$V(s) = \frac{sV_o(s) + 2}{s + 2.5} \quad \text{..... (1)}$$

Step **5** of 6

Apply Kirchhoff's current law at node $V_o(s)$.

$$\frac{V_o(s)}{2\text{ k}\Omega} + \frac{V_o(s) - V(s) + \frac{2}{s}}{\frac{5000}{s}} = 0$$

$$\frac{V_o(s)}{2} + \frac{sV_o(s) - sV(s) + 2}{5} = 0$$

$$\left(\frac{1}{2} + \frac{s}{5}\right)V_o(s) - \frac{sV(s)}{5} = -\frac{2}{5}$$

$$\left(\frac{2s + 5}{10}\right)V_o(s) - \frac{sV(s)}{5} = -\frac{2}{5}$$

$$(s + 2.5)V_o(s) - sV(s) = -2 \quad \text{..... (2)}$$

Step **6** of 6

Recall equation (2).

$$(s + 2.5)V_o(s) - sV(s) = -2$$

Substitute $\frac{sV_o(s) + 2}{s + 2.5}$ for $V(s)$ in the equation.

$$(s + 2.5)V_o(s) - (s)\left(\frac{sV_o(s) + 2}{s + 2.5}\right) = -2$$

$$\left(s + 2.5 - \frac{s^2}{s + 2.5}\right)V_o(s) = \frac{2s}{s + 2.5} - 2$$

$$\left(\frac{(s + 2.5)(s + 2.5) - s^2}{s + 2.5}\right)V_o(s) = \frac{2s - 2s - 5}{s + 2.5}$$

$$\left(\frac{s^2 + 5s + 6.25 - s^2}{s + 2.5}\right)V_o(s) = \frac{-5}{s + 2.5}$$

$$5(s + 1.25)V_o(s) = -5$$

$$V_o(s) = \frac{-1}{s + 1.25}$$

Apply inverse Laplace.

$$v_o(t) = -e^{-1.25t}u(t)\text{ V}$$

Therefore, the output voltage, $v_o(t)$ for $t > 0$ is $\boxed{-e^{-1.25t}u(t)\text{ V}}$.

Step 1 of 5

For $t = 0^-$, the switch in the circuit is closed for long time, so circuit reaches steady state. At steady state inductor acts as short circuit. The modified circuit is shown in Figure 1.

Figure 1

Step 2 of 5

Calculate the initial current through inductor.

$$\begin{aligned} i_L(0^-) &= \left(\frac{6\ \Omega}{12\ \Omega + 6\ \Omega}\right)(6\ \text{A}) \\ &= \left(\frac{6\ \Omega}{18\ \Omega}\right)(6\ \text{A}) \\ &= \left(\frac{1}{3}\right)(6\ \text{A}) \\ &= 2\ \text{A} \end{aligned}$$

Step 3 of 5

For $t > 0$, the switch in the circuit is closed and the s-domain circuit is shown in Figure 2.

Figure 2

Step 4 of 5

Apply Kirchhoff's current law at node $V(s)$.

$$\frac{V(s)}{3s} + \frac{V(s)}{4} + \frac{V(s)}{12+6} = -\frac{2}{s}$$

$$\left(\frac{1}{3s} + \frac{1}{4} + \frac{1}{18}\right)V(s) = -\frac{2}{s}$$

$$\left(\frac{12 + 9s + 2s}{36s}\right)V(s) = -\frac{2}{s}$$

$$V(s) = -\frac{72}{11s + 12}$$

Step 5 of 5

Calculate the output current.

$$\begin{aligned} I_o(s) &= \frac{V(s)}{12+6} \\ &= \frac{\frac{-72}{11s+12}}{18} \\ &= \frac{-4}{11s+12} \\ &= \frac{-0.36}{s+1.09} \end{aligned}$$

Apply inverse Laplace transform.

$$i_o(t) = -0.36e^{-1.09t}u(t)\ \text{A}$$

Therefore, the current, $i_o(t)$ for $t > 0$ is $\boxed{-0.36e^{-1.09t}u(t)\ \text{A}}$.

Step 1 of 4

14.050 P

Refer to Figure P14.50 in the text book for the circuit.

For $t < 0$ when the switch is open, inductor acts as a short circuit. Redraw the circuit by replacing the inductor with a short circuit.

Figure 1

Step 2 of 4

Observe from Figure 1 that the output voltage at $t = 0$ is,

$$v_o(0) = 0 \text{ V}$$

$$i_o(0) = \frac{24}{2+6}$$
$$= 3 \text{ A}$$

A voltage source is added in series with the inductor, whose value is,

$$Li(0) = 12 \text{ V}$$

The switch is closed for $t > 0$. Draw the circuit in *s*-domain

Figure 2

Step 3 of 4

The circuit forms a source free *RL* circuit.

Apply Kirchhoff's current law at node 1.

$$\frac{V_1(s)}{6} + \frac{V_1(s)+12}{4s} + \frac{V_1(s)-V_o(s)}{1} = 0$$

$$\left(\frac{1}{6} + \frac{1}{4s} + 1\right)V_1(s) + \frac{3}{s} = V_o(s)$$

$$V_1(s) = \frac{12s}{14s+3}V_o(s) + \frac{3}{s}$$

Apply Kirchhoff's current law at node 2.

$$\frac{V_o(s)}{2} + \frac{V_o(s)-V_1(s)}{1} = 0$$

$$-V_1(s) + \frac{3}{2}V_o(s) = 0$$

Substitute $\frac{12s}{14s+3}V_o(s) + \frac{3}{s}$ for $V_1(s)$.

$$-\frac{12s}{14s+3}V_o(s) - \frac{3}{s} + \frac{3}{2}V_o(s) = 0$$

$$\frac{18s+9}{2(14s+3)}V_o(s) = \frac{3}{s}$$

$$\frac{9(2s+1)}{2(14s+3)}V_o(s) = \frac{3}{s}$$

$$V_o(s) = \frac{2(14s+3)}{3s(2s+1)}$$

Step 4 of 4

Apply partial fraction expansion to $V_o(s)$.

$$V_o(s) = \frac{2(14s+3)}{3s(2s+1)}$$
$$= \frac{14s+3}{3s(2s+1)}$$
$$= \frac{2}{s} + \frac{8}{3\left(s+\frac{1}{2}\right)}$$

Apply inverse Laplace transform.

$$v_o(t) = \left(2 + \frac{8}{3}e^{-\frac{1}{2}t}\right)u(t) \text{ V}$$

Thus, the output voltage $v_o(t)$ is $\boxed{\left(2 + \frac{8}{3}e^{-\frac{1}{2}t}\right)u(t) \text{ V}}$.

Step 1 of 4

Refer to Figure P14.51 in the text book for the circuit.

For $t < 0$ when the switch is closed, inductor acts as a short circuit and capacitor acts as an open circuit. Redraw the circuit by replacing the inductor with a short circuit.

Figure 1

Step 2 of 4

Observe from Figure that the initial inductor current,

$$i_L(0) = \frac{24}{2+6}$$
$$= 3 \text{ A}$$

The initial capacitor voltage is,

$$v_C(0) = 24 - 2i_L(0)$$
$$= 24 - 6$$
$$= 18 \text{ V}$$

A voltage source is added in series with the inductor, whose value is,

$$Li(0) = 6 \text{ V}$$

A voltage source is added in series with the capacitor, whose value is,

$$\frac{v_C(0)}{s} = \frac{18}{s}$$

Draw the circuit for $t > 0$ when the switch is open in s-domain along with initial conditions.

Figure 2

Step 3 of 4

Apply Kirchhoff's voltage law to the first loop.

$$-\frac{18}{s} + \frac{I_1(s)}{s} + 6I_1(s) + 2s\left[I_1(s) - I_2(s)\right] - 6 = 0$$

$$\left(\frac{1}{s} + 2s + 6\right)I_1(s) - 2sI_2(s) = 6 + \frac{18}{s}$$

$$\left(\frac{2s^2 + 6s + 1}{s}\right)I_1(s) - 2sI_2(s) = \frac{6(s+3)}{s}$$

$$I_1(s) = \frac{6(s+3)}{2s^2 + 6s + 1} + \frac{2s^2}{2s^2 + 6s + 1}I_2(s)$$

Apply Kirchhoff's voltage law to the second loop.

$$6 + 2s\left[I_2(s) - I_1(s)\right] + 3I_2(s) = 0$$

$$(2s+3)I_2(s) - 2sI_1(s) = -6$$

Substitute $\frac{6(s+3)}{2s^2 + 6s + 1} + \frac{2s^2}{2s^2 + 6s + 1}I_2(s)$ for $I_1(s)$.

$$(2s+3)I_2(s) - 2s\left[\frac{6(s+3)}{2s^2 + 6s + 1} + \frac{2s^2}{2s^2 + 6s + 1}I_2(s)\right] = -6$$

$$\left(2s + 3 - \frac{4s^3}{2s^2 + 6s + 1}\right)I_2(s) = \frac{12(s+3)}{2s^2 + 6s + 1} - 6$$

$$\left(\frac{18s^2 + 20s + 3}{2s^2 + 6s + 1}\right)I_2(s) = \frac{-12s^2 - 24s + 30}{2s^2 + 6s + 1}$$

$$I_2(s) = \frac{-12s^2 - 24s + 30}{18s^2 + 20s + 3}$$

$$I_2(s) = -\frac{2}{3} - \frac{4s - 32}{18s^2 + 20s + 3}$$

Step 4 of 4

The output voltage is,

$$V_o(s) = 2I_2(s)$$
$$= -\frac{4}{3} - \frac{8(s-8)}{18s^2 + 20s + 3}$$
$$= -\frac{4}{3} - \frac{8(s-8)}{18\left(s^2 + 1.11s + 0.167\right)}$$
$$= -\frac{4}{3} - \frac{4}{9}\frac{(s-8)}{(s+0.555)^2 - 0.376^2}$$

$$V_o(s) = -\frac{4}{3} - \frac{4}{9}\left[\frac{s + 0.555}{(s+0.555)^2 - 0.376^2}\right] + 91\left[\frac{0.376}{(s+0.555)^2 - 0.376^2}\right]$$

Apply inverse Laplace transform.

$$v_o(t) = \left[-\frac{4}{3} - \frac{4}{9}e^{-0.555t}\cosh(0.376t) + 91e^{-0.555t}\sinh(0.376t)\right]u(t) \text{ V}$$

Thus, the output voltage is,

$$\boxed{v_o(t) = \left[-\frac{4}{3} - \frac{4}{9}e^{-0.555t}\cosh(0.376t) + 91e^{-0.555t}\sinh(0.376t)\right]u(t) \text{ V}}.$$

14.052

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14.053

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Step 1 of 9

Refer to the circuit in Figure P14.41 in the text book.

For $t < 0$, if we assume that the circuit has reached the steady state, as switch is closed and inductor shorted, it can be redrawn as shown in Figure 1.

Figure 1

Step 2 of 9

Since there exist short circuit across $6\ \Omega$ resistance and $3\ \Omega$ resistance. The resultant circuit is as shown in Figure 2.

Figure 2

Step 3 of 9

From Figure 2, the current $i_L(0)$ is,

$$i_L(0) = (6)\frac{4}{2+4}$$
$$= 4\text{ A}$$

Step 4 of 9

Now the s-domain circuit for $t > 0$ is shown in Figure 3.

Figure 3

Step 5 of 9

Apply Kirchhoff's Current Law in loop 2.

$$6(I_2(s) - I_1(s)) + 4s(I_2(s)) - 16 = 0$$

$$-6I_1(s) + (6+4s)I_2(s) = 16 \quad \ldots\ldots (1)$$

Appy Kirchhoff's Current Law in loop 3.

$$2(I_3(s) - I_1(s)) + 4(I_3(s)) + 3I_3(s) = 0$$

$$-2I_1(s) + 9I_3(s) = 0 \quad \ldots\ldots (2)$$

From Figure 2,

$$I_1(s) = \frac{6}{s} \quad \ldots\ldots (3)$$

Step 6 of 9

Substitute equation (3) in equation (1).

$$-6\left(\frac{6}{s}\right) + (6+4s)I_2(s) = 16$$

$$(6+4s)I_2(s) = 16 + \frac{36}{s}$$

$$I_2(s) = \frac{16 + \frac{36}{s}}{(6+4s)}$$

$$I_2(s) = \frac{6s+18}{s(3+2s)} \quad \ldots\ldots (4)$$

Substitute equation (3) in equation (2).

$$-2\left(\frac{6}{s}\right) + 9I_3(s) = 0$$

$$9I_3(s) = \frac{12}{s}$$

$$I_3(s) = \frac{4}{3s} \quad \ldots\ldots (5)$$

Step 7 of 9

From Figure 3, we have,

$$V_o(s) = 3I_3(s) + 4sI_2(s) - 16 \quad \ldots\ldots (6)$$

Substitute equation (4) and equation (5) in equation (6).

$$V_o(s) = 3\left(\frac{4}{3s}\right) + 4s\left(\frac{8s+18}{s(3+2s)}\right) - 16$$
$$= \frac{4}{s} + \frac{32s+72}{3+2s} - 16$$
$$= \frac{4(3+2s) + (32s+72)s - 16s(3+2s)}{s(3+2s)}$$
$$= \frac{32s+12}{s(3+2s)}$$

Split $V_o(s)$ as partial fractions.

$$\frac{32s+12}{s(3+2s)} = \frac{K_{11}}{s} + \frac{K_{12}}{2s+3}$$

Step 8 of 9

Evaluate the constants.

$$K_{11} = s\left.\frac{32s+12}{s(3+2s)}\right|_{s=0}$$
$$= \frac{32(0)+12}{(3+2(0))}$$
$$= \frac{12}{3}$$
$$= 4$$

And

$$K_{12} = (2s+3)\left.\frac{32s+12}{s(3+2s)}\right|_{s=-\frac{3}{2}}$$
$$= \frac{32\left(\frac{-3}{2}\right)+12}{\left(\frac{-3}{2}\right)}$$
$$= \frac{-96+24}{-3}$$
$$= 24$$

Step 9 of 9

Hence $V_o(s)$ can be expressed as

$$V_o(s) = \frac{32s+12}{s(3+2s)}$$
$$= \frac{4}{s} + \frac{24}{2s+3}$$
$$= 4\left(\frac{1}{s}\right) + 12\left(\frac{1}{s+1.5}\right)$$

Apply Inverse Lapiace transform.

$$v_o(t) = 4u(t) + 12e^{-1.5}u(t)$$
$$= \left(4 + 12e^{-1.5}\right)u(t)\text{ V}$$

Thus the value of $v_o(t)$ is $\boxed{\left(4 + 12e^{-1.5}\right)u(t)\text{ V}}$

Step 1 of 6

Refer to the circuit in Figure P14.42 in the text book.

Draw the circuit at $t = 0^-$.

Figure 1

Step 2 of 6

Determine the voltage V_A.

$$V_A = 16\left[\frac{12k}{12k+4k}\right]$$
$$= 12V$$

Determine the voltage V_B.

$$-12+(6k+3k)I = 0$$

$$I = \frac{12}{9k} \quad V_B = 12-6k\left(\frac{12}{9k}\right)$$
$$= 4V$$

The voltage across the capacitor at $t = 0^-$ is,

$$V_C(0^-) = V_A - V_B$$
$$= 12-4$$
$$= 8\ V$$

Step 3 of 6

Draw the circuit for $t > 0$.

Figure 2

Step 4 of 6

By source transformation,

$$I = \frac{\left(\frac{16}{s}\right)}{4\ k}$$
$$= \frac{4}{s}mA$$

Draw the Equivalent circuit.

Figure 3

Step 5 of 6

The equivalent resistance of the parallel combination of $4\ k\Omega$ and $12\ k\Omega$ is,

$$R_{eq} = 4k \| 12k$$
$$= 3k\Omega$$

Use source transformation.

$$V = \left(\frac{4}{s}m\right)(3k)$$
$$= \frac{12}{s}V$$

Draw the equivalent circuit.

Figure 4

Step 6 of 6

Apply Kirchhoff's voltage law in the loop as shown in Figure 4.

$$-\frac{12}{s} + 3k\ (I_o) + \left(\frac{10k}{s}\right)I_o + \frac{8}{s} + (3k)\ (I_o) = 0$$

$$I_o\left[\frac{10k}{s} + 6k\right] = \frac{4}{s}$$

$$I_o\left[10k + s(6k)\right] = 4$$

$$I_o = \frac{4}{(2k)[5+3s]}$$

Simplify further.

$$I_o(s) = \frac{2m}{5+3s}$$
$$= \frac{\frac{2}{3}m}{s+\frac{5}{3}}$$

Apply inverse Laplace transform.

$$i_o(t) = \frac{2}{3}e^{-\left(\frac{5}{3}\right)t}u(t)\ mA$$

Thus, the expression of $i_o(t), t > 0$ is $\boxed{\frac{2}{3}e^{-\left(\frac{5}{3}\right)t}u(t)\ mA}$.

14.056

P

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Step 1 of 7

Refer to Figure P14.43 in the text book.

The circuit reaches steady state at $t = 0^-$.

Replace the capacitor with open circuit.

Draw the modified circuit.

Figure 1

Step 2 of 7

Determine the voltage across the capacitor at $t = 0^-$.

$$v_C(0^-) = 12 \text{ V}$$

Step 3 of 7

Draw the circuit for $t > 0$.

Figure 2

Step 4 of 7

Simplify further the circuit in Figure 2.

The modified circuit is,

Figure 3

Step 5 of 7

Draw the Laplace equivalent for the circuit in Figure 3.

Figure 4

Step 6 of 7

Write the mesh equations for the circuit in Figure 4.

$$I_1(s)\left[6\text{k} + \frac{1.66\text{k}}{s}\right] - I_2(s)\left[2\text{k} + \frac{1.66\text{k}}{s}\right] = \frac{12}{s} - \frac{12}{s} \quad \text{..... (1)}$$

$$-\left[2\text{k} + \frac{1.66\text{k}}{s}\right] I_1(s) + I_2(s)\left[6\text{k} + \frac{1.66\text{k}}{s}\right] = \frac{-4}{s} + \frac{12}{s} \quad \text{..... (2)}$$

Simplify the Equations (1) and (2).

$$\begin{bmatrix} \frac{(6\text{k})s + 1.66\text{k}}{s} & -\frac{(2\text{k})s + 1.66\text{k}}{s} \\ -\frac{(2\text{k})s + 1.66\text{k}}{s} & \frac{(6\text{k})s + 1.66\text{k}}{s} \end{bmatrix} \begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{8}{s} \end{bmatrix}$$

$$\Delta = \frac{32s + 13.26}{s}$$

$$\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \left[\frac{s}{32s + 13.26}\right] \begin{bmatrix} \frac{6s + 1.66}{s} & \frac{2s + 1.66}{s} \\ \frac{2s + 1.66}{s} & \frac{6s + 1.66}{s} \end{bmatrix} \begin{bmatrix} 0 \\ \frac{8}{s} \end{bmatrix}$$

Step 7 of 7

The expression of the current $I_2(s)$ is,

$$\begin{aligned} I_2(s) &= \left(\frac{s}{32s + 13.26}\right)\left[\frac{8}{s} \cdot \frac{6s + 1.66}{s}\right] \\ &= \frac{48s + 13.28}{s(32s + 13.26)} \end{aligned}$$

Determine the expression for the output voltage $V_o(s)$.

$$\begin{aligned} V_o(s) &= 4I_2(s) \\ &= 4\left[\frac{48s + 13.28}{s(32s + 13.26)}\right] \\ &= 4\left[\frac{1}{s} + \frac{16}{32s + 13.26}\right] \\ &= \frac{4}{s} + \frac{2}{s + 0.4144} \end{aligned}$$

Apply inverse Laplace transform.

$$\begin{aligned} V_o(t) &= L^{-1}\left[V_o(s)\right] \\ &= L^{-1}\left[\frac{4}{s} + \frac{2}{s + 0.4144}\right] \\ &= \left(4 + 2e^{-0.4144t}\right)u(t) \end{aligned}$$

Thus, the expression of the voltage $v_o(t)$ is $\boxed{\left(4 + 2e^{-0.4144t}\right)u(t)}$.

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Step 1 of 18

Refer to Figure P14.44 in the text book

At $t = 0^-$ the circuit is under steady state and the capacitor charges fully.

Replace the capacitor with open circuit.

Draw the equivalent circuit at $t = 0^-$

Figure 1

Step 2 of 18

Apply Mesh Analysis to the circuit in Figure 1

Apply Kirchhoff's current law in loop (1)

$$-12+(4k)I_1+(2k)I_1+(3k)(I_1-I_2)+24=0$$

$$9000I_1-3000I_2=-36 \qquad (1)$$

Apply Kirchhoff's current law in loop (2)

$$-24+(2k)(I_2-I_1)+(2k)I_2+(4k)(I_2-I_1)+(4k)(I_2-I_3)=0$$

$$-3000I_1+11000I_2-6000I_3=24 \quad \ldots\ldots (2)$$

Apply Kirchhoff's current law in loop (3)

$$(4k+2k)(I_3-I_2)+(8k+4k)I_3=4$$

$$-6000I_2+18000I_3=0 \qquad (3)$$

Step 3 of 18

Represent the Equations (1), (2) and (3) in matrix form

$$\begin{bmatrix} 9000 & -3000 & 0 \\ -3000 & 11000 & -6000 \\ 0 & -6000 & 18000 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}=\begin{bmatrix} -36 \\ 24 \\ 8 \end{bmatrix}$$

Step 4 of 18

Determine the voltage $V_x(0^-)$

$$V_x(0^-)=(I_2-I_3)(4k)-I_2(4k)$$
$$=(1.5\times10^{-3}-8.5\times10^{-3})(4\times10^3)-(0.5\times10^{-3})(4\times10^3)$$
$$=(1\times10^{-3}-8.5\times10^{-3})(4\times10^3)$$
$$=2\ \text{V}$$

Step 5 of 18

Draw the circuit for $t > 0$

Figure 2

Step 8 of 18

Apply Mesh Analysis to the circuit in Figure 2.

Apply Kirchhoff's current law in loop (1)

$$12+(4K+2K)I_1+(3K)(I_1-I_2)+24=0$$

$$9000I_1-3000I_2=-36$$

Apply Laplace transform on both sides.

$$9000I_1(s)-3000I_2(s)=\frac{-36}{s} \quad \ldots\ldots (4)$$

Step 7 of 18

Apply Kirchhoff's current law in loop (2)

$$-24+(3K)(I_2-I_1)+(2K+2K)I_2+(4K)(I_2-I_3)=8$$

$$-3000I_1+11000I_2-4000I_3=24$$

Apply Laplace transform on both sides.

$$-3000I_1(s)+11000I_2(s)-4000I_3(s)=\frac{24}{s} \qquad (5)$$

Step 8 of 18

Apply Kirchhoff's current law in loop (3).

$$(4K)(I_3-I_2)+\frac{1}{100\mu F}\int_0^t i_3dt+2+(4K)I_3=0$$

$$-4000I_2+8000I_3+10000\int_0^t i_3dt=-2$$

Apply Laplace transform on both sides.

$$-4000I_2(s)+8000I_3(s)+10000\frac{I_3(s)}{s}=\frac{-2}{s}$$

$$-4000I_2(s)+\left(8000+\frac{10000}{s}\right)I_3(s)=\frac{-2}{s} \qquad (6)$$

Step 9 of 18

Express the equations (4), (5) and (6) in matrix form

$$\begin{bmatrix} 9000 & -3000 & 0 \\ -3000 & 11000 & -4000 \\ 0 & -4000 & \left(8000+\frac{10000}{s}\right) \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \\ I_3(s) \end{bmatrix}=\begin{bmatrix} \frac{-36}{s} \\ \frac{24}{s} \\ \frac{-2}{s} \end{bmatrix}$$

$$\begin{bmatrix} I_1(s) \\ I_2(s) \\ I_3(s) \end{bmatrix}=\begin{bmatrix} 9000 & -3000 & 0 \\ -3000 & 11000 & -4000 \\ 0 & -4000 & \left(8000+\frac{10000}{s}\right) \end{bmatrix}^{-1}\begin{bmatrix} \frac{-36}{s} \\ \frac{24}{s} \\ \frac{-2}{s} \end{bmatrix}$$

Step 10 of 18

Find the determinant of the matrix $M=\begin{bmatrix} 9000 & -3000 & 0 \\ -3000 & 11000 & -4000 \\ 0 & -4000 & \left(8000+\frac{10000}{s}\right) \end{bmatrix}$

$$\det(M)=\left(\begin{array}{l} 9000\left((11000)\left(8000+\frac{10000}{s}\right)-(-4000)(-4000)\right) \\ -(-3000)\left(-3000\left(8000+\frac{10000}{s}\right)-0\right) \end{array}\right)$$
$$=9000\left(72\times10^6+\frac{118}{s}\times10^9\right)-\left(-3000\left(-24\times10^6-\frac{30\times10^9}{s}\right)\right)$$
$$=648\times10^9+\frac{990}{s}\times10^9-72\times10^9-\frac{90}{s}\times10^9$$
$$=576\times10^9+\frac{900}{s}\times10^9$$

Step 11 of 18

Determine the cofactors M_{11}

$$M_{11}=\begin{vmatrix} 11000 & -4000 \\ -4000 & \left(8000+\frac{10000}{s}\right) \end{vmatrix}$$
$$=\left(88+\frac{110}{s}-16\right)\times10^6$$
$$=\left(72+\frac{110}{s}\right)\times10^6$$

Step 12 of 18

Determine the cofactors M_{12} and M_{13}

$$M_{12}=\begin{vmatrix} -3000 & -4000 \\ 0 & \left(8000+\frac{10000}{s}\right) \end{vmatrix}$$
$$=\left(-24-\frac{30}{s}\right)\times10^6$$
$$M_{13}=\begin{vmatrix} -3000 & 11000 \\ 0 & -4000 \end{vmatrix}$$
$$=12\times10^6$$

Step 13 of 18

Determine the cofactors M_{21}, M_{22} and M_{23}

$$M_{21}=\begin{vmatrix} -3000 & 0 \\ -4000 & \left(8000+\frac{10000}{s}\right) \end{vmatrix}$$
$$=\left(-24-\frac{30}{s}\right)\times10^6$$
$$M_{22}=\begin{vmatrix} 9000 & 0 \\ 0 & \left(8000+\frac{10000}{s}\right) \end{vmatrix}$$
$$=\left(72+\frac{90}{s}\right)\times10^6$$
$$M_{23}=\begin{vmatrix} 9000 & -3000 \\ 0 & -4000 \end{vmatrix}$$
$$=-36\times10^6$$

Step 14 of 18

Determine the cofactors M_{31}, M_{32} and M_{33}

$$M_{31}=\begin{vmatrix} -3000 & 0 \\ 11000 & -4000 \end{vmatrix}$$
$$=12\times10^6$$
$$M_{32}=\begin{vmatrix} 9000 & 0 \\ -3000 & -4000 \end{vmatrix}$$
$$=-36\times10^6$$
$$M_{33}=\begin{vmatrix} 9000 & -3000 \\ -3000 & 11000 \end{vmatrix}$$
$$=(99-9)\times10^6$$
$$=90\times10^6$$

Step 15 of 18

Determine the matrix $adj(M)$

$$adj(M)=\begin{bmatrix} \left(72+\frac{118}{s}\right)\times10^6 & -\left(-24-\frac{30}{s}\right)\times10^6 & 12\times10^6 \\ -\left(-24-\frac{30}{s}\right)\times10^6 & \left(72+\frac{90}{s}\right)\times10^6 & -(-36\times10^6) \\ 12\times10^6 & -(-36\times10^6) & 90\times10^6 \end{bmatrix}$$
$$=\begin{bmatrix} \left(72+\frac{110}{s}\right)\times10^6 & \left(24+\frac{30}{s}\right)\times10^6 & 12\times10^6 \\ \left(24+\frac{30}{s}\right)\times10^6 & \left(72+\frac{90}{s}\right)\times10^6 & (36\times10^6) \\ 12\times10^6 & (36\times10^6) & 90\times10^6 \end{bmatrix}$$

Step 16 of 18

Determine the inverse of the matrix M

$$M^{-1}=\frac{1}{\det(M)}\{adj(M)\}$$
$$=\frac{1}{576\times10^9+\frac{900}{s}\times10^9}\begin{bmatrix} \left(72+\frac{110}{s}\right)\times10^6 & \left(24+\frac{30}{s}\right)\times10^6 & 12\times10^6 \\ \left(24+\frac{30}{s}\right)\times10^6 & \left(72+\frac{90}{s}\right)\times10^6 & (36\times10^6) \\ 12\times10^6 & (36\times10^6) & 90\times10^6 \end{bmatrix}$$

$$M^{-1}=\begin{bmatrix} \frac{\left(72+\frac{110}{s}\right)\times10^6}{576\times10^9+\frac{900}{s}\times10^9} & \frac{\left(24+\frac{30}{s}\right)\times10^6}{576\times10^9+\frac{900}{s}\times10^9} & \frac{12\times10^6}{576\times10^9+\frac{900}{s}\times10^9} \\ \frac{\left(24+\frac{30}{s}\right)\times10^6}{576\times10^9+\frac{900}{s}\times10^9} & \frac{\left(72+\frac{90}{s}\right)\times10^6}{576\times10^9+\frac{900}{s}\times10^9} & \frac{(36\times10^6)}{576\times10^9+\frac{900}{s}\times10^9} \\ \frac{12\times10^6}{576\times10^9+\frac{900}{s}\times10^9} & \frac{(36\times10^6)}{576\times10^9+\frac{900}{s}\times10^9} & \frac{90\times10^6}{576\times10^9+\frac{900}{s}\times10^9} \end{bmatrix}$$

$$M^{-1}=\begin{bmatrix} \frac{\left(72+\frac{118}{s}\right)\times16^{-9}}{576+\frac{900}{s}} & \frac{\left(24+\frac{30}{s}\right)\times16^{-9}}{576+\frac{900}{s}} & \frac{12\times10^{-9}}{576+\frac{900}{s}} \\ \frac{\left(24+\frac{30}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{\left(72+\frac{90}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{(36\times10^{-9})}{576+\frac{900}{s}} \\ \frac{12\times10^{-9}}{576+\frac{900}{s}} & \frac{(36\times10^{-9})}{576+\frac{900}{s}} & \frac{90\times10^{-9}}{576+\frac{900}{s}} \end{bmatrix}$$

Step 17 of 18

The simplified expression for the current matrix is

$$\begin{bmatrix} I_1(s) \\ I_2(s) \\ I_3(s) \end{bmatrix}=\begin{bmatrix} \frac{\left(72+\frac{118}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{\left(24+\frac{30}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{12\times10^{-9}}{526+\frac{900}{s}} \\ \frac{\left(24+\frac{30}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{\left(72+\frac{90}{s}\right)\times10^{-9}}{576+\frac{900}{s}} & \frac{(36\times10^{-9})}{526+\frac{900}{s}} \\ \frac{12\times10^{-9}}{576+\frac{900}{s}} & \frac{(36\times10^{-9})}{576+\frac{900}{s}} & \frac{90\times10^{-9}}{526+\frac{900}{s}} \end{bmatrix}\begin{bmatrix} \frac{-36}{s} \\ \frac{24}{s} \\ \frac{-2}{s} \end{bmatrix}$$

$$=\begin{bmatrix} \frac{\left(\left(72+\frac{118}{s}\right)\times16^{-9}\right)\left(\frac{-36}{s}\right)+\left(\left(24+\frac{30}{s}\right)\times16^{-9}\right)\left(\frac{24}{s}\right)+\left(12\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \\ \frac{\left(\left(24+\frac{30}{s}\right)\times18^{-9}\right)\left(\frac{-36}{s}\right)+\left(\left(72+\frac{90}{s}\right)\times10^{-9}\right)\left(\frac{24}{s}\right)+\left(36\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \\ \frac{\left(12\times16^{-9}\right)\left(\frac{-36}{s}\right)+\left(36\times10^{-9}\right)\left(\frac{24}{s}\right)+\left(90\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \end{bmatrix}$$

$$=\begin{bmatrix} \frac{1\left(-2.04-\frac{3.24}{s}\right)}{576+\frac{900}{s}} \\ \frac{1\left(8.792+\frac{1.08}{s}\right)}{576+\frac{900}{s}} \\ \frac{}{576+\frac{900}{s}} \end{bmatrix}$$

$$\begin{array}{ll} \frac{}{576+\frac{900}{s}} & \frac{}{526+\frac{900}{s}} \end{array}$$

$$=\begin{bmatrix} \frac{\left(\left(72+\frac{118}{s}\right)\times10^{-9}\right)\left(\frac{-36}{s}\right)+\left(\left(24+\frac{30}{s}\right)\times10^{-9}\right)\left(\frac{24}{s}\right)+\left(12\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \\ \frac{\left(\left(24+\frac{30}{s}\right)\times18^{-9}\right)\left(\frac{-36}{s}\right)+\left(\left(72+\frac{90}{s}\right)\times10^{-9}\right)\left(\frac{24}{s}\right)+\left(36\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \\ \frac{\left(12\times10^{-9}\right)\left(\frac{-36}{s}\right)+\left(36\times10^{-9}\right)\left(\frac{24}{s}\right)+\left(90\times10^{-9}\right)\left(\frac{-2}{s}\right)}{576+\frac{900}{s}} \end{bmatrix}$$

$$=\begin{bmatrix} \frac{1\left(-2.04-\frac{3.24}{s}\right)}{576+\frac{900}{s}} \\ \frac{1\left(8.792+\frac{1.08}{s}\right)}{576+\frac{900}{s}} \\ \frac{}{576+\frac{900}{s}} \end{bmatrix}$$

Step 18 of 18

Determine the expression for $V_x(t)$

$$V_x(t)=(4K)\{I_2(t)-I_3(t)\}$$
$$=(4K)\left(\frac{0.173\times10^{-3}}{s+1.56}+\frac{1.2\times10^{-3}}{s}-\frac{(0.4375\times10^{-3})}{s-1.56}\right)$$
$$=\frac{-0.058}{s+1.56}+\frac{4.8}{s}$$

Apply inverse Laplace transform.

$$v_x(t)=\left\{-1.658e^{-1.56t}+4.8\right\}u(t)$$

Thus the expression of $v_x(t)$ is $\boxed{\left\{-1.658e^{-1.56t}+4.8\right\}u(t)}$

Step 1 of 11

Consider the following circuit diagram.

Figure 1

Step 2 of 11

Redraw the Figure 1 in S-Domain as shown in Figure 2.

Figure 2

Step 3 of 11

Apply Kirchhoff's voltage law to the left side mesh.

$$\frac{10}{s}=2I_1(s)+\frac{2}{s}\left[I_1(s)-I_2(s)\right]$$

$$\left(2+\frac{2}{s}\right)I_1(s)-\frac{2}{s}I_2(s)=\frac{10}{s}$$

$$(2s+2)I_1(s)-2I_2(s)=10$$

$$(s+1)I_1(s)-I_2(s)=5 \text{ ..... (1)}$$

Step 4 of 11

Apply Kirchhoff's voltage law to the middle mesh.

$$\frac{2}{s}\left[I_2(s)-I_1(s)\right]+6I_2(s)+4sI_2(s)-2sI_3(s)=0$$

$$-\frac{2}{s}I_1(s)+\left(\frac{2}{s}+6+4s\right)I_2(s)-2sI_3(s)=0$$

$$-2I_1(s)+\left(2+6s+4s^2\right)I_2(s)-2s^2I_3(s)=0$$

$$-I_1(s)+\left(2s^2+3s+1\right)I_2(s)-s^2I_3(s)=0 \text{ ..... (2)}$$

Step 5 of 11

Apply Kirchhoff's voltage law to the right hand side mesh.

$$8sI_3(s)-2sI_2(s)+8I_3(s)+4I_3(s)=0$$

$$-2sI_2(s)+(12+8s)I_3(s)=0$$

$$-sI_2(s)+(4s+6)I_3(s)=0 \text{ ..... (3)}$$

Step 6 of 11

Write the matrix form of the equations (1), (2) and (3).

$$\begin{bmatrix} s+1 & -1 & 0 \\ -1 & 2s^2+3s+1 & -s^2 \\ 0 & -s & 4s+6 \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \\ I_3(s) \end{bmatrix}=\begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix}$$

Apply Cramer's rule to find the current I_3.

$$I_3(s)=\frac{\Delta_3}{\Delta} \text{ ..... (4)}$$

Step 7 of 11

Find the value of the sub-determinant Δ_3.

$$\Delta_3=\begin{bmatrix} s+1 & -1 & 5 \\ -1 & 2s^2+3s+1 & 0 \\ 0 & -s & 0 \end{bmatrix}$$

$$=\left\{\begin{array}{l}(s+1)\left[\left(2s^2+3s+1\right)(0)-(0)(s)\right]+(1)\left[(-1)(0)-(0)(0)\right] \\ +5\left[(-1)(-s)-\left(2s^2+3s+1\right)(0)\right]\end{array}\right\}$$

$$=5s$$

Step 8 of 11

Find the value of the determinant Δ.

$$\Delta=\begin{vmatrix} s+1 & -1 & 0 \\ -1 & 2s^2+3s+1 & -s^2 \\ 0 & -s & 4s+6 \end{vmatrix}$$

$$=\left\{\begin{array}{l}(s+1)\left[\left(2s^2+3s+1\right)(4s+6)-\left(-s^2\right)(-s)\right]+(1)\left[(-1)(4s+6)-\left(-s^2\right)(0)\right] \\ +0\left[(-1)(-s)-\left(2s^2+3s+1\right)(0)\right]\end{array}\right\}$$

$$=(s+1)\left[8s^3+12s^2+12s^2+18s+4s+6-s^3\right]-4s-6$$

Simplify further.

$$\Delta=(s+1)\left[7s^3+24s^2+22s+6\right]-4s-6$$

$$=7s^4+24s^3+22s^2+6s+7s^3+24s^2+22s+6-4s-6$$

$$=7s^4+31s^3+46s^2+24s$$

$$=s\left(7s^3+31s^2+46s+24\right)$$

Step 9 of 11

Substitute the values of Δ_3 and Δ in equation (4), to find the current I_3.

$$I_3(s)=\frac{5s}{s\left(7s^3+31s^2+46s+24\right)}$$

$$=\frac{5}{\left(7s^3+31s^2+46s+24\right)}$$

Step 10 of 11

Now, calculate the output voltage, $V_o(s)$.

$$V_o(s)=4\left[I_3(s)\right]$$

$$=4\left(\frac{5}{7s^3+31s^2+46s+24}\right)$$

$$=\frac{20}{7s^3+31s^2+46s+24}$$

$$=\frac{\frac{20}{7}}{s^3+\frac{31}{7}s^2+\frac{46}{7}s+\frac{24}{7}}$$

Simplify further.

$$V_o(s)=\frac{\frac{20}{7}}{(s+2)(s+1.214-j0.4897)(s+1.214+j0.4897)}$$

Use partial fractions to expand the voltage output function.

$$V_o(s)=\frac{k_0}{s+2}+\frac{k_1}{(s+1.214-j0.4897)}+\frac{k_1^*}{(s+1.214+j0.4897)}$$

Calculate the unknown value of k_0.

$$k_0=\left.\frac{\frac{20}{7}}{(s+1.214-j0.4897)(s+1.214+j0.4897)}\right|_{s=-2}$$

$$=\frac{\frac{20}{7}}{(-2+1.214-j0.4897)(-2+1.214+j0.4897)}$$

$$=\frac{\frac{20}{7}}{(-0.786-j0.4897)(-0.786+j0.4897)}$$

$$=3.33$$

Calculate the unknown value of k_1.

$$k_1=\left.\frac{\frac{20}{7}}{(s+2)(s+1.214+j0.4897)}\right|_{s=-1.214+j0.4897}$$

$$=\frac{\frac{20}{7}}{(-1.214+j0.4897+2)(-1.214+j0.4897+1.214+j0.4897)}$$

$$=\frac{\frac{20}{7}}{(0.786+j0.4897)(j0.9794)}$$

$$k_1=3.15\angle-122^\circ$$

$$k_1^*=3.15\angle122^\circ$$

Step 11 of 11

The output voltage is,

$$V_o(s)=\frac{k_0}{s+2}+\frac{k_1}{(s+1.214-j0.4897)}+\frac{k_1^*}{(s+1.214+j0.4897)}$$

$$=\frac{3.33}{s+2}+\frac{3.15\angle-122^\circ}{(s+1.214-j0.4897)}+\frac{3.15\angle122^\circ}{(s+1.214+j0.4897)}$$

Applying inverse Laplace transforms on both sides to obtain the output voltage in time domain.

$$v_o(t)=3.33e^{-2t}u(t)+2(3.15)e^{-1.214t}\cos(0.4897t-122^\circ)u(t)$$

$$=\left[3.33e^{-2t}+6.3e^{-1.214t}\cos(0.4897t-122^\circ)\right]u(t) \text{ V}$$

Thus, the value of output voltage $v_o(t)$ is

$$\boxed{\left[3.33e^{-2t}+6.3e^{-1.214t}\cos(0.4897t-122^\circ)\right]u(t) \text{ V}}.$$

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Step 1 of 7

Refer to the circuit in Figure P14.45 in the text book.

Draw the circuit in s-domain.

Figure 1

Step 2 of 7

Apply Kirchhoff's Voltage Law to the primary side of the circuit in Figure 1.

$$\frac{-4}{s}+(1)I_1(s)+2\left[sI_1(s)-i_{L1}(0^-)\right]+sI_2(s)=0$$

Where $i_{L1}(0^-)=0$ A

$$(1+2s)I_1(s)+sI_2(s)=\frac{4}{s} \text{ ..... (1)}$$

Apply Kirchhoff's Voltage Law to the secondary side of the circuit.

$$2I_2(s)+2\left[sI_2(s)-i_{L2}(0^-)\right]+sI_1(s)=0$$

Where $i_{L2}(0^-)=0$ A

$$sI_1(s)+(2+2s)I_2(s)=0 \text{ ..... (2)}$$

Step 3 of 7

Express the Equations (1) and (2) in matrix form.

$$\begin{bmatrix}(1+2s) & s\\ s & (2+2s)\end{bmatrix}\begin{bmatrix}I_1(s)\\ I_2(s)\end{bmatrix}=\begin{bmatrix}\frac{4}{s}\\ 0\end{bmatrix}$$

$$\begin{aligned}I_2(s)&=\frac{\begin{vmatrix}2+2s & \frac{4}{s}\\ -s & 0\end{vmatrix}}{\begin{vmatrix}2+2s & -s\\ -s & 1+2s\end{vmatrix}}\\ &=\frac{(2+2s)(0)-\left(\frac{4}{s}\right)(-s)}{(2+2s)(1+2s)-(-s)(-s)}\\ &=\frac{4}{3s^2+6s+2}\end{aligned}$$

Step 4 of 7

The expression for the output voltage $V_o(s)$.

$$\begin{aligned}V_0(s)&=(1)I_2(s)\\ &=I_2(s)\\ &=\frac{4}{3s^2+6s+2}\\ &=\frac{\frac{4}{3}}{s^2+2s+\frac{2}{3}}\end{aligned}$$

Simplify further.

$$\begin{aligned}V_0(s)&=\frac{\frac{4}{3}}{s^2+2s+\frac{2}{3}}\\ &=\frac{\frac{4}{3}}{(s+0.4226)(s+1.5774)}\end{aligned}$$

Split the expression of $V_o(s)$ into partial fractions.

$$\frac{\frac{4}{3}}{(s+0.4226)(s+1.5774)}=\frac{K_1}{s+0.4226}+\frac{K_2}{s+1.5774}$$

Step 5 of 7

Determine the value for K_1.

$$\begin{aligned}K_1&=\left.\frac{\frac{4}{3}}{(s+1.5774)}\right|_{s=-0.4226}\\ &=\frac{\frac{4}{3}}{(-0.4226+1.5774)}\\ &=\frac{\frac{4}{3}}{1.1548}\\ &=1.155\end{aligned}$$

Step 6 of 7

Determine the value for K_2.

$$\begin{aligned}K_2&=\left.\frac{\frac{4}{3}}{(s+0.4226)}\right|_{s=-1.5774}\\ &=\frac{\frac{4}{3}}{(-1.5774+0.4226)}\\ &=\frac{\frac{4}{3}}{-1.1548}\\ &=-1.155\end{aligned}$$

Step 7 of 7

The expression of the output voltage $V_o(s)$ is,

$$V_0(s)=\frac{1.155}{s+0.4223}-\frac{1.155}{s+1.5774}$$

Apply inverse Laplace transforms.

$$L^{-1}\left[V_0(s)\right]=L^{-1}\left[\frac{1.155}{s+0.4223}-\frac{1.155}{s+1.5774}\right]$$

$$L^{-1}\left[V_0(s)\right]=L^{-1}\left[\frac{1.155}{s+0.4223}\right]-L^{-1}\left[\frac{1.155}{s+1.5774}\right]$$

$$v_0(t)=1.155e^{-0.4223t}-1.155e^{-1.5774t}$$

Thus, the expression of the output voltage $v_o(t)$ is $\boxed{1.155\left(e^{-0.4223t}-e^{-1.5774t}\right)u(t)\text{ V}}$.

Step 1 of 6

14.065 P

Refer to the circuit in Figure P14.48 in the text book.

Draw the circuit in s-domain.

Figure 1

Step 2 of 6

The value of the turns ratio n is,

$$n = \frac{N_2}{N_1}$$
$$= \frac{2}{1}$$
$$= 2$$

Refer the primary side to the secondary side.

$$Z_1 = n^2 Z_P$$

$$Z_1 = 2^2\left(2 + \frac{1}{s}\right)$$

$$Z_1 = 8 + \frac{4}{s}$$

Step 3 of 6

Determine the expression for the voltage V_2.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$
$$= \left(\frac{2}{1}\right)V_1$$
$$= 2\left(\frac{12}{s}\right)$$
$$= \frac{24}{s}$$

Step 4 of 6

Draw the modified circuit.

Figure 2

Step 5 of 6

Use voltage division principle and determine the expression for the out voltage $V_o(s)$.

$$V_0(s) = \left(\frac{24}{s}\right)\left(\frac{4}{4 + 8 + \frac{4}{s} + 4 + \frac{4}{s}}\right)$$
$$= \left(\frac{24}{s}\right)\left(\frac{4}{16 + \frac{8}{s}}\right)$$
$$= \left(\frac{24}{s}\right)\left(\frac{4s}{16s + 8}\right)$$
$$= \frac{96}{(16s + 8)}$$

Simplify further.

$$V_0(s) = \frac{96}{16\left(s + \frac{1}{2}\right)}$$
$$= \frac{6}{\left(s + \frac{1}{2}\right)}$$

Step 6 of 6

Apply inverse Laplace transform on both sides.

$$L^{-1}\left[V_0(s)\right] = L^{-1}\left[\frac{6}{\left(s + \frac{1}{2}\right)}\right]$$

$$v_0(t) = 6e^{-\frac{1}{2}t}u(t)\ \text{V}$$

Thus, the expression of $v_o(t)$ for $t > 0$ is $\boxed{6e^{-\frac{1}{2}t}u(t)\ \text{V}}$.

Step 1 of 6

Draw the circuit in Laplace domain.

Figure 1

Step 2 of 6

Apply Kirchhoff's voltage law in loop (1).

$$I_1(s) = \frac{4}{s} \quad \text{..... (1)}$$

Apply Kirchhoff's voltage law in loop (2).

$$2\left[I_2(s) - I_1(s)\right] + 2sI_2(s) + \frac{1}{s}\left[I_2(s) - I_3(s)\right] = 0$$

$$-2I_1(s) + I_2(s)\left[2 + 2s + \frac{1}{s}\right] - \frac{1}{s}I_3(s) = 0$$

Substitute $\frac{4}{s}$ for $I_1(s)$.

$$-\frac{8}{s} + I_2\left[2 + 2s + \frac{1}{s}\right] - \frac{1}{s}I_3(s) = 0 \quad \text{..... (2)}$$

Step 3 of 6

Apply Kirchhoff's voltage law in loop (3).

$$\frac{1}{s}\left[I_3(s) - I_2(s)\right] + 2I_3(s) = 0$$

$$I_3(s)\left[2 + \frac{1}{s}\right] = \frac{1}{s}I_2(s) \quad \text{..... (3)}$$

Substitute Equation (3) in Equation (2).

$$I_3(s)\left[1 + 2s\right] = I_2(s)$$

$$-\frac{8}{s} + (1 + 2s)\left(2 + 2s + \frac{1}{s}\right)I_3(s) - \frac{1}{s}I_3(s) = 0$$

$$I_3(s)\left[(1 + 2s)\left(2 + 2s + \frac{1}{s}\right) - \frac{1}{s}\right] = \frac{8}{s}$$

$$I_3(s)\left[(1 + 2s)\left(2s + 2s^2 + 1\right) - 1\right] = 8$$

Step 4 of 6

Simplify further.

$$\begin{aligned} I_3(s) &= \frac{8}{\left[(1 + 2s)\left(2s + 2s^2 + 1\right) - 1\right]} \\ &= \frac{8}{2s + 2s^2 + 1 + 4s^2 + 4s^3 + 2s - 1} \\ &= \frac{8}{4s^3 + 6s^2 + 4s} \\ &= \frac{8}{s\left(4s^2 + 6s + 4\right)} \end{aligned}$$

The expression for the output voltage $V_o(s)$ is,

$$\begin{aligned} V_0(s) &= 2I_3(s) \\ &= \frac{16}{s\left(4s^2 + 6s + 4\right)} \end{aligned}$$

Step 5 of 6

Determine the initial value of the voltage $v_o(t)$.

$$\begin{aligned} V_0(0) &= \lim_{s \to \infty} s \ V(s) \\ &= \lim_{s \to \infty} \frac{16}{4s^2 + 6s + 4} \\ &= \frac{16}{\infty} \\ &= 0 \end{aligned}$$

Thus, the initial value of the voltage $v_o(t)$ is $\boxed{0\text{ V}}$.

Step 6 of 6

Determine the final value of the voltage $v_o(t)$.

$$\begin{aligned} V_0(\infty) &= \lim_{s \to \infty} sV_0(s) \\ &= \lim_{s \to \infty} \frac{16}{4s^2 + 6s + 4} \\ &= \frac{16}{4} \\ &= 4 \end{aligned}$$

Thus, the final value of the voltage $v_o(t)$ is $\boxed{4\text{ V}}$.

Step 1 of 4

14.067
P

Refer to the circuit in Figure P14.50 in the text book.

Draw the circuit in s-domain.

Figure 1

Step 2 of 4

Determine the equivalent impedance of the parallel combination of 2Ω resistor and $\frac{2}{s}\Omega$ capacitor.

$$\begin{aligned} Z &= 2 \parallel \frac{2}{s} \\ &= \frac{2\left(\frac{2}{s}\right)}{2+\frac{2}{s}} \\ &= \frac{2}{s+1} \end{aligned}$$

Step 3 of 4

Use current division principle to find the expression of the current $I_o(s)$.

$$\begin{aligned} I_0(s) &= \frac{1}{\left(1+s+\frac{2}{1+s}\right)}\left(\frac{6}{s}\right) \\ &= \frac{s+1}{\left((1+s)^2+2\right)}\left(\frac{6}{s}\right) \\ &= \frac{6(s+1)}{s\left(s^2+2s+3\right)} \end{aligned}$$

Determine the expression of the output voltage $V_o(s)$.

$$\begin{aligned} V_0(s) &= \left(\frac{2}{1+s}\right) I_0(s) \\ &= \left(\frac{2}{1+s}\right)\frac{6(s+1)}{s\left(s^2+2s+3\right)} \\ &= \frac{12}{s\left(s^2+2s+3\right)} \end{aligned}$$

Step 4 of 4

Write the expression of the final value of the output voltage $v_0(t)$ as $t \to \infty$.

$$\lim_{t\to\infty} v_0(t) = \lim_{s\to 0} sV_0(s)\,[\text{Final value theorem}]$$

Substitute $\frac{12}{s\left(s^2+2s+3\right)}$ for $V_o(s)$.

$$\begin{aligned} \lim_{t\to\infty} v_0(t) &= \lim_{s\to 0}\frac{12s}{s\left(s^2+2s+3\right)} \\ &= \lim_{s\to 0}\frac{12}{\left(s^2+2s+3\right)} \\ &= \frac{12}{3} \\ &= 4\text{ V} \end{aligned}$$

Thus, the final value of the output voltage $v_0(t)$ as $t \to \infty$ is $\boxed{4\text{ V}}$.

Step 1 of 5

14.068 P

Refer to Figure P14.54 (b) in the text book.

The expression for the input voltage is,

$$v_i(t) = 6\left(u(t) - u(t-1)\right)$$

Apply Laplace transform on both sides.

$$\begin{aligned} V_i(s) &= 6\left(\frac{1}{s} - \frac{1}{s}e^{-s}\right) \\ &= \frac{6}{s}\left(1 - e^{-s}\right) \end{aligned}$$

Refer to the circuit in Figure P14.54 in the text book.

Draw the equivalent circuit in Laplace domain.

Figure 1

Step 2 of 5

Apply Kirchhoff's voltage law to loop (1).

$$I_1(s)\left(\frac{1}{s}\right) + I_1(s)(1) + \left(I_1(s) - I_2(s)\right)(2) + V_i(s) = 0$$

$$I_1(s)\left(\frac{1}{s} + 1 + 2\right) - I_2(s)(2) + V_i(s) = 0$$

$$I_1(s)\left(\frac{1}{s} + 3\right) - 2I_2(s) = -V_i(s)$$

$$I_1(s)\left(\frac{1+3s}{s}\right) - 2I_2(s) = -\frac{6}{s}\left(1 - e^{-s}\right) \quad \text{..... (1)}$$

Step 3 of 5

Apply Kirchhoff's voltage law to loop (2).

$$-V_i(s) + \left(I_2(s) - I_1(s)\right)(2) + I_2(s)(3) + I_2(s)(1) = 0$$

$$-2I_1(s) + I_2(s)(2+3+1) = V_i(s)$$

$$-2I_1(s) + 6I_2(s) = V_i(s)$$

$$-2I_1(s) + 6I_2(s) = \frac{6}{s}\left(1 - e^{-s}\right) \quad \text{..... (2)}$$

Step 4 of 5

Multiply equation (1) with (3) and then add to equation (2).

$$I_1(s)\left(\frac{3(1+3s)}{s} - 2\right) = 3\left(-\frac{6}{s}\left(1 - e^{-s}\right)\right) + \frac{6}{s}\left(1 - e^{-s}\right)$$

$$I_1(s)\left(\frac{3+7s}{s}\right) = -2\left(\frac{6}{s}\left(1 - e^{-s}\right)\right)$$

$$I_1(s) = \frac{-12\left(1 - e^{-s}\right)}{3+7s}$$

Substitute $\frac{-12\left(1 - e^{-s}\right)}{3+7s}$ for $I_1(s)$ in equation (2).

$$-2\left(\frac{-12\left(1 - e^{-s}\right)}{3+7s}\right) + 6I_2(s) = \frac{6}{s}\left(1 - e^{-s}\right)$$

$$6I_2(s) = \left(\frac{-24}{3+7s} + \frac{6}{s}\right)\left(1 - e^{-s}\right)$$

$$6I_2(s) = \frac{18(s+1)}{s(3+7s)}\left(1 - e^{-s}\right)$$

$$I_2(s) = \frac{3(s+1)}{s(3+7s)}\left(1 - e^{-s}\right)$$

Step 5 of 5

The expression for the output voltage $V_o(s)$ is,

$$\begin{aligned} V_o(s) &= I_2(s)(1) \\ &= I_2(s) \\ &= \frac{3(s+1)}{s(3+7s)}\left(1 - e^{-s}\right) \\ &= \frac{\frac{3}{7}(s+1)}{s\left(s + \frac{3}{7}\right)} \end{aligned}$$

Split the expression of $V_o(s)$ into partial fractions.

$$\begin{aligned} V_o(s) &= \left(\frac{1}{s} - \frac{\frac{4}{7}}{s + \frac{3}{7}}\right)\left(1 - e^{-s}\right) \\ &= \left(\frac{1}{s} - \frac{\frac{4}{7}}{s + \frac{3}{7}}\right) - \left(\frac{1}{s} - \frac{\frac{4}{7}}{s + \frac{3}{7}}\right)e^{-s} \end{aligned}$$

Apply inverse Laplace transform on both sides.

$$\begin{aligned} v_o(t) &= \left(u(t) - \frac{4}{7}e^{-\frac{3}{7}t}u(t)\right) - \left(u(t-1) - \frac{4}{7}e^{-\frac{3}{7}(t-1)}u(t-1)\right) \\ &= \left(u(t) - u(t-1)\right) + \left(-\frac{4}{7}e^{-\frac{3}{7}t}u(t) + \frac{4}{7}e^{-\frac{3}{7}(t-1)}u(t-1)\right) \\ &= \left(u(t) - u(t-1)\right) + \frac{4}{7}\left(e^{-\frac{3}{7}(t-1)}u(t-1) - e^{-\frac{3}{7}t}u(t)\right) \end{aligned}$$

Thus, the output voltage $v_o(t)$ is $\boxed{\left(u(t) - u(t-1)\right) + \frac{4}{7}\left(e^{-\frac{3}{7}(t-1)}u(t-1) - e^{-\frac{3}{7}t}u(t)\right)\ \text{V}}$.

Step 1 of 6

Refer to Figure P14.56 in the text book.

The expression of the input voltage is,

$$V_i(t) = u(t) - u(t-1)$$

Apply Laplace Transform on both sides.

$$V_i(s) = \frac{1}{s} - \frac{e^{-s}}{s}$$
$$= \frac{1-e^{-s}}{s}$$

Step 2 of 6

Draw the circuit in Laplace domain.

Figure 1

Step 3 of 6

Apply Kirchhoff's current law at the node voltage $V_1(s)$.

$$\frac{V_1(s)-V_i(s)}{1} + \frac{V_1(s)}{1} + \frac{V_1(s)-V_2(s)}{\frac{s}{s+1}} = 0$$

$$V_1(s)\left[2+\frac{s+1}{s}\right] - V_2(s)\left[\frac{s+1}{s}\right] = V_i(s) \text{ .....(1)}$$

Apply Kirchhoff's current law at the node voltage $V_2(s)$.

$$\frac{V_2(s)-V_1(s)}{\frac{s}{s+1}} + \frac{V_2(s)}{\frac{1}{s}} + \frac{V_2(s)}{1} = 0$$

$$-V_1(s)\left[\frac{s+1}{s}\right] + V_2(s)\left[\frac{s^2+2s+1}{s}\right] = 0 \text{ .....(2)}$$

Step 4 of 6

Write equations (1) and (2) in matrix form.

$$\begin{bmatrix} 2+\frac{s+1}{s} & -\frac{s+1}{s} \\ -\frac{s+1}{s} & \frac{s^2+2s+1}{s} \end{bmatrix} \begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \begin{bmatrix} V_i(s) \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} \frac{3s+1}{s} & -\frac{s+1}{s} \\ -\frac{s+1}{s} & \frac{s^2+2s+1}{s} \end{bmatrix} \begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \begin{bmatrix} \frac{1-e^{-s}}{s} \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \left[\frac{1}{\begin{vmatrix} \frac{3s+1}{s} & -\frac{s+1}{s} \\ -\frac{s+1}{s} & \frac{s^2+2s+1}{s} \end{vmatrix}} \right] \begin{bmatrix} \frac{s^2+2s+1}{s} & \frac{s+1}{s} \\ \frac{s+1}{s} & \frac{3s+1}{s} \end{bmatrix} \begin{bmatrix} \frac{1-e^{-s}}{s} \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \left[\frac{s}{3s^2+6s+3} \right] \begin{bmatrix} \frac{s^2+2s+1}{s} & \frac{s+1}{s} \\ \frac{s+1}{s} & \frac{3s+1}{s} \end{bmatrix} \begin{bmatrix} \frac{1-e^{-s}}{s} \\ 0 \end{bmatrix}$$

Step 5 of 6

The expression of the voltage $V_2(s)$ is,

$$V_2(s) = \left(\frac{s}{3s^2+6s+3}\right)\left(\frac{s+1}{s} \times \frac{1-e^{-s}}{s}\right)$$

$$V_2(s) = \frac{(s+1)(1-e^{-s})}{s(3s^2+6s+3)}$$

$$V_2(s) = \left(\frac{1}{3}\right)\frac{(s+1)(1-e^{-s})}{s(s^2+2s+1)}$$

$$V_2(s) = \left(\frac{1}{3}\right)\frac{(s+1)(1-e^{-s})}{s(s+1)^2}$$

Step 6 of 6

Simplify further.

$$V_2(s) = \left(\frac{1}{3}\right)\frac{(1-e^{-s})}{s(s+1)}$$

$$V_2(s) = \left(\frac{1}{3}\right)\left(\frac{1}{s} - \frac{1}{s+1}\right)(1-e^{-s})$$

$$V_2(s) = \left(\frac{1}{3}\right)\left(\frac{1}{s} - \frac{1}{s+1} - \frac{e^{-s}}{s} + \frac{e^{-s}}{s+1}\right)$$

The expression of the output voltage is,

$$V_2(s) = V_o(s)$$

$$V_o(s) = \left(\frac{1}{3}\right)\left(\frac{1}{s} - \frac{1}{s+1} - \frac{e^{-s}}{s} + \frac{e^{-s}}{s+1}\right)$$

Apply Inverse Laplace transform on both sides.

$$v_o(t) = \left(\frac{1}{3}\right)\left[u(t) - e^{-t}u(t) - u(t-1) + e^{-(t-1)}u(t-1)\right]$$

Thus, the expression of the output voltage $v_o(t)$ is

$$\boxed{v_o(t) = \frac{1}{3}(1-e^{-t})u(t) - \frac{1}{3}\left(1-e^{-(t-1)}\right)u(t-1) \text{ (V)}}$$

Step 1 of 4

14.070 P

Refer to Figure P14.57 in the text book.

Draw the circuit in Laplace domain.

Step 2 of 4

Figure 1

Apply Kirchhoff's current law at the node voltage $V_1(s)$.

$$-I_1(s)+\frac{V_1(s)}{2}+\frac{V_1(s)-V_0(s)}{s}=0$$

$$V_1(s)\left[\frac{1}{2}+\frac{1}{s}\right]-\frac{1}{s}V_0(s)=I_1(s) \quad \text{..... (1)}$$

Apply Kirchhoff's current law at the node voltage $V_2(s)$.

$$\frac{V_0(s)-V_1(s)}{s}+\frac{V_0(s)}{\left(\frac{1}{s}\right)}+\frac{V_0(s)}{2}=0$$

$$-\frac{1}{s}V_1(s)+V_0(s)\left[\frac{1}{s}+s+\frac{1}{2}\right]=0$$

$$\frac{1}{s}V_1(s)=V_0(s)\left[\frac{1}{s}+s+\frac{1}{2}\right]$$

$$V_1(s)=V_0(s)\left[\frac{2+2s^2+s}{2}\right] \quad \text{..... (2)}$$

Step 3 of 4

Substitute Equation (2) in Equation (1).

$$V_0(s)\left[\frac{2+2s^2+s}{2}\right]\left[\frac{s+2}{2s}\right]-\frac{1}{s}V_0(s)=I_1(s)$$

$$V_0(s)\left[\frac{(2s^2+s+2)(s+2)}{4s}-\frac{1}{s}\right]=I_1(s)$$

$$V_0(s)\left[\frac{(2s^2+s+2)(s+2)-4}{4s}\right]=I_1(s)$$

$$V_0(s)=I_1(s)\left[\frac{4s}{(2s^2+s+2)(s+2)-4}\right]$$

Step 4 of 4

The expression for the output current is,

$$I_0(s)=\frac{V_0(s)}{2}$$

$$I_0(s)=I_1(s)\left[\frac{2s}{(2s^2+s+2)(s+2)-4}\right]$$

$$\frac{I_0(s)}{I_1(s)}=\frac{2s}{(2s^3+4s^2+s^2+2s+2s+4-4)}$$

$$\frac{I_0(s)}{I_1(s)}=\frac{2s}{2s^3+5s^2+4s}$$

Simplify further.

$$\frac{I_0(s)}{I_1(s)}=\frac{2s}{s(2s^2+5s+4)}$$

Thus, the transfer function $\frac{I_0(s)}{I_1(s)}$ is $\boxed{\frac{2}{2s^2+5s+4}}$.

Step 1 of 3

Refer to Figure P14.58 in the text book.

Draw the circuit in Laplace Domain.

Figure 1

Step 2 of 3

Apply Kirchhoff's Current Law at node voltage $V_1(s)$.

$$\frac{V_1(s)-V_i(s)}{2}+\frac{V_1(s)}{1+\frac{1}{s}}+\frac{V_1(s)}{3+1}=0$$

$$V_1(s)\left(\frac{1}{2}+\frac{1}{1+\frac{1}{s}}+\frac{1}{4}\right)-\frac{V_i(s)}{2}=0$$

$$V_1(s)\left(\frac{1}{2}+\frac{s}{s+1}+\frac{1}{4}\right)=\frac{V_i(s)}{2}$$

$$V_1(s)\left(\frac{2(s+1)+4s+(s+1)}{4(s+1)}\right)=\frac{V_i(s)}{2}$$

Simplify further.

$$V_1(s)\left(\frac{7s+3}{2(s+1)}\right)=V_i(s)$$

$$V_1(s)=\left(\frac{2(s+1)}{7s+3}\right)V_i(s)$$

Step 3 of 3

Use voltage division principle.

The expression for the output voltage $V_o(s)$ is,

$$V_o(s)=\frac{V_1(s)}{3+1}(1)$$
$$=\frac{V_1(s)}{4}$$

Substitute $\left(\frac{2(s+1)}{7s+3}\right)V_i(s)$ for $V_1(s)$.

$$V_o(s)=\frac{\left(\frac{2(s+1)}{7s+3}\right)V_i(s)}{4}$$

$$\frac{V_o(s)}{V_i(s)}=\left(\frac{(s+1)}{2(7s+3)}\right)$$

Thus, the expression of $\frac{V_o(s)}{V_i(s)}$ is $\boxed{\left(\frac{(s+1)}{2(7s+3)}\right)}$.

Step 1 of 4

Refer to the circuit diagram in Figure P14.69 in the textbook.

Form Figure, inductor 6 H, capacitor 1 F and resistor $1\ \Omega$ are in parallel.

The equivalent impedance of parallel combination is,

$$\begin{aligned}\frac{1}{Z_1} &= \frac{1}{X_L}+\frac{1}{X_C}+\frac{1}{R}\\ &= \frac{1}{6s}+\frac{1}{\frac{1}{s}}+\frac{1}{1}\\ &= \frac{1}{6s}+s+1\\ &= \frac{1+6s^2+6s}{6s}\end{aligned}$$

Equivalent impedance of parallel combination is,

$$\begin{aligned}Z_1 &= \frac{6s}{6s^2+6s+1}\\ &= \frac{6s}{6\left(s^2+s+\frac{1}{6}\right)}\\ &= \frac{s}{s^2+s+0.166}\end{aligned}$$

Step 2 of 4

Draw the *s*-domain equivalent of the Figure.

Figure 1

Step 3 of 4

Apply voltage division rule to find the expression for $V_o(s)$. $V_o(s)=\frac{Z_1}{Z_1+\frac{1}{sC}}V_s(s)$

Substitute $\frac{s}{s^2+s+0.166}$ for Z_1 in the expression.

$$\begin{aligned}V_o(s) &= \frac{\frac{s}{s^2+s+0.166}}{\frac{s}{s^2+s+0.166}+\frac{1}{sC}}V_s(s)\\ &= \frac{Cs^2}{Cs^2+s^2+s+0.166}V_s(s)\\ &= \frac{Cs^2}{s^2(C+1)+s+0.166}V_s(s)\end{aligned}$$

Characteristic equation of the network is,

$$s^2(C+1)+s+0.166=0$$

$$s^2+\frac{1}{C+1}s+\frac{0.166}{C+1}=0$$

Write the characteristic equation of the standard second order system.

$$s^2+2\zeta\omega_n s+\omega_n^2=0$$

Compare constants.

$$\omega_n^2=\frac{0.166}{C+1}$$

$$\omega_n=\sqrt{\frac{0.166}{C+1}}\ \text{rad/sec}$$

Compare s coefficient.

$$2\zeta\omega_n=\frac{1}{C+1}$$

Step 4 of 4

For critical damped system damping ratio is 1 or $\zeta=1$.
Substitute 1 for ζ in the equation.

$$2(1)\left(\sqrt{\frac{0.166}{C+1}}\right)=\frac{1}{C+1}$$

$$4\left(\frac{0.166}{C+1}\right)=\frac{1}{(C+1)^2}$$

$$\frac{4}{6(C+1)}=\frac{1}{(C+1)^2}$$

$$4(C+1)=6$$

Solve for capacitor C.

$$\begin{aligned}C &= \frac{6-4}{4}\\ &= \frac{2}{4}\\ &= \frac{1}{2}\\ &= 0.5\ \text{F}\end{aligned}$$

Thus, the value of capacitor for the critically damped network is $\boxed{0.5\ \text{F}}$.

Step 1 of 2

14.073 P

Voltage response of the network to a unit step input is,

$$\begin{aligned}\mathbf{V_o}(s) &= \frac{2(s+1)}{s(s^2+10s+25)} \\ &= \frac{2(s+1)}{(s^2+10s+25)}\cdot\frac{1}{s}\end{aligned}$$

For unit step input, $\mathbf{V_i}(s)=\frac{1}{s}$.

$$\mathbf{V_o}(s) = \frac{2(s+1)}{(s^2+10s+25)}\cdot\mathbf{V_i}(s)$$

Define transfer function.

$$\begin{aligned}G(s) &= \frac{\mathbf{V_o}(s)}{\mathbf{V_i}(s)} \\ &= \frac{2(s+1)}{(s^2+10s+25)}\end{aligned}$$

Step 2 of 2

Characteristic equation of the transfer function is,

$$s^2+10s+25=0$$

Write the standard equation.

$$s^2+2\xi\omega_n s+\omega_n^2=0$$

Compare constant.

$$\omega_n^2=25$$

$$\omega_n=5\text{ rad/sec}$$

Compare s coefficient.

$$2\xi\omega_n=10$$

Substitute 5 for ω_n equation.

$$2\xi(5)=10$$

$$\xi=1\text{ rad/sec}$$

Thus, damping ratio ξ is 1. The response is **critically damped**.

Step 1 of 5

Refer to Figure P14.55 in the text book.

The expression for the current $i_o(t)$ is,

$$i_0(t) = 12[u(t)-u(t-1)]$$

Apply Laplace transform on both sides.

$$I_0(s) = 12\left[\frac{1}{s}-\frac{e^{-s}}{s}\right]$$
$$= 12\left[\frac{1-e^{-s}}{s}\right]$$

Step 2 of 5

Draw the circuit in Laplace domain.

Figure 1

Step 3 of 5

Apply Kirchhoff's current law at the node $V_1(s)$.

$$\frac{V_1(s)}{2}+\frac{V_1(s)-V_2(s)}{s} = \frac{12(1-e^{-s})}{s}$$

$$V_1(s)\left[\frac{1}{2}+\frac{1}{s}\right]-V_2(s)\left[\frac{1}{s}\right] = \frac{12(1-e^{-s})}{s} \quad \rightarrow \text{(1)}$$

Apply Kirchhoff's current law at the node voltage $V_2(s)$.

$$\frac{V_2(s)-V_1(s)}{s}+\frac{V_2(s)}{6}+\frac{V_2(s)}{3} = 0$$

$$-V_1(s)\left[\frac{1}{s}\right]+V_2(s)\left[\frac{1}{s}+\frac{1}{6}+\frac{1}{3}\right] = 0 \quad \rightarrow \text{(2)}$$

Step 4 of 5

Solve equations (1) and (2).

$$\begin{bmatrix} \frac{s+2}{2s} & \frac{-1}{s} \\ \frac{-1}{s} & \frac{6+s+2s}{6s} \end{bmatrix}\begin{bmatrix} V_1(s) \\ V_2(s) \end{bmatrix} = \begin{bmatrix} \frac{12(1-e^{-s})}{s} \\ 0 \end{bmatrix}$$

$$V_2(s) = \frac{4s}{s+4}\begin{bmatrix} \frac{(s+2)}{2s} & +\frac{1}{s} \\ +\frac{1}{s} & \frac{s+2}{2s} \end{bmatrix}\begin{bmatrix} \frac{12(1-e^{-s})}{s} \\ 0 \end{bmatrix}$$

$$= \frac{4s}{s+4}\begin{bmatrix} \frac{(s+2)}{2s} & +\frac{1}{s} \\ +\frac{1}{s} & \frac{s+2}{2s} \end{bmatrix}\begin{bmatrix} \frac{12(1-e^{-s})}{s} \\ 0 \end{bmatrix}$$

$$= \frac{4s}{s+4}\left[\frac{+12(1-e^{-s})}{s^2}\right]$$

Simplify further.

$$V_2(s) = \frac{+48(1-e^{-s})}{s(s+4)}$$

Step 5 of 5

The expression for the output voltage $V_o(s)$ is,

$$V_0(s) = \frac{2V_2(s)}{3}$$

$$= +\frac{2}{3}\cdot\frac{48(1-e^{-s})}{s(s+4)}$$

$$= +\frac{32(1-e^{-s})}{s(s+4)}$$

Apply inverse Laplace Transform.

$$v_o(t) = 32L^{-1}\left[\frac{-e^{-s}}{s(s+4)}+\frac{1}{s(s+4)}\right]$$
$$= -32L^{-1}\left[\frac{e^{-s}}{s(s+4)}+\frac{k_1}{s}+\frac{k_2}{s+4}\right]$$

Here,

$k_1 = \frac{-1}{4}$ and $k_2 = \frac{1}{4}$.

$$V_0(t) = -32L^{-1}\left\{e^{-s}\left[\frac{0.25}{s+4}-\frac{0.25}{s}\right]+\frac{0.25}{s+4}-\frac{0.25}{s}\right\}$$
$$= -32L^{-1}\left\{\frac{0.25e^{-s}}{s+4}-\frac{0.25e^{-s}}{s}+\frac{0.25}{s+4}-\frac{0.25}{s}\right\}$$
$$= -32\left[0.25\left\{e^{-4(t-1)}-u(t-1)+e^{-4t}-u(t)\right\}\right]$$
$$= -8\left[e^{-4(t-1)}-u(t-1)+e^{-4t}-1\right]u(t)$$

Thus, the expression of $v_o(t)$ is $\boxed{-8\left[e^{-4(t-1)}-u(t-1)+e^{-4t}-1\right]\text{ V}}$.

Step 1 of 2

The transfer function of the network is,

$$\begin{aligned} G(s) &= \frac{2(s+10)}{s^2+6s+9} \\ &= \frac{2(s+10)}{(s+3)(s+3)} \end{aligned}$$

The denominator of the closed loop transfer function is the characteristic equation of the network. The poles of the transfer function are -3 **and** -3 , which are real and equal. Therefore, the system is said to be critically damped.

Step 2 of 2

From the transfer function, the characteristic equation of the network is,

$$s^2+6s+9=0$$

Compare the characteristic equation with standard form.

$$s^2+2\zeta\omega_0 s+\omega_0^2=0$$

Determine the value of natural frequency.

$$\begin{aligned} \omega_0^2 &= 9 \\ \omega_0 &= 3 \text{ rad/s} \end{aligned}$$

Hence, the value of natural frequency, ω_0 is $\boxed{3 \text{ rad/s}}$.

Determine the value of damping ratio.

$$\begin{aligned} 2\zeta\omega_0 &= 6 \\ \zeta &= \frac{6}{2\omega_0} \end{aligned}$$

Substitute 3 rad/s for ω_0 in the equation.

$$\begin{aligned} \zeta &= \frac{6}{2(3)} \\ &= 1 \end{aligned}$$

Hence, the value of damping ratio, ζ is $\boxed{1}$.

Thus, the value of damping ratio is equals to one. Hence, the response of network is **critically damped**.

14.078
P

Step 1 of 2

The voltage response of a network to a unit step input is,

$$\mathbf{V}_o(s) = \frac{10}{s\left(s^2+8s+18\right)}$$

$$\mathbf{V}_o(s) = \left(\frac{10}{s^2+8s+18}\right)\cdot\left(\frac{1}{s}\right)$$

For unit step input, $\mathbf{V}_i(s) = \frac{1}{s}$.

$$\mathbf{V}_o(s) = \frac{10}{\left(s^2+8s+18\right)}\mathbf{V}_i(s)$$

Define transfer function.

$$G(s) = \frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}$$
$$= \frac{10}{s^2+8s+18}$$

Step 2 of 2

Characteristic equation of the transfer function is,

$$s^2+8s+18=0$$

Write the standard equation.

$$s^2+2\zeta\omega_n s+\omega_n^2=0$$

Compare constant.

$$\omega_n^2 = 18$$
$$\omega_n = 4.242 \text{ rad/sec}$$

Compare s coefficient.

$$2\zeta\omega_n = 8$$

Substitute 4.242 for ω_n equation.

$$2\zeta(4.242)=8$$

Solve for

$$\zeta = \frac{8}{2(4.242)}$$
$$= 0.942 < 1$$

Damping ratio $\zeta < 1$

Thus, the system is **under damped.**

Step 1 of 2

14.079
P

The transfer function of the network is,

$$G(s) = \frac{100s}{s^2+22s+40}$$

Find the roots of the characteristic equation.

$$G(s) = \frac{100s}{(s+2)(s+20)}$$

Identify the poles and zeros location on *s*-plane.

Figure 1

Step 2 of 2

As the denominator of the closed loop transfer function is nothing but the characteristic equation and the poles of the transfer function are nothing but the roots of the characteristic equation. The roots of the transfer function are -2 and -20, which are real, unequal and negative.

Write the characteristic equation of the standard second order system.

$$s^2+2\zeta\omega_n s+\omega_n^2=0$$

Recall the characteristic equation of the network.

$$s^2+22s+40=0$$

Compare constants.

$$\omega_n^2=40$$

$$\omega_n = 6.32 \text{ rad/sec}$$

Compare s coefficient.

$$2\zeta\omega_n = 22$$

Substitute 6.32 for ω_n in the equation.

$$2\zeta(6.32)=22$$
$$\zeta=1.739>1$$

Thus, response of the system is **overdamped**.

Damping ratio ζ of the system is $\boxed{1.739}$.

Natural frequency ω_n of system is $\boxed{6.32 \text{ rad/sec}}$.

14.080

P

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Step 1 of 7

Refer to Figure P14.81 in the text book.

Calculate the impedance of the $2\ \text{H}$ inductor.

$$\begin{aligned}\mathbf{Z}_L &= sL\\ &= 2s\end{aligned}$$

Calculate the impedance of the $1\ \text{F}$ capacitor.

$$\begin{aligned}\mathbf{Z}_C &= \frac{1}{sC}\\ &= \frac{1}{s(1)}\\ &= \frac{1}{s}\end{aligned}$$

Step 2 of 7

Draw the circuit diagram in frequency domain.

Figure 1

Step 3 of 7

Apply nodal analysis at node $\mathbf{V}_1(s)$.

$$\frac{\mathbf{V}_1(s)-\mathbf{V}_i(s)}{2}+\frac{\mathbf{V}_1(s)}{2s+\frac{1}{s}}+\frac{\mathbf{V}_1(s)-\mathbf{V}_o(s)}{1}=0$$

$$\mathbf{V}_1(s)\left(\frac{1}{2}+\frac{1}{2s+\frac{1}{s}}+1\right)-\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\mathbf{V}_1(s)\left(\frac{3}{2}+\frac{s}{2s^2+1}\right)-\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\mathbf{V}_1(s)\left(\frac{3(2s^2+1)+2s}{2(2s^2+1)}\right)-\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\mathbf{V}_1(s)\left(\frac{6s^2+3+2s}{2(2s^2+1)}\right)-\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}\quad\text{..... (1)}$$

Step 4 of 7

Apply nodal analysis at output node.

$$\frac{\mathbf{V}_o(s)-\mathbf{V}_1(s)}{1}+\frac{\mathbf{V}_o(s)}{3}=0$$

$$\mathbf{V}_o(s)\left(1+\frac{1}{3}\right)=\mathbf{V}_1(s)$$

$$\mathbf{V}_o(s)\left(\frac{4}{3}\right)=\mathbf{V}_1(s)$$

$$\mathbf{V}_1(s)=\frac{4}{3}\mathbf{V}_o(s)$$

Step 5 of 7

Substitute $\frac{4}{3}\mathbf{V}_o(s)$ for $\mathbf{V}_1(s)$ in equation (1) to determine the transfer function of the network.

$$\frac{4}{3}\mathbf{V}_o(s)\left(\frac{6s^2+3+2s}{2(2s^2+1)}\right)-\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\left(\frac{2}{3}\left(\frac{6s^2+3+2s}{(2s^2+1)}\right)-1\right)\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\left(\frac{12s^2+6+4s-6s^2-3}{3(2s^2+1)}\right)\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\left(\frac{6s^2+4s+3}{3(2s^2+1)}\right)\mathbf{V}_o(s)=\frac{\mathbf{V}_i(s)}{2}$$

$$\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}=\frac{3(2s^2+1)}{2(6s^2+4s+3)}$$

$$\mathbf{H}(s)=\frac{3(2s^2+1)}{2(6s^2+4s+3)}\qquad\left(\text{since } \mathbf{H}(s)=\frac{\mathbf{V}_o(s)}{\mathbf{V}_i(s)}\right)$$

Step 6 of 7

The forcing function of the network is, $4\cos t\ \text{V}$, then $V_M = 4\ \text{V}$ and $\omega = 1\ \text{rad/s}$.

$$\mathbf{H}(j\omega)=\frac{3(2(j\omega)^2+1)}{2(6(j\omega)^2+4(j\omega)+3)}$$

Substitute $1\ \text{rad/s}$ for ω in the equation.

$$\begin{aligned}\mathbf{H}(j1)&=\frac{3(2(j1)^2+1)}{2(6(j1)^2+4(j1)+3)}\\ &=\frac{3(-2+1)}{2(-6+4j+3)}\\ &=\frac{-3}{-6+8j}\end{aligned}$$

$$\begin{aligned}&=0.18+0.24j\\ &=0.3\angle 53.13^\circ\end{aligned}$$

Therefore,

$$\begin{aligned}|\mathbf{H}(j1)|&=0.3\ \text{V}\\ \phi(j1)&=\angle 53.13^\circ\end{aligned}$$

Step 7 of 7

Therefore, the value of steady state response of the network is,

$$v_o(t)=V_M|\mathbf{H}(j1)|\cos[t+\phi(j1)]$$

Substitute $4\ \text{V}$ for V_M, $0.3\ \text{V}$ for $|\mathbf{H}(j1)|$ and 53.13° for $\phi(j1)$ in the equation.

$$\begin{aligned}v_o(t)&=(4)(0.3)\cos[t+53.13^\circ]\\ &=1.2\cos(t+53.13^\circ)\ \text{V}\end{aligned}$$

Hence, the steady state response of the network, $v_o(t)$ is $\boxed{1.2\cos(t+53.13^\circ)\ \text{V}}$.

Step 1 of 3

14.085 P

Refer to the circuit diagram in Figure P14.71 in the textbook.

Draw the s - domain equivalent circuit of the figure.

Figure 1

Step 2 of 3

Find the Laplace transform for the current signal.

$$L\left(i(t)\right)=L\left(10\cos t\right)$$
$$=\frac{10s}{s^2+1} \quad \text{since } \left\{\mathcal{L}\left(\cos\omega t\right)=\frac{s}{s^2+\omega^2}\right\}$$

Apply Kirchhoff's law at node 1.

$$\frac{\mathbf{V}_1(s)}{s}+\frac{\mathbf{V}_1(s)}{1}+\frac{\mathbf{V}_1(s)-\mathbf{V}_2(s)}{2}+1=0$$

Substitute $\frac{10s}{s^2+1}$ for 1 in the equation.

$$\mathbf{V}_1(s)\left(\frac{1}{s}+1+\frac{1}{2}\right)-\frac{\mathbf{V}_2(s)}{2}=-\left(\frac{10s}{s^2+1}\right)$$
$$\mathbf{V}_1(s)\left(\frac{2s+2+s}{2s}\right)-\frac{\mathbf{V}_2(s)}{2}=-\left(\frac{10s}{s^2+1}\right)$$
$$\mathbf{V}_1(s)\left(\frac{3s+2}{2s}\right)-\frac{\mathbf{V}_2(s)}{2}=-\left(\frac{10s}{s^2+1}\right) \text{ ..... (1)}$$

Apply Kirchhoff's law at node 2.

$$\frac{\mathbf{V}_2(s)}{\frac{1}{s}}+\frac{\mathbf{V}_2(s)}{1}+\frac{\mathbf{V}_2(s)-\mathbf{V}_1(s)}{2}=1$$
$$\mathbf{V}_2(s)\left(\frac{1}{\frac{1}{s}}+1+\frac{1}{2}\right)-\frac{\mathbf{V}_1(s)}{2}=\left(\frac{10s}{s^2+1}\right)$$
$$\mathbf{V}_2(s)(s+1.5)-\frac{\mathbf{V}_1(s)}{2}=\left(\frac{10s}{s^2+1}\right) \text{ ..... (2)}$$

Step 3 of 3

Write equation (1) and equation (2) in matrix form.

$$\begin{bmatrix}\left(\frac{3s+2}{2s}\right) & -\frac{1}{2}\\ -\frac{1}{2} & s+1.5\end{bmatrix}\begin{bmatrix}\mathbf{V}_1\\ \mathbf{V}_2\end{bmatrix}=\begin{bmatrix}-\frac{10s}{s^2+1}\\ \frac{10s}{s^2+1}\end{bmatrix}$$

Solve equations.

$$\mathbf{V}_2=\frac{\begin{vmatrix}\left(\frac{3s+2}{2s}\right) & -\frac{10s}{s^2+1}\\ -\frac{1}{2} & \frac{10s}{s^2+1}\end{vmatrix}}{\begin{vmatrix}\left(\frac{3s+2}{2s}\right) & -\frac{1}{2}\\ -\frac{1}{2} & s+1.5\end{vmatrix}}$$
$$=\frac{\left(\frac{3s+2}{2s}\right)\left(\frac{10s}{s^2+1}\right)-\left(\frac{1}{2}\right)\left(\frac{10s}{s^2+1}\right)}{\left(\frac{3s+2}{2s}\right)(s+1.5)-0.25}$$
$$=\frac{\frac{10s+10}{s^2+1}}{\frac{3s^2+6.5s+3-0.5s}{2s}}$$
$$=\frac{\frac{10s+10}{s^2+1}}{\frac{3s^2+6s+3}{2s}}$$

Simplify further.

$$\mathbf{V}_2=\frac{20s(s+1)}{3(s^2+1)(s^2+2s+1)}$$
$$=\frac{6.666s(s+1)}{(s^2+1)(s^2+2s+1)}$$

Take partial fraction.

$$\mathbf{V}_2(s)=\frac{3.333s+3.333}{s^2+1}-\frac{3.333}{s+1}$$
$$=3.333\left(\frac{s+1}{s^2+1}\right)-\frac{3.333}{s+1}$$
$$=3.333\sqrt{2}\left(\frac{\frac{s}{\sqrt{2}}+\frac{1}{\sqrt{2}}}{s^2+1}\right)-\frac{3.333}{s+1}$$
$$=4.7\left(\frac{s\sin 45^\circ+\cos 45^\circ}{s^2+1}\right)-\frac{3.33}{s+1}$$

Apply inverse Laplace transform.

$$v_2(t)=4.7\sin(t+45^\circ)-3.33e^{-t}\ \text{V}$$

Thus voltage across capacitor is same as voltage across $1\ \Omega$ resistor.

So, $v_2(t)=v_o(t)$.

Since

$$L^{-1}\left\{\frac{s\sin\theta+\omega\cos\theta}{s^2+\omega^2}\right\}=\sin(\omega t+\theta)$$
$$L^{-1}\left\{\frac{1}{s+a}\right\}=e^{-at}$$

Thus, the voltage across $1\ \Omega$ resistor $v_o(t)$ is $\boxed{4.7\sin(t+45^\circ)-3.33e^{-t}\ \text{V}}$.

Step 1 of 2

14.086 P

Refer to the waveform in textbook Figure E15.1.

The time period (T_0) of the waveform is,

$$\begin{aligned} T_0 &= \frac{2\pi}{\omega_0} \\ &= \frac{2\pi}{2\pi(f)} \\ &= \frac{2\pi}{2\pi(0.5)} \\ &= 2 \end{aligned}$$

Find the Fourier coefficients of the waveform.

$$\begin{aligned} c_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)dt \\ &= \frac{1}{2}\int_{-1}^{0} 0dt + \frac{1}{2}\int_{0}^{1} 1dt \\ &= \frac{1}{2}t\Big|_0^1 \\ &= \frac{1}{2} \end{aligned}$$

Therefore we have $c_0 = \frac{1}{2}$.

Step 2 of 2

Find the Fourier coefficient c_n.

$$\begin{aligned} c_n &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)e^{-jn\omega_0 t}dt \\ &= \frac{1}{2}\int_{-1}^{0}(0)e^{-jn\omega_0 t}dt + \frac{1}{2}\int_{0}^{1}(1)e^{-jn\omega_0 t}dt \\ &= \frac{1}{2}\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Bigg|_0^1 \end{aligned}$$

Angular frequency is,

$$\begin{aligned} \omega_0 &= 2\pi f \\ &= 2\pi(0.5) \\ &= \pi \end{aligned}$$

Substitute π for ω_0 in the equation.

$$\begin{aligned} c_n &= \left(\frac{1}{2}\right)\frac{e^{-jn\pi t}}{-jn\pi}\Bigg|_0^1 \\ &= \frac{1-e^{-j\pi n}}{2j\pi n} \end{aligned}$$

Therefore Fourier coefficient c_n is $\frac{1-e^{-jn\pi}}{2j\pi n}$.

Therefore the Fourier coefficients for the waveform are $\boxed{c_0 = \frac{1}{2}}$ and $\boxed{c_n = \frac{1-e^{-jn\pi}}{j2\pi n}}$.

Step 1 of 4

14.087 P

Refer to the circuit diagram in Figure P14.72 in the textbook.

Draw the frequency domain equivalent circuit.

Figure 1

Step 2 of 4

Apply Kirchhoff's current law at super node (1, 2).

$$\frac{\mathbf{V}_1(s)}{1+s}+\frac{\mathbf{V}_1(s)}{2}+\frac{\mathbf{V}_2(s)}{\frac{1}{s}}+\frac{\mathbf{V}_2(s)-\mathbf{V}_o(s)}{2}=0$$

$$\mathbf{V}_1(s)\left(\frac{1}{1+s}+\frac{1}{2}\right)+\mathbf{V}_2(s)\left(s+\frac{1}{2}\right)=\frac{\mathbf{V}_o(s)}{2}$$

$$\mathbf{V}_1(s)\left(\frac{2+s+1}{2(s+1)}\right)+\mathbf{V}_2(s)\left(\frac{2s+1}{2}\right)=\frac{\mathbf{V}_o(s)}{2}$$

$$\mathbf{V}_1(s)\left(\frac{s+3}{2(s+1)}\right)+\mathbf{V}_2(s)\left(\frac{2s+1}{2}\right)=\frac{\mathbf{V}_o(s)}{2} \quad \text{..... (1)}$$

Apply Kirchhoff's current law at node $\mathbf{V}_o(s)$.

$$\frac{\mathbf{V}_o(s)}{1}+\frac{\mathbf{V}_o(s)-\mathbf{V}_2(s)}{2}=0$$

$$\mathbf{V}_o(s)\left(1+\frac{1}{2}\right)-\frac{\mathbf{V}_2(s)}{2}=0$$

$$1.5\mathbf{V}_o(s)=0.5\mathbf{V}_2(s)$$

$$\mathbf{V}_2(s)=3\mathbf{V}_o(s)$$

Write the super node equation.

$$\mathbf{V}_2(s)-\mathbf{V}_1(s)=\frac{12s}{s^2+1}$$

$$\mathbf{V}_1(s)=\mathbf{V}_2(s)-\frac{12s}{s^2+1}$$

Substitute $3\mathbf{V}_o(s)$ for $\mathbf{V}_2(s)$ in the equation. $\mathbf{V}_1(s)=3\mathbf{V}_o(s)-\frac{12s}{s^2+1}$

Step 3 of 4

Recall equation (1).

$$\mathbf{V}_1(s)\left(\frac{s+3}{2(s+1)}\right)+\mathbf{V}_2(s)\left(\frac{2s+1}{2}\right)=\frac{\mathbf{V}_o(s)}{2}$$

Substitute $3\mathbf{V}_o(s)-\frac{12s}{s^2+1}$ for $\mathbf{V}_1(s)$ and $3\mathbf{V}_o(s)$ for $\mathbf{V}_2(s)$ in the equation.

$$\left(3\mathbf{V}_o(s)-\frac{12s}{s^2+1}\right)\left(\frac{s+3}{2(s+1)}\right)+\left(3\mathbf{V}_o(s)\right)\left(\frac{2s+1}{2}\right)=\frac{\mathbf{V}_o(s)}{2}$$

$$\left(3\mathbf{V}_o(s)\left(\frac{s+3}{2(s+1)}\right)\right)-\left(\frac{12s}{s^2+1}\right)\left(\frac{s+3}{2(s+1)}\right)+\left(3\mathbf{V}_o(s)\right)\left(\frac{2s+1}{2}\right)=\frac{\mathbf{V}_o(s)}{2}$$

$$\mathbf{V}_o(s)\left(\frac{3(s+3)}{2(s+1)}+\frac{3(2s+1)}{2}-\frac{1}{2}\right)=\left(\frac{12s}{s^2+1}\right)\left(\frac{s+3}{2(s+1)}\right)$$

$$\mathbf{V}_o(s)\left(\frac{3(s+3)+3(2s+1)(s+1)-(s+1)}{2(s+1)}\right)=\frac{12s(s+3)}{2(s^2+1)(s+1)}$$

Simplify further.

$$\mathbf{V}_o(s)\left(\frac{3s+9+6s^2+9s+3-s-1}{2(s+1)}\right)=\frac{12s(s+3)}{2(s^2+1)(s+1)}$$

$$\mathbf{V}_o(s)\left(6s^2+11s+11\right)\left(s^2+1\right)=12s(s+3)$$

$$\mathbf{V}_o(s)=\frac{12s(s+3)}{\left(s^2+1\right)\left(6s^2+11s+11\right)}$$

Step 4 of 4

Apply inverse Laplace transform to the output voltage expression.

$$\mathbf{V}_o(s)=\frac{12s(s+3)}{\left(s^2+1\right)\left(6s^2+11s+11\right)}$$

Take partial fraction.

$$\begin{aligned}\mathbf{V}_o(s)&=\frac{12(13s+14)}{73\left(s^2+1\right)}-\frac{24(39s+77)}{73\left(6s^2+11s+11\right)}\\&=\frac{156}{73}\left(\frac{s}{s^2+1}\right)+\frac{168}{73}\left(\frac{1}{s^2+1}\right)-\frac{24(39s+77)}{73\left(6s^2+11s+11\right)}\\&=\frac{156}{73}\left(\frac{s}{s^2+1}\right)+\frac{168}{73}\left(\frac{1}{s^2+1}\right)-\frac{24(39s)}{73\left(6s^2+11s+11\right)}+\frac{24(77)}{73\left(6s^2+11s+11\right)}\\&=\frac{156}{73}\left(\frac{s}{s^2+1}\right)+\frac{168}{73}\left(\frac{1}{s^2+1}\right)-\frac{24(39s)}{73\left(6s^2+11s+11\right)}+\frac{24(77)}{73\left(6s^2+11s+11\right)}\end{aligned}$$

Apply inverse Laplace transform.

$$v_o(t)=\frac{156}{73}\cos(t)+\frac{168}{73}\sin t-\frac{156\exp\left(-\frac{11}{12}t\right)}{73}\left(\cos\left(\frac{\sqrt{143}t}{12}\right)+\frac{15\sqrt{143}}{169}\sin\left(\frac{\sqrt{143}t}{12}\right)\right)$$

The steady-state response $v_o(t)$ of the circuit is

$$\boxed{\frac{156}{73}\cos(t)+\frac{168}{73}\sin t-\frac{156}{73}\exp\left(-\frac{11}{12}t\right)\left(\cos\left(\frac{\sqrt{143}t}{12}\right)+\frac{15\sqrt{143}}{169}\sin\left(\frac{\sqrt{143}t}{12}\right)\right)}.$$

Step 1 of 7

14.088 P

Refer to Figure P14.77 in the textbook for the circuit diagram.

Draw the circuit in *s*-domain.

Figure 1

Step 2 of 7

From Figure 1, observe that the node voltage $V_2(s)$ is,

$$V_2(s)=\frac{8s}{s^2+4} \text{ ..... (1)}$$

From the circuit, observe that the circuit contains two super nodes.

$$V_1(s)-V_O(s)=\frac{4s}{s^2+4} \text{ ..... (2)}$$

$$V_3(s)-V_1(s)=2I_O(s) \text{ ..... (3)}$$

And the current $I_O(s)$ is,

$$I_O(s)=\frac{V_1(s)}{1}$$

Step 3 of 7

Substitute $V_1(s)$ for $I_O(s)$ in equation (3).

$$V_3(s)-V_1(s)=2V_1(s)$$

$$V_3(s)=3V_1(s) \text{ ..... (4)}$$

Apply Kirchhoff's current law at the super node.

$$\frac{V_3(s)-V_2(s)}{s}+\frac{V_1(s)-V_2(s)}{\left(\frac{1}{s}\right)}+\frac{V_1(s)}{1}+\frac{V_O(s)}{1}=0$$

$$\frac{V_3(s)-V_2(s)}{s}+sV_1(s)-sV_2(s)+V_1(s)+V_O(s)=0$$

$$V_1(s)[s+1]+V_2(s)\left[-s-\frac{1}{s}\right]+\frac{V_3(s)}{s}+V_O(s)=0 \text{ ..... (5)}$$

From equation (2),

$$V_1(s)=V_O(s)+\frac{4s}{s^2+4}$$

From equation (4),

$$V_3(s)=3V_O(s)+\frac{12s}{s^2+4}$$

Step 4 of 7

Substitute $V_O(s)+\frac{4s}{s^2+4}$ for $V_1(s)$, $\frac{8s}{s^2+4}$ for $V_2(s)$ and $3V_O(s)+\frac{12s}{s^2+4}$ for $V_3(s)$ in equation (5).

$$\left[V_O(s)+\frac{4s}{s^2+4}\right](s+1)+\left(\frac{8s}{s^2+4}\right)\left(\frac{-s^2-1}{s}\right)+\frac{3}{s}V_O(s)+\frac{12}{s^2+4}+V_O(s)=0$$

$$V_O(s)\left[(s+1)+\frac{3}{s}+1\right]+\frac{4s(s+1)}{s^2+4}-\frac{8(s^2+1)}{(s^2+4)}+\frac{12}{s^2+4}=0$$

$$V_O(s)\left[\frac{s^2+s+3+s}{s}\right]=\frac{8(s^2+1)}{(s^2+4)}-\frac{4s(s+1)}{s^2+4}-\frac{12}{s^2+4}$$

$$V_O(s)\left[\frac{s^2+2s+3}{s}\right]=\frac{8s^2+8-4s^2-4s-12}{s^2+4}$$

$$V_O(s)=\frac{s(4s^2-4s-4)}{(s^2+4)(s^2+2s+3)}$$

Step 5 of 7

Apply partial fraction rule.

$$V_O(s)=\frac{k_0}{(s-2j)}+\frac{k_0^*}{(s+2j)}+\frac{k_1}{(s+1-j\sqrt{2})}+\frac{k_1^*}{(s+1+j\sqrt{2})}$$

Calculate the value of k_0.

$$k_0=\left.\frac{(4s^2-4s-4)s}{(s+2j)(s^2+2s+3)}\right|_{s=2j}$$

$$=\frac{[4(-4)-4(2j)-4](2j)}{(2j+2j)(-4+4j+3)}$$

$$=\frac{(20-8j)(2j)}{(4j)(4j-1)}$$

$$=\frac{-10-4j}{-1+4j}$$

$$=\frac{10.77\angle-158.198^\circ}{4.123\angle104.036^\circ}$$

$$=2.6121\angle-262.234^\circ$$

And,

$$k_0^*=2.6121\angle262.234^\circ$$

Step 6 of 7

Calculate the value of k_1.

$$k_1=\left.\frac{(4s^2-4s-4)(s)}{(s+4)(s+1+j\sqrt{2}_2)}\right|_{s=-1+j\sqrt{2}}$$

$$=\frac{[4(-1-j2.828)-4(-1+j1.414)-4][-1+j1.414]}{[-1-j2.828+4][-1+j1.414+1+j1.414]}$$

$$=\frac{[-4-j11.312+4-j5.656-4][-1+j1.414]}{(3-j2.828)[j2.828]}$$

$$=\frac{[-4-j16.928][-1+j1.414]}{(3-j2.828)[j2.828]}$$

$$=\frac{(17.433\angle-103.26^\circ)(1.7318\angle125.268^\circ)}{(4.1228\angle-43.3095)(2.828\angle90^0)}$$

$$=2.589398\angle-24.6825$$

$$k_1^*=2.58939\angle24.6825^\circ$$

Step 7 of 7

Therefore, the output expression is,

$$V_O(s)=\left\{\frac{2.6121\angle-262.234^\circ}{s-2j}+\frac{2.6124\angle262.234^\circ}{s+2j}+\frac{2.58939\angle-24.6825^\circ}{(s+1-j\sqrt{2})}+\frac{2.58939\angle24.6825^\circ}{(s+1+j\sqrt{2})}\right\}$$

Now apply inverse Laplace transform.

$$v_O(t)=5.2242\cos(2t-262.234^\circ)+5.17878e^{-t}\cos\left(\sqrt{2}t-24.6825^\circ\right)\text{ V}$$

For steady state response, $t\to\infty$. So,

$$v_O(t)=5.2242\cos(2t-262.234^\circ)+5.17878e^{-\infty}\cos\left(\sqrt{2}t-24.6825^\circ\right)\text{ V}$$

$$=5.2242\cos(2t-262.234^\circ)u(t)\text{ V}$$

Therefore, the steady state response $v_{OSS}(t)$ is, $\boxed{5.2242\cos(2t-262.234^\circ)u(t)\text{ V}}$.

Step 1 of 4

14.089 P

Refer to Figure P14.74 in the text book.

Draw the circuit diagram in s-domain.

Figure 1

Step 2 of 4

From Figure 1,

$$I_1(s)=\frac{V_1(s)}{1s} \quad \text{..... (1)}$$

$$V_o(s)=1\left(I_o(s)\right)$$

$$V_o(s)=I_o(s) \quad \text{..... (2)}$$

Apply Kirchhoff's current law at node $V_o(s)$.

$$\frac{V_o(s)-V_1(s)}{\frac{2}{s}}+\frac{V_o(s)}{1}+2I_1(s)=0$$

$$\frac{s}{2}V_o(s)-\frac{s}{2}V_1(s)+V_o(s)+2I_1(s)=0$$

$$\left(\frac{s}{2}+1\right)V_o(s)-\frac{s}{2}V_1(s)+2I_1(s)=0$$

Substitute $\frac{V_1(s)}{1s}$ for $I_1(s)$ and $I_o(s)$ for $V_o(s)$.

$$\left(\frac{s}{2}+1\right)I_o(s)-\frac{s}{2}V_1(s)+\frac{2}{s}V_1(s)=0$$

$$\left(\frac{s}{2}+1\right)I_o(s)+\left(\frac{2}{s}-\frac{s}{2}\right)V_1(s)=0$$

$$\left(\frac{s}{2}+1\right)I_o(s)=\left(\frac{s}{2}-\frac{2}{s}\right)V_1(s)$$

$$\left(\frac{s+2}{2}\right)I_o(s)=\left(\frac{s^2-4}{2s}\right)V_1(s)$$

$$\frac{I_o(s)}{V_1(s)}=\left(\frac{s^2-4}{s(s+2)}\right)$$

$$H(s)=\frac{s^2-4}{s(s+2)} \quad \text{..... (3)}$$

Step 3 of 4

Substitute $j\omega_o$ for s in the equation (3).

$$H(j\omega_o)=\frac{(j\omega_o)^2-4}{(j\omega_o)(j\omega_o+2)}$$

The forcing function of the circuit is, $12\cos 2t\ \mathrm{u(t)}$.

Compare the forcing function with $V_M\cos\omega_o t\ \mathrm{u(t)}$.

$V_M=12$ and $\omega_o=2$

Substitute 2 for ω_o in equation, $H(j\omega_o)=\frac{(j\omega_o)^2-4}{(j\omega_o)(j\omega_o+2)}$.

$$\begin{aligned}H(j2)&=\frac{(j2)^2-4}{(j2)(j2+2)}\\&=\frac{-8}{-4+j4}\\&=\sqrt{2}\angle 45^\circ\end{aligned}$$

Step 4 of 4

Write the formula for the steady state response.

$$i_{oss}(t)=V_M\left|H(j2)\right|\cos\left(2t+\phi(j2)\right)$$

Substitute 12 for V_M, $\sqrt{2}$ for $\left|H(j2)\right|$ and 45° for $\phi(j2)$.

$$\begin{aligned}i_{oss}(t)&=(12)\left(\sqrt{2}\right)\cos(2t+45^\circ)\\&=16.97\cos(2t+45^\circ)\ \mathrm{A}\end{aligned}$$

Therefore, the steady state response, $i_{oss}(t)$ is $\boxed{16.97\cos(2t+45^\circ)\ \mathrm{A}}$.

Step 1 of 2

15.001
P

Refer to the waveform in Figure P15.2 in the textbook.

The time period for the waveform is $T_0 = 5$.

Angular frequency is,

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0}\\ &= \frac{2\pi}{5}\end{aligned}$$

Find exponential Fourier coefficients for the waveform.

$$\begin{aligned}c_n &= \frac{1}{T_0}\left[\int_2^3 6.e^{-jn\omega_0 t}dt + \int_3^7 0.e^{-jn\omega_0 t}dt\right]\\ &= \frac{1}{T_0}\left[6.\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Bigg|_2^3\right]\\ &= \frac{1}{T_0}\left[(6)\left(\frac{e^{-jn\omega_0 3}}{-jn\omega_0} - \frac{e^{-jn\omega_0 2}}{-jn\omega_0}\right)\right]\end{aligned}$$

Substitute $\frac{2\pi}{5}$ for ω_0 in the equation.

$$c_n = \frac{3}{-jn\pi}\left[e^{\frac{-jn6\pi}{5}} - e^{\frac{-jn4\pi}{5}}\right]$$

Step 2 of 2

The exponential Fourier series is,

$$\begin{aligned}f(t) &= \sum_{n=-\infty}^{\infty} c_n e^{jn\omega_0 t}\\ &= \sum_{n=-\infty}^{\infty}\left[\frac{3}{-jn\pi}\left(e^{\frac{-jn6\pi}{5}} - e^{\frac{-jn4\pi}{5}}\right)\right]e^{jn\omega_0 t}\\ &= \sum_{n=-\infty}^{\infty}\left[\frac{6}{-2jn\pi}\left(e^{-j\left(n\pi+\frac{n\pi}{5}\right)} - e^{-j\left(n\pi-\frac{n\pi}{5}\right)}\right)\right]e^{jn\omega_0 t}\\ &= \sum_{n=-\infty}^{\infty}\left[\frac{6}{-n\pi}e^{-jn\pi}\left(\frac{e^{-j\left(\frac{n\pi}{5}\right)} - e^{j\left(\frac{n\pi}{5}\right)}}{2j}\right)\right]e^{jn\omega_0 t}\end{aligned}$$

Therefore the exponential Fourier series for the function $f(t)$ is,

$$\boxed{\sum_{n=-\infty}^{\infty}\left[\frac{6}{n\pi}e^{-jn\pi}\sin\left(\frac{n\pi}{5}\right)\right]e^{jn\omega_0 t}}.$$

Step 1 of 1

15.01FE

Refer to Figure 15PFE-1 in the textbook for the waveform.

Observe that the waveform is symmetrical about the origin. Note that an odd function is symmetrical about the origin and has $a_n = 0$ and $a_0 = 0$.

Therefore the Fourier coefficient a_n has a zero value for all values of n .

Hence, the correct option is $\boxed{\text{b}}$.

Step 1 of 2

15.002

E

Consider the waveform shown in textbook Figure E15.2.

The time period for the waveform is 6.

Calculate the Fourier coefficients.

$$c_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)\,dt$$

$$= \frac{1}{6}\left[\int_{-2}^{-1}(4)\,dt + \int_{-1}^{1}(2)\,dt + \int_{1}^{2}(4)\,dt + \int_{2}^{4}(0)\,dt\right]$$

$$= \frac{1}{6}\left[4(-1+2)+2(1+1)+4(2-1)\right]$$

$$= \frac{12}{6}$$

Therefore, Fourier coefficient is $c_0 = 2$.

Step 2 of 2

The Fourier coefficient c_n is,

$$c_n = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)e^{-jn\omega_0 t}\,dt$$

$$= \frac{1}{6}\left[\int_{-2}^{-1}(4)e^{-jn\omega_0 t}\,dt + \int_{-1}^{0}(2)e^{-jn\omega_0 t}\,dt + \int_{0}^{1}(2)e^{-jn\omega_0 t}\,dt + \int_{1}^{2}(4)e^{-jn\omega_0 t}\,dt\right]$$

$$= \frac{1}{6}\left[(4)\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_{-2}^{-1} + (2)\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_{-1}^{0} + (2)\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_{0}^{1} + (4)\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_{1}^{2}\right]$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{3}$

$$= \frac{1}{2(-jn\pi)}\left[\begin{array}{l} 4\left(e^{jn\frac{\pi}{3}} - e^{jn\frac{2\pi}{3}}\right) + 2\left(1 - e^{jn\frac{\pi}{3}}\right) + 2\left(e^{-jn\frac{\pi}{3}} - 1\right) \\ +4\left(e^{-jn\frac{2\pi}{3}} - e^{-jn\frac{\pi}{3}}\right) \end{array}\right]$$

$$= \frac{-1}{n\pi}\left[\left(\frac{2e^{jn\frac{\pi}{3}} - 2e^{-jn\frac{\pi}{3}}}{2j}\right) + \left(\frac{4e^{-jn\frac{2\pi}{3}} - 4e^{jn\frac{2\pi}{3}}}{2j}\right)\right]$$

$$= \frac{2}{n\pi}\left[2\sin\frac{2n\pi}{3} - \sin\frac{n\pi}{3}\right]$$

Therefore the Fourier coefficients for the waveform are $\boxed{c_0 = 2}$ and $\boxed{c_n = \frac{2}{n\pi}\left[2\sin\frac{2n\pi}{3} - \sin\frac{n\pi}{3}\right]}$.

Step 1 of 3

Refer to Figure P15.1 for periodic pulse train in the textbook.

Write the expression for exponential Fourier series.

$$v(t) = c_0 + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} c_n e^{jn\omega_0 t} \quad \text{..... (1)}$$

The time period for the pulse train is 1. Therefore,

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0} \\ &= \frac{2\pi}{1} \\ &= 2\pi\end{aligned}$$

Calculate the Fourier series coefficient, c_0 .

$$\begin{aligned}c_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)\,dt \\ &= \frac{1}{1}\int_0^1 v(t)\,dt\end{aligned}$$

$$\begin{aligned}&= \int_0^{0.1}(10)dt + \int_{0.1}^{1}(0)dt \\ &= 10(0.1-0)+0 \\ &= 1\end{aligned}$$

Step 2 of 3

Calculate the Fourier series coefficient, c_n .

$$\begin{aligned}c_n &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)e^{-jn\omega_0 t}dt \\ &= \frac{1}{1}\int_0^1 v(t)e^{-jn\omega_0 t}dt \\ &= \int_0^{0.1}(10)e^{-jn2\pi t}dt + \int_{0.1}^{1}(0)e^{-jn2\pi t}dt \qquad (\text{since } \omega_0 = 2\pi) \\ &= 10\left[\left.\frac{e^{-jn2\pi t}}{-jn2\pi}\right|_0^{0.1}\right] \\ &= -\frac{10}{jn2\pi}\left[e^{-0.2jn\pi}-1\right] \\ &= \frac{5}{jn\pi}\left[1-e^{-0.2jn\pi}\right]\end{aligned}$$

Step 3 of 3

Substitute $\frac{5}{jn\pi}\left[1-e^{-0.2jn\pi}\right]$ for c_n and 1 for c_0 in equation (1).

$$\begin{aligned}v(t) &= 1 + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{5}{jn\pi}\left[1-e^{-0.2jn\pi}\right]e^{jn\omega_0 t} \\ &= 1 + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{5}{jn\pi}\left[1-e^{-0.2jn\pi}\right]e^{j2\pi nt} \qquad (\text{since } \omega_0 = 2\pi)\end{aligned}$$

Thus, the exponential Fourier series for the periodic pulse train is,

$$\boxed{v(t) = 1 + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{5}{jn\pi}\left[1-e^{-0.2jn\pi}\right]e^{j2\pi nt}}.$$

Step 1 of 2

15.02E

Refer to Figure 15PFE-2 in the textbook.

The time period of the function is, T_0 .

Draw the function $f\left(t-\frac{T_0}{2}\right)$.

Figure 1

Step 2 of 2

Draw the function $-f\left(t-\frac{T_0}{2}\right)$.

Figure 2

The functions $f(t)$ and $-f\left(t-\frac{T_0}{2}\right)$ are same. Therefore, the function shown in Figure 15PFE-2 in the textbook obeys **half-wave symmetry**.

Consider the following for half-wave symmetry of a periodic function:

$$b_n = \begin{cases} 0, & \text{for } n \text{ even,} \\ \frac{4}{T_0}\int_0^{\frac{T_0}{2}} f(t)\sin n\omega_0 t dt, & \text{for } n \text{ odd.} \end{cases}$$

Therefore, **option (d)** is correct.

15.004

E

Step 1 of 3

Refer to the circuit diagram in Figure PFE15.4 in the textbook.

Consider the input signal.

$$v_s(t) = 20 + 10\cos(377t + 60°) + 4\cos(1131t + 45°) \quad \text{..... (1)}$$

Find the response of the DC source.

Inductor acts as short circuit for low frequencies.

Find the current due to dc source.

$$\begin{aligned} I_{DC} &= \frac{20}{2} \\ &= 10 \text{ A} \end{aligned}$$

Find the individual responses of the AC sources.

From the voltage expression of equation (1), angle of the first term is,

$$L = 10\text{mH}$$

$$\omega_1 = 377\frac{rad}{\sec}$$

$$\theta_1 = 60°$$

$$R = 2\Omega$$

Similarly, angle of the second term is,

$$\theta_2 = 45°$$

$$\omega_2 = 1131\frac{rad}{\sec}$$

The angular frequency of the first term is,

$$\omega_1 = 377 \ rad/s$$

Inductor impedance for the angular frequency is,

$$\begin{aligned} j\omega L &= j\omega_1 L \\ &= j(377)(10\times10^{-3})\Omega \\ &= j3.77\Omega \end{aligned}$$

Therefore $j\omega L = j3.77\Omega$

Find the current flow through the circuit due to first term.

$$\begin{aligned} I_{377} &= \frac{10\angle 60°}{2 + j3.77} \\ &= \frac{10\angle 60°}{4.267\angle 62.05°} \\ &= 2.34\angle -2.05° \text{ A} \end{aligned}$$

Therefore $I_{377} = 2.34\angle -2.05° \text{ A}$

Step 2 of 3

Angular frequency of the second term is,

At $\omega_2 = 1131 \ rad/s$

Inductor impedance is,

$$\begin{aligned} j\omega L &= j\omega_2 L \\ &= j(1131)(10\times10^{-3})\Omega \\ &= j11.31\Omega \end{aligned}$$

Therefore $j\omega L = j11.31\Omega$

Find the current flow through the circuit due to second term.

$$\begin{aligned} I_{1131} &= \frac{4\angle 45°}{2 + j11.31} \\ &= \frac{4\angle 45°}{11.485\angle 79.9°} \\ &= 0.348\angle -34.9° \text{ A} \end{aligned}$$

Therefore $I_{1131} = 0.348\angle -34.9° \text{ A}$

Step 3 of 3

Therefore the total current is,

$$i(t) = 10 + 2.34\angle -2.05° + 0.348\angle -34.9° \text{ A}$$

The average power is,

$$P = V_{DC}I_{DC} + \sum_{n=1}^{\infty}\frac{V_n I_n}{2}\cos(\theta_{v_n} - \theta_{i_n})$$

Therefore the average power absorbed by the network is,

$$\begin{aligned} P &= (20)(10) + \frac{(10)(2.34)}{2}\cos(60° + 2.05) + \frac{(4)(0.348)}{2}\cos(45° + 34.9) \\ &= 200 + 11.7(0.4617) + 0.7(0.1754) \\ &= 200 + 5.402 + 0.123 \\ &= 205.52 \end{aligned}$$

Therefore average power P is $\boxed{205.52 \text{ W}}$.

Step 1 of 3

Consider the waveform in textbook in Figure P15.4. The waveform has a period of $T_0 = 2$. The waveform is defined as,

$$f(t) = \begin{cases} t & \text{for } 0 \le t < 1 \\ 2-t & \text{for } 1 \le t \le 2 \end{cases}$$

Calculate the value of ω_0.

$$\begin{aligned} \omega_0 &= \frac{2\pi}{T_0} \\ &= \pi \end{aligned}$$

Write the exponential Fourier series for a function.

$$f(t) = \sum_{n=-\infty}^{\infty} \mathbf{c}_n \, e^{jn\omega_0 t} dt$$

Write the expression for the exponential Fourier series coefficient, $\mathbf{c}_n$.

$$\mathbf{c}_n = \frac{1}{T_0} \int_{t_1}^{t_1+T_0} f(t) e^{-jn\omega_0 t} dt$$

Calculate the exponential Fourier series coefficient, $\mathbf{c}_n$.

$$\begin{aligned} \mathbf{c}_n &= \frac{1}{T_0} \int_{t_1}^{t_1+T_0} f(t) e^{-jn\omega_0 t} dt \\ &= \frac{1}{2}\left[\int_0^1 t e^{-jn\omega_0 t} dt + \int_1^2 (2-t) e^{-jn\omega_0 t} dt \right] \end{aligned}$$

Step 2 of 3

Consider the formula for integration by parts.

$$\int_0^t uv\,dt = u\int_0^t v\,dt - \int_0^t (u')\int v\,dt \quad \text{and} \quad \int_0^t (u-v)\,dt = \int_0^t u\,dt - \int_0^t v\,dt$$

Simplify the expression.

$$\begin{aligned} \mathbf{c}_n &= \frac{1}{2}\left[t\int_0^1 e^{-jn\omega_0 t} dt - \int_0^1 (1)\int e^{-jn\omega_0 t} dt + 2\int_1^2 e^{-jn\omega_0 t} dt - \int_1^2 t e^{-jn\omega_0 t} dt \right] \\ &= \frac{1}{2}\left[t\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_0^1 - \frac{e^{-jn\omega_0 t}}{(-jn\omega_0)^2}\bigg|_0^1 + 2\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_1^2 - \left\{ t\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\bigg|_1^2 - \frac{e^{-jn\omega_0 t}}{(-jn\omega_0)^2}\bigg|_1^2 \right\} \right] \\ &= \frac{1}{2}\left[\begin{array}{l} \dfrac{e^{-jn\omega_0}}{-jn\omega_0} - 0 - \dfrac{e^{-jn\omega_0}}{(-jn\omega_0)^2} + \dfrac{1}{(-jn\omega_0)^2} + 2\dfrac{e^{-2jn\omega_0}}{-jn\omega_0} - 2\dfrac{e^{-jn\omega_0}}{-jn\omega_0} \\ -\left(\dfrac{2e^{-2jn\omega_0}}{-jn\omega_0} - \dfrac{e^{-jn\omega_0}}{-jn\omega_0} - \dfrac{e^{-2jn\omega_0}}{(-jn\omega_0)^2} + \dfrac{e^{-jn\omega_0}}{(-jn\omega_0)^2} \right) \end{array} \right] \\ &= \frac{1}{2}\left[-\frac{2e^{-jn\omega_0}}{(-jn\omega_0)^2} + \frac{1}{(-jn\omega_0)^2} + \frac{e^{-2jn\omega_0}}{(-jn\omega_0)^2} \right] \end{aligned}$$

Step 3 of 3

Now substitute π for ω_0.

$$\begin{aligned} \mathbf{c}_n &= \frac{1}{2}\left[-\frac{2e^{-jn\omega_0}}{(-jn\omega_0)^2} + \frac{1}{(-jn\omega_0)^2} + \frac{e^{-2jn\omega_0}}{(-jn\omega_0)^2} \right] \\ &= \frac{1}{2}\left[-\frac{2e^{-jn\pi}}{(n\pi)^2} + \frac{1}{(n\pi)^2} + \frac{e^{-2jn\pi}}{(n\pi)^2} \right] \\ &= \frac{1}{2}\left[-\frac{2\{\cos n\pi - j\sin n\pi\}}{(n\pi)^2} + \frac{1}{(n\pi)^2} + \frac{\{\cos 2n\pi - j\sin 2n\pi\}}{(n\pi)^2} \right] \end{aligned}$$

Use the following expressions.

$\sin n\pi = \sin 2n\pi = 0$ and $\cos 2n\pi = 1$.

$$\begin{aligned} \mathbf{c}_n &= \frac{1}{2}\left[-\frac{2\{\cos n\pi - j(0)\}}{(n\pi)^2} + \frac{1}{(n\pi)^2} + \frac{\{1 - j(0)\}}{(n\pi)^2} \right] \\ &= \frac{1}{2}\left[-\frac{2\cos n\pi}{(n\pi)^2} + \frac{2}{(n\pi)^2} \right] \\ &= \frac{1-\cos n\pi}{(n\pi)^2} \end{aligned}$$

Therefore, the exponential Fourier series for a function is, $\boxed{f(t) = \sum_{n=-\infty}^{\infty} \left[\frac{1-\cos n\pi}{(n\pi)^2} \right] e^{jn\omega_0 t} dt}$.

Step 1 of 1

15.005

E

Refer to Figure 15PFE-5 in the textbook for the waveform.

Write the function $v(t)$ in mathematical form.

$$v(t)=\begin{cases}10\text{ V}, & \text{for } 0<t<2\text{ s},\\ -2\text{ V}, & \text{for } 2<t<4\text{ s}.\end{cases}$$

Observe that the time period of the waveform is $T_0 = 4\text{ s}$.

The average value of the waveform is,

$$\begin{aligned}a_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)\,dt\\ &= \frac{1}{4}\left[\int_0^2 (10)\,dt+\int_2^4 (-2)\,dt\right]\\ &= \frac{1}{4}\left[(10)t\Big|_0^2-(2)t\Big|_2^4\right]\\ &= \frac{1}{4}\left[10(2-0)-2(4-2)\right]\end{aligned}$$

$$\begin{aligned}a_0 &= \frac{1}{4}(20-4)\\ &= 4\text{ V}\end{aligned}$$

Therefore the average value of the waveform is 4 V, and hence the correct option is $\boxed{\text{b}}$.

Step 1 of 3

15.005

Consider the voltage waveform shown in textbook Figure E15.4. The time period for the waveform is 4. The waveform exhibits half wave symmetry because, if we invert the waveform from -2 to 0, it is similar to the waveform from 0 to 2. For a waveform that possess half wave symmetry, the Fourier coefficients are given as follows

$$a_0 = 0$$

$$a_n = b_n = 0 \quad \text{for } n \text{ even}$$

$$a_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} f(t)\cos n\omega_0 t dt \quad \text{for } n \text{ odd}$$

$$b_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} f(t)\sin n\omega_0 t dt \quad \text{for } n \text{ odd}$$

Step 2 of 3

The Fourier coefficient a_n is given by

$$a_n = \frac{4}{4}\int_0^2 v(t)\cos n\omega_0 t dt$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{2}$

$$= \int_0^1 (2)\cos\frac{n\pi}{2} t dt + \int_1^2 (1)\cos\frac{n\pi}{2} t dt$$

$$= 2\left.\frac{\sin\frac{n\pi}{2}t}{\frac{n\pi}{2}}\right|_0^1 + \left.\frac{\sin\frac{n\pi}{2}t}{\frac{n\pi}{2}}\right|_1^2$$

$$= 2\left[\frac{\sin\frac{n\pi}{2}}{\frac{n\pi}{2}}\right] + \frac{\sin n\pi}{\frac{n\pi}{2}} - \frac{\sin\frac{n\pi}{2}}{\frac{n\pi}{2}}$$

$$= \frac{2}{n\pi}\left[\sin\frac{n\pi}{2} + \sin n\pi\right]$$

Therefore $a_n = \frac{2}{n\pi}\left[\sin\frac{n\pi}{2}\right]$.

Step 3 of 3

The Fourier coefficient b_n is given by

$$b_n = \frac{4}{4}\int_0^2 v(t)\sin n\omega_0 t dt$$

$$= \int_0^1 (2)\sin\frac{n\pi}{2} t dt + \int_1^2 (1)\sin\frac{n\pi}{2} t dt$$

$$= 2\left.\frac{-\cos\frac{n\pi}{2}t}{\frac{n\pi}{2}}\right|_0^1 + \left.\frac{-\cos\frac{n\pi}{2}t}{\frac{n\pi}{2}}\right|_1^2$$

$$= \frac{2}{n\pi}\left[2 - \cos n\pi\right]$$

Therefore $b_n = \frac{2}{n\pi}\left[2 - \cos n\pi\right]$

Therefore the trigonometric Fourier series for the given voltage waveform is

$$\boxed{v(t) = \sum_{\substack{n=1 \\ n \text{ odd}}}^{\infty} \frac{2}{n\pi}\sin\frac{n\pi}{2}\cos\frac{n\pi}{2}t + \frac{2}{n\pi}(2 - \cos n\pi)\sin\frac{n\pi}{2}t}.$$

15.006
P

The function $f(t)$ is,

$$f(t)=e^{-t} \qquad -1\le t<1$$

The formula for the calculation of Fourier coefficients is,

$$c_n=\frac{1}{T}\int_{t_1}^{t_1+T} f(t)e^{-jn\omega_0 t}\,dt$$

Here, T is the fundamental time period of the waveform and one period of the waveform is defined from t_1 to t_1+T .

The time period of $f(t)$ is 2.

The Fourier coefficients are,

$$\begin{aligned}
c_n &= \frac{1}{2}\int_{-1}^{1} e^{-t}e^{-jn\omega_0 t}\,dt \\
&= \frac{1}{2}\int_{-1}^{1} e^{-t(1+jn\omega_0)}\,dt \\
&= \frac{1}{2}\left(\left.\frac{e^{-t(1+jn\omega_0)}}{(1+jn\omega_0)}\right|_{-1}^{1}\right) \\
&= \frac{1}{2}\left(\frac{e^{-(1+jn\omega_0)}-e^{(1+jn\omega_0)}}{(1+jn\omega_0)}\right)
\end{aligned}$$

The value of ω_0 is,

$$\begin{aligned}
\omega_0 &= \frac{2\pi}{T} \\
&= \pi
\end{aligned}$$

Substitute π in place of ω_0 in the equation of c_n .

$$\begin{aligned}
c_n &= \frac{1}{2}\left(\frac{e^{-1}e^{-jn\pi}}{(1+jn\pi)}-\frac{e^{1}e^{jn\pi}}{(1+jn\pi)}\right) \qquad \text{since } e^{-jn\pi}=e^{jn\pi}=(-1)^n \\
&= \left[\frac{(-1)^n}{1+j\pi n}\right]\left[\frac{e^{-1}-e^{1}}{2}\right]
\end{aligned}$$

The exponential Fourier series is,

$$\begin{aligned}
f(t) &= \sum_{n=-\infty}^{\infty} c_n e^{jn\omega_0 t} \\
&= \sum_{n=-\infty}^{\infty}\left[\frac{(-1)^n}{1+j\pi n}\right]\left[\frac{e^{-1}-e^{1}}{2}\right]e^{jn\omega_0 t}
\end{aligned}$$

Hence, it is shown that the exponential Fourier series of, $f(t)$, is expressed as,

$$\boxed{\sum_{n=-\infty}^{\infty}\left[\frac{(-1)^n}{1+j\pi n}\right]\left[\frac{e^{-1}-e^{1}}{2}\right]e^{jn\omega_0 t}}\ .$$

15.007 E

Step 1 of 5

Refer to Figure P15.7 in the textbook.

The function, $v(t)$, over one period is expressed as,

$$v(t)=\begin{cases}2, & 0<t<1\\ 0, & 1<t<2\\ -1, & 2<t<3\\ 0, & 3<t<4\end{cases}$$

The formula for calculation of trigonometric Fourier series coefficients is,

$$a_n=\frac{2}{T}\int_{t_1}^{t_1+T} f(t)\cos n\omega_0 t\,dt$$

$$b_n=\frac{2}{T}\int_{t_1}^{t_1+T} f(t)\sin n\omega_0 t\,dt$$

Here, T is the fundamental time period of the waveform and one period of the waveform is defined from t_1 to t_1+T .

The time period of $v(t)$ is 4.

Step 2 of 5

The Fourier coefficients are,

$$\begin{aligned}a_n&=\frac{2}{4}\int_0^4 f(t)\cos n\omega_0 t\,dt\\ &=\frac{1}{2}\left\{\int_0^1(2)\cos n\omega_0 t\,dt+\int_1^2(0)\cos n\omega_0 t\,dt+\int_2^3(-1)\cos n\omega_0 t\,dt+\int_3^4(0)\cos n\omega_0 t\,dt\right\}\\ &=\frac{1}{2}\left\{2\left(\frac{\sin n\omega_0 t}{n\omega_0}\Big|_0^1\right)+(-1)\left(\frac{\sin n\omega_0 t}{n\omega_0}\Big|_2^3\right)\right\}\\ &=\frac{2\sin n\omega_0-\sin 3n\omega_0+\sin 2n\omega_0}{2n\omega_0}\end{aligned}$$

$$\begin{aligned}b_n&=\frac{2}{4}\int_0^4 f(t)\sin n\omega_0 t\,dt\\ &=\frac{1}{2}\left\{\int_0^1(2)\sin n\omega_0 t\,dt+\int_1^2(0)\sin n\omega_0 t\,dt+\int_2^3(-1)\sin n\omega_0 t\,dt+\int_3^4(0)\sin n\omega_0 t\,dt\right\}\\ &=\frac{1}{2}\left\{2\left(\frac{-\cos n\omega_0 t}{n\omega_0}\Big|_0^1\right)+(-1)\left(\frac{-\cos n\omega_0 t}{n\omega_0}\Big|_2^3\right)\right\}\\ &=\frac{-2\cos n\omega_0+2+\cos 3n\omega_0-\cos 2n\omega_0}{2n\omega_0}\end{aligned}$$

The value of ω_0 is,

$$\begin{aligned}\omega_0&=\frac{2\pi}{T}\\ &=\frac{\pi}{2}\end{aligned}$$

Step 3 of 5

Substitute $\frac{\pi}{2}$ in place of ω_0 in the equation of a_n and b_n .

$$\begin{aligned}a_n&=\frac{2\sin n\left(\frac{\pi}{2}\right)-\sin 3n\left(\frac{\pi}{2}\right)+\sin 2n\left(\frac{\pi}{2}\right)}{2n\left(\frac{\pi}{2}\right)}\\ &=\frac{2\sin\left(\frac{n\pi}{2}\right)+\sin(n\pi)-\sin\left(\frac{3n\pi}{2}\right)}{n\pi}\\ &=\frac{2\sin(0.5n\pi)+\sin(n\pi)-\sin(1.5n\pi)}{n\pi}\end{aligned}$$

$$\begin{aligned}b_n&=\frac{-2\cos n\left(\frac{\pi}{2}\right)+2+\cos 3n\left(\frac{\pi}{2}\right)-\cos 2n\left(\frac{\pi}{2}\right)}{2n\left(\frac{\pi}{2}\right)}\\ &=\frac{-2\cos\left(\frac{n\pi}{2}\right)-\cos(n\pi)+\cos\left(\frac{3n\pi}{2}\right)+2}{n\pi}\\ &=\frac{-2\cos(0.5n\pi)-\cos(n\pi)+\cos(1.5n\pi)+2}{n\pi}\end{aligned}$$

Step 4 of 5

The value of a_0 , is,

$$\begin{aligned}a_0&=\frac{1}{4}\int_0^4 v(t)dt\\ &=\frac{1}{4}\left[2t\Big|_0^1-t\Big|_2^3\right]\\ &=0.25\end{aligned}$$

The values of the Fourier series coefficients are,

$$\begin{aligned}a_1&=\frac{2\sin(0.5\pi)+\sin(\pi)-\sin\left(\frac{3\pi}{2}\right)}{\pi}\\ &=0.955\end{aligned}$$

$$\begin{aligned}b_1&=\frac{-2\cos(0.5\pi)-\cos(\pi)+\cos(1.5n\pi)+2}{\pi}\\ &=0.955\end{aligned}$$

$$\begin{aligned}a_2&=\frac{2\sin\pi+\sin(2\pi)-\sin(3\pi)}{2\pi}\\ &=0\end{aligned}$$

$$\begin{aligned}b_2&=\frac{-2\cos(\pi)-\cos(2\pi)+\cos(3\pi)+2}{2\pi}\\ &=0.318\end{aligned}$$

$$\begin{aligned}a_3&=\frac{2\sin(1.5\pi)+\sin(3\pi)-\sin(4.5\pi)}{3\pi}\\ &=-0.318\end{aligned}$$

$$\begin{aligned}b_3&=\frac{-2\cos(1.5\pi)-\cos(3\pi)+\cos(4.5\pi)+2}{3\pi}\\ &=0.318\end{aligned}$$

Step 5 of 5

The trigonometric Fourier series expansion of $v(t)$ is,

$$\begin{aligned}v(t)&=a_0+\sum_{n=1}^{\infty}\left(a_n\cos n\omega_0 t+b_n\cos n\omega_0 t\right)\\ &=0.25+\sum_{n=1}^{\infty}\left(\left(\frac{2\sin(0.5n\pi)+\sin(n\pi)-\sin(1.5n\pi)}{n\pi}\right)\cos n\omega_0 t+\left(\frac{-2\cos(0.5n\pi)+\cos(n\pi)-\cos(1.5n\pi)+2}{n\pi}\right)\sin n\omega_0 t\right)\\ &=0.25+\sum_{n=1}^{\infty}\left(\left(\frac{2\sin(0.5n\pi)+\sin(n\pi)-\sin(1.5n\pi)}{n\pi}\right)\cos n\left(\frac{\pi}{2}\right)t+\left(\frac{-2\cos(0.5n\pi)+\cos(n\pi)-\cos(1.5n\pi)+2}{n\pi}\right)\sin n\left(\frac{\pi}{2}\right)t\right)\end{aligned}$$

The trigonometric Fourier series expansion for the waveform is,

$$\boxed{\begin{aligned}&0.25+0.955\cos(0.5\pi t)+0.955\sin(0.5\pi t)+\\ &0.318\sin(\pi t)-0.318\cos(1.5\pi t)+0.318\sin(1.5\pi t)+\ldots\ \text{V}\end{aligned}}$$

Step 1 of 2

15.007
P

Consider the waveform in textbook Figure E15.8. The time period (T_0) is 2. From the waveform the Fourier coefficients are obtained as follows

$$c_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)\,dt$$

$$= \frac{1}{2}\int_{-1}^{0} 1\,dt + \frac{1}{2}\int_{0}^{1} 0\,dt$$

$$= \frac{1}{2}(1)$$

$$= \frac{1}{2}$$

Therefore we have $c_0 = \frac{1}{2}$.

Step 2 of 2

Now the Fourier coefficient c_n is

$$c_n = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v(t)e^{-jn\omega_0 t}\,dt$$

$$= \frac{1}{2}\int_{-1}^{0} (1)e^{-jn\omega_0 t}\,dt$$

$$= \frac{1}{2}\left.\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\right|_{-1}^{0}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \pi$

$$= \left(\frac{1}{2}\right)\left[\frac{1}{-jn\pi} - \frac{e^{jn\pi}}{-jn\pi}\right]$$

$$= -\left(\frac{1-e^{jn\pi}}{2jn\pi}\right)$$

Therefore we have $c_n = -\left(\frac{1-e^{jn\pi}}{2jn\pi}\right)$ ..... (1)

The Fourier coefficients for the waveform in textbook Figure E15.1 are

$c_0 = \frac{1}{2}$ and $c_n = -\left(\frac{1-e^{-jn\pi}}{j2\pi n}\right)$ ..... (2)

From expressions (1) and (2) we can say that the coefficients differ by an angle $n(180°)$.

15.008

We don't have the solution to this problem yet.

P

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Step 1 of 5

15.009 E

Consider the waveforms shown in textbook Figure E15.9 in the text book. The period of the waveform is $T_0 = 6$.

Calculate the Fourier coefficients for the function $v_1(t)$.

$$c_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_1(t)dt$$

$$= \frac{1}{6}\int_{-1}^{1} 2dt$$

$$= \frac{2}{6}\int_{-1}^{1} 1dt$$

$$= \frac{1}{3}(t)\Big|_{-1}^{1}$$

$$= \frac{1}{3}(1-(-1))$$

$$= \frac{1}{3}(1+1)$$

Therefore, $c_0 = \frac{2}{3}$.

Step 2 of 5

Calculate the Fourier coefficient c_n .

$$c_n = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_1(t)e^{-jn\omega_0 t}dt$$

$$= \frac{2}{6}\int_{-1}^{1} 1e^{-jn\omega_0 t}dt$$

$$= \frac{1}{3}\left[\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Big|_{-1}^{1}\right]$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{3}$ in the above equation.

$$c_n = \frac{1}{3}\left[\frac{e^{-jn\frac{\pi}{3}}}{-jn\frac{\pi}{3}} + \frac{e^{jn\frac{\pi}{3}}}{jn\frac{\pi}{3}}\right]$$

$$= \frac{1}{3}\left[\frac{e^{jn\frac{\pi}{3}} - e^{-jn\frac{\pi}{3}}}{jn\frac{\pi}{3}}\right]$$

$$= \frac{2}{2}\left[\frac{e^{jn\frac{\pi}{3}} - e^{-jn\frac{\pi}{3}}}{jn\pi}\right]$$

$$= \frac{2}{n\pi}\left[\frac{e^{jn\frac{\pi}{3}} - e^{-jn\frac{\pi}{3}}}{j2}\right]$$

$$= \frac{2}{n\pi}\left[\sin n\frac{\pi}{3}\right]$$

Therefore $c_n = \frac{2}{n\pi}\left[\sin n\frac{\pi}{3}\right]$

Therefore $\boxed{v_1(t) = \frac{2}{3} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{2}{n\pi}\left[\sin n\frac{\pi}{3}\right]e^{jn\omega_0 t}}$.

Step 3 of 5

Now calculate the Fourier coefficients for the function $v_2(t)$.

$$c_0 = \frac{1}{t_0}\int_{t_1}^{t_1+T_0} v_2(t)dt$$

$$= \frac{1}{3}\int_{-2}^{-1} 4dt \qquad = \frac{4}{3}(-1-(-2))$$

$$= \frac{4}{3}\int_{-2}^{-1} 1dt$$

$$= \frac{4}{3}t\Big|_{-2}^{-1}$$

Therefore $c_0 = \frac{4}{3}$

Now calculate the Fourier coefficient c_n for the function $v_2(t)$.

$$c_n = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_2(t)e^{-jn\omega_0 t}dt$$

$$= \frac{1}{3}\int_{-2}^{-1} 4e^{-jn\omega_0 t}dt$$

$$= \frac{4}{3}\left[\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Big|_{-2}^{-1}\right]$$

$$= \frac{4}{3}\left[\frac{e^{j2n\omega_0}}{jn\omega_0} - \frac{e^{jn\omega_0}}{jn\omega_0}\right]$$

Step 4 of 5

The period of the waveform is $T_0 = 3$. Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{3}$.

$$c_n = \frac{4}{3}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)}}{jn\frac{2\pi}{3}} - \frac{e^{jn\left(\frac{2\pi}{3}\right)}}{jn\frac{2\pi}{3}}\right]$$

$$= 4\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)}}{jn2\pi} - \frac{e^{jn\left(\frac{2\pi}{3}\right)}}{jn2\pi}\right]$$

$$= \frac{4}{n\pi}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)} - e^{jn\left(\frac{2\pi}{3}\right)}}{j2}\right]$$

Therefore,

$$c_n = \frac{4}{n\pi}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)} - e^{jn\left(\frac{2\pi}{3}\right)}}{j2}\right]$$

Therefore $v_2(t) = \frac{4}{3} + \frac{4}{n\pi}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)} - e^{jn\left(\frac{2\pi}{3}\right)}}{j2}\right]$

Step 5 of 5

Now add the two results.

$$v(t) = v_1(t) + v_2(t)$$

$$= \frac{2}{3} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{2}{n\pi}\left[\sin n\frac{\pi}{3}\right]e^{jn\omega_0 t} + \frac{4}{3} + \sum_{n=-\infty}^{n=\infty} \frac{4}{n\pi}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)} - e^{jn\left(\frac{2\pi}{3}\right)}}{j2}\right]e^{jn\omega_0 t}$$

Therefore the required solution is

$$\boxed{v(t) = \frac{2}{3} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{2}{n\pi}\left[\sin n\frac{\pi}{3}\right]e^{jn\omega_0 t} + \frac{4}{3} + \sum_{n=-\infty}^{n=\infty} \frac{4}{n\pi}\left[\frac{e^{jn\left(\frac{4\pi}{3}\right)} - e^{jn\left(\frac{2\pi}{3}\right)}}{j2}\right]e^{jn\omega_0 t}} \diamond$$

Step 1 of 4

Refer to Figure P15.7 (a) in the textbook.

Draw the function $f(-t)$.

Figure 1

Step 2 of 4

Draw the function $-f(-t)$.

Figure 2

The functions $f(t)$ and $-f(-t)$ are same. Therefore, the function shown in Figure P15.7 (a) in the textbook obeys **odd symmetry**.

Step 3 of 4

(b)

Refer to Figure P15.7 (b) in the textbook.

The time period of the function is, $T_0 = 4$.

Draw the function $f\left(t-\frac{T_0}{2}\right)$.

Figure 3

Step 4 of 4

Draw the function $-f\left(t-\frac{T_0}{2}\right)$.

Figure 4

The functions $f(t)$ and $-f\left(t-\frac{T_0}{2}\right)$ are same. Therefore, the function shown in Figure P15.7 (b) in the textbook obeys **half-wave symmetry**.

Step 1 of 3

Refer to Figure P15.9 in the textbook for a waveform.

The waveform has a period, $T_0 = 4$.

Find the value of angular frequency, ω_0 .

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0}\\ &= \frac{2\pi}{4}\\ &= \frac{\pi}{2}\end{aligned}$$

Clearly the waveform possesses half-wave symmetry, because the inverted version of each half cycle is same as the adjacent half-cycle.

The trigonometric Fourier series of the function is,

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

Consider the following since the waveform exhibits half-wave symmetry:

$$\left.\begin{aligned}a_0 &= 0\\ a_n &= 0\\ b_n &= 0\end{aligned}\right\} \quad \text{for } n \text{ even}$$

$$\left.\begin{aligned}a_n &= \frac{4}{T_0}\int_0^{\frac{T_0}{2}} v(t)\cos n\omega_0 t dt\\ b_n &= \frac{4}{T_0}\int_0^{\frac{T_0}{2}} v(t)\sin n\omega_0 t dt\end{aligned}\right\} \quad \text{for } n \text{ odd}$$

Step 2 of 3

Find the Fourier coefficient a_n .

$$\begin{aligned}a_n &= \frac{4}{T_0}\left[\int_0^{\frac{T_0}{2}} v(t)\cos n\omega_0 t dt\right]\\ &= \frac{4}{4}\left[\int_0^1 (1)\cos n\omega_0 t dt + \int_1^2 (2)\cos n\omega_0 t dt\right]\\ &= \left[\left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_0^1 + 2\left(\left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_1^2\right)\right]\end{aligned}$$

Substitute $\frac{\pi}{2}$ for ω_0 in the equation.

$$\begin{aligned}a_n &= \frac{\sin n\frac{\pi}{2}}{n\frac{\pi}{2}} + 2\frac{\sin n\pi}{n\frac{\pi}{2}} - 2\frac{\sin n\frac{\pi}{2}}{n\frac{\pi}{2}}\\ &= \frac{2}{n\pi}\left[2\sin n\pi - \sin n\frac{\pi}{2}\right]\\ &= \frac{-2}{n\pi}\sin\left(\frac{n\pi}{2}\right) \left(\text{since } \sin n\pi = 0\right)\end{aligned}$$

Step 3 of 3

Find the Fourier coefficient, b_n .

$$\begin{aligned}b_n &= \frac{4}{T_0}\left[\int_0^{\frac{T_0}{2}} v(t)\sin n\omega_0 t\, dt\right]\\ &= \frac{4}{4}\left[\int_0^1 (1)\sin n\omega_0 t dt + \int_1^2 (2)\sin n\omega_0 t\right]\\ &= -\left.\frac{\cos n\omega_0 t}{n\omega_0}\right|_0^1 - 2\left.\frac{\cos n\omega_0 t}{n\omega_0}\right|_1^2\end{aligned}$$

Substitute $\frac{\pi}{2}$ for ω_0 in the equation.

$$\begin{aligned}b_n &= \frac{-\cos n\frac{\pi}{2}}{n\frac{\pi}{2}} + \frac{1}{n\frac{\pi}{2}} - \frac{2\cos n\pi}{n\frac{\pi}{2}} + \frac{2\cos n\frac{\pi}{2}}{n\frac{\pi}{2}}\\ &= \frac{2}{n\pi}\left[1 - 2\cos n\pi\right]\end{aligned}$$

Therefore, the trigonometric Fourier series of the function is,

$$\boxed{v(t) = \sum_{\substack{n=1\\ n \text{ odd}}}^{\infty}\left[\frac{-2}{n\pi}\sin\left(\frac{n\pi}{2}\right)\cos\frac{n\pi}{2}t + \frac{2}{n\pi}\left[1 - 2\cos n\pi\right]\sin\frac{n\pi}{2}t\right]}$$

Step 1 of 2

15.011 E

Refer to Figure E15.11 in the textbook.

The value of $D_n\angle\theta_n$ at each point of frequency in the discrete line spectrum is as follows:

At zero frequency is,

$$\begin{aligned} D_0\angle\theta_0 &= 0.25\angle 0^\circ \\ &= 0.25\cos\left(2\pi(0)t + 0^\circ\right) \\ &= 0.25 \end{aligned}$$

At 20Hz frequency is,

$$\begin{aligned} D_1\angle\theta_1 &= 1.35\angle -135^\circ \\ &= 1.35\cos\left(2\pi(20)t - 135^\circ\right) \\ &= 1.35\cos\left(40\pi t - 135^\circ\right) \end{aligned}$$

At 40Hz frequency is,

$$\begin{aligned} D_2\angle\theta_2 &= 1\angle -90^\circ \\ &= \cos\left(2\pi(40)t - 90^\circ\right) \\ &= \cos\left(80\pi t - 90^\circ\right) \end{aligned}$$

Step 2 of 2

At 60Hz frequency is,

$$\begin{aligned} D_3\angle\theta_3 &= 0.5\angle -45^\circ \\ &= 0.5\cos\left(2\pi(60)t - 45^\circ\right) \\ &= 0.5\cos\left(120\pi t - 45^\circ\right) \end{aligned}$$

At 80Hz frequency is,

$$\begin{aligned} D_4\angle\theta_4 &= 0.35\angle -90^\circ \\ &= 0.35\cos\left(2\pi(80)t - 90^\circ\right) \\ &= 0.35\cos\left(160\pi t - 90^\circ\right) \end{aligned}$$

Therefore, the periodic function, $f(t)$, can be expressed as,

$$\boxed{\begin{aligned} &0.25 + 1.35\cos\left(40\pi t - 135^\circ\right) + \cos\left(80\pi t - 90^\circ\right) + \\ &0.5\cos\left(120\pi t - 45^\circ\right) + 0.35\cos\left(160\pi t - 90^\circ\right) \end{aligned}}$$

Step 1 of 2

15.011 P

Consider the waveform shown in Figure P15.5 (a) in the textbook.

Calculate Fourier coefficients of the waveform.

$$\begin{aligned} c_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_1(t)\,dt \\ &= \frac{1}{4}\int_0^1 2dt \\ &= \frac{1}{4}[2t]_0^1 \\ &= \frac{1}{2} \end{aligned}$$

Now calculate c_n as shown below

$$\begin{aligned} c_n &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_1(t)e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{4}\int_0^1 2e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{2}\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Bigg|_0^1 \end{aligned}$$

Substitute $\frac{\pi}{2}$ for ω_0 in the equation.

$$\begin{aligned} c_n &= \frac{1}{2}\left[\frac{e^{\frac{-jn\pi}{2}}}{-\frac{jn\pi}{2}} - \frac{1}{\frac{-jn\pi}{2}}\right] \\ &= \frac{1}{jn\pi}\left[1-e^{\frac{-jn\pi}{2}}\right] \end{aligned}$$

Therefore the exponential Fourier series for Figure P15.5 (a) is,

$$v_1(t) = \frac{1}{2} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{1}{jn\pi}\left[1-e^{\frac{-jn\pi}{2}}\right] \quad \text{..... (1)}$$

Step 2 of 2

Consider the waveform shown in textbook Figure P15.5 (b). Calculate the Fourier coefficients as shown below.

$$\begin{aligned} c_0 &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_2(t)\,dt \\ &= \frac{1}{4}\int_1^2 1dt \\ &= \frac{1}{4} \end{aligned}$$

Now calculate c_n as shown below

$$\begin{aligned} c_n &= \frac{1}{T_0}\int_{t_1}^{t_1+T_0} v_2(t)e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{4}\int_1^2 e^{-jn\omega_0 t}\,dt \\ &= \frac{1}{4}\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\Bigg|_1^2 \end{aligned}$$

Substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{2}$ in the above equation. Therefore

$$\begin{aligned} c_n &= \frac{1}{4}\left[\frac{e^{-jn\pi}}{-jn\pi/2} - \frac{e^{\frac{-jn\pi}{2}}}{-jn\pi/2}\right] \\ &= \frac{1}{2jn\pi}\left[e^{\frac{-jn\pi}{2}} - e^{-jn\pi}\right] \end{aligned}$$

Therefore the exponential Fourier series for Figure P15.5 (b) is

$$v_2(t) = \frac{1}{4} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{1}{2jn\pi}\left[e^{\frac{-jn\pi}{2}} - e^{-jn\pi}\right] \quad \text{..... (2)}$$

Now add the exponential Fourier series of the two waveforms. Hence the result $v(t)$ is

$$\boxed{\frac{3}{4} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty}\left[\frac{1}{2jn\pi}\left(e^{\frac{-jn\pi}{2}} - e^{-jn\pi}\right) + \frac{1}{jn\pi}\left(1-e^{\frac{-jn\pi}{2}}\right)\right]}.$$

Step 1 of 5

15.012 E

Refer to Figure E15.12 in the textbook.

The input voltage, $v_S(t) = \frac{20}{\pi} + \sum_{n=1}^{\infty} \frac{-40}{\pi(4n^2-1)} \cos 2nt$ V

Determine the expression for the steady-state current $i(t)$.

Note that when a linear network is forced with a non-sinusoidal periodic signal, the voltages and currents throughout the network are in the following form:

$$v(t) = V_{DC} + \sum_{n=1}^{\infty} V_n \cos(n\omega_0 t - \theta_{v_n})$$

$$i(t) = I_{DC} + \sum_{n=1}^{\infty} I_n \cos(n\omega_0 t - \theta_{i_n})$$

Calculate the impedance of the network.

Redraw the circuit to calculate the impedance of the network.

Figure 1

Step 2 of 5

Clearly, from Figure 1, the impedance of the network is,

$$\begin{aligned} Z &= 1\,\Omega + \left(2 \parallel \frac{1}{0.5j\omega}\right) \\ &= 1\,\Omega + \left(\frac{(2)\left(\frac{1}{0.5j\omega}\right)}{2 + \frac{1}{0.5j\omega}}\right) \\ &= 1\,\Omega + \frac{2}{j\omega + 1}\,\Omega \\ &= \frac{j\omega + 3}{j\omega + 1}\,\Omega \end{aligned}$$

Hence, the impedance of the network is,

$$Z = \frac{j\omega + 3}{j\omega + 1}\,\Omega$$

Step 3 of 5

Calculate the value of I_{DC}.

$$I_{DC} = \frac{V_{DC}}{Z_{DC}}$$

Here, $Z_{DC} = Z|_{\omega=0}$.

Substitute $\omega = 0$ in the expression of Z.

$$\begin{aligned} Z_{DC} &= \left(\frac{j\omega + 3}{j\omega + 1}\,\Omega\right)\Bigg|_{\omega=0} \\ &= \left(\frac{j(0) + 3}{j(0) + 1}\,\Omega\right)\Bigg|_{\omega=0} \\ &= 3\,\Omega \end{aligned}$$

Compare the expression for $v(t)$ with the expression for $v_S(t)$.

$$V_{DC} = \frac{20}{\pi}\text{ V}$$

Substitute $\frac{20}{\pi}$ V for V_{DC} and $3\,\Omega$ for Z_{DC} in the expression of I_{DC}.

$$\begin{aligned} I_{DC} &= \frac{\frac{20}{\pi}\text{ V}}{3\,\Omega} \\ &= \frac{20}{3\pi}\text{ A} \end{aligned}$$

Step 4 of 5

Convert the impedance Z into phasor form.

$$\mathbf{Z} = \left|\frac{j\omega + 3}{j\omega + 1}\right| \angle\left[\tan^{-1}\left(\frac{\omega}{3}\right) - \tan^{-1}\left(\frac{\omega}{1}\right)\right]$$

Compare the expression for $v(t)$ with the expression for $v_S(t)$.

$$\omega = 2$$

Hence,

$$\begin{aligned} \mathbf{Z} &= \left|\frac{2j + 3}{2j + 1}\right| \angle\left[\tan^{-1}\left(\frac{2}{3}\right) - \tan^{-1}\left(\frac{2}{1}\right)\right] \\ &= \frac{\sqrt{13}}{\sqrt{5}} \angle[33.69° - 63.43°] \\ &= 1.61\angle -29.74° \end{aligned}$$

Calculate the values of I_n and θ_{i_n}.

$$I_n \cos(n\omega_0 t - \theta_{i_n}) = \frac{V_n \cos(n\omega_0 t - \theta_{v_n})}{\mathbf{Z}}$$

Compare the expression for $v(t)$ with the expression for $v_S(t)$.

$$V_n \cos(n\omega_0 t - \theta_{v_n}) = \frac{-40}{\pi(4n^2 - 1)} \cos(2nt)$$

Hence,

$$\begin{aligned} I_n \cos(n\omega_0 t - \theta_{i_n}) &= \frac{-40}{\pi(4n^2 - 1)} \cos(2nt) \\ &= \frac{-40}{\pi(4n^2 - 1)(1.61\angle -29.74°)} \cos(2nt) \\ &= \frac{-40}{\pi(4n^2 - 1)} \frac{1}{(1.61)} \cos(2nt - 29.74°) \\ &= \frac{-40}{\pi(4n^2 - 1)} \frac{1}{A_n} \cos(2nt - \theta_{i_n}) \end{aligned}$$

Therefore,

$$I_n = \frac{-40}{\pi(4n^2 - 1)} \frac{1}{A_n}, \text{ where } A_n = 1.61$$

$$\theta_{i_n} = 29.74°$$

Step 5 of 5

Substitute $\frac{20}{3\pi}$ A for I_{DC}, $\frac{-40}{\pi(4n^2 - 1)} \frac{1}{(1.61)}$ for I_n, $29.74°$ for θ_{i_n}, and $\omega_0 = 2$ in the expression for $i(t)$.

$$\begin{aligned} i(t) &= I_{DC} + \sum_{n=1}^{\infty} I_n \cos(n\omega_0 t - \theta_{i_n}) \\ &= \frac{20}{3\pi}\text{ A} + \sum_{n=1}^{\infty} \frac{-40}{\pi(4n^2 - 1)} \frac{1}{(1.61)} \cos(2nt - 29.74°)\text{ A} \\ &= 2.12 + \sum_{n=1}^{\infty} \frac{-40}{\pi(4n^2 - 1)} \frac{1}{(1.61)} \cos(2nt - 29.74°)\text{ A} \end{aligned}$$

Thus, the expression for the steady state current $i(t)$ is,

$$\boxed{i(t) = 2.12 + \sum_{n=1}^{\infty} \frac{-40}{\pi(4n^2 - 1)} \frac{1}{(1.61)} \cos(2nt - 29.74°)\text{ A}}.$$

Step 1 of 1

15.012 P

For a given network, the voltage and current expressions are given by

$$v(t) = 64 + 36\cos(377t + 60°) - 24\cos(754t + 102°) \text{ V}$$
$$i(t) = 1.8\cos(377t + 45°) + 1.2\cos(754t + 100°) \text{ A}$$

Now calculate the average power

$$\begin{aligned} P_{ave} &= v(t)i(t) \\ &= (64)(0) + \frac{(36)(1.8)}{2}\cos(60° - 45°) - \frac{(24)(1.2)}{2}\cos(102° - 100°) \\ &= 32.4\cos(15°) - 14.4\cos(2°) \\ &= 16.9 \text{ W} \end{aligned}$$

Therefore the average power is given by $\boxed{P_{ave} = 16.9 \text{ W}}$.

Step 1 of 4

15.013 P

Refer to the Figure P15.13 in the text book.

Determine the expression of wave form in the interval $0 < t < 1$.

Determine the equation of line between the points $(0,0)$ and $(1,2)$.

$$v(t) - 0 = \left(\frac{2-0}{1-0}\right)(t-0)$$
$$v(t) = 2t$$

The time period of the signal is, $T = 1$

Determine the value of fundamental frequency.

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T}\\ &= \frac{2\pi}{1}\\ &= 2\pi\end{aligned}$$

Determine the value of Fourier coefficient a_0.

$$\begin{aligned}a_0 &= \frac{1}{T_0}\int_0^{T_0} f(t)\,dt\\ &= \frac{1}{1}\int_0^1 f(t)\,dt\\ &= \frac{1}{1}\left[\int_0^1 (2t)\,dt\right]\\ &= 2\left[\frac{t^2}{2}\right]_0^1\end{aligned}$$
$$= 2\left[\frac{1}{2} - 0\right]$$
$$= 1$$

Step 2 of 4

Determine the value of Fourier coefficient a_n.

$$\begin{aligned}a_n &= \frac{2}{T_0}\int_0^{T_0} f(t)\cos(n\omega_0 t)\,dt\\ &= \frac{2}{1}\int_0^{2\pi} f(t)\cos(n(2\pi)t)\,dt\\ &= 2\left[\int_0^1 (2t)\cos(n(2\pi)t)\,dt\right]\\ &= 4\left[\int_0^1 t\cos(2\pi nt)\,dt\right]\end{aligned}$$
$$= 4\left[t\frac{\sin(2\pi nt)}{2\pi n} - \int_0^1 (1)\left(\frac{\sin(2\pi nt)}{2\pi n}\right)dt\right]$$
$$= 4\left[t\frac{\sin(2\pi nt)}{2\pi n} + \left(\frac{\cos(2\pi nt)}{(2\pi n)^2}\right)\right]_0^1$$
$$= 4\left[\frac{\sin(2\pi n)}{2\pi n} + \left(\frac{\cos(2\pi n)}{(2\pi n)^2}\right)\right] - \left[0 + \left(\frac{\cos(0)}{(2\pi n)^2}\right)\right]$$
$$= 4\left[\frac{2\pi n\sin(2\pi n) + \cos(2\pi n) - 1}{(2\pi n)^2}\right]$$
$$= 4\left[\frac{2\pi n(0) + (-1)^{2n} - 1}{(2\pi n)^2}\right]$$
$$= 4\left[\frac{0+1-1}{(2\pi n)^2}\right]$$
$$= 0$$

Determine the value of Fourier coefficient b_n.

$$\begin{aligned}b_n &= \frac{2}{T_0}\int_0^{T_0} f(t)\sin(n\omega_0 t)\,dt\\ &= \frac{2}{1}\int_0^{2\pi} f(t)\sin(n(2\pi)t)\,dt\\ &= 2\left[\int_0^1 (2t)\sin(n(2\pi)t)\,dt\right]\\ &= 4\left[\int_0^1 t\sin(2\pi nt)\,dt\right]\end{aligned}$$
$$= 4\left[-t\frac{\cos(2\pi nt)}{2\pi n} - \int_0^1 (1)\left(-\frac{\cos(2\pi nt)}{2\pi n}\right)dt\right]$$
$$= 4\left[-(t)\frac{\cos(2\pi nt)}{2\pi n} + \left(\frac{\sin(2\pi nt)}{(2\pi n)^2}\right)\right]_0^1$$
$$= 4\left[-\frac{\cos(2\pi n)}{2\pi n} + \left(\frac{\sin(2\pi n)}{(2\pi n)^2}\right)\right] - \left[-\frac{0}{2\pi n} + \left(\frac{\sin(0)}{(2\pi n)^2}\right)\right]$$
$$= 4\left[\frac{-2\pi n\cos(2\pi n) + \sin(2\pi n)}{(2\pi n)^2}\right]$$

Step 3 of 4

Further simplification yields,

$$\begin{aligned}b_n &= 4\left[\frac{-2\pi n(-1)^{2n} + 0}{(2\pi n)^2}\right]\\ &= 2\frac{(-1)^{2n}(-1)^1}{\pi n}\\ &= \frac{2(1)(-1)}{\pi n}\\ &= -\frac{2}{\pi n}\end{aligned}$$

Step 4 of 4

Write the expression of trigonometric Fourier series.

$$\begin{aligned}v(t) &= a_0 + \sum_{n=1}^{\infty}\left[a_n\cos(n\omega_0 t) + b_n\sin(n\omega_0 t)\right]\\ &= 1 + \sum_{n=1}^{\infty}\left[(0)\cos(n\omega_0 t) + \left(\frac{-2}{\pi n}\right)\sin(n(2\pi)t)\right]\\ &= 1 - \left(\frac{2}{\pi}\right)\sum_{n=1}^{\infty}\left[\left(\frac{1}{n}\right)\sin(2\pi nt)\right]\end{aligned}$$

Therefore, the trigonometric Fourier series is $\boxed{f(t) = 1 - \left(\frac{2}{\pi}\right)\sum_{n=1}^{\infty}\left[\left(\frac{1}{n}\right)\sin(2\pi nt)\right]}$.

Hence, the expression is proved.

15.014
E

Step 1 of 3

Refer to Figure E15.14 in the textbook.

The input voltage is,

$$v(t)=\frac{30}{\pi}+15\sin 10t+\sum_{\substack{n=1\\ n\text{even}}}^{\infty}\frac{60}{\pi\left(1-n^2\right)}\cos 10nt\ \text{V}$$

The input signal expression can be expanded as,

$$\begin{aligned}v(t)&=\frac{30}{\pi}+15\sin 10t+\frac{60}{\pi(-3)}\cos 20t+\frac{60}{\pi(-15)}\cos 40t+\ldots\\&=\frac{30}{\pi}+15\sin 10t-\frac{20}{\pi}\cos 20t-\frac{4}{\pi}\cos 40t+\ldots\end{aligned}$$

The equivalent resistance of the network is,

$$\begin{aligned}R&=3+\left\{0.1j\omega\|\left(2+\frac{10}{j\omega}\right)\right\}\\&=3+\left\{\frac{(0.1j\omega)\left(2+\frac{10}{j\omega}\right)}{0.1j\omega+2+\frac{10}{j\omega}}\right\}\\&=3+\left\{\frac{-0.2\omega^2+j\omega}{-0.1\omega^2+2j\omega+10}\right\}\\&=\frac{-0.3\omega^2+6j\omega+30-0.2\omega^2+j\omega}{-0.1\omega^2+2j\omega+10}\\&=\frac{-0.5\omega^2+7j\omega+30}{-0.1\omega^2+2j\omega+10}\end{aligned}$$

Step 2 of 3

The Fourier transform of the current, $i(t)$ is expressed as,

$$\mathbf{I}=\frac{\mathbf{V}}{R}$$

Substitute the values of $\mathbf{V}$ and R in the equation of current.

$$\mathbf{I}=\frac{\mathbf{V}\left(-0.1\omega^2+2j\omega+10\right)}{\left(-0.5\omega^2+7j\omega+30\right)}\quad\ldots\ldots(1)$$

The components of $i(t)$ due to the frequency components present in the input voltage are as follows:

There is a dc component present in the voltage signal. At zero frequency that is, at $\omega=0$, the value of current is,

$$\begin{aligned}\mathbf{I}\big|_{\omega=0}&=\frac{\mathbf{V}\big|_{\omega=0}(10)}{31}\\&=\frac{\frac{30}{\pi}(10)}{30}\\&=3.18\text{A}\end{aligned}$$

Step 3 of 3

Substitute 10 in place of ω in equation (1).

$$\begin{aligned}\mathbf{I}\big|_{\omega=10}&=\frac{\mathbf{V}\big|_{\omega=10}(-10+20j+10)}{-50+70j+30}\\&=\frac{15\angle 90^\circ(20\angle 90^\circ)}{72.8\angle 106^\circ}\\&=4.12\angle 106^\circ\text{A}\\&=4.12\cos(10t+106^\circ)\text{A}\end{aligned}$$

Substitute 20 in place of ω in equation (1).

$$\begin{aligned}\mathbf{I}\big|_{\omega=20}&=\frac{\mathbf{V}\big|_{\omega=20}(-40+40j+10)}{-200+140j+30}\\&=\frac{-6.36\angle 0^\circ(50\angle 126.86^\circ)}{220.2\angle 140.5^\circ}\\&=1.45\angle 166^\circ\text{A}\\&=1.45\cos(20t+116^\circ)\end{aligned}$$

Hence, the first three terms of the steady state current $i(t)$ are,

$$\boxed{3.18+4.12\cos(10t+106^\circ)+1.45\cos(20t+166^\circ)\text{A}}.$$

Step 1 of 4

Refer to the Figure P15.14 in the text book.

The time period of the signal is, $T_0 = \pi$

Determine the value of fundamental frequency.

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0}\\ &= \frac{2\pi}{\pi}\\ &= 2\end{aligned}$$

Determine the value of Fourier coefficient a_0.

$$\begin{aligned}c_n &= \frac{1}{T_0}\int_0^{T_0} f(t)e^{-jn\omega_0 t}dt\\ &= \frac{1}{\pi}\int_0^{\pi} f(t)e^{-jn\omega_0 t}dt\\ &= \frac{1}{\pi}\left[\int_0^{\pi} A|\sin t|e^{-jn\omega_0 t}dt\right]\\ &= \frac{A}{\pi}\left[\int_0^{\pi}(\sin t)e^{-jn(2)t}dt\right]\end{aligned}$$

$$\begin{aligned}&= \frac{A}{\pi}\left[\int_0^{\pi}(\sin t)e^{-j2nt}dt\right]\\ &= \frac{A}{\pi}\int_0^{\pi}(\sin t)e^{-j(2n)t}dt\\ &= \frac{A}{\pi}\int_0^{\pi}(\sin t)e^{-j(2n)t}dt\\ &= \frac{A}{\pi}\int_0^{\pi}\left(\frac{e^{jt}-e^{-jt}}{2j}\right)e^{-j(2n)t}dt\\ &= \frac{A}{\pi}\frac{1}{2j}\int_0^{\pi}\left(e^{-j(2n-1)t}+e^{-j(2n+1)t}\right)dt\end{aligned}$$

Step 2 of 4

Further simplification yields,

$$\begin{aligned}c_n &= \frac{A}{\pi}\frac{1}{2j}\left[\frac{e^{-j(2n-1)t}}{-j(2n-1)}-\frac{e^{-j(2n+1)t}}{-j(2n+1)}\right]_0^{\pi}\\ &= \frac{A}{\pi}\frac{1}{2j}\left[\left[\frac{e^{-j(2n-1)\pi}}{-j(2n-1)}-\frac{e^{-j(2n+1)\pi}}{-j(2n+1)}\right]-\left[\frac{e^{0}}{-j(2n-1)}-\frac{e^{0}}{-j(2n+1)}\right]\right]\\ &= \frac{A}{\pi}\frac{1}{2j}\left[\left[\frac{e^{-j(2n-1)\pi}}{-j(2n-1)}-\frac{e^{-j(2n+1)\pi}}{-j(2n+1)}\right]-\left[\frac{1}{-j(2n-1)}-\frac{1}{-j(2n+1)}\right]\right]\\ &= \frac{A}{\pi}\frac{1}{2j}\left[\frac{e^{-j(2n-1)\pi}-1}{-j(2n-1)}-\frac{e^{-j(2n+1)\pi}-1}{-j(2n+1)}\right]\end{aligned}$$

$$\begin{aligned}c_n &= \frac{A}{\pi}\frac{1}{2j}\left[\frac{1-e^{-j(2n-1)\pi}}{j(2n-1)}-\frac{1-e^{-j(2n+1)\pi}}{j(2n+1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{1-e^{-j(2n-1)\pi}}{(2n-1)}-\frac{1-e^{-j(2n+1)\pi}}{(2n+1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{\left(1-e^{-j(2n-1)\pi}\right)(2n+1)-\left(1-e^{-j(2n+1)\pi}\right)(2n-1)}{(2n-1)(2n+1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{\left(1-e^{-j2n\pi}e^{+j\pi}\right)(2n+1)-\left(1-e^{-j2n\pi}e^{-j\pi}\right)(2n-1)}{(4n^2-1)}\right]\end{aligned}$$

Step 3 of 4

Further simplification yields,

$$\begin{aligned}c_n &= -\frac{A}{2\pi}\left[\frac{\left(1+e^{-j2n\pi}\right)(2n+1)-\left(1+e^{-j2n\pi}\right)(2n-1)}{(4n^2-1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{\left(1+e^{-j2n\pi}\right)(2n+1-2n+1)}{(4n^2-1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{2\left(1+e^{-j2n\pi}\right)}{(4n^2-1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{2\left(1+\left(\cos(2n\pi)-j\sin(2n\pi)\right)\right)}{(4n^2-1)}\right]\end{aligned}$$

$$\begin{aligned}c_n &= -\frac{A}{2\pi}\left[\frac{2\left(1+\left((-1)^{2n}-j(0)\right)\right)}{(4n^2-1)}\right]\\ &= -\frac{A}{2\pi}\left[\frac{2(1+1-0)}{(4n^2-1)}\right]\\ &= -\left[\frac{2A}{(4n^2-1)\pi}\right]\\ &= \frac{2A}{(1-4n^2)\pi}\end{aligned}$$

Step 4 of 4

Write the exponential Fourier series.

$$\begin{aligned}v(t) &= \sum_{n=-\infty}^{\infty} c_n e^{jn\omega_0 t}\\ &= \sum_{n=-\infty}^{\infty}\left[\frac{2A}{(1-4n^2)\pi}\right]e^{jn\omega_0 t}\end{aligned}$$

Therefore, the exponential Fourier series is, $\boxed{v(t) = \sum_{n=-\infty}^{\infty}\left[\frac{2A}{(1-4n^2)\pi}\right]e^{jn\omega_0 t}}$.

Step 1 of 1

15.015

E

The voltage, $v(t)$ is,

$$v(t) = 20 + 5\cos 377t + 3.5\cos(754t - 20°)\,\text{V}$$

The current, $i(t)$ is,

$$i(t) = 1.2\cos(377t - 30°) + 0.8\cos(754t + 45°)\,\text{A}$$

The formula for the average power is,

$$P = V_{DC}I_{DC} + \sum_{N=1}^{\infty} \frac{V_n I_n}{2}\cos\left(\theta_{v_n} - \theta_{i_n}\right)$$

Here, V_{DC} and I_{DC} are the DC components of the voltage and current and n represents the number of frequency components and V_n and I_n are the amplitude at those frequencies with corresponding phases θ_{v_n} and θ_{i_n} of voltage and current respectively.

$$\begin{aligned} P &= (20)(0) + \frac{(5)(1.2)}{2}\cos(0 - 30°) + \frac{(3.5)(0.8)}{2}\cos(-20° - 45°) \\ &= 2.598 + 0.591 \\ &= 3.189\,\text{W} \end{aligned}$$

Hence, the average power absorbed by the network is, $\boxed{3.189\ \text{W}}$.

15.015

P

We don't have the solution to this problem yet.

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Step 1 of 1

15.016

E

The given function is $f(t) = \sin \omega_0 t$. We know that $\sin \omega_0 t = \dfrac{e^{j\omega_0 t} - e^{-j\omega_0 t}}{2j}$.

Now calculate the Fourier transform of the given function as shown below

$$\begin{aligned} F(\omega) &= \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt \\ &= \int_{-\infty}^{\infty} \left(\frac{e^{j\omega_0 t} - e^{-j\omega_0 t}}{2j} \right) e^{-j\omega t} dt \\ &= \frac{1}{2j} \left[\int_{-\infty}^{\infty} e^{-j(\omega-\omega_0)t} dt - \int_{-\infty}^{\infty} e^{-j(\omega+\omega_0)t} dt \right] \\ &= j\pi \left[\delta(\omega+\omega_0) - \delta(\omega-\omega_0) \right] \end{aligned}$$

Therefore Fourier transform of $\sin \omega_0 t$ is $\boxed{j\pi \left[\delta(\omega+\omega_0) - \delta(\omega-\omega_0) \right]}$.

Step 1 of 1

15.016

P

Consider the textbook Figure E15.17. The input signal is $v_i(t) = e^{-t}u(t)$ V and the impulse response is $h(t) = e^{-2t}u(t)$. It is given that all initial conditions are zero. The output function $v_0(t)$ is given by

$$v_0(t) = v_i(t) * h(t) \text{ or}$$
$$\mathrm{v}(\omega) = \mathrm{v}_i(\omega)\mathrm{H}(\omega)$$

We know that Fourier transform of $e^{-at}u(t)$ is $\frac{1}{(a+j\omega)}$. Therefore we have

$$\begin{aligned}
\mathrm{v}_0(\omega) &= \left(\frac{1}{1+j\omega}\right)\left(\frac{1}{2+j\omega}\right) \\
&= \frac{1}{(2-1)(1+j\omega)} - \frac{1}{(2-1)(2+j\omega)} \\
v_0(t) &= F^{-1}\left[\mathrm{v}_0(\omega)\right] \\
&= \frac{1}{(2-1)}\left[e^{-t} - e^{-2t}\right]u(t) \text{ V}
\end{aligned}$$

Therefore output for the given Figure is $\boxed{v_0(t) = \left(e^{-t} - e^{-2t}\right)u(t) \text{ V}}$.

Step 1 of 2

15.017 P

Refer to the Figure P15.17 in the text book.

The time period of the signal is, $T = 2\pi$

Determine the value of fundamental frequency.

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T}\\ &= \frac{2\pi}{2\pi}\\ &= 1\end{aligned}$$

Determine the value of Fourier coefficient a_0.

$$\begin{aligned}a_0 &= \frac{1}{T_0}\int_0^{T_0} f(t)\,dt\\ &= \frac{1}{2\pi}\int_0^{2\pi} f(t)\,dt\\ &= \frac{1}{2\pi}\left[\int_0^{\pi}(0)\,dt + \int_{\pi}^{2\pi}(1)\,dt\right]\\ &= \frac{1}{2\pi}\left[0 + [t]_{\pi}^{2\pi}\right]\\ &= \frac{1}{2\pi}[2\pi - \pi]\\ &= 0.5\end{aligned}$$

Step 2 of 2

Determine the value of Fourier coefficient a_n.

$$\begin{aligned}a_n &= \frac{2}{T_0}\int_0^{T_0} f(t)\cos(n\omega_0 t)\,dt\\ &= \frac{2}{2\pi}\int_0^{2\pi} f(t)\,dt\\ &= \frac{1}{\pi}\left[\int_0^{\pi}(0)\cos(n\omega_0 t)\,dt + \int_{\pi}^{2\pi}(1)\cos(n\omega_0 t)\,dt\right]\\ &= \frac{1}{\pi}\left[0 + \int_{\pi}^{2\pi}\cos(nt)\,dt\right]\\ &= \frac{1}{\pi}\left[\frac{\sin(nt)}{n}\right]_{\pi}^{2\pi}\\ &= \frac{1}{n\pi}[\sin(2\pi n) - \sin(\pi n)]\\ &= \frac{1}{n\pi}[0-0]\\ &= 0\end{aligned}$$

Determine the value of Fourier coefficient b_n.

$$\begin{aligned}b_n &= \frac{2}{T_0}\int_0^{T_0} f(t)\sin(n\omega_0 t)\,dt\\ &= \frac{2}{2\pi}\int_0^{2\pi} f(t)\sin(n\omega_0 t)\,dt\\ &= \frac{1}{\pi}\left[\int_0^{\pi}(0)\sin(n\omega_0 t)\,dt + \int_{\pi}^{2\pi}(1)\sin(n\omega_0 t)\,dt\right]\\ &= \frac{1}{\pi}\left[0 + \int_{\pi}^{2\pi}\sin(nt)\,dt\right]\\ &= -\frac{1}{\pi}\left[\frac{\cos(nt)}{n}\right]_{\pi}^{2\pi}\\ &= -\frac{1}{n\pi}[\cos(2\pi n) - \cos(\pi n)]\\ &= -\frac{1}{n\pi}[1-(-1)^n]\\ &= \frac{1}{n\pi}[(-1)^n - 1]\end{aligned}$$

Write the expression of trigonometric Fourier series.

$$\begin{aligned}f(t) &= a_0 + \sum_{n=1}^{\infty}[a_n\cos(n\omega_0 t) + b_n\sin(n\omega_0 t)]\\ &= 0.5 + \sum_{n=1}^{\infty}\left[(0)\cos(n\omega_0 t) + 0.5\left((-1)^n - 1\right)\sin(n(1)t)\right]\\ &= 0.5 + 0.5\sum_{n=1}^{\infty}[(-1)^n - 1]\sin(nt)\end{aligned}$$

Therefore, the trigonometric Fourier series is $\boxed{f(t) = 0.5 + 0.5\sum_{n=1}^{\infty}[(-1)^n - 1]\sin(nt)}$.

Step 1 of 2

15.018

E

The signal is $v_i(t) = e^{-2t}u(t)\ \text{V}$.

The total $1\ \Omega$ energy content of the signal in time domain is,

$$W_i = \int_0^\infty \left[v_i(t)\right]^2 dt$$

$$= \int_0^\infty \left(e^{-2t}\right)^2 dt$$

$$= \int_0^\infty e^{-4t} dt$$

$$= \left.\frac{e^{-4t}}{-4}\right|_0^\infty$$

$$= \frac{1}{4}$$

$$= 0.25\ \text{J}$$

Therefore the energy content of the signal in time domain is $\boxed{0.25\ \text{J}}$.

Step 2 of 2

The energy content of the signal in frequency domain is given by

$$W_0 = \frac{1}{2\pi}\int_{-\infty}^{\infty} \left|\text{V}_i(\omega)\right|^2 d\omega$$

We know that $\text{V}_i(\omega) = \frac{1}{(2+j\omega)}$. Therefore the energy content in frequency domain is

$$W_0 = \frac{1}{2\pi}\int_{-\infty}^{\infty} \left|\frac{1}{2+j\omega}\right|^2 d\omega$$

$$= (2)\frac{1}{2\pi}\int_0^\infty \frac{1}{4+\omega^2} d\omega$$

Substitute corresponding values and change the integration from 0 to $\frac{\pi}{2}$.

Angular frequency is,

$$\omega = 2\tan\theta$$

$$\frac{d\omega}{d\theta} = 2\sec^2\theta$$

$$d\omega = 2\sec^2\theta\, d\theta$$

Therefore the energy content is,

$$\omega_0 = \frac{1}{\pi}\int_0^{\pi/2} \frac{1}{4+4\tan^2\theta}\left(2\sec^2\theta\right) d\theta$$

$$= \frac{1}{2\pi}\int_0^{\pi/2} \frac{\sec^2\theta}{1+\tan^2\theta} d\theta$$

$$= \frac{1}{2\pi}\left[\left.\theta\right|_0^{\pi/2}\right]$$

$$= 0.25\ \text{J}$$

Therefore the energy content of the signal in frequency domain

$\boxed{0.25\ \text{J}}$.

Step 1 of 18

15.019 P

Refer to waveform shown in Figure P15.16 in the text book.

Write the Fourier series expression for a periodic waveform.

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos n\omega_o t + b_n \sin n\omega_o t\right) \quad \text{..... (1)}$$

Here,

a_0, a_n and b_n are Fourier series coefficients.

Step 2 of 18

Define the coefficients.

$$a_0 = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)dt \quad \text{..... (2)}$$

$$a_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\cos n\omega_o t dt \quad \text{..... (3)}$$

$$b_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\sin n\omega_o t dt \quad \text{..... (4)}$$

Step 3 of 18

With reference to wave form shown in Figure P15.16 the wave form is even symmetry since the shape of wave form over the interval $(-2 \le t \le 0)$ is time reversal of the wave form over the time interval $(0 \le t \le 2)$. Therefore the wave form is even symmetry with a time period of four units.

Step 4 of 18

To get the Fourier series for the wave form, at first, find out the Fourier series coefficients a_0, a_n and b_n. For this it is needed to express the wave form in mathematical form in order to calculate coefficients.

Express the waveforms in mathematical form for this utilize two point equations formula.

Write two points equation formula for the points (x_1, y_1) and (y_1, y_2).

$$(y - y_1)(x_2 - x_1) = (x - x_1)(y_2 - y_1) \quad \text{..... (5)}$$

Refer to waveform shown in Figure P15.16 and deduce wave form expression $v(t)$ for the time period $-2 \le t \le -1$ and the co-ordinates are $(-2,-1)$ and $(-1,-1)$.

Step 5 of 18

Substitute the co-ordinates $(-2,-1)$ and $(-1,-1)$ in equation (5) and deduce expression for $v(t)$ in the range of $-2 \le t \le 0$.

$$\left[v(t) - (-1)\right]\left[(-1) - (-2)\right] = \left[t - (-2)\right]\left[-1 - (-1)\right]$$
$$\left[v(t) + 1\right] = \left[t + 2\right]\left[0\right]$$

$$v(t) = -1 \text{ for } -2 \le t \le -1 \quad \text{..... (6)}$$

Step 6 of 18

Deduce wave form expression $v(t)$ for the time period $-1 \le t \le 0$ and the co-ordinates are $(-1,1)$ and $(0,0)$.

Substitute the co-ordinates $(-1,1)$ and $(0,0)$ in equation (5) and deduce expression for $v(t)$ in the range of $-1 \le t \le 0$.

$$\left[v(t) - 1\right]\left[0 - (-1)\right] = \left[t - (-1)\right]\left[0 - 1\right]$$
$$\left[v(t) - 1\right] = \left[t + 1\right]\left[-1\right]$$

$$v(t) = -t \text{ for } -1 \le t \le 0 \quad \text{.....(7)}$$

Step 7 of 18

Write the waveform expression over the time interval $-2 \le t \le 0$.

$$v(t) = \begin{cases} -1 & \text{for } -2 \le t \le -1 \\ -t & \text{for } -1 \le t \le 0 \end{cases} \quad \text{..... (8)}$$

Step 8 of 18

Similarly deduce wave form expression $v(t)$ for the time period $0 \le t \le 1$ and the co-ordinates are $(0,0)$ and $(1,1)$.

Substitute the co-ordinates $(0,0)$ and $(1,1)$ in equation (5) and deduce expression for $v(t)$ in the range of $0 \le t \le 1$

$$\left[v(t) - 0\right]\left[1 - 0\right] = \left[t - 0\right]\left[1 - 0\right]$$
$$\left[v(t)\right]\left[1\right] = \left[t\right]\left[1\right]$$

$$v(t) = -t \text{ for } 0 \le t \le 1 \quad \text{.....(9)}$$

Step 9 of 18

Deduce wave form expression $v(t)$ for the time period $1 \le t \le 2$ and the co-ordinates are $(1,-1)$ and $(2,-1)$.

Substitute the co-ordinates $(1,-1)$ and $(2,-1)$ in equation (5) and deduce expression for $v(t)$ in the range of $1 \le t \le 2$

$$\left[v(t) - (-1)\right]\left[2 - 1\right] = \left[t - 1\right]\left[-1 - (-1)\right]$$
$$\left[v(t) + 1\right]\left[1\right] = \left[t - 1\right]\left[0\right]$$

$$v(t) = -1 \text{ for } 1 \le t \le 2 \quad \text{.....(10)}$$

Step 10 of 18

Write the waveform expression over the time interval $-2 \le t \le 0$.

$$v(t) = \begin{cases} t & \text{for } 0 \le t \le 1 \\ -1 & \text{for } 1 \le t \le 2 \end{cases} \quad \text{..... (11)}$$

Step 11 of 18

Compare equation (8) and (11). By comparison it is noted that $v(t)_{-2 \le t \le 0} = v(-t)_{0 \le t \le 2}$ is the time reversal function over the interval $-2 \le t \le 2$.

$$v(t)_{-2 \le t \le 0} = v(-t)_{0 \le t \le 2}$$

Therefore, $v(t)$ is even symmetry.

Once the function is even symmetry the Fourier series coefficient b_n becomes zero.

$$b_n = 0 \quad \text{..... (12)}$$

Step 12 of 18

Calculate the Fourier series coefficient a_0.

Substitute $v(t)$ in place of $f(t)$ in equation (2) to calculate a_0.

$$\begin{aligned} a_0 &= \frac{1}{T}\int_{-2}^{2} v(t)dt \\ &= \left[\frac{1}{4}\left(\int_{-2}^{-1}(-1)dt + \int_{-1}^{0}(-t)dt + \int_{0}^{1}(t)dt + \int_{1}^{2}(-1)dt\right)\right] \\ &= \left[-\frac{1}{4}\left((t)_{-2}^{-1} + \left(\frac{t^2}{2}\right)_{-1}^{0}\right) + \frac{1}{4}\left(\left(\frac{t^2}{2}\right)_{0}^{1} - (t)_{1}^{2}\right)\right] \end{aligned}$$

Step 13 of 18

Simplify further.

$$\begin{aligned} a_0 &= \left[-\frac{1}{4}\left((1) + \left(-\frac{1}{2}\right)\right) + \frac{1}{4}\left(\left(\frac{1}{2}\right) - (1)\right)\right] \\ &= \left[\left(-\frac{1}{4}\right)\left(\frac{1}{2}\right) + \left(\frac{1}{4}\right)\left(-\frac{1}{2}\right)\right] \end{aligned}$$

$$a_0 = -\frac{1}{4} \quad \text{..... (13)}$$

Step 14 of 18

Calculate the Fourier series coefficient a_n.

Substitute $v(t)$ in place of $f(t)$ in equation (3) to calculate a_n.

$$a_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\cos n\omega_o t dt$$

$$a_n = \frac{2}{T}\left[\begin{aligned} &\left(\int_{-2}^{-1}(-1)\cos n\omega_o t dt\right) + \left(\int_{-1}^{0}(-t)\cos n\omega_o t dt\right) + \\ &\left(\int_{0}^{1}(t)\cos n\omega_o t dt\right) + \left(\int_{1}^{2}(-1)\cos n\omega_o t dt\right) \end{aligned}\right] \quad \text{..... (14)}$$

Step 15 of 18

As the wave form is even symmetry write the equation (14) into compact form in order to simplify easily.

$$\begin{aligned} a_n &= 2\cdot\frac{2}{T}\left[\left(\int_{0}^{1}(t)\cos n\omega_o t dt\right) + \left(\int_{1}^{2}(-1)\cos n\omega_o t dt\right)\right] \\ &= \left(\frac{4}{4}\right)\left[\left(\int_{0}^{1} t\cos n\omega_o t dt\right) - \left(\int_{1}^{2}\cos n\omega_o t dt\right)\right] \\ &= \left(t\frac{\sin n\omega_o t}{n\omega_o t} - \int_{0}^{1}(1)\left(\frac{\sin n\omega_o t}{n\omega_o t}\right)dt\right) - \left(\int_{1}^{2}\cos n\omega_o t dt\right) \\ &= \left[t\frac{\sin n\omega_o t}{n\omega_o} + \left(\frac{\cos n\omega_o t}{(n\omega_o)^2}\right)\right]_0^1 - \left[\frac{\sin n\omega_o t}{n\omega_o}\right]_1^2 \end{aligned}$$

Step 16 of 18

Simplify further.

$$\begin{aligned} a_n &= \left[(1)\frac{\sin n\omega_o(1)}{n\omega_o} + \left(\frac{\cos n\omega_o(1)}{(n\omega_o)^2}\right)\right] - \left[\frac{0 + \cos n\omega_o(0)}{(n\omega_o)^2}\right] - \\ &\quad \left[\frac{\sin n\omega_o(2)}{n\omega_o} - \frac{\sin n\omega_o(1)}{n\omega_o}\right] \\ &= \left[\frac{\sin n\omega_o}{n\omega_o} + \frac{\cos n\omega_o}{(n\omega_o)^2}\right] - \left[\frac{1}{(n\omega_o)^2}\right] - \left[\frac{\sin 2n\omega_o - \sin n\omega_o}{n\omega_o}\right] \\ &= \left[\frac{\sin n\left(\frac{2\pi}{4}\right)}{n\omega_o} + \frac{\cos n\left(\frac{2\pi}{4}\right)}{(n\omega_o)^2}\right] - \left[\frac{1}{(n\omega_o)^2}\right] - \\ &\quad \left[\frac{\sin 2n\left(\frac{2\pi}{4}\right) - \sin n\left(\frac{2\pi}{4}\right)}{n\omega_o}\right] \end{aligned}$$

Step 17 of 18

Perform further simplification.

$$\begin{aligned} a_n &= \left[\frac{\sin\left(\frac{n\pi}{2}\right)}{n\omega_o} + \frac{\cos\left(\frac{n\pi}{2}\right)}{(n\omega_o)^2}\right] - \left[\frac{1}{(n\omega_o)^2}\right] - \left[\frac{0 - \sin\left(\frac{n\pi}{2}\right)}{n\omega_o}\right] \\ &= \left[\frac{\cos\left(\frac{n\pi}{2}\right)}{(n\omega_o)^2}\right] - \left[\frac{1}{(n\omega_o)^2}\right] + \frac{2\sin\left(\frac{n\pi}{2}\right)}{n\omega_o} \\ &= \frac{(4)^2}{n(2\pi)^2}\left[\cos\left(\frac{n\pi}{2}\right) - 1\right] + \left(\frac{4}{n\pi}\right)\sin\left(\frac{n\pi}{2}\right) \end{aligned}$$

$$a_n = \frac{4}{(n\pi)^2}\left[\cos\left(\frac{n\pi}{2}\right) - 1\right] + \left[\frac{4}{n\pi}\sin\left(\frac{n\pi}{2}\right)\right] \quad \text{..... (15)}$$

Step 18 of 18

Therefore, the Fourier series coefficients are:

$$\boxed{\begin{aligned} a_0 &= -\frac{1}{4} \\ a_n &= \frac{4}{(n\pi)^2}\left[\cos\left(\frac{n\pi}{2}\right) - 1\right] + \left[\frac{4}{n\pi}\sin\left(\frac{n\pi}{2}\right)\right] \\ b_n &= 0 \end{aligned}}$$

Step 1 of 2

The given signal is $v_i(t) = e^{-2t}u(t)\ \text{V}$. The signal is represented in frequency domain as

$$\text{V}_i(\omega) = \frac{1}{2 + j\omega}.$$

The $1\ \Omega$ energy content of the signal in frequency domain is

$$W_i = (2)\frac{1}{2\pi}\int_0^\infty |\text{V}_i(\omega)|^2\, d\omega$$

Now take the limits 0 to $1\ \text{rad/s}$. Therefore

$$= \frac{1}{\pi}\int_0^\infty \frac{1}{4+\omega^2}\, d\omega$$

$$\text{W}_i = \frac{1}{\pi}\int_0^1 \frac{1}{4+\omega^2}\, d\omega \quad \ldots\ldots (1)$$

Angular frequency is,

$$\omega = 2\tan\theta$$

Consider $\theta = \tan^{-1}\left(\frac{\omega}{2}\right)$. Thus,

$$d\omega = 2\sec^2$$

Step 2 of 2

Substitute corresponding values in equation (1).

$$\text{W}_i = \frac{1}{\pi}\int_0^1 \frac{1}{4}\frac{2\sec^2\theta}{\left(1+\tan^2\theta\right)}\, d\theta$$

$$= \frac{1}{2\pi}\theta\Big|_0^1$$

$$= \frac{1}{2\pi}\tan^{-1}\left(\frac{1}{2}\right)$$

$$= 0.07\ \text{J}$$

Therefore the energy content of the given signal is $\boxed{0.07\ \text{J}}$.

Step 1 of 3

Consider the waveform in textbook Figure P15.8. The waveform has a period T_0. The trigonometric Fourier series of a function is given by

$$f(t)=a_0+\sum_{n=1}^{\infty}\left[a_n\cos n\omega_0 t+b_n\sin n\omega_0 t\right]$$

$$a_0=\frac{1}{T_0}\int_{t_1}^{t_1+T_0} f(t)\,dt$$

$$a_n=\frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\cos n\omega_0 t\,dt$$

$$b_n=\frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\sin n\omega_0 t\,dt$$

Now find the Fourier coefficient a_0 as shown below

$$\begin{aligned}
a_0&=\frac{1}{T_0}\left[\int_{-\frac{T_0}{2}}^{0}(0)\,dt+\int_{0}^{\frac{T_0}{4}}(1)\,dt+\int_{\frac{T_0}{4}}^{\frac{T_0}{2}}(2)\,dt\right]\\
&=\frac{1}{T_0}\left[(1)\left(\frac{T_0}{4}\right)+2\left(\frac{T_0}{2}-\frac{T_0}{4}\right)\right]\\
&=\frac{1}{T_0}\left[\frac{T_0}{4}+T_0-\frac{T_0}{2}\right]\\
&=\frac{3}{4}
\end{aligned}$$

Therefore $a_0=\frac{3}{4}$.

Step 2 of 3

Now find the Fourier coefficient a_n as shown below

$$\begin{aligned}
a_n&=\frac{2}{T_0}\left[\int_{-\frac{T_0}{2}}^{0}(0)\cos n\omega_0 t\,dt+\int_{0}^{\frac{T_0}{4}}(1)\cos n\omega_0 t\,dt+\int_{\frac{T_0}{4}}^{\frac{T_0}{2}}(2)\cos n\omega_0 t\,dt\right]\\
&=\frac{2}{T_0}\left[\left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_{0}^{\frac{T_0}{4}}+2\left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_{\frac{T_0}{4}}^{\frac{T_0}{2}}\right]
\end{aligned}$$

Now substitute $\omega_0=\frac{2\pi}{T_0}$ in the above equation. Therefore we have

$$\begin{aligned}
a_n&=\frac{2}{T_0}\left[\frac{1}{n\frac{2\pi}{T_0}}\sin n\left(\frac{2\pi}{T_0}\frac{T_0}{4}\right)+2\left(\frac{\sin n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n\frac{2\pi}{T_0}}-\frac{\sin n\left(\frac{2\pi}{T_0}\frac{T_0}{4}\right)}{n\frac{2\pi}{T_0}}\right)\right]\\
&=\frac{1}{n\pi}\left[\sin\frac{n\pi}{2}+2\sin n\pi-2\sin\frac{n\pi}{2}\right]\\
&=\frac{1}{n\pi}\left[-\sin\frac{n\pi}{2}\right]
\end{aligned}$$

Therefore $a_n=\frac{1}{n\pi}\left[-\sin\frac{n\pi}{2}\right]$.

Step 3 of 3

Now find the Fourier coefficient b_n as shown below

$$\begin{aligned}
b_n&=\frac{2}{T_0}\left[\int_{-\frac{T_0}{2}}^{0}(0)\sin n\omega_0 t\,dt+\int_{0}^{\frac{T_0}{4}}(1)\sin n\omega_0 t\,dt+\int_{\frac{T_0}{4}}^{\frac{T_0}{2}}(2)\sin n\omega_0 t\,dt\right]\\
&=\frac{2}{T_0}\left[\left.\frac{-\cos n\omega_0 t}{n\omega_0}\right|_{0}^{\frac{T_0}{4}}-2\left.\frac{\cos n\omega_0 t}{n\omega_0}\right|_{\frac{T_0}{4}}^{\frac{T_0}{2}}\right]
\end{aligned}$$

Now substitute $\omega_0=\frac{2\pi}{T_0}$ in the above equation. Therefore we have

$$\begin{aligned}
b_n&=\frac{2}{T_0}\left[\frac{-\cos n\left(\frac{2\pi}{T_0}\frac{T_0}{4}\right)}{n\left(\frac{2\pi}{T_0}\right)}+\frac{\cos n\left(\frac{2\pi}{T_0}(0)\right)}{n\left(\frac{2\pi}{T_0}\right)}-\frac{2\cos n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n\left(\frac{2\pi}{T_0}\right)}+\frac{2\cos n\left(\frac{2\pi}{T_0}\frac{T_0}{4}\right)}{n\left(\frac{2\pi}{T_0}\right)}\right]\\
&=\frac{1}{n\pi}\left[1-2\cos n\pi+2\cos\frac{n\pi}{2}\right]\\
&=\frac{1}{n\pi}\left[1+2\cos\frac{n\pi}{2}-2\cos n\pi\right]
\end{aligned}$$

Therefore $b_n=\frac{1}{n\pi}\left[1+2\cos\frac{n\pi}{2}-2\cos n\pi\right]$

Therefore the trigonometric Fourier series of the given function is

$$\boxed{f(t)=\frac{3}{4}+\sum_{n=1}^{\infty}\left[\left(\frac{-1}{n\pi}\right)\sin\frac{n\pi}{2}\cos n\omega_0 t+\frac{1}{n\pi}\left(1+2\cos\frac{n\pi}{2}-2\cos n\pi\right)\sin n\omega_0 t\right]}.$$

Step 1 of 4

15.021

Consider the waveform in textbook Figure P15.10. The function is defined as $f(t) = \frac{At}{T_0}$. The trigonometric Fourier series of a function is,

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

$$a_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} f(t)\,dt$$

$$a_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\cos n\omega_0 t\,dt$$

$$b_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\sin n\omega_0 t\,dt$$

Find the Fourier coefficient a_0.

$$\begin{aligned} a_0 &= \frac{1}{T_0}\int_0^{T_0}\frac{At}{T_0}dt \\ &= \frac{1}{T_0}\frac{A}{T_0}\frac{t^2}{2}\Big|_0^{T_0} \\ &= \frac{A}{T_0^2}\left[\frac{T_0^2}{2} - 0\right] \\ &= \frac{A}{2} \end{aligned}$$

Therefore $a_0 = \frac{A}{2}$.

Step 2 of 4

Now find the Fourier coefficient a_n.

$$\begin{aligned} a_n &= \frac{2}{T_0}\int_0^{T_0}\frac{At}{T_0}\cos n\omega_0 t\,dt \\ &= \frac{2A}{T_0^2}\int_0^{T_0} t\cos n\omega_0 t\,dt \\ &= \frac{2A}{T_0^2}\left[t\int_0^{T_0}\cos n\omega_0 t\,dt - \int_0^{T_0}(1)\int_0^{T_0}\cos n\omega_0 t\,dt\right] \\ &= \frac{2A}{T_0^2}\left[\frac{t\sin n\omega_0 t}{n\omega_0}\Big|_0^{T_0} + \frac{1}{n^2\omega_0^2}\cos n\omega_0 t\Big|_0^{T_0}\right] \end{aligned}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0}$ in the above equation. Therefore we have

$$a_n = \frac{2A}{T_0^2}\left[\frac{1}{n^2\frac{4\pi^2}{T_0^2}}\cos n2\pi - \frac{1}{n^2\frac{4\pi^2}{T_0^2}} + T_0\frac{\sin 2n\pi}{n\frac{2\pi}{T_0}}\right]$$

We know that $\cos 2n\pi = 1$ and $\sin 2n\pi = 0$. Therefore we have

$$a_n = 0$$

Step 3 of 4

Now find the Fourier coefficient b_n as shown below

$$\begin{aligned} b_n &= \frac{2}{T_0}\int_0^{T_0}\frac{At}{T_0}\sin n\omega_0 t\,dt \\ &= \frac{2A}{T_0^2}\int_0^{T_0} t\sin n\omega_0 t\,dt \\ &= \frac{2A}{T_0^2}\left[\frac{-t\cos n\omega_0 t}{n\omega_0}\Big|_0^{T_0} - \int_0^{T_0}(1)\int_0^{T_0}\sin n\omega_0 t\,dt\right] \\ &= \frac{2A}{T_0^2}\left[\frac{-t\cos n\omega_0 t}{n\omega_0}\Big|_0^{T_0} + \frac{1}{n^2\omega_0^2}\sin n\omega_0 t\Big|_0^{T_0}\right] \end{aligned}$$

Step 4 of 4

Now substitute $\omega_0 = \frac{2\pi}{T_0}$ in the above equation.

$$b_n = \frac{2A}{T_0^2}\left[\frac{1}{n^2\frac{4\pi^2}{T_0^2}}\sin n2\pi - \frac{T_0}{n\frac{2\pi}{T_0}}\right]$$

It is know that $\sin 2n\pi = 0$. Therefore we have

$$b_n = \frac{-A}{n\pi}$$

Therefore Fourier series of the given function is

$$\boxed{f(t) = \frac{A}{2} + \sum_{n=1}^{\infty}\left(\frac{-A}{n\pi}\right)\sin\frac{2n\pi}{T_0}t}.$$

15.022

P

Step 1 of 5

Step 2 of 5

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right)$$

$$a_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\cos n\omega_0 t\, dt$$

$$b_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\sin n\omega_0 t\, dt$$

$$a_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} f(t)\, dt$$

Step 3 of 5

$$a_0 = \frac{1}{2}\int_0^1 t\,dt + \frac{1}{2}\int_1^2 1\, dt$$

$$= \frac{1}{2}.\left.\frac{t^2}{2}\right|_0^1 + \frac{1}{2}.\left.t\right|_1^2$$

$$= \frac{1}{4} + \frac{1}{2}$$

$$\boxed{\therefore\ a_0 = \frac{3}{4}}$$

Step 4 of 5

$$a_n = \int_0^1 t.\sin n\omega_0 t\, dt + \int_1^2 (1)\sin n\omega_0 t\, dt$$

$$= \left[\frac{1}{(n\omega_0)^2}.\sin n\omega_0 t - \frac{1}{n\omega_0} t\cos n\omega_0 t\right]_0^1 + \frac{-1}{n\omega_0}.\left[\cos n\omega_0 t\right]_1^2$$

$$= \frac{1}{n\omega_0}\left[\frac{1}{n\pi}.\left(\sin\frac{2\pi}{2}.n - \cos n\pi - 0 + 0\right)\right] - \frac{1}{n\pi}\left(\cos 2n\pi - \cos n\pi\right)$$

$$= \frac{1}{n\pi}\left[\frac{-\cos n\pi}{n\pi}\right] - \frac{1}{n\pi}\left(1 - \cos n\pi\right)$$

Step 5 of 5

When n is even , $a_n = \frac{-1}{n^2\pi^2}$

When n is odd , $a_n = \frac{-1}{n^2\pi^2} - \frac{2}{n\pi}$

Similarly, $b_n = 0$ (n is even)

$b_n = \frac{-2}{(n\pi)^2}$ (n is odd)

$$\therefore\ \boxed{v(t) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right)}$$

Step 1 of 3

Consider the waveform in textbook Figure P15.14. The waveform has a period $T_0 = 2$. The waveform is defined as

$$v(t) = \begin{cases} t-1 & \text{for } 0 \le t < 1 \\ 1 & \text{for } 1 \le t \le 2 \end{cases}$$

The trigonometric Fourier series of a function is given by

$$v(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

$$a_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} f(t)\,dt$$

$$a_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\cos n\omega_0 t\,dt$$

$$b_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\sin n\omega_0 t\,dt$$

Now find the Fourier coefficient a_0 as shown below

$$\begin{aligned} a_0 &= \frac{1}{2}\left[\int_0^1 (t-1)\,dt + \int_1^2 (1)\,dt\right] \\ &= \frac{1}{2}\left[\left.\frac{t^2}{2}\right|_0^1 - (1-0) + (2-1)\right] \\ &= \frac{1}{2}\left[\frac{1}{2} - 1 + 1\right] \\ &= \frac{1}{4} \end{aligned}$$

Therefore $a_0 = \frac{1}{4}$.

Step 2 of 3

Now find the Fourier coefficient a_n as shown below

$$\begin{aligned} a_n &= \frac{2}{2}\left[\int_0^1 (t-1)\cos n\omega_0 t\,dt + \int_1^2 (1)\cos n\omega_0 t\,dt\right] \\ &= \int_0^1 (t)\cos n\omega_0 t\,dt - \int_0^1 \cos n\omega_0 t\,dt + \int_1^2 \cos n\omega_0 t\,dt \\ &= \left.\frac{t\sin n\omega_0 t}{n\omega_0}\right|_0^1 + \left.\frac{\cos n\omega_0 t}{n^2\omega_0^2}\right|_0^1 - \left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_0^1 + \left.\frac{\sin n\omega_0 t}{n\omega_0}\right|_1^2 \end{aligned}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \pi$ in the above equation. Therefore we have

$$a_n = \frac{\sin n\pi}{n\pi} + \frac{\cos n\pi}{n^2\pi^2} - \frac{1}{n^2\pi^2} - \frac{\sin n\pi}{n\pi} + \frac{\sin 2n\pi}{n\pi} - \frac{\sin n\pi}{n\pi}$$

We know that $\sin n\pi = \sin 2n\pi = 0$. Therefore we have

$$a_n = \frac{1}{n^2\pi^2}\left[\cos n\pi - 1\right].$$

Step 3 of 3

Now find the Fourier coefficient a_n as shown below

$$\begin{aligned} b_n &= \frac{2}{2}\left[\int_0^1 (t-1)\sin n\omega_0 t\,dt + \int_1^2 (1)\sin n\omega_0 t\,dt\right] \\ &= \int_0^1 (t)\sin n\omega_0 t\,dt - \int_0^1 \sin n\omega_0 t\,dt + \int_1^2 \sin n\omega_0 t\,dt \\ &= \left.\frac{-t\cos n\omega_0 t}{n\omega_0}\right|_0^1 + \left.\frac{\sin n\omega_0 t}{n^2\omega_0^2}\right|_0^1 + \left.\frac{\cos n\omega_0 t}{n\omega_0}\right|_0^1 - \left.\frac{\cos n\omega_0 t}{n\omega_0}\right|_1^2 \end{aligned}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \pi$ in the above equation. Therefore we have

$$b_n = \frac{-\cos n\pi}{n\pi} + \frac{\sin n\pi}{n^2\pi^2} + \frac{\cos n\pi}{n\pi} - \frac{1}{n\pi} - \frac{\cos 2n\pi}{n\pi} + \frac{\cos n\pi}{n\pi}$$

We know that $\sin n\pi = 0$ and $\cos 2n\pi = 1$. Therefore we have

$$b_n = \frac{1}{n\pi}\left[\cos n\pi - 2\right]$$

Therefore the trigonometric Fourier series of the given function is

$$\boxed{f(t) = \frac{1}{4} + \sum_{n=1}^{\infty}\left[\frac{1}{n^2\pi^2}\left[\cos n\pi - 1\right]\cos n\pi t + \frac{1}{n\pi}\left[\cos n\pi - 2\right]\sin n\pi t\right]}.$$

15.024
P

Step 1 of 4

Step 2 of 4

$$a_0=\frac{1}{T_0}\left[\int_0^{\pi} t\,dt+\int_{\pi}^{2\pi}(-\pi)\,dt\right]$$

$$=\frac{1}{2\pi}\left[\left[\frac{t^2}{2}\right]_0^{\pi}+\left[-\pi t\right]_{\pi}^{2\pi}\right]$$

$$=\frac{1}{2\pi}\left[\frac{\pi^2}{2}-\left(2\pi^2-\pi^2\right)\right]$$

$$=\frac{1}{2\pi}\left(-\frac{\pi^2}{2}\right)$$

$$\boxed{\therefore\ a_0=-\frac{\pi}{4}}$$

Step 3 of 4

$$a_n=\frac{2}{T_0}\left[\left[\int_0^{\pi} t.\cos n\omega_0 t\ dt\right]+\int_{\pi}^{2\pi}(-\pi)\cos n\omega_0 t\ dt\right]$$

$$=\frac{2}{2\pi}\left[\left[t.\frac{\sin n\omega_0 t}{n\omega_0}\right]_0^{\pi}-\frac{1}{n\omega_0}\int_0^{\pi}\sin n\omega_0 t dt-\pi\left[\frac{\sin n\omega_0 t}{n\omega_0}\right]_{\pi}^{2\pi}\right.$$

$$=\boxed{\frac{1}{n^2\pi}(\cos n\pi-1)}$$

Step 4 of 4

$$b_n=\frac{2}{T_0}\left[\int_0^{\pi}(t)\sin n\omega_0 t\ dt+\int_{\pi}^{2\pi}(-\pi)\sin n\omega_0 t\ dt\right]$$

$$=\frac{1}{\pi}\left[-\frac{\pi}{n}(\cos n\pi-1)+\frac{1}{n^2}(\sin n\pi)+\frac{\pi}{n}(\cos 2n\pi-\cos n\pi)\right]$$

$$\boxed{=\frac{1}{n}(1-2\cos n\pi)}$$

And $\boxed{v(t)=a_0+\sum_{n=1}^{\infty}(a_n\cos n\omega_0 t+b_n\sin n\omega_0 t)}$

Step 1 of 3

15.027 P

Consider the waveform in textbook Figure P15.19. The waveform has a period T_0. Clearly the waveform posses half-wave symmetry because the inverted version of each half cycle is same as the adjacent half-cycle. The waveform is defined as

$$v(t) = \frac{t}{\frac{T_0}{2}}(V)$$
$$= \frac{2V}{T_0} \qquad \text{for } 0 \le t \le \frac{T_0}{2}$$

The trigonometric Fourier series of a function is given by

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

Since the waveform exhibits half-wave symmetry, we have

$$a_0 = 0;\ a_n = b_n = 0 \quad \text{for } n \text{ even}$$

$$a_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} v(t)\cos n\omega_0 t\ dt \quad \text{for } n \text{ odd}$$

$$b_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} v(t)\sin n\omega_0 t\ dt \quad \text{for } n \text{ odd}$$

Now find the Fourier coefficient a_n as shown below

$$a_n = \frac{4}{T_0}\left[\int_0^{\frac{T_0}{2}}\left(\frac{2V}{T_0}\right)t\cos n\omega_0 t\ dt\right]$$
$$= \frac{8V}{T_0^2}\left[t\int_0^{\frac{T_0}{2}}\cos n\omega_0 t dt - \int_0^{\frac{T_0}{2}}(1)\int_0^{\frac{T_0}{2}}\cos n\omega_0 t\right]$$
$$= \frac{8V}{T_0^2}\left[t\frac{\sin n\omega_0 t}{n\omega_0}\Big|_0^{\frac{T_0}{2}} - \int_0^{\frac{T_0}{2}}\frac{\sin n\omega_0 t}{n\omega_0}dt\right]$$
$$= \frac{8V}{T_0^2}\left[t\frac{\sin n\omega_0 t}{n\omega_0}\Big|_0^{\frac{T_0}{2}} + \frac{\cos n\omega_0 t}{(n\omega_0)^2}\Big|_0^{\frac{T_0}{2}}\right]$$

Now substitute $\omega_0 = \frac{2\pi}{T_0}$ in the above equation. Therefore we have

$$a_n = \frac{8V}{T_0^2}\left[\frac{T_0}{2}\frac{\sin n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n\left(\frac{2\pi}{T_0}\right)} + \frac{\cos n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n^2\frac{4\pi^2}{T_0^2}} - \frac{1}{n^2\frac{4\pi^2}{T_0^2}}\right]$$
$$= \frac{8V}{T_0^2}\frac{T_0^2}{4n\pi}\left[\sin n\pi + \frac{\cos n\pi}{n\pi} - \frac{1}{n\pi}\right]$$

We know that $\sin n\pi = 0$ and $\cos n\pi = -1$ for n odd. Therefore we have

$$a_n = \frac{2V}{n\pi}\left[\frac{-1}{n\pi} - \frac{1}{n\pi}\right]$$
$$= \frac{-4V}{n^2\pi^2}$$

Therefore $a_n = \frac{-4V}{n^2\pi^2}$.

Step 2 of 3

Now find the Fourier coefficient b_n as shown below

$$b_n = \frac{4}{T_0}\left[\int_0^{\frac{T_0}{2}}\left(\frac{2V}{T_0}\right)t\sin n\omega_0 t\ dt\right]$$
$$= \frac{8V}{T_0^2}\left[t\int_0^{\frac{T_0}{2}}\sin n\omega_0 t dt - \int_0^{\frac{T_0}{2}}(1)\int_0^{\frac{T_0}{2}}\sin n\omega_0 t\right]$$
$$= \frac{8V}{T_0^2}\left[-t\frac{\cos n\omega_0 t}{n\omega_0}\Big|_0^{\frac{T_0}{2}} + \int_0^{\frac{T_0}{2}}\frac{\cos n\omega_0 t}{n\omega_0}dt\right]$$
$$= \frac{8V}{T_0^2}\left[-t\frac{\cos n\omega_0 t}{n\omega_0}\Big|_0^{\frac{T_0}{2}} + \frac{\sin n\omega_0 t}{(n\omega_0)^2}\Big|_0^{\frac{T_0}{2}}\right]$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{2}$ in the above equation. Therefore we have

$$b_n = \frac{8V}{T_0^2}\left[-\frac{T_0}{2}\frac{\cos n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n\left(\frac{2\pi}{T_0}\right)} + \frac{\sin n\left(\frac{2\pi}{T_0}\frac{T_0}{2}\right)}{n^2\frac{4\pi^2}{T_0^2}}\right]$$
$$= \frac{8V}{T_0^2}\frac{T_0^2}{4n\pi}\left[-\cos n\pi + \frac{\sin n\pi}{n\pi}\right]$$

We know that $\sin n\pi = 0$ and $\cos n\pi = -1$ for n odd. Therefore we have

$$b_n = \frac{2V}{n\pi}\left[-(-1) + 0\right]$$
$$= \frac{2V}{n\pi}$$

Step 3 of 3

Therefore $b_n = \frac{2V}{n\pi}$

Therefore the trigonometric Fourier series of the given function is

$$\boxed{v(t) = \sum_{\substack{n=1\\ n \text{ odd}}}^{\infty}\left[\frac{-4V}{n^2\pi^2}\cos n\omega_0 t + \frac{2V}{n\pi}\sin n\omega_0 t\right]}.$$

Step 1 of 4

15.028
P

Consider the waveform shown in Figure P15.21 in the textbook. The waveform has a period, $T_0 = \pi$.

The function is,

$$v(t) = A|\sin t|$$

Determine the angular frequency ω_0 .

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0}\\ &= \frac{2\pi}{\pi}\\ &= 2\end{aligned}$$

The trigonometric Fourier series of a function is,

$$v(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

The function is even. The Fourier coefficients are,

$$b_n = 0$$

$$a_0 = \frac{2}{T_0}\int_0^{\frac{T_0}{2}} v(t)\,dt$$

$$a_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} v(t)\cos n\omega_0 t\ dt$$

Step 2 of 4

Find the Fourier coefficient a_0 .

$$\begin{aligned}a_0 &= \frac{2}{\pi}\int_0^{\frac{\pi}{2}} A|\sin t|dt\\ &= \frac{2A}{\pi}\left(-\cos t\Big|_0^{\frac{\pi}{2}}\right)\\ &= \frac{2A}{\pi}(0+1)\\ &= \frac{2A}{\pi}\end{aligned}$$

Therefore, $a_0 = \frac{2A}{\pi}$

Step 3 of 4

Find the Fourier coefficient a_n .

$$\begin{aligned}a_n &= \frac{4}{T_0}\int_0^{\frac{T_0}{2}} A|\sin t|\cos n\omega_0 t dt\\ &= \frac{4A}{T_0}\int_0^{\frac{T_0}{2}} A\sin t\cos n\omega_0 t dt\end{aligned}$$

Use the formula, $\sin A\cos B = \frac{\sin(A+B)+\sin(A-B)}{2}$

$$a_n = \frac{4A}{\pi}\left[\int_0^{\frac{\pi}{2}}\frac{\sin(1+n\omega_0)t+\sin(1-n\omega_0)t}{2}dt\right]$$

Substitute 2 for ω_0 .

$$\begin{aligned}a_n &= \frac{4A}{\pi}\left[\int_0^{\frac{\pi}{2}}\frac{\sin(1+2n)t}{2}dt+\int_0^{\frac{\pi}{2}}\frac{\sin(1-2n)t}{2}dt\right]\\ &= \frac{2A}{\pi}\left[\frac{-\cos(1+2n)t}{(1+2n)}\Bigg|_0^{\frac{\pi}{2}}-\frac{\cos(1-2n)t}{(1-2n)}\Bigg|_0^{\frac{\pi}{2}}\right]\\ &= \frac{2A}{\pi}\left[0+\frac{1}{(1+2n)}-0+\frac{1}{(1-2n)}\right]\\ &= \frac{2A}{\pi}\left[\frac{1-2n+1+2n}{1-4n^2}\right]\\ &= \frac{4A}{\pi(1-4n^2)}\end{aligned}$$

Step 4 of 4

The Fourier series is,

$$\begin{aligned}v(t) &= a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]\\ &= \frac{2A}{\pi}+\sum_{n=1}^{\infty}\left[\frac{4A}{\pi(1-4n^2)}\cos n2t+0\right]\\ &= \frac{2A}{\pi}\left(1+\sum_{n=1}^{\infty}\frac{2}{(1-4n^2)}\cos 2nt\right)\end{aligned}$$

Thus, the Fourier series expansion of the function is

$$\boxed{v(t) = \frac{2A}{\pi}\left(1+\sum_{n=1}^{\infty}\frac{2}{(1-4n^2)}\cos 2nt\right)}.$$

Step 1 of 2

15.030 P

The amplitude and phase spectrum for a periodic function are as shown in Figure P15.22 in the textbook.

$T_0 = 0.1\ \text{s}$

Get the amplitudes and phases from the waveforms.

$D_1 = 8$

$D_2 = 6$

$D_3 = 4$

$D_4 = 2$

$\theta_1 = 80^0$

$\theta_2 = 80^0$

$\theta_3 = 15^0$

$\theta_4 = -45^0$

The angular frequency is,

$$\begin{aligned}\omega_0 &= \frac{2\pi}{T_0}\\ &= \frac{2\pi}{0.1}\\ &= 20\pi\ \ rad/s\end{aligned}$$

Step 2 of 2

The expression for $v(t)$ is,

$$v(t) = V_{DC} + \sum_{n=1}^{\infty} v_n \cos\left(n\omega_0 t - \theta_{v_n}\right)$$

$V_{DC} = 0.$

Therefore from the amplitude and phase waveforms the expression for $v(t)$ is

$$v(t) = \begin{pmatrix} 8\cos\left(20\pi t + 80^0\right) + 6\cos\left(40\pi t + 80^0\right) + 4\cos\left(60\pi t + 15^0\right) + \\ 2\cos\left(80\pi t - 45^0\right) \end{pmatrix}$$

Therefore the expression for $v(t)$ is

$$\boxed{v(t) = \begin{pmatrix} 8\cos\left(20\pi t + 80^0\right) + 6\cos\left(40\pi t + 80^0\right) + 4\cos\left(60\pi t + 15^0\right) + \\ 2\cos\left(80\pi t - 45^0\right) \end{pmatrix}}.$$

Step 1 of 3

Consider the waveform in textbook Figure P15.18. The waveform has a period $T_0 = 4$. The trigonometric Fourier series of a function is given by

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right]$$

$$a_0 = \frac{1}{T_0}\int_{t_1}^{t_1+T_0} f(t)\,dt$$

$$a_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\cos n\omega_0 t\,dt$$

$$b_n = \frac{2}{T_0}\int_{t_1}^{t_1+T_0} f(t)\sin n\omega_0 t\,dt$$

Now find the Fourier coefficient a_0 as shown below

$$\begin{aligned} a_0 &= \frac{1}{4}\left[\int_0^2(-t)\,dt + \int_2^3(0)\,dt + \int_3^4(-1)\,dt\right] \\ &= \frac{1}{4}\left[-\frac{t^2}{2}\Big|_0^2 + 0 - (4-3)\right] \\ &= \frac{1}{4}[-2-1] \\ &= \frac{-3}{4} \end{aligned}$$

Therefore $a_0 = \frac{-3}{4}$.

Step 2 of 3

Now find the Fourier coefficient a_n as shown below

$$\begin{aligned} a_n &= \frac{2}{T_0}\left[\int_0^2(-t)\cos n\omega_0 t\,dt + \int_3^4(-1)\cos n\omega_0 t\,dt\right] \\ &= \frac{-2}{4}\left[t\frac{\sin n\omega_0 t}{n\omega_0}\Big|_0^2 - \int_0^2\frac{\sin n\omega_0 t}{n\omega_0}dt + \frac{\sin n\omega_0 t}{n\omega_0}\Big|_3^4\right] \end{aligned}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{2}$ in the above equation.

$$\begin{aligned} a_n &= \frac{-1}{2}\left[\frac{2\sin n\left(\frac{\pi}{2}2\right)}{n\frac{\pi}{2}} + \frac{\cos n\frac{\pi}{2}t}{\frac{n^2\pi^2}{4}}\Big|_0^2 + \left(\frac{\sin n2\pi}{\frac{n\pi}{2}} - \frac{\sin\frac{3n\pi}{2}}{\frac{n\pi}{2}}\right)\right] \\ &= \frac{-1}{n\pi}\left[2\sin n\pi + \sin 2n\pi - \sin\frac{3n\pi}{2} + \frac{\cos n\pi}{\frac{n\pi}{2}} - \frac{1}{\frac{n\pi}{2}}\right] \\ &= \frac{-1}{n\pi}\left[\frac{2}{n\pi}(\cos n\pi - 1) - \sin\frac{3n\pi}{2}\right] \end{aligned}$$

Therefore $a_n = \frac{-1}{n\pi}\left[\frac{2}{n\pi}(\cos n\pi - 1) - \sin\frac{3n\pi}{2}\right]$.

Step 3 of 3

Now find the Fourier coefficient b_n as shown below

$$\begin{aligned} b_n &= \frac{2}{T_0}\left[-\int_0^2 t\sin n\omega_0 t\,dt - \int_3^4 \sin n\omega_0 t\,dt\right] \\ &= \frac{2}{4}\left[-\left(-t\frac{\cos n\omega_0 t}{n\omega_0}\Big|_0^2 - \int_0^2\frac{-\cos n\omega_0 t}{n\omega_0}dt\right) - \frac{-\cos n\omega_0 t}{n\omega_0}\Big|_3^4\right] \end{aligned}$$

Now substitute $\omega_0 = \frac{2\pi}{T_0} = \frac{\pi}{2}$ in the above equation.

$$\begin{aligned} b_n &= \frac{-1}{2}\left[\frac{-2\cos\left(\frac{n\pi}{2}2\right)}{\frac{n\pi}{2}} + \frac{\sin\frac{n\pi}{2}t}{\frac{n\pi}{2}}\Big|_0^2 - \left(\frac{\cos 2n\pi}{\frac{n\pi}{2}} - \frac{\cos\frac{3n\pi}{2}}{\frac{n\pi}{2}}\right)\right] \\ &= \frac{-1}{n\pi}\left[-2\cos n\pi + \sin n\pi - \cos 2n\pi + \cos\frac{3n\pi}{2}\right] \\ &= \frac{-1}{n\pi}\left[\cos\frac{3n\pi}{2} - 2\cos n\pi - 1\right] \end{aligned}$$

Therefore $b_n = \frac{-1}{n\pi}\left[\cos\frac{3n\pi}{2} - 2\cos n\pi - 1\right]$

Therefore, the trigonometric Fourier series of the given function is

$$\boxed{f(t) = -\frac{3}{4} + \sum_{n=1}^{\infty}\left[\begin{aligned}&\frac{-1}{n\pi}\left[\frac{2}{n\pi}(\cos n\pi - 1) - \sin\frac{3n\pi}{2}\right]\cos n\omega_0 t - \\ &\frac{1}{n\pi}\left[\cos\frac{3n\pi}{2} - 2\cos n\pi - 1\right]\sin n\omega_0 t\end{aligned}\right]}.$$

15.032

P

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15.033

P

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Step 1 of 4

Consider the signal given in Figure P15.24 in the text book.

The signal is,

$$f(t)=\sum_{\substack{n=1\\ n\text{ odd}}}^{\infty}\frac{-2}{n\pi}\sin\frac{n\pi}{2}\cos n\omega_0 t+\frac{6}{n\pi}\sin n\omega_0 t$$

$$a_n=\frac{-2}{n\pi}\sin\frac{n\pi}{2}$$

$$b_n=\frac{6}{n\pi}$$

$$\begin{aligned}D_n\angle\theta_n&=a_n-jb_n\\&=\sqrt{a^2+b^2}\angle\tan^{-1}\left(\frac{-b_n}{a_n}\right)\end{aligned}$$

Step 2 of 4

Therefore the first four terms for the signal are,

$$\begin{aligned}D_1\angle\theta_1&=a_1-jb_1\\&=-\frac{2}{\pi}\sin\frac{\pi}{2}-j\frac{6}{\pi}\\&=-\frac{2}{\pi}-j\frac{6}{\pi}\\&=2.013\angle-108^\circ\end{aligned}$$

$$\begin{aligned}D_3\angle\theta_3&=a_3-jb_3\\&=-\frac{1}{\pi}\sin\pi-j\frac{3}{\pi}\\&=-j\frac{3}{\pi}\\&=0.95\angle-90^\circ\end{aligned}$$

$$\begin{aligned}D_5\angle\theta_5&=a_5-jb_5\\&=-\frac{2}{3\pi}\sin\frac{3\pi}{2}-j\frac{2}{\pi}\\&=\frac{2}{3\pi}-j\frac{2}{\pi}\\&=0.671\angle-71.5^\circ\end{aligned}$$

$$\begin{aligned}D_7\angle\theta_7&=a_7-jb_7\\&=-\frac{1}{2\pi}\sin 2\pi-j\frac{3}{2\pi}\\&=-j\frac{3}{2\pi}\\&=0.477\angle-90^\circ\end{aligned}$$

Step 3 of 4

Plot the amplitude spectrum.

Step 4 of 4

Plot the phase spectrum.

Therefore the amplitude and phase plots are drawn.

Step 1 of 7

The given circuit is shown in the below Figure1.

Figure 1

Step 2 of 7

The circuit in Frequency domain is shown in the below Figure 2.

Figure 2

Step 3 of 7

Apply KCL at node V . Therefore we have

$$\frac{V-V_s}{1}+\frac{V}{j\omega_n 2}+\frac{V}{2}=0$$

$$V+\frac{V}{j\omega_n 2}+\frac{V}{2}=V_s$$

$$V\left(1+\frac{1}{j\omega_n 2}+\frac{1}{2}\right)=V_s$$

$$V\left(1.5-\frac{j1}{2\omega_n}\right)=V_s$$

$$V\left(\frac{3\omega_n-j1}{2\omega_n}\right)=V_s$$

$$V=V_s\left(\frac{2\omega_n}{3\omega_n-j1}\right)$$

Therefore, $V=V_s\left(\frac{2\omega_n}{3\omega_n-j1}\right)$.

Step 4 of 7

The current, I_0 is,

$$I_0=\frac{V}{2}$$

$$I_0=\frac{V_s\left(\frac{2\omega_n}{3\omega_n-j1}\right)}{2}$$

$$=V_s\left(\frac{2\omega_n}{2(3\omega_n-j1)}\right)$$

$$=V_s\left(\frac{\omega_n}{3\omega_n-j1}\right)$$

Since, $\omega_n=n\omega_0$, the current $I_0=V_s\left(\frac{n\omega_0}{3n\omega_0-j1}\right)$.

Consider the waveform shown in the below Figure3. It is the input to the given circuit diagram.

Figure 3

Step 5 of 7

The waveform has a period of $T_0=2\pi$

The trigonometric Fourier series of a function is given by

$$v(t)=a_0+\sum_{n=1}^{\infty}\left[a_n\cos n\omega_0 t+b_n\sin n\omega_0 t\right]$$

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Since the waveform exhibits odd symmetry

$a_0=0$

$a_n=0$ for all n ≥ 0

$$b_n=\frac{4}{T_0}\int_0^{T_0}f(t)\sin n\omega_0 t\,dt$$

Now find the Fourier coefficient b_n as shown below

$$b_n=\frac{4}{2\pi}\int_0^{\pi}\frac{10t}{\pi}\sin n\omega_0 t\,dt$$

$$=\frac{40}{2\pi^2}\left[\frac{t(-\cos n\omega_0 t)}{n\omega_0}\Bigg|_0^{\pi}-\int(1)\int_0^{\pi}\sin n\omega_0 t\,dt\right]$$

$$=\frac{40}{2\pi^2}\left[\frac{-\pi(\cos n\omega_0\pi)}{n\omega_0}+0+\frac{\sin n\omega_0 t}{n^2\omega_o^2}\Bigg|_0^{\pi}\right]$$

$$=\frac{40}{2\pi^2}\left[\frac{-\pi(\cos n\omega_0\pi)}{n\omega_0}+\frac{\sin n\omega_0 t}{n^2\omega_o^2}-\frac{\sin 0°}{n^2\omega_o^2}\right]$$

$$=\frac{40}{2\pi^2}\left[\frac{-\pi\cos(n\omega_0\pi)}{n\omega_0}+\frac{\sin n\omega_0\pi}{n^2\omega_0^2}\right]$$

Now substitute $\omega_0=\frac{2\pi}{T_0}=1$ in the above equation.

$$b_n=\frac{20}{\pi^2}\left[\frac{-\pi(\cos n\pi)}{n}+\frac{\sin n\pi}{n^2}\right]$$

$$b_n=\frac{20}{n\pi}(-1)^{n+1}$$

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Therefore trigonometric Fourier series expression for the given signal is

$$V_s(t)=\sum_{n=1}^{\infty}(-1)^{n+1}\left(\frac{20}{n\pi}\right)\sin nt$$

$$=\sum_{n=1}^{\infty}(-1)^{n+1}\left(\frac{20}{n\pi}\right)\cos(nt-90°)V$$

The amplitude and phase for the first four terms of the signal are obtained from expression $D_n\angle\theta_n=a_n-jb_n$

Therefore

$$D_1\angle\theta_1=-j\left[(-1)^2\left(\frac{20}{\pi}\right)\right]$$

$$=6.37\angle-90°$$

$$D_2\angle\theta_2=-j\left[(-1)^3\left(\frac{20}{2\pi}\right)\right]$$

$$=3.18\angle 90°$$

$$D_3\angle\theta_3=-j\left[(-1)^4\left(\frac{20}{3\pi}\right)\right]$$

$$=2.12\angle-90°$$

$$D_4\angle\theta_4=-j\left[(-1)^5\left(\frac{20}{4\pi}\right)\right]$$

$$=1.59\angle 90°$$

Hence the time domain representation of input signal is

$$V_s(t)=\begin{bmatrix}6.37\cos(t-90°)+3.18\cos(2t+90°)+2.12\cos(3t-90°)+\\1.59\cos(4t-90°)\end{bmatrix}$$

Therefore the current is given by

$$I_0=V_s\left(\frac{n\omega_0}{3n\omega_0-j1}\right)$$

$$=V_s\left(\frac{n}{3n-j1}\right)$$

$$=V_s\left[\sqrt{a^2+b^2}\angle\tan^{-1}\left(\frac{1}{3n}\right)\right]$$

$$=V_s\left[\frac{n}{\sqrt{(3n)^2+1^2}}\angle\tan^{-1}\left(\frac{1}{3n}\right)\right]$$

Substituting the values of V_s in the above equation, we get

$$I_0=\left[\sum_{n=1}^{\infty}(-1)^{n+1}\left(\frac{20}{n\pi}\right)\cos(nt-90°)\right]\left[\frac{n}{\sqrt{9n^2+1^2}}\angle\tan^{-1}\left(\frac{1}{3n}\right)\right]$$

Therefore the steady state current for the given circuit diagram is

$$\boxed{I_0=\left[\sum_{n=1}^{\infty}(-1)^{n+1}\left(\frac{20}{n\pi}\right)\cos(nt-90°)\right]\left[\frac{n}{\sqrt{9n^2+1^2}}\angle\tan^{-1}\left(\frac{1}{3n}\right)\right]}$$