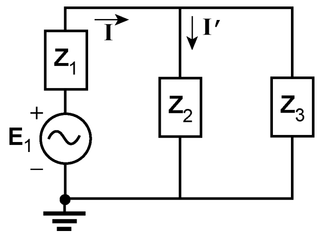
Chapter 19

1.

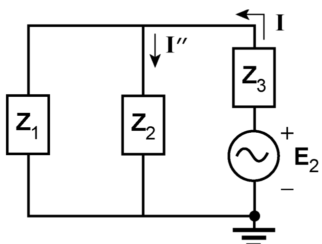


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 8\ \Omega\ \angle 90°$, $\mathbf{Z}_3 = 6\ \Omega\ \angle -90°$

$\mathbf{Z}_2 \parallel \mathbf{Z}_3 = 8\ \Omega\ \angle 90° \parallel 6\ \Omega\ \angle -90° = 24\ \Omega\ \angle -90°$

$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2 \parallel \mathbf{Z}_3} = \frac{30\text{ V}\angle 30°}{3\ \Omega - j24\ \Omega} = 1.24\text{ A }\angle 112.875°$$

$$\mathbf{I}' = \frac{\mathbf{Z}_3\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(6\ \Omega\ \angle -90°)(1.24\text{ A }\angle 112.875°)}{2\ \Omega\ \angle 90°} = 3.72\text{ A }\angle -67.125°$$



$\mathbf{Z}_1 \parallel \mathbf{Z}_2 = 3\ \Omega\ \angle 0° \parallel 8\ \Omega\ \angle 90° = 2.809\ \Omega\ \angle 20.556°$

$$\mathbf{I} = \frac{\mathbf{E}_2}{\mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2} = \frac{60\text{ V }\angle 10°}{-j6\ \Omega + 2.630\ \Omega + j0.986\ \Omega}$$

$= 10.597\text{ A }\angle 72.322°$

$$\mathbf{I}'' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(3\ \Omega\ \angle 0°)(10.597\text{ A }\angle 72.322°)}{3\ \Omega + j8\ \Omega} = 3.721\text{ A }\angle 2.878°$$

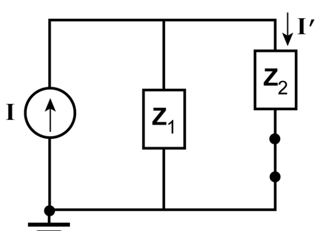
$\mathbf{I}_{L_1} = \mathbf{I}' + \mathbf{I}'' = 3.72\text{ A }\angle -67.125° + 3.721\text{ A }\angle 2.878°$

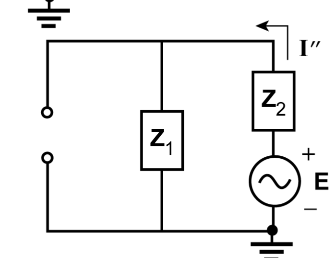
$= 1.446\text{ A} - j3.427\text{ A} + 3.716\text{ A} + j0.187\text{ A}$

$= 5.162\text{ A} - j3.24\text{ A}$

$= \mathbf{6.09\ A\ \angle -32.12°}$

2.





$\mathbf{Z}_1 = 8\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 5\ \Omega\ \angle -90°$

$\mathbf{I} = 0.3\text{ A }\angle 60°$, $\mathbf{E} = 10\text{ V }\angle 0°$

$$\mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(8\ \Omega\ \angle 90°)(0.3\text{ A }\angle 60°)}{+j8\ \Omega - j5\ \Omega} = \frac{2.4\text{ A }\angle 150°}{3\angle 90°}$$

$= 0.8\text{A }\angle 60°$

$$\mathbf{I}'' = \frac{\mathbf{E}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{10\text{ V }\angle 0°}{+j8\ \Omega - j5\ \Omega} = \frac{10\text{ A}\angle 0°}{3\angle 90°}$$

$= 3.33\text{ A }\angle -90°$

$\mathbf{I}_C = \mathbf{I}' - \mathbf{I}''$

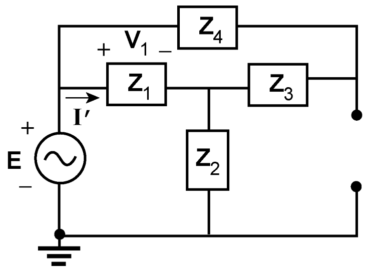
$= 0.8\text{ A }\angle 60° - 3.33\text{ A }\angle -90°$

$= (0.4\text{ A} + j0.69\text{ A}) + j3.33\text{ A}$

$= 0.4\text{ A} + j4.02\text{ A}$

$= \mathbf{4.04\ A\ \angle 84.32°}$

3. **E**:



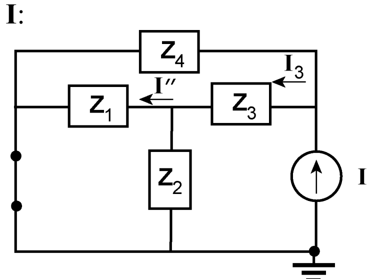
$\mathbf{Z}_1 = 3\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 7\ \Omega\ \angle -90°$
$\mathbf{E} = 10\ \text{V}\ \angle 90°$
$\mathbf{Z}_3 = 6\ \Omega\ \angle -90°$, $\mathbf{Z}_4 = 4\ \Omega\ \angle 0°$

$$\begin{aligned}\mathbf{Z}' &= \mathbf{Z}_1 \parallel (\mathbf{Z}_3 + \mathbf{Z}_4)\\ &= 3\ \Omega\ \angle 90° \parallel (4\ \Omega - j6\ \Omega)\\ &= 3\ \Omega\ \angle 90° \parallel 7.21\ \Omega\ \angle -56.31°\\ &= 4.33\ \Omega\ \angle 70.56°\end{aligned}$$

$$\begin{aligned}\mathbf{V}_1 &= \frac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_2}\\ &= \frac{(4.33\ \Omega\ \angle 70.56°)(10\ \text{V}\ \angle 90°)}{(1.44\ \Omega + j4.08\ \Omega) - j7\ \Omega}\\ &= \frac{43.3\ \text{V}\ \angle 160.56°}{3.26\ \angle -63.75°} = 13.28\ \text{V}\ \angle 224.31°\end{aligned}$$

$$\begin{aligned}\mathbf{I}' &= \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{13.28\ \text{V}\ \angle 224.31°}{3\ \Omega\ \angle 90°}\\ &= 4.43\ \text{A}\ \angle 134.31°\end{aligned}$$

I:



$$\begin{aligned}\mathbf{Z}'' &= \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2\\ &= -j6\ \Omega + 3\ \Omega\ \angle 90° \parallel 7\ \Omega\ \angle -90°\\ &= -j6\ \Omega + 5.25\ \Omega\ \angle 90°\\ &= -j6\ \Omega + j5.25\ \Omega\\ &= -j0.75\ \Omega = 0.75\ \Omega \angle -90°\end{aligned}$$

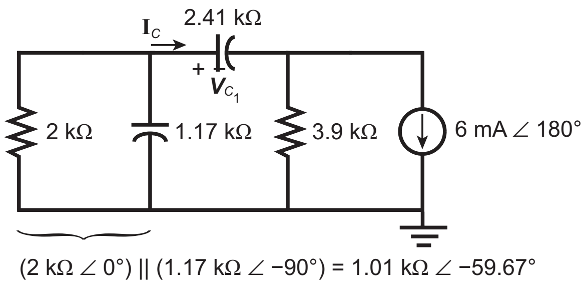
CDR: $$\begin{aligned}\mathbf{I}_3 &= \frac{\mathbf{Z}_4\mathbf{I}}{\mathbf{Z}_4 + \mathbf{Z}''} = \frac{(4\ \Omega\ \angle 0°)(0.6\ \text{A}\ \angle 120°)}{4\ \Omega - j0.75\ \Omega} = \frac{2.4\ \text{A}\ \angle 120°}{4.07\ \angle -10.62°}\\ &= 0.59\ \text{A}\ \angle 130.62°\end{aligned}$$

$$\begin{aligned}\mathbf{I}'' &= \frac{\mathbf{Z}_2\mathbf{I}_3}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(7\ \Omega\ \angle -90°)(0.59\ \text{A}\ \angle 130.62°)}{-j7\ \Omega + j3\ \Omega} = \frac{4.13\ \text{A}\ \angle 40.62°}{4\ \angle -90°}\\ &= 1.03\ \text{A}\ \angle 130.62°\end{aligned}$$

$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)

$$\begin{aligned}&= 4.43\ \text{A}\ \angle 134.31° - 1.03\ \text{A}\ \angle 130.62°\\ &= (-3.09\ \text{A} + j3.17\ \text{A}) - (-0.67\ \text{A} + j0.78\ \text{A}) = -2.42\ \text{A} + j2.39\ \text{A}\\ &= \mathbf{3.40\ A\ \angle 135.36°}\end{aligned}$$

4. **I**:



$$X_{C_1} = \frac{1}{2\pi(20\text{ kHz})(6.8\text{ nF})} = 1.17\text{ k}\Omega$$

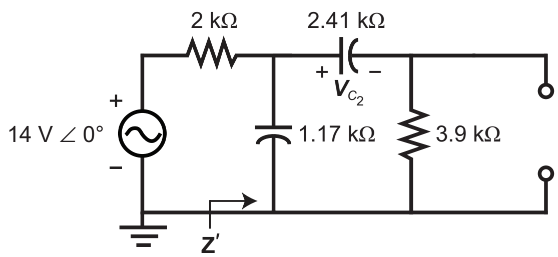
$$X_{C_2} = \frac{1}{2\pi(20\text{ kHz})(3.3\text{ nF})} = 2.41\text{ k}\Omega$$

$$\begin{aligned}\mathbf{Z}' &= 2.41\text{ k}\Omega\ \angle{-90^\circ} + 1.01\text{ k}\Omega\ \angle{-59.67^\circ}\\ &= -j2.41\text{ k}\Omega + 0.510\text{ k}\Omega - j0.871\text{ k}\Omega\\ &= 0.510\text{ k}\Omega - j3.28\text{ k}\Omega\end{aligned}$$

$$\begin{aligned}\mathbf{I}_C &= \frac{\mathbf{R}_2\mathbf{I}}{\mathbf{R}_2 + \mathbf{Z}'} = \frac{(3.9\text{ k}\Omega\ \angle 0^\circ)(6\text{ mA}\angle 180^\circ)}{3.9\text{ k}\Omega + 0.510\text{ k}\Omega - j3.28\text{ k}\Omega}\\ &= \frac{23.4\text{ mA}\angle 180^\circ}{4.41\angle - j3.28} = \frac{23.4\text{ mA}\angle 180^\circ}{5.5\angle -36.64^\circ}\\ &= 4.25\text{ mA}\ \angle 216.64^\circ\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{C_1} &= \mathbf{I}_C\mathbf{X}_{C_2} = (4.25\text{ mA}\ \angle 216.64^\circ)(2.41\text{ k}\Omega\ \angle{-90^\circ})\\ &= 10.24\text{ V}\ \angle 126.64^\circ\end{aligned}$$

E:



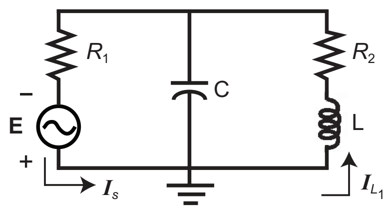
$$\begin{aligned}\mathbf{Z}' &= (1.17\text{ k}\Omega\ \angle{-90^\circ}) \,||\, (3.9\text{ k}\Omega - j2.41\text{ k}\Omega) = (1.17\text{ k}\Omega\ \angle{-90^\circ}) \,||\, (4.58\text{ k}\Omega\ \angle{-31.71^\circ})\\ &= \frac{(1.17\text{ k}\Omega\angle -90^\circ)(4.58\text{ k}\Omega\angle -31.71^\circ)}{-j1.17\text{ k}\Omega + j3.9\text{ k}\Omega - j2.41\text{ k}\Omega} = \frac{5.36\text{ k}\Omega\angle -121.71^\circ}{3.9 - j3.58}\\ &= \frac{5.36\text{ k}\Omega\angle -121.71^\circ}{5.29\angle -42.55^\circ} = 1.01\text{ k}\Omega\ \angle{-79.16^\circ}\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{\mathbf{Z}'} &= \frac{\mathbf{Z}'(\mathbf{E})}{\mathbf{Z}' + \mathbf{R}_1} = \frac{(1.01\text{ k}\Omega\angle -79.16^\circ)(14\text{ V}\angle 0^\circ)}{2\text{ k}\Omega + 1.01\text{ k}\Omega\angle -79.16^\circ}\\ &= \frac{14.14\text{ V}\ \angle -79.16^\circ}{2 + 0.189 - j0.991} = \frac{14.14\text{ V}\ \angle -79.16^\circ}{2.189 - j0.991} = \frac{14.14\text{ V}\ \angle -79.16^\circ}{2.4\angle -24.36^\circ}\\ &= 5.89\text{ V}\ \angle{-54.8^\circ}\end{aligned}$$

$$\begin{aligned}\mathbf{V}_{C_2} &= \frac{\mathbf{X}_{C_2}\mathbf{V}_{\mathbf{Z}}{}'}{\mathbf{X}_{C_2} + \mathbf{R}_2} = \frac{(2.41\text{ k}\Omega\ \angle -90^\circ)(5.89\text{ V}\angle -54.8^\circ)}{-j2.41\text{ k}\Omega + 3.9\text{ k}\Omega} = \frac{14.195\text{ V}\angle -144.8^\circ}{3.9\text{ k}\Omega - j2.41\text{ k}\Omega}\\ &= \frac{14.195\text{ V}\angle -144.8^\circ}{4.58\angle -31.71^\circ} = 3.1\text{ V}\ \angle{-113^\circ}\end{aligned}$$

$\mathbf{V}_C = \mathbf{V}_{C_1} + \mathbf{V}_{C_2}$
$= 10.24 \text{ V} \angle 126.64° + 3.1 \text{ V} \angle -113°$
$= (-6.11 \text{ V} + j8.21 \text{ V}) + (-1.21 \text{ V} - j2.85 \text{ V})$
$= -7.31 \text{ V} + j5.36 \text{ V}$
$= \mathbf{9.06 \text{ V} \angle 143.75°}$

5. **E**:



$X_L = 2\pi fL = 2\pi(10 \text{ kHz})(20 \text{ mH})$
$= 1.26 \text{ k}\Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(10 \text{ kHz})(0.01 \mu\text{F})}$
$= 1.59 \text{ k}\Omega$

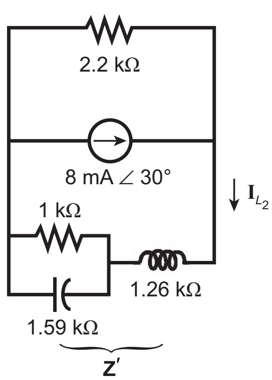
$\mathbf{Z}_T = R_1 \angle 0° + X_C \angle -90°) \parallel (R_2 \angle 0° + X_L \angle 90°)$
$= 1 \text{ k}\Omega + (1.59 \text{ k}\Omega \angle -90°) \parallel (\underbrace{2.2 \text{ k}\Omega + j1.26 \text{ k}\Omega}_{2.54 \text{ k}\Omega \angle 29.8°})$
$= 1 \text{ k}\Omega + \dfrac{(1.59 \text{ k}\Omega \angle -90°)(2.54 \text{ k}\Omega \angle 29.8°)}{-j1.59 \text{ k}\Omega + 2.2 \text{ k}\Omega + j1.26 \text{ k}\Omega}$
$= 1 \text{ k}\Omega + \dfrac{4.04 \text{ k}\Omega \angle -60.2°}{2.2 - j0.33} = 1 \text{ k}\Omega + \dfrac{4.04 \text{ k}\Omega \angle -60.2°}{2.23 \angle -8.46°}$
$= 1 \text{ k}\Omega + 1.81 \text{ k}\Omega \angle -51.74° = 1 \text{ k}\Omega + (1.12 \text{ k}\Omega - j1.42 \text{ k}\Omega)$
$= 2.12 \text{ k}\Omega - j1.42 \text{ k}\Omega$
$= 2.55 \text{ k}\Omega \angle -33.82°$

$\mathbf{I}_s = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{16 \text{ V} \angle 60°}{2.55 \text{ k}\Omega \angle -33.82°} = 6.27 \text{ mA} \angle 93.82°$

$\mathbf{I}_{L_1} = \dfrac{(X_C \angle -90°)(\mathbf{I}_s)}{X_C \angle -90° + R_2 \angle 0° + X_L \angle 90°}$
$= \dfrac{(1.59 \text{ k}\Omega \angle -90°)(6.27 \text{ mA} \angle 93.82°)}{-j1.59 \text{ k}\Omega + 2.2 \text{ k}\Omega + j1.26 \text{ k}\Omega}$
$= \dfrac{9.97 \text{ mA} \angle 3.82°}{2.2 - j0.33} = \dfrac{9.97 \text{ mA} \angle 3.82°}{2.22 \angle -8.53°}$

$\uparrow \mathbf{I}_{L_1} = 4.49 \text{ mA} \angle 12.35°$

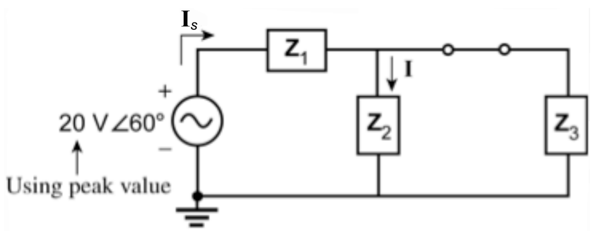
I:



$(1 \text{ k}\Omega \angle 0°) \parallel (1.59 \text{ k}\Omega \angle -90°) = 847.74 \ \Omega \angle -32.17°$
$\mathbf{Z}' = \mathbf{X}_L + 847.74 \ \Omega \angle -32.17°$
$= j1.26 \text{ k}\Omega + 717.59 \ \Omega - j451.36 \ \Omega$
$= 0.72 \text{ k}\Omega + j0.81 \text{ k}\Omega$
$= 1.08 \text{ k}\Omega \angle 48.36°$

$$\mathbf{I}_{L_2} = \frac{\mathbf{R}_2(\mathbf{I})}{\mathbf{R}_2 + \mathbf{Z}'} = \frac{(2.2\text{ k}\Omega\ \angle 0°)(8\text{ mA}\ \angle 30°)}{2.2\text{ k}\Omega + 0.72\text{ k}\Omega + j0.81\text{ k}\Omega}$$
$$= \frac{17.6\text{ mA}\ \angle 30°}{2.92 + j0.81} = \frac{17.6\text{ mA}\ \angle 30°}{3.03\ \angle 15.50°}$$
$$= 5.81\text{ mA}\ \angle 14.5°$$
$$\mathbf{I}_L = \mathbf{I}_{L_1} - \mathbf{I}_{L_2}\ \text{(direction of } \mathbf{I}_{L_1})$$
$$= (4.49\text{ mA}\ \angle 12.35°) - (5.81\text{ mA}\ \angle 14.5°)$$
$$= (4.39\text{ mA} + j0.96\text{ mA}) - (5.62\text{ mA} + j1.45\text{ mA})$$
$$= -1.23\text{ mA} - j0.49\text{ mA}$$
$$= \mathbf{1.32\text{ mA}\ \angle -158.2°}$$

6. AC:



$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C} = \frac{1}{(1000)(4.7\ \mu\text{F})}$$
$$= 212.77\ \Omega$$
$$X_L = 2\pi fL = \omega L = (1000)(47\text{ mH})$$
$$= 47\ \Omega$$

$\mathbf{Z}_1 = 212.77\ \Omega\ \angle -90°$, $\mathbf{Z}_2 = 47\ \Omega\ \angle 0°$, $\mathbf{Z}_3 = 22\ \Omega + j47\ \Omega = 51.89\ \Omega\ \angle 64.92°$

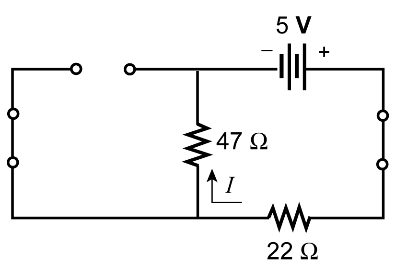
$\mathbf{Z}_2 \| \mathbf{Z}_3 = 29.23\ \Omega\ \angle 30.66°$

$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 = -j212.77\ \Omega + 25.14\ \Omega + j14.91\ \Omega$$
$$= 25.14\ \Omega - j197.86\ \Omega = 199.45\ \Omega\ \angle -82.76°$$

$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{20\text{ V}\ \angle 60°}{199.45\ \Omega\ \angle -82.76°} = 0.1\text{ A}\ \angle 142.76°$$

$$\mathbf{I} = \frac{\mathbf{Z}_3 \mathbf{I}_s}{\mathbf{Z}_3 + \mathbf{Z}_2} = \frac{(51.89\ \Omega\ \angle 64.92°)(0.1\text{ A}\ \angle 142.76°)}{22\ \Omega + j47\ \Omega + 47\ \Omega} = \frac{5.19\text{ A}\ \angle 207.68°}{83.49\ \angle 34.26°}$$
$$\mathbf{I} = 62.16\text{ mA}\ \angle 173.42°$$
and $\boldsymbol{i = 62.16 \times 10^{-3} \sin (1000t + 173.42°)}$

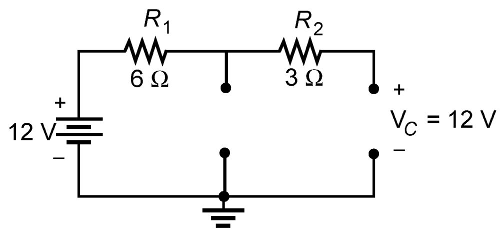
DC:



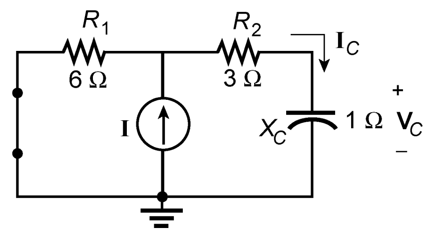
$$I = \frac{5\text{ V}}{22\ \Omega + 47\ \Omega} = \frac{5\text{ V}}{69\ \Omega}$$
$$= \mathbf{72.46\text{ mA}}$$

$\boldsymbol{i = -72.46\text{ mA} + 62.16 \times 10^{-3} \sin (1000t + 173.42°)}$

7. DC:



AC:



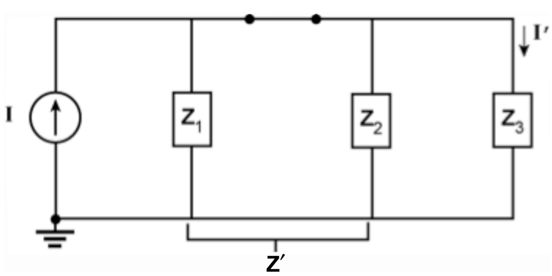
$$\mathbf{I}_C = \frac{(6\ \Omega \angle 0°)(\mathbf{I})}{6\ \Omega + 3\ \Omega - j1\ \Omega} = \frac{(6\ \Omega \angle 0°)(4\ \text{A} \angle 0°)}{9\ \Omega - j1\ \Omega} = \frac{24\ \text{A} \angle 0°}{9.055 \angle -6.34°} = 2.65\ \text{A} \angle 6.34°$$

$\mathbf{V}_C = \mathbf{I}_C\mathbf{X}_C = (2.65\ \text{A} \angle 6.34°)(1\ \Omega \angle -90°) = 2.65\ \text{V} \angle -83.66°$

$= \mathbf{12\ V + 2.65\ V \angle -83.66°}$

$\upsilon_C = \mathbf{12\ V + 3.75\ sin(\omega \mathit{t} - 83.66°)}$

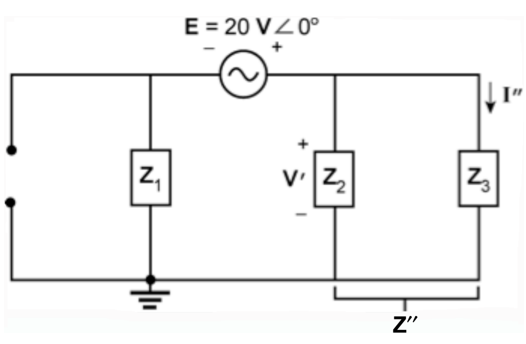
8.



$\mathbf{E} = 20\ \text{V} \angle 0°$
$\mathbf{Z}_1 = 10\ \text{k}\Omega \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega$
$= 7.071\ \text{k}\Omega \angle -45°$
$\mathbf{Z}_3 = 5\ \text{k}\Omega \angle 90°$
$\mathbf{I} = 5\ \text{mA} \angle 0°$

$\mathbf{Z}' = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = 10\ \text{k}\Omega \angle 0° \parallel 7.071\ \text{k}\Omega \angle -45° = 4.472\ \text{k}\Omega \angle -26.57°$

(CDR) $$\mathbf{I}' = \frac{\mathbf{Z}'\mathbf{I}}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(4.472\ \text{k}\Omega \angle -26.57°)(5\ \text{mA} \angle 0°)}{4\ \text{k}\Omega - j2\ \text{k}\Omega + j5\ \text{k}\Omega} = \frac{22.36\ \text{mA} \angle -26.57°}{5 \angle 36.87°}$$
$= 4.472\ \text{mA} \angle -63.44°$



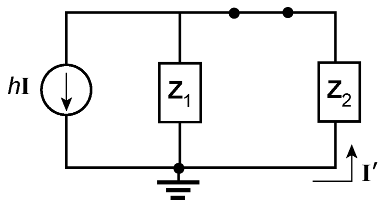
$\mathbf{Z}'' = \mathbf{Z}_2 \parallel \mathbf{Z}_3$
$= 7.071\ \text{k}\Omega \angle -45° \parallel 5\ \text{k}\Omega \angle 90°$
$= 7.071\ \text{k}\Omega \angle 45°$

(VDR) $$\mathbf{V}' = \frac{\mathbf{Z}''\mathbf{E}}{\mathbf{Z}'' + \mathbf{Z}_1} = \frac{(7.071\ \text{k}\Omega \angle 45°)(20\ \text{V} \angle 0°)}{(5\ \text{k}\Omega + j5\ \text{k}\Omega) + (10\ \text{k}\Omega)} = \frac{141.42\ \text{V} \angle 45°}{15.81 \angle 18.435°}$$
$= 8.945\ \text{V} \angle 26.565°$

$$\mathbf{I}'' = \frac{\mathbf{V}'}{\mathbf{Z}_3} = \frac{8.945\text{ V }\angle 26.565^\circ}{5\text{ k}\Omega\ \angle 90^\circ} = 1.789\text{ mA }\angle{-63.435^\circ} = 0.8\text{ mA} - j1.6\text{ mA}$$

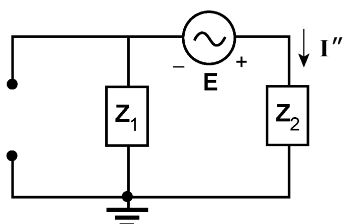
$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = (2\text{ mA} - j4\text{ mA}) + (0.8\text{ mA} - j1.6\text{ mA}) = 2.8\text{ mA} - j5.6\text{ mA}$$
$$= \mathbf{6.26\ mA\ \angle{-63.43^\circ}}$$

9.



$\mathbf{Z}_1 = 20\text{ k}\Omega\ \angle 0^\circ$
$\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 90^\circ$
$\mathbf{I} = 2\text{ mA }\angle 0^\circ$
$\mathbf{E} = 10\text{ V }\angle 0^\circ$

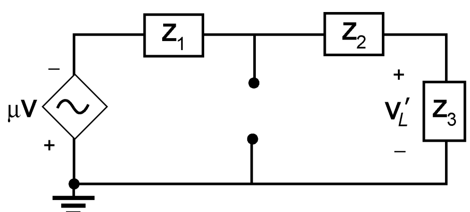
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\text{ k}\Omega\ \angle 0^\circ)(100)(2\text{ mA }\angle 0^\circ)}{20\text{ k}\Omega + j10\text{ k}\Omega} = 0.179\text{ A }\angle{-26.57^\circ}$$



$$\mathbf{I}'' = \frac{\mathbf{E}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{10\text{ V }\angle 0^\circ}{22.36\text{ k}\Omega\ \angle 26.57^\circ}$$
$$= 0.447\text{ mA }\angle{-26.57^\circ}$$

$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$= 179\text{ mA }\angle{-26.57^\circ} - 0.447\text{ mA }\angle{-26.57^\circ}$
$= \mathbf{178.55\ mA\ \angle{-26.57^\circ}}$

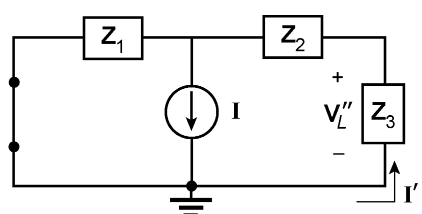
10. $\mu\mathbf{V}$:



$\mathbf{Z}_1 = 5\text{ k}\Omega\ \angle 0^\circ$, $\mathbf{Z}_2 = 1\text{ k}\Omega\ \angle{-90^\circ}$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle 0^\circ$
$\mathbf{V} = 2\text{ V }\angle 0^\circ$, $\mu = 20$

$$\mathbf{V}'_L = \frac{-\mathbf{Z}_3(\mu\mathbf{V})}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{-(4\text{ k}\Omega\ \angle 0^\circ)(20)(2\text{ V }\angle 0^\circ)}{5\text{ k}\Omega - j1\text{ k}\Omega + 4\text{ k}\Omega} = -17.67\text{ V }\angle 6.34^\circ$$

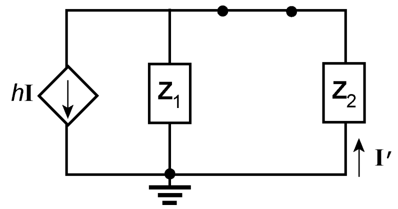
I:



$$\text{CDR: } \mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3}$$
$$= \frac{(5\text{ k}\Omega\ \angle 0^\circ)(2\text{ mA }\angle 0^\circ)}{9.056\text{ k}\Omega\ \angle{-6.34^\circ}}$$
$$= 1.104\text{ mA }\angle 6.34^\circ$$

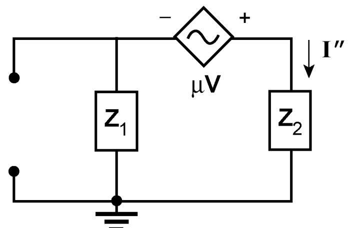
$\mathbf{V}''_L = -\mathbf{I}'\mathbf{Z}_3 = -(1.104\text{ mA }\angle 6.34^\circ)(4\text{ k}\Omega\ \angle 0^\circ) = -4.416\text{ V }\angle 6.34^\circ$
$\mathbf{V}_L = \mathbf{V}'_L + \mathbf{V}''_L = -17.67\text{ V }\angle 6.34^\circ - 4.416\text{ V }\angle 6.34^\circ = \mathbf{-22.09\ V\ \angle 6.34^\circ}$

11.



$\mathbf{Z}_1 = 20\text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega + j5\text{ k}\Omega$

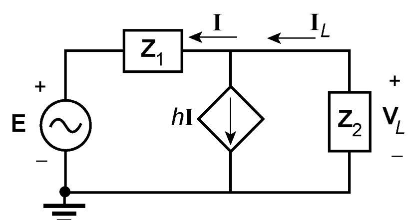
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\text{ k}\Omega \angle 0°)(100)(1\text{ mA} \angle 0°)}{20\text{ k}\Omega + 5\text{ k}\Omega + j5\text{ k}\Omega} = 78.45\text{ mA} \angle -11.31°$$



$$\mathbf{I}'' = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(10\text{ V} \angle 0°)}{25.495\text{ k}\Omega \angle 11.31°}$$
$$= 7.845\text{ mA} \angle -11.31°$$

$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$= 78.45\text{ mA} \angle -11.31° - 7.845\text{ mA} \angle -11.31°$
$= \mathbf{70.61\text{ mA} \angle -11.31°}$

12.



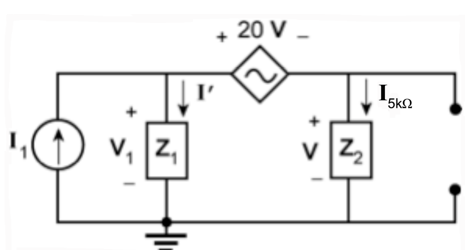
$\mathbf{Z}_1 = 2\text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 2\text{ k}\Omega \angle 0°$
$\mathbf{V}_L = -\mathbf{I}_L\mathbf{Z}_2$
$\mathbf{I}_L = h\mathbf{I} + \mathbf{I} = (h + 1)\mathbf{I}$
$\mathbf{V}_L = -(h + 1)\mathbf{I}\mathbf{Z}_2$
and by KVL: $\mathbf{V}_L = \mathbf{I}\mathbf{Z}_1 + \mathbf{E}$
so that $\mathbf{I} = \dfrac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}$

$$\mathbf{V}_L = -(h + 1)\mathbf{I}\mathbf{Z}_2 = -(h + 1)\left[\frac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}\right]\mathbf{Z}_2$$

Subt. for $\mathbf{Z}_1$, $\mathbf{Z}_2$

$\mathbf{V}_L = -(h + 1)(\mathbf{V}_L - \mathbf{E})$
$\mathbf{V}_L(2 + h) = \mathbf{E}(h + 1)$
$$\mathbf{V}_L = \frac{(h+1)}{(h+2)}\mathbf{E} = \frac{51}{52}(20\text{ V} \angle 53°) = \mathbf{19.62\text{ V} \angle 53°}$$

13. $\mathbf{I}_1$:



$\mathbf{I}_1 = 1\text{ mA} \angle 0°$
$\mathbf{Z}_1 = 2\text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega \angle 0°$

KVL: $\mathbf{V}_1 - 20\text{ }\mathbf{V} - \mathbf{V} = 0$

$\mathbf{I}' = \dfrac{\mathbf{V}_1}{\mathbf{Z}_1}$ $\therefore$ $\mathbf{I}' = \dfrac{21\mathbf{V}}{\mathbf{Z}_1}$ or $\mathbf{V} = \dfrac{\mathbf{Z}_1}{21}\mathbf{I}'$

$\mathbf{V}_1 = 21\text{ }\mathbf{V}$

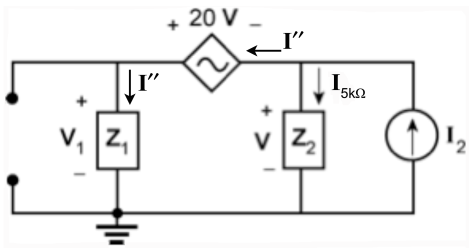
$\mathbf{V} = \mathbf{I}_{5k\Omega}\mathbf{Z}_2 = [\mathbf{I}_1 - \mathbf{I}']\mathbf{Z}_2$

$\dfrac{\mathbf{Z}_1}{21}\mathbf{I}' = \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}'\mathbf{Z}_2$

$\mathbf{I}'\left[\dfrac{\mathbf{Z}_1}{21} + \mathbf{Z}_2\right] = \mathbf{I}_1\mathbf{Z}_2$

and $\mathbf{I}' = \dfrac{\mathbf{Z}_2}{\dfrac{\mathbf{Z}_1}{21} + \mathbf{Z}_2}[\mathbf{I}_1] = \dfrac{(5\text{ k}\Omega\angle 0°)(1\text{ mA}\angle 0°)}{\left(\dfrac{2\text{ k}\Omega\angle 0°}{21}\right) + 5\text{ k}\Omega\angle 0°} = 0.981\text{ mA}\angle 0°$

$\mathbf{I}_2$:



$\mathbf{V}_1 = 20\text{ V} + \mathbf{V} = 21\text{ V}$

$\mathbf{I}'' = \dfrac{\mathbf{V}_1}{\mathbf{Z}_1} = \dfrac{21\text{ V}}{\mathbf{Z}_1} \Rightarrow \mathbf{V} = \dfrac{\mathbf{Z}_1}{21}\mathbf{I}''$

$\mathbf{I}_{5k\Omega} = \dfrac{\mathbf{V}}{\mathbf{Z}_2} = \dfrac{\mathbf{Z}_1}{21\,\mathbf{Z}_2}\mathbf{I}''$

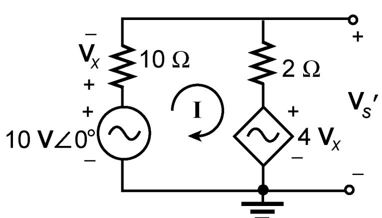
$\mathbf{I}'' = \mathbf{I}_2 - \mathbf{I}_{5k\Omega} = \mathbf{I}_2 - \dfrac{\mathbf{Z}_1}{21\,\mathbf{Z}_2}\mathbf{I}''$

$\mathbf{I}''\left[1 + \dfrac{\mathbf{Z}_1}{21\mathbf{Z}_2}\right] = \mathbf{I}_2$

$\mathbf{I}'' = \dfrac{\mathbf{I}_2}{1 + \dfrac{\mathbf{Z}_1}{21\,\mathbf{Z}_2}} = \dfrac{2\text{ mA}\angle 0°}{1 + \dfrac{2\text{ k}\Omega}{21(5\text{ k}\Omega)}} = 1.963\text{ mA}\angle 0°$

$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = 0.981\text{ mA}\angle 0° + 1.963\text{ mA}\angle 0°$
$= \mathbf{2.94\text{ mA}\angle 0°}$

14. $\mathbf{E}_1$:



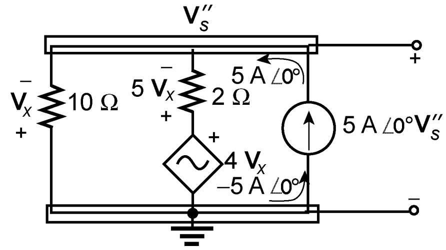
$10\text{ V}\angle 0° - \mathbf{I}\,10\,\Omega - \mathbf{I}\,2\,\Omega - 4\,\mathbf{V}_x = 0$
with $\mathbf{V}_x = \mathbf{I}\,10\,\Omega$

Solving for **I**:

$\mathbf{I} = \dfrac{10\text{ V}\angle 0°}{52\,\Omega} = 192.31\text{ mA}\angle 0°$

$\mathbf{V}_s' = 10\text{ V}\angle 0° - \mathbf{I}(10\,\Omega) = 10\text{ V} - (192.31\text{ mA}\angle 0°)(10\,\Omega\angle 0°) = 8.08\text{ V}\angle 0°$

I:



$$\Sigma \mathbf{I}_i = \Sigma \mathbf{I}_o$$

$$5\text{ A}\angle 0° + \frac{\mathbf{V}_x}{10\,\Omega} + \frac{5\,\mathbf{V}_x}{2\,\Omega} = 0$$

$$5\text{ A} + 0.1\,\mathbf{V}_x + 2.5\,\mathbf{V}_x = 0$$

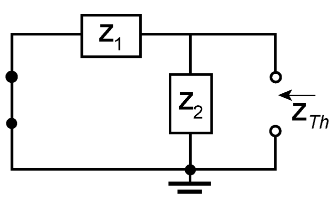
$$2.6\,\mathbf{V}_x = -5\text{ A}$$

$$\mathbf{V}_x = -\frac{5}{2.6}\mathbf{V} = -1.923\text{ V}$$

$$\mathbf{V}_s'' = -\mathbf{V}_x = -(-1.923\text{ V}) = 1.923\text{ V}\angle 0°$$

$$\mathbf{V}_s = \mathbf{V}_s' + \mathbf{V}_s'' = 8.08\text{ V}\angle 0° + 1.923\text{ V}\angle 0° = \mathbf{10\text{ V}\angle 0°}$$

15. $\mathbf{Z}_{Th}$:



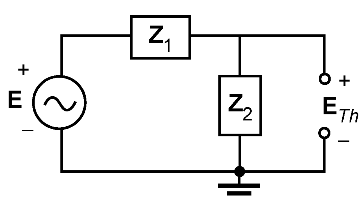
$\mathbf{Z}_1 = 3\,\Omega\angle 0°$, $\mathbf{Z}_2 = 4\,\Omega\angle 90°$

$\mathbf{E} = 100\text{ V}\angle 0°$

$\mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = (3\,\Omega\angle 0° \parallel 4\,\Omega\angle 90°)$

$= \mathbf{2.4\,\Omega\angle 36.87° = 1.92\,\Omega + \mathit{j}1.44\,\Omega}$

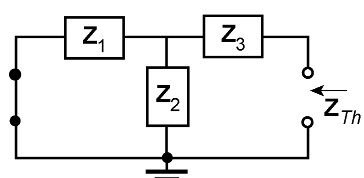
$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(4\,\Omega\angle 90°)(100\text{ V}\angle 0°)}{5\,\Omega\angle 53.13°}$$

$$= \mathbf{80\text{ V}\angle 36.87°}$$

16. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$

$= +j6\text{ k}\Omega + (2\text{ k}\Omega\angle 0° \parallel 3\text{ k}\Omega\angle -90°)$

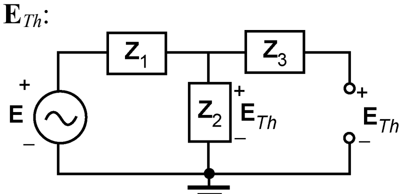
$= +j6\text{ k}\Omega + 1.664\text{ k}\Omega\angle -33.69°$

$= +j6\text{ k}\Omega + 1.385\text{ k}\Omega - j0.923\text{ k}\Omega$

$= 1.385\text{ k}\Omega + j5.077\text{ k}\Omega$

$= \mathbf{5.26\text{ k}\Omega\angle 74.74°}$

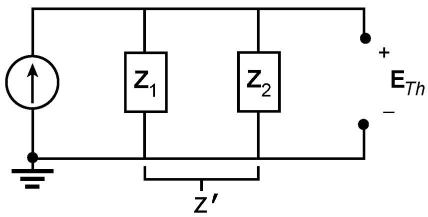
$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(3\text{ k}\Omega\angle -90°)(20\text{ V}\angle 0°)}{2\text{ k}\Omega - j3\text{ k}\Omega}$$

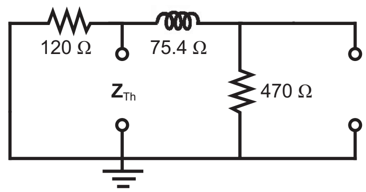
$$= \frac{60\text{ V}\angle -90°}{3.606\angle -56.31°} = \mathbf{16.64\text{ V}\angle -33.69°}$$

17. From #35. $\mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2$
$\mathbf{Z}_{Th} = \mathbf{Z}_N = \mathbf{21.31\ \Omega \angle 32.2°}$



$\mathbf{E}_{Th} = \mathbf{IZ'} = \mathbf{IZ}_{Th}$
$= (0.1\ \text{A} \angle 0°)(21.31\ \Omega \angle 32.12°)$
$= \mathbf{2.13\ V \angle 32.2°}$

18. $\mathbf{Z}_{Th}$



$X_L = 2\pi fL = 2\pi(1\ \text{kHz})(12\ \text{mH}) = 75.4\ \Omega$

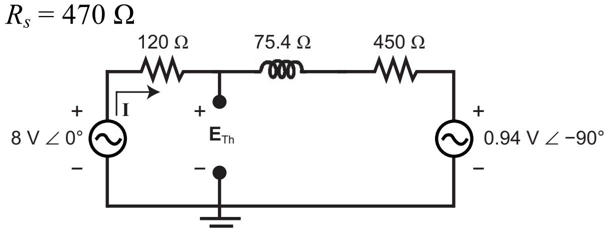
$$\mathbf{Z}_{Th} = (120\ \Omega \angle 0°) \parallel \underbrace{(470\ \Omega + j75.4\ \Omega)}_{476.01 \angle 9.11°}$$

$$= \frac{(120\ \Omega \angle 0°)(476.01\ \Omega \angle 9.11°)}{120\ \Omega + 470\ \Omega + j75.4\ \Omega}$$

$$= \frac{57.12\ \text{k}\Omega \angle 9.11°}{\underbrace{590 + j75.4\ \Omega}_{594.8 \angle 7.28°}}$$

$\mathbf{Z}_{Th} = \mathbf{96.03\ \Omega \angle 1.83°}$

$\mathbf{E}_{Th}$ Source conversion:
$\mathbf{E}_2 = \mathbf{IZ} = (2\ \text{mA} \angle -90°)(470\ \Omega \angle 0°) = 0.94\ \text{V} \angle -90°$
$R_s = 470\ \Omega$



$$\mathbf{I} = \frac{8\ \text{V} \angle 0° - 0.94\ \text{V} \angle -90°}{120\ \Omega + 470\ \Omega + j75.4\ \Omega}$$

$$= \frac{8\ \text{V} \angle 0° - (-j0.94\ \text{V})}{590\ \Omega + j75.4\ \Omega} = \frac{8\ \text{V} + j0.94\ \text{V}}{594.8\ \Omega \angle 7.28°}$$

$$= \frac{8.055\ \text{V} \angle 6.70°}{594.8\ \Omega \angle 7.28°}$$

$= 13.54\ \text{mA} \angle -0.58°$

$\mathbf{E}_{Th} = 8\ \text{V} \angle 0° - \mathbf{IR} = 8\ \text{V} \angle 0° - (13.54\ \text{mA} \angle -0.58°)(120\ \Omega)$
$= 8\ \text{V} \angle 0° - 1.62\ \text{V} \angle -0.58°$
$= 8\ \text{V} - (1.62\ \text{V} - j16.4 \times 10^{-3}\ \text{V})$
$= 8\ \text{V} - 1.62\ \text{V} + j16.4 \times 10^{-3}\ \text{V}$
$= 8\ \text{V} - 1.62\ \text{V} + j0.016\ \text{V}$
$= 6.38\ \text{V} + j16.4 \times 10^{-3}\ \text{V}$

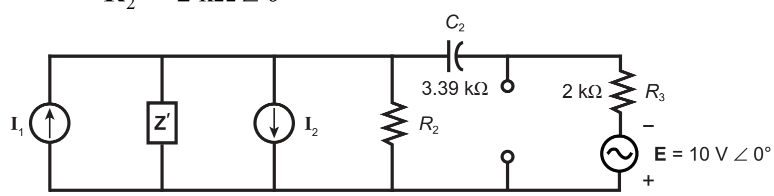
19. $X_{C_1} = X_{C_2} = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(1\text{ kHz})(0.047\ \mu\text{F})} = 3.39\text{ k}\Omega$

Source conversions:

$\mathbf{Z}' = \mathbf{R}_1 + \mathbf{X}_{C_1} = 2\text{ k}\Omega - j3.39\text{ k}\Omega = 3.94\text{ k}\Omega\ \angle{-59.46°}$

$\mathbf{I}_1 = \dfrac{\mathbf{E}_1}{\mathbf{Z}'} = \dfrac{10\text{ V}\angle 0°}{3.94\text{ k}\Omega\angle -59.46°} = 2.53\text{ mA}\ \angle 59.46°$

$\mathbf{I}_2 = \dfrac{\mathbf{E}_2}{\mathbf{R}_2} = \dfrac{10\text{ V}\angle 0°}{2\text{ k}\Omega\angle 0°} = 5\text{ mA}\ \angle 0°$, $\mathbf{E} = \mathbf{IZ} = (5\text{ mA}\ \angle 0°)(2\text{ k}\Omega\ \angle 0°) = 10\text{ V}\ \angle 0°$



$\mathbf{I}_T = \mathbf{I}_1 - \mathbf{I}_2 = 2.53\text{ mA}\ \angle 59.46° - 5\text{ mA}\ \angle 0°$
$= 1.29\text{ mA} + j2.18\text{ mA} - 5\text{ mA}$
$= -2.47\text{ mA} + j2.18\text{ mA}$
$= 3.29\text{ mA}\ \angle 138.57°$

$Z' \parallel R_2 = (3.94\text{ k}\Omega\ \angle{-59.46°}) \parallel (2\text{ k}\Omega\ \angle 0°)$

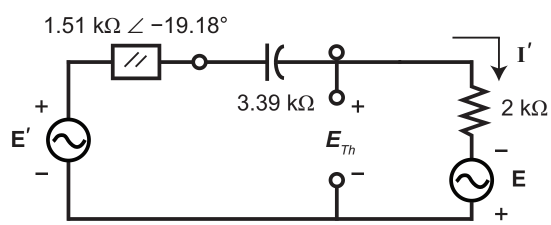
$$= \frac{(3.94\text{ k}\Omega\angle -59.46°)(2\text{ k}\Omega\angle 0°)}{2\text{ k}\Omega - j3.39\text{ k}\Omega + 2\text{ k}\Omega}$$

$$= \frac{7.88\text{ k}\Omega\angle -59.46°}{4 - j3.39} = \frac{7.88\text{ k}\Omega\angle -59.46°}{5.24\angle -40.28°}$$

$= 1.51\text{ k}\Omega\ \angle{-19.18°}$

Source conversion:

$\mathbf{E}' = \mathbf{IZ} = (3.29\text{ mA}\ \angle 138.57°)(1.51\text{ k}\Omega\ \angle{-19.18°})$
$= 4.97\text{ V}\ \angle 119.39°$



$\mathbf{Z}_{Th} = (2\text{ k}\Omega\ \angle 0°) \parallel (1.51\text{ k}\Omega\ \angle{-19.18°} - j3.39\text{ k}\Omega)$
$= (2\text{ k}\Omega\ \angle 0°) \parallel (1.43\text{ k}\Omega - j0.496\text{ k}\Omega - j3.39\text{ k}\Omega)$
$= (2\text{ k}\Omega\ \angle 0°) \parallel (1.43\text{ k}\Omega - j3.89\text{ k}\Omega)$
$= (2\text{ k}\Omega\ \angle 0°) \parallel (4.14\text{ k}\Omega\ \angle{-69.82°})$

$$= \frac{(2\text{ k}\Omega\angle 0°)(4.14\text{ k}\Omega\angle -69.82°)}{2\text{ k}\Omega + 1.43\text{ k}\Omega - j3.89\text{ k}\Omega}$$

$$= \frac{8.28\text{ k}\Omega\angle -69.82°}{3.43 - j3.89}$$

$$= \frac{8.28\text{ k}\Omega \angle -69.82°}{5.19 \angle -48.6°}$$

$\mathbf{Z}_{Th}$ = **1.6 kΩ ∠−21.22°**

$$\mathbf{I'} = \frac{\mathbf{E'} + \mathbf{E}}{2\text{ k}\Omega - j3.39\text{ k}\Omega + 1.51\text{ k}\Omega \angle -19.18°}$$

$$= \frac{4.97\text{ V} \angle 119.39° + 10\text{ V} \angle 0°}{2\text{ k}\Omega - j3.39\text{ k}\Omega + 1.43\text{ k}\Omega \angle - j0.496\text{ k}\Omega}$$

$$= \frac{-2.44\text{ V} + j4.33\text{ V} + 10\text{ V}}{3.43\text{ k}\Omega - j3.89\text{ k}\Omega}$$

$$= \frac{7.56\text{ V} + j4.33\text{ V}}{5.19\text{ k}\Omega \angle -48.6°} = \frac{8.71\text{ V} \angle 29.8°}{5.19\text{ k}\Omega \angle -48.6°}$$

$= 1.68\text{ mA} \angle 78.4°$

$\mathbf{E}_{Th} - \mathbf{V}_{2\text{k}\Omega} + \mathbf{E} = 0$

$\mathbf{E}_{Th} = \mathbf{V}_{2\text{k}\Omega} - \mathbf{E}$

$= (\mathbf{I'})(2\text{ k}\Omega) - 10\text{ V} \angle 0°$

$= (1.68\text{ mA} \angle 78.4°)(2\text{ k}\Omega \angle 0°) - 10\text{ V}$

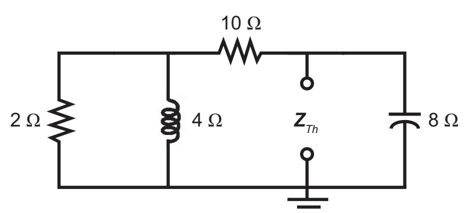
$= 3.36\text{ V} \angle 78.40° - 10\text{ V}$

$= 0.68\text{ V} + j3.29\text{ V} - 10\text{ V}$

$= -9.32\text{ V} + j3.29\text{ V}$

$\mathbf{E}_{Th}$ = **9.88 V ∠160.56°**

20.



$\mathbf{Z}_{Th} = (8\ \Omega \angle -90°) \parallel (10\ \Omega + 2\ \Omega \parallel 4\ \Omega \angle 90°)$

$$= (8\ \Omega \angle -90°) \parallel \underbrace{\left(10\ \Omega + \frac{8\ \Omega \angle 90°}{2 + j4}\right)}$$

$$\underbrace{10\ \Omega + \frac{8\ \Omega \angle 90°}{4.47 \angle 63.44°}}$$

$$\underbrace{10\ \Omega + 1.79\ \Omega \angle 26.56°}$$

$$\underbrace{10\ \Omega + 1.6\ \Omega + j0.8\ \Omega}$$

$$\underbrace{11.6\ \Omega + j0.8\ \Omega}$$

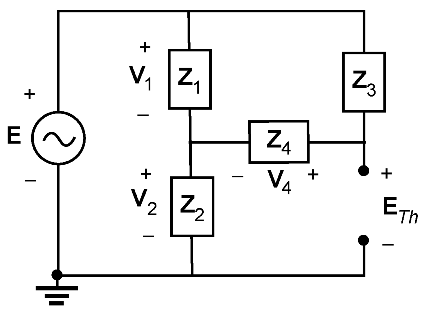
$$11.63\ \Omega \angle 3.95°$$

$= (8\ \Omega \angle -90°) \parallel (11.63\ \Omega \angle 3.95°)$

$$= \frac{92.8\ \Omega \angle -86.05°}{-j8 + 11.6 + j0.8} = \frac{92.8\ \Omega \angle -86.05°}{11.6 - j7.2}$$

$$= \frac{92.8\ \Omega \angle -86.05°}{13.65 \angle -31.83°}$$

$\mathbf{Z}_{Th} = \mathbf{Z}_{\text{N}}$ = **6.79 Ω ∠−54.22°**



$\mathbf{Z}_1 = 2\ \Omega\ \angle 0°$, $\mathbf{Z}_3 = 8\ \Omega\ \angle{-90°}$
$\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_4 = 10\ \Omega\ \angle 0°$
$\mathbf{E} = 50\ \text{V}\ \angle 0°$
$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4$

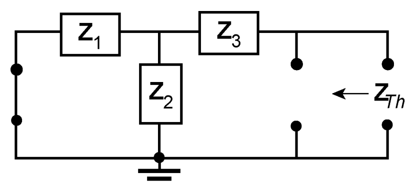
$$\mathbf{V}_2 = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1 \parallel (\mathbf{Z}_3 + \mathbf{Z}_4)}$$
$$= \frac{(4\ \Omega \angle 90°)(50\ \text{V} \angle 0°)}{+j4\ \text{k}\Omega + 2\ \Omega \angle 0° \parallel (10\ \Omega - j8\ \Omega)}$$
$$= 47.248\ \text{V}\ \angle 24.7°$$

$\mathbf{V}_1 = \mathbf{E} - \mathbf{V}_2 = 50\ \text{V}\ \angle 0° - 47.248\ \text{V}\ \angle 24.7° = 20.972\ \text{V}\ \angle{-70.285°}$

$$\mathbf{V}_4 = \frac{\mathbf{Z}_4\mathbf{V}_1}{\mathbf{Z}_4 + \mathbf{Z}_3} = \frac{(10\ \Omega \angle 0°)(20.972\ \text{V} \angle -70.285°)}{10\ \Omega - j8\ \Omega} = 16.377\ \text{V}\ \angle{-31.625°}$$

$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4 = 47.248\ \text{V}\ \angle 24.7° + 16.377\ \text{V}\ \angle{-31.625°}$
$= (42.925\ \text{V} + j19.743\ \text{V}) + (13.945\ \text{V} - j8.587\ \text{V})$
$= 56.870\ \text{V} + j11.156\ \text{V} =$ $\mathbf{57.95\ V\ \angle 11.10°}$

21. $\mathbf{Z}_{Th}$:

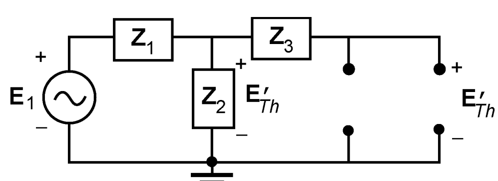


$\mathbf{Z}_1 = 10\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 8\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 8\ \Omega\ \angle{-90°}$

$\mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$
$= -j8\ \Omega + 10\ \Omega\ \angle 0° \parallel 8\ \Omega\ \angle 90°$
$= -j8\ \Omega + 6.247\ \Omega\ \angle 51.34°$
$= -j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega$
$= 3.902\ \Omega - j3.122\ \Omega$
$=$ $\mathbf{5.00\ \Omega\ \angle{-38.66°}}$

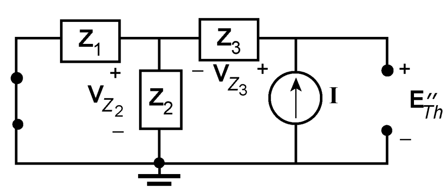
$\mathbf{E}_{Th}$: Superposition:

($\mathbf{E}_1$)



$$\mathbf{E}'_{Th} = \frac{(8\ \Omega\ \angle 90°)(120\ \text{V}\ \angle 0°)}{10\ \Omega + j8\ \Omega}$$
$$= \frac{960\ \text{V}\ \angle 90°}{12.806\ \angle 38.66°}$$
$$= 74.965\ \text{V}\ \angle 51.34°$$

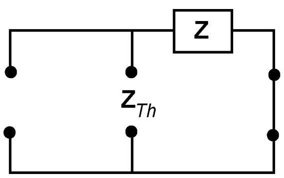
($\mathbf{I}$)



$$\mathbf{E''}_{Th} = \mathbf{V}_{Z_2} + \mathbf{V}_{Z_3}$$
$$= \mathbf{I}\mathbf{Z}_3 + \mathbf{I}(\mathbf{Z}_1 \parallel \mathbf{Z}_2)$$
$$= \mathbf{I}(\mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2)$$
$$= (0.5\text{ A}\angle 60°)(-j8\ \Omega + 10\ \Omega\angle 0° \parallel 8\ \Omega\angle 90°)$$
$$= (0.5\text{ A}\angle 60°)(-j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega)$$
$$= (0.5\text{ A}\angle 60°)(3.902\ \Omega - j3.122\ \Omega)$$
$$= (0.5\text{ A}\angle 60°)(4.997\ \Omega\angle -38.663°)$$
$$= 2.499\text{ V}\angle 21.337°$$

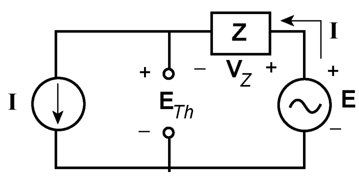
$$\mathbf{E}_{Th} = \mathbf{E'}_{Th} + \mathbf{E''}_{Th}$$
$$= 74.965\text{ V}\angle 51.34° + 2.449\text{ V}\angle 21.337°$$
$$= (46.83\text{ V} + j58.538\text{ V}) + (2.328\text{ V} + j0.909\text{ V})$$
$$= 49.158\text{ V} + j59.447\text{ V} = \mathbf{77.14\text{ V}\angle 50.41°}$$

22. $\mathbf{Z}_{Th}$:



$$\mathbf{Z}_{Th} = \mathbf{Z} = 10\ \Omega - j10\ \Omega = \mathbf{14.14\ \Omega\angle -45°}$$

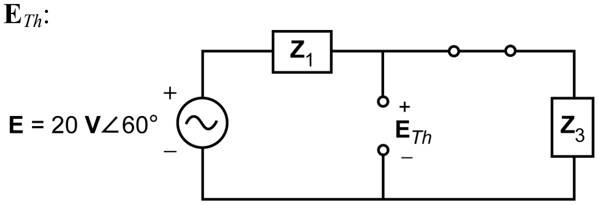
$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \mathbf{E} - \mathbf{V}_Z$$
$$= 20\text{ V}\angle 40° - \mathbf{IZ}$$
$$= 20\text{ V}\angle 40° - (0.6\text{ A}\angle 90°)(14.14\ \Omega\angle -45°)$$
$$= 20\text{ V}\angle 40° - 8.484\text{ V}\angle 45°$$
$$= (15.321\text{ V} + j12.856\text{ V}) - (6\text{ V} + j6\text{ V})$$
$$= 9.321\text{ V} + j6.856\text{ V}$$
$$= \mathbf{11.57\text{ V}\angle 36.34°}$$

23. a. AC:

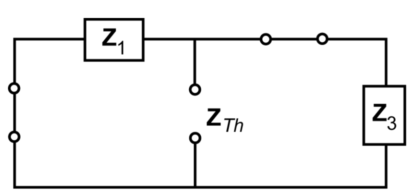
$\mathbf{E}_{Th}$:



$$\mathbf{Z}_1 = \frac{1}{\omega C}\angle -90° = 212.77\ \Omega\angle -90°$$
$$\mathbf{Z}_3 = 22\ \Omega + \omega L\angle 90°$$
$$= 22\ \Omega + j47\ \Omega$$
$$= 51.89\ \Omega\angle 64°$$

$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_3\mathbf{E}}{\mathbf{Z}_3 + \mathbf{Z}_1} = \frac{(51.89\ \Omega\angle 64.92°)(20\text{ V}\angle 60°)}{22\ \Omega + j47\text{ k}\Omega - j212.77\ \Omega} = \mathbf{6.21\text{ V}\angle 207.36°}$$

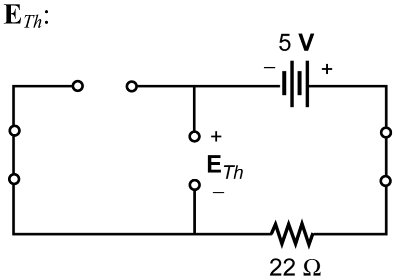
$\mathbf{Z}_{Th}$:



$$\mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = \frac{(212.77\ \Omega\angle -90°)(51.89\ \Omega\angle 64.92°)}{-j212.77\ \Omega + 22\ \Omega + j47\ \text{k}\Omega}$$

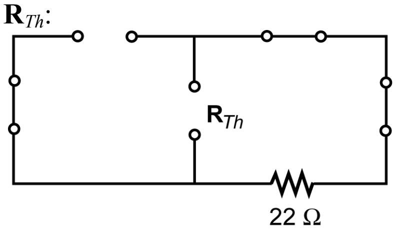
$$= \mathbf{66.04\ \Omega\ \angle 57.36° = 35.62\ \Omega + \mathit{j}55.61\ \Omega}$$

DC: $\mathbf{E}_{Th}$:



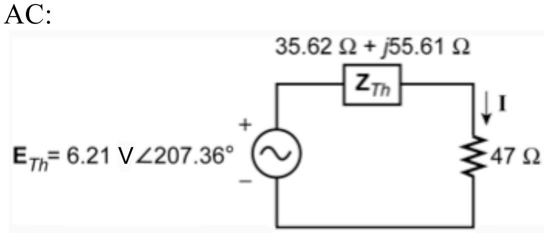
$\mathbf{E}_{Th} = \mathbf{-5\ V}$

$\mathbf{R}_{Th}$:



$\mathbf{R}_{Th} = \mathbf{22\ \Omega}$

b. AC:



$$\mathbf{I} = \frac{\mathbf{E}_{Th}}{\mathbf{Z}_{Th} + \mathbf{R}_L}$$

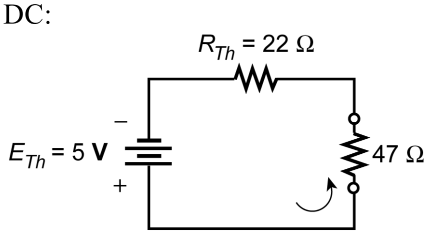
$$= \frac{6.21\ \text{V}\angle 207.36°}{35.62\ \Omega + j55.61\ \Omega + 47\ \Omega}$$

$$= \frac{6.21\ \text{V}\angle 207.36°}{82.62\ \Omega + j55.61\ \Omega}$$

$$= \frac{6.21\ \text{V}\angle 207.36°}{99.59\ \Omega\angle 33.94°}$$

$$= \mathbf{62.36\ mA\ \angle 173.42°}$$

DC:

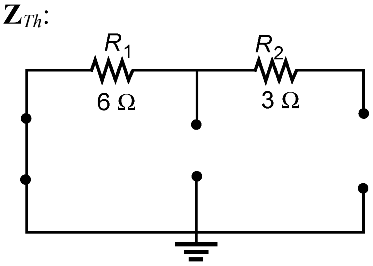


$$I = \frac{5\ \text{V}}{22\ \Omega + 47\ \Omega} = \frac{5\ \text{V}}{69\ \Omega}$$

$$= \mathbf{72.46\ mA}$$

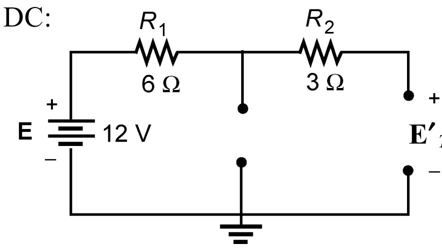
$\boldsymbol{i = -72.46\ \text{mA} + 62.36 \times 10^{-3} \sin(1000t + 173.42°)}$
matching the results of Problem 4.

24. a. $\mathbf{Z}_{Th}$:



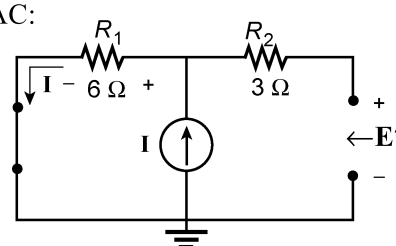
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_{R_1} + \mathbf{Z}_{R_2} = 6\ \Omega + 3\ \Omega = \mathbf{9\ \Omega}$

DC:



$\mathbf{E}'_{Th} = 12\ \text{V}$

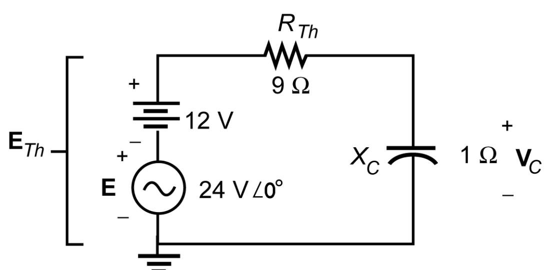
AC:



$\leftarrow \mathbf{E}''_{Th} = \mathbf{I}\mathbf{Z}_{R_1} = (4\ \text{A} \angle 0°)(6\ \Omega \angle 0°) = 24\ \text{V} \angle 0°$

$\mathbf{E}_{Th} = 12\ \text{V} + 24\ \text{V} \angle 0°$
(DC) (AC)

b.



DC: $\mathbf{V}_C = 12\ \text{V}$

AC: $\mathbf{V}_C = \dfrac{\mathbf{Z}_C\mathbf{E}}{\mathbf{Z}_C + \mathbf{Z}_{R_{Th}}}$

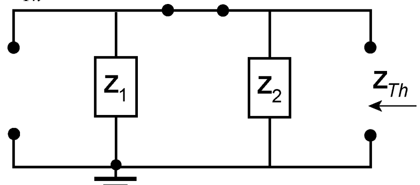
$= \dfrac{(1\,\Omega \angle -90°)(24\ \text{V} \angle 0°)}{-j1\,\Omega + 9\,\Omega}$

$= \dfrac{24\ \text{V} \angle -90°}{9.055 \angle -6.34°}$

$\mathbf{V}_C = 2.65\ \text{V} \angle -83.66°$

$\upsilon_C = 12\ \text{V} + 2.65\ \text{V} \angle -83.66°$
$= \mathbf{12\ V + 3.75\ \sin(\omega t - 83.66°)}$

25. a. $\mathbf{Z}_{Th}$:

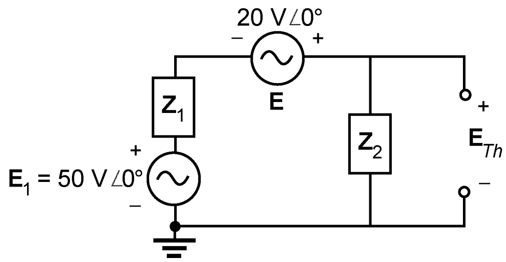


$\mathbf{Z}_1 = 10\ \text{k}\Omega \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega$
$= 7.071\ \text{k}\Omega \angle -45°$

$\mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = (10\ \text{k}\Omega \angle 0°) \parallel (7.071\ \text{k}\Omega \angle -45°) = \mathbf{4.47\ k\Omega \angle -26.57°}$

Source conversion:

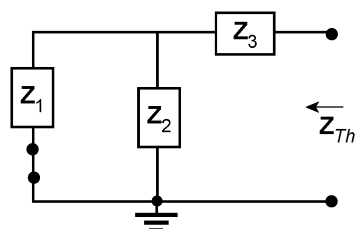
$\mathbf{E}_1 = (I\angle\theta)(R_1\angle 0°) = (5 \text{ mA} \angle 0°)(10 \text{ k}\Omega \angle 0°) = 50 \text{ V} \angle 0°$



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2(\mathbf{E} + \mathbf{E}_1)}{\mathbf{Z}_2 + \mathbf{Z}_1}$$
$$= \frac{(7.071 \text{ k}\Omega \angle -45°)(20 \text{ V} \angle 0° + 50 \text{ V} \angle 0°)}{(5 \text{ k}\Omega - j5 \text{ k}\Omega) + (10 \text{ k}\Omega)}$$
$$= \frac{(7.071 \text{ k}\Omega \angle -45°)(70 \text{ V} \angle 0°)}{(15 \text{ k}\Omega - j5 \text{ k}\Omega)}$$
$$= \frac{494.97 \text{ V} \angle -45°}{15.811 \angle -18.435°}$$
$$= \mathbf{31.31 \text{ V} \angle -26.57°}$$

b. $$\mathbf{I} = \frac{\mathbf{E}_{Th}}{\mathbf{Z}_{Th} + \mathbf{Z}_L} = \frac{31.31 \text{ V} \angle -26.565°}{4.472 \text{ k}\Omega \angle -26.565° + 5 \text{ k}\Omega \angle 90°}$$
$$= \frac{31.31 \text{ V} \angle -26.565°}{4 \text{ k}\Omega - j2 \text{ k}\Omega + j5 \text{ k}\Omega} = \frac{31.31 \text{ V} \angle -26.565°}{4 \text{ k}\Omega + j3 \text{ k}\Omega}$$
$$= \frac{31.31 \text{ V} \angle -26.565°}{5 \text{ k}\Omega \angle 36.87°} = \mathbf{6.26 \text{ mA} \angle 63.44°}$$

26.

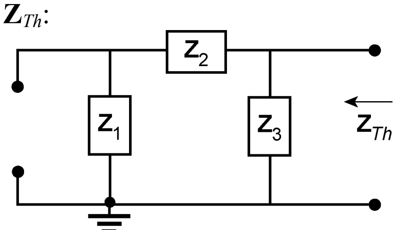


$\mathbf{Z}_1 = 10 \text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 10 \text{ k}\Omega \angle 0°$
$\mathbf{Z}_3 = 1 \text{ k}\Omega \angle -90°$

$\mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2 = 5 \text{ k}\Omega - j1 \text{ k}\Omega \cong \mathbf{5.1 \text{ k}\Omega \angle -11.31°}$

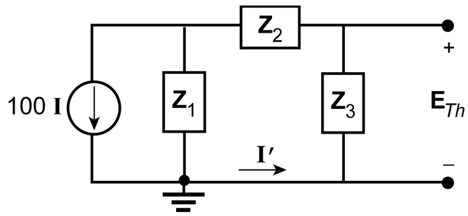
$\mathbf{E}_{Th}$: (VDR) $$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2(20 \text{ V})}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(10 \text{ k}\Omega \angle 0°)(20 \text{ V})}{10 \text{ k}\Omega + 10 \text{ k}\Omega} = \mathbf{10 \text{ V}}$$

27. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 40 \text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 0.2 \text{ k}\Omega \angle -90°$
$\mathbf{Z}_3 = 5 \text{ k}\Omega \angle 0°$

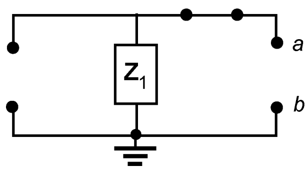
$\mathbf{Z}_{Th} = \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2) = 5 \text{ k}\Omega \angle 0° \parallel (40 \text{ k}\Omega - j0.2 \text{ k}\Omega) = \mathbf{4.44 \text{ k}\Omega \angle -0.03°}$



$$\mathbf{I}' = \frac{\mathbf{Z}_1(100\,\mathbf{I})}{\mathbf{Z}_1+\mathbf{Z}_2+\mathbf{Z}_3} = \frac{(40\,\text{k}\Omega\,\angle 0°)(100\,\mathbf{I})}{45\,\text{k}\Omega\,\angle -0.255°} = 88.89\,\mathbf{I}\,\angle 0.255°$$

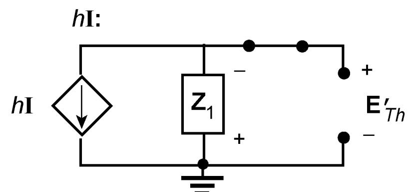
$$\mathbf{E}_{Th} = -\mathbf{I}'\mathbf{Z}_3 = -(88.89\,\mathbf{I}\,\angle 0.255°)(5\,\text{k}\Omega\,\angle 0°) = \mathbf{-444.45 \times 10^3\,I\,\angle 0.26°}$$

28. $\mathbf{Z}_{Th}$:



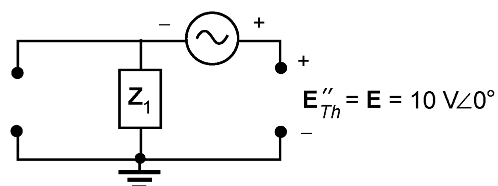
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 = \mathbf{20\,k\Omega\,\angle 0°}$

$\mathbf{E}_{Th}$:



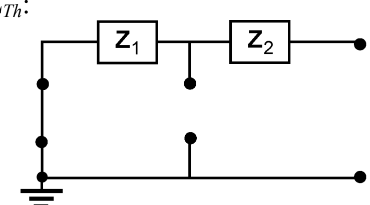
$$\mathbf{E}'_{Th} = -(h\mathbf{I})(\mathbf{Z}_1) = -(100)(2\text{ mA}\angle 0°)(20\text{ k}\Omega\angle 0°) = -4\text{ kV}\angle 0°$$

E:



$$\mathbf{E}_{Th} = \mathbf{E}'_{Th} + \mathbf{E}''_{Th} = -4\text{ kV}\angle 0° + 10\text{ V}\angle 0° = \mathbf{-3990\,V\,\angle 0°}$$

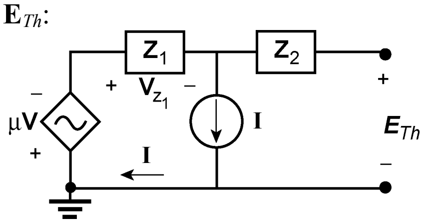
29. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 5\,\text{k}\Omega\angle 0°$ $\quad\quad$ $\mathbf{Z}_2 = -j1$

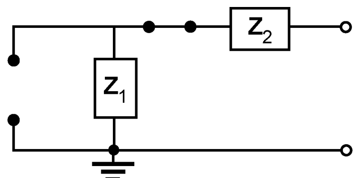
$$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega = \mathbf{5.10\,k\Omega\,\angle -11.31°}$$

$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = [\mu\mathbf{V} + \mathbf{V}_{Z_1}]$$
$$= -\mu\mathbf{V} - \mathbf{I}\mathbf{Z}_1$$
$$= -(20)(2\text{ V}\angle 0°) - (2\text{ mA}\angle 0°)(5\text{ k}\Omega\angle 0°)$$
$$= \mathbf{-50\text{ V}\angle 0°}$$

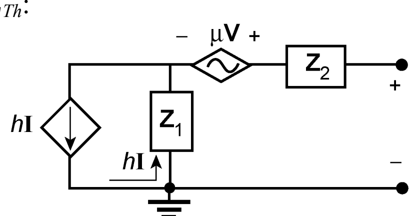
30. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 20\text{ k}\Omega\angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega\angle 0°$

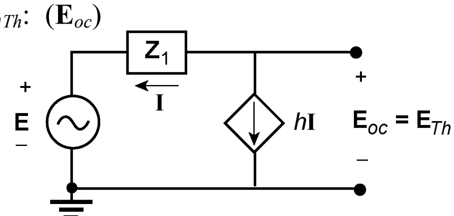
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\text{ k}\Omega\angle 0°}$

$\mathbf{E}_{Th}$:



$$E_{Th} = \mu\mathbf{V} - (h\mathbf{I})(\mathbf{Z}_1)$$
$$= (20)(10\text{ V}\angle 0°) - (100)(1\text{ mA}\angle 0°)(20\text{ k}\Omega\angle 0°)$$
$$= \mathbf{-1800\text{ V}\angle 0°}$$

31. $\mathbf{E}_{Th}$: $(\mathbf{E}_{oc})$



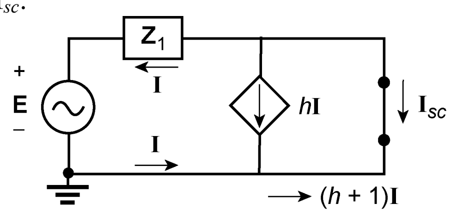
$h\mathbf{I} = -\mathbf{I}$ $\quad\quad$ $\mathbf{Z}_1 = 2\text{ k}\Omega\angle 0°$

$\therefore \mathbf{I} = 0$

and $\quad h\mathbf{I} = 0$

with $\quad \mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{E} = \mathbf{20\text{ V}\angle 53°}$

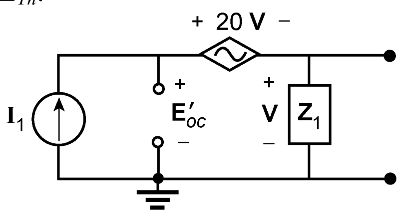
$\mathbf{I}_{sc}$:



$$\mathbf{I}_{sc} = -(h+1)\mathbf{I}$$
$$= -(h+1)(10\text{ mA}\angle 53°)$$
$$= -510\text{ mA}\angle 53°$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{20\text{ V}\angle 53°}{-510\text{ mA}\angle 53°} = \mathbf{-39.22\ \Omega\angle 0°}\ \text{(negative resistance)}$$

32. $\mathbf{E}_{Th}$:



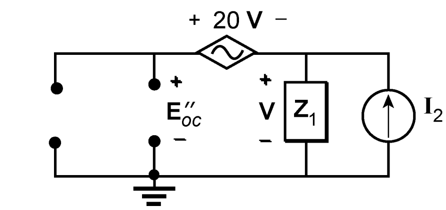
$\mathbf{E'}_{oc} = 21\ \mathbf{V}$ $\quad\quad$ $\mathbf{Z}_1 = 5\ \text{k}\Omega\ \angle 0°$

$\mathbf{V} = \mathbf{I}_1\mathbf{Z}_1 = (1\ \text{mA}\ \angle 0°)(5\ \text{k}\Omega\ \angle 0°)$

$= 5\ \text{V}\ \angle 0°$

$\mathbf{E'}_{oc} = \mathbf{E'}_{Th} = 21\ \mathbf{V} = 21(5\ \text{V}\ \angle 0°)$

$= 105\ \text{V}\ \angle 0°$



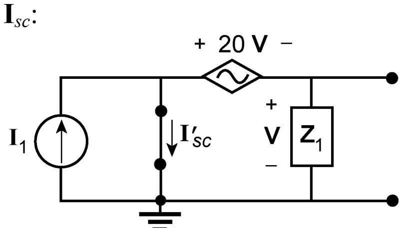
$\mathbf{V} = \mathbf{I}_2\mathbf{Z}_1$

$= (2\ \text{mA}\ \angle 0°)(5\ \text{k}\Omega\ \angle 0°)$

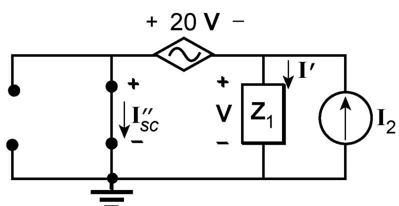
$= 10\ \text{V}\ \angle 0°$

$\mathbf{E''}_{oc} = \mathbf{E''}_{Th} = \mathbf{V} + 20\ \mathbf{V} = 21\ \mathbf{V} = 210\ \text{V}\ \angle 0°$

$\mathbf{I}_{sc}$:



$\mathbf{I'}_{sc} = \mathbf{I}_1$



$20\ \mathbf{V} = \mathbf{V}\ \therefore\ \mathbf{V} = 0\ \text{V}$

and $\mathbf{I'} = 0\ \text{A}$

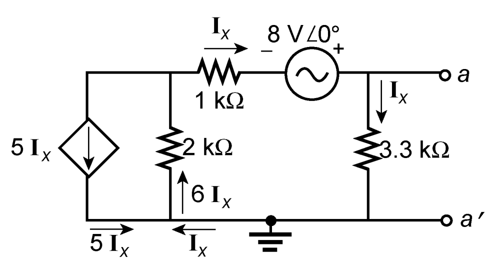
$\therefore\ \mathbf{I''}_{sc} = \mathbf{I}_2$

$\mathbf{I}_{sc} = \mathbf{I'}_{sc} + \mathbf{I''}_{sc} = 3\ \text{mA}\ \angle 0°$

$\mathbf{E}_{oc} = \mathbf{E'}_{oc} + \mathbf{E''}_{oc} = 105\ \angle 0° + 210\ \text{V}\ \angle 0° = 315\ \text{V}\ \angle 0° = \mathbf{E}_{Th}$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{315\ \text{V}\ \angle 0°}{3\ \text{mA}\ \angle 0°} = \mathbf{105\ k\Omega\ \angle 0°}$$

33. $\mathbf{E}_{oc}$:
($\mathbf{E}_{Th}$)

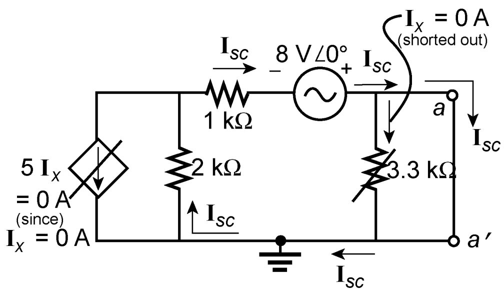


KVL: $-6\ \mathbf{I}_x(2\ \text{k}\Omega) - \mathbf{I}_x(1\ \text{k}\Omega) + 8\ \text{V}\ \angle 0° - \mathbf{I}_x(3.3\ \text{k}\Omega) = 0$

$$\mathbf{I}_x = \frac{8\ \text{V}\ \angle 0°}{16.3\ \text{k}\Omega} = 0.491\ \text{mA}\ \angle 0°$$

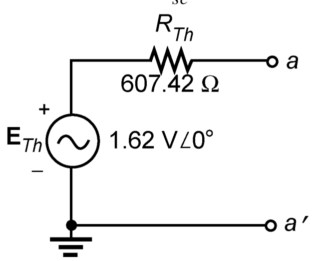
$\mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{I}_x(3.3\ \text{k}\Omega) = \mathbf{1.62\ V\ \angle 0°}$

$\mathbf{I}_{sc}$:



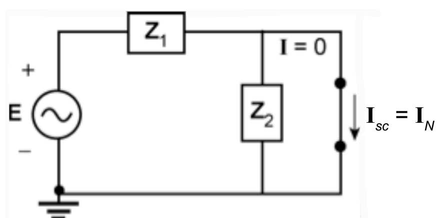
$$\mathbf{I}_{sc} = \frac{8\text{ V}}{3\text{ k}\Omega} = 2.667\text{ mA }\angle 0°$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{1.62\text{ V }\angle 0°}{2.667\text{ mA }\angle 0°} = \mathbf{607.42\ \Omega\ \angle 0°}$$



34. From Problem 15: $\mathbf{Z}_N = \mathbf{Z}_{Th} = 1.92\ \Omega + j1.44\ \Omega$ = **2.4 Ω ∠36.87°**

$\mathbf{I}_N$:

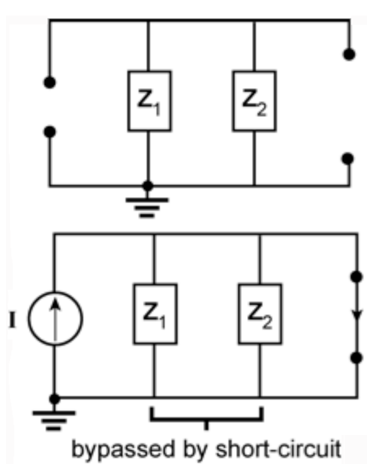


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{100\text{ V }\angle 0°}{3\ \Omega\ \angle 0°}$$

= **33.33 A ∠0°**

35.



$\mathbf{Z}_1 = 20\ \Omega + j20\ \Omega = 28.284\ \Omega\ \angle 45°$

$\mathbf{Z}_2 = 68\ \Omega\ \angle 0°$

←$\mathbf{Z}_N = \mathbf{Z}_1 \parallel \mathbf{Z}_2$

= (28.284 Ω ∠45°) ∥ (68 Ω ∠0°)

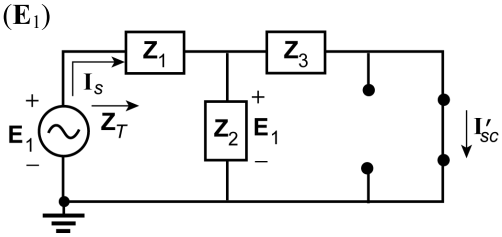
= 21.31 Ω ∠32.2°

←$\mathbf{I}_{sc} = \mathbf{I} = \mathbf{I}_N = 0.1\text{ A }\angle 0°$

36. From Problem 21: $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{5.00\ \Omega\ \angle{-38.66°}}$

$\mathbf{I}_N$: Superposition:

$(\mathbf{E}_1)$



$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 \parallel \mathbf{Z}_3$

$= 10\ \Omega + 8\ \Omega\ \angle 90° \parallel\ 8\ \Omega\ \angle{-90°}$

$= 10\ \Omega + \dfrac{64\ \Omega\ \angle 0°}{0}$

= very large impedance

$\mathbf{I}_s = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = 0\text{ A}$

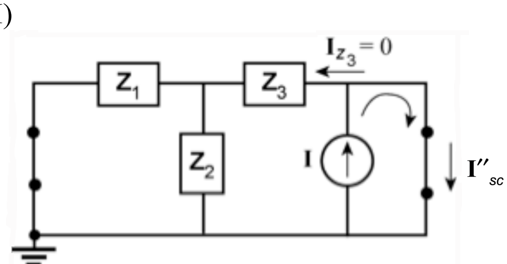
and $\mathbf{V}_{\mathbf{Z}_1} = 0\text{ V}$

with $\mathbf{V}_{Z_2} = \mathbf{V}_{Z_3} = \mathbf{E}_1 = 120\text{ V}\ \angle 0°$

so that $\mathbf{I}'_{sc} = \dfrac{\mathbf{E}_1}{\mathbf{Z}_3} = \dfrac{120\text{ V}\ \angle 0°}{8\ \Omega\ \angle{-90°}}$

$= 15\text{ A}\ \angle 90°$

(I)

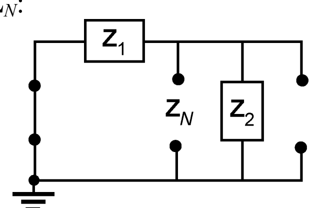


$\mathbf{I}''_{sc} = \mathbf{I} = 0.5\text{ A}\ \angle 60°$

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = +j15\text{ A} + 0.5\text{ A}\ \angle 60° = +j15\text{ A} + 0.25\text{ A} + j0.433\text{ A}$

$= 0.25\text{ A} + j15.433\text{ A} = \mathbf{15.44\text{ A}\ \angle 89.07°}$

37. a. $\mathbf{Z}_N$:



$\mathbf{E} = 20\text{ V}\ \angle 0°,\ \mathbf{I}_2 = 0.4\text{ A}\ \angle 20°$

$\mathbf{Z}_1 = 6\ \Omega + j8\ \Omega = 10\ \Omega\ \angle 53.13°$

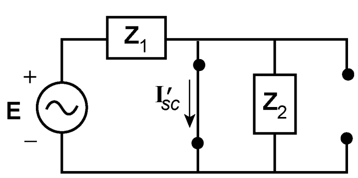
$\mathbf{Z}_2 = 9\ \Omega - j12\ \Omega = 15\ \Omega\ \angle{-53.13°}$

$\mathbf{Z}_N = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = (10\ \Omega\ \angle 53.13°) \parallel (15\ \Omega\ \angle{-53.13°})$

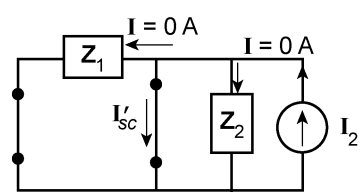
$= \mathbf{9.66\ \Omega\ \angle 14.93°}$

$\mathbf{I}_N$:

(E)



(I₂)



$\mathbf{I}'_{sc} = \mathbf{E}/\mathbf{Z}_1 = 20\text{ V}\ \angle 0°/10\ \Omega\ \angle 53.13°$

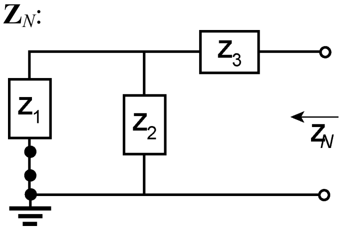
$= 2\text{ A}\ \angle{-53.13°}$

$\mathbf{I}''_{sc} = \mathbf{I}_2 = 0.4\text{ A}\ \angle 20°$

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 2\text{ A}\ \angle{-53.13°} + 0.4\text{ A}\ \angle 20°$

$= \mathbf{2.15\text{ A}\ \angle{-42.87°}}$

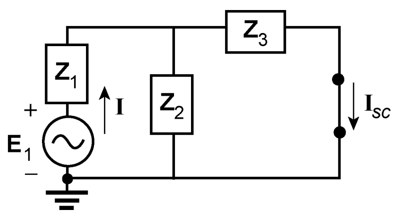
38. $\mathbf{Z}_N$:



$\mathbf{E}_1 = 120\text{ V}\angle 30°$, $\mathbf{Z}_1 = 3\ \Omega\angle 0°$
$\mathbf{Z}_2 = 8\ \Omega - j8\ \Omega$, $\mathbf{Z}_3 = 4\ \Omega\angle 90°$

$$\begin{aligned}\mathbf{Z}_N &= \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2\\ &= 4\ \Omega\angle 90° + (3\ \Omega\angle 0°) \parallel (8\ \Omega - j8\ \Omega)\\ &= \mathbf{4.37\ \Omega\angle 55.67° = 2.47\ \Omega + \mathit{j}3.61\ \Omega}\end{aligned}$$

$\mathbf{I}_N$:



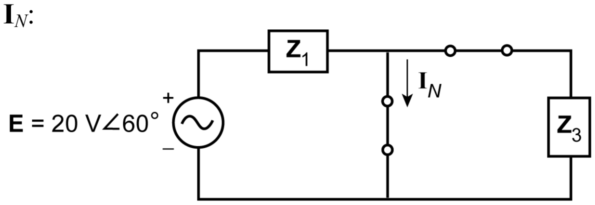
$$\begin{aligned}\mathbf{I} &= \frac{\mathbf{E}_1}{\mathbf{Z}_T} = \frac{120\text{ V}\angle 30°}{\mathbf{Z}_1 + \mathbf{Z}_2 \parallel \mathbf{Z}_3}\\ &= \frac{120\text{ V}\angle 30°}{3\ \Omega + (8\ \Omega - j8\Omega) \parallel 4\Omega\angle 90°}\\ &= \frac{120\text{ V}\angle 30°}{6.65\ \Omega\angle 46.22°}\\ &= 18.05\text{ A}\angle -16.22°\end{aligned}$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2(\mathbf{I})}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(8\ \Omega - j8\Omega)(18.05\text{ A}\angle -16.22°)}{8\ \Omega - j8\ \Omega + j4\ \Omega} = \mathbf{22.83\text{ A}\angle -34.65°}$$

39. a. AC:

$\mathbf{I}_N$:

$\mathbf{Z}_1 = 212.77\ \Omega\angle -90°$
$\mathbf{Z}_3 = 22\ \Omega + j47\ \Omega$
$= 51.89\ \Omega\angle 64°$

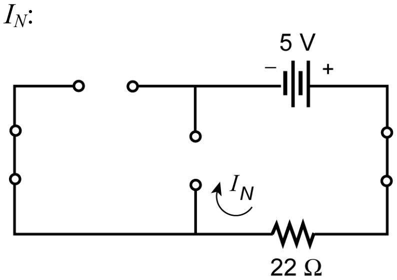


$$\mathbf{I}_N = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{20\text{ V}\angle 60°}{212.77\ \Omega\angle -90°} = \mathbf{94\text{ mA}\angle 150°}$$

$\mathbf{Z}_N = \mathbf{Z}_{Th}$ (problem 23) = $\mathbf{66.04\angle 57.36° = 35.62\ \Omega + \mathit{j}55.61\ \Omega}$

DC:

I_N:

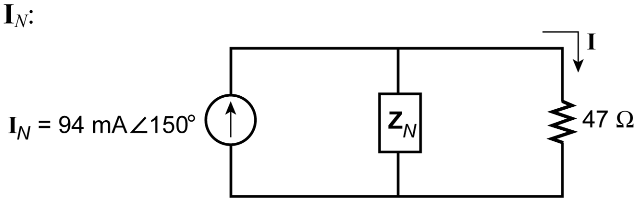


$$I_N = \frac{5\text{ V}}{22\ \Omega} = \mathbf{227.27\text{ mA}}$$

$R_N = R_{Th}$ = (problem 23) = $\mathbf{22\ \Omega}$

b. AC:

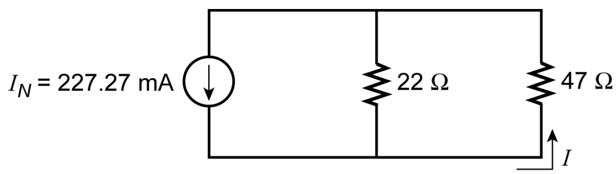
$\mathbf{I}_N$:



$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_N)}{\mathbf{Z}_N + 47\ \Omega} = \frac{(66.04\ \Omega \angle 57.36°)(94\ \text{mA} \angle 150°)}{35.62\ \Omega + j55.61\ \Omega + 47\ \Omega}$$

$$= \frac{6.21\ \text{A} \angle 207.36°}{99.08 \angle 34.14°} = \mathbf{62.68\ mA \angle 173.22°}$$

DC:



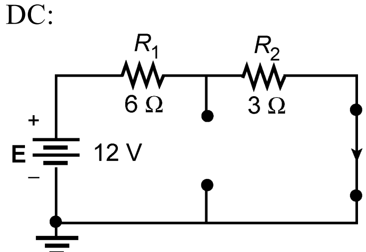
$$I = \frac{22\ \Omega(227.27\ \text{mA})}{22\ \Omega + 47\ \Omega} = \mathbf{72.46\ mA}$$

and $i = \mathbf{-72.46\ mA + 62.68 \times 10^{-3} \sin(1000t + 173.22°)}$

Same as Problem 6 and 23.

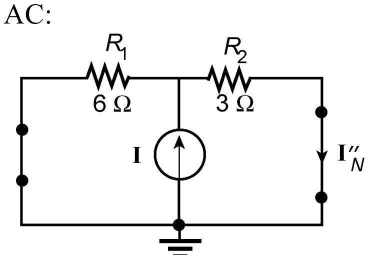
40. a. From #24 $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{9\ \Omega \angle 0°}$

DC:



$$I'_N = \frac{E}{R_T} = \frac{12\ \text{V}}{9\ \Omega} = 1.33\ \text{A}$$

AC:

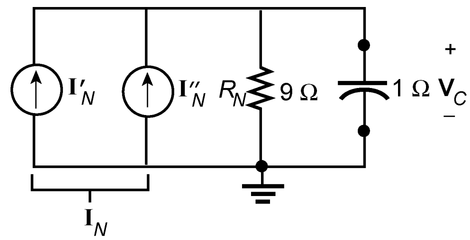


$$\mathbf{I}''_N = \frac{R_1\mathbf{I}}{R_1 + R_2} = \frac{(6\ \Omega \angle 0°)(4\ \text{A} \angle 0°)}{9\ \Omega \angle 0°}$$

$$= \frac{24\ \text{V} \angle 0°}{9\ \Omega \angle 0°} = 2.67\ \text{A} \angle 0°$$

$\mathbf{I}_N = \mathbf{1.33\ A + 2.67\ A \angle 0°}$

b.



DC: $V_C = IR$
$= (1.33\text{ A})(9\ \Omega)$
$= 12\text{ V}$

AC: $\mathbf{Z}' = 9\ \Omega\ \angle 0° \parallel 1\ \Omega\ \angle -90°$
$= 0.994\ \Omega\ \angle -83.66°$

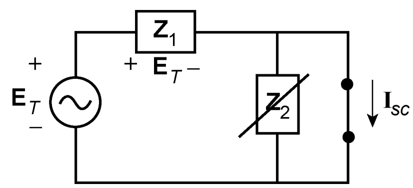
$\mathbf{V}_C = \mathbf{I}\mathbf{Z}' = (2.667\text{ A}\ \angle 0°)(0.994\ \Omega\ \angle -83.66°)$
$= 2.65\text{ V}\ \angle -83.66°$

$V_C = \mathbf{12\ V + 2.65\ V\ \angle -83.66°}$

41. a. Note Problem 25(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.47\ k\Omega\ \angle -26.57°}$

Using the same source conversion: $\mathbf{E}_1 = 50\text{ V}\ \angle 0°$

Defining $\mathbf{E}_T = \mathbf{E}_1 + \mathbf{E} = 50\text{ V}\ \angle 0° + 20\text{ V}\ \angle 0° = 70\text{ V}\ \angle 0°$



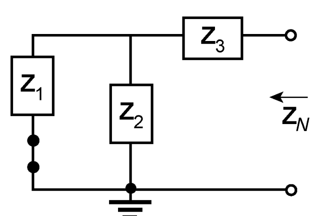
$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega - j5\text{ k}\Omega = 7.071\text{ k}\Omega\ \angle -45°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_T}{\mathbf{Z}_1} = \frac{70\text{ V}\ \angle 0°}{10\text{ k}\Omega\ \angle 0°} = 7\text{ mA}\ \angle 0°$$

$\mathbf{I}_N = \mathbf{I}_{sc} = \mathbf{7\ mA\ \angle 0°}$

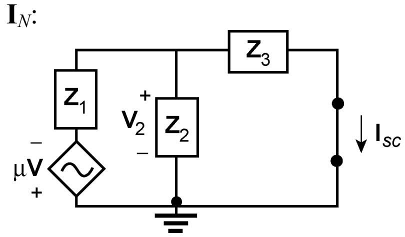
b.
$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_N)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4.472\text{ k}\Omega \angle -26.565°)(7\text{ mA} \angle 0°)}{4.472\text{ k}\Omega\ \angle -26.565° + 5\text{ k}\Omega\ \angle 90°}$$
$$= \frac{31.30\text{ mA} \angle -26.565°}{4 - j2 + j5} = \frac{31.30\text{ mA} \angle -26.565°}{4 + j3}$$
$$= \frac{31.30\text{ mA} \angle -26.565°}{5 \angle 36.87°} = \mathbf{6.26\ mA\ \angle 63.44°}$$ as obtained in Problem 25.

42.
$\mathbf{Z}_N$:



$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0$
$\mathbf{Z}_3 = -j1\text{ k}\Omega$
$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$
$= \mathbf{5.1\ k\Omega\ \angle -11.31°}$

$\mathbf{I}_N$:



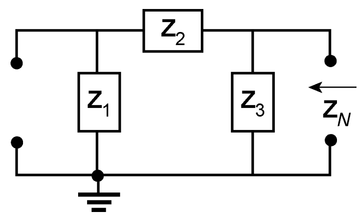
$$\mathbf{V}_2 = \frac{-(\mathbf{Z}_2 \parallel \mathbf{Z}_3)20\text{ V}}{(\mathbf{Z}_2 \parallel \mathbf{Z}_3) + \mathbf{Z}_1}$$

$$= \frac{-(0.995\text{ k}\Omega \angle -84.29°)(20\text{ V})}{0.1\text{ k}\Omega - j0.99\text{ k}\Omega + 10\text{ k}\Omega}$$

$$\mathbf{V}_2 = -1.961\text{ V} \angle -78.69°$$

$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{V}_2}{\mathbf{Z}_3} = \frac{-1.961\text{ V} \angle -78.69°}{1\text{ k}\Omega \angle -90°} = \mathbf{-1.96 \times 10^{-3}\text{ V} \angle 11.31°}$$

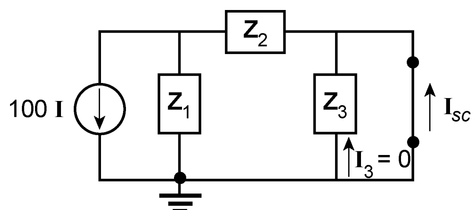
43. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 40\text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 0.2\text{ k}\Omega \angle -90°$
$\mathbf{Z}_3 = 5\text{ k}\Omega \angle 0°$

$$\mathbf{Z}_N = \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2)$$
$$= 5\text{ k}\Omega \angle 0° \parallel (40\text{ k}\Omega - j0.2\text{ k}\Omega)$$
$$= \mathbf{4.44\text{ k}\Omega \angle -0.03°}$$

$\mathbf{I}_N$:

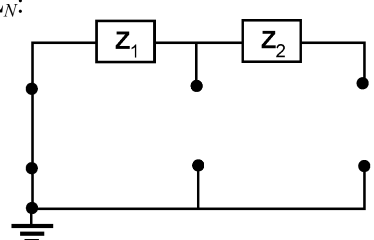


$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{Z}_1(100\,\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$

$$= \frac{(40\text{ k}\Omega \angle 0°)(100\,\mathbf{I})}{40\text{ k}\Omega \angle -0.286°}$$

$$= \mathbf{100\,I \angle 0.29°}$$

44. $\mathbf{Z}_N$:

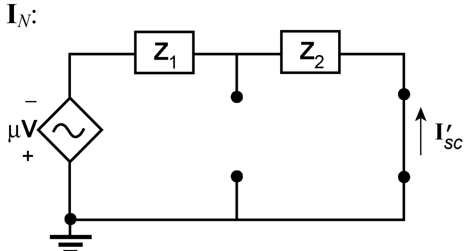


$\mathbf{Z}_1 = 5\text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 1\text{ k}\Omega \angle -90°$

$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$
$= \mathbf{5.1\text{ k}\Omega \angle -11.31°}$

.

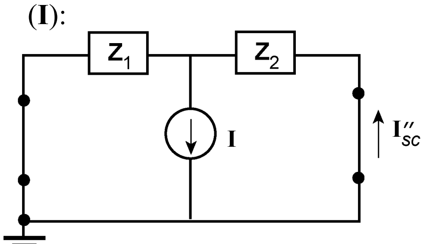
$\mathbf{I}_N$:



$$\mathbf{I}'_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(2\text{ V} \angle 0°)}{5.1\text{ k}\Omega \angle -11.31°}$$

$$= 7.843\text{ mA} \angle 11.31°$$

($\mathbf{I}$):



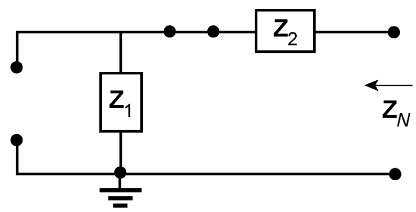
$$\mathbf{I}''_{sc} = \frac{\mathbf{Z}_1(\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$

$$= \frac{(5\text{ k}\Omega \angle 0°)(2\text{ mA} \angle 0°)}{5.1\text{ k}\Omega \angle -11.31°}$$

$$= 1.96\text{ mA} \angle 11.31°$$

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 7.843 \text{ mA} \angle 11.31° + 1.96 \text{ mA} \angle 11.31°$
$= \mathbf{9.81 \text{ mA} \angle 11.31°}$

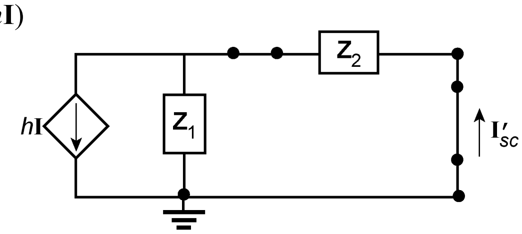
45. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 20 \text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 5 \text{ k}\Omega \angle 0°$
$\mathbf{V} = 10 \text{ V} \angle 0°$, $\mu = 20$, $h = 100$
$\mathbf{I} = 1 \text{ mA} \angle 0°$

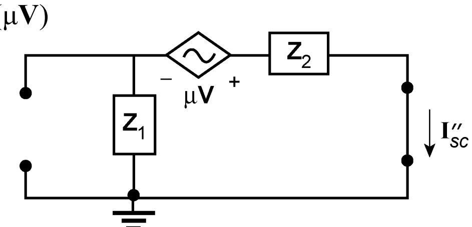
$\mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25 \text{ k}\Omega \angle 0°}$

$\mathbf{I}_N$: ($h\mathbf{I}$)



$$\mathbf{I}'_{sc} = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20 \text{ k}\Omega \angle 0°)(h\mathbf{I})}{20 \text{ k}\Omega \angle 0° + 5 \text{ k}\Omega \angle 0°} = 80 \text{ mA} \angle 0°$$

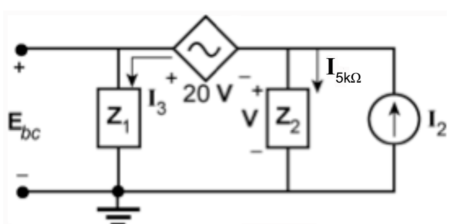
($\mu\mathbf{V}$)



$$\mathbf{I}''_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(10 \text{ V} \angle 0°)}{25 \text{ k}\Omega} = 8 \text{ mA} \angle 0°$$

$\mathbf{I}_N$ (direction of $\mathbf{I}'_{sc}$) $= \mathbf{I}'_{sc} - \mathbf{I}''_{sc} = 80 \text{ mA} \angle 0° - 8 \text{ mA} \angle 0° = \mathbf{72 \text{ mA} \angle 0°}$

46.



$\mathbf{Z}_1 = 2 \text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 5 \text{ k}\Omega \angle 0°$

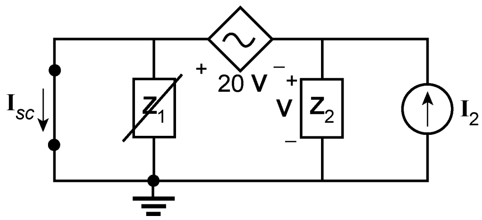
$\mathbf{I}_2 = \mathbf{I}_3 + \mathbf{I}_{5k\Omega}$
$\mathbf{V} = \mathbf{I}_{5k\Omega}\mathbf{Z}_2 = (\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$
$\mathbf{E}_{oc} = \mathbf{E}_{Th} = 21\ \mathbf{V} = 21(\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$

$$= 21\left(\mathbf{I}_2 - \frac{\mathbf{E}_{oc}}{\mathbf{Z}_1}\right)\mathbf{Z}_2$$

$$\mathbf{E}_{oc}\left[1 + 21\frac{\mathbf{Z}_2}{\mathbf{Z}_1}\right] = 21\ \mathbf{Z}_2\mathbf{I}_2$$

$$\mathbf{E}_{oc} = \frac{21\mathbf{Z}_2\mathbf{I}_2}{1 + 21\dfrac{\mathbf{Z}_2}{\mathbf{Z}_1}} = \frac{21(5 \text{ k}\Omega \angle 0°)(2 \text{ mA} \angle 0°)}{1 + 21\left(\dfrac{5 \text{ k}\Omega \angle 0°}{2 \text{ k}\Omega \angle 0°}\right)}$$

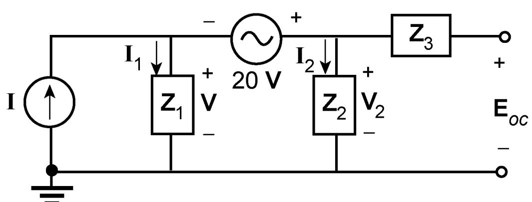
$\mathbf{E}_{Th} = \mathbf{E}_{oc} = 3.925 \text{ V} \angle 0°$



$20\ \mathbf{V} \neq -\mathbf{V}\ \therefore\ \mathbf{V} = 0$
and $\mathbf{I}_N = \mathbf{I}_{sc} = \mathbf{I}_2 = \mathbf{2\ mA\ \angle 0°}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{3.925\ \text{V}\ \angle 0°}{2\ \text{mA}\ \angle 0°} = \mathbf{1.96\ k\Omega}$$

47.



$\mathbf{Z}_1 = 1\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 3\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = 4\ \text{k}\Omega\ \angle 0°$

$$\mathbf{V}_2 = 21\ \mathbf{V} = \mathbf{E}_{oc} \Rightarrow \mathbf{V} = \frac{\mathbf{E}_{oc}}{21}$$

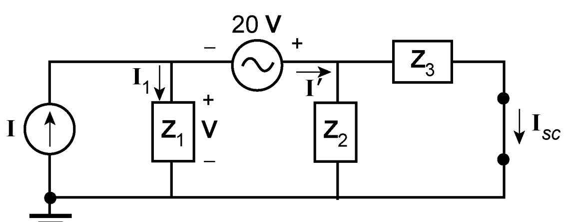
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2,\ \mathbf{I}_1 = \frac{\mathbf{V}}{\mathbf{Z}_1} = \frac{\mathbf{E}_{oc}}{21\,\mathbf{Z}_1}$$

$$\mathbf{I}_2 = \frac{\mathbf{E}_{oc}}{\mathbf{Z}_2},\ \mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = \frac{\mathbf{E}_{oc}}{21\,\mathbf{Z}_1} + \frac{\mathbf{E}_{oc}}{\mathbf{Z}_2} = \mathbf{E}_{oc}\left[\frac{1}{21\,\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2}\right]$$

$$\mathbf{I} = \mathbf{E}_{oc}\left[\frac{\mathbf{Z}_2 + 21\ \mathbf{Z}_1}{21\ \mathbf{Z}_1\mathbf{Z}_2}\right]$$

and $$\mathbf{E}_{oc} = \frac{21\mathbf{Z}_1\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + 21\mathbf{Z}_1} = \frac{(21)(1\ \text{k}\Omega \angle 0°)(3\ \text{k}\Omega \angle 0°)(2\ \text{mA} \angle 0°)}{3\ \text{k}\Omega + 21(1\ \text{k}\Omega \angle 0°)}$$

$\mathbf{E}_{Th} = \mathbf{E}_{oc} = 5.25\ \text{V}\ \angle 0°$



$$\mathbf{I}_{sc} = \frac{\mathbf{V}_3}{\mathbf{Z}_3} = \frac{21\,\mathbf{V}}{\mathbf{Z}_3} \Rightarrow \mathbf{V} = \frac{\mathbf{Z}_3}{21}\mathbf{I}_{sc}$$

$\mathbf{V} = \mathbf{I}_1\mathbf{Z}_1$
$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}'$

$$\mathbf{I}_{sc} = \frac{\mathbf{Z}_2\mathbf{I}'}{\mathbf{Z}_2 + \mathbf{Z}_3} \Rightarrow \mathbf{I}' = \left(\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right)\mathbf{I}_{sc}$$

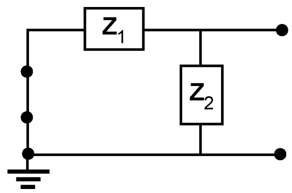
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}' = \frac{\mathbf{V}}{\mathbf{Z}_1} + \left(\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right)\mathbf{I}_{sc} = \left[\frac{\mathbf{Z}_3}{21\mathbf{Z}_1} + \frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

$$\mathbf{I}_{sc} = \frac{\mathbf{I}}{\frac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \frac{\mathbf{Z}_3 + \mathbf{Z}_2}{\mathbf{Z}_2}} = \frac{2\ \text{mA}\ \angle 0°}{\frac{4\ \text{k}\Omega}{21\ \text{k}\Omega} + \frac{7\ \text{k}\Omega}{3\ \text{k}\Omega}} = 0.79\ \text{mA}\ \angle 0°$$

$\therefore$ $\mathbf{I}_N = \mathbf{0.79\ mA\ \angle 0°}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{5.25\ \text{V}\ \angle 0°}{0.79\ \text{mA}\ \angle 0°} = \mathbf{6.65\ k\Omega\ \angle 0°}$$

48.



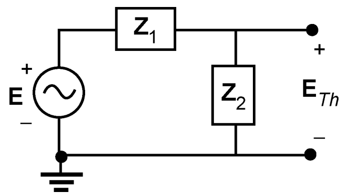
$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega$, $\mathbf{Z}_2 = -j6\ \Omega$

$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2$

$= 5\ \Omega\ \angle 53.13° \parallel 6\ \Omega\ \angle -90°$

$= 8.32\ \Omega\ \angle -3.18°$

$\mathbf{Z}_L = \mathbf{8.32\ \Omega\ \angle 3.18° = 8.31\ \Omega - \mathit{j}0.46\ \Omega}$



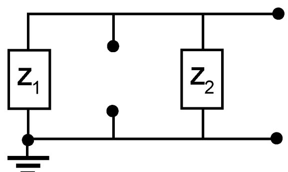
$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1}$$

$$= \frac{(6\ \Omega\ \angle -90°)(120\ \text{V}\ \angle 0°)}{3.61\ \Omega\ \angle -33.69°}$$

$$= \mathbf{199.45\ V\ \angle -56.31°}$$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3.124\ \text{V})^2}{4(8.31\ \Omega)} = \mathbf{1198.2\ W}$$

49.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$

$\mathbf{Z}_2 = 2\ \Omega\ \angle 0°$

$\leftarrow \mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2$

$= 5\ \Omega\ \angle 53.13° \parallel 2\ \Omega\ \angle 0°$

$$= \frac{10\ \Omega\ \angle 53.13°}{2 + 3\ + j4}$$

$$= \frac{10\ \Omega\ \angle 53.13°}{5 + j4}$$

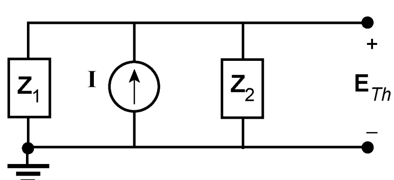
$$= \frac{10\ \Omega\ \angle 53.13°}{6.403\ \angle 38.66°}$$

$= \mathbf{1.56\ \Omega\ \angle 14.47°}$

$\mathbf{Z}_{Th} = 1.56\ \Omega\ \angle 14.47°$

$= 1.51\ \Omega + j0.39\ \Omega$

$\mathbf{Z}_L = \mathbf{1.51\ \ \Omega - \mathit{j}0.39\ \Omega}$



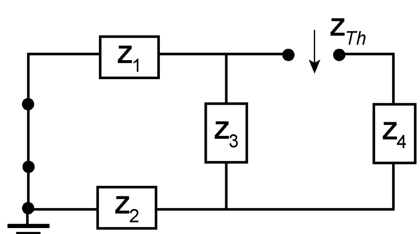
$\mathbf{E}_{Th} = \mathbf{I}(\mathbf{Z}_1 \parallel \mathbf{Z}_2)$

$= (2\ \text{A}\ \angle 30°)(1.562\ \Omega\ \angle 14.47°)$

$= \mathbf{3.12\ V\ \angle 44.47°}$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3.12\ \text{V})^2}{4(1.51\ \Omega)} = \mathbf{1.61\ W}$$

50. $\mathbf{Z}_{Th}$:



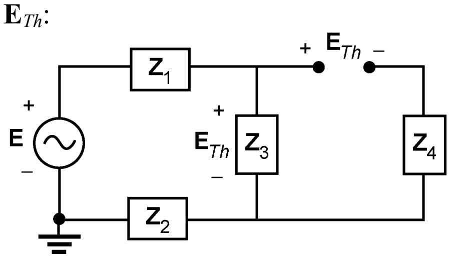
$\mathbf{Z}_1 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 10\ \Omega\ \angle 0°$

$\mathbf{Z}_3 = 5\ \Omega\ \angle -90°$, $\mathbf{Z}_4 = 6\ \Omega\ \angle -90°$

$\mathbf{E} = 60\ \text{V}\ \angle 60°$

$\mathbf{Z}_{Th} = \mathbf{Z}_4 + \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2) = -j6\ \Omega + (5\ \Omega \angle -90°) \parallel (10\ \Omega + j4\ \Omega)$
$= 2.475\ \Omega - j4.754\ \Omega$
$= 11.04\ \Omega \angle -77.03°$
$\mathbf{Z}_L = \mathbf{11.04\ \Omega \angle 77.03°}$

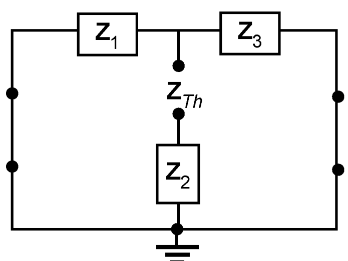
$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_3(\mathbf{E})}{\mathbf{Z}_3 + \mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(5\ \Omega \angle -90°)(60\ \text{V} \angle 60°)}{-j5\ \Omega + j4\ \Omega + 10\ \Omega} = \mathbf{29.85\ V \angle -24.29°}$$

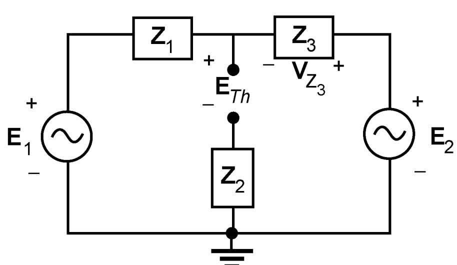
$P_{max} = E_{Th}^2/4R_{Th} = (29.85\ \text{V})^2/4(2.475\ \Omega) = \mathbf{90\ W}$

51.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega \angle 53.13°$
$\mathbf{Z}_2 = -j8\ \Omega$
$\mathbf{Z}_3 = 12\ \Omega + j9\ \Omega$

$\mathbf{Z}_{Th} = \mathbf{Z}_2 + \mathbf{Z}_1 \parallel \mathbf{Z}_3 = -j8\ \Omega + (5\ \Omega \angle 53.13°) \parallel (15\ \Omega \angle 36.87°)$
$= 5.71\ \Omega \angle -64.30° = 2.475\ \Omega - j5.143\ \Omega$
$\mathbf{Z}_L = \mathbf{5.71\ \Omega \angle 64.30°} = \mathbf{2.48\ \Omega + j5.15\ \Omega}$



$\mathbf{E}_{Th} + \mathbf{V}_{Z_3} - \mathbf{E}_2 = 0$
$\mathbf{E}_{Th} = \mathbf{E}_2 - \mathbf{V}_{Z_3}$

$$\mathbf{V}_{Z_3} = \frac{\mathbf{Z}_3(\mathbf{E}_2 - \mathbf{E}_1)}{\mathbf{Z}_3 + \mathbf{Z}_1} = 168.97\ \text{V} \angle 112.53°$$

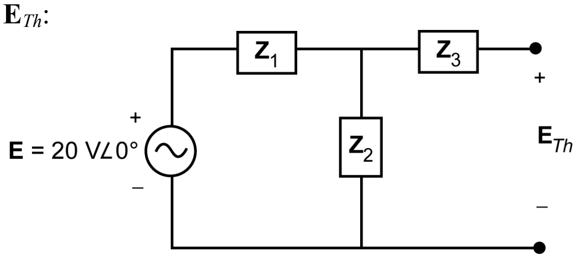
$\mathbf{E}_{Th} = \mathbf{E}_2 - \mathbf{V}_{Z_3} = 200\ \text{V} \angle 90° - 168.97\ \text{V} \angle 112.53° = \mathbf{78.24\ V \angle 34.16°}$
$P_{max} = E_{Th}^2/4R_{Th} = (78.24\ \text{V})^2/4(2.475\ \Omega) = \mathbf{618.33\ W}$

52. $\mathbf{I} = \dfrac{E\angle 0°}{R_1\angle 0°} = \dfrac{1\ \text{V} \angle 0°}{1\ \text{k}\Omega \angle 0°} = 1\ \text{mA} \angle 0°$

$\mathbf{Z}_{Th} = 40\ \text{k}\Omega \angle 0°$
$\mathbf{E}_{Th} = (50\ \mathbf{I})(40\ \text{k}\Omega \angle 0°) = (50)(1\ \text{mA} \angle 0°)(40\ \text{k}\Omega \angle 0°) = 2000\ \text{V} \angle 0°$

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(2\ \text{kV})^2}{4(40\ \text{k}\Omega)} = \mathbf{25\ W}$$

53. $\mathbf{E}_{Th}$:

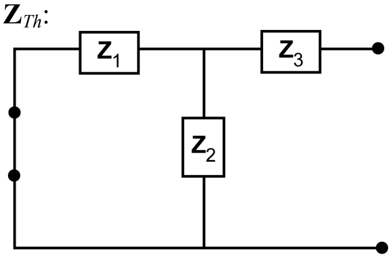


$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 3\text{ k}\Omega\ \angle{-90°}$
$\mathbf{Z}_3 = 6\text{ k}\Omega\ \angle 90°$

$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(3\text{ k}\Omega \angle 90°)(20\text{ V} \angle 0°)}{-j3\text{ k}\Omega + 2\text{ k}\Omega}$$

$$= \frac{60\text{ V} \angle -90°}{3.61 \angle -56.31°} = \mathbf{16.62\ V\ \angle{-33.69°}}$$

$\mathbf{Z}_{Th}$:



$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$

$$\mathbf{Z}_{Th} = +j6\text{ k}\Omega + \frac{(2\text{ k}\Omega \angle 0°)(3\text{ k}\Omega \angle -90°)}{2\text{ k}\Omega - j3\text{ k}\Omega}$$

$= +j6\text{ k}\Omega + 1.66\text{ k}\Omega\ \angle{-33.69°}$
$= +j6\text{ k}\Omega + 1.38\text{ k}\Omega - j920.8\ \Omega$
$= 1.38\text{ k}\Omega + j5.08\text{ k}\Omega$
$= 5.26\text{ k}\Omega\ \angle +74.80°$

$\therefore \mathbf{Z}_L = \mathbf{5.36\ k\Omega\ \angle{-74.80°} = 1.38k\Omega - \mathit{j}5.08\ k\Omega}$

b. $$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(16.62\text{ V})^2}{4(1.38\text{ k}\Omega)} = \mathbf{50.04\ mW}$$

54. From #24, $\mathbf{Z}_{Th} = 9\ \Omega$, $\mathbf{E}_{Th} = 12\text{ V} + 24\text{ V} \angle 0°$

a. $\therefore\ \mathbf{Z}_L = 9\ \Omega$

b. $$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(12\text{ V})^2}{4(9\ \Omega)} + \frac{(24\text{ V})^2}{4(9\ \Omega)} = 4\text{ W} + 16\text{ W} = \mathbf{20\ W}$$

or $E_{Th} = \sqrt{V_0^2 + V_{1_{eff}}^2} = 26.833\text{ V}$

and $P_{max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(26.833\text{ V})^2}{4(9\ \Omega)} = \mathbf{20\ W}$

55. a. Problem 25(a):

$\mathbf{Z}_{Th}$ = 4.47 kΩ ∠–26.57° = 4 kΩ – j2 kΩ

$\mathbf{Z}_L$ = **4 kΩ + *j*2 kΩ**

$\mathbf{E}_{Th}$ = **31.31 V ∠–26.57°**

b. $P_{max} = E_{Th}^2/4R_{Th}$ = (31.31 V)^2/4(4 kΩ) = **61.27 mW**

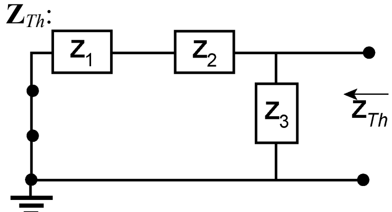
56. a. $\mathbf{Z}_{Th}$ = 2 kΩ ∠0° ‖ 2 kΩ ∠–90° = 1 kΩ – j1 kΩ

$$R_L = \sqrt{R_{Th}^2 + (X_{Th} + X_{\text{Load}})^2}$$
$$= \sqrt{(1\text{ k}\Omega)^2 + (-1\text{ k}\Omega + 2\text{ k}\Omega)^2}$$
$$= \sqrt{(1\text{ k}\Omega)^2 + (1\text{ k}\Omega)^2}$$
$$= \mathbf{1.41\text{ k}\Omega}$$

b. $R_{av} = (R_{Th} + R_{\text{Load}})/2$ = (1 kΩ + 1.41 kΩ)/2 = 1.21 kΩ

$$P_{max} = \frac{E_{Th}^2}{4R_{av}} = \frac{(50\text{ V})^2}{4(1.21\text{ k}\Omega)} = \mathbf{516.53\text{ mW}}$$

57. **a.** $\mathbf{Z}_{Th}$:



$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(10\text{ kHz})(4\text{ nF})}$$
$$\cong 3978.87\ \Omega$$
$$X_L = 2\pi fL = 2\pi(10\text{ kHz})(30\text{ mH})$$
$$\cong 1884.96\ \Omega$$

$\mathbf{Z}_1$ = 1 kΩ ∠0°, $\mathbf{Z}_2$ = 1884.96 Ω ∠90°

$\mathbf{Z}_3$ = 3978.87 Ω ∠–90°

$\mathbf{Z}_{Th} = (\mathbf{Z}_1 + \mathbf{Z}_2) \parallel \mathbf{Z}_3$ = (1 kΩ + j1884.96 Ω) ‖ 3978.87 Ω ∠–90°)

= 2133.79 Ω ∠62.05° ‖ 3978.87 Ω ∠–90°)

= 3658.65 Ω ∠36.52°

∴ $\mathbf{Z}_L$ = **3658.65 Ω ∠–36.52° = 2940.27 Ω – *j*2177.27 Ω**

$$C = \frac{1}{2\pi fX_C} = \frac{1}{2\pi(10\text{ kHz})(2177.27\ \Omega)} = \mathbf{7.31\text{ nF}}$$

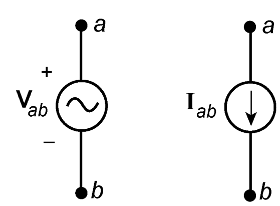
b. $R_L = R_{Th}$ = **2940.27 Ω**

c. $$\mathbf{E}_{Th} = \frac{\mathbf{Z}_3(\mathbf{E})}{\mathbf{Z}_3 + \mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(3978.87\ \Omega\angle -90°)(2\text{ V}\angle 0°)}{1\text{ k}\Omega + j1884.96\ \Omega - j3978.87\ \Omega} = 3.43\text{ V}\angle{-25.53°})$$

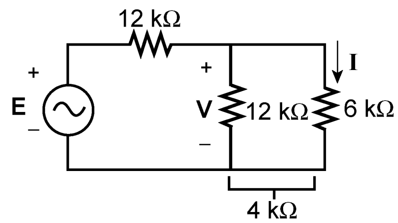
$P_{max} = E_{Th}^2/4R_{Th}$ = (3.43 V)^2/4(2940.27Ω) = **1 mW**

58. $$\mathbf{I}_{ab} = \frac{(4\text{ k}\Omega\ \angle 0°)(4\text{ mA}\ \angle 0°)}{4\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{1.33\text{ mA}\ \angle 0°}$$

$\mathbf{V}_{ab} = (\mathbf{I}_{ab})$(8 kΩ ∠0°) = **10.67 V ∠0°**

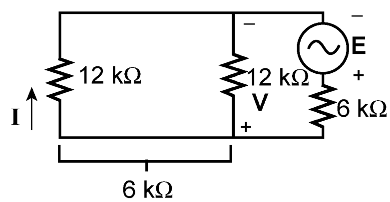


59. a.



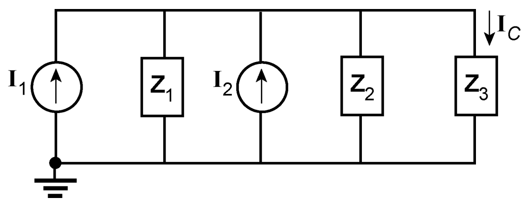
$$\mathbf{V} = \frac{4\,\text{k}\Omega(\mathbf{E})}{4\,\text{k}\Omega + 12\,\text{k}\Omega} = \frac{1}{4}(20\text{ V}\angle 0°)$$
$$= 5\text{ V}\angle 0°$$
$$\mathbf{I} = \frac{5\text{ V}\angle 0°}{6\,\text{k}\Omega} = \mathbf{0.83\text{ mA}\angle 0°}$$

b.



$$\mathbf{V} = \frac{6\,\text{k}\Omega(\mathbf{E})}{6\,\text{k}\Omega + 6\,\text{k}\Omega} = \frac{1}{2}(20\text{ V}\angle 0°)$$
$$= 10\text{ V}\angle 0°$$
$$\mathbf{I} = \frac{10\text{ V}\angle 0°}{12\,\text{k}\Omega} = \mathbf{0.83\text{ mA}\angle 0°}$$

60.



$$\mathbf{I}_1 = \frac{100\text{ V}\angle 0°}{2\,\text{k}\Omega\angle 0°} = 50\text{ mA}\angle 0°$$
$$\mathbf{I}_2 = \frac{50\text{ V}\angle 0°}{4\,\text{k}\Omega\angle 90°}$$
$$= 12.5\text{ mA}\angle -90°$$
$\mathbf{Z}_1 = 2\text{ k}\Omega\angle 0°$
$\mathbf{Z}_2 = 4\text{ k}\Omega\angle 90°$
$\mathbf{Z}_3 = 4\text{ k}\Omega\angle -90°$

$\mathbf{I}_T = \mathbf{I}_1 - \mathbf{I}_2 = (50\text{ mA}\angle 0° - 12.5\text{ mA}\angle -90°) = 50\text{ mA} + j12.5\text{ mA}$
$= 51.54\text{ mA}\angle 14.04°$
$\mathbf{Z}' = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = (2\text{ k}\Omega\angle 0°) \parallel (4\text{ k}\Omega\angle 90°) = 1.79\text{ k}\Omega\angle 26.57°$

$$\mathbf{I}_C = \frac{\mathbf{Z}'\mathbf{I}_T}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(1.79\text{ k}\Omega\angle 26.57°)(51.54\text{ mA}\angle 14.04°)}{1.6\text{ k}\Omega + j0.8\text{ k}\Omega - j4\text{ k}\Omega}$$
$$= \mathbf{25.77\text{ mA}\angle 104.04°}$$