Chapter 10, Solution 1.

$$\omega = 1$$

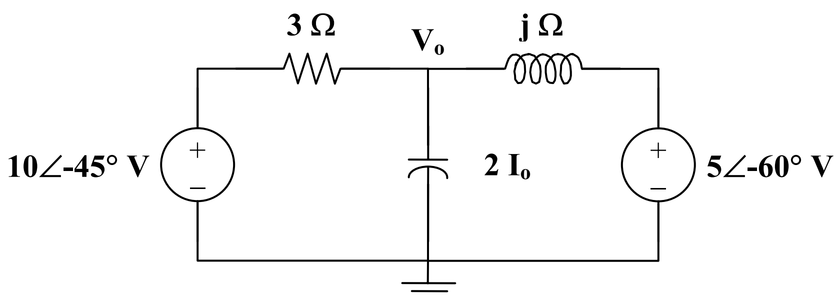
$$10\cos(t - 45°) \longrightarrow 10\angle\text{-}45°$$

$$5\sin(t + 30°) \longrightarrow 5\angle\text{-}60°$$

$$1\text{ H} \longrightarrow j\omega L = j$$

$$1\text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-}j$$

The circuit becomes as shown below.



Applying nodal analysis,

$$\frac{(10\angle\text{-}45°) - \mathbf{V}_o}{3} + \frac{(5\angle\text{-}60°) - \mathbf{V}_o}{j} = \frac{\mathbf{V}_o}{\text{-}j}$$

$$j10\angle\text{-}45° + 15\angle\text{-}60° = j\mathbf{V}_o$$

$$\mathbf{V}_o = 10\angle\text{-}45° + 15\angle\text{-}150° = 15.73\angle 247.9°$$

Therefore, $v_o(t) =$ **15.73 cos(t + 247.9°) V**

Chapter 10, Solution 2.

$$\omega = 10$$

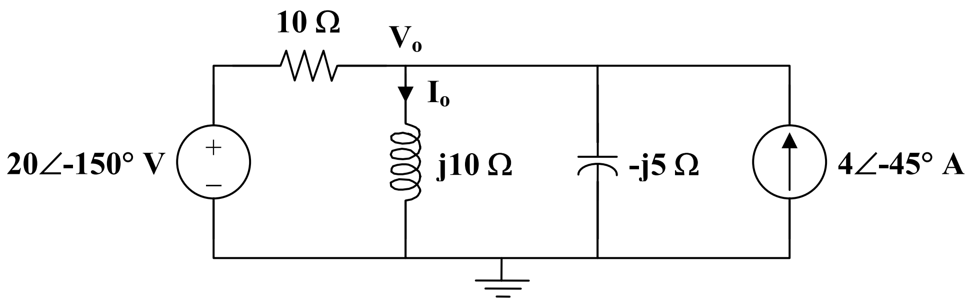
$$4\cos(10t - \pi/4) \longrightarrow 4\angle\text{-}45°$$

$$20\sin(10t + \pi/3) \longrightarrow 20\angle\text{-}150°$$

$$1\text{ H} \longrightarrow j\omega L = j10$$

$$0.02\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j0.2} = \text{-}j5$$

The circuit becomes that shown below.



Applying nodal analysis,

$$\frac{(20\angle -150°) - \mathbf{V}_o}{10} + 4\angle -45° = \frac{\mathbf{V}_o}{j10} + \frac{\mathbf{V}_o}{-j5}$$

$$20\angle -150° + 4\angle -45° = 0.1(1 + j)\mathbf{V}_o$$

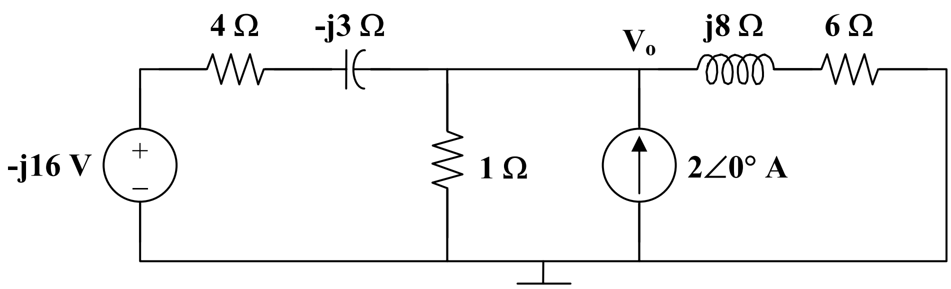
$$\mathbf{I}_o = \frac{\mathbf{V}_o}{j10} = \frac{2\angle -150° + 4\angle -45°}{j(1+j)} = 2.816\angle 150.98°$$

Therefore, $i_o(t) =$ **2.816 cos(10t + 150.98°) A**

Chapter 10, Solution 3.

$$\omega = 4$$
$$2\cos(4t) \longrightarrow 2\angle 0°$$
$$16\sin(4t) \longrightarrow 16\angle -90° = -j16$$
$$2\ \text{H} \longrightarrow j\omega L = j8$$
$$1/12\ \text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(4)(1/12)} = -j3$$

The circuit is shown below.



Applying nodal analysis,

$$\frac{-j16 - \mathbf{V}_o}{4 - j3} + 2 = \frac{\mathbf{V}_o}{1} + \frac{\mathbf{V}_o}{6 + j8}$$

$$\frac{-j16}{4 - j3} + 2 = \left(1 + \frac{1}{4 - j3} + \frac{1}{6 + j8}\right)\mathbf{V}_o$$

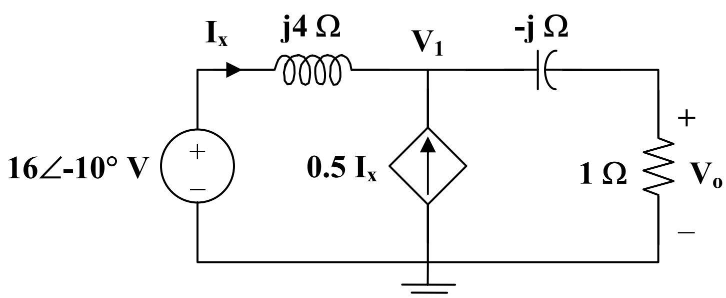
$$\mathbf{V}_o = \frac{3.92 - j2.56}{1.22 + j0.04} = \frac{4.682\angle -33.15°}{1.2207\angle 1.88°} = 3.835\angle -35.02°$$

Therefore, $v_o(t) =$ **<u>3.835 cos(4t – 35.02°) V</u>**

Chapter 10, Solution 4.

$$16\sin(4t - 10°) \longrightarrow 16\angle -10°, \quad \omega = 4$$
$$1\text{ H} \longrightarrow j\omega L = j4$$

$$0.25\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(4)(1/4)} = -j$$



$$\frac{(16\angle -10°) - \mathbf{V}_1}{j4} + \frac{1}{2}\mathbf{I}_x = \frac{\mathbf{V}_1}{1 - j}$$

But

$$\mathbf{I}_x = \frac{(16\angle -10°) - \mathbf{V}_1}{j4}$$

So, $$\frac{3((16\angle -10°) - \mathbf{V}_1)}{j8} = \frac{\mathbf{V}_1}{1 - j}$$

$$\mathbf{V}_1 = \frac{48\angle\text{-}10°}{\text{-}1 + j4}$$

Using voltage division,

$$\mathbf{V}_o = \frac{1}{1 - j}\mathbf{V}_1 = \frac{48\angle\text{-}10°}{(1\text{-}j)(\text{-}1 + j4)} = 8.232\angle\text{-}69.04°$$

Therefore, $v_o(t) =$ $\underline{\textbf{8.232 sin(4t – 69.04°) V}}$

Chapter 10, Solution 5.

Let the voltage across the capacitor and the inductor be V_x and we get:

$$\frac{V_x - 0.5I_x - 10\angle 30°}{4} + \frac{V_x}{-j2} + \frac{V_x}{j3} = 0$$

$$(3 + j6 - j4)V_x - 1.5I_x = 30\angle 30° \text{ but } I_x = \frac{V_x}{-j2} = j0.5V_x$$

Combining these equations we get:

$$(3 + j2 - j0.75)V_x = 30\angle 30° \text{ or } V_x = \frac{30\angle 30°}{3 + j1.25}$$

$$I_x = j0.5\frac{30\angle 30°}{3 + j1.25} = \underline{4.615\angle 97.38°\,\text{A}}$$

Chapter 10, Solution 6.

Let V_o be the voltage across the current source. Using nodal analysis we get:

$$\frac{V_o - 4V_x}{20} - 3 + \frac{V_o}{20 + j10} = 0 \quad \text{where } V_x = \frac{20}{20 + j10}V_o$$

Combining these we get:

$$\frac{V_o}{20} - \frac{4V_o}{20 + j10} - 3 + \frac{V_o}{20 + j10} = 0 \rightarrow (1 + j0.5 - 3)V_o = 60 + j30$$

$$V_o = \frac{60 + j30}{-2 + j0.5} \text{ or } V_x = \frac{20(3)}{-2 + j0.5} = \underline{\mathbf{29.11\angle{-166}^\circ\ V}}.$$

Chapter 10, Solution 7.

At the main node,

$$\frac{120\angle -15^o - V}{40 + j20} = 6\angle 30^o + \frac{V}{-j30} + \frac{V}{50} \longrightarrow \frac{115.91 - j31.058}{40 + j20} - 5.196 - j3 =$$
$$V\left(\frac{1}{40 + j20} + \frac{j}{30} + \frac{1}{50}\right)$$

$$V = \frac{-3.1885 - j4.7805}{0.04 + j0.0233} = \underline{124.08\angle -154^o \text{ V}}$$

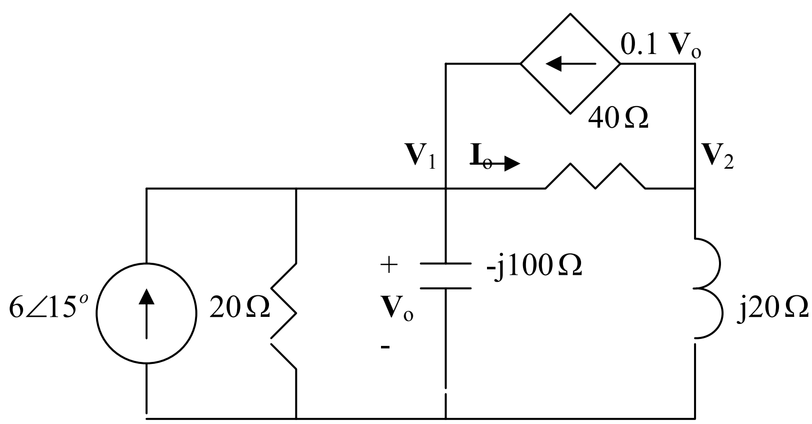
Chapter 10, Solution 8.

$\omega = 200,$

$100\text{mH} \longrightarrow j\omega L = j200 \text{x} 0.1 = j20$

$50\mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j200 \text{x} 50 \text{x} 10^{-6}} = -j100$

The frequency-domain version of the circuit is shown below.



At node 1,

$$6\angle 15^o + 0.1V_1 = \frac{V_1}{20} + \frac{V_1}{-j100} + \frac{V_1 - V_2}{40}$$

or $\qquad 5.7955 + j1.5529 = (-0.025 + j0.01)V_1 - 0.025V_2 \qquad (1)$

At node 2,

$$\frac{V_1 - V_2}{40} = 0.1V_1 + \frac{V_2}{j20} \quad\longrightarrow\quad 0 = 3V_1 + (1 - j2)V_2 \qquad (2)$$

From (1) and (2),

$$\begin{bmatrix} (-0.025 + j0.01) & -0.025 \\ 3 & (1 - j2) \end{bmatrix} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} (5.7955 + j1.5529) \\ 0 \end{pmatrix} \quad \text{or} \quad AV = B$$

Using MATLAB,

V = inv(A)*B

leads to $V_1 = -70.63 - j127.23, \qquad V_2 = -110.3 + j161.09$

$$I_o = \frac{V_1 - V_2}{40} = 7.276\angle -82.17^o$$

Thus,

$$\underline{i_o(t) = 7.276\cos(200t - 82.17^o)\ A}$$

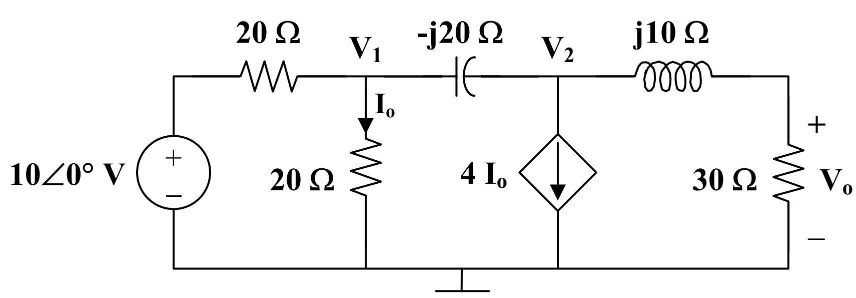
Chapter 10, Solution 9.

$$10\cos(10^3 t) \longrightarrow 10\angle 0°, \quad \omega = 10^3$$

$$10\ \text{mH} \longrightarrow j\omega L = j10$$

$$50\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(10^3)(50 \times 10^{-6})} = \text{-}j20$$

Consider the circuit shown below.



At node 1,

$$\frac{10 - \mathbf{V}_1}{20} = \frac{\mathbf{V}_1}{20} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{\text{-}j20}$$

$$10 = (2 + j)\mathbf{V}_1 - j\mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{-j20} = (4)\frac{\mathbf{V}_1}{20} + \frac{\mathbf{V}_2}{30 + j10}, \text{ where } \mathbf{I}_o = \frac{\mathbf{V}_1}{20} \text{ has been substituted.}$$

$$(-4 + j)\mathbf{V}_1 = (0.6 + j0.8)\mathbf{V}_2$$

$$\mathbf{V}_1 = \frac{0.6 + j0.8}{-4 + j}\mathbf{V}_2 \qquad (2)$$

Substituting (2) into (1)

$$10 = \frac{(2 + j)(0.6 + j0.8)}{-4 + j}\mathbf{V}_2 - j\mathbf{V}_2$$

or $$\mathbf{V}_2 = \frac{170}{0.6 - j26.2}$$

$$\mathbf{V}_o = \frac{30}{30 + j10}\mathbf{V}_2 = \frac{3}{3 + j} \cdot \frac{170}{0.6 - j26.2} = 6.154\angle 70.26°$$

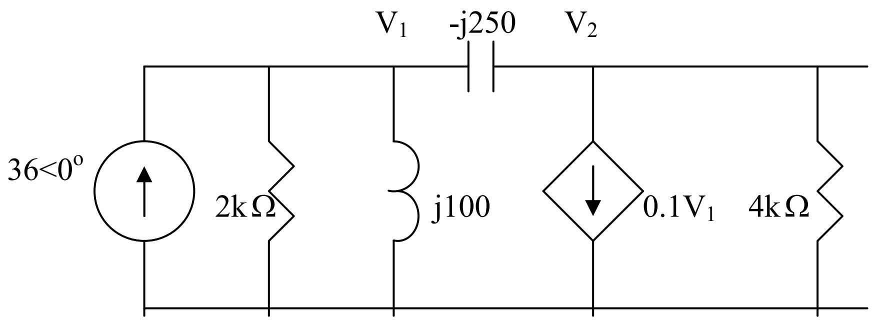
Therefore, $v_o(t) =$ **$6.154 \cos(10^3 t + 70.26°)$ V**

Chapter 10, Solution 10.

$$50 \text{ mH} \longrightarrow j\omega L = j2000x50x10^{-3} = j100, \qquad \omega = 2000$$

$$2\mu F \longrightarrow \frac{1}{j\omega C} = \frac{1}{j2000x2x10^{-6}} = -j250$$

Consider the frequency-domain equivalent circuit below.



At node 1,

$$36 = \frac{V_1}{2000} + \frac{V_1}{j100} + \frac{V_1 - V_2}{-j250} \longrightarrow 36 = (0.0005 - j0.006)V_1 - j0.004V_2 \quad (1)$$

At node 2,

$$\frac{V_1 - V_2}{-j250} = 0.1V_1 + \frac{V_2}{4000} \longrightarrow 0 = (0.1 - j0.004)V_1 + (0.00025 + j0.004)V_2 \quad (2)$$

Solving (1) and (2) gives

$$V_o = V_2 = -535.6 + j893.5 = 8951.1\angle 93.43^o$$

v_o (t) = **8.951 sin(2000t +93.43°) kV**

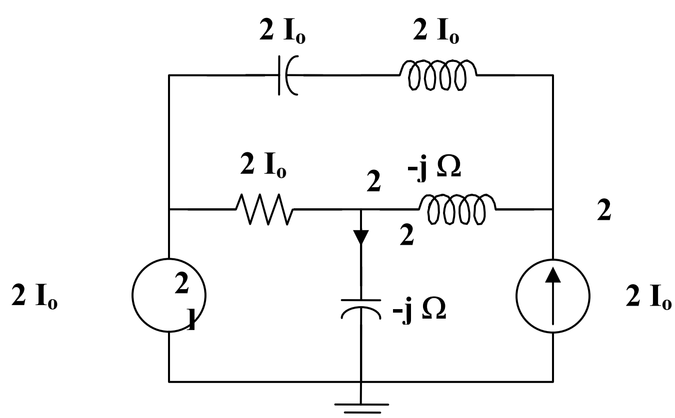
Chapter 10, Solution 11.

$$\cos(2t) \longrightarrow 1\angle 0°, \quad \omega = 2$$
$$8\sin(2t + 30°) \longrightarrow 8\angle\text{-}60°$$

$$1\text{ H} \longrightarrow j\omega L = j2 \qquad 1/2\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/2)} = \text{-}j$$

$$2\text{ H} \longrightarrow j\omega L = j4 \qquad 1/4\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/4)} = \text{-}j2$$

Consider the circuit below.



At node 1,

$$\frac{(8\angle\text{-}60°) - \mathbf{V}_1}{2} = \frac{\mathbf{V}_1}{\text{-}j} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j2}$$

$$8\angle\text{-}60° = (1 + j)\,\mathbf{V}_1 + j\,\mathbf{V}_2 \qquad (1)$$

At node 2,

$$1 + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j2} + \frac{(8\angle\text{-}60°) - \mathbf{V}_2}{j4 - j2} = 0$$

$$\mathbf{V}_2 = 4\angle\text{-}60° + j + 0.5\,\mathbf{V}_1 \qquad (2)$$

Substituting (2) into (1),

$$1 + 8\angle\text{-}60° - 4\angle 30° = (1 + j1.5)\,\mathbf{V}_1$$

$$\mathbf{V}_1 = \frac{1 + 8\angle\text{-}60° - 4\angle 30°}{1 + j1.5}$$

$$\mathbf{I}_o = \frac{\mathbf{V}_1}{\text{-}j} = \frac{1 + 8\angle\text{-}60° - 4\angle 30°}{1.5 - j} = 5.024\angle\text{-}46.55°$$

Therefore, $i_o(t) =$ **5.024 cos(2t – 46.55°)**

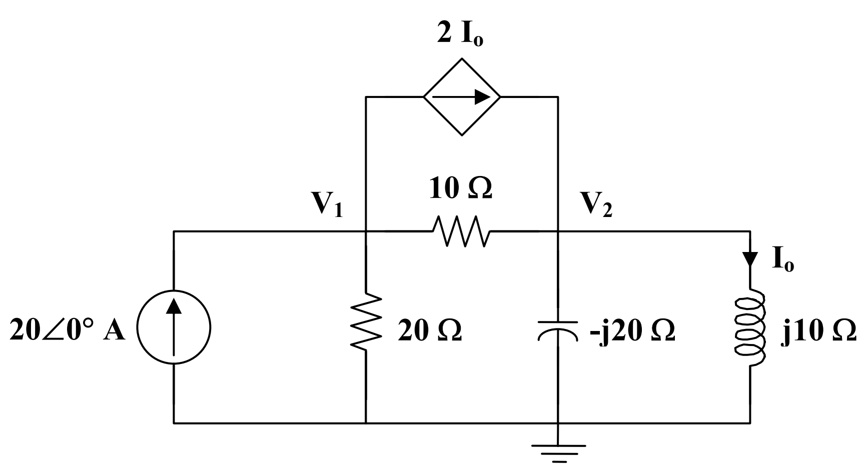
Chapter 10, Solution 12.

$$20\sin(1000t) \longrightarrow 20\angle 0°, \quad \omega = 1000$$

$$10 \text{ mH} \longrightarrow j\omega L = j10$$

$$50\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(10^3)(50\times 10^{-6})} = \text{-}j20$$

The frequency-domain equivalent circuit is shown below.



At node 1,

$$20 = 2\mathbf{I}_o + \frac{\mathbf{V}_1}{20} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{10},$$

where

$$\mathbf{I}_o = \frac{\mathbf{V}_2}{j10}$$

$$20 = \frac{2\mathbf{V}_2}{j10} + \frac{\mathbf{V}_1}{20} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{10}$$

$$400 = 3\mathbf{V}_1 - (2 + j4)\,\mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{2\mathbf{V}_2}{j10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{10} = \frac{\mathbf{V}_2}{-j20} + \frac{\mathbf{V}_2}{j10}$$

$$j2\,\mathbf{V}_1 = (-3 + j2)\,\mathbf{V}_2$$

or $\quad \mathbf{V}_1 = (1 + j1.5)\,\mathbf{V}_2 \qquad (2)$

Substituting (2) into (1),

$$400 = (3 + j4.5)\,\mathbf{V}_2 - (2 + j4)\,\mathbf{V}_2 = (1 + j0.5)\,\mathbf{V}_2$$

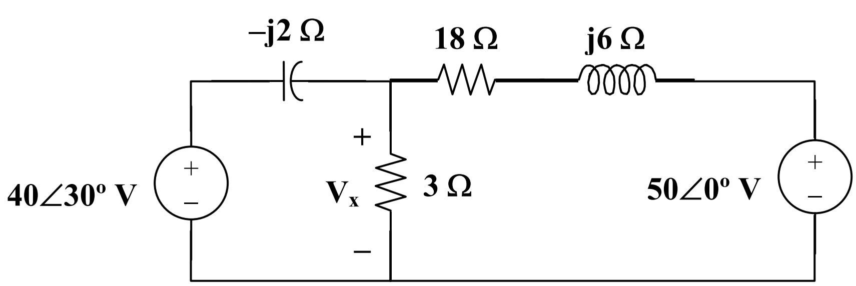
$$\mathbf{V}_2 = \frac{400}{1 + j0.5}$$

$$\mathbf{I}_o = \frac{\mathbf{V}_2}{j10} = \frac{40}{j(1 + j0.5)} = 35.74\angle -116.6°$$

Therefore, $\quad i_o(t) =$ **35.74 sin(1000t – 116.6°) A**

Chapter 10, Solution 13.

Nodal analysis is the best approach to use on this problem. We can make our work easier by doing a source transformation on the right hand side of the circuit.



$$\frac{V_x - 40\angle 30°}{-j2} + \frac{V_x}{3} + \frac{V_x - 50}{18 + j6} = 0$$

which leads to V_x = **$29.36\angle 62.88°$ A**.

Chapter 10, Solution 14.

At node 1,

$$\frac{0 - \mathbf{V}_1}{-j2} + \frac{0 - \mathbf{V}_1}{10} + \frac{\mathbf{V}_2 - \mathbf{V}_1}{j4} = 20\angle 30°$$

$$-(1 + j2.5)\,\mathbf{V}_1 - j2.5\,\mathbf{V}_2 = 173.2 + j100 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_2}{j2} + \frac{\mathbf{V}_2}{-j5} + \frac{\mathbf{V}_2 - \mathbf{V}_1}{j4} = 20\angle 30°$$

$$-j5.5\,\mathbf{V}_2 + j2.5\,\mathbf{V}_1 = 173.2 + j100 \qquad (2)$$

Equations (1) and (2) can be cast into matrix form as

$$\begin{bmatrix} 1 + j2.5 & j2.5 \\ j2.5 & -j5.5 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} -200\angle 30° \\ 200\angle 30° \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 1 + j2.5 & j2.5 \\ j2.5 & -j5.5 \end{vmatrix} = 20 - j5.5 = 20.74\angle -15.38°$$

$$\Delta_1 = \begin{vmatrix} -200\angle 30° & j2.5 \\ 200\angle 30° & -j5.5 \end{vmatrix} = j3(200\angle 30°) = 600\angle 120°$$

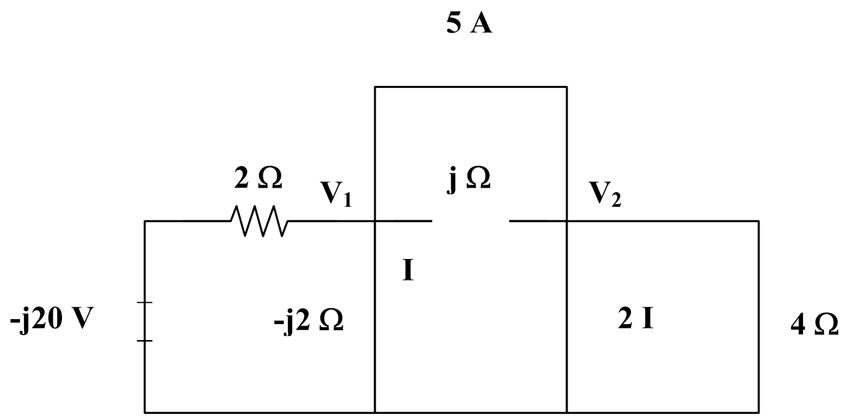
$$\Delta_2 = \begin{vmatrix} 1 + j2.5 & -200\angle 30° \\ j2.5 & 200\angle 30° \end{vmatrix} = (200\angle 30°)(1 + j5) = 1020\angle 108.7°$$

$$\mathbf{V}_1 = \frac{\Delta_1}{\Delta} = 28.93\angle 135.38°$$

$$\mathbf{V}_2 = \frac{\Delta_2}{\Delta} = 49.18\angle 124.08°$$

Chapter 10, Solution 15.

We apply nodal analysis to the circuit shown below.



At node 1,

$$\frac{-j20-\mathbf{V}_1}{2}=5+\frac{\mathbf{V}_1}{-j2}+\frac{\mathbf{V}_1-\mathbf{V}_2}{j}$$

$$-5-j10=(0.5-j0.5)\,\mathbf{V}_1+j\,\mathbf{V}_2 \qquad (1)$$

At node 2,

$$5+2\mathbf{I}+\frac{\mathbf{V}_1-\mathbf{V}_2}{j}=\frac{\mathbf{V}_2}{4},$$

where $\mathbf{I}=\dfrac{\mathbf{V}_1}{-j2}$

$$\mathbf{V}_2=\frac{5}{0.25-j}\mathbf{V}_1 \qquad (2)$$

Substituting (2) into (1),

$$-5-j10-\frac{j5}{0.25-j}=0.5(1-j)\,\mathbf{V}_1$$

$$(1-j)\,\mathbf{V}_1=-10-j20-\frac{j40}{1-j4}$$

$$(\sqrt{2}\angle-45°)\,\mathbf{V}_1=-10-j20+\frac{160}{17}-\frac{j40}{17}$$

$$\mathbf{V}_1=15.81\angle 313.5°$$

$$\mathbf{I} = \frac{\mathbf{V}_1}{-j2} = (0.5\angle 90°)(15.81\angle 313.5°)$$

$$\mathbf{I} = \underline{\mathbf{7.906\angle 43.49°\ A}}$$

Chapter 10, Solution 16.

At node 1,

$$j2 = \frac{\mathbf{V}_1}{20} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j5}$$

$$j40 = (3 + j4)\,\mathbf{V}_1 - (2 + j4)\,\mathbf{V}_2$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j5} + 1 + j = \frac{\mathbf{V}_2}{j10}$$

$$10\,(1 + j) = -(1 + j2)\,\mathbf{V}_1 + (1 + j)\,\mathbf{V}_2$$

Thus,

$$\begin{bmatrix} j40 \\ 10\,(1+j) \end{bmatrix} = \begin{bmatrix} 3 + j4 & -2\,(1 + j2) \\ -(1 + j2) & 1 + j \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 3 + j4 & -2\,(1 + j2) \\ -(1 + j2) & 1 + j \end{vmatrix} = 5 - j = 5.099\angle -11.31°$$

$$\Delta_1 = \begin{vmatrix} j40 & -2\,(1 + j2) \\ 10\,(1 + j) & 1 + j \end{vmatrix} = -60 + j100 = 116.62\angle 120.96°$$

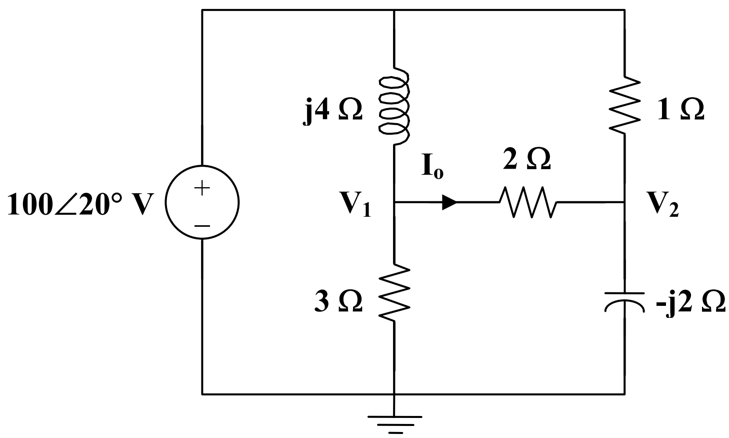
$$\Delta_2 = \begin{vmatrix} 3 + j4 & j40 \\ -(1 + j2) & 10\,(1 + j) \end{vmatrix} = -90 + j110 = 142.13\angle 129.29°$$

$$\mathbf{V}_1 = \frac{\Delta_1}{\Delta} = \underline{\mathbf{22.87\angle 132.27°\ V}}$$

$$\mathbf{V}_2 = \frac{\Delta_2}{\Delta} = \underline{\mathbf{27.87\angle 140.6°\ V}}$$

Chapter 10, Solution 17.

Consider the circuit below.



At node 1,

$$\frac{100\angle 20° - \mathbf{V}_1}{j4} = \frac{\mathbf{V}_1}{3} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{2}$$

$$100\angle 20° = \frac{\mathbf{V}_1}{3}(3 + j10) - j2\,\mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{100\angle 20° - \mathbf{V}_2}{1} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{2} = \frac{\mathbf{V}_2}{-j2}$$

$$100\angle 20° = -0.5\,\mathbf{V}_1 + (1.5 + j0.5)\,\mathbf{V}_2 \qquad (2)$$

From (1) and (2),

$$\begin{bmatrix} 100\angle 20° \\ 100\angle 20° \end{bmatrix} = \begin{bmatrix} -0.5 & 0.5(3 + j) \\ 1 + j10/3 & -j2 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} -0.5 & 1.5 + j0.5 \\ 1 + j10/3 & -j2 \end{vmatrix} = 0.1667 - j4.5$$

$$\Delta_1 = \begin{vmatrix} 100\angle 20° & 1.5 + j0.5 \\ 100\angle 20° & -j2 \end{vmatrix} = -55.45 - j286.2$$

$$\Delta_2 = \begin{vmatrix} -0.5 & 100\angle 20° \\ 1 + j10/3 & 100\angle 20° \end{vmatrix} = -26.95 - j364.5$$

$$\mathbf{V}_1 = \frac{\Delta_1}{\Delta} = 64.74\angle\text{-}13.08°$$

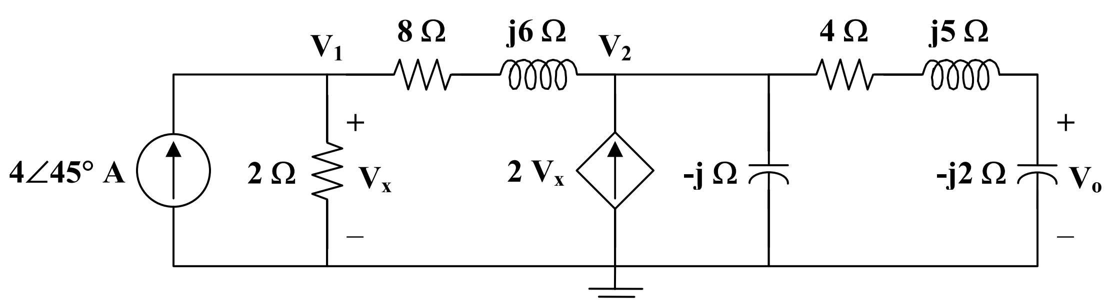
$$\mathbf{V}_2 = \frac{\Delta_2}{\Delta} = 81.17\angle\text{-}6.35°$$

$$\mathbf{I}_o = \frac{\mathbf{V}_1 - \mathbf{V}_2}{2} = \frac{\Delta_1 - \Delta_2}{2\Delta} = \frac{-28.5 + j78.31}{0.3333 - j9}$$

$$\mathbf{I}_o = 9.25\angle\text{-}162.12°$$

Chapter 10, Solution 18.

Consider the circuit shown below.



At node 1,

$$4\angle 45° = \frac{\mathbf{V}_1}{2} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{8 + j6}$$

$$200\angle 45° = (29 - j3)\,\mathbf{V}_1 - (4 - j3)\,\mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{8 + j6} + 2\mathbf{V}_x = \frac{\mathbf{V}_2}{-j} + \frac{\mathbf{V}_2}{4 + j5 - j2}, \qquad \text{where} \quad \mathbf{V}_x = \mathbf{V}_1$$

$$(104 - j3)\,\mathbf{V}_1 = (12 + j41)\,\mathbf{V}_2$$

$$\mathbf{V}_1 = \frac{12 + j41}{104 - j3}\mathbf{V}_2 \qquad (2)$$

Substituting (2) into (1),

$$200\angle 45° = (29 - j3)\frac{(12 + j41)}{104 - j3}\mathbf{V}_2 - (4 - j3)\,\mathbf{V}_2$$

$$200\angle 45° = (14.21\angle 89.17°)\,\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{200\angle 45°}{14.21\angle 89.17°}$$

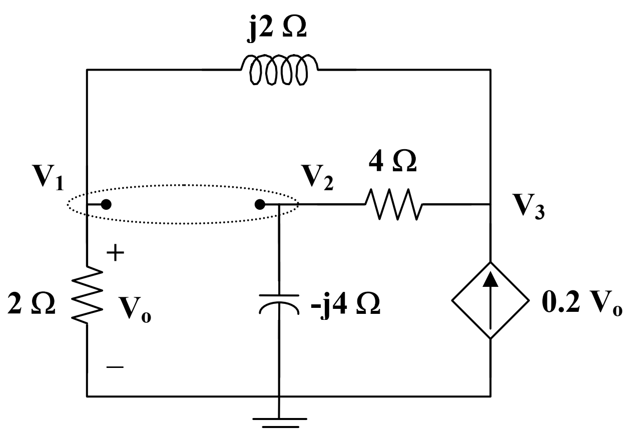
$$\mathbf{V}_o = \frac{-j2}{4 + j5 - j2}\mathbf{V}_2 = \frac{-j2}{4 + j3}\mathbf{V}_2 = \frac{-6 - j8}{25}\mathbf{V}_2$$

$$\mathbf{V}_o = \frac{10\angle 233.13°}{25} \cdot \frac{200\angle 45°}{14.21\angle 89.17°}$$

$$\mathbf{V}_o = \underline{\mathbf{5.63\angle 189°\ V}}$$

Chapter 10, Solution 19.

We have a supernode as shown in the circuit below.



Notice that $\mathbf{V}_o = \mathbf{V}_1$.

At the supernode,

$$\frac{\mathbf{V}_3 - \mathbf{V}_2}{4} = \frac{\mathbf{V}_2}{-j4} + \frac{\mathbf{V}_1}{2} + \frac{\mathbf{V}_1 - \mathbf{V}_3}{j2}$$

$$0 = (2 - j2)\,\mathbf{V}_1 + (1 + j)\,\mathbf{V}_2 + (-1 + j2)\,\mathbf{V}_3 \qquad (1)$$

At node 3,

$$0.2\mathbf{V}_1 + \frac{\mathbf{V}_1 - \mathbf{V}_3}{j2} = \frac{\mathbf{V}_3 - \mathbf{V}_2}{4}$$

$$(0.8 - j2)\,\mathbf{V}_1 + \mathbf{V}_2 + (-1 + j2)\,\mathbf{V}_3 = 0 \qquad (2)$$

Subtracting (2) from (1),

$$0 = 1.2\mathbf{V}_1 + j\mathbf{V}_2 \qquad (3)$$

But at the supernode,

$$\mathbf{V}_1 = 12\angle 0° + \mathbf{V}_2$$

or $$\mathbf{V}_2 = \mathbf{V}_1 - 12 \qquad (4)$$

Substituting (4) into (3),

$$0 = 1.2\mathbf{V}_1 + j(\mathbf{V}_1 - 12)$$

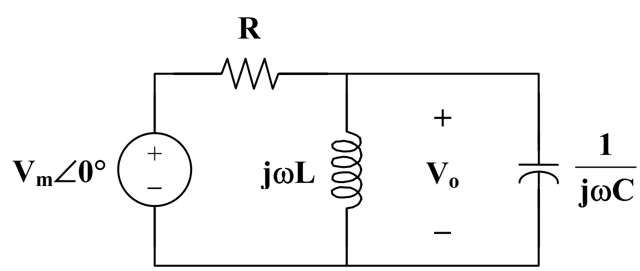
$$\mathbf{V}_1 = \frac{j12}{1.2 + j} = \mathbf{V}_o$$

$$\mathbf{V}_o = \frac{12\angle 90°}{1.562\angle 39.81°}$$

$$\mathbf{V}_o = \underline{\mathbf{7.682\angle 50.19°\ V}}$$

Chapter 10, Solution 20.

The circuit is converted to its frequency-domain equivalent circuit as shown below.



Let $$\mathbf{Z} = j\omega L \parallel \frac{1}{j\omega C} = \frac{\frac{L}{C}}{j\omega L + \frac{1}{j\omega C}} = \frac{j\omega L}{1 - \omega^2 LC}$$

$$\mathbf{V}_o = \frac{\mathbf{Z}}{R + \mathbf{Z}} V_m = \frac{\frac{j\omega L}{1-\omega^2 LC}}{R + \frac{j\omega L}{1 - \omega^2 LC}} V_m = \frac{j\omega L}{R(1 - \omega^2 LC) + j\omega L} V_m$$

$$\mathbf{V}_o = \frac{\omega L\, V_m}{\sqrt{R^2 (1 - \omega^2 LC)^2 + \omega^2 L^2}} \angle\left(90° - \tan^{-1}\frac{\omega L}{R(1 - \omega^2 LC)}\right)$$

If $\mathbf{V}_o = A\angle\phi$, then

$$A = \underline{\frac{\boldsymbol{\omega L V_m}}{\sqrt{\mathbf{R^2 (1-\omega^2 LC)^2 + \omega^2 L^2}}}}$$

and $$\phi = \underline{\mathbf{90° - tan^{-1}} \frac{\boldsymbol{\omega L}}{\mathbf{R(1-\omega^2 LC)}}}$$

Chapter 10, Solution 21.

(a) $$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}} = \frac{1}{1-\omega^2 LC + j\omega RC}$$

At $\omega = 0$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{1} = \underline{\mathbf{1}}$

As $\omega \to \infty$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \underline{\mathbf{0}}$

At $\omega = \frac{1}{\sqrt{LC}}$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{jRC \cdot \frac{1}{\sqrt{LC}}} = \underline{\frac{\mathbf{-j}}{\mathbf{R}}\sqrt{\frac{\mathbf{L}}{\mathbf{C}}}}$

(b) $$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j\omega L}{R + j\omega L + \frac{1}{j\omega C}} = \frac{-\omega^2 LC}{1-\omega^2 LC + j\omega RC}$$

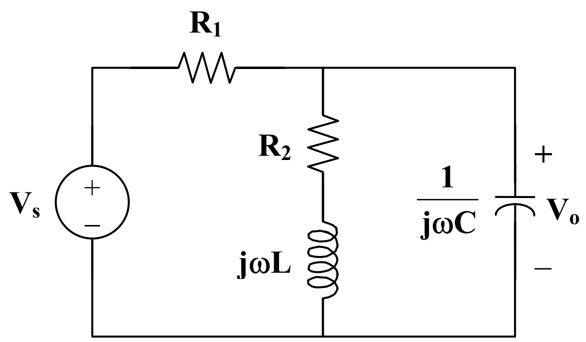
At $\omega = 0$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \underline{\mathbf{0}}$

As $\omega \to \infty$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{1} = \underline{\mathbf{1}}$

At $\omega = \frac{1}{\sqrt{LC}}$, $\quad \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{-1}{jRC \cdot \frac{1}{\sqrt{LC}}} = \underline{\frac{\mathbf{j}}{\mathbf{R}}\sqrt{\frac{\mathbf{L}}{\mathbf{C}}}}$

Chapter 10, Solution 22.

Consider the circuit in the frequency domain as shown below.



Let $\mathbf{Z} = (R_2 + j\omega L) \,||\, \frac{1}{j\omega C}$

$$\mathbf{Z} = \frac{\frac{1}{j\omega C}(R_2 + j\omega L)}{R_2 + j\omega L + \frac{1}{j\omega C}} = \frac{R_2 + j\omega L}{1 + j\omega R_2 - \omega^2 LC}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{\mathbf{Z}}{\mathbf{Z} + R_1} = \frac{\frac{R_2 + j\omega L}{1 - \omega^2 LC + j\omega R_2 C}}{R_1 + \frac{R_2 + j\omega L}{1 - \omega^2 LC + j\omega R_2 C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \underline{\frac{\mathbf{R_2 + j\omega L}}{\mathbf{R_1 + R_2 - \omega^2 LCR_1 + j\omega(L + R_1 R_2 C)}}}$$

Chapter 10, Solution 23.

$$\frac{V - V_S}{R} + \frac{V}{j\omega L + \frac{1}{j\omega C}} + j\omega CV = 0$$

$$V + \frac{j\omega RCV}{-\omega^2 LC + 1} + j\omega RCV = V_S$$

$$\left(\frac{1 - \omega^2 LC + j\omega RC + j\omega RC - j\omega^3 RLC^2}{1 - \omega^2 LC}\right) V = V_S$$

$$V = \frac{(1-\omega^2 LC)V_s}{1-\omega^2 LC + j\omega RC(2-\omega^2 LC)}$$

Chapter 10, Solution 24.

For mesh 1,

$$\mathbf{V}_s = \left(\frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}\right)\mathbf{I}_1 - \frac{1}{j\omega C_2}\mathbf{I}_2 \qquad (1)$$

For mesh 2,

$$0 = \frac{-1}{j\omega C_2}\mathbf{I}_1 + \left(R + j\omega L + \frac{1}{j\omega C_2}\right)\mathbf{I}_2 \qquad (2)$$

Putting (1) and (2) into matrix form,

$$\begin{bmatrix} \mathbf{V}_s \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2} & \frac{-1}{j\omega C_2} \\ \frac{-1}{j\omega C_2} & R + j\omega L + \frac{1}{j\omega C_2} \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

$$\Delta = \left(\frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}\right)\left(R + j\omega L + \frac{1}{j\omega C_2}\right) + \frac{1}{\omega^2 C_1 C_2}$$

$$\Delta_1 = \mathbf{V}_s\left(R + j\omega L + \frac{1}{j\omega C_2}\right) \quad \text{and} \quad \Delta_2 = \frac{\mathbf{V}_s}{j\omega C_2}$$

$$\mathbf{I}_1 = \frac{\Delta_1}{\Delta} = \frac{\mathbf{V}_s\left(\mathbf{R} + \mathbf{j\omega L} + \frac{\mathbf{1}}{\mathbf{j\omega C_2}}\right)}{\left(\frac{\mathbf{1}}{\mathbf{j\omega C_1}} + \frac{\mathbf{1}}{\mathbf{j\omega C_2}}\right)\left(\mathbf{R} + \mathbf{j\omega L} + \frac{\mathbf{1}}{\mathbf{j\omega C_2}}\right) + \frac{\mathbf{1}}{\omega^2 \mathbf{C_1 C_2}}}$$

$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \frac{\frac{\mathbf{V}_s}{\mathbf{j\omega C_2}}}{\left(\frac{\mathbf{1}}{\mathbf{j\omega C_1}} + \frac{\mathbf{1}}{\mathbf{j\omega C_2}}\right)\left(\mathbf{R} + \mathbf{j\omega L} + \frac{\mathbf{1}}{\mathbf{j\omega C_2}}\right) + \frac{\mathbf{1}}{\omega^2 \mathbf{C_1 C_2}}}$$

Chapter 10, Solution 25.

$$\omega = 2$$

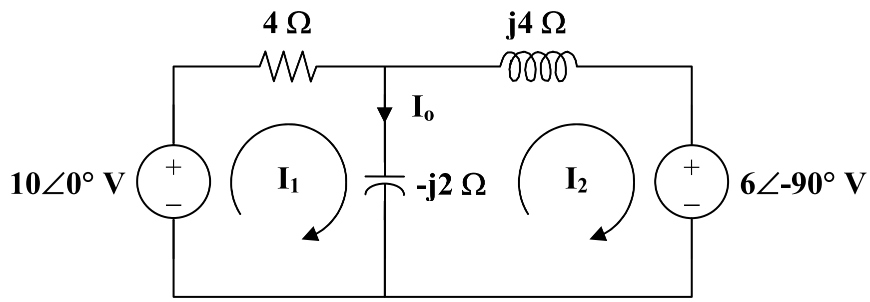
$$10\cos(2t) \longrightarrow 10\angle 0°$$

$$6\sin(2t) \longrightarrow 6\angle -90° = -j6$$

$$2\text{ H} \longrightarrow j\omega L = j4$$

$$0.25\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/4)} = -j2$$

The circuit is shown below.



For loop 1,

$$-10 + (4 - j2)\mathbf{I}_1 + j2\mathbf{I}_2 = 0$$

$$5 = (2 - j)\mathbf{I}_1 + j\mathbf{I}_2 \qquad (1)$$

For loop 2,

$$j2\mathbf{I}_1 + (j4 - j2)\mathbf{I}_2 + (-j6) = 0$$

$$\mathbf{I}_1 + \mathbf{I}_2 = 3 \qquad (2)$$

In matrix form (1) and (2) become

$$\begin{bmatrix} 2-j & j \\ 1 & 1 \end{bmatrix}\begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$$

$$\Delta = 2(1 - j), \qquad \Delta_1 = 5 - j3, \qquad \Delta_2 = 1 - j3$$

$$\mathbf{I}_o = \mathbf{I}_1 - \mathbf{I}_2 = \frac{\Delta_1 - \Delta_2}{\Delta} = \frac{4}{2(1-j)} = 1 + j = 1.414\angle 45°$$

Therefore, $i_o(t) =$ **<u>1.414 cos(2t + 45°) A</u>**

Chapter 10, Solution 26.

We apply mesh analysis to the circuit shown below.

For mesh 1,

$$-10 + 40\mathbf{I}_1 - 20\mathbf{I}_2 = 0$$

$$1 = 4\mathbf{I}_1 - 2\mathbf{I}_2 \qquad (1)$$

For the supermesh,

$$(20 - j20)\mathbf{I}_2 - 20\mathbf{I}_1 + (30 + j10)\mathbf{I}_3 = 0$$

$$-2\mathbf{I}_1 + (2 - j2)\mathbf{I}_2 + (3 + j)\mathbf{I}_3 = 0 \qquad (2)$$

At node A,

$$\mathbf{I}_o = \mathbf{I}_1 - \mathbf{I}_2 \qquad (3)$$

At node B,

$$\mathbf{I}_2 = \mathbf{I}_3 + 4\mathbf{I}_o \qquad (4)$$

Substituting (3) into (4)

$$\mathbf{I}_2 = \mathbf{I}_3 + 4\mathbf{I}_1 - 4\mathbf{I}_2$$

$$\mathbf{I}_3 = 5\mathbf{I}_2 - 4\mathbf{I}_1 \qquad (5)$$

Substituting (5) into (2) gives

$$0 = \text{-}(14 + j4)\mathbf{I}_1 + (17 + j3)\mathbf{I}_2 \qquad (6)$$

From (1) and (6),

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 4 & -2 \\ -(14 + j4) & 17 + j3 \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

$$\Delta = 40 + j4$$

$$\Delta_1 = \begin{vmatrix} 1 & -2 \\ 0 & 17 + j3 \end{vmatrix} = 17 + j3, \qquad \Delta_2 = \begin{vmatrix} 4 & 1 \\ -(14 + j4) & 0 \end{vmatrix} = 14 + j4$$

$$\mathbf{I}_3 = 5\mathbf{I}_2 - 4\mathbf{I}_1 = \frac{5\Delta_2 - 4\Delta_1}{\Delta} = \frac{2 + j8}{40 + j4}$$

$$\mathbf{V}_o = 30\mathbf{I}_3 = \frac{15(1 + j4)}{10 + j} = 6.154\angle 70.25°$$

Therefore, $v_o(t) =$ **6.154 cos(10^3 t + 70.25°) V**

Chapter 10, Solution 27.

For mesh 1,

$$-40\angle 30° + (j10 - j20)\mathbf{I}_1 + j20\mathbf{I}_2 = 0$$

$$4\angle 30° = -j\mathbf{I}_1 + j2\mathbf{I}_2 \qquad (1)$$

For mesh 2,

$$50\angle 0° + (40 - j20)\mathbf{I}_2 + j20\mathbf{I}_1 = 0$$

$$5 = -j2\mathbf{I}_1 - (4 - j2)\mathbf{I}_2 \qquad (2)$$

From (1) and (2),

$$\begin{bmatrix} 4\angle 30° \\ 5 \end{bmatrix} = \begin{bmatrix} -j & j2 \\ -j2 & -(4 - j2) \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

$$\Delta = -2 + 4j = 4.472\angle 116.56°$$

$$\Delta_1 = -(4\angle 30°)(4 - j2) - j10 = 21.01\angle 211.8°$$

$$\Delta_2 = -j5 + 8\angle 120° = 4.44\angle 154.27°$$

$$\mathbf{I}_1 = \frac{\Delta_1}{\Delta} = \underline{\mathbf{4.698\angle 95.24°\ A}}$$

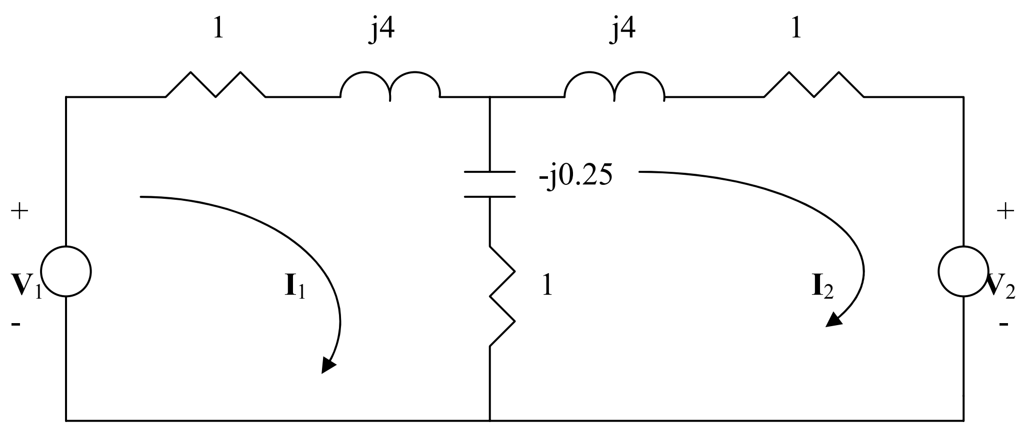
$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \underline{\mathbf{0.9928\angle 37.71°\ A}}$$

Chapter 10, Solution 28.

$$1\text{H} \longrightarrow j\omega L = j4, \qquad 1\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j1x4} = -j0.25$$

The frequency-domain version of the circuit is shown below, where

$V_1 = 10\angle 0^o$, $V_2 = 20\angle -30^o$.



$V_1 = 10\angle 0^o$, $V_2 = 20\angle -30^o$

Applying mesh analysis,

$$10 = (2 + j3.75)I_1 - (1 - j0.25)I_2 \qquad (1)$$

$$-20\angle -30^o = -(1 - j0.025)I_1 + (2 + j3.75)I_2 \qquad (2)$$

From (1) and (2), we obtain

$$\begin{pmatrix} 10 \\ -17.32 + j10 \end{pmatrix} = \begin{pmatrix} 2 + j3.75 & -1 + j0.25 \\ -1 + j0.25 & 2 + j3.75 \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$$

Solving this leads to

$$I_1 = 1.3602 - j0.9769 = 1.6747\angle -35.69^o, \qquad I_2 = -4.1438 + j2.111 = 4.6505\angle 153^o$$

Hence,

$$\underline{i_1 = 1.675\cos(4t - 35.69^o)\ \text{A}, \qquad i_2 = 4.651\cos(46 + 153^o)\ \text{A}}$$

Chapter 10, Solution 29.

For mesh 1,

$$(5 + j5)\mathbf{I}_1 - (2 + j)\mathbf{I}_2 - 30\angle 20° = 0$$
$$30\angle 20° = (5 + j5)\mathbf{I}_1 - (2 + j)\mathbf{I}_2 \qquad (1)$$

For mesh 2,

$$(5 + j3 - j6)\mathbf{I}_2 - (2 + j)\mathbf{I}_1 = 0$$
$$0 = -(2 + j)\mathbf{I}_1 + (5 - j3)\mathbf{I}_2 \qquad (2)$$

From (1) and (2),

$$\begin{bmatrix} 30\angle 20° \\ 0 \end{bmatrix} = \begin{bmatrix} 5 + j5 & -(2 + j) \\ -(2 + j) & 5 - j3 \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

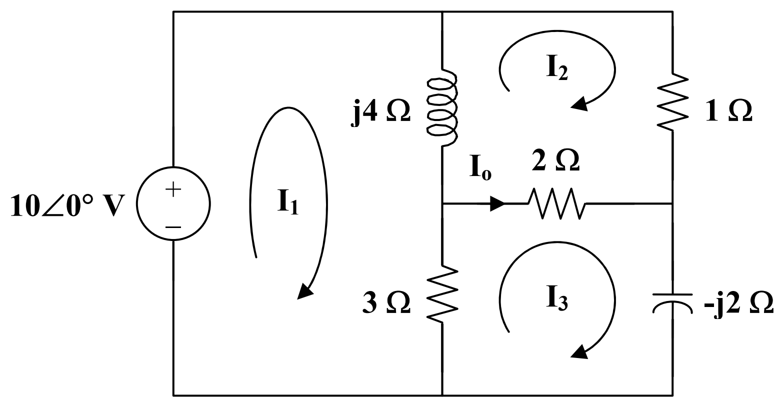
$$\Delta = 37 + j6 = 37.48\angle 9.21°$$
$$\Delta_1 = (30\angle 20°)(5.831\angle -30.96°) = 175\angle -10.96°$$
$$\Delta_2 = (30\angle 20°)(2.356\angle 26.56°) = 67.08\angle 46.56°$$

$$\mathbf{I}_1 = \frac{\Delta_1}{\Delta} = \underline{\mathbf{4.67\angle -20.17°\ A}}$$

$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \underline{\mathbf{1.79\angle 37.35°\ A}}$$

Chapter 10, Solution 30.

Consider the circuit shown below.



For mesh 1,

$$100\angle 20° = (3 + j4)\mathbf{I}_1 - j4\mathbf{I}_2 - 3\mathbf{I}_3 \qquad (1)$$

For mesh 2,

$$0 = -j4\mathbf{I}_1 + (3 + j4)\mathbf{I}_2 - j2\mathbf{I}_3 \qquad (2)$$

For mesh 3,

$$0 = -3\mathbf{I}_1 - 2\mathbf{I}_2 + (5 - j2)\mathbf{I}_3 \qquad (3)$$

Put (1), (2), and (3) into matrix form.

$$\begin{bmatrix} 3+j4 & -j4 & -3 \\ -j4 & 3+j4 & -j2 \\ -3 & -2 & 5-j2 \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \\ \mathbf{I}_3 \end{bmatrix} = \begin{bmatrix} 100\angle 20° \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 3+j4 & -j4 & -3 \\ -j4 & 3+j4 & -j2 \\ -3 & -2 & 5-j2 \end{vmatrix} = 106 + j30$$

$$\Delta_2 = \begin{vmatrix} 3+j4 & 100\angle 20° & -3 \\ -j4 & 0 & -j2 \\ -3 & 0 & 5-j2 \end{vmatrix} = (100\angle 20°)(8 + j26)$$

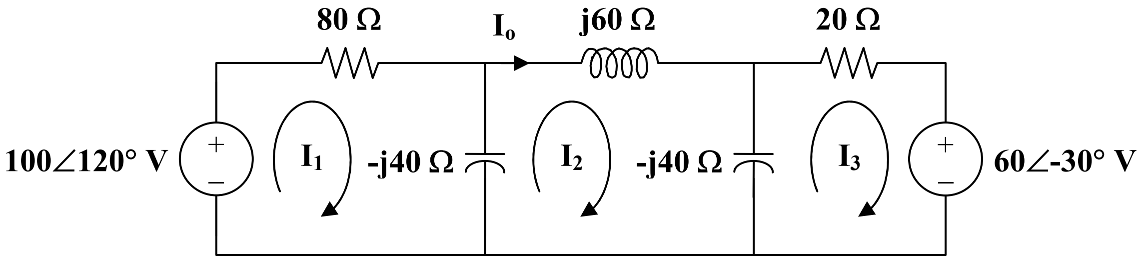
$$\Delta_3 = \begin{vmatrix} 3+j4 & -j4 & 100\angle 20° \\ -j4 & 3+j4 & 0 \\ -3 & -2 & 0 \end{vmatrix} = (100\angle 20°)(9 + j20)$$

$$\mathbf{I}_o = \mathbf{I}_3 - \mathbf{I}_2 = \frac{\Delta_3 - \Delta_2}{\Delta} = \frac{(100\angle 20°)(1 - j6)}{106 + j30}$$

$\mathbf{I}_o =$ **5.521∠-76.34° A**

Chapter 10, Solution 31.

Consider the network shown below.



For loop 1,

$$-100\angle 20° + (80 - j40)\mathbf{I}_1 + j40\mathbf{I}_2 = 0$$

$$10\angle 20° = 4(2 - j)\mathbf{I}_1 + j4\mathbf{I}_2 \qquad (1)$$

For loop 2,

$$j40\mathbf{I}_1 + (j60 - j80)\mathbf{I}_2 + j40\mathbf{I}_3 = 0$$

$$0 = 2\mathbf{I}_1 - \mathbf{I}_2 + 2\mathbf{I}_3 \qquad (2)$$

For loop 3,

$$60\angle -30° + (20 - j40)\mathbf{I}_3 + j40\mathbf{I}_2 = 0$$

$$-6\angle -30° = j4\mathbf{I}_2 + 2(1 - j2)\mathbf{I}_3 \qquad (3)$$

From (2),

$$2\mathbf{I}_3 = \mathbf{I}_2 - 2\mathbf{I}_1$$

Substituting this equation into (3),

$$-6\angle -30° = -2(1 - j2)\mathbf{I}_1 + (1 + j2)\mathbf{I}_2 \qquad (4)$$

From (1) and (4),

$$\begin{bmatrix} 10\angle 120° \\ -6\angle -30° \end{bmatrix} = \begin{bmatrix} 4(2-j) & j4 \\ -2(1-j2) & 1+j2 \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix}$$

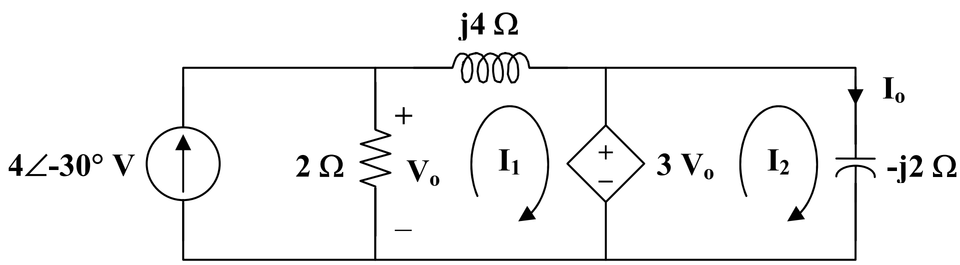
$$\Delta = \begin{vmatrix} 8 - j4 & -j4 \\ -2 + j4 & 1 + j2 \end{vmatrix} = 32 + j20 = 37.74\angle 32°$$

$$\Delta_2 = \begin{vmatrix} 8 - j4 & 10\angle 120° \\ -2 + j4 & -6\angle -30° \end{vmatrix} = -4.928 + j82.11 = 82.25\angle 93.44°$$

$$\mathbf{I}_o = \mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \underline{\mathbf{2.179\angle 61.44°\ A}}$$

Chapter 10, Solution 32.

Consider the circuit below.



For mesh 1,

$$(2 + j4)\mathbf{I}_1 - 2(4\angle -30°) + 3\mathbf{V}_o = 0$$

where
$$\mathbf{V}_o = 2(4\angle -30° - \mathbf{I}_1)$$

Hence,

$$(2 + j4)\mathbf{I}_1 - 8\angle -30° + 6(4\angle -30° - \mathbf{I}_1) = 0$$
$$4\angle -30° = (1 - j)\mathbf{I}_1$$

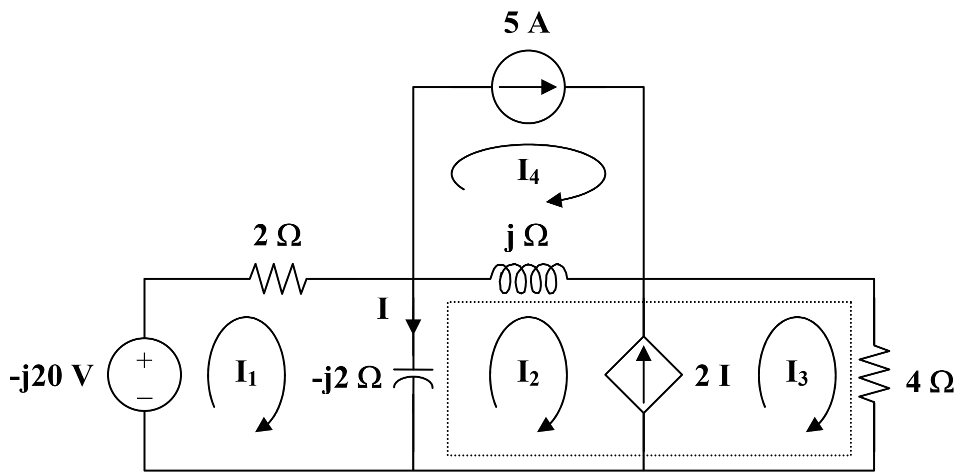
or
$$\mathbf{I}_1 = 2\sqrt{2}\angle 15°$$

$$\mathbf{I}_o = \frac{3\mathbf{V}_o}{-j2} = \frac{3}{-j2}(2)(4\angle -30° - \mathbf{I}_1)$$
$$\mathbf{I}_o = j3(4\angle -30° - 2\sqrt{2}\angle 15°)$$
$$\mathbf{I}_o = \underline{\mathbf{8.485\angle 15°\ A}}$$

$$\mathbf{V}_o = \frac{-j2\mathbf{I}_o}{3} = \underline{\mathbf{5.657\angle -75°\ V}}$$

Chapter 10, Solution 33.

Consider the circuit shown below.



For mesh 1,

$$j20 + (2 - j2)\mathbf{I}_1 + j2\mathbf{I}_2 = 0$$

$$(1 - j)\mathbf{I}_1 + j\mathbf{I}_2 = -j10 \qquad (1)$$

For the supermesh,

$$(j - j2)\mathbf{I}_2 + j2\mathbf{I}_1 + 4\mathbf{I}_3 - j\mathbf{I}_4 = 0 \qquad (2)$$

Also,

$$\mathbf{I}_3 - \mathbf{I}_2 = 2\mathbf{I} = 2(\mathbf{I}_1 - \mathbf{I}_2)$$

$$\mathbf{I}_3 = 2\mathbf{I}_1 - \mathbf{I}_2 \qquad (3)$$

For mesh 4,

$$\mathbf{I}_4 = 5 \qquad (4)$$

Substituting (3) and (4) into (2),

$$(8 + j2)\mathbf{I}_1 - (-4 + j)\mathbf{I}_2 = j5 \qquad (5)$$

Putting (1) and (5) in matrix form,

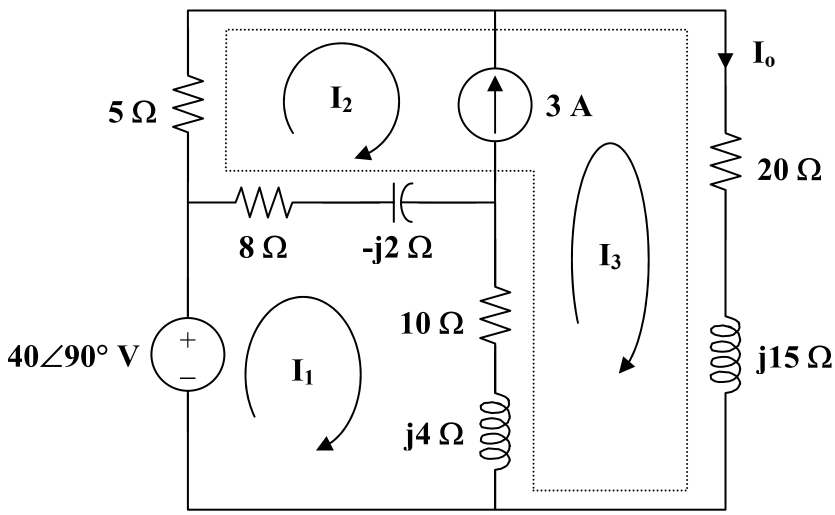
$$\begin{bmatrix} 1 - j & j \\ 8 + j2 & 4 - j \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} -j10 \\ j5 \end{bmatrix}$$

$$\Delta = -3 - j5, \qquad \Delta_1 = -5 + j40, \qquad \Delta_2 = -15 + j85$$

$$\mathbf{I} = \mathbf{I}_1 - \mathbf{I}_2 = \frac{\Delta_1 - \Delta_2}{\Delta} = \frac{10 - j45}{-3 - j5} = \underline{\mathbf{7.906\angle 43.49^\circ\ A}}$$

Chapter 10, Solution 34.

The circuit is shown below.



For mesh 1,

$$- j40 + (18 + j2)\mathbf{I}_1 - (8 - j2)\mathbf{I}_2 - (10 + j4)\mathbf{I}_3 = 0 \qquad (1)$$

For the supermesh,

$$(13 - j2)\mathbf{I}_2 + (30 + j19)\mathbf{I}_3 - (18 + j2)\mathbf{I}_1 = 0 \qquad (2)$$

Also,

$$\mathbf{I}_2 = \mathbf{I}_3 - 3 \qquad (3)$$

Adding (1) and (2) and incorporating (3),

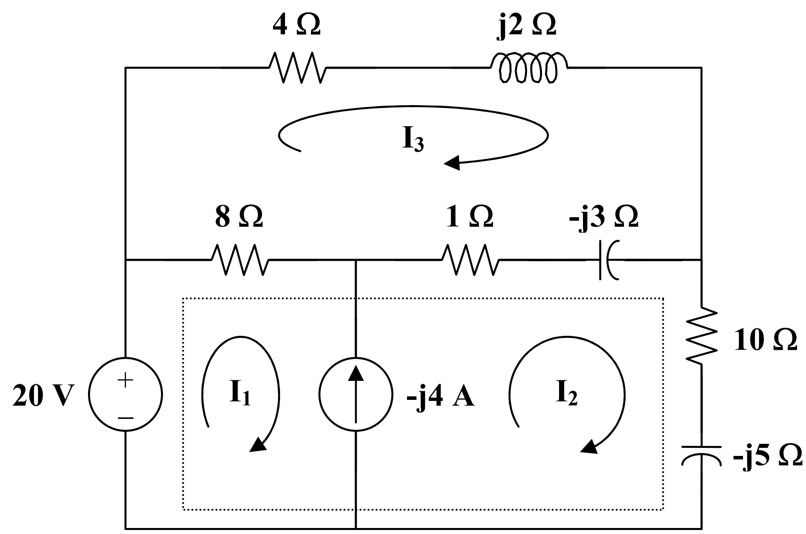
$$- j40 + 5(\mathbf{I}_3 - 3) + (20 + j15)\mathbf{I}_3 = 0$$

$$\mathbf{I}_3 = \frac{3 + j8}{5 + j3} = 1.465\angle 38.48°$$

$$\mathbf{I}_o = \mathbf{I}_3 = \underline{\mathbf{1.465\angle 38.48° \ A}}$$

Chapter 10, Solution 35.

Consider the circuit shown below.



For the supermesh,

$$-20 + 8\mathbf{I}_1 + (11 - j8)\mathbf{I}_2 - (9 - j3)\mathbf{I}_3 = 0 \qquad (1)$$

Also,

$$\mathbf{I}_1 = \mathbf{I}_2 + j4 \qquad (2)$$

For mesh 3,

$$(13 - j)\mathbf{I}_3 - 8\mathbf{I}_1 - (1 - j3)\mathbf{I}_2 = 0 \qquad (3)$$

Substituting (2) into (1),

$$(19 - j8)\mathbf{I}_2 - (9 - j3)\mathbf{I}_3 = 20 - j32 \qquad (4)$$

Substituting (2) into (3),

$$-(9 - j3)\mathbf{I}_2 + (13 - j)\mathbf{I}_3 = j32 \qquad (5)$$

From (4) and (5),

$$\begin{bmatrix} 19 - j8 & -(9 - j3) \\ -(9 - j3) & 13 - j \end{bmatrix} \begin{bmatrix} \mathbf{I}_2 \\ \mathbf{I}_3 \end{bmatrix} = \begin{bmatrix} 20 - j32 \\ j32 \end{bmatrix}$$

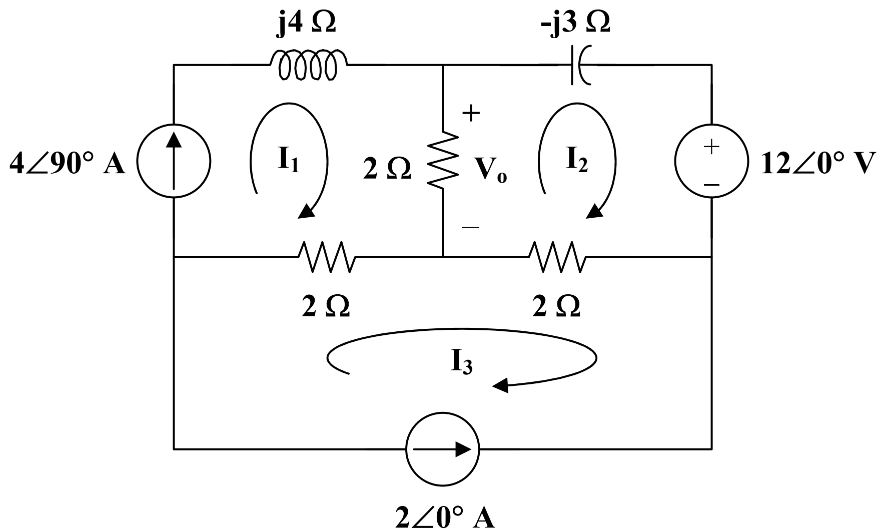
$$\Delta = 167 - j69, \qquad \Delta_2 = 324 - j148$$

$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \frac{324 - j148}{167 - j69} = \frac{356.2\angle -24.55^\circ}{180.69\angle -22.45^\circ}$$

$$\mathbf{I}_2 = \underline{\mathbf{1.971\angle -2.1^\circ\ A}}$$

Chapter 10, Solution 36.

Consider the circuit below.



Clearly,

$$\mathbf{I}_1 = 4\angle 90° = j4 \qquad \text{and} \qquad \mathbf{I}_3 = -2$$

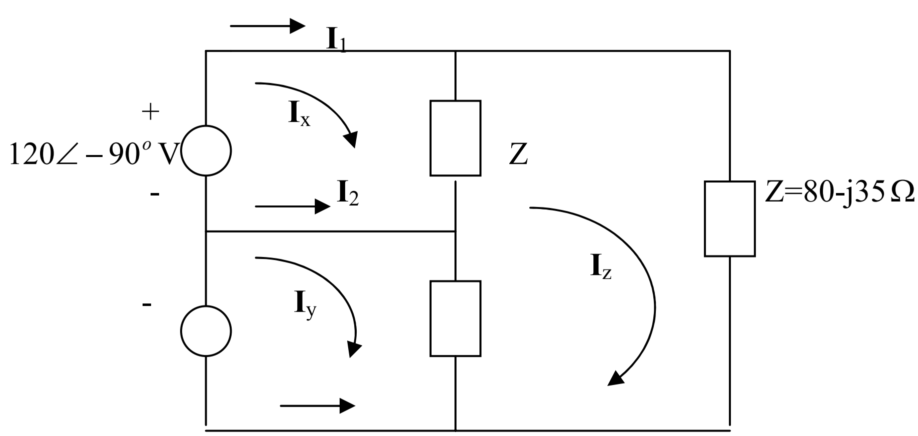
For mesh 2,

$$(4 - j3)\mathbf{I}_2 - 2\mathbf{I}_1 - 2\mathbf{I}_3 + 12 = 0$$
$$(4 - j3)\mathbf{I}_2 - j8 + 4 + 12 = 0$$
$$\mathbf{I}_2 = \frac{-16 + j8}{4 - j3} = -3.52 - j0.64$$

Thus,

$$\mathbf{V}_o = 2(\mathbf{I}_1 - \mathbf{I}_2) = (2)(3.52 + j4.64) = 7.04 + j9.28$$
$$\mathbf{V}_o = \underline{\mathbf{11.648\angle 52.82°\ V}}$$

Chapter 10, Solution 37.



$120\angle -30^o$ V Z
+ $\mathbf{I}_3$

For mesh x,

$$ZI_x - ZI_z = -j120 \quad (1)$$

For mesh y,

$$ZI_y - ZI_z = -120\angle 30^o = -103.92 + j60 \quad (2)$$

For mesh z,

$$-ZI_x - ZI_y + 3ZI_z = 0 \quad (3)$$

Putting (1) to (3) together leads to the following matrix equation:

$$\begin{pmatrix} (80-j35) & 0 & (-80+j35) \\ 0 & (80-j35) & (-80+j35) \\ (-80+j35) & (-80+j35) & (240-j105) \end{pmatrix} \begin{pmatrix} I_x \\ I_y \\ I_z \end{pmatrix} = \begin{pmatrix} -j120 \\ -103.92+j60 \\ 0 \end{pmatrix} \longrightarrow AI = B$$

Using MATLAB, we obtain

$$I = inv(A)*B = \begin{pmatrix} -1.9165 + j1.4115 \\ -2.1806 - j0.954 \\ -1.3657 + j0.1525 \end{pmatrix}$$

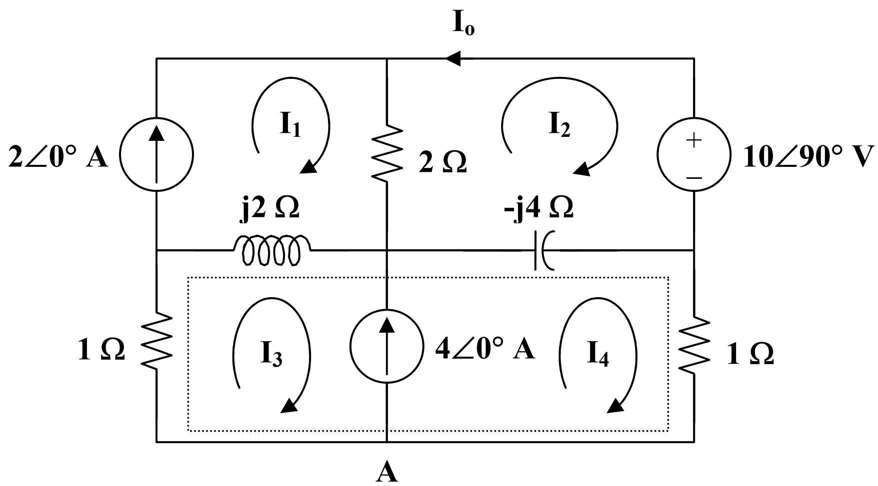
$$I_1 = I_x = -1.9165 + j1.4115 = \underline{2.3802\angle 143.6^o} \text{ A}$$

$$I_2 = I_y - I_x = -0.2641 - j2.3655 = \underline{2.3802\angle -96.37^o} \text{ A}$$

$$I_3 = -I_y = 2.1806 + j0.954 = \underline{2.3802\angle 23.63^o \text{ A}}$$

Chapter 10, Solution 38.

Consider the circuit below.



Clearly,

$$\mathbf{I}_1 = 2 \tag{1}$$

For mesh 2,

$$(2 - j4)\mathbf{I}_2 - 2\mathbf{I}_1 + j4\mathbf{I}_4 + 10\angle 90° = 0 \tag{2}$$

Substitute (1) into (2) to get

$$(1 - j2)\mathbf{I}_2 + j2\mathbf{I}_4 = 2 - j5$$

For the supermesh,

$$(1 + j2)\mathbf{I}_3 - j2\mathbf{I}_1 + (1 - j4)\mathbf{I}_4 + j4\mathbf{I}_2 = 0$$

$$j4\mathbf{I}_2 + (1 + j2)\mathbf{I}_3 + (1 - j4)\mathbf{I}_4 = j4 \tag{3}$$

At node A,

$$\mathbf{I}_3 = \mathbf{I}_4 - 4 \tag{4}$$

Substituting (4) into (3) gives

$$j2\mathbf{I}_2 + (1 - j)\mathbf{I}_4 = 2(1 + j3) \tag{5}$$

From (2) and (5),

$$\begin{bmatrix} 1 - j2 & j2 \\ j2 & 1 - j \end{bmatrix} \begin{bmatrix} \mathbf{I}_2 \\ \mathbf{I}_4 \end{bmatrix} = \begin{bmatrix} 2 - j5 \\ 2 + j6 \end{bmatrix}$$

$$\Delta = 3 - j3, \qquad \Delta_1 = 9 - j11$$

$$\mathbf{I}_o = -\mathbf{I}_2 = \frac{-\Delta_1}{\Delta} = \frac{-(9 - j11)}{3 - j3} = \frac{1}{3}(-10 + j)$$

$\mathbf{I}_o =$ **<u>3.35∠174.3° A</u>**

Chapter 10, Solution 39.

For mesh 1,

$$(28 - j15)I_1 - 8I_2 + j15I_3 = 12\angle 64^o \qquad (1)$$

For mesh 2,

$$-8I_1 + (8 - j9)I_2 - j16I_3 = 0 \qquad (2)$$

For mesh 3,

$$j15I_1 - j16I_2 + (10 + j)I_3 = 0 \qquad (3)$$

In matrix form, (1) to (3) can be cast as

$$\begin{pmatrix} (28 - j15) & -8 & j15 \\ -8 & (8 - j9) & -j16 \\ j15 & -j16 & (10 + j) \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ I_3 \end{pmatrix} = \begin{pmatrix} 12\angle 64^o \\ 0 \\ 0 \end{pmatrix} \quad \text{or} \quad AI = B$$

Using MATLAB,

I = inv(A)*B

$I_1 = -0.128 + j0.3593 = \underline{0.3814\angle 109.6^o\ A}$

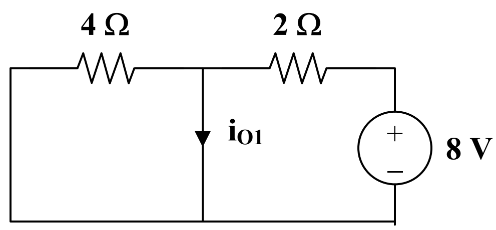
$I_2 = -0.1946 + j0.2841 = \underline{0.3443\angle 124.4^o\ A}$

$I_3 = 0.0718 - j0.1265 = \underline{0.1455\angle -60.42^o\ A}$

$$I_x = I_1 - I_2 = 0.0666 + j0.0752 = \underline{0.1005\angle 48.5^{o}\ \text{A}}$$

Chapter 10, Solution 40.

Let $i_O = i_{O1} + i_{O2}$, where i_{O1} is due to the dc source and i_{O2} is due to the ac source. For i_{O1}, consider the circuit in Fig. (a).

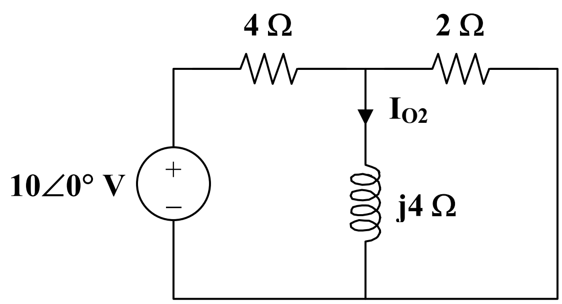


(a)

Clearly,

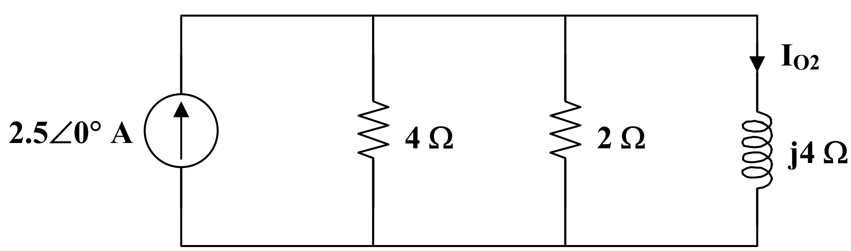
$$i_{O1} = 8/2 = 4\ \text{A}$$

For i_{O2}, consider the circuit in Fig. (b).



(b)

If we transform the voltage source, we have the circuit in Fig. (c), where $4 \,\|\, 2 = 4/3\ \Omega$.



(c)

By the current division principle,

$$\mathbf{I}_{O2} = \frac{4/3}{4/3 + j4}(2.5\angle 0°)$$

$$\mathbf{I}_{O2} = 0.25 - j0.75 = 0.79\angle -71.56°$$

Thus, $i_{O2} = 0.79\cos(4t - 71.56°)$ A

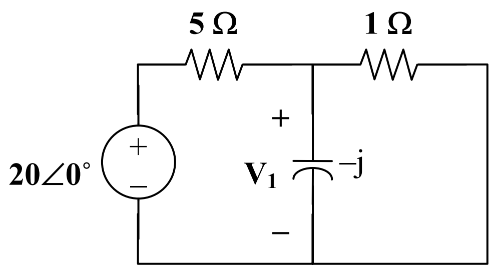
Therefore,

$$i_O = i_{O1} + i_{O2} = 4 + 0.79\cos(4t - 71.56°)\text{ A}$$

Chapter 10, Solution 41.

Let $v_x = v_1 + v_2$.

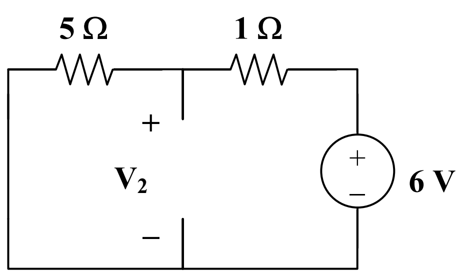
For v_1 we let the DC source equal zero.



$$\frac{V_1 - 20}{5} + \frac{V_1}{-j} + \frac{V_1}{1} = 0 \text{ which simplifies to } (1j - 5 + 5j)V_1 = 100j$$

$V_1 = 2.56\angle{-39.8^\circ}$ or $v_1 = 2.56\sin(500t - 39.8^\circ)$ V

Setting the AC signal to zero produces:



The 1-ohm resistor in series with the 5-ohm resistor creating a simple voltage divider yielding:

$v_2 = (5/6)6 = 5$ V.

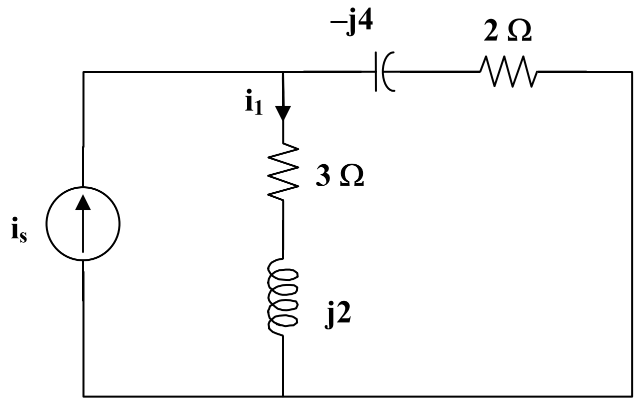
$v_x =$ **<u>{2.56sin(500t – 39.8˚) + 5} V.</u>**

Chapter 10, Solution 42.

Let $i_x = i_1 + i_2$, where i_1 and i_2 which are generated by i_s and v_s respectively. For i_1 we let $i_s = 6\sin 2t$ A becomes $I_s = 6\angle 0^\circ$, where $\omega = 2$.

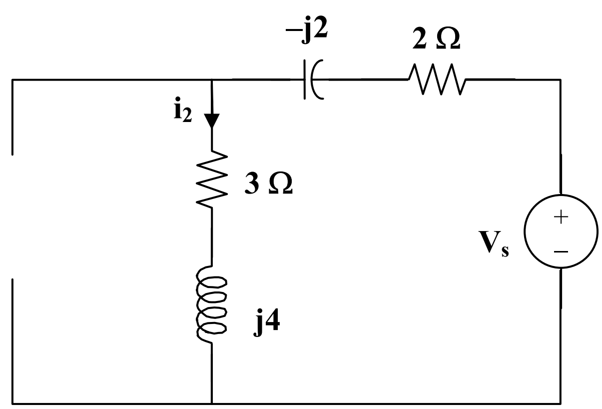
$$I_1 = \frac{2 - j4}{3 + j2 + 2 - j4} 6 = 12\frac{1 - j2}{5 - j2} = 3.724 - j3.31 = 4.983\angle -41.63^\circ$$

$i_1 = 4.983\sin(2t - 41.63^\circ)$ A



For i_2, we transform $v_s = 12\cos(4t - 30^\circ)$ into the frequency domain and get $V_s = 12\angle -30^\circ$.

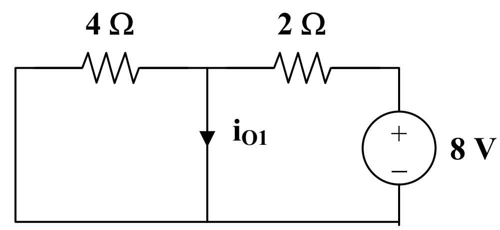
Thus, $I_2 = \dfrac{12\angle -30^\circ}{2 - j2 + 3 + j4} = 5.385\angle 8.2^\circ$ or $i_2 = 5.385\cos(4t + 8.2^\circ)$ A



i_x = **$[5.385\cos(4t + 8.2^\circ) + 4.983\sin(2t - 41.63^\circ)]$ A**.

Chapter 10, Solution 43.

Let $i_O = i_{O1} + i_{O2}$, where i_{O1} is due to the dc source and i_{O2} is due to the ac source. For i_{O1}, consider the circuit in Fig. (a).

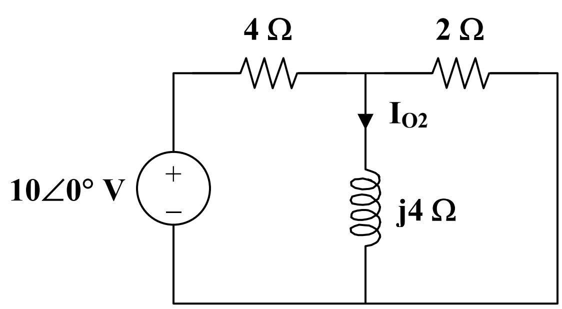


(a)

Clearly,

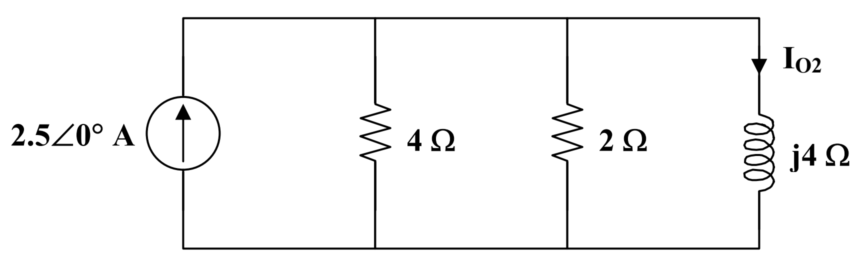
$$i_{O1} = 8/2 = 4 \text{ A}$$

For i_{O2}, consider the circuit in Fig. (b).



(b)

If we transform the voltage source, we have the circuit in Fig. (c), where $4 \,||\, 2 = 4/3\,\Omega$.



(c)

By the current division principle,

$$\mathbf{I}_{O2} = \frac{4/3}{4/3 + j4}(2.5\angle 0°)$$

$$\mathbf{I}_{O2} = 0.25 - j0.75 = 0.79\angle -71.56°$$

Thus,

$$i_{O2} = 0.79\cos(4t - 71.56°) \text{ A}$$

Therefore,

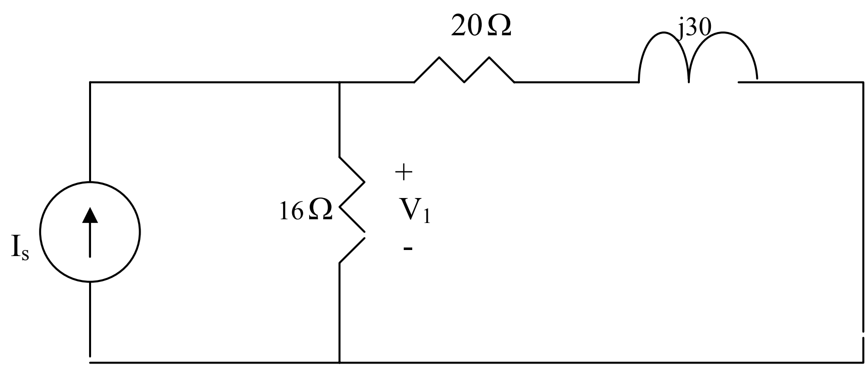
$$i_O = i_{O1} + i_{O2} = \underline{\mathbf{4 + 0.79\ cos\ (89)(4t - 71.56°)\ A}}$$

Chapter 10, Solution 44.

Let $v_x = v_1 + v_2$, where v_1 and v_2 are due to the current source and voltage source respectively.

For v_1, $\omega = 6$, $5\,H \longrightarrow j\omega L = j30$

The frequency-domain circuit is shown below.

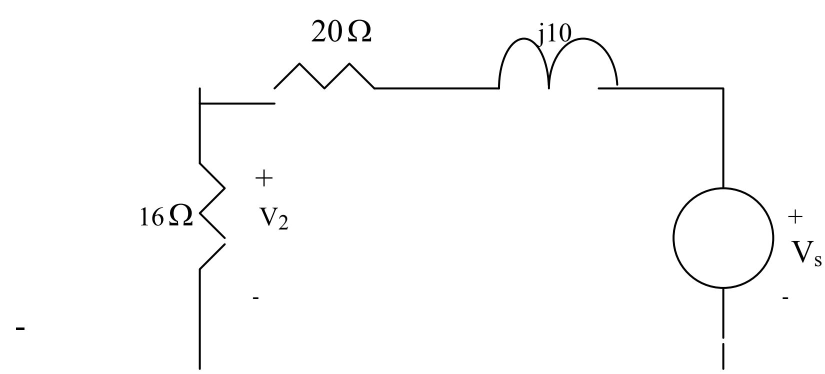


Let $Z = 16 // (20 + j30) = \dfrac{16(20 + j30)}{36 + j30} = 11.8 + j3.497 = 12.31\angle 16.5^o$

$V_1 = I_s Z = (12\angle 10^o)(12.31\angle 16.5^o) = 147.7\angle 26.5^o \longrightarrow v_1 = 147.7\cos(6t + 26.5^o)$ V

For v_2, $\omega = 2$, $5\,H \longrightarrow j\omega L = j10$

The frequency-domain circuit is shown below.



Using voltage division,

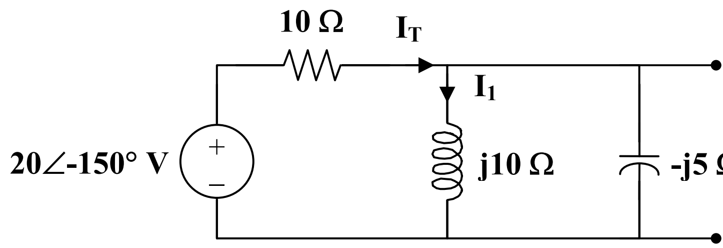
$$V_2 = \frac{16}{16+20+j10} V_s = \frac{16(50\angle 0^o)}{36+j10} = 21.41\angle -15.52^o \longrightarrow v_2 = 21.41\sin(2t-15.52^o)\ V$$

Thus,

$$v_x = \underline{147.7\cos(6t+26.5^o) + 21.41\sin(2t-15.52^o)\ V}$$

Chapter 10, Solution 45.

Let $\mathbf{I}_o = \mathbf{I}_1 + \mathbf{I}_2$, where $\mathbf{I}_1$ is due to the voltage source and $\mathbf{I}_2$ is due to the current source. For $\mathbf{I}_1$, consider the circuit in Fig. (a).



(a)

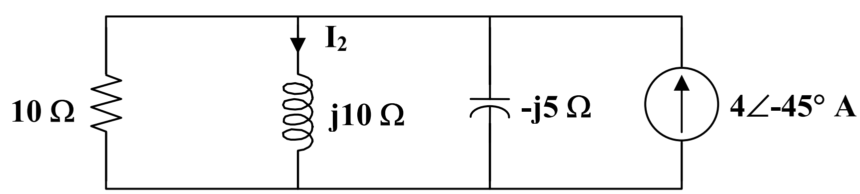
$$j10 \parallel -j5 = -j10$$

$$\mathbf{I}_T = \frac{20\angle -150°}{10-j10} = \frac{2\angle -150°}{1-j}$$

Using current division,

$$\mathbf{I}_1 = \frac{-j5}{j10-j5}\mathbf{I}_T = \frac{-j5}{j5}\cdot\frac{2\angle -150°}{1-j} = -(1+j)\angle -150°$$

For $\mathbf{I}_2$, consider the circuit in Fig. (b).



(b)

$$10 \parallel -j5 = \frac{-j10}{2-j}$$

Using current division,

$$\mathbf{I}_2 = \frac{-j10/(2-j)}{-j10/(2-j)+j10}(4\angle -45°) = -2(1+j)\angle -45°$$

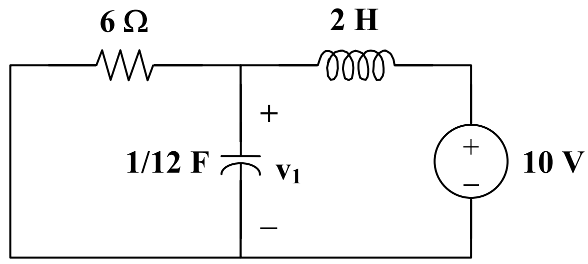
$$\mathbf{I}_o = \mathbf{I}_1 + \mathbf{I}_2 = -\sqrt{2}\angle -105° - 2\sqrt{2}\angle 0°$$

$$\mathbf{I}_o = -2.462 + j1.366 = 2.816\angle 150.98°$$

Therefore, $i_o =$ **2.816 cos(10t + 150.98°) A**

Chapter 10, Solution 46.

Let $v_o = v_1 + v_2 + v_3$, where v_1, v_2, and v_3 are respectively due to the 10-V dc source, the ac current source, and the ac voltage source. For v_1 consider the circuit in Fig. (a).



(a)

The capacitor is open to dc, while the inductor is a short circuit. Hence,

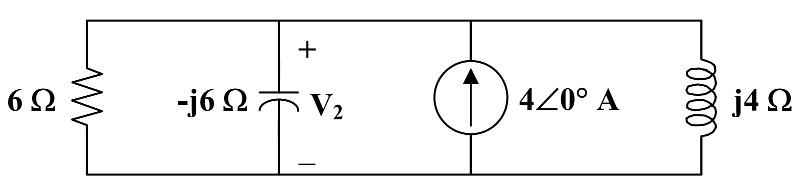
$$v_1 = 10 \text{ V}$$

For v_2, consider the circuit in Fig. (b).

$$\omega = 2$$

$$2 \text{ H} \longrightarrow j\omega L = j4$$

$$\frac{1}{12}\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/12)} = -j6$$



(b)

Applying nodal analysis,

$$4 = \frac{\mathbf{V}_2}{6} + \frac{\mathbf{V}_2}{-j6} + \frac{\mathbf{V}_2}{j4} = \left(\frac{1}{6} + \frac{j}{6} - \frac{j}{4}\right)\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{24}{1-j0.5} = 21.45\angle 26.56°$$

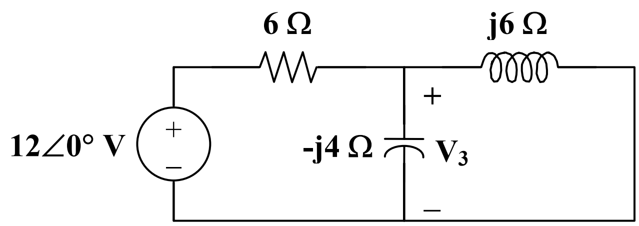
Hence, $v_2 = 21.45\sin(2t + 26.56°)$ V

For v_3, consider the circuit in Fig. (c).

$$\omega = 3$$

$$2\text{ H} \longrightarrow j\omega L = j6$$

$$\frac{1}{12}\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(3)(1/12)} = \text{-}j4$$



(c)

At the non-reference node,

$$\frac{12 - \mathbf{V}_3}{6} = \frac{\mathbf{V}_3}{\text{-}j4} + \frac{\mathbf{V}_3}{j6}$$

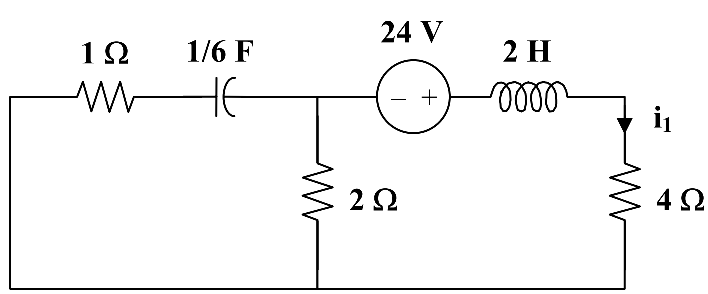
$$\mathbf{V}_3 = \frac{12}{1 + j0.5} = 10.73\angle\text{-}26.56°$$

Hence, $v_3 = 10.73\cos(3t - 26.56°)$ V

Therefore, $v_o =$ **<u>10 + 21.45 sin(2t + 26.56°) + 10.73 cos(3t – 26.56°) V</u>**

Chapter 10, Solution 47.

Let $i_o = i_1 + i_2 + i_3$, where i_1, i_2, and i_3 are respectively due to the 24-V dc source, the ac voltage source, and the ac current source. For i_1, consider the circuit in Fig. (a).



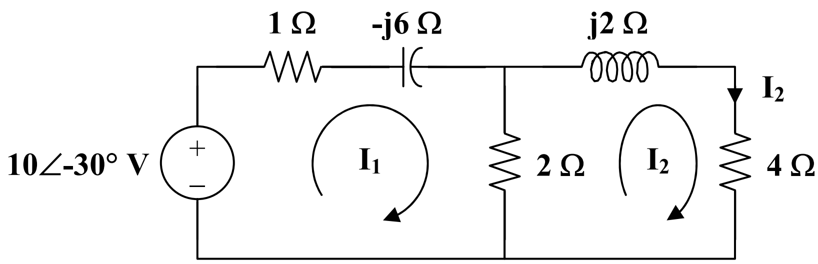
(a)

Since the capacitor is an open circuit to dc,

$$i_1 = \frac{24}{4+2} = 4 \text{ A}$$

For i_2, consider the circuit in Fig. (b).

$$\omega = 1$$
$$2 \text{ H} \longrightarrow j\omega L = j2$$
$$\frac{1}{6} \text{ F} \longrightarrow \frac{1}{j\omega C} = \text{-}j6$$



(b)

For mesh 1,

$$\text{-}10\angle\text{-}30° + (3 - j6)\mathbf{I}_1 - 2\mathbf{I}_2 = 0$$
$$10\angle\text{-}30° = 3(1 - 2j)\mathbf{I}_1 - 2\mathbf{I}_2$$
(1)

For mesh 2,

$$0 = \text{-}2\mathbf{I}_1 + (6 + j2)\mathbf{I}_2$$
$$\mathbf{I}_1 = (3 + j)\mathbf{I}_2$$
(2)

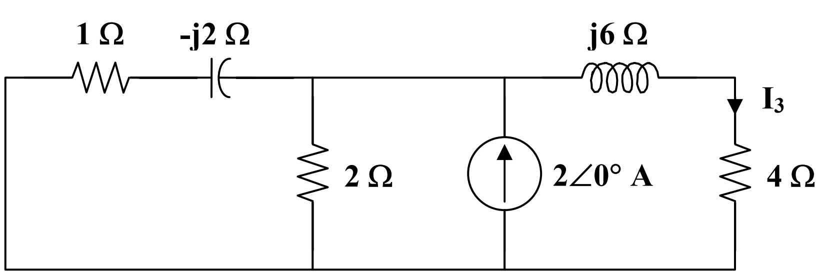
Substituting (2) into (1)

$$10\angle\text{-}30° = 13 - j15\mathbf{I}_2$$
$$\mathbf{I}_2 = 0.504\angle 19.1°$$

Hence, $i_2 = 0.504\sin(t + 19.1°) \text{ A}$

For i_3, consider the circuit in Fig. (c).

$$\omega = 3$$
$$2 \text{ H} \longrightarrow j\omega L = j6$$
$$\frac{1}{6} \text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(3)(1/6)} = \text{-}j2$$



(c)

$$2 \parallel (1-j2) = \frac{2(1-j2)}{3-j2}$$

Using current division,

$$\mathbf{I}_3 = \frac{\dfrac{2(1-j2)}{3-j2}\cdot(2\angle 0°)}{4+j6+\dfrac{2(1-j2)}{3-j2}} = \frac{2(1-j2)}{13+j3}$$

$$\mathbf{I}_3 = 0.3352\angle\text{-}76.43°$$

Hence $\quad i_3 = 0.3352\cos(3t - 76.43°)$ A

Therefore, $\quad i_o =$ **4 + 0.504 sin(t + 19.1°) + 0.3352 cos(3t – 76.43°) A**

Chapter 10, Solution 48.

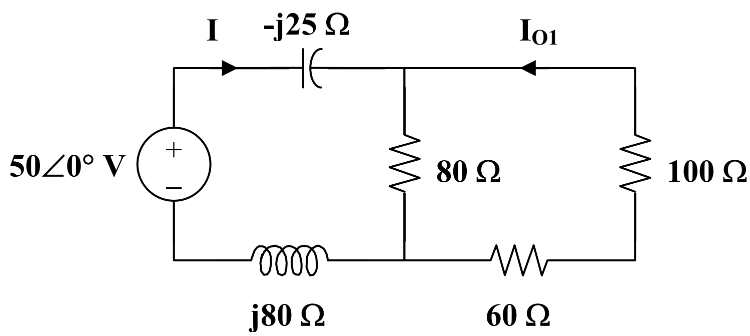
Let $i_O = i_{O1} + i_{O2} + i_{O3}$, where i_{O1} is due to the ac voltage source, i_{O2} is due to the dc voltage source, and i_{O3} is due to the ac current source. For i_{O1}, consider the circuit in Fig. (a).

$$\omega = 2000$$

$$50\cos(2000t) \longrightarrow 50\angle 0°$$

$$40 \text{ mH} \longrightarrow j\omega L = j(2000)(40\times 10^{-3}) = j80$$

$$20\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2000)(20\times 10^{-6})} = \text{-}j25$$



(a)

$$80 \parallel (60+100) = 160/3$$

$$\mathbf{I} = \frac{50}{160/3 + j80 - j25} = \frac{30}{32+j33}$$

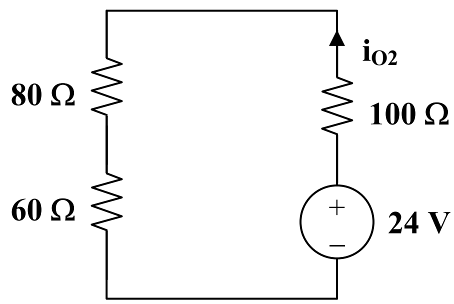
Using current division,

$$\mathbf{I}_{O1} = \frac{-80\,\mathbf{I}}{80+160} = \frac{-1}{3}\mathbf{I} = \frac{10\angle 180°}{46\angle 45.9°}$$

$$\mathbf{I}_{O1} = 0.217\angle 134.1°$$

Hence, $i_{O1} = 0.217\cos(2000t + 134.1°)$ A

For i_{O2}, consider the circuit in Fig. (b).



(b)

$$i_{O2} = \frac{24}{80+60+100} = 0.1 \text{ A}$$

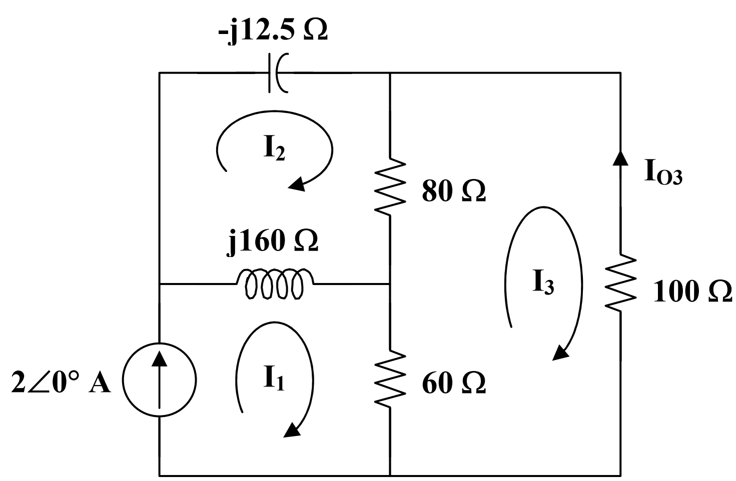
For i_{O3}, consider the circuit in Fig. (c).

$$\omega = 4000$$

$$2\cos(4000t) \longrightarrow 2\angle 0°$$

$$40 \text{ mH} \longrightarrow j\omega L = j(4000)(40\times 10^{-3}) = j160$$

$$20\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(4000)(20\times 10^{-6})} = -j12.5$$



(c)

For mesh 1,

$$\mathbf{I}_1 = 2 \qquad (1)$$

For mesh 2,

$$(80 + j160 - j12.5)\mathbf{I}_2 - j160\mathbf{I}_1 - 80\mathbf{I}_3 = 0$$

Simplifying and substituting (1) into this equation yields

$$(8 + j14.75)\mathbf{I}_2 - 8\mathbf{I}_3 = j32 \qquad (2)$$

For mesh 3,

$$240\mathbf{I}_3 - 60\mathbf{I}_1 - 80\mathbf{I}_2 = 0$$

Simplifying and substituting (1) into this equation yields

$$\mathbf{I}_2 = 3\mathbf{I}_3 - 1.5 \qquad (3)$$

Substituting (3) into (2) yields

$$(16 + j44.25)\mathbf{I}_3 = 12 + j54.125$$

$$\mathbf{I}_3 = \frac{12 + j54.125}{16 + j44.25} = 1.1782\angle 7.38°$$

$$\mathbf{I}_{O3} = -\mathbf{I}_3 = -1.1782\angle 7.38°$$

Hence, $i_{O3} = -1.1782\sin(4000t + 7.38°)$ A

Therefore, i_O = **0.1 + 0.217 cos(2000t + 134.1°) – 1.1782 sin(4000t + 7.38°) A**

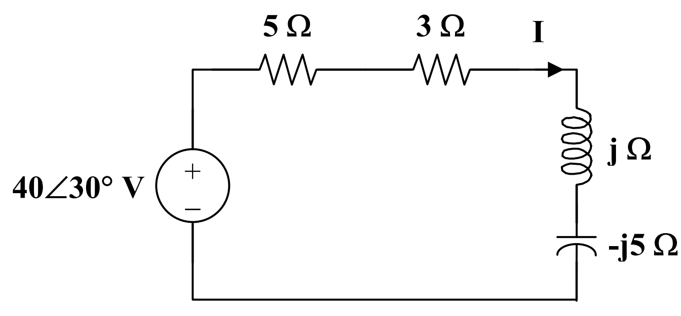
Chapter 10, Solution 49.

$$8\sin(200t + 30°) \longrightarrow 8\angle 30°, \quad \omega = 200$$

$$5 \text{ mH} \longrightarrow j\omega L = j(200)(5 \times 10^{-3}) = j$$

$$1 \text{ mF} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(200)(1 \times 10^{-3})} = -j5$$

After transforming the current source, the circuit becomes that shown in the figure below.



$$\mathbf{I} = \frac{40\angle 30°}{5 + 3 + j - j5} = \frac{40\angle 30°}{8 - j4} = 4.472\angle 56.56°$$

i = **4.472 sin(200t + 56.56°) A**

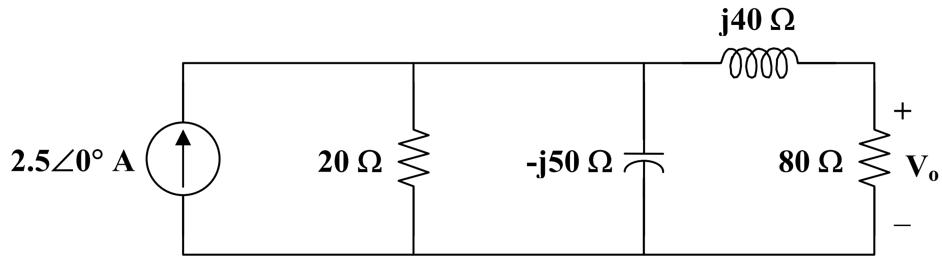
Chapter 10, Solution 50.

$$50\cos(10^5 t) \longrightarrow 50\angle 0°, \quad \omega = 10^5$$

$$0.4 \text{ mH} \longrightarrow j\omega L = j(10^5)(0.4\times 10^{-3}) = j40$$

$$0.2\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(10^5)(0.2\times 10^{-6})} = -j50$$

After transforming the voltage source, we get the circuit in Fig. (a).

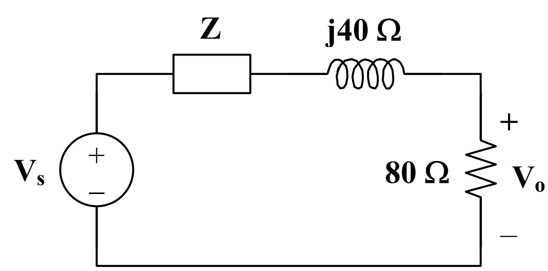


(a)

Let $\mathbf{Z} = 20 \,||\, -j50 = \dfrac{-j100}{2 - j5}$

and $\mathbf{V}_s = (2.5\angle 0°)\,\mathbf{Z} = \dfrac{-j250}{2 - j5}$

With these, the current source is transformed to obtain the circuit in Fig.(b).



(b)

By voltage division,

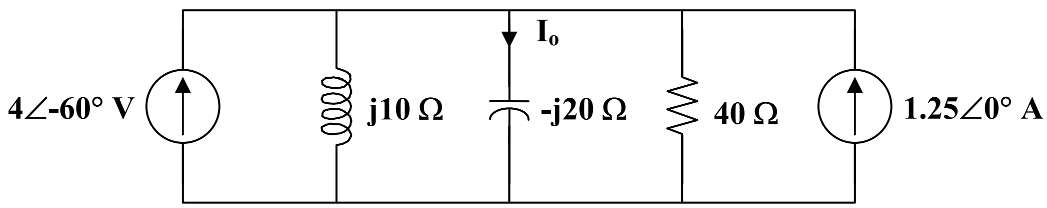
$$\mathbf{V}_o = \frac{80}{\mathbf{Z} + 80 + j40}\mathbf{V}_s = \frac{80}{\dfrac{-j100}{2 - j5} + 80 + j40} \cdot \frac{-j250}{2 - j5}$$

$$\mathbf{V}_o = \frac{8(-j250)}{36 - j42} = 36.15\angle -40.6°$$

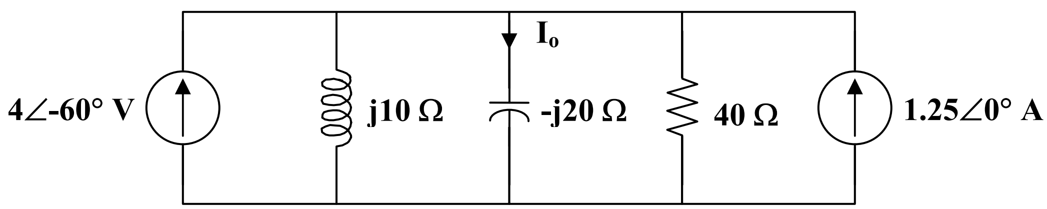
Therefore, $v_o =$ **<u>36.15 cos(10⁵ t – 40.6°) V</u>**

Chapter 10, Solution 51.

The original circuit with mesh currents and a node voltage labeled is shown below.



The following circuit is obtained by transforming the voltage sources.



Use nodal analysis to find $\mathbf{V}_x$.

$$4\angle\text{-}60° + 1.25\angle 0° = \left(\frac{1}{j10} + \frac{1}{\text{-}j20} + \frac{1}{40}\right)\mathbf{V}_x$$

$$3.25 - j3.464 = (0.025 - j0.05)\,\mathbf{V}_x$$

$$\mathbf{V}_x = \frac{3.25 - j3.464}{0.025 - j0.05} = 81.42 + j24.29 = 84.97\angle 16.61°$$

Thus, from the original circuit,

$$\mathbf{I}_1 = \frac{40\angle 30° - \mathbf{V}_x}{j10} = \frac{(34.64 + j20) - (81.42 + j24.29)}{j10}$$

$$\mathbf{I}_1 = \frac{\text{-}46.78 - j4.29}{j10} = \text{-}0.429 + j4.678 = \underline{\mathbf{4.698\angle 95.24°\ A}}$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_x - 50\angle 0°}{40} = \frac{31.42 + j24.29}{40}$$

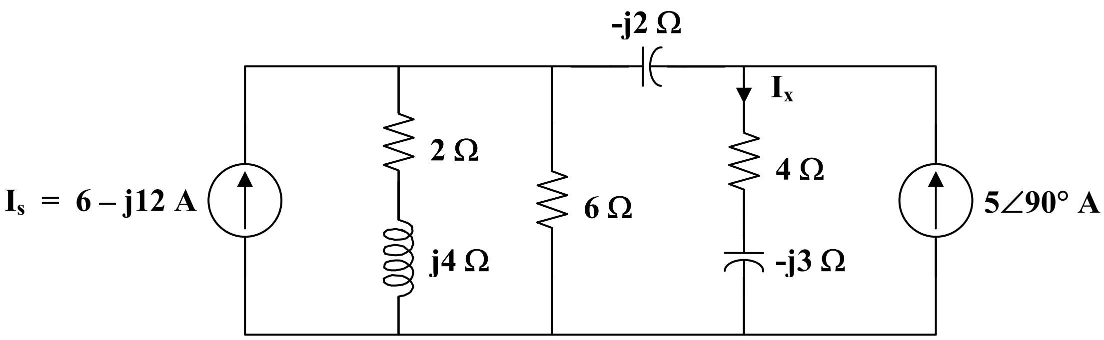
$$\mathbf{I}_2 = 0.7855 + j0.6072 = 0.9928\angle 37.7° = \underline{\mathbf{0.9928\angle 37.7°\ A}}$$

Chapter 10, Solution 52.

We transform the voltage source to a current source.

$$\mathbf{I}_s = \frac{60\angle 0°}{2 + j4} = 6 - j12$$

The new circuit is shown in Fig. (a).

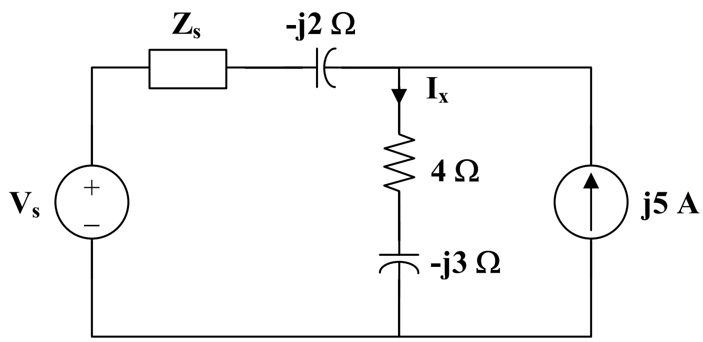


(a)

Let $$\mathbf{Z}_s = 6 \,\|\, (2 + j4) = \frac{6(2 + j4)}{8 + j4} = 2.4 + j1.8$$

$$\mathbf{V}_s = \mathbf{I}_s\,\mathbf{Z}_s = (6 - j12)(2.4 + j1.8) = 36 - j18 = 18(2 - j)$$

With these, we transform the current source on the left hand side of the circuit to a voltage source. We obtain the circuit in Fig. (b).

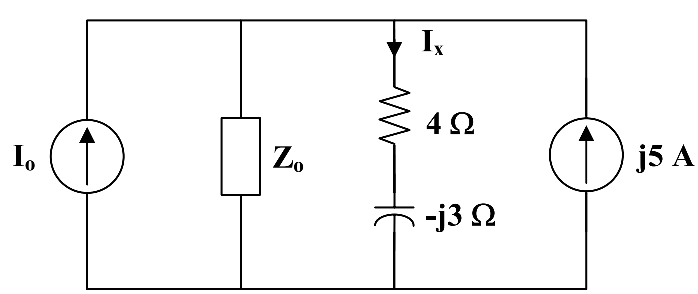


(b)

Let $$\mathbf{Z}_o = \mathbf{Z}_s - j2 = 2.4 - j0.2 = 0.2(12 - j)$$

$$\mathbf{I}_o = \frac{\mathbf{V}_s}{\mathbf{Z}_o} = \frac{18(2 - j)}{0.2(12 - j)} = 15.517 - j6.207$$

With these, we transform the voltage source in Fig. (b) to a current source. We obtain the circuit in Fig. (c).



(c)

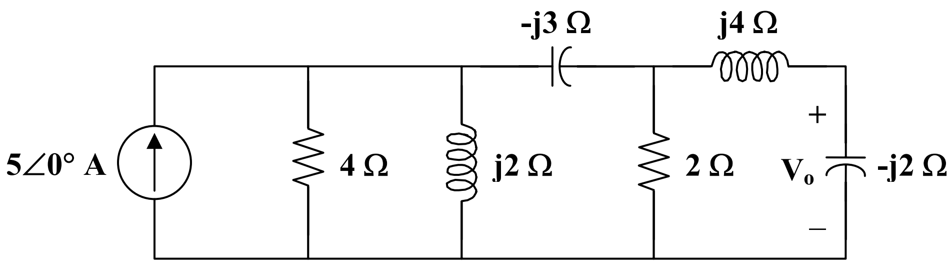
Using current division,

$$\mathbf{I}_x = \frac{\mathbf{Z}_o}{\mathbf{Z}_o + 4 - j3}(\mathbf{I}_o + j5) = \frac{2.4 - j0.2}{6.4 - j3.2}(15.517 - j1.207)$$

$$\mathbf{I}_x = 5 + j1.5625 = \underline{\mathbf{5.238\angle 17.35^\circ\ A}}$$

Chapter 10, Solution 53.

We transform the voltage source to a current source to obtain the circuit in Fig. (a).

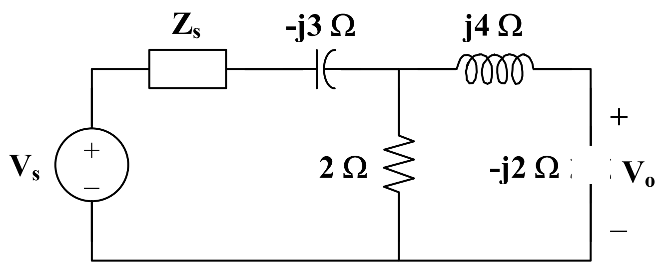


(a)

Let $\mathbf{Z}_s = 4 \,||\, j2 = \dfrac{j8}{4 + j2} = 0.8 + j1.6$

$$\mathbf{V}_s = (5\angle 0^\circ)\,\mathbf{Z}_s = (5)(0.8 + j1.6) = 4 + j8$$

With these, the current source is transformed so that the circuit becomes that shown in Fig. (b).

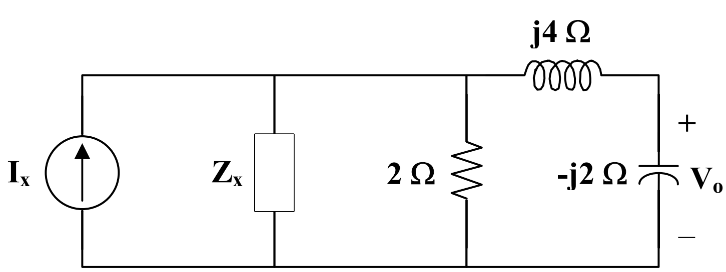


(b)

Let $\mathbf{Z}_x = \mathbf{Z}_s - j3 = 0.8 - j1.4$

$$\mathbf{I}_x = \frac{\mathbf{V}_s}{\mathbf{Z}_s} = \frac{4 + j8}{0.8 - j1.4} = -3.0769 + j4.6154$$

With these, we transform the voltage source in Fig. (b) to obtain the circuit in Fig. (c).

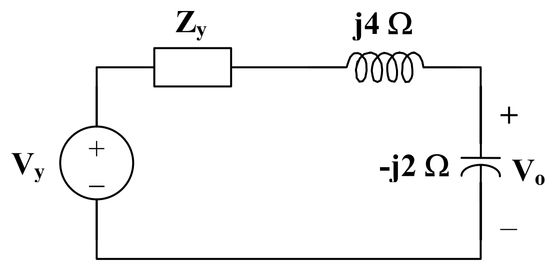


(c)

Let $\mathbf{Z}_y = 2 \parallel \mathbf{Z}_x = \frac{1.6 - j2.8}{2.8 - j1.4} = 0.8571 - j0.5714$

$$\mathbf{V}_y = \mathbf{I}_x \mathbf{Z}_y = (-3.0769 + j4.6154) \cdot (0.8571 - j0.5714) = j5.7143$$

With these, we transform the current source to obtain the circuit in Fig. (d).



(d)

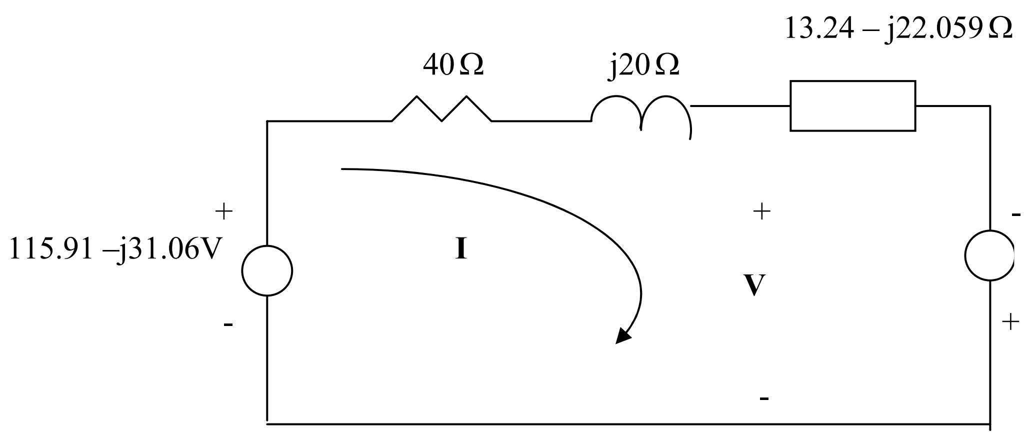
Using current division,

$$\mathbf{V}_o = \frac{-j2}{\mathbf{Z}_y + j4 - j2}\mathbf{V}_y = \frac{-j2(j5.7143)}{0.8571 - j0.5714 + j4 - j2} = \underline{\mathbf{(3.529 - j5.883)\ V}}$$

Chapter 10, Solution 54.

$$50 // (-j30) = \frac{50x(-j30)}{50 - j30} = 13.24 - j22.059$$

We convert the current source to voltage source and obtain the circuit below.



Applying KVL gives

-115.91 + j31.058 + (53.24-j2.059)I -134.95 + j74.912 = 0

or $I = \frac{-250.86 + j105.97}{53.24 - j2.059} = -4.7817 + j1.8055$

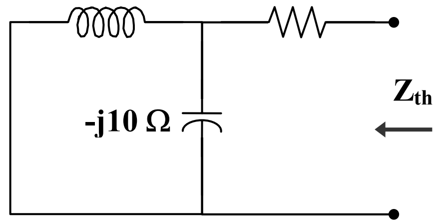
But $-V + (40 + j20)I + V = 0 \longrightarrow V = V_s - (40 + j20)I$

$$V = 115.91 - j31.05 - (40 + j20)(-4.7817 + j1.8055) = \underline{124.06\angle -154^{o}\ V}$$

which agrees with the result in Prob. 10.7.

Chapter 10, Solution 55.

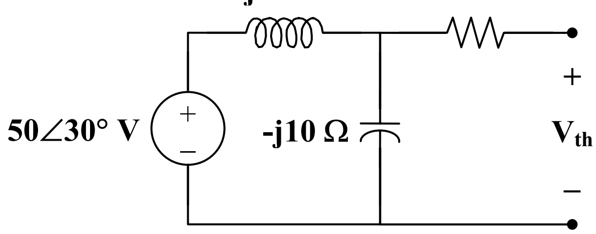
(a) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).



(a)

$$\mathbf{Z}_N = \mathbf{Z}_{th} = 10 + j20 \,||\, (-j10) = 10 + \frac{(j20)(-j10)}{j20 - j10}$$
$$= 10 - j20 = \underline{\mathbf{22.36\angle -63.43^\circ\ \Omega}}$$

To find $\mathbf{V}_{th}$, consider the circuit in Fig. (b).

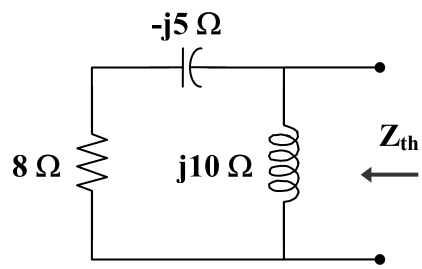


(b)

$$\mathbf{V}_{th} = \frac{-j10}{j20 - j10}(50\angle 30^\circ) = \underline{\mathbf{-50\angle 30^\circ\ V}}$$

$$\mathbf{I}_N = \frac{\mathbf{V}_{th}}{\mathbf{Z}_{th}} = \frac{-50\angle 30^\circ}{22.36\angle -63.43^\circ} = \underline{\mathbf{2.236\angle 273.4^\circ\ A}}$$

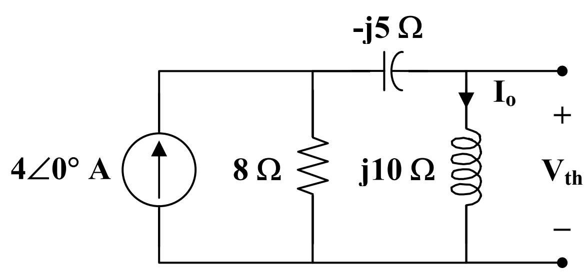
(b) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (c).



(c)

$$\mathbf{Z}_N = \mathbf{Z}_{th} = j10 \,||\, (8 - j5) = \frac{(j10)(8 - j5)}{j10 + 8 - j5} = \underline{\mathbf{10\angle 26^\circ\ \Omega}}$$

To obtain $\mathbf{V}_{th}$, consider the circuit in Fig. (d).



(d)

By current division,

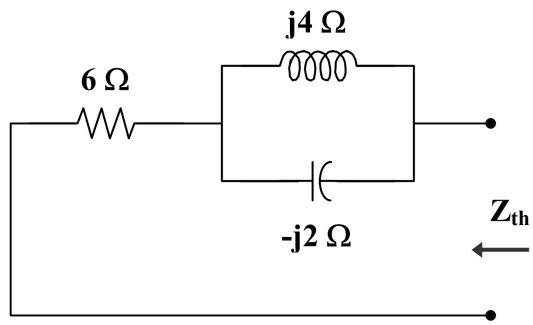
$$\mathbf{I}_o = \frac{8}{8 + j10 - j5}(4\angle 0^\circ) = \frac{32}{8 + j5}$$

$$\mathbf{V}_{th} = j10\mathbf{I}_o = \frac{j320}{8 + j5} = \underline{\mathbf{33.92\angle 58^\circ\ V}}$$

$$\mathbf{I}_N = \frac{\mathbf{V}_{th}}{\mathbf{Z}_{th}} = \frac{33.92\angle 58^\circ}{10\angle 26^\circ} = \underline{\mathbf{3.392\angle 32^\circ\ A}}$$

Chapter 10, Solution 56.

(a) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).



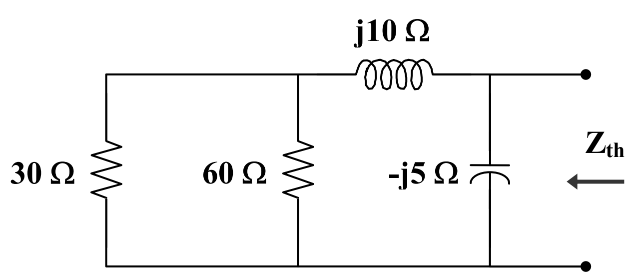
(a)

$$\mathbf{Z}_N = \mathbf{Z}_{th} = 6 + j4 \,||\, (-j2) = 6 + \frac{(j4)(-j2)}{j4 - j2} = 6 - j4$$
$$= \underline{\mathbf{7.211\angle\text{-}33.69° \ \Omega}}$$

By placing short circuit at terminals a-b, we obtain,
$\mathbf{I}_N = \underline{\mathbf{2\angle 0° \ A}}$

$$\mathbf{V}_{th} = \mathbf{Z}_{th}\,\mathbf{I}_{th} = (7.211\angle -33.69°)(2\angle 0°) = \underline{\mathbf{14.422\angle\text{-}33.69° \ V}}$$

(b) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (b).

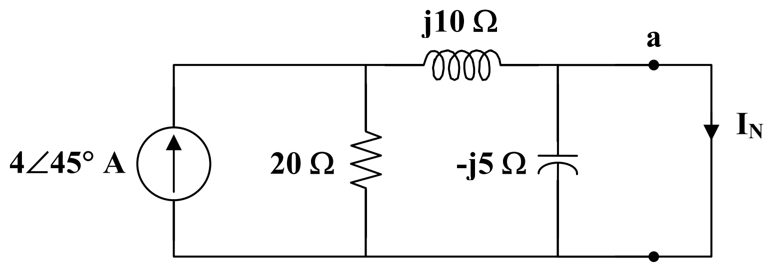


(b)

$$30 \,||\, 60 = 20$$

$$\mathbf{Z}_N = \mathbf{Z}_{th} = -j5 \,||\, (20 + j10) = \frac{(-j5)(20 + j10)}{20 + j5}$$
$$= \underline{\mathbf{5.423\angle\text{-}77.47° \ \Omega}}$$

To find $\mathbf{V}_{th}$ and $\mathbf{I}_N$, we transform the voltage source and combine the 30 Ω and 60 Ω resistors. The result is shown in Fig. (c).



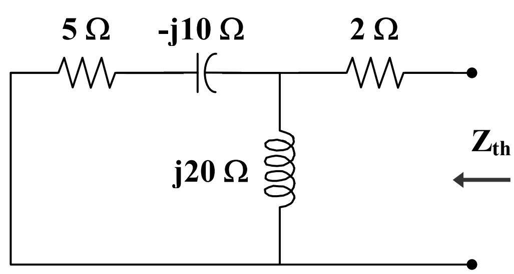
(c)

$$\mathbf{I}_N = \frac{20}{20 + j10}(4\angle 45°) = \frac{2}{5}(2 - j)(4\angle 45°)$$
$$= \underline{\mathbf{3.578\angle 18.43°\ A}}$$

$$\mathbf{V}_{th} = \mathbf{Z}_{th}\,\mathbf{I}_N = (5.423\angle -77.47°)(3.578\angle 18.43°)$$
$$= \underline{\mathbf{19.4\angle -59°\ V}}$$

Chapter 10, Solution 57.

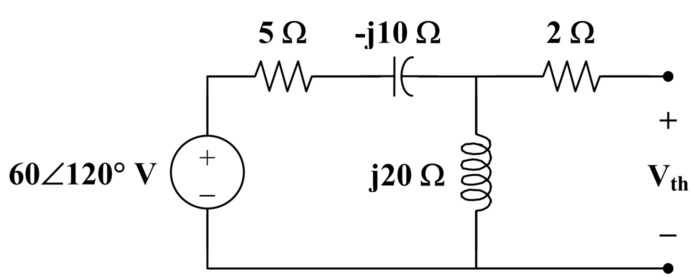
To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).



(a)

$$\mathbf{Z}_N = \mathbf{Z}_{th} = 2 + j20 \,||\, (5 - j10) = 2 + \frac{(j20)(5 - j10)}{5 + j10}$$
$$= 18 - j12 = \underline{\mathbf{21.633\angle -33.7°\ \Omega}}$$

To find $\mathbf{V}_{th}$, consider the circuit in Fig. (b).



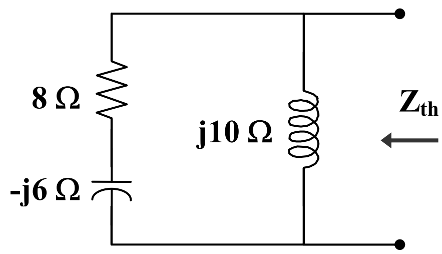
(b)

$$\mathbf{V}_{th} = \frac{j20}{5 - j10 + j20}(60\angle 120°) = \frac{j4}{1 + j2}(60\angle 120°)$$
$$= \underline{\mathbf{107.3\angle 146.56°\ V}}$$

$$\mathbf{I}_N = \frac{\mathbf{V}_{th}}{\mathbf{Z}_{th}} = \frac{107.3\angle 146.56°}{21.633\angle -33.7°} = \underline{\mathbf{4.961\angle -179.7°\ A}}$$

Chapter 10, Solution 58.

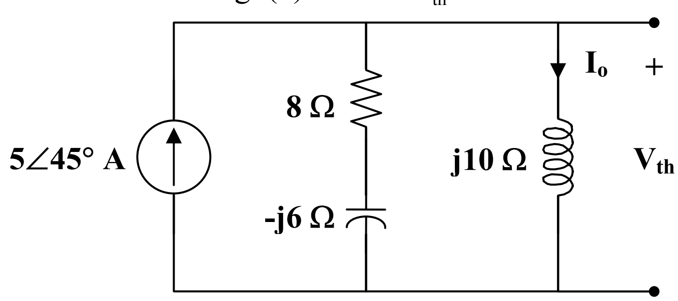
Consider the circuit in Fig. (a) to find $\mathbf{Z}_{th}$.



(a)

$$\mathbf{Z}_{th} = j10 \,||\, (8 - j6) = \frac{(j10)(8 - j6)}{8 + j4} = 5(2 + j)$$
$$= \underline{\mathbf{11.18\angle 26.56°\ \Omega}}$$

Consider the circuit in Fig. (b) to find $\mathbf{V}_{th}$.



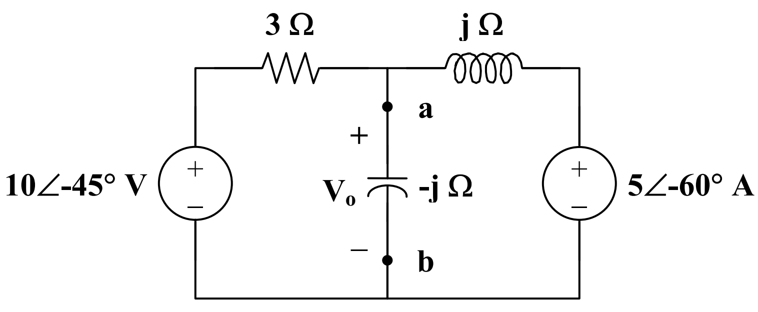
(b)

$$\mathbf{I}_o = \frac{8 - j6}{8 - j6 + j10}(5\angle 45°) = \frac{4 - j3}{4 + j2}(5\angle 45°)$$

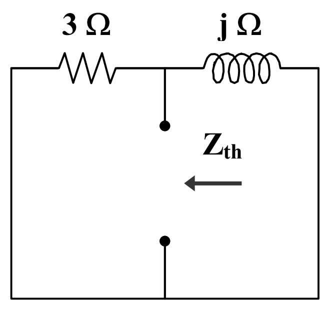
$$\mathbf{V}_{th} = j10\mathbf{I}_o = \frac{(j10)(4 - j3)(5\angle 45°)}{(2)(2 + j)} = \underline{\mathbf{55.9\angle 71.56°\ V}}$$

Chapter 10, Solution 59.

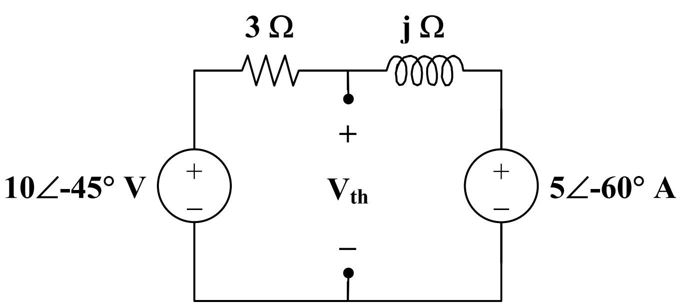
The frequency-domain equivalent circuit is shown in Fig. (a). Our goal is to find $\mathbf{V}_{\text{th}}$ and $\mathbf{Z}_{\text{th}}$ across the terminals of the capacitor as shown in Figs. (b) and (c).



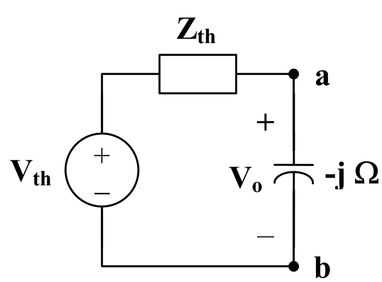
(a)



(b)



(c)



(d)

From Fig. (b),

$$\mathbf{Z}_{\text{th}} = 3 \parallel j = \frac{j3}{3+j} = \frac{3}{10}(1+j3)$$

From Fig.(c),

$$\frac{10\angle\text{-}45° - \mathbf{V}_{\text{th}}}{3} + \frac{5\angle\text{-}60° - \mathbf{V}_{\text{th}}}{j} = 0$$

$$\mathbf{V}_{\text{th}} = \frac{10\angle\text{-}45° - 15\angle 30°}{1 - j3}$$

From Fig. (d),

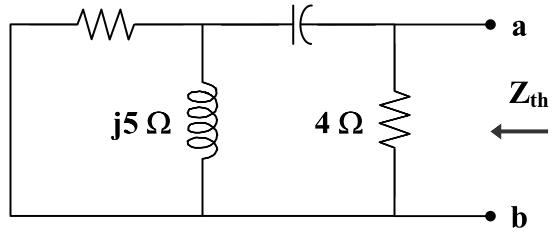
$$\mathbf{V}_o = \frac{-j}{\mathbf{Z}_{th} - j}\mathbf{V}_{th} = 10\angle -45° - 15\angle 30°$$

$$\mathbf{V}_o = 15.73\angle 247.9° \text{ V}$$

Therefore, $v_o = \underline{\mathbf{15.73\cos(t + 247.9°)\ V}}$

Chapter 10, Solution 60.

(a) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).

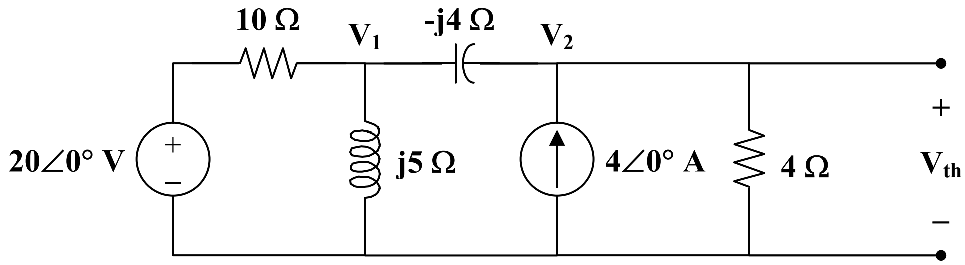


(a)

$$\mathbf{Z}_{th} = 4 \,||\, (-j4 + 10 \,||\, j5) = 4 \,||\, (-j4 + 2 + j4)$$

$$\mathbf{Z}_{th} = 4 \,||\, 2 = \underline{1.333\ \Omega}$$

To find $\mathbf{V}_{th}$, consider the circuit in Fig. (b).



(b)

At node 1,

$$\frac{20 - \mathbf{V}_1}{10} = \frac{\mathbf{V}_1}{j5} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j4}$$

$$(1 + j0.5)\mathbf{V}_1 - j2.5\mathbf{V}_2 = 20$$

(1)

At node 2,

$$4 + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j4} = \frac{\mathbf{V}_2}{4}$$

$$\mathbf{V}_1 = (1 - j)\,\mathbf{V}_2 + j16 \qquad (2)$$

Substituting (2) into (1) leads to

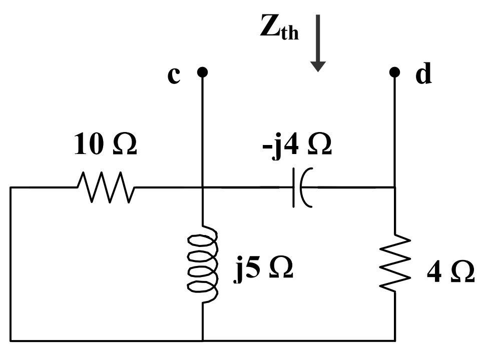
$$28 - j16 = (1.5 - j3)\,\mathbf{V}_2$$

$$\mathbf{V}_2 = \frac{28 - j16}{1.5 - j3} = 8 + j5.333$$

Therefore,

$$\mathbf{V}_{th} = \mathbf{V}_2 = \underline{\mathbf{9.615\angle 33.69° \ V}}$$

(b) To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (c).



(c)

$$\mathbf{Z}_{th} = -j4 \,||\, (4 + 10 \,||\, j5) = -j4 \,||\left(4 + \frac{j10}{2 + j}\right)$$

$$\mathbf{Z}_{th} = -j4 \,||\, (6 + j4) = \frac{-j4}{6}(6 + j4) = \underline{\mathbf{2.667 - j4\ \Omega}}$$

To find $\mathbf{V}_{th}$,we will make use of the result in part (a).

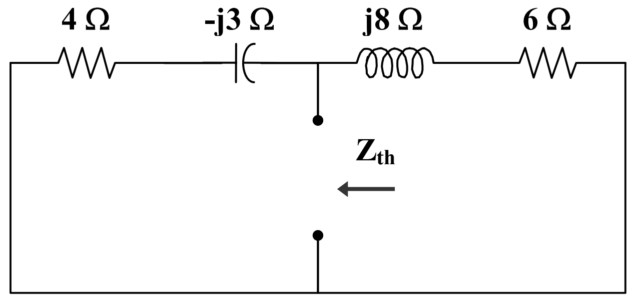
$$\mathbf{V}_2 = 8 + j5.333 = (8/3)(3 + j2)$$

$$\mathbf{V}_1 = (1 - j)\,\mathbf{V}_2 + j16 = j16 + (8/3)(5 - j)$$

$$\mathbf{V}_{th} = \mathbf{V}_1 - \mathbf{V}_2 = 16/3 + j8 = \underline{\mathbf{9.614\angle 56.31° \ V}}$$

Chapter 10, Solution 61.

First, we need to find $\mathbf{V}_{th}$ and $\mathbf{Z}_{th}$ across the 1 Ω resistor.

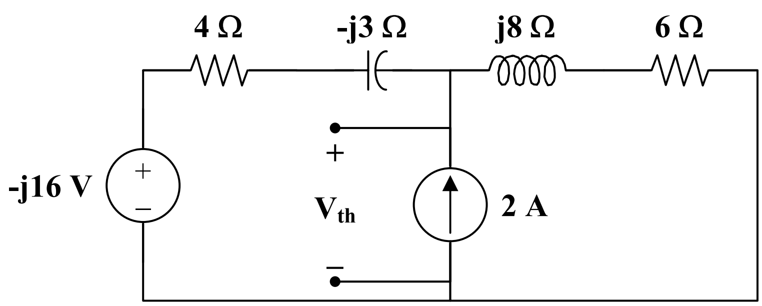


(a)

From Fig. (a),

$$\mathbf{Z}_{th} = (4 - j3) \parallel (6 + j8) = \frac{(4 - j3)(6 + j8)}{10 + j5} = 4.4 - j0.8$$

$$\mathbf{Z}_{th} = \underline{\mathbf{4.472\angle\text{-}10.3° \ \Omega}}$$



(b)

From Fig. (b),

$$\frac{-j16 - \mathbf{V}_{th}}{4 - j3} + 2 = \frac{\mathbf{V}_{th}}{6 + j8}$$

$$\mathbf{V}_{th} = \frac{3.92 - j2.56}{0.22 + j0.4} = 20.93\angle -43.45°$$

$$\mathbf{V}_{o} = \frac{\mathbf{V}_{th}}{1 + \mathbf{Z}_{th}} = \frac{20.93\angle -43.45°}{5.46\angle -8.43°}$$

$$\mathbf{V}_{o} = 3.835\angle -35.02°$$

Therefore, v_o = **<u>3.835 cos(4t – 35.02°) V</u>**

Chapter 10, Solution 62.

First, we transform the circuit to the frequency domain.

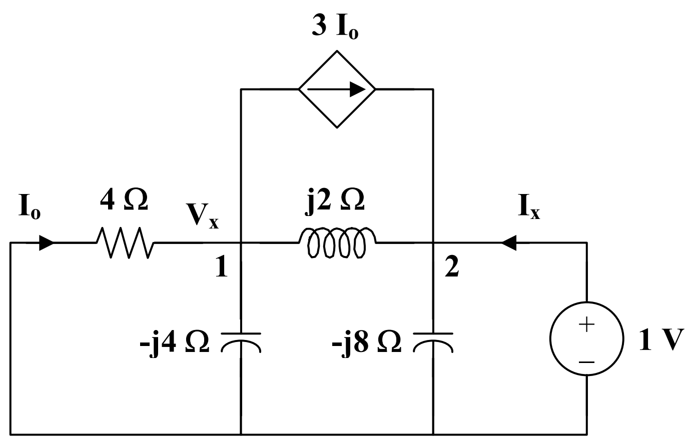
$$12\cos(t) \longrightarrow 12\angle 0°, \quad \omega = 1$$

$$2\text{ H} \longrightarrow j\omega L = j2$$

$$\frac{1}{4}\text{F} \longrightarrow \frac{1}{j\omega C} = \text{-}j4$$

$$\frac{1}{8}\text{F} \longrightarrow \frac{1}{j\omega C} = \text{-}j8$$

To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).



(a)

At node 1,

$$\frac{\mathbf{V}_x}{4} + \frac{\mathbf{V}_x}{\text{-}j4} + 3\mathbf{I}_o = \frac{1 - \mathbf{V}_x}{j2}, \qquad \text{where } \mathbf{I}_o = \frac{\text{-}\mathbf{V}_x}{4}$$

Thus,

$$\frac{\mathbf{V}_x}{\text{-}j4} - \frac{2\mathbf{V}_x}{4} = \frac{1 - \mathbf{V}_x}{j2}$$

$$\mathbf{V}_x = 0.4 + j0.8$$

At node 2,

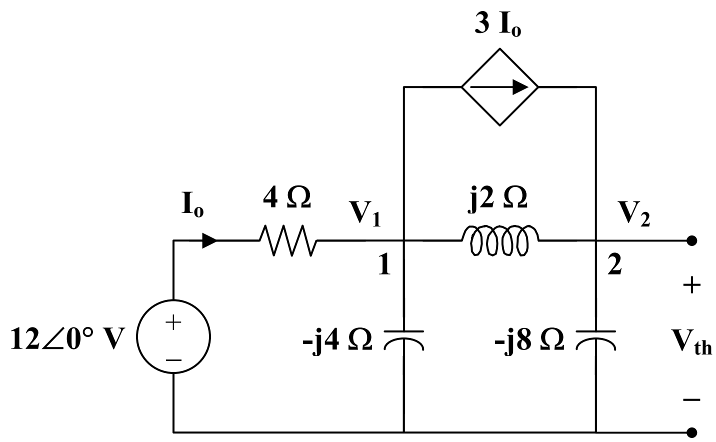
$$\mathbf{I}_x + 3\mathbf{I}_o = \frac{1}{\text{-}j8} + \frac{1 - \mathbf{V}_x}{j2}$$

$$\mathbf{I}_x = (0.75 + j0.5)\mathbf{V}_x - j\frac{3}{8}$$

$$\mathbf{I}_x = \text{-}0.1 + j0.425$$

$$\mathbf{Z}_{th} = \frac{1}{\mathbf{I}_x} = \text{-}0.5246 - j2.229 = 2.29\angle\text{-}103.24°\,\Omega$$

To find $\mathbf{V}_{th}$, consider the circuit in Fig. (b).



(b)

At node 1,

$$\frac{12-\mathbf{V}_1}{4} = 3\mathbf{I}_o + \frac{\mathbf{V}_1}{-j4} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j2}, \qquad \text{where} \quad \mathbf{I}_o = \frac{12-\mathbf{V}_1}{4}$$

$$24 = (2+j)\,\mathbf{V}_1 - j2\,\mathbf{V}_2 \tag{1}$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{j2} + 3\mathbf{I}_o = \frac{\mathbf{V}_2}{-j8}$$

$$72 = (6+j4)\,\mathbf{V}_1 - j3\,\mathbf{V}_2 \tag{2}$$

From (1) and (2),

$$\begin{bmatrix} 24 \\ 72 \end{bmatrix} = \begin{bmatrix} 2+j & -j2 \\ 6+j4 & -j3 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix}$$

$$\Delta = -5 + j6, \qquad \Delta_2 = -j24$$

$$\mathbf{V}_{th} = \mathbf{V}_2 = \frac{\Delta_2}{\Delta} = 3.073\angle -219.8°$$

Thus,

$$\mathbf{V}_o = \frac{2}{2+\mathbf{Z}_{th}}\mathbf{V}_{th} = \frac{(2)(3.073\angle -219.8°)}{1.4754 - j2.229}$$

$$\mathbf{V}_o = \frac{6.146\angle -219.8°}{2.673\angle -56.5°} = 2.3\angle -163.3°$$

Therefore, $v_o =$ **2.3 cos(t – 163.3°) V**

Chapter 10, Solution 63.

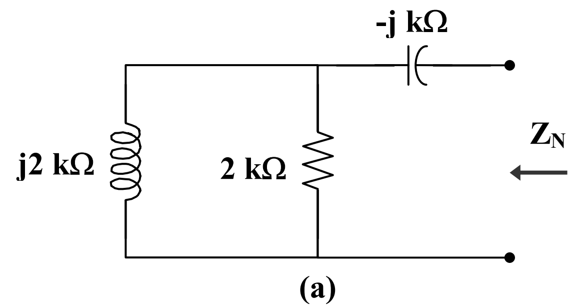
Transform the circuit to the frequency domain.

$$4\cos(200t + 30°) \longrightarrow 4\angle 30°, \quad \omega = 200$$

$$10 \text{ H} \longrightarrow j\omega L = j(200)(10) = j2 \text{ k}\Omega$$

$$5\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(200)(5\times 10^{-6})} = -j \text{ k}\Omega$$

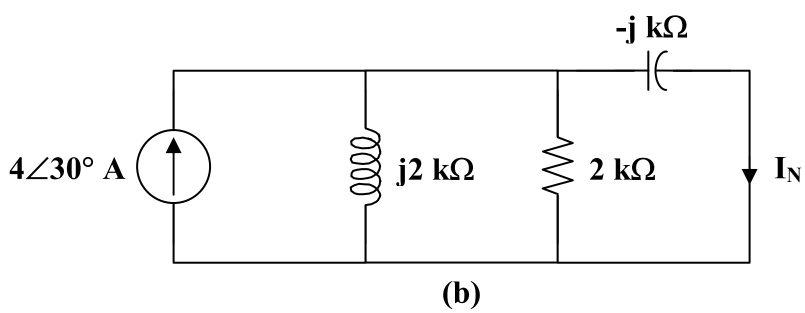
$\mathbf{Z}_N$ is found using the circuit in Fig. (a).



(a)

$$\mathbf{Z}_N = -j + 2 \parallel j2 = -j + 1 + j = 1 \text{ k}\Omega$$

We find $\mathbf{I}_N$ using the circuit in Fig. (b).



(b)

$$j2 \parallel 2 = 1 + j$$

By the current division principle,

$$\mathbf{I}_N = \frac{1+j}{1+j-j}(4\angle 30°) = 5.657\angle 75°$$

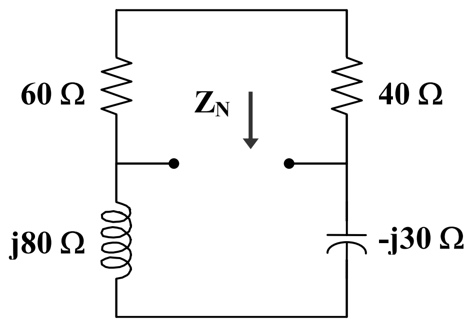
Therefore,

$$i_N = \underline{\mathbf{5.657\cos(200t + 75°)\ A}}$$

$$\mathbf{Z}_N = \underline{\mathbf{1\ k\Omega}}$$

Chapter 10, Solution 64.

$\mathbf{Z}_N$ is obtained from the circuit in Fig. (a).

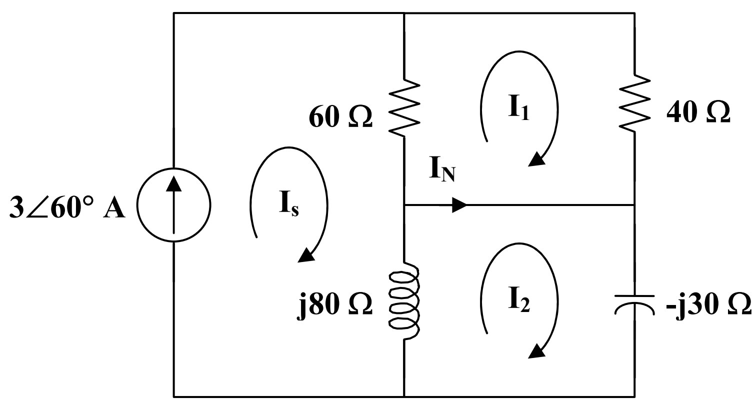


(a)

$$\mathbf{Z}_N = (60+40) \,||\, (j80 - j30) = 100 \,||\, j50 = \frac{(100)(j50)}{100 + j50}$$

$$\mathbf{Z}_N = 20 + j40 = \underline{\mathbf{44.72\angle 63.43° \ \Omega}}$$

To find $\mathbf{I}_N$, consider the circuit in Fig. (b).



(b)

$$\mathbf{I}_s = 3\angle 60°$$

For mesh 1,

$$100\mathbf{I}_1 - 60\mathbf{I}_s = 0$$

$$\mathbf{I}_1 = 1.8\angle 60°$$

For mesh 2,

$$(j80 - j30)\mathbf{I}_2 - j80\mathbf{I}_s = 0$$

$$\mathbf{I}_2 = 4.8\angle 60°$$

$$\mathbf{I}_N = \mathbf{I}_1 - \mathbf{I}_2 = \underline{\mathbf{3\angle 60° \ A}}$$

Chapter 10, Solution 65.

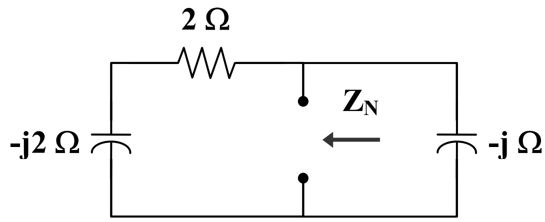
$$5\cos(2t) \longrightarrow 5\angle 0°, \quad \omega = 2$$

$$4\text{ H} \longrightarrow j\omega L = j(2)(4) = j8$$

$$\frac{1}{4}\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/4)} = -j2$$

$$\frac{1}{2}\text{ F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(2)(1/2)} = -j$$

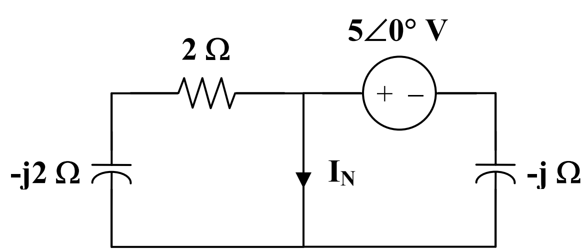
To find $\mathbf{Z}_N$, consider the circuit in Fig. (a).



(a)

$$\mathbf{Z}_N = -j \,||\, (2 - j2) = \frac{-j(2 - j2)}{2 - j3} = \frac{1}{13}(2 - j10)$$

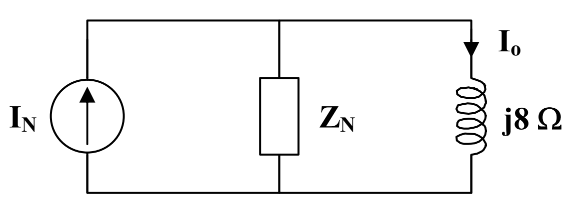
To find $\mathbf{I}_N$, consider the circuit in Fig. (b).



(b)

$$\mathbf{I}_N = \frac{5\angle 0°}{-j} = j5$$

The Norton equivalent of the circuit is shown in Fig. (c).



(c)

Using current division,

$$\mathbf{I}_o = \frac{\mathbf{Z}_N}{\mathbf{Z}_N + j8}\mathbf{I}_N = \frac{(1/13)(2 - j10)(j5)}{(1/13)(2 - j10) + j8} = \frac{50 + j10}{2 + j94}$$

$$\mathbf{I}_o = 0.1176 - j0.5294 = 0542\angle\text{-}77.47°$$

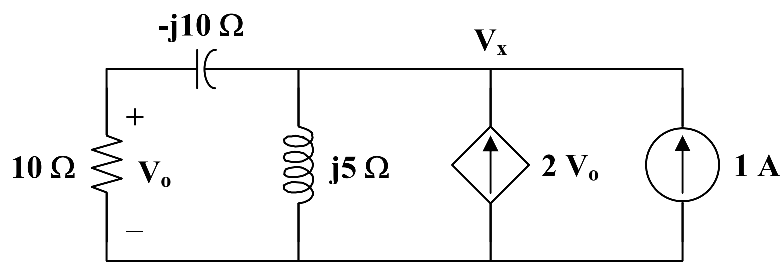
Therefore, i_o = **<u>0.542 cos(2t – 77.47°) A</u>**

Chapter 10, Solution 66.

$$\omega = 10$$

$$0.5\text{ H} \longrightarrow j\omega L = j(10)(0.5) = j5$$

$$10\text{ mF} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(10)(10\times10^{-3})} = \text{-}j10$$



(a)

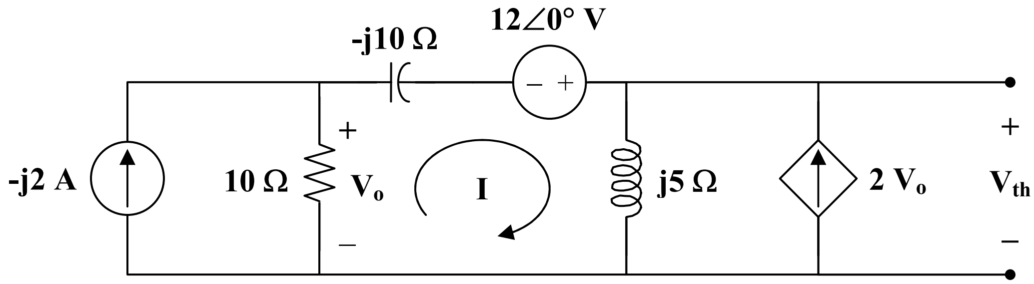
To find $\mathbf{Z}_{th}$, consider the circuit in Fig. (a).

$$1 + 2\mathbf{V}_o = \frac{\mathbf{V}_x}{j5} + \frac{\mathbf{V}_x}{10 - j10}, \qquad \text{where } \mathbf{V}_o = \frac{10\mathbf{V}_x}{10 - j10}$$

$$1 + \frac{19\mathbf{V}_x}{10 - j10} = \frac{\mathbf{V}_x}{j5} \longrightarrow \mathbf{V}_x = \frac{\text{-}10 + j10}{21 + j2}$$

$$\mathbf{Z}_N = \mathbf{Z}_{th} = \frac{\mathbf{V}_x}{1} = \frac{14.142\angle 135°}{21.095\angle 5.44°} = \underline{\mathbf{0.67\angle 129.56°\ \Omega}}$$

To find $\mathbf{V}_{th}$ and $\mathbf{I}_N$, consider the circuit in Fig. (b).



(b)

$$(10 - j10 + j5)\mathbf{I} - (10)(\text{-}j2) + j5(2\mathbf{V}_o) - 12 = 0$$

where $\mathbf{V}_o = (10)(\text{-}j2 - \mathbf{I})$

Thus,

$$(10 - j105)\mathbf{I} = \text{-}188 - j20$$

$$\mathbf{I} = \frac{188 + j20}{\text{-}10 + j105}$$

$$\mathbf{V}_{th} = j5(\mathbf{I} + 2\mathbf{V}_o) = j5(21\mathbf{I} + j40) = j105\mathbf{I} - 200$$

$$\mathbf{V}_{th} = \frac{j105(188 + j20)}{\text{-}10 + j105} - 200 = \text{-}11.802 + j2.076$$

$$\mathbf{V}_{th} = \underline{\mathbf{11.97\angle 170^\circ\ V}}$$

$$\mathbf{I}_N = \frac{\mathbf{V}_{th}}{\mathbf{Z}_{th}} = \frac{11.97\angle 170^\circ}{0.67\angle 129.56^\circ} = \underline{\mathbf{17.86\angle 40.44^\circ\ A}}$$

Chapter 10, Solution 67.

$$Z_N = Z_{Th} = 10//(13 - j5) + 12//(8 + j6) = \frac{10(13 - j5)}{23 - j5} + \frac{12(8 + j6)}{20 + j6} = \underline{11.243 + j1.079\Omega}$$

$$V_a = \frac{10}{23 - j5}(60\angle 45^o) = 13.78 + j21.44, \qquad V_b = \frac{(8 + j6)}{20 + j6}(60\angle 45^o) = 25.93 + j454.37\Omega$$

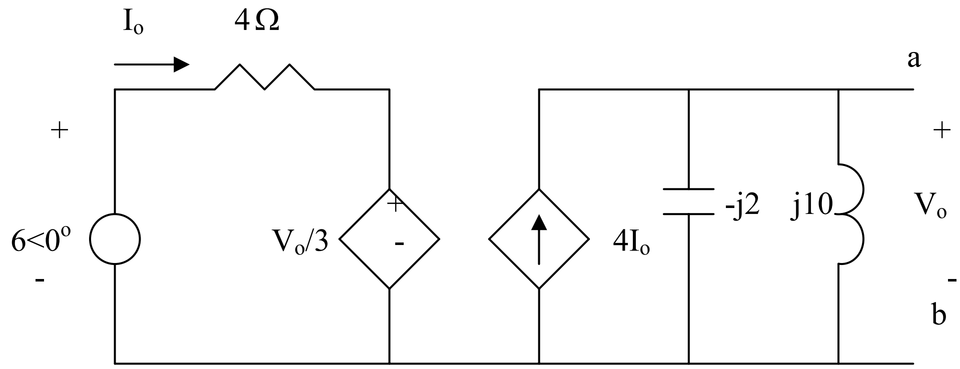
$$V_{Th} = V_a - V_b = \underline{433.1\angle -1.599^o}\ V, \qquad I_N = \frac{V_{Th}}{Z_{Th}} = \underline{38.34\angle -97.09^o}\ A$$

Chapter 10, Solution 68.

$$1H \longrightarrow j\omega L = j10x1 = j10$$

$$\frac{1}{20}F \longrightarrow \frac{1}{j\omega C} = \frac{1}{j10x\frac{1}{20}} = -j2$$

We obtain V_{Th} using the circuit below.



$$j10//(-j2) = \frac{j10(-j2)}{j10 - j2} = -j2.5$$

$$V_o = 4I_o x(-j2.5) = -j10I_o \qquad (1)$$

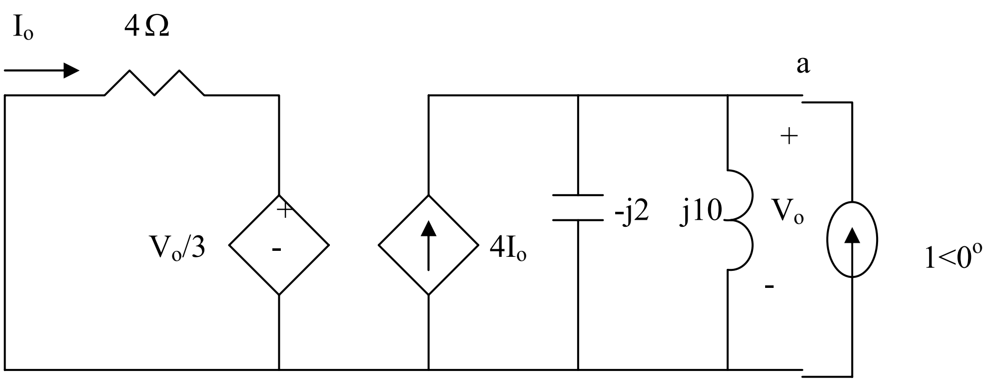
$$-6 + 4I_o + \frac{1}{3}V_o = 0 \qquad (2)$$

Combining (1) and (2) gives

$$I_o = \frac{6}{4 - j10/3}, \qquad V_{Th} = V_o = -j10I_o = \frac{-j60}{4 - j10/3} = 11.52\angle -50.19^o$$

$$\underline{v_{Th} = 11.52\sin(10t - 50.19^o)}$$

To find $R_{Th,}$ we insert a 1-A source at terminals a-b, as shown below.



$$4I_o + \frac{1}{3}V_o = 0 \longrightarrow I_o = -\frac{V_o}{12}$$

$$1 + 4I_o = \frac{V_o}{-j2} + \frac{V_o}{j10}$$

Combining the two equations leads to

$$V_o = \frac{1}{0.333 + j0.4} = 1.2293 - j1.4766$$

$$Z_{Th} = \frac{V_o}{1} = \underline{1.2293 - 1.477\Omega}$$

Chapter 10, Solution 69.

This is an inverting op amp so that

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i} = \frac{-R}{1/j\omega C} = \underline{\mathbf{-j\omega RC}}$$

When $\mathbf{V}_s = V_m$ and $\omega = 1/RC$,

$$\mathbf{V}_o = -j \cdot \frac{1}{RC} \cdot RC \cdot V_m = -j V_m = V_m \angle -90°$$

Therefore,

$$v_o(t) = V_m \sin(\omega t - 90°) = \underline{\mathbf{- V_m \cos(\omega t)}}$$

Chapter 10, Solution 70.

This may also be regarded as an inverting amplifier.

$$2\cos(4\times10^4 t) \longrightarrow 2\angle 0°, \quad \omega = 4\times10^4$$

$$10\text{ nF} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(4\times10^4)(10\times10^{-9})} = -j2.5\text{ k}\Omega$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i}$$

where $\mathbf{Z}_i = 50\text{ k}\Omega$ and $\mathbf{Z}_f = 100k \parallel (-j2.5k) = \frac{-j100}{40 - j}\text{ k}\Omega$.

Thus, $$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-j2}{40 - j}$$

If $\mathbf{V}_s = 2\angle 0°$,

$$\mathbf{V}_o = \frac{-j4}{40 - j} = \frac{4\angle -90°}{40.01\angle -1.43°} = 0.1\angle -88.57°$$

Therefore,

$$v_o(t) = \underline{\mathbf{0.1\cos(4x10^4 t - 88.57°)\ V}}$$

Chapter 10, Solution 71.

$$8\cos(2t+30^\circ) \longrightarrow 8\angle 30^\circ$$

$$0.5\mu F \longrightarrow \frac{1}{j\omega C} = \frac{1}{j2x0.5x10^{-6}} = -j1k\Omega$$

At the inverting terminal,

$$\frac{V_o - 8\angle 30^\circ}{-j1k} + \frac{V_o - 8\angle 30^\circ}{10k} = \frac{8\angle 30^\circ}{2k} \longrightarrow V_o(0.1+j) = 8\angle 30(0.6+j)$$

$$V_o = \frac{(6.9282+j4)(0.6+j)}{0.1+j} = 9.283\angle 4.747^\circ$$

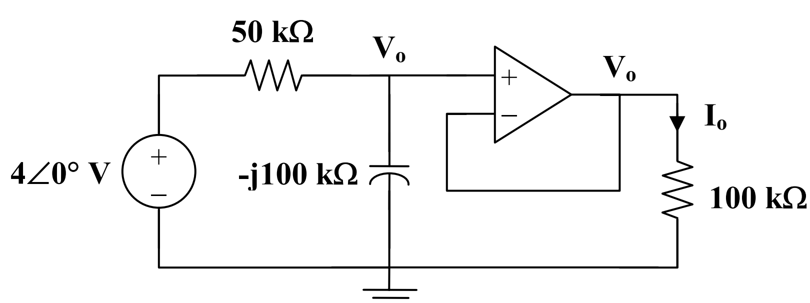
$v_o(t)$ = **$9.283\cos(2t + 4.75^\circ)$ V**

Chapter 10, Solution 72.

$$4\cos(10^4 t) \longrightarrow 4\angle 0^\circ, \quad \omega = 10^4$$

$$1\text{ nF} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(10^4)(10^{-9})} = \text{-j}100\text{ k}\Omega$$

Consider the circuit as shown below.



At the noninverting node,

$$\frac{4 - \mathbf{V}_o}{50} = \frac{\mathbf{V}_o}{-j100} \longrightarrow \mathbf{V}_o = \frac{4}{1+j0.5}$$

$$\mathbf{I}_o = \frac{\mathbf{V}_o}{100k} = \frac{4}{(100)(1+j0.5)}\text{mA} = 35.78\angle -26.56^\circ\ \mu\text{A}$$

Therefore,

$i_o(t)$ = **$35.78\cos(10^4 t - 26.56^\circ)$ μA**

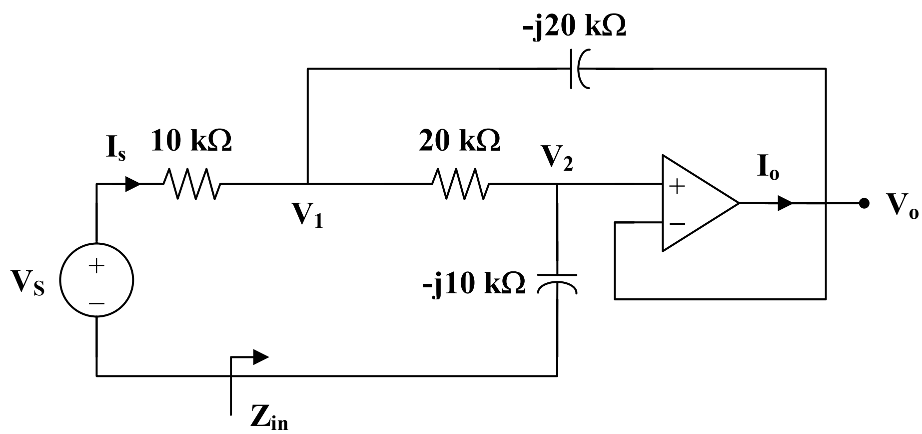
Chapter 10, Solution 73.

As a voltage follower, $\mathbf{V}_2 = \mathbf{V}_o$

$$C_1 = 10\text{ nF} \longrightarrow \frac{1}{j\omega C_1} = \frac{1}{j(5\times10^3)(10\times10^{-9})} = \text{-j}20\text{ k}\Omega$$

$$C_2 = 20\text{ nF} \longrightarrow \frac{1}{j\omega C_2} = \frac{1}{j(5\times10^3)(20\times10^{-9})} = \text{-j}10\text{ k}\Omega$$

Consider the circuit in the frequency domain as shown below.



At node 1,

$$\frac{\mathbf{V}_s - \mathbf{V}_1}{10} = \frac{\mathbf{V}_1 - \mathbf{V}_o}{\text{-}j20} + \frac{\mathbf{V}_1 - \mathbf{V}_o}{20}$$

$$2\,\mathbf{V}_s = (3 + j)\mathbf{V}_1 - (1 + j)\mathbf{V}_o \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_o}{20} = \frac{\mathbf{V}_o - 0}{\text{-}j10}$$

$$\mathbf{V}_1 = (1 + j2)\mathbf{V}_o \qquad (2)$$

Substituting (2) into (1) gives

$$2\,\mathbf{V}_s = j6\mathbf{V}_o \quad \text{or} \quad \mathbf{V}_o = \text{-}j\frac{1}{3}\mathbf{V}_s$$

$$\mathbf{V}_1 = (1 + j2)\mathbf{V}_o = \left(\frac{2}{3} - j\frac{1}{3}\right)\mathbf{V}_s$$

$$\mathbf{I}_s = \frac{\mathbf{V}_s - \mathbf{V}_1}{10\text{k}} = \frac{(1/3)(1 - j)}{10\text{k}}\mathbf{V}_s$$

$$\frac{\mathbf{I}_s}{\mathbf{V}_s} = \frac{1-j}{30k}$$

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_s}{\mathbf{I}_s} = \frac{30k}{1-j} = 15(1+j)\,k$$

$$\mathbf{Z}_{in} = \underline{\mathbf{21.21\angle 45^\circ\ k\Omega}}$$

Chapter 10, Solution 74.

$$\mathbf{Z}_i = R_1 + \frac{1}{j\omega C_1}, \qquad \mathbf{Z}_f = R_2 + \frac{1}{j\omega C_2}$$

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i} = \frac{R_2 + \frac{1}{j\omega C_2}}{R_1 + \frac{1}{j\omega C_1}} = \underline{\left(\frac{\mathbf{C_1}}{\mathbf{C_2}}\right)\left(\frac{\mathbf{1 + j\omega R_2 C_2}}{\mathbf{1 + j\omega R_1 C_1}}\right)}$$

At $\omega = 0$, $\qquad \mathbf{A}_v = \underline{\frac{\mathbf{C_1}}{\mathbf{C_2}}}$

As $\omega \to \infty$, $\qquad \mathbf{A}_v = \underline{\frac{\mathbf{R_2}}{\mathbf{R_1}}}$

At $\omega = \frac{1}{R_1 C_1}$, $\qquad \mathbf{A}_v = \underline{\left(\frac{\mathbf{C_1}}{\mathbf{C_2}}\right)\left(\frac{\mathbf{1 + jR_2C_2/R_1C_1}}{\mathbf{1+j}}\right)}$

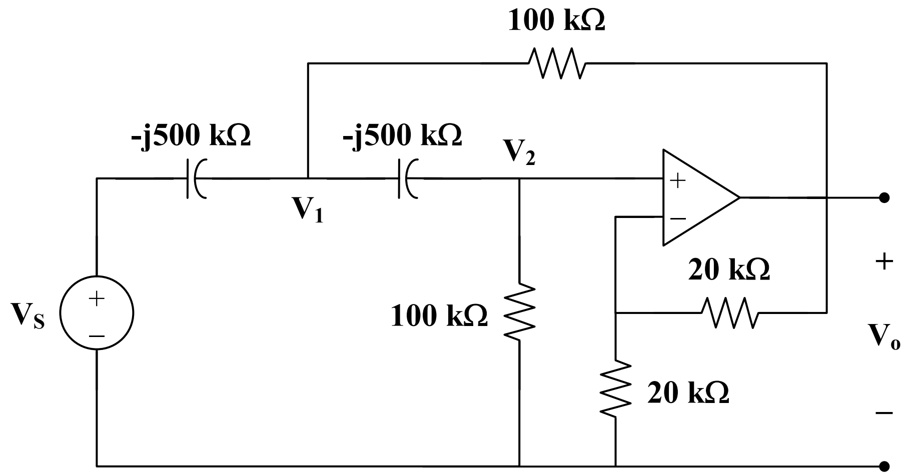
At $\omega = \frac{1}{R_2 C_2}$, $\qquad \mathbf{A}_v = \underline{\left(\frac{\mathbf{C_1}}{\mathbf{C_2}}\right)\left(\frac{\mathbf{1+j}}{\mathbf{1 + jR_1C_1/R_2C_2}}\right)}$

Chapter 10, Solution 75.

$\omega = 2\times 10^3$

$$C_1 = C_2 = 1\text{ nF} \longrightarrow \frac{1}{j\omega C_1} = \frac{1}{j(2\times 10^3)(1\times 10^{-9})} = -j500\text{ k}\Omega$$

Consider the circuit shown below.



At node 1,

$$\frac{\mathbf{V}_s - \mathbf{V}_1}{-j500} = \frac{\mathbf{V}_o - \mathbf{V}_1}{100} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{-j500}$$

$$\mathbf{V}_s = (2 + j5)\,\mathbf{V}_1 - j5\,\mathbf{V}_o - \mathbf{V}_2 \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{-j500} = \frac{\mathbf{V}_2}{100}$$

$$\mathbf{V}_1 = (1 - j5)\,\mathbf{V}_2 \qquad (2)$$

But

$$\mathbf{V}_2 = \frac{R_3}{R_3 + R_4}\mathbf{V}_o = \frac{\mathbf{V}_o}{2} \qquad (3)$$

From (2) and (3),

$$\mathbf{V}_1 = \frac{1}{2}\cdot(1 - j5)\,\mathbf{V}_o \qquad (4)$$

Substituting (3) and (4) into (1),

$$\mathbf{V}_s = \frac{1}{2}\cdot(2 + j5)(1 - j5)\,\mathbf{V}_o - j5\,\mathbf{V}_o - \frac{1}{2}\mathbf{V}_o$$

$$\mathbf{V}_s = \frac{1}{2}\cdot(26 - j25)\,\mathbf{V}_o$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{2}{26 - j25} = \underline{\mathbf{0.0554\angle 43.88^\circ}}$$

Chapter 10, Solution 76.

Let the voltage between the -jkΩ capacitor and the 10kΩ resistor be $\mathbf{V}_1$.

$$\frac{2\angle 30^o - V_1}{-j4k} = \frac{V_1 - V_o}{10k} + \frac{V_1 - V_o}{20k} \longrightarrow \quad (1)$$

$$2\angle 30^o = (1 - j0.6)V_1 + j0.6V_o$$

Also,

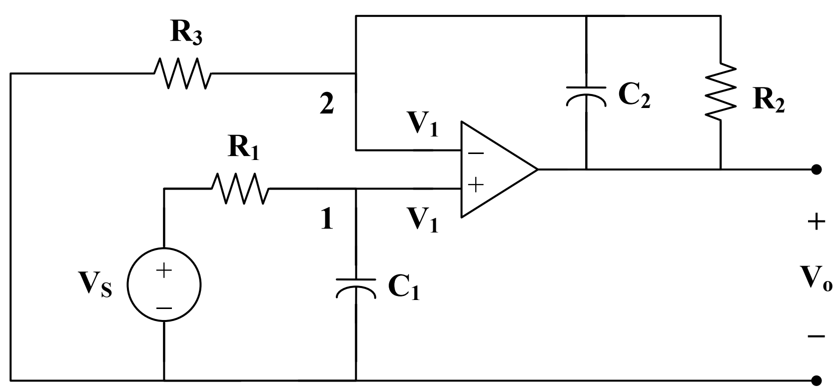
$$\frac{V_1 - V_o}{10k} = \frac{V_o}{-j2k} \longrightarrow V_1 = (1 + j5)V_o \quad (2)$$

Solving (2) into (1) yields

$$V_o = 0.047 - j0.3088 = \underline{0.3123\angle -81.34^o \text{ V}}$$

Chapter 10, Solution 77.

Consider the circuit below.



At node 1,

$$\frac{\mathbf{V}_s - \mathbf{V}_1}{R_1} = j\omega C\,\mathbf{V}_1$$

$$\mathbf{V}_s = (1 + j\omega R_1 C_1)\,\mathbf{V}_1 \quad (1)$$

At node 2,

$$\frac{0 - \mathbf{V}_1}{R_3} = \frac{\mathbf{V}_1 - \mathbf{V}_o}{R_2} + j\omega C_2\,(\mathbf{V}_1 - \mathbf{V}_o)$$

$$\mathbf{V}_1 = (\mathbf{V}_o - \mathbf{V}_1)\left(\frac{R_3}{R_2} + j\omega C_2 R_3\right)$$

$$\mathbf{V}_o = \left(1 + \frac{1}{(R_3/R_2) + j\omega C_2 R_3}\right)\mathbf{V}_1 \qquad (2)$$

From (1) and (2),

$$\mathbf{V}_o = \frac{\mathbf{V}_s}{1 + j\omega R_1 C_1}\left(1 + \frac{R_2}{R_3 + j\omega C_2 R_2 R_3}\right)$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \underline{\frac{\mathbf{R_2 + R_3 + j\omega C_2 R_2 R_3}}{\mathbf{(1 + j\omega R_1 C_1)(R_3 + j\omega C_2 R_2 R_3)}}}$$

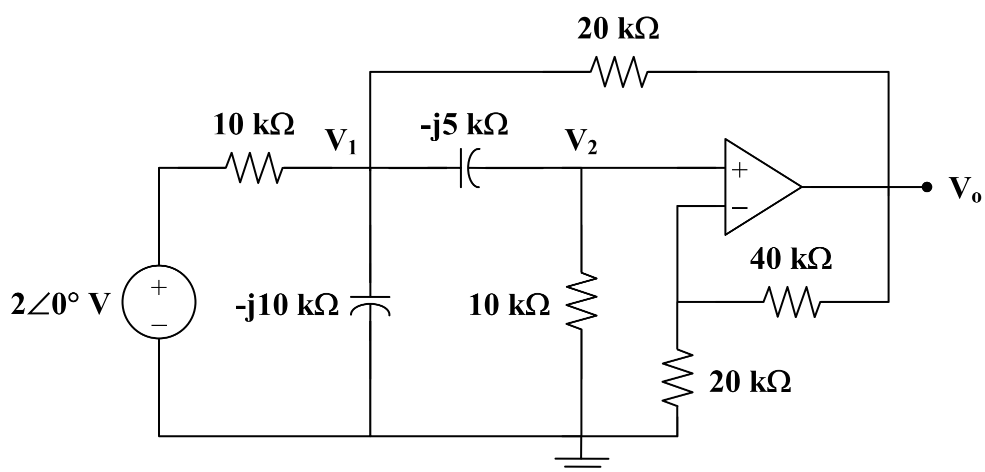
Chapter 10, Solution 78.

$$2\sin(400t) \longrightarrow 2\angle 0^\circ, \quad \omega = 400$$

$$0.5\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(400)(0.5 \times 10^{-6})} = \text{-}j5\ \text{k}\Omega$$

$$0.25\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(400)(0.25 \times 10^{-6})} = \text{-}j10\ \text{k}\Omega$$

Consider the circuit as shown below.



At node 1,

$$\frac{2 - \mathbf{V}_1}{10} = \frac{\mathbf{V}_1}{\text{-}j10} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{\text{-}j5} + \frac{\mathbf{V}_1 - \mathbf{V}_o}{20}$$

$$4 = (3 + j6)\,\mathbf{V}_1 - j4\,\mathbf{V}_2 - \mathbf{V}_o \qquad (1)$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{-j5} = \frac{\mathbf{V}_2}{10}$$

$$\mathbf{V}_1 = (1 - j0.5)\,\mathbf{V}_2 \qquad (2)$$

But

$$\mathbf{V}_2 = \frac{20}{20 + 40}\mathbf{V}_o = \frac{1}{3}\mathbf{V}_o \qquad (3)$$

From (2) and (3),

$$\mathbf{V}_1 = \frac{1}{3}\cdot(1 - j0.5)\,\mathbf{V}_o \qquad (4)$$

Substituting (3) and (4) into (1) gives

$$4 = (3 + j6)\cdot\frac{1}{3}\cdot(1 - j0.5)\,\mathbf{V}_o - j\frac{4}{3}\mathbf{V}_o - \mathbf{V}_o = \left(1 - j\frac{1}{6}\right)\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{24}{6 - j} = 3.945\angle 9.46°$$

Therefore,

$$v_o(t) = \underline{\mathbf{3.945\ sin(400t + 9.46°)\ V}}$$

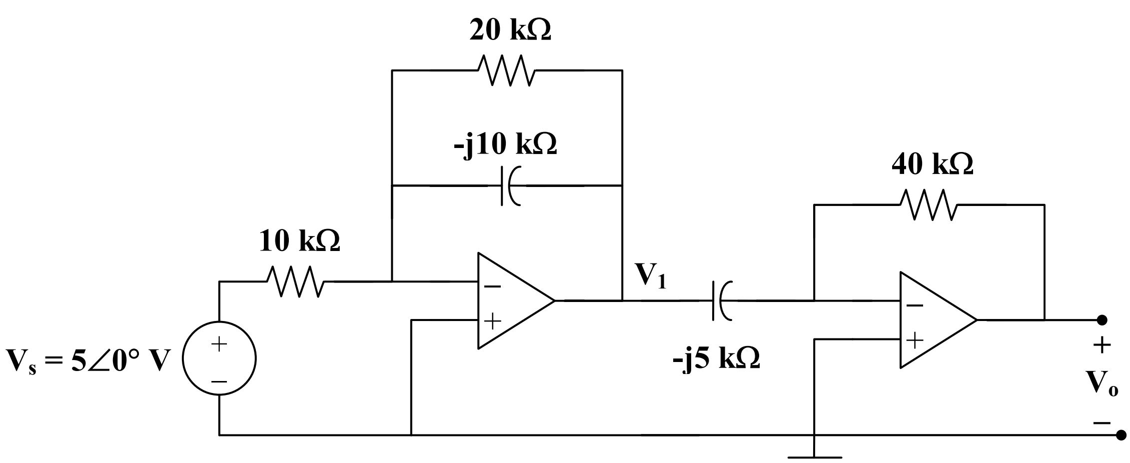
Chapter 10, Solution 79.

$$5\cos(1000t) \longrightarrow 5\angle 0°, \quad \omega = 1000$$

$$0.1\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(1000)(0.1\times 10^{-6})} = \text{-j10 k}\Omega$$

$$0.2\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(1000)(0.2\times 10^{-6})} = \text{-j5 k}\Omega$$

Consider the circuit shown below.



Since each stage is an inverter, we apply $\mathbf{V}_o = \frac{-\mathbf{Z}_f}{\mathbf{Z}_i}\mathbf{V}_i$ to each stage.

$$\mathbf{V}_o = \frac{-40}{-j15}\mathbf{V}_1 \qquad (1)$$

and

$$\mathbf{V}_1 = \frac{-20 \,||\, (-j10)}{10}\mathbf{V}_s \qquad (2)$$

From (1) and (2),

$$\mathbf{V}_o = \left(\frac{-j8}{10}\right)\left(\frac{-(20)(-j10)}{20 - j10}\right) 5\angle 0°$$

$$\mathbf{V}_o = 16(2 + j) = 35.78\angle 26.56°$$

Therefore, $v_o(t) =$ **35.78 cos(1000t + 26.56°) V**

Chapter 10, Solution 80.

$$4\cos(1000t - 60°) \longrightarrow 4\angle -60°, \quad \omega = 1000$$

$$0.1\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(1000)(0.1\times 10^{-6})} = -j10\ \text{k}\Omega$$

$$0.2\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(1000)(0.2\times 10^{-6})} = -j5\ \text{k}\Omega$$

The two stages are inverters so that

$$\mathbf{V}_o = \left(\frac{20}{-j10}\cdot(4\angle -60°) + \frac{20}{50}\mathbf{V}_o\right)\left(\frac{-j5}{10}\right)$$

$$= \frac{-j}{2}\cdot(j2)\cdot(4\angle -60°) + \frac{-j}{2}\cdot\frac{2}{5}\mathbf{V}_o$$

$$(1 + j/5)\,\mathbf{V}_o = 4\angle -60°$$

$$\mathbf{V}_o = \frac{4\angle -60°}{1 + j/5} = 3.922\angle -71.31°$$

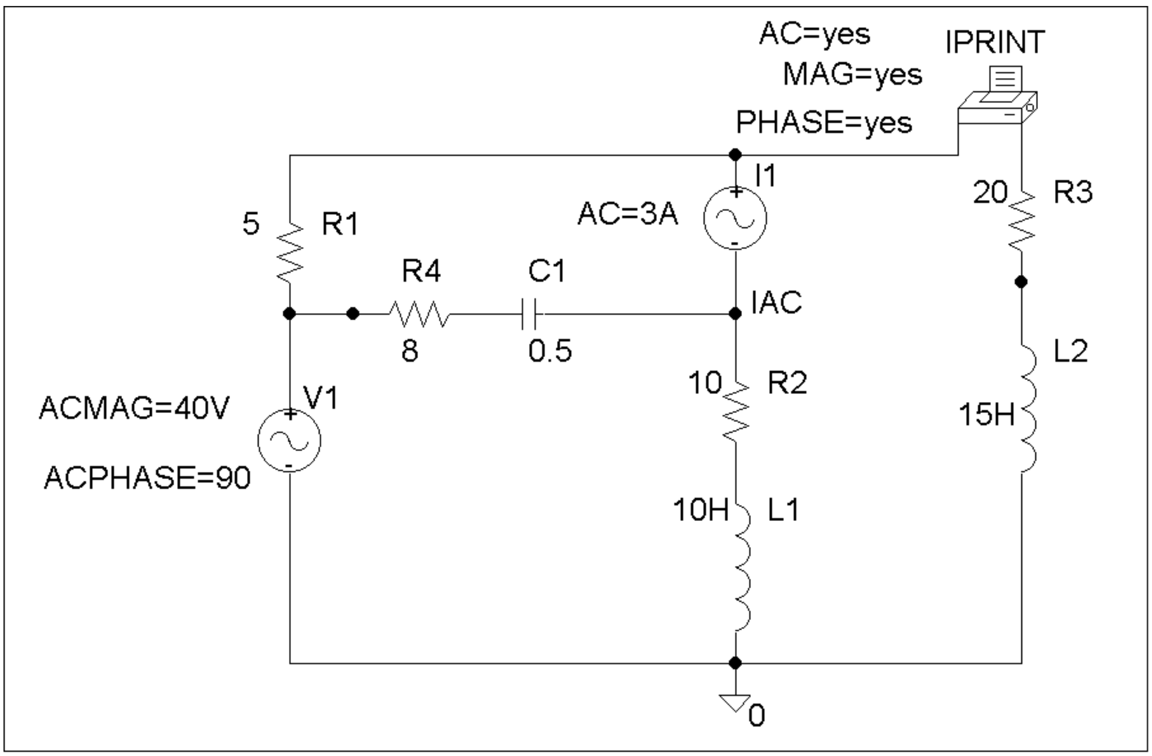
Therefore, $v_o(t) =$ **3.922 cos(1000t – 71.31°) V**

Chapter 10, Solution 81.

The schematic is shown below. The pseudocomponent IPRINT is inserted to print the value of I_o in the output. We click Analysis/Setup/AC Sweep and set Total Pts. = 1, Start Freq = 0.1592, and End Freq = 0.1592. Since we assume that w = 1. The output file includes:

FREQ	IM(V_PRINT1)	IP(V_PRINT1)
1.592 E-01	1.465 E+00	7.959 E+01

Thus, I_o = **$1.465\angle 79.59^o$ A**

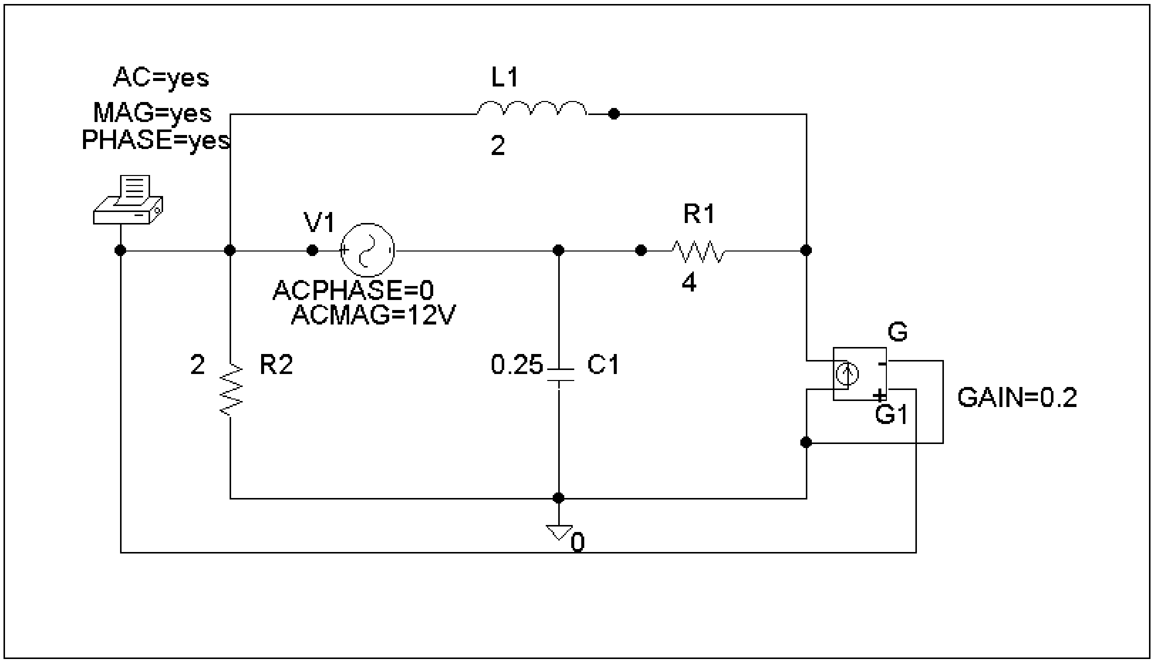


Chapter 10, Solution 82.

The schematic is shown below. We insert PRINT to print V_o in the output file. For AC Sweep, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, we print out the output file which includes:

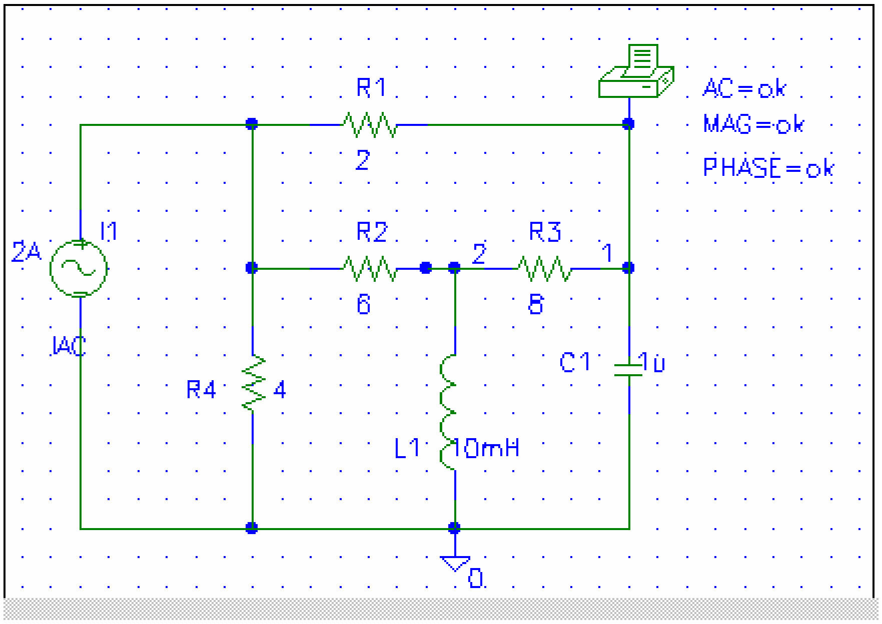
FREQ	VM($N_0001)	VP($N_0001)
1.592 E-01	7.684 E+00	5.019 E+01

which means that V_o = **$7.684\angle 50.19^o$ V**



Chapter 10, Solution 83.

The schematic is shown below. The frequency is $f = \omega/2\pi = \dfrac{1000}{2\pi} = 159.15$



When the circuit is saved and simulated, we obtain from the output file

FREQ	VM(1)	VP(1)
1.592E+02	6.611E+00	-1.592E+02

Thus,

$$v_o = \underline{\mathbf{6.611\cos(1000t - 159.2^o)\ \ V}}$$

Chapter 10, Solution 84.

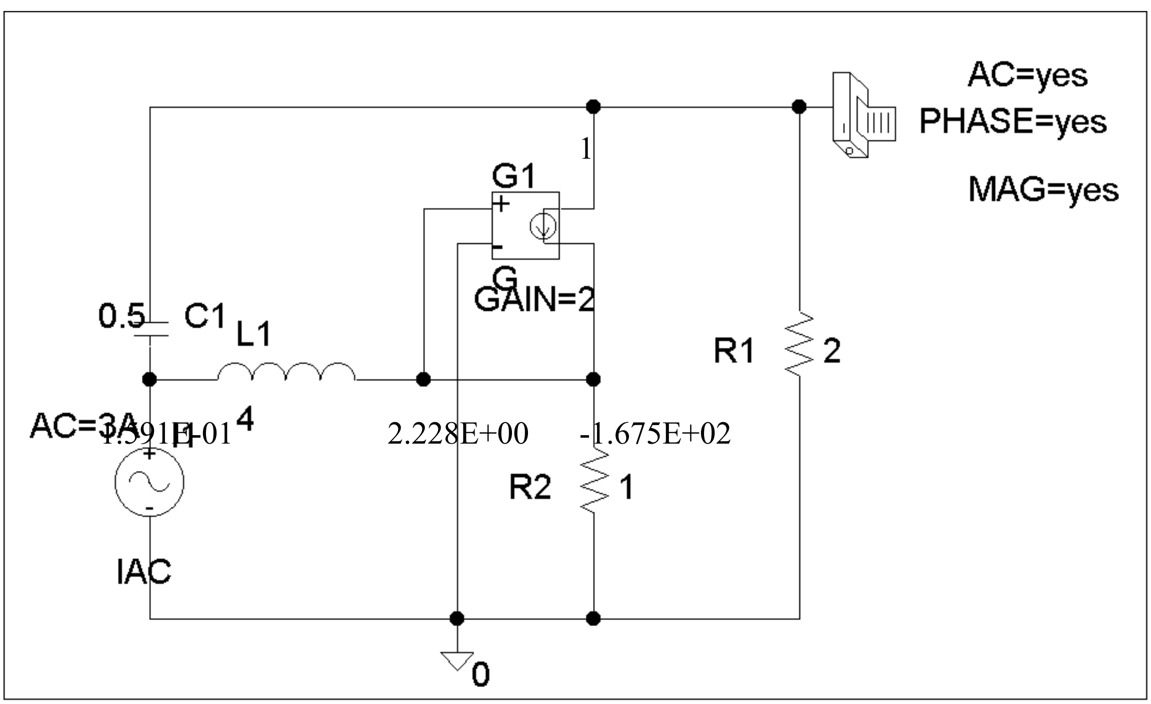
The schematic is shown below. We set PRINT to print V_o in the output file. In AC Sweep box, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After simulation, we obtain the output file which includes:

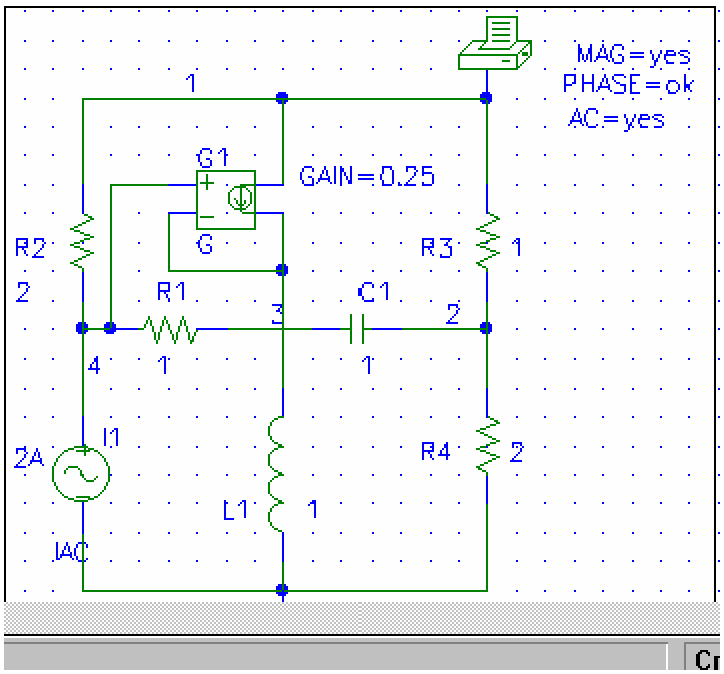
FREQ	VM($N_0003)	VP($N_0003)
1.592 E-01	1.664 E+00	-1.646 E+02

Namely,

$$V_o = \underline{\mathbf{1.664\angle\text{-}146.4^o\ V}}$$

Chapter 10, Solution 85.





Chapter 10, Solution 86.

We insert three pseudocomponent PRINTs at nodes 1, 2, and 3 to print V_1, V_2, and V_3, into the output file. Assume that w = 1, we set Total Pts = 1, Start Freq = 0.1592, and End Freq = 0.1592. After saving and simulating the circuit, we obtain the output file which includes:

FREQ	VM($N_0002)	VP($N_0002)
1.592 E-01	6.000 E+01	3.000 E+01

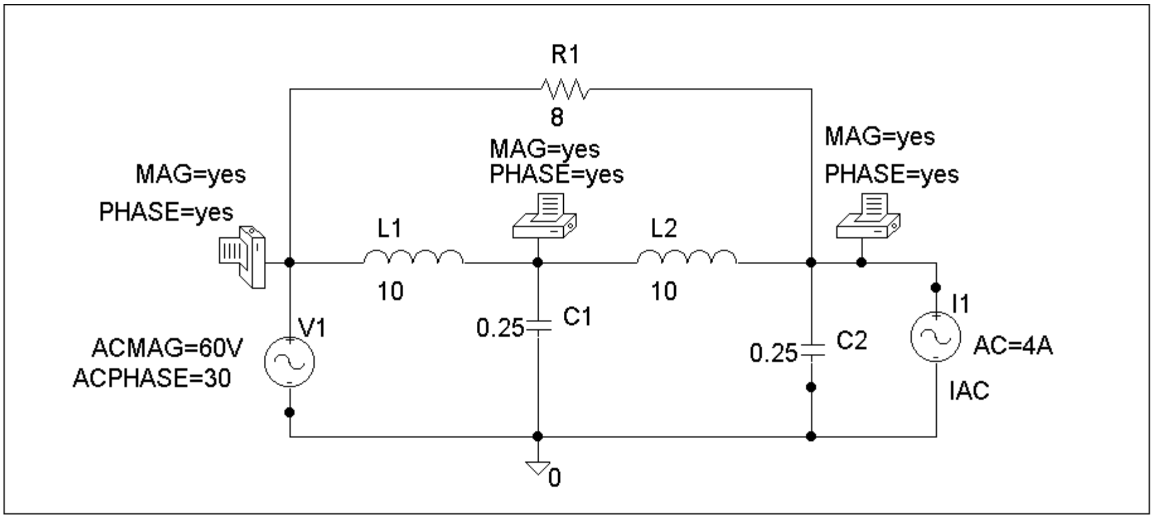
FREQ	VM($N_0003)	VP($N_0003)
1.592 E-01	2.367 E+02	-8.483 E+01

FREQ VM($N_0001) VP($N_0001)

FREQ	VM($N_0001)	VP($N_0001)
1.592 E-01	1.082 E+02	1.254 E+02

Therefore,

$$V_1 = \underline{\mathbf{60\angle 30^o\ V}} \quad V_2 = \underline{\mathbf{236.7\angle -84.83^o\ V}} \quad V_3 = \underline{\mathbf{108.2\angle 125.4^o\ V}}$$



Chapter 10, Solution 87.

The schematic is shown below. We insert three PRINTs at nodes 1, 2, and 3. We set Total Pts = 1, Start Freq = 0.1592, End Freq = 0.1592 in the AC Sweep box. After simulation, the output file includes:

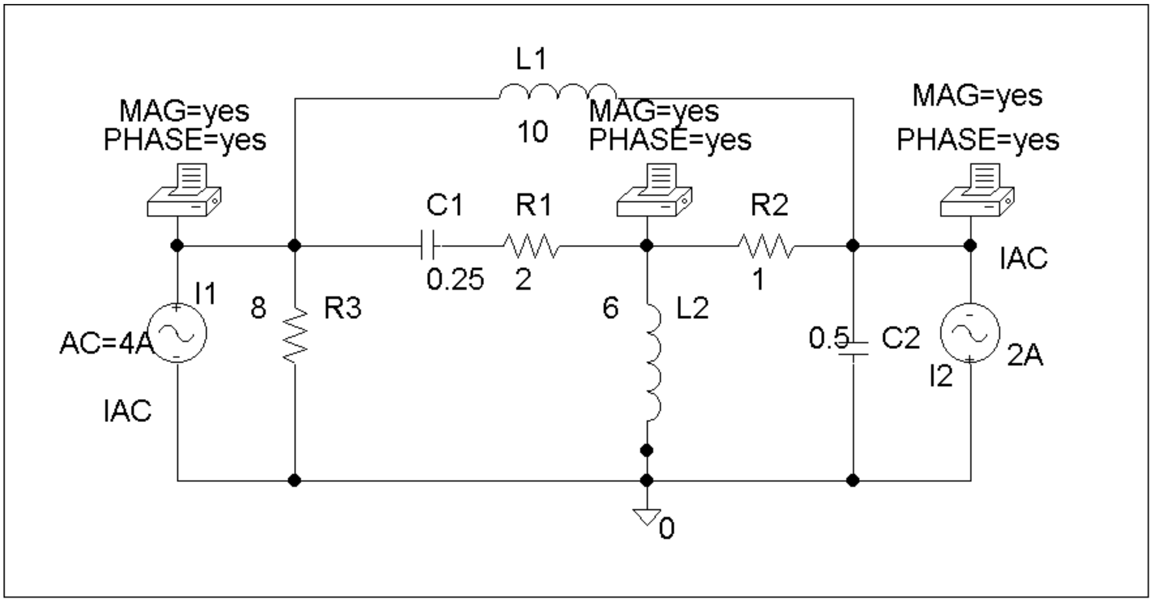
FREQ	VM($N_0004)	VP($N_0004)
1.592 E-01	1.591 E+01	1.696 E+02

FREQ	VM($N_0001)	VP($N_0001)
1.592 E-01	5.172 E+00	-1.386 E+02

FREQ VM($N_0003)
VP($N_0003)
1.592 E-01 2.270 E+00 -1.524
E+02

Therefore,

V_1 = **15.91∠169.6° V** V_2 = **5.172∠-138.6° V** V_3 = **2.27∠-152.4° V**



Chapter 10, Solution 88.

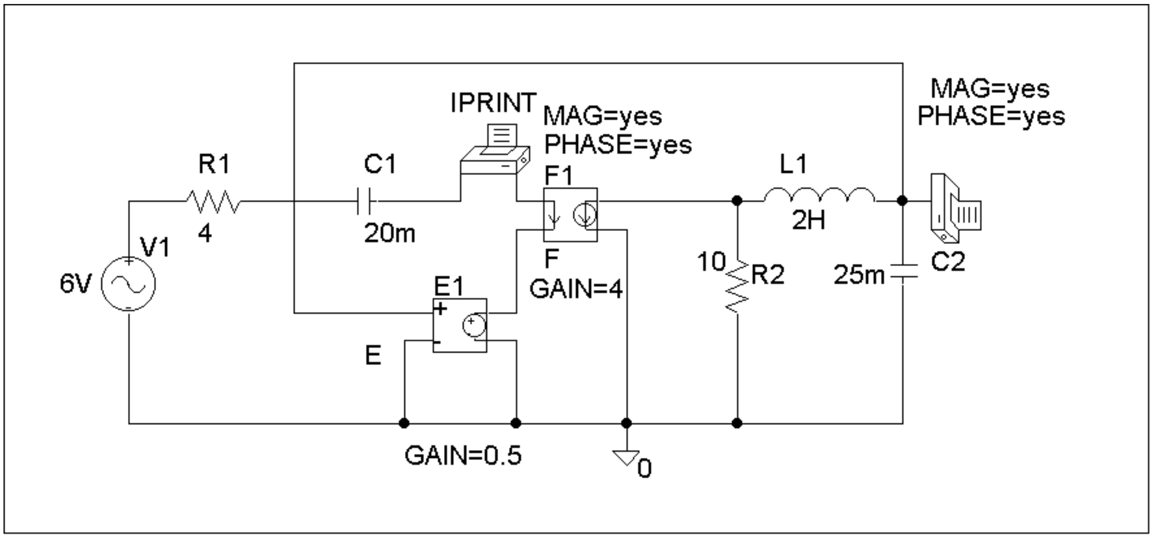
The schematic is shown below. We insert IPRINT and PRINT to print I_o and V_o in the output file. Since w = 4, f = w/2π = 0.6366, we set Total Pts = 1, Start Freq = 0.6366, and End Freq = 0.6366 in the AC Sweep box. After simulation, the output file includes:

FREQ VM($N_0002)
VP($N_0002)
6.366 E-01 3.496 E+01 1.261
E+01

FREQ IM(V_PRINT2) IP
(V_PRINT2)
6.366 E-01 8.912 E-01
-8.870 E+01

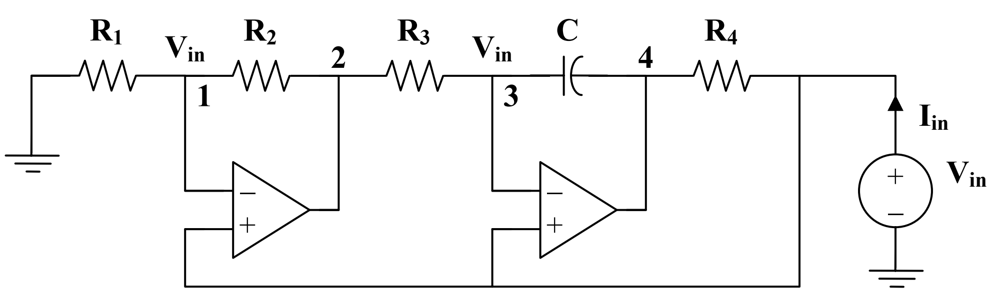
Therefore, $\mathbf{V}_o = 34.96\angle 12.6^o$ V, $\mathbf{I}_o = 0.8912\angle -88.7^o$ A

v_o = **<u>34.96 cos(4t + 12.6°)V</u>**, i_o = **<u>0.8912cos(4t - 88.7°)A</u>**



Chapter 10, Solution 89.

Consider the circuit below.



At node 1,

$$\frac{0 - \mathbf{V}_{in}}{R_1} = \frac{\mathbf{V}_{in} - \mathbf{V}_2}{R_2}$$

$$-\mathbf{V}_{in} + \mathbf{V}_2 = \frac{R_2}{R_1}\mathbf{V}_{in} \qquad (1)$$

At node 3,

$$\frac{\mathbf{V}_2 - \mathbf{V}_{in}}{R_3} = \frac{\mathbf{V}_{in} - \mathbf{V}_4}{1/j\omega C}$$

$$-\mathbf{V}_{in} + \mathbf{V}_4 = \frac{\mathbf{V}_{in} - \mathbf{V}_2}{j\omega C R_3} \qquad (2)$$

From (1) and (2),

$$-\mathbf{V}_{in} + \mathbf{V}_4 = \frac{-R_2}{j\omega C R_3 R_1}\mathbf{V}_{in}$$

Thus,

$$\mathbf{I}_{in} = \frac{\mathbf{V}_{in} - \mathbf{V}_4}{R_4} = \frac{R_2}{j\omega C R_3 R_1 R_4}\mathbf{V}_{in}$$

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_{in}}{\mathbf{I}_{in}} = \frac{j\omega C R_1 R_3 R_4}{R_2} = j\omega L_{eq}$$

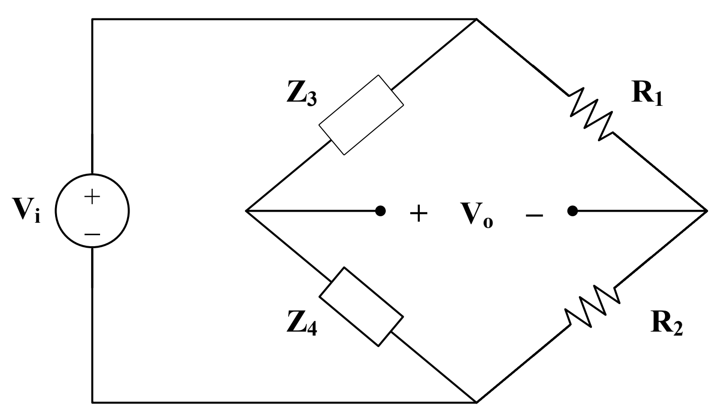
where $$\underline{\mathbf{L}_{eq} = \frac{\mathbf{R}_1\mathbf{R}_3\mathbf{R}_4\mathbf{C}}{\mathbf{R}_2}}$$

Chapter 10, Solution 90.

Let $$\mathbf{Z}_4 = R \,\|\, \frac{1}{j\omega C} = \frac{R}{1 + j\omega RC}$$

$$\mathbf{Z}_3 = R + \frac{1}{j\omega C} = \frac{1 + j\omega RC}{j\omega C}$$

Consider the circuit shown below.



$$\mathbf{V}_o = \frac{\mathbf{Z}_4}{\mathbf{Z}_3 + \mathbf{Z}_4}\mathbf{V}_i - \frac{R_2}{R_1 + R_2}\mathbf{V}_i$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\dfrac{R}{1 + j\omega C}}{\dfrac{R}{1 + j\omega C} + \dfrac{1 + j\omega RC}{j\omega C}} - \frac{R_2}{R_1 + R_2}$$

$$= \frac{j\omega RC}{j\omega RC + (1 + j\omega RC)^2} - \frac{R_2}{R_1 + R_2}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j\omega RC}{1 - \omega^2 R^2 C^2 + j3\omega RC} - \frac{R_2}{R_1 + R_2}$$

For $\mathbf{V}_o$ and $\mathbf{V}_i$ to be in phase, $\frac{\mathbf{V}_o}{\mathbf{V}_i}$ must be purely real. This happens when

$$1 - \omega^2 R^2 C^2 = 0$$

$$\omega = \frac{1}{RC} = 2\pi f$$

or $$f = \frac{1}{2\pi RC}$$

At this frequency,

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{3} - \frac{R_2}{R_1 + R_2}$$

Chapter 10, Solution 91.

(a) Let $\mathbf{V}_2 =$ voltage at the noninverting terminal of the op amp

$\mathbf{V}_o =$ output voltage of the op amp

$\mathbf{Z}_p = 10\ \text{k}\Omega = R_o$

$\mathbf{Z}_s = R + j\omega L + \frac{1}{j\omega C}$

As in Section 10.9,

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\mathbf{Z}_p}{\mathbf{Z}_s + \mathbf{Z}_p} = \frac{R_o}{R + R_o + j\omega L - \frac{j}{\omega C}}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\omega C R_o}{\omega C(R + R_o) + j(\omega^2 LC - 1)}$$

For this to be purely real,

$$\omega_o^2 LC - 1 = 0 \longrightarrow \omega_o = \frac{1}{\sqrt{LC}}$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.4\times10^{-3})(2\times10^{-9})}}$$

$f_o =$ **180 kHz**

(b) At oscillation,

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\omega_o C R_o}{\omega_o C(R + R_o)} = \frac{R_o}{R + R_o}$$

This must be compensated for by

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_2} = 1 + \frac{80}{20} = 5$$

$$\frac{R_o}{R + R_o} = \frac{1}{5} \longrightarrow R = 4R_o = \underline{\mathbf{40\ k\Omega}}$$

Chapter 10, Solution 92.

Let $\mathbf{V}_2 =$ voltage at the noninverting terminal of the op amp

$\mathbf{V}_o =$ output voltage of the op amp

$\mathbf{Z}_s = R_o$

$$\mathbf{Z}_p = j\omega L \,||\, \frac{1}{j\omega C} \,||\, R = \frac{1}{\frac{1}{R} + j\omega C + \frac{1}{j\omega L}} = \frac{\omega RL}{\omega L + jR(\omega^2 LC - 1)}$$

As in Section 10.9,

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\mathbf{Z}_p}{\mathbf{Z}_s + \mathbf{Z}_p} = \frac{\frac{\omega RL}{\omega L + jR(\omega^2 LC - 1)}}{R_o + \frac{\omega RL}{\omega L + jR(\omega^2 LC - 1)}}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\omega RL}{\omega RL + \omega R_o L + jR_o R(\omega^2 LC - 1)}$$

For this to be purely real,

$$\omega_o^2 LC = 1 \quad \longrightarrow \quad f_o = \frac{1}{2\pi\sqrt{LC}}$$

(a) At $\omega = \omega_o$,

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{\omega_o RL}{\omega_o RL + \omega_o R_o L} = \frac{R}{R + R_o}$$

This must be compensated for by

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_2} = 1 + \frac{R_f}{R_o} = 1 + \frac{1000k}{100k} = 11$$

Hence,

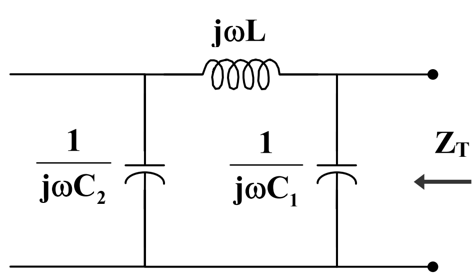
$$\frac{R}{R + R_o} = \frac{1}{11} \quad \longrightarrow \quad R_o = 10R = \underline{\mathbf{100\ k\Omega}}$$

(b) $$f_o = \frac{1}{2\pi\sqrt{(10 \times 10^{-6})(2 \times 10^{-9})}}$$

$$f_o = \underline{\mathbf{1.125\ MHz}}$$

Chapter 10, Solution 93.

As shown below, the impedance of the feedback is



$$\mathbf{Z}_T = \frac{1}{j\omega C_1} \parallel \left(j\omega L + \frac{1}{j\omega C_2} \right)$$

$$\mathbf{Z}_T = \frac{\frac{-j}{\omega C_1}\left(j\omega L + \frac{-j}{\omega C_2}\right)}{\frac{-j}{\omega C_1} + j\omega L + \frac{-j}{\omega C_2}} = \frac{\frac{1}{\omega} - \omega L C_2}{j(C_1 + C_2 - \omega^2 L C_1 C_2)}$$

In order for $\mathbf{Z}_T$ to be real, the imaginary term must be zero; i.e.

$$C_1 + C_2 - \omega_o^2 L C_1 C_2 = 0$$

$$\omega_o^2 = \frac{C_1 + C_2}{L C_1 C_2} = \frac{1}{L C_T}$$

$$\mathbf{f_o = \frac{1}{2\pi\sqrt{LC_T}}}$$

Chapter 10, Solution 94.

If we select $C_1 = C_2 = 20\text{ nF}$

$$C_T = \frac{C_1 C_2}{C_1 + C_2} = \frac{C_1}{2} = 10\text{ nF}$$

Since $f_o = \frac{1}{2\pi\sqrt{LC_T}}$,

$$L = \frac{1}{(2\pi f)^2 C_T} = \frac{1}{(4\pi^2)(2500\times10^6)(10\times10^{-9})} = 10.13\text{ mH}$$

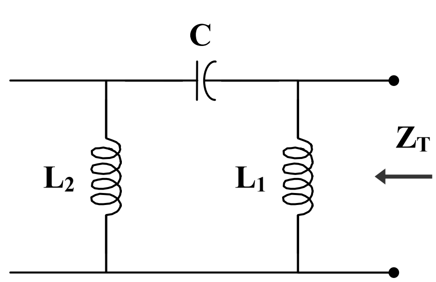
$$X_c = \frac{1}{\omega C_2} = \frac{1}{(2\pi)(50\times10^3)(20\times10^{-9})} = 159\ \Omega$$

We may select $R_i = 20\text{ k}\Omega$ and $R_f \geq R_i$, say $R_f = 20\text{ k}\Omega$.
Thus,

$C_1 = C_2 =$ <u>**20 nF**</u>, $L =$ **<u>10.13 mH</u>** $R_f = R_i =$ **<u>20 kΩ</u>**

Chapter 10, Solution 95.

First, we find the feedback impedance.



$$\mathbf{Z}_T = j\omega L_1 \parallel \left(j\omega L_2 + \frac{1}{j\omega C} \right)$$

$$\mathbf{Z}_T = \frac{j\omega L_1 \left(j\omega L_2 - \frac{j}{\omega C} \right)}{j\omega L_1 + j\omega L_2 - \frac{j}{\omega C}} = \frac{\omega^2 L_1 C (1 - \omega L_2)}{j(\omega^2 C (L_1 + L_2) - 1)}$$

In order for $\mathbf{Z}_T$ to be real, the imaginary term must be zero; i.e.

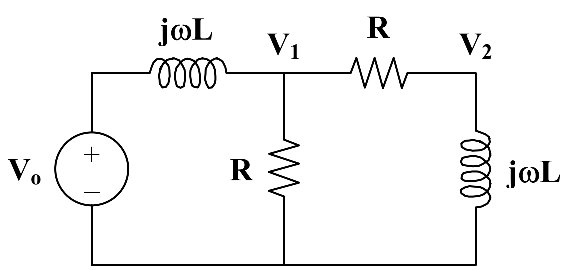
$$\omega_o^2 C (L_1 + L_2) - 1 = 0$$

$$\omega_o = 2\pi f_o = \frac{1}{C(L_1 + L_2)}$$

$$\mathbf{f_o = \frac{1}{2\pi\sqrt{C(L_1 + L_2)}}}$$

Chapter 10, Solution 96.

(a) Consider the feedback portion of the circuit, as shown below.



$$\mathbf{V_2} = \frac{j\omega L}{R + j\omega L} \mathbf{V_1} \longrightarrow \mathbf{V}_1 = \frac{R + j\omega L}{j\omega L} \mathbf{V}_2 \qquad (1)$$

Applying KCL at node 1,

$$\frac{\mathbf{V}_o - \mathbf{V}_1}{j\omega L} = \frac{\mathbf{V}_1}{R} + \frac{\mathbf{V}_1}{R + j\omega L}$$

$$\mathbf{V}_o - \mathbf{V}_1 = j\omega L\, \mathbf{V}_1 \left(\frac{1}{R} + \frac{1}{R + j\omega L} \right)$$

$$\mathbf{V}_o = \mathbf{V}_1\left(1 + \frac{j2\omega RL - \omega^2 L^2}{R\,(R + j\omega L)}\right)$$

(2)

From (1) and (2),

$$\mathbf{V}_o = \left(\frac{R + j\omega L}{j\omega L}\right)\left(1 + \frac{j2\omega RL - \omega^2 L^2}{R\,(R + j\omega L)}\right)\mathbf{V}_2$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_2} = \frac{R^2 + j\omega RL + j2\omega RL - \omega^2 L^2}{j\omega RL}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{1}{3 + \dfrac{R^2 - \omega^2 L^2}{j\omega RL}}$$

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \underline{\frac{\mathbf{1}}{\mathbf{3 + j(\omega L/R - R/\omega L)}}}$$

(b) Since the ratio $\dfrac{\mathbf{V}_2}{\mathbf{V}_o}$ must be real,

$$\frac{\omega_o L}{R} - \frac{R}{\omega_o L} = 0$$

$$\omega_o L = \frac{R^2}{\omega_o L}$$

$$\omega_o = 2\pi f_o = \frac{R}{L}$$

$$\underline{\mathbf{f_o = \frac{R}{2\pi L}}}$$

(c) When $\omega = \omega_o$

$$\frac{\mathbf{V}_2}{\mathbf{V}_o} = \frac{1}{3}$$

This must be compensated for by $\mathbf{A}_v = 3$. But

$$\mathbf{A}_v = 1 + \frac{R_2}{R_1} = 3$$

$$\underline{\mathbf{R_2 = 2\,R_1}}$$