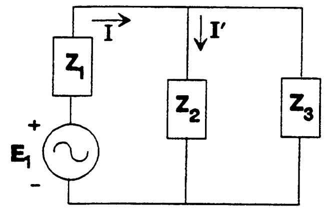
# CHAPTER 18 (Odd)

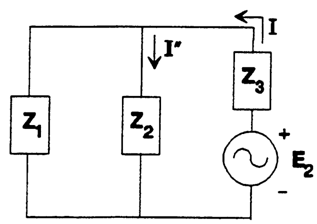
1. a.




$Z_1 = 3\ \Omega\ \angle 0°$, $Z_2 = 8\ \Omega\ \angle 90°$, $Z_3 = 6\ \Omega\ \angle -90°$
$Z_2 \| Z_3 = 8\ \Omega\ \angle 90° \| 6\ \Omega\ \angle -90° = 24\ \Omega\ \angle -90°$

$$\mathbf{I} = \frac{E_1}{Z_1 + Z_2 \| Z_3} = \frac{30\ \text{V}\ \angle 30°}{3\ \Omega - j24\ \Omega} = 1.24\ \text{A}\ \angle 112.875°$$

$$\mathbf{I}' = \frac{Z_3 \mathbf{I}}{Z_2 + Z_3} = \frac{(6\ \Omega\ \angle -90°)(1.24\ \text{A}\ \angle 112.875°)}{2\ \Omega\ \angle 90°} = 3.72\ \text{A}\ \angle -67.125°$$



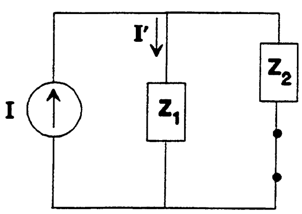

$Z_1 \| Z_2 = 3\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90° = 2.809\ \Omega\ \angle 20.556°$

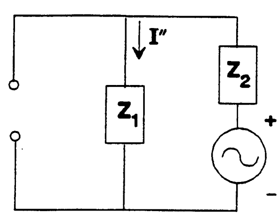
$$\mathbf{I} = \frac{E_2}{Z_3 + Z_1 \| Z_2} = \frac{60\ \text{V}\ \angle 10°}{-j6\ \Omega + 2.630\ \Omega + j0.986\ \Omega}$$
$$= 10.597\ \text{A}\ \angle 72.322°$$

$$\mathbf{I}'' = \frac{Z_1 \mathbf{I}}{Z_1 + Z_2} = \frac{(3\ \Omega\ \angle 0°)(10.597\ \text{A}\ \angle 72.322°)}{3\ \Omega + j8\ \Omega} = 3.721\ \text{A}\ \angle 2.878°$$

$$\mathbf{I}_{L_1} = \mathbf{I}' + \mathbf{I}'' = 3.72\ \text{A}\ \angle -67.125° + 3.721\ \text{A}\ \angle 2.878°$$
$$= 1.446\ \text{A} - j3.427\ \text{A} + 3.716\ \text{A} + j0.187\ \text{A}$$
$$= 5.162\ \text{A} - j3.24\ \text{A}$$
$$= \mathbf{6.095\ A\ \angle -32.115°}$$

b.



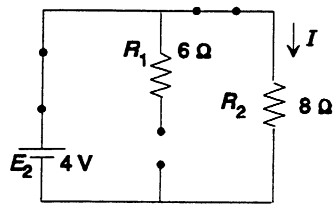

$Z_1 = 8\ \Omega\ \angle 90°$, $Z_2 = 5\ \Omega\ \angle -90°$
$\mathbf{I} = 0.3\ \text{A}\ \angle 60°$, $\mathbf{E} = 10\ \text{V}\ \angle 0°$

$$\mathbf{I}' = \frac{Z_2 \mathbf{I}}{Z_2 + Z_1} = \frac{(5\ \Omega\ \angle -90°)(0.3\ \text{A}\ \angle 60°)}{+j8\ \Omega - j5\ \Omega}$$
$$= 0.5\text{A}\ \angle -120°$$

$$\mathbf{I}'' = \frac{\mathbf{E}}{Z_1 + Z_2} = \frac{10\ \text{V}\ \angle 0°}{3\ \Omega\ \angle 90°} = 3.33\ \text{A}\ \angle -90°$$

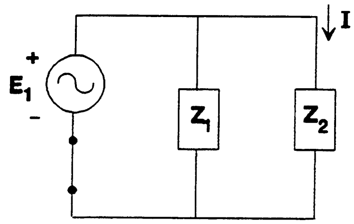
$$\mathbf{I}_{Z_1} = \mathbf{I}_{L_1} = \mathbf{I}' + \mathbf{I}''$$
$$= 0.5\ \text{A}\ \angle -120° + 3.33\ \text{A}\ \angle -90°$$
$$= -0.25\ \text{A} - j0.433\ \text{A} - j3.33\ \text{A}$$
$$= -0.25\ \text{A} - j3.763\ \text{A}$$
$$= \mathbf{3.77\ A\ \angle -93.8°}$$

3. DC:




$$I_{DC} = \frac{4\text{ V}}{8\ \Omega} = 0.5\text{ A}$$

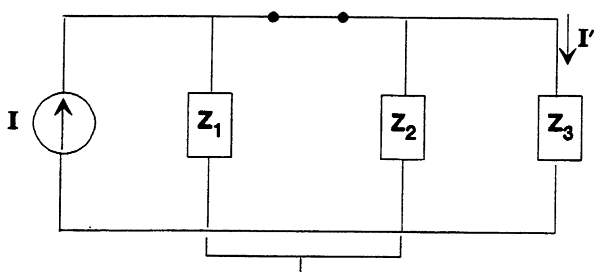
AC:




$$\mathbf{Z}_2 = R_2 + jX_L = 8\ \Omega + j4\ \Omega$$
$$= 8.944\ \Omega\ \angle 26.565°$$
$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10\text{ V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°}$$
$$= 1.118\text{ A}\ \angle -26.565°$$

$$\mathbf{I = 0.5\text{ A} + 1.118\text{ A}\ \angle -26.565°}$$
$$\boldsymbol{i = 0.5\text{ A} + 1.581 \sin(\omega t - 26.565°)}$$

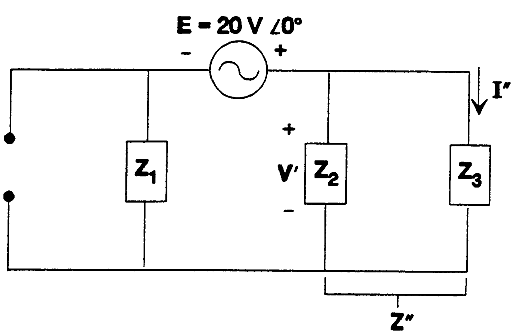
5.




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

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

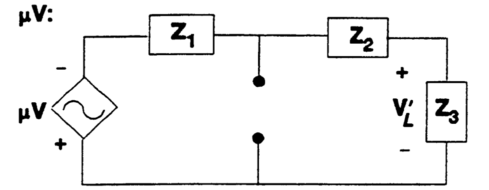
(CDR) $$\mathbf{I}' = \frac{\mathbf{Z}'\mathbf{I}}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(4.472\text{ k}\Omega\ \angle -26.57°)(5\text{ mA}\ \angle 0°)}{4\text{ k}\Omega - j2\text{ k}\Omega + j5\text{ k}\Omega} = \frac{22.36\text{ mA}\ \angle -26.57°}{5\ \angle 36.87°}$$
$$= 4.472\text{ mA}\ \angle -63.44°$$




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

(VDR) $$\mathbf{V}' = \frac{\mathbf{Z}''\mathbf{E}}{\mathbf{Z}'' + \mathbf{Z}_1} = \frac{(7.071\text{ k}\Omega\ \angle 45°)(20\text{ V}\ \angle 0°)}{(5\text{ k}\Omega + j5\text{ k}\Omega) + (10\text{ k}\Omega)} = \frac{141.42\text{ V}\ \angle 45°}{15.81\ \angle 18.435°}$$
$$= 8.945\text{ V}\ \angle 26.565°$$
$$\mathbf{I}'' = \frac{\mathbf{V}'}{\mathbf{Z}_3} = \frac{8.945\text{ V}\ \angle 26.565°}{5\text{ k}\Omega\ \angle 90°} = 1.789\text{ mA}\ \angle -63.435° = 0.8\text{ mA} - j1.6\text{ mA}$$
$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = (2\text{ mA} - j4\text{ mA}) + (0.8\text{ mA} - j1.6\text{ mA}) = 2.8\text{ mA} - j5.6\text{ mA}$$
$$\mathbf{= 6.261\text{ mA}\ \angle -63.43°}$$

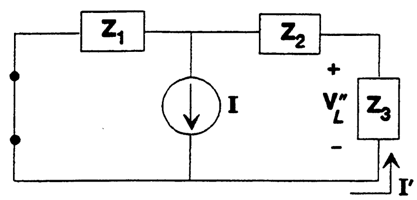
7. $\mu$V:




$Z_1 = 5\text{ k}\Omega \angle 0°$, $Z_2 = 1\text{ k}\Omega \angle -90°$
$Z_3 = 4\text{ k}\Omega \angle 0°$
$V = 2\text{ V} \angle 0°$, $\mu = 20$

$$V'_L = \frac{-Z_3(\mu V)}{Z_1 + Z_2 + Z_3} = \frac{-(4\text{ k}\Omega \angle 0°)(20)(2\text{ V} \angle 0°)}{5\text{ k}\Omega - j1\text{ k}\Omega + 4\text{ k}\Omega} = -17.67\text{ V} \angle 6.34°$$

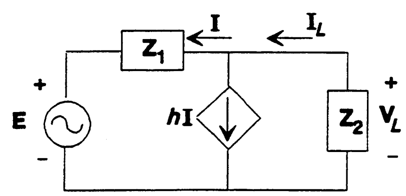
I:




$$\text{CDR: } I' = \frac{Z_1 I}{Z_1 + Z_2 + Z_3}$$
$$= \frac{(5\text{ k}\Omega \angle 0°)(2\text{ mA} \angle 0°)}{9.056\text{ k}\Omega \angle -6.34°}$$
$$= 1.104\text{ mA} \angle 6.34°$$

$V''_L = -I'Z_3 = -(1.104\text{ mA} \angle 6.34°)(4\text{ k}\Omega \angle 0°) = -4.416\text{ V} \angle 6.34°$
$V_L = V'_L + V''_L = -17.67\text{ V} \angle 6.34° - 4.416\text{ V} \angle 6.34° = \mathbf{-22.09\text{ V} \angle 6.34°}$

9.




$Z_1 = 2\text{ k}\Omega \angle 0°$, $Z_2 = 2\text{ k}\Omega \angle 0°$
$V_L = -I_L Z_2$
$I_L = hI + I = (h + 1)I$
$V_L = -(h + 1)IZ_2$
and by KVL: $V_L = IZ_1 + E$

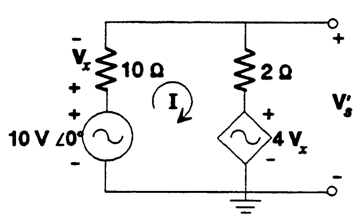
so that $I = \dfrac{V_L - E}{Z_1}$

$$V_L = -(h + 1)IZ_2 = -(h + 1)\left[\frac{V_L - E}{Z_1}\right]Z_2$$

Subt. for $Z_1$, $Z_2$

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

11. $E_1$:



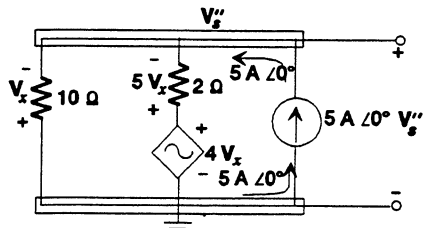

$10\text{ V} \angle 0° - I\,10\,\Omega - I\,2\,\Omega - 4\,V_x = 0$
with $V_x = I\,10\,\Omega$

Solving for I:

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

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

I:




$$\Sigma I_i = \Sigma I_o$$

$$5\text{ A }\angle 0° + \frac{V_x}{10\ \Omega} + \frac{5\ V_x}{2\ \Omega} = 0$$

$$5\text{ A} + 0.1\ V_x + 2.5\ V_x = 0$$

$$2.6\ V_x = -5\text{ A}$$

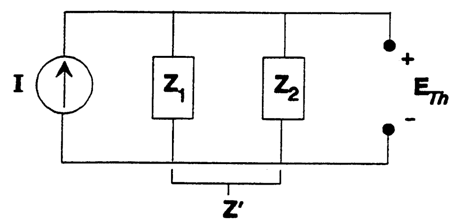
$$V_x = -\frac{5}{2.6}\text{V} = -1.923\text{ V}$$

$$V_s'' = -V_x = -(-1.923\text{ V}) = 1.923\text{ V }\angle 0°$$

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

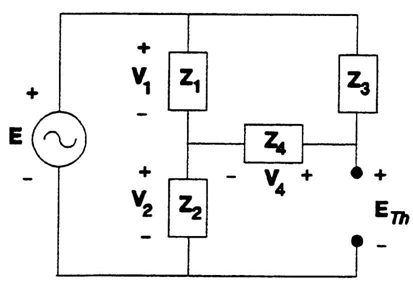
13. a. From #27. $Z_{Th} = Z_1 \| Z_2$

$Z_{Th} = Z_N = \mathbf{21.312\ \Omega\ \angle 32.196°}$




$$E_{Th} = IZ' = IZ_{Th}$$
$$= (0.1\text{ A }\angle 0°)(21.312\ \Omega\ \angle 32.196°)$$
$$= \mathbf{2.131\ V \angle 32.196°}$$

b. From #27. $Z_{Th} = Z_N = \mathbf{6.813\ \Omega\ \angle -54.228°} = 3.983\ \Omega - j5.528\ \Omega$




$Z_1 = 2\ \Omega\ \angle 0°$, $Z_3 = 8\ \Omega \angle -90°$

$Z_2 = 4\ \Omega\ \angle 90°$, $Z_4 = 10\ \Omega\ \angle 0°$

$E = 50\text{ V }\angle 0°$

$E_{Th} = V_2 + V_4$

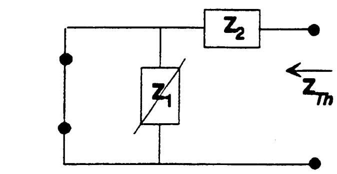
$$V_2 = \frac{Z_2 E}{Z_2 + Z_1 \| (Z_3 + Z_4)}$$
$$= \frac{(4\ \Omega\ \angle 90°)(50\text{ V }\angle 0°)}{+j4\ \Omega + 2\ \Omega\ \angle 0° \| (10\ \Omega - j8\ \Omega)}$$
$$= 47.248\text{ V }\angle 24.7°$$

$$V_1 = E - V_2 = 50\text{ V }\angle 0° - 47.248\text{ V }\angle 24.7° = 20.972\text{ V }\angle -70.285°$$

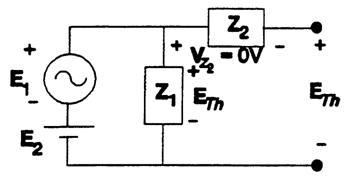
$$V_4 = \frac{Z_4 V_1}{Z_4 + Z_3} = \frac{(10\ \Omega\ \angle 0°)(20.972\text{ V }\angle -70.285°)}{10\ \Omega - j8\ \Omega} = 16.377\text{ V }\angle -31.625°$$

$$E_{Th} = V_2 + V_4 = 47.248\text{ V }\angle 24.7° + 16.377\text{ V }\angle -31.625°$$
$$= (42.925\text{ V} + j19.743\text{ V}) + (13.945\text{ V} - j8.587\text{ V})$$
$$= 56.870\text{ V} + j11.156\text{ V} = \mathbf{57.954\ V\ \angle 11.099°}$$

15. a.



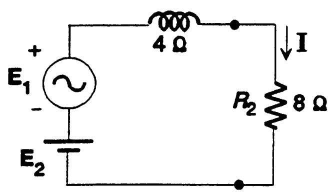

$\mathbf{Z}_1 = 6\ \Omega - j2\ \Omega = 6.325\ \Omega\ \angle -18.435°$
$\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$
$\mathbf{Z}_{Th} = \mathbf{Z}_2 = \mathbf{4\ \Omega\ \angle 90°}$




By inspection:

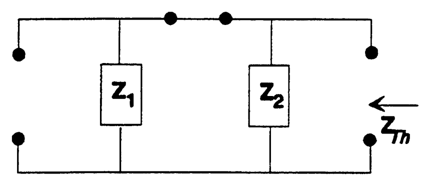
$\mathbf{E}_{Th} = E_2 + \mathbf{E}_1$
$= \underset{\text{DC}}{4\ \text{V}} + \underset{\text{AC}}{10\ \text{V}}\ \angle 0°$

b.




$$\mathbf{I} = \frac{E_2}{R_2} + \frac{\mathbf{E}_1}{R_2 + jX_L}$$
$$= \frac{4\ \text{V}}{8\ \Omega} + \frac{10\ \text{V}\ \angle 0°}{8\ \Omega + j4\ \Omega}$$
$$= 0.5\ \text{A} + \frac{10\ \text{V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°}$$
$$= \underset{\text{(dc)}}{0.5\ \text{A}} + \underset{\text{(ac)}}{1.118\ \text{A}\ \angle -26.565°}$$

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

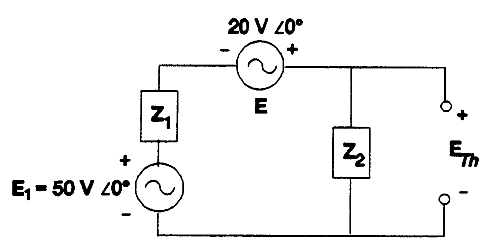



$\mathbf{Z}_1 = 10\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega$
$= 7.071\ \text{k}\Omega\ \angle -45°$

$$\mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2 = (10\ \text{k}\Omega\ \angle 0°) \| (7.071\ \text{k}\Omega\ \angle -45°) = \mathbf{4.472\ k\Omega\ \angle -26.565°}$$

Source conversion:

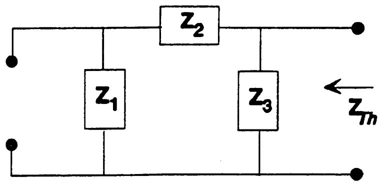
$$\mathbf{E}_1 = (I\angle\theta)(R_1\angle 0°) = (5\ \text{mA}\ \angle 0°)(10\ \text{k}\Omega\ \angle 0°) = 50\ \text{V}\ \angle 0°$$




$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2(\mathbf{E} + \mathbf{E}_1)}{\mathbf{Z}_2 + \mathbf{Z}_1}$$
$$= \frac{(7.071\ \text{k}\Omega\ \angle -45°)(20\ \text{V}\ \angle 0° + 50\ \text{V}\ \angle 0°)}{(5\ \text{k}\Omega - j5\ \text{k}\Omega) + (10\ \text{k}\Omega)}$$
$$= \frac{(7.071\ \text{k}\Omega\ \angle -45°)(70\ \text{V}\ \angle 0°)}{(15\ \text{k}\Omega - j5\ \text{k}\Omega)}$$
$$= \frac{494.97\ \text{V}\ \angle -45°}{15.811\ \angle -18.435°}$$
$$= \mathbf{31.31\ V\ \angle -26.565°}$$

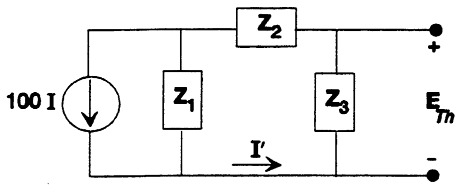
b.
$$\mathbf{I} = \frac{\mathbf{E}_{Th}}{\mathbf{Z}_{Th} + \mathbf{Z}_L} = \frac{31.31\ \text{V}\ \angle -26.565°}{4.472\ \text{k}\Omega\ \angle -26.565° + 5\ \text{k}\Omega\ \angle 90°}$$
$$= \frac{31.31\ \text{V}\ \angle -26.565°}{4\ \text{k}\Omega - j2\ \text{k}\Omega + j5\ \text{k}\Omega} = \frac{31.31\ \text{V}\ \angle -26.565°}{4\ \text{k}\Omega + j3\ \text{k}\Omega}$$
$$= \frac{31.31\ \text{V}\ \angle -26.565°}{5\ \text{k}\Omega\ \angle 36.87°} = \mathbf{6.26\ mA\ \angle 63.435°}$$

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




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

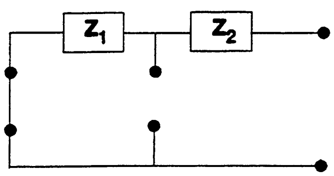
$$\mathbf{Z}_{Th} = \mathbf{Z}_3 \| (\mathbf{Z}_1 + \mathbf{Z}_2) = 5\ \text{k}\Omega\ \angle 0° \| (40\ \text{k}\Omega - j0.2\ \text{k}\Omega) = \mathbf{4.44\ k\Omega\ \angle -0.031°}$$




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

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

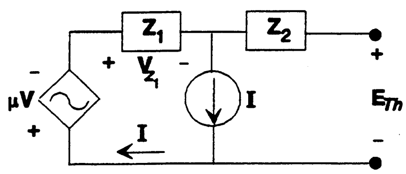
21. $\mathbf{Z}_{Th}$:




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

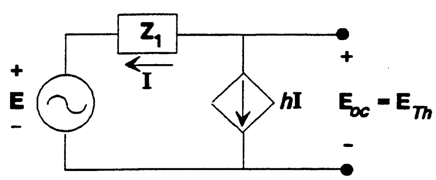
$$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\ \text{k}\Omega - j1\ \text{k}\Omega = 5.099\ \text{k}\Omega\ \angle -11.31°$$

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



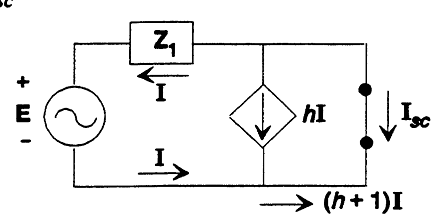

$$\mathbf{E}_{Th} = -[\mu\mathbf{V} + \mathbf{V}_{Z_1}] = -\mu\mathbf{V} - \mathbf{I}\mathbf{Z}_1 = -(20)(2\ \text{V}\ \angle 0°) - (2\ \text{mA}\ \angle 0°)(5\ \text{k}\Omega\ \angle 0°) = \mathbf{-50\ V\ \angle 0°}$$

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




$h\mathbf{I} = -\mathbf{I}$ $\quad$ $\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°$
$\therefore$ $\quad \mathbf{I} = 0$
and $\quad h\mathbf{I} = 0$
with $\quad \mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{E} = 20\ \text{V}\ \angle 53°$

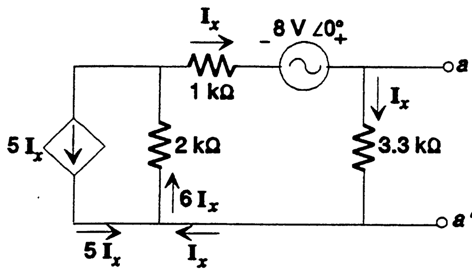
$\mathbf{I}_{sc}$:




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

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{20\ \text{V}\ \angle 53°}{-510\ \text{mA}\ \angle 53°} = \mathbf{-39.215\ \Omega\ \angle 0°}$$

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

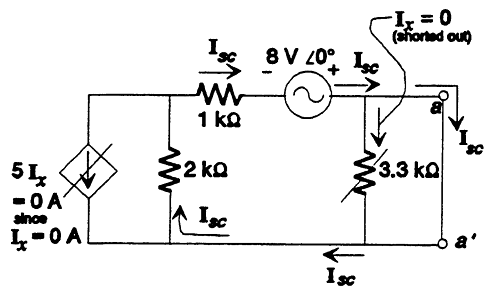



$$\text{KVL: } -6\,\mathbf{I}_x(2\text{ k}\Omega) - \mathbf{I}_x(1\text{ k}\Omega) + 8\text{ V }\angle 0° - \mathbf{I}_x(3.3\text{ k}\Omega) = 0$$

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

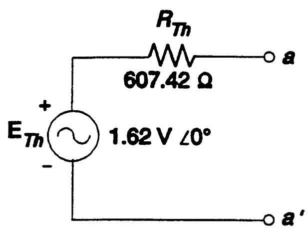
$$\mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{I}_x(3.3\text{ k}\Omega) = \mathbf{1.62\ V\ \angle 0°}$$

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

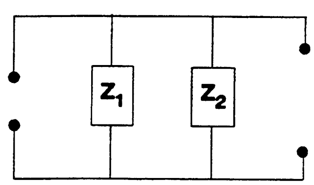



$$\mathbf{I}_{sc} = \frac{8\text{ V}}{3\text{ k}\Omega} = 2.667\text{ mA }\angle 0°$$

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

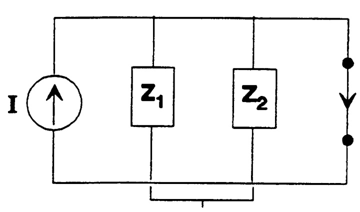



27. a.




$\mathbf{Z}_1 = 20\ \Omega + j20\ \Omega = 28.284\ \Omega\ \angle 45°$
$\mathbf{Z}_2 = 68\ \Omega\ \angle 0°$

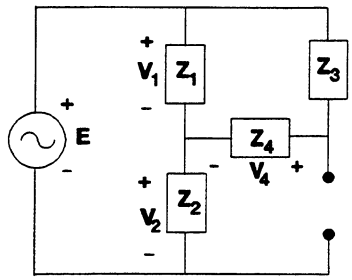
$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 \| \mathbf{Z}_2$
$= (28.284\ \Omega\ \angle 45°) \| (68\ \Omega\ \angle 0°)$
$= 21.312\ \Omega\ \angle 32.196°$




Z′ bypassed by short-circuit

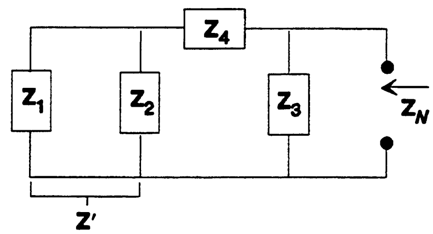
$\mathbf{I}_{sc} = \mathbf{I} = \mathbf{I}_N = 0.1\text{ A }\angle 0°$

b.

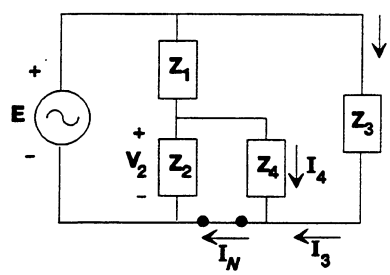



$\mathbf{Z}_1 = 2\ \Omega\ \angle 0°,\ \mathbf{Z}_2 = 4\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 8\ \Omega\ \angle -90°,\ \mathbf{Z}_4 = 10\ \Omega\ \angle 0°$
$\mathbf{E} = 50\ \mathrm{V}\ \angle 0°$

$\mathbf{Z}_N$:



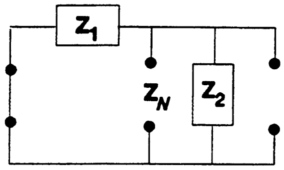

$$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = 2\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90°$$
$$= 1.789\ \Omega\ \angle 26.565° = 1.6\ \Omega + j0.8\ \Omega$$
$$\mathbf{Z}' + \mathbf{Z}_4 = 1.6\ \Omega + j0.8\ \Omega + 10\ \Omega = 11.6\ \Omega + j0.8\ \Omega = 11.628\ \Omega\ \angle 3.945°$$
$$\mathbf{Z}_N = \mathbf{Z}_3 \| (\mathbf{Z}' + \mathbf{Z}_4) = (8\ \Omega\ \angle -90°) \| (11.628\ \Omega\ \angle 3.945°) = \mathbf{6.813\ \Omega\ \angle -54.228°}$$
$$= \mathbf{3.983\ \Omega - j5.528\ \Omega}$$




$$\mathbf{I}_3 = \frac{\mathbf{E}}{\mathbf{Z}_3} = \frac{50\ \mathrm{V}\ \angle 0°}{8\ \Omega\ \angle -90°} = 6.250\ \mathrm{A}\ \angle 90°$$
$$\mathbf{Z}' = \mathbf{Z}_2 \| \mathbf{Z}_4 = 4\ \Omega\ \angle 90° \| 10\ \Omega\ \angle 0°$$
$$= 3.714\ \Omega\ \angle 68.2°$$
$$\mathbf{V}_2 = \frac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_1} = \frac{(3.714\ \Omega\ \angle 68.2°)(50\ \mathrm{V}\ \angle 0°)}{1.378\ \Omega + j3.448\ \Omega + 2\ \Omega}$$
$$= \frac{185.7\ \mathrm{V}\ \angle 68.2°}{4.827\ \angle 45.588°} = 38.471\ \mathrm{V}\ \angle 22.612°$$

$$\mathbf{I}_4 = \frac{\mathbf{V}_2}{\mathbf{Z}_4} = \frac{38.471\ \mathrm{V}\ \angle 22.612°}{10\ \Omega\ \angle 0°} = 3.847\ \mathrm{A}\ \angle 22.612°$$
$$\mathbf{I}_N = \mathbf{I}_3 + \mathbf{I}_4 = 6.250\ \mathrm{A}\ \angle 90° + 3.847\ \mathrm{A}\ \angle 22.612°$$
$$= +j6.25\ \mathrm{A} + 3.551\ \mathrm{A} + j1.479\ \mathrm{A} = 3.551\ \mathrm{A} + j7.729\ \mathrm{A}$$
$$= \mathbf{8.506\ A\ \angle 65.324°}$$

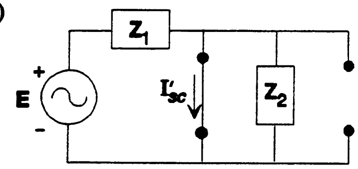
29. a. $\mathbf{Z}_N$:



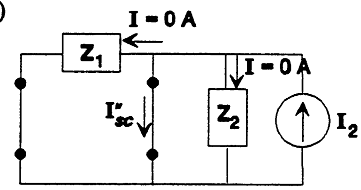

$\mathbf{E} = 20\text{ V}\ \angle 0°$, $\mathbf{I}_2 = 0.4\text{ A}\ \angle 20°$
$\mathbf{Z}_1 = 6\ \Omega + j8\ \Omega = 10\ \Omega\ \angle 53.13°$
$\mathbf{Z}_2 = 9\ \Omega - j12\ \Omega = 15\ \Omega\ \angle -53.13°$
$\mathbf{Z}_N = \mathbf{Z}_1 \| \mathbf{Z}_2 = (10\ \Omega\ \angle 53.13°) \| (15\ \Omega\ \angle -53.13°)$
$= \mathbf{9.66\ \Omega\ \angle 14.93°}$

$\mathbf{I}_N$:

(E)




($\mathbf{I}_2$)

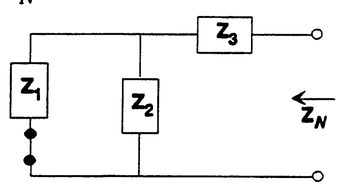



$\mathbf{I}'_{sc} = \mathbf{E}/\mathbf{Z}_1 = 20\text{ V}\ \angle 0°/10\ \Omega\ \angle 53.13°$
$= 2\text{ A}\ \angle -53.13°$

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

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 2\text{A}\ \angle -53.13° + 0.4\text{ A}\ \angle 20°$
$= \mathbf{2.15\ A\ \angle -42.87°}$

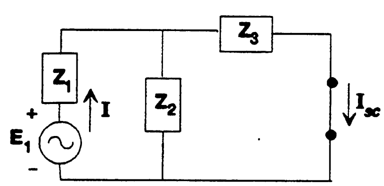
b. $\mathbf{Z}_N$:




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

$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2$
$= 4\ \Omega\ \angle 90° + (3\ \Omega\ \angle 0°) \| (8\ \Omega - j8\ \Omega)$
$= \mathbf{4.37\ \Omega\ \angle 55.67° = 2.465\ \Omega + j3.61\ \Omega}$

$\mathbf{I}_N$:

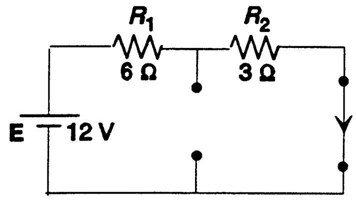



$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_T} = \frac{120\text{ V}\ \angle 30°}{\mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3}$$
$$= \frac{120\text{ V}\ \angle 30°}{3\ \Omega + (8\ \Omega - j8\ \Omega) \| 4\ \Omega\ \angle 90°}$$
$$= \frac{120\text{ V}\ \angle 30°}{6.65\ \Omega\ \angle 46.22°}$$
$$=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

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

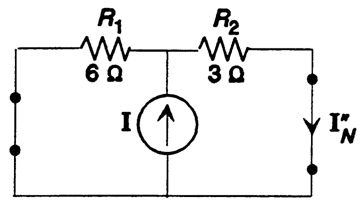
31. a. From #15 $\mathbf{Z}_N = \mathbf{Z}_{Th} = 9\ \Omega\ \angle 0°$

DC:




$$\mathbf{I}'_N = \frac{E}{R_T} = \frac{12\ \text{V}}{9\ \Omega} = 1.333\ \text{A}$$

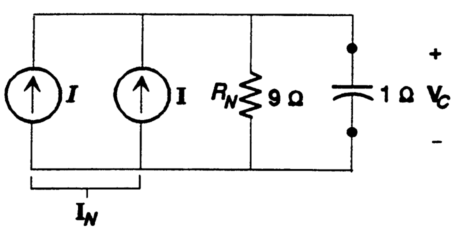
AC:




$$\mathbf{I}''_N = \frac{R_1\mathbf{I}}{R_1 + R_2} = \frac{(6\ \Omega\ \angle 0°)(4\ \text{A}\ \angle 0°)}{9\ \Omega\ \angle 0°}$$
$$= \frac{24\ \text{V}\ \angle 0°}{9\ \Omega\ \angle 0°} = 2.667\ \text{A}\ \angle 0°$$

$\mathbf{I}_N = \mathbf{1.333\ A + 2.667\ A\ \angle 0°}$

b.

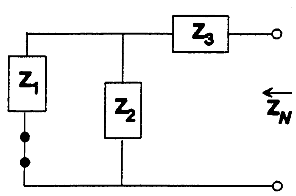



DC: $V_C = IR$
$= (1.333\ \text{A})(9\ \Omega)$
$= 12\ \text{V}$

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

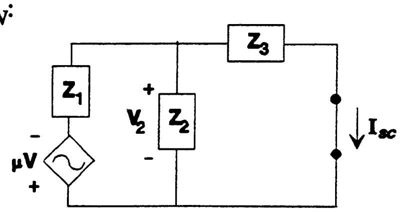
$V_C = \mathbf{IZ}' = (2.667\ \text{A}\ \angle 0°)(0.994\ \Omega\ \angle -83.66°)$
$= 2.65\ \text{V}\ \angle -83.66°$
$V_C = 12\ \text{V} + 2.65\ \text{V}\ \angle -83.66°$

33. $\mathbf{Z}_N$:




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

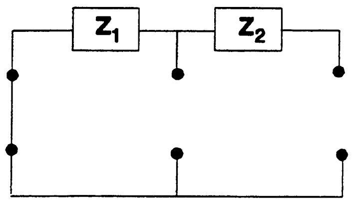
$\mathbf{I}_N$:




$$\mathbf{V}_2 = \frac{-(\mathbf{Z}_2 \parallel \mathbf{Z}_3)20\ \text{V}}{(\mathbf{Z}_2 \parallel \mathbf{Z}_3) + \mathbf{Z}_1}$$
$$= \frac{-(0.995\ \text{k}\Omega\ \angle -84.29°)(20\ \text{V})}{0.1\ \text{k}\Omega - j0.99\ \text{k}\Omega + 10\ \text{k}\Omega}$$
$$\mathbf{V}_2 = -1.961\ \text{V}\ \angle -78.69°$$

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

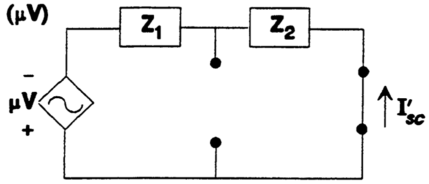
35. $\mathbf{Z}_N$:




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

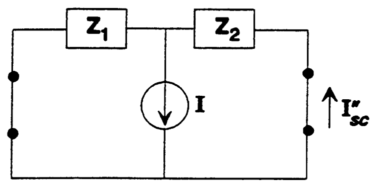
$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$
$= 5.1\text{ k}\Omega\ \angle -11.31°$

$\mathbf{I}_N$: $(\mu\mathbf{V})$




$$\mathbf{I}'_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(2\text{ V}\ \angle 0°)}{5.1\text{ k}\Omega\ \angle -11.31°} = 7.843\text{ mA}\ \angle 11.31°$$

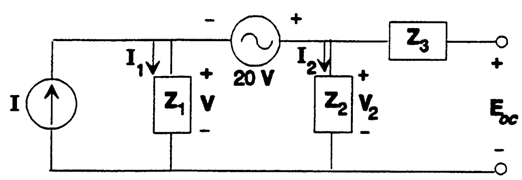
(I)




$$\mathbf{I}''_{sc} = \frac{\mathbf{Z}_1(\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(5\text{ k}\Omega\ \angle 0°)(2\text{ mA}\ \angle 0°)}{5.1\text{ k}\Omega\ \angle -11.31°} = 1.96\text{ mA}\ \angle 11.31°$$

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

37.




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

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

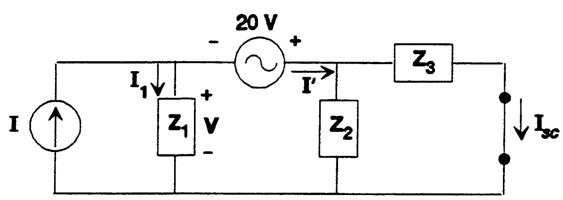
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2,\ \mathbf{I}_1 = \frac{\mathbf{V}}{\mathbf{Z}_1} = \frac{\mathbf{E}_{oc}}{21\ \mathbf{Z}_1}$$

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

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

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

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




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

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

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

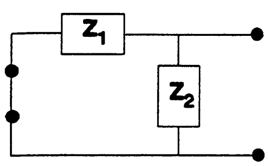
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}' = \frac{\mathbf{V}}{\mathbf{Z}_1} + \left[\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc} = \left[\frac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

$$\mathbf{I}_{sc} = \frac{\mathbf{I}}{\dfrac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \dfrac{\mathbf{Z}_3 + \mathbf{Z}_2}{\mathbf{Z}_2}} = \frac{2\text{ mA } \angle 0^\circ}{\dfrac{4\text{ k}\Omega}{21\text{ k}\Omega} + \dfrac{7\text{ k}\Omega}{3\text{ k}\Omega}} = 0.792\text{ mA } \angle 0^\circ$$

$\therefore$ $\mathbf{I}_N = \mathbf{0.792\ mA\ \angle 0^\circ}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{5.25\text{ V } \angle 0^\circ}{0.792\text{ mA } \angle 0^\circ} = \mathbf{6.63\ k\Omega\ \angle 0^\circ}$$

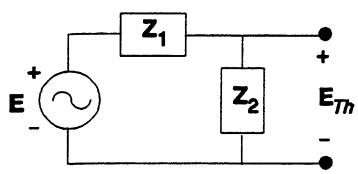
39. a.




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

$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2$
$= 5\ \Omega\ \angle 53.13^\circ \parallel 6\ \Omega\ \angle -9$
$= 8.32\ \Omega\ \angle -3.18^\circ$

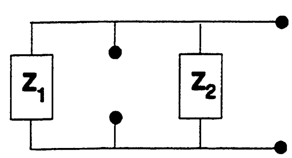
$\mathbf{Z}_L = 8.32\ \Omega\ \angle 3.18^\circ = \mathbf{8.31\ \Omega - j0.462\ \Omega}$




$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(6\ \Omega\ \angle -90^\circ)(120\text{ V } \angle 0^\circ)}{3.61\ \Omega\ \angle -33.69^\circ} = \mathbf{199.45\ V\ \angle -56.31^\circ}$$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(199.45\text{ V})^2}{4(8.31\ \Omega)} = \mathbf{1198.2\ W}$$

b.

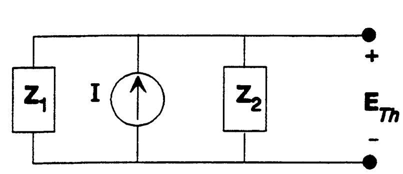



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13^\circ$
$\mathbf{Z}_2 = 2\ \Omega\ \angle 0^\circ$

$$\leftarrow \mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{Z}_1 \parallel \mathbf{Z}_2 = 5\ \Omega\ \angle 53.13^\circ \parallel 2\ \Omega\ \angle 0^\circ = \frac{10\ \Omega\ \angle 53.13^\circ}{2 + 3 + j4} = \frac{10\ \Omega\ \angle 53.13^\circ}{5 + j4} = \frac{10\ \Omega\ \angle 53.13^\circ}{6.403\ \angle 38.66^\circ} = \mathbf{1.562\ \Omega\ \angle 14.47^\circ}$$

$\mathbf{Z}_{Th} = 1.562\ \Omega\ \angle 14.47^\circ$
$= 1.512\ \Omega + j0.39\ \Omega$

$\mathbf{Z}_L = \mathbf{1.512\ \Omega - j0.39\ \Omega}$




$\mathbf{E}_{Th} = \mathbf{I}(\mathbf{Z}_1 \parallel \mathbf{Z}_2)$
$= (2\text{ A } \angle 30^\circ)(1.562\ \Omega\ \angle 14.47^\circ)$
$= \mathbf{3.124\ V\ \angle 44.47^\circ}$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3.124\text{ V})^2}{4(1.512\ \Omega)} = \mathbf{1.614\ W}$$

41. $\mathbf{I} = \dfrac{E\angle 0^\circ}{R_1\angle 0^\circ} = \dfrac{1\text{ V }\angle 0^\circ}{1\text{ k}\Omega\ \angle 0^\circ} = 1\text{ mA }\angle 0^\circ$

$\mathbf{Z}_{Th} = 40\text{ k}\Omega\ \angle 0^\circ$

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

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

43. From #16, $\mathbf{Z}_{Th} = 9\ \Omega$, $\mathbf{E}_{Th} = 12\text{ V} + 24\text{ V }\angle 0^\circ$

a. $\therefore Z_L = 9\ \Omega$

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

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

45. a. $\mathbf{Z}_{Th} = 2\text{ k}\Omega\ \angle 0^\circ \,\|\, 2\text{ k}\Omega\ \angle -90^\circ = 1\text{ k}\Omega - j1\text{ k}\Omega$

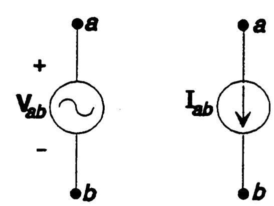
$$\begin{aligned} R_L &= \sqrt{R_{Th}^2 + (X_{Th} + X_{\text{Load}})^2} \\ &= \sqrt{(1\text{ k}\Omega)^2 + (-1\text{ k}\Omega + 2\text{ k}\Omega)^2} \\ &= \sqrt{(1\text{ k}\Omega)^2 + (1\text{ k}\Omega)^2} \\ &= \mathbf{1.414\ k\Omega} \end{aligned}$$

b. $R_{\text{av}} = (R_{Th} + R_{\text{Load}})/2 = (1\text{ k}\Omega + 1.414\text{ k}\Omega)/2 = 1.207\text{ k}\Omega$

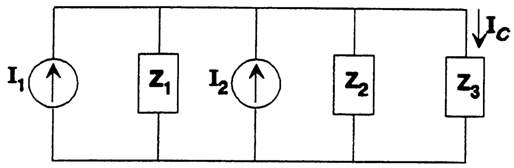
$$P_{\max} = \frac{E_{Th}^2}{4R_{\text{av}}} = \frac{(50\text{ V})^2}{4(1.207\text{ k}\Omega)} = \mathbf{0.518\ W}$$

47. $\mathbf{I}_{ab} = \dfrac{(4\text{ k}\Omega\ \angle 0^\circ)(4\text{ mA }\angle 0^\circ)}{4\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{1.333\ mA\ \angle 0^\circ}$

$\mathbf{V}_{ab} = (\mathbf{I}_{ab})(8\text{ k}\Omega\ \angle 0^\circ) = \mathbf{10.67\ V\ \angle 0^\circ}$



49.




$$\mathbf{I}_1 = \frac{100\text{ V }\angle 0°}{2\text{ k}\Omega\ \angle 0°} = 50\text{ mA }\angle 0°$$

$$\mathbf{I}_2 = \frac{50\text{ V }\angle 0°}{4\text{ k}\Omega\ \angle 90°} = 12.5\text{ mA }\angle -90°$$

$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 4\text{ k}\Omega\ \angle 90°$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle -90°$

$$\mathbf{I}_T = \mathbf{I}_1 - \mathbf{I}_2 = (50\text{ mA }\angle 0° - 12.5\text{ mA }\angle -90°) = 50\text{ mA} + j12.5\text{ mA} = 51.54\text{ mA }\angle 14.04°$$

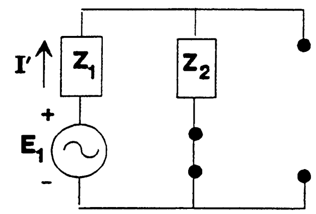
$$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = (2\text{ k}\Omega\ \angle 0°) \| (4\text{ k}\Omega\ \angle 90°) = 1.79\text{ k}\Omega\ \angle 26.57°$$

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

$$= \mathbf{25.77\text{ mA }\angle 104.04°}$$

# CHAPTER 18 (Even)

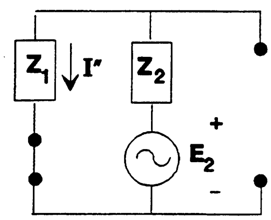
2. a. $\mathbf{E}_1$:




$\mathbf{E}_1 = 20\text{ V}\angle 0°,\ \mathbf{Z}_1 = 4\ \Omega + j3\ \Omega = 5\ \Omega\angle 36.87°$
$\mathbf{Z}_2 = 1\ \Omega\angle 0°$

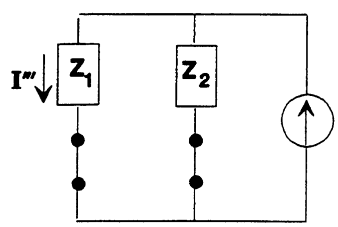
$$\mathbf{I}' = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{20\text{ V}\angle 0°}{4\ \Omega + j3\ \Omega + 1\ \Omega} = 3.43\text{ A}\angle -30.96°$$

$\mathbf{E}_2$:




$$\mathbf{I}'' = \frac{\mathbf{E}_2}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{120\text{ V}\angle 0°}{5.83\ \Omega\angle 30.96°} = 20.58\text{ A}\angle -30.96°$$

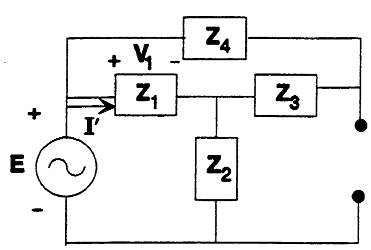
**I**:




$$\mathbf{I}''' = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(1\ \Omega\angle 0°)(0.5\text{ A}\angle 60°)}{5.83\ \Omega\angle 30.96°} = 0.0858\text{ A}\angle 29.04°$$

$\uparrow \mathbf{I}_L = \mathbf{I}' - \mathbf{I}'' - \mathbf{I}'''$
$= (3.43\text{ A}\angle -30.96°) - (20.58\text{ A}\angle -30.96°) - (0.0858\text{ A}\angle 29.04°)$
$= \mathbf{17.20\ A\ \angle 149.30°}$ or $\mathbf{17.20\ A\ \angle -30.70°}\downarrow$

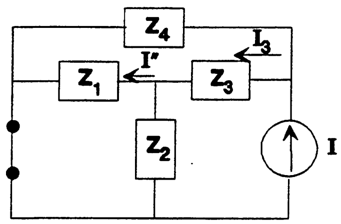
b. **E**:




$\mathbf{Z}_1 = 3\ \Omega\angle 90°, \mathbf{Z}_2 = 7\ \Omega\angle -90°$
$\mathbf{E} = 10\text{ V}\angle 90°$
$\mathbf{Z}_3 = 6\ \Omega\angle -90°, \mathbf{Z}_4 = 4\ \Omega\angle 0°$
$\mathbf{Z}' = \mathbf{Z}_1 \| (\mathbf{Z}_3 + \mathbf{Z}_4)$
$= 3\ \Omega\angle 90° \| (4\ \Omega - j6\ \Omega)$
$= 3\ \Omega\angle 90° \| 7.21\ \Omega\angle -56.31°$
$= 4.33\ \Omega\angle 70.56°$

$$\mathbf{V}_1 = \frac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_2}$$
$$= \frac{(4.33\ \Omega\ \angle 70.56°)(10\ \text{V}\ \angle 90°)}{(1.44\ \Omega + j4.08\ \Omega) - j7\Omega}$$
$$= \frac{43.3\ \text{V}\ \angle 160.56°}{3.26\ \angle -63.75°} = 13.28\ \text{V}\ \angle 224.31°$$
$$\mathbf{I}' = \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{13.28\ \text{V}\ \angle 224.31°}{3\ \Omega\ \angle 90°}$$
$$= 4.43\ \text{A}\ \angle 134.31°$$

**I:**

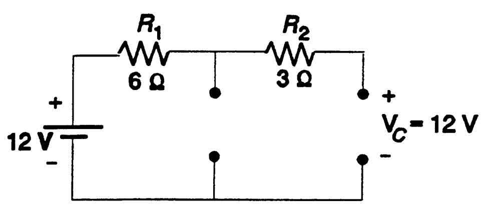



$$\mathbf{Z}'' = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$$
$$= -j6\ \Omega + 3\ \Omega\ \angle 90° \parallel 7\ \Omega\ \angle -90°$$
$$= -j6\ \Omega + 5.25\ \Omega\ \angle 90°$$
$$= -j6\ \Omega + j5.25\ \Omega$$
$$= -j0.75\ \Omega = 0.75\ \Omega \angle -90°$$

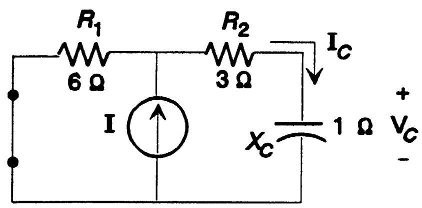
CDR: $$\mathbf{I}_3 = \frac{\mathbf{Z}_4\mathbf{I}}{\mathbf{Z}_4 + \mathbf{Z}''} = \frac{(4\ \Omega\ \angle 0°)(0.6\ \text{A}\ \angle 120°)}{4\ \Omega - j0.75\ \Omega} = \frac{2.4\ \text{A}\ \angle 120°}{4.07\ \angle -10.62°}$$
$$= 0.59\ \text{A}\ \angle 130.62°$$
$$\mathbf{I}'' = \frac{\mathbf{Z}_2\mathbf{I}_3}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(7\ \Omega\ \angle -90°)(0.59\ \text{A}\ \angle 130.62°)}{-j7\ \Omega + j3\ \Omega} = \frac{4.13\ \text{A}\ \angle 40.62°}{4\ \angle -90°}$$
$$= 1.03\ \text{A}\ \angle 130.62°$$

$$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''\ \text{(direction of } \mathbf{I}')$$
$$= 4.43\ \text{A}\ \angle 134.31° - 1.03\ \text{A}\ \angle 130.62°$$
$$= (-3.09\ \text{A} + j3.17\ \text{A}) - (-0.67\ \text{A} + j0.78\ \text{A}) = -2.42\ \text{A} + j2.39\ \text{A}$$
$$= \mathbf{3.40\ A\ \angle 135.36°}$$

4. DC:



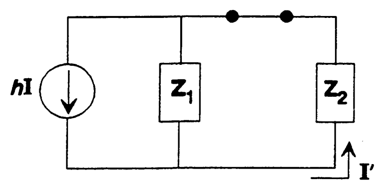

AC:




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

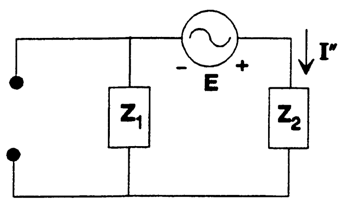
$$\mathbf{V}_C = \mathbf{I}_C\mathbf{X}_C = (2.65\ \text{A}\ \angle 6.34°)(1\ \Omega\ \angle -90°) = 2.65\ \text{V}\ \angle -83.66°$$
$$= \mathbf{12\ V + 2.65\ V\ \angle -83.66°}$$
$$v_C = \mathbf{12\ V + 3.747\ \sin(\omega t - 83.66°)}$$

6.




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

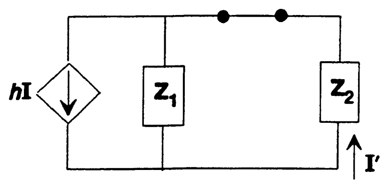
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\ \text{k}\Omega\ \angle 0°)(100)(2\ \text{mA}\ \angle 0°)}{20\ \text{k}\Omega + j10\ \text{k}\Omega} = 0.179\ \text{A}\ \angle -26.57°$$




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

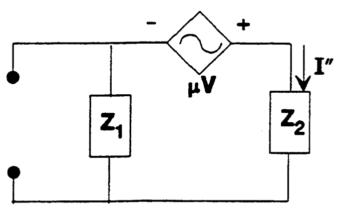
$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$= 179\ \text{mA}\ \angle -26.57° - 0.447\ \text{mA}\ \angle -26.57°$
$= \mathbf{178.55\ mA\ \angle -26.57°}$

8.




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

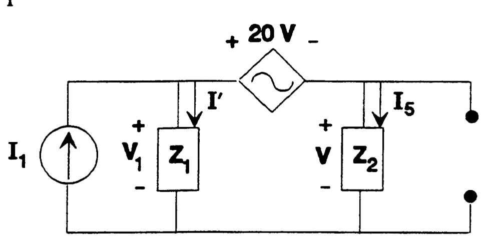
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\ \text{k}\Omega\ \angle 0°)(100)(1\ \text{mA}\ \angle 0°)}{20\ \text{k}\Omega + 5\ \text{k}\Omega + j5\ \text{k}\Omega} = 78.45\ \text{mA}\ \angle -11.31°$$




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

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

10. $\mathbf{I}_1$:




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

KVL: $\mathbf{V}_1 - 20\ \text{V} - \mathbf{V} = 0 \quad \mathbf{I}' = \dfrac{\mathbf{V}_1}{\mathbf{Z}_1}\ \therefore\ \mathbf{I}' = \dfrac{21\ \mathbf{V}}{\mathbf{Z}_1}$ or $\mathbf{V} = \dfrac{\mathbf{Z}_1}{21}\mathbf{I}'$

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

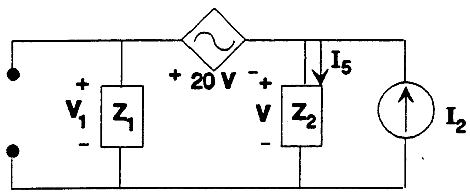
$$\mathbf{V} = \mathbf{I}_5\mathbf{Z}_2 = [\mathbf{I}_1 - \mathbf{I}']\mathbf{Z}_2$$

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

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

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

$\mathbf{I}_2$:




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

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

$$\mathbf{I}_5 = \frac{\mathbf{V}}{\mathbf{Z}_2} = \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

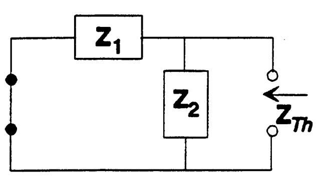
$$\mathbf{I}'' = \mathbf{I}_2 - \mathbf{I}_5 = \mathbf{I}_2 - \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

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

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

$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = 0.981\text{ mA}\ \angle 0° + 1.963\text{ mA}\ \angle 0°$$
$$= \mathbf{2.944\text{ mA}\ \angle 0°}$$

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

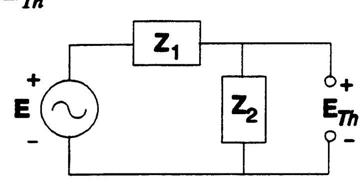



$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$\mathbf{E} = 100\text{ V}\ \angle 0°$

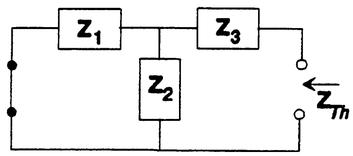
$$\mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2 = (3\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90°)$$
$$= 2.4\ \Omega\ \angle 36.87° = 1.92\ \Omega + j1.44\ \Omega$$

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



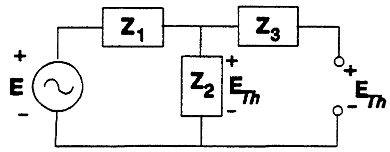

$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(4\ \Omega\ \angle 90°)(100\text{ V}\ \angle 0°)}{5\ \Omega\ \angle 53.13°}$$
$$= \mathbf{80\text{ V}\ \angle 36.87°}$$

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



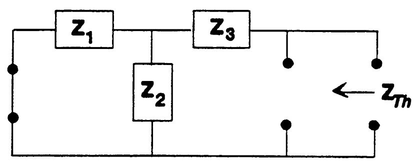

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 \\ &= +j6\text{ k}\Omega + (2\text{ k}\Omega\ \angle 0° \| 3\text{ k}\Omega\ \angle -90°) \\ &= +j6\text{ k}\Omega + 1.664\text{ k}\Omega\ \angle -33.69° \\ &= +j6\text{ k}\Omega + 1.385\text{ k}\Omega - j0.923\text{ k}\Omega \\ &= 1.385\text{ k}\Omega + j5.077\text{ k}\Omega \\ &= \mathbf{5.263\ k\Omega\ \angle 74.741°}\end{aligned}$$

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




$$\begin{aligned}\mathbf{E}_{Th} &= \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(3\text{ k}\Omega\ \angle -90°)(20\text{ V}\ \angle 0°)}{2\text{ k}\Omega - j3\text{ k}\Omega} \\ &= \frac{60\text{ V}\ \angle -90°}{3.606\ \angle -56.31°} = \mathbf{16.639\ V\ \angle -33.69°}\end{aligned}$$

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

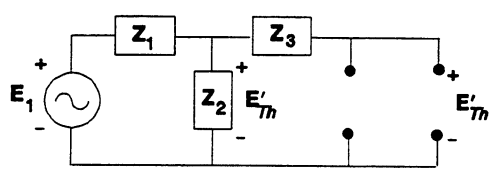



$\mathbf{Z}_1 = 10\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 8\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 8\ \Omega\ \angle -90°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 \\ &= -j8\ \Omega + 10\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90° \\ &= -j8\ \Omega + 6.247\ \Omega\ \angle 51.34° \\ &= -j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega \\ &= 3.902\ \Omega - j3.122\ \Omega \\ &= \mathbf{4.997\ \Omega\ \angle -38.663°}\end{aligned}$$

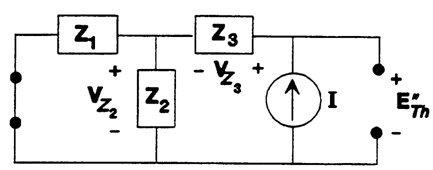
$\mathbf{E}_{Th}$: Superposition:

($\mathbf{E}_1$)




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

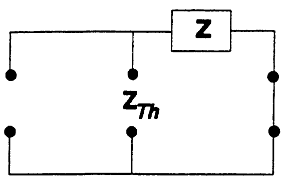
(I)




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

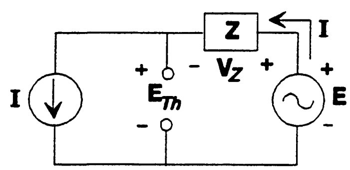
$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E}'_{Th} + \mathbf{E}''_{Th}\\ &= 74.965\text{ V }\angle 51.34° + 2.449\text{ V }\angle 21.337°\\ &= (46.83\text{ V} + j58.538\text{ V}) + (2.328\text{ V} + j0.909\text{ V})\\ &= 49.158\text{ V} + j59.447\text{ V} = \mathbf{77.139\ V\ \angle 50.412°}\end{aligned}$$

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



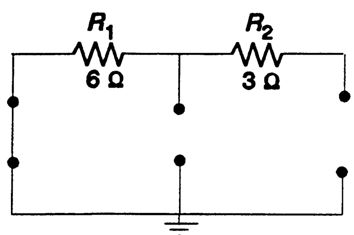

$$\mathbf{Z}_{Th} = \mathbf{Z} = 10\ \Omega - j10\ \Omega = 14.142\ \Omega\ \angle -45°$$

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



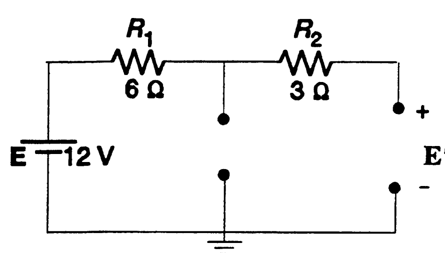

$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E} - \mathbf{V}_Z\\ &= 20\text{ V }\angle 40° - \mathbf{IZ}\\ &= 20\text{ V }\angle 40° - (0.6\text{ A }\angle 90°)(14.142\ \Omega\ \angle -45°)\\ &= 20\text{ V }\angle 40° - 8.485\text{ V }\angle 45°\\ &= (15.321\text{ V} + j12.856\text{ V}) - (6\text{ V} + j6\text{ V})\\ &= 9.321\text{ V} + j6.856\text{ V}\\ &= \mathbf{11.571\ V\ \angle 36.336°}\end{aligned}$$

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



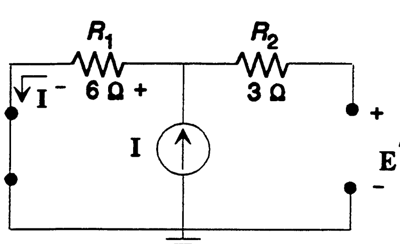

$$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_{R_1} + \mathbf{Z}_{R_2} = 6\ \Omega + 3\ \Omega = \mathbf{9\ \Omega}$$

DC:




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

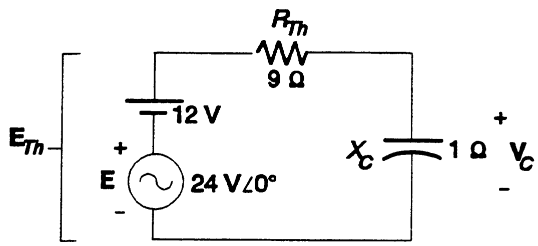
AC:




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

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

b.




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

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

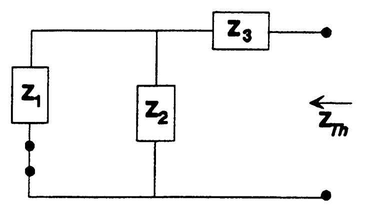
$= \dfrac{(1\ \Omega\ \angle -90°)(24\ \text{V}\ \angle 0°)}{-j1\ \Omega + 9\ \Omega}$

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

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

$v_C = 12\ \text{V} + 2.65\ \text{V}\ \angle -83.66°$
$\quad = \mathbf{12\ V + 3.747\ sin(\omega t - 83.66°)}$

18.

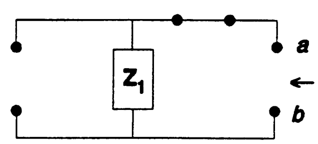



$\mathbf{Z}_1 = 10\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 10\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = 1\ \text{k}\Omega\ \angle -90°$

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

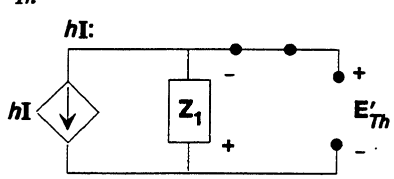
$\mathbf{E}_{Th}$: (VDR) $\qquad \mathbf{E}_{Th} = \dfrac{\mathbf{Z}_2(20\ \text{V})}{\mathbf{Z}_2 + \mathbf{Z}_1} = \dfrac{(10\ \text{k}\Omega\ \angle 0°)(20)\text{V}}{10\ \text{k}\Omega + 10\ \text{k}\Omega} = \mathbf{10\ V}$

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



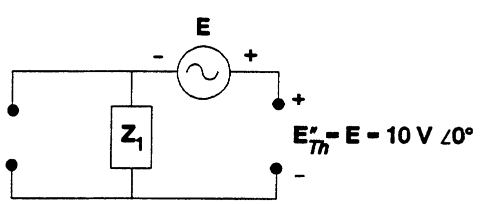

$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 = \mathbf{20\ k\Omega\ \angle 0°}$

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



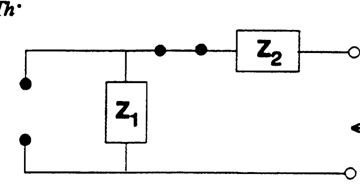

$\mathbf{E'}_{Th} = -(h\mathbf{I})(\mathbf{Z}_1)$
$\quad = -(100)(2\ \text{mA}\ \angle 0°)(20\ \text{k}\Omega\ \angle 0°)$
$\quad = -4\ \text{kV}\ \angle 0°$

E:




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

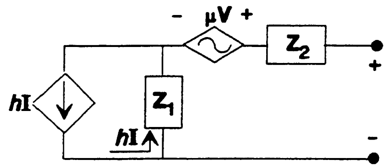
22. $\mathbf{Z}_{Th}$:




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

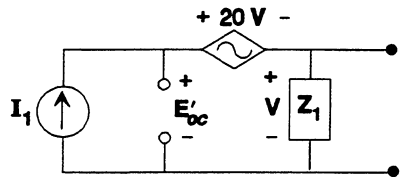
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\ k\Omega\ \angle 0°}$

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

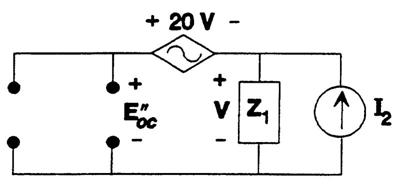



$$\begin{aligned}\mathbf{E}_{Th} &= \mu\mathbf{V} - (h\mathbf{I})(\mathbf{Z}_1)\\ &= (20)(10\text{ V}\angle 0°) - (100)(1\text{ mA}\angle 0°)(20\text{ k}\Omega\angle 0°)\\ &= \mathbf{-1800\text{ V}\angle 0°}\end{aligned}$$

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

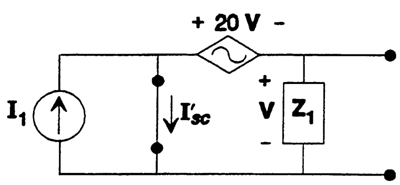



$$\begin{aligned}\mathbf{E}'_{oc} &= 21\text{ V} \qquad \mathbf{Z}_1 = 5\text{ k}\Omega\angle 0°\\ \mathbf{V} &= \mathbf{I}_1\mathbf{Z}_1 = (1\text{ mA}\angle 0°)(5\text{ k}\Omega\angle 0°)\\ &= 5\text{ V}\angle 0°\\ \mathbf{E}'_{oc} &= \mathbf{E}'_{Th} = 21(5\text{ V}\angle 0°)\\ &= 105\text{ V}\angle 0°\end{aligned}$$

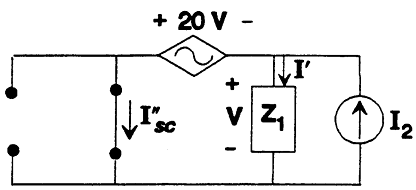



$$\begin{aligned}\mathbf{V} &= \mathbf{I}_2\mathbf{Z}_1\\ &= (2\text{ mA}\angle 0°)(5\text{ k}\Omega\angle 0°)\\ &= 10\text{ V}\angle 0°\\ \mathbf{E}''_{oc} &= \mathbf{E}''_{Th} = 21\text{ V} = 210\ V\angle 0°\end{aligned}$$

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




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

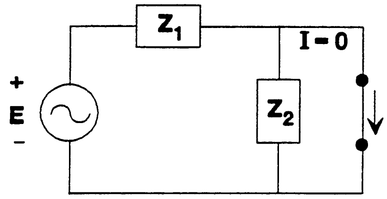



$$\begin{aligned}20\text{ V} = \mathbf{V} \therefore \mathbf{V} &= 0\text{ V}\\ \text{and } \mathbf{I}' &= 0\text{ A}\\ \therefore\ \mathbf{I}''_{sc} &= \mathbf{I}_2\end{aligned}$$

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

26. a. From Problem 12(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 1.92\ \Omega + j1.44\ \Omega = \mathbf{2.4\ \Omega\ \angle 36.87°}$

$\mathbf{I}_N$:

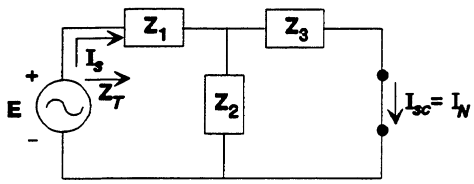



$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°,\ \mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{100\text{ V}\ \angle 0°}{3\ \Omega\ \angle 0°} = \mathbf{33.33\ A\ \angle 0°}$$

b. From Problem 12(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 5.263\text{ k}\Omega\ \angle 74.741° = \mathbf{1.385\ k\Omega + j6.923\ k\Omega}$

$\mathbf{I}_N$:




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

$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 2\text{ k}\Omega + 3\text{ k}\Omega\ \angle -90° \| 6\text{ k}\Omega\ \angle 90° \\ &= 2\text{ k}\Omega + 6\text{ k}\Omega\ \angle -90° \\ &= 2\text{ k}\Omega - j6\text{ k}\Omega \\ &= 6.325\text{ k}\Omega\ \angle -71.565°\end{aligned}$$

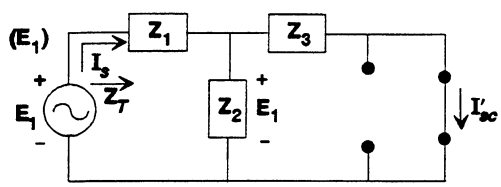
$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{20\text{ V}\ \angle 0°}{6.325\text{ k}\Omega\ \angle -71.565°} = 3.162\text{ mA}\ \angle 71.565°$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2\mathbf{I}_s}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(3\text{ k}\Omega\ \angle -90°)(3.162\text{mA}\ \angle 71.565°)}{-j3\text{ k}\Omega + j6\text{ k}\Omega}$$

$$= \frac{9.486\text{ mA}\ \angle -18.435°}{3\ \angle 90°} = \mathbf{3.162\ mA\ \angle -108.435°}$$

28. a. From Problem 14(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.997\ \Omega\ \angle -38.663°}$

$\mathbf{I}_N$: Superposition:




$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 10\ \Omega + 8\ \Omega\ \angle 90° \| 8\ \Omega\ \angle -90° \\ &= 10\ \Omega + \frac{64\ \Omega\ \angle 0°}{0} \\ &= \text{very large impedance}\end{aligned}$$

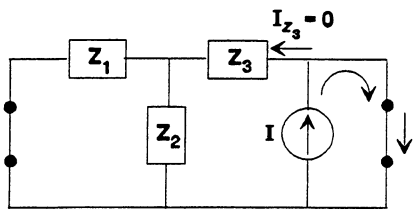
$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = 0\text{ A}$$

and $\mathbf{V}_{Z_1} = 0\text{ V}$

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

$$\text{so that } \mathbf{I}'_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_3} = \frac{120\text{ V}\ \angle 0°}{8\ \Omega\ \angle -90°} = 15\text{ A}\ \angle 90°$$

(I)

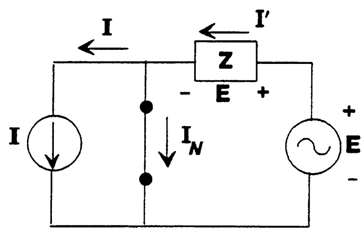



$\mathbf{I''}_{sc} = \mathbf{I} = 0.5 \text{ A } \angle 60°$

$$\mathbf{I}_N = \mathbf{I'}_{sc} + \mathbf{I''}_{sc} = +j15 \text{ A} + 0.5 \text{ A } \angle 60° = +j15 \text{ A} + 0.25 \text{ A} + j0.433 \text{ A}$$
$$= 0.25 \text{ A} + j15.433 \text{ A} = \mathbf{15.435 \text{ A } \angle 89.072°}$$

b. From Problem 14(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 10\ \Omega - j10\ \Omega = \mathbf{14.142\ \Omega \angle -45°}$

$\mathbf{I}_N$:

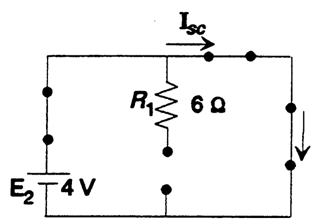



$$\mathbf{I}_N = \mathbf{I'} - \mathbf{I}$$
$$= \frac{\mathbf{E}}{\mathbf{Z}} - \mathbf{I}$$
$$= \frac{20 \text{ V } \angle 40°}{14.142\ \Omega \angle -45°} - 0.6 \text{ A } \angle 90°$$
$$= 1.414 \text{ A } \angle 85° - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j1.409 \text{ A} - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j0.809 \text{ A}$$
$$= \mathbf{0.818 \text{ A } \angle 81.355°}$$

30. a. Note Problem 15(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4\ \Omega \angle 90°}$

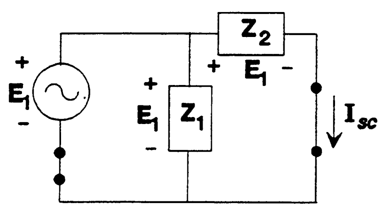
$\mathbf{I}_N$:

DC




$$\mathbf{I}_{sc} = \frac{E_2}{0\ \Omega} = \frac{4 \text{ V}}{0\ \Omega}$$

AC

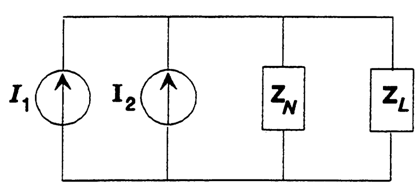



$\mathbf{Z}_1 = 6\ \Omega - j2\ \Omega$
$\mathbf{Z}_2 = 4\ \Omega \angle 90°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10 \text{ V } \angle 0°}{4\ \Omega \angle 90°} = 2.5 \text{ A } \angle -90°$$

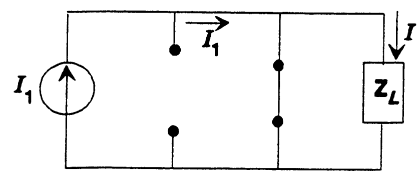
$$\mathbf{I}_N = \frac{4 \text{ V}}{0\ \Omega} + 2.5 \text{ A } \angle -90° \quad \left(\text{dc: } \mathbf{E}_{Th} = I_N Z_N = \frac{4 \text{ V}}{(0\ \Omega)}(0\ \Omega) = 4 \text{ V}\right)$$

b.




$\mathbf{Z}_N = 4\ \Omega \angle 90°$
$\mathbf{Z}_L = 8\ \Omega \angle 0°$

DC:




(CDR)

$$I = \frac{(0\ \Omega)I_1}{0\ \Omega + 8\ \Omega}$$

$$= \frac{(0\ \Omega)\left[\frac{4\ \text{V}}{0\ \Omega}\right]}{0\ \Omega + 8\ \Omega} = \frac{4\ \text{V}}{8\ \Omega} = 0.5\ \text{A}$$

as obtained in Problem 15

AC:

$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_2)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4\ \Omega\ \angle 90°)(2.5\ \text{A}\ \angle -90°)}{+j4\ \Omega + 8\ \Omega}$$

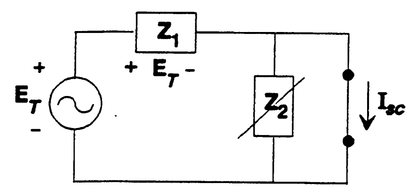
$$= \frac{10\ \text{V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°} = \mathbf{1.118\ A\ \angle -26.565°}$$ as obtained in Problem 15

$$I_{8\Omega} = \underset{\text{(dc)}}{0.5\ \text{A}} + \underset{\text{(ac)}}{1.118\ \text{A}\ \angle -26.565°}$$

32. a. Note Problem 17(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.472\ k\Omega\ \angle -26.565°}$

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

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




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

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

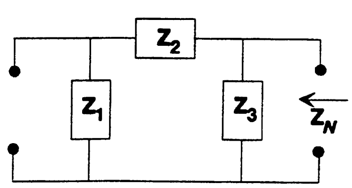
$\mathbf{I}_N = \mathbf{I}_{sc} = \mathbf{7\ mA\ \angle 0°}$

b.
$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_N)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4.472\ \text{k}\Omega\ \angle -26.565°)(7\ \text{mA}\ \angle 0°)}{4.472\ \text{k}\Omega\ \angle -26.565° + 5\ \text{k}\Omega\ \angle 90°}$$

$$= \frac{31.30\ \text{mA}\ \angle -26.565°}{4 - j2 + j5} = \frac{31.30\ \text{mA}\ \angle -26.565°}{4 + j3}$$

$$= \frac{31.30\ \text{mA}\ \angle -26.565°}{5\ \angle 36.87°} = 6.26\ \text{mA}\ \angle 63.435°$$ as obtained in Problem 17.

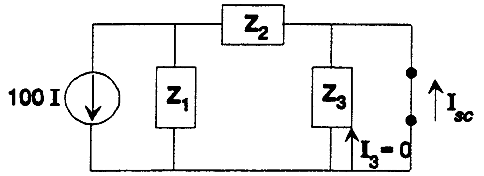
34. $\mathbf{Z}_N$:




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

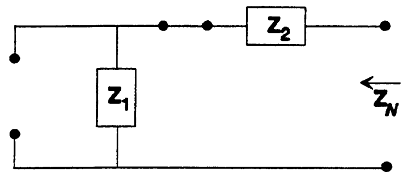
$$\mathbf{Z}_N = \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2)$$
$$= 5\ \text{k}\Omega\ \angle 0° \parallel (40\ \text{k}\Omega - j0.2\ \text{k}\Omega)$$
$$= \mathbf{4.44\ k\Omega\ \angle -0.031°}$$

$I_N$:




$$I_N = I_{sc} = \frac{Z_1(100\ I)}{Z_1 + Z_2} = \frac{(40\ k\Omega\ \angle 0°)(100\ I)}{40\ k\Omega\ \angle -0.286°} = \mathbf{100\ I\ \angle 0.286°}$$

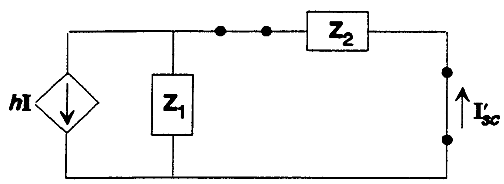
36. $Z_N$:




$Z_1 = 20\ k\Omega\ \angle 0°$, $Z_2 = 5\ k\Omega\ \angle 0°$
$V = 10\ V\ \angle 0°$, $\mu = 20$, $h = 100$
$I = 1\ mA\ \angle 0°$

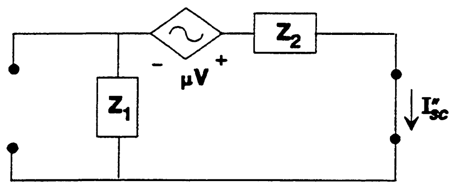
$$Z_N = Z_1 + Z_2 = \mathbf{25\ k\Omega\ \angle 0°}$$

$I_N$: ($h$I)




$$I'_{sc} = \frac{Z_1(hI)}{Z_1 + Z_2} = \frac{(20\ k\Omega\ \angle 0°)(hI)}{20\ k\Omega\ \angle 0° + 5\ k\Omega\ \angle 0°} = 80\ mA\ \angle 0°$$

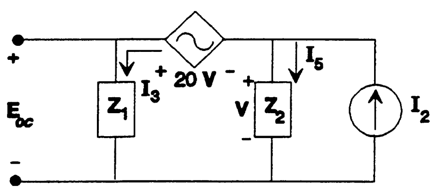
($\mu$V)




$$I''_{sc} = \frac{\mu V}{Z_1 + Z_2} = \frac{(20)(10\ V\ \angle 0°)}{25\ k\Omega} = 8\ mA\ \angle 0°$$

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

38.

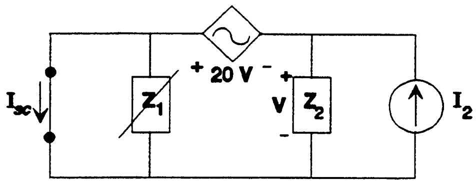



$Z_1 = 2\ k\Omega\ \angle 0°$
$Z_2 = 5\ k\Omega\ \angle 0°$

$$I_2 = I_3 + I_5$$
$$V = I_5 Z_2 = (I_2 - I_3)Z_2$$
$$E_{oc} = E_{Th} = 21\ V = 21(I_2 - I_3)Z_2$$
$$= 21\left(I_2 - \frac{E_{oc}}{Z_1}\right)Z_2$$
$$E_{oc}\left[1 + 21\frac{Z_2}{Z_1}\right] = 21\ Z_2 I_2$$

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

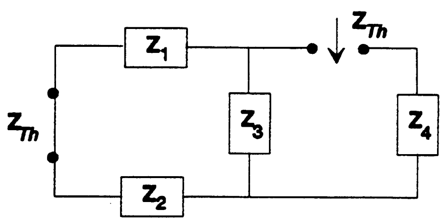
$$\mathbf{E}_{Th} = \mathbf{E}_{oc} = \mathbf{3.925\ V\ \angle 0°}$$




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

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{3.925\text{ V}\ \angle 0°}{2\text{ mA}\ \angle 0°} = \mathbf{1.9625\ k\Omega}$$

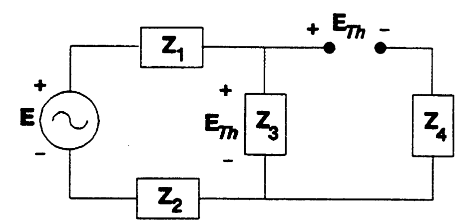
40. a. $\mathbf{Z}_{Th}$:




$\mathbf{Z}_1 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 10\ \Omega\ \angle 0°$
$\mathbf{Z}_3 = 5\ \Omega\ \angle -90°$, $\mathbf{Z}_4 = 6\ \Omega\ \angle -90°$
$\mathbf{E} = 60\text{ V}\ \angle 60°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_4 + \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2) = -j6\ \Omega + (5\ \Omega\ \angle -90°) \parallel (10\ \Omega + j4\ \Omega)\\ &= 2.475\ \Omega - j4.754\ \Omega\\ &= 11.035\ \Omega\ \angle -77.03°\\ \mathbf{Z}_L &= \mathbf{11.035\ \Omega\ \angle 77.03°}\end{aligned}$$

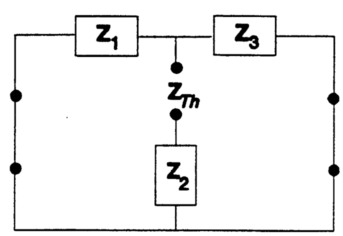
$\mathbf{E}_{Th}$:




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

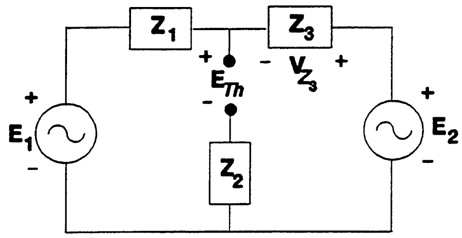
$$P_{\max} = E_{Th}^2/4R_{Th} = (29.85\text{ V})^2/4(2.475\ \Omega) = \mathbf{90\ W}$$

b.




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

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




$$\mathbf{E}_{Th} + \mathbf{V}_{Z_3} - \mathbf{E}_2 = 0$$
$$\mathbf{E}_{Th} = \mathbf{E}_2 - \mathbf{V}_{Z_3}$$
$$\mathbf{V}_{Z_3} = \frac{\mathbf{Z}_3(\mathbf{E}_2 - \mathbf{E}_1)}{\mathbf{Z}_3 + \mathbf{Z}_1} = 168.97\text{ V }\angle 112.53°$$

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

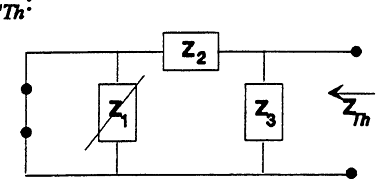
42. a. $\mathbf{Z}_{Th} = 4\ \Omega\ \angle 90°$ (Problem 15(a))
$\mathbf{Z}_L = \mathbf{4\text{ k}\Omega\ \angle -90°}$

b. Since load purely reactive $P_{max}$ undefined ($P_{max} = \dfrac{E_{Th}^2}{4R_{Th}}$, $R_{Th} = 0\ \Omega$)

44. a. Problem 17(a):
$\mathbf{Z}_{Th} = 4.472\text{ k}\Omega\ \angle -26.565° = 4\text{ k}\Omega - j2\text{ k}\Omega$
$\mathbf{Z}_L = \mathbf{4\text{ k}\Omega + j2\text{ k}\Omega}$
$\mathbf{E}_{Th} = \mathbf{31.31\text{ V }\angle -26.565°}$

b. $P_{max} = E_{Th}^2/4R_{Th} = (31.31\text{ V})^2/4(4\text{ k}\Omega) = \mathbf{61.27\text{ mW}}$

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



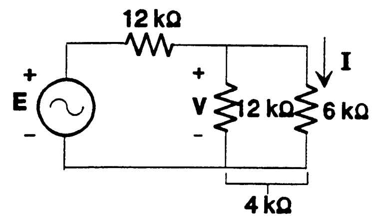

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(10\text{ kHz})(3.98\text{ nF})} \cong 4\text{ k}\Omega$$
$$X_L = 2\pi fL = 2\pi(10\text{ kHz})(31.8\text{ mH}) \cong 2\text{ k}\Omega$$
$\mathbf{Z}_1 = 1\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 2\text{ k}\Omega\ \angle 90°$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle -90°$

$$\mathbf{Z}_{Th} = \mathbf{Z}_2 \| \mathbf{Z}_3 = (2\text{ k}\Omega\ \angle 90°) \| (4\text{ k}\Omega\ \angle -90°) = \mathbf{4\text{ k}\Omega\ \angle 90°},\ \mathbf{Z}_L = \mathbf{4\text{ k}\Omega\ \angle -90°}$$
$$X_C = \frac{1}{2\pi fC} = 4\text{ k}\Omega,\ C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(10\text{ kHz})(4\text{ k}\Omega)} = \mathbf{3.97\text{ nF}}$$

b. $R_{Th} = 0\ \Omega\ \therefore\ R_L = 0\ \Omega$

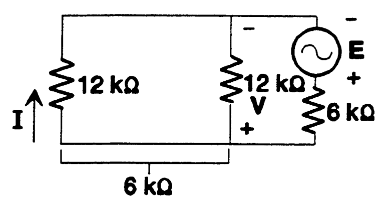
c. Undefined since $P_{max} = E_{Th}^2/4R_{Th}$ and $R_{Th} = 0\ \Omega$

48. a.




$$\mathbf{V} = \frac{4\ \text{k}\Omega(\mathbf{E})}{4\ \text{k}\Omega + 12\ \text{k}\Omega} = \frac{1}{4}(20\ \text{V} \angle 0°)$$
$$= 5\ \text{V} \angle 0°$$
$$\mathbf{I} = \frac{5\ \text{V} \angle 0°}{6\ \text{k}\Omega} = \mathbf{0.833\ mA} \angle \mathbf{0°}$$

b.




$$\mathbf{V} = \frac{6\ \text{k}\Omega(\mathbf{E})}{6\ \text{k}\Omega + 6\ \text{k}\Omega} = \frac{1}{2}(20\ \text{V} \angle 0°)$$
$$= 10\ \text{V} \angle 0°$$
$$\mathbf{I} = \frac{10\ \text{V} \angle 0°}{12\ \text{k}\Omega} = \mathbf{0.833\ mA} \angle \mathbf{0°}$$