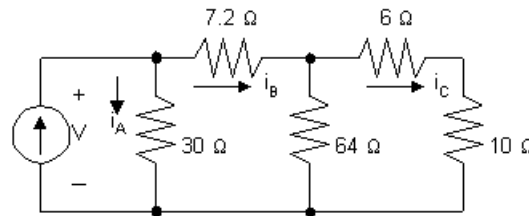


Some Circuit Simplification Techniques

Drill Exercises

DE 2.1



$$16 \parallel 64 = 12.8 \, \Omega, \quad 12.8 + 7.2 = 20 \, \Omega, \quad 20 \parallel 30 = 12 \, \Omega$$

$$[\mathbf{a}] \quad v = 5(12) = 60 \, \text{V}$$

$$[\mathbf{b}] \quad p_{5\text{A}(\text{del})} = (5)(60) = 300 \, \text{W}$$

$$[\mathbf{c}] \quad i_A = 60/30 = 2 \, \text{A} \quad i_C = 3(64)/(80) = 2.4 \, \text{A}$$

$$i_B = 5 - 2 = 3 \, \text{A} \quad p_{10\Omega} = (2.4)^2 10 = 57.6 \, \text{W}$$

$$\text{DE 2.2 } [\mathbf{a}] \quad v_o(\text{no load}) = 200(75)/100 = 150 \, \text{V}$$

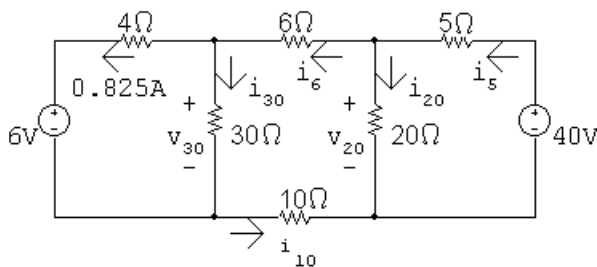
$$[\mathbf{b}] \quad 75 \parallel 150 = 50 \, \text{k}\Omega, \quad \text{therefore} \quad v_o = 200(50)/75 = 133.3 \, \text{V}$$

$$[\mathbf{c}] \quad i = 200/25,000 = 8 \, \text{mA}, \quad p_{25k} = (8 \times 10^{-3})^2 (25,000) = 1.6 \, \text{W}$$

$$[\mathbf{d}] \quad \text{Maximum dissipation at no load since } v_o \text{ is maximum}$$

$$p = \frac{v_o^2}{75,000} = 0.3 \, \text{W}$$

DE 2.3



$$v_{30} = 6 + 4(0.825) = 9.3 \text{ V}; \quad i_{30} = \frac{v_{30}}{30} = 0.31 \text{ A}$$

$$i_6 = i_{30} + 0.825 = 1.135 \text{ A}; \quad i_{10} = 0.825 + 0.31 = 1.135 \text{ A}$$

$$-v_{30} - 6i_6 + v_{20} - 10i_{10} = 0$$

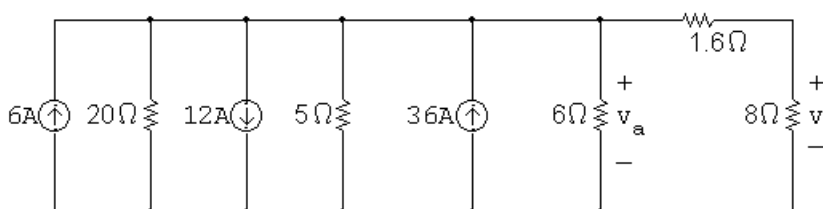
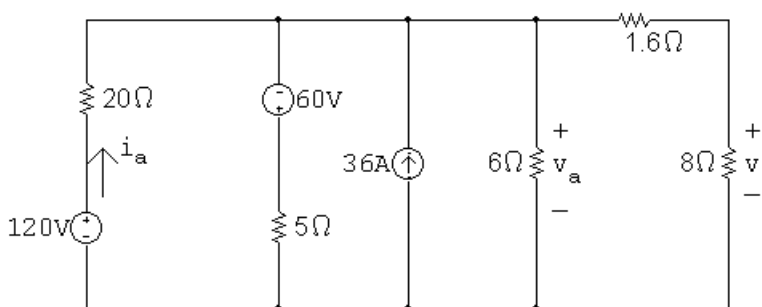
$$\therefore v_{20} = 9.3 + 16(1.135) = 27.46 \text{ V}$$

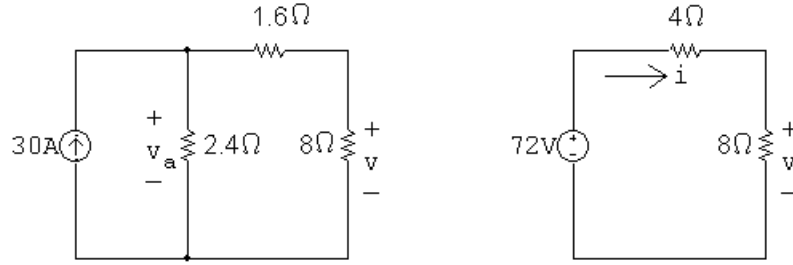
$$i_{20} = \frac{27.46}{20} = 1.373 \text{ A}; \quad i_5 = i_6 + i_{20} = 2.508 \text{ A}$$

$$i_{30} = 0.31 \text{ A}; \quad i_6 = 1.135 \text{ A}; \quad i_{10} = 1.135 \text{ A};$$

$$i_{20} = 1.373 \text{ A}; \quad \text{and} \quad i_5 = 2.508 \text{ A}$$

DE 2.4



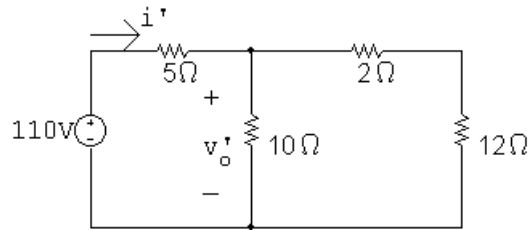


$$i = \frac{72}{12} = 6 \text{ A}$$

$$[\mathbf{a}] \quad v = \frac{72}{12}(8) = 48 \text{ V}, \quad i_{120\text{V}} = \frac{120 - 57.6}{20} = 3.12 \text{ A}$$

$$[\mathbf{b}] \quad v_a = 6(9.6) = 57.6 \text{ V}, \quad p_{120\text{V}}(\text{del}) = 120i_a = 374.40 \text{ W}$$

DE 2.5 [a] 110 V source acting alone:

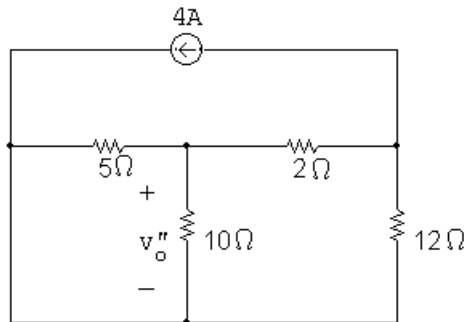


$$R_e = \frac{10(14)}{24} = \frac{35}{6} \Omega$$

$$i' = \frac{110}{5 + 35/6} = \frac{132}{13} \text{ A}$$

$$v_o' = \left(\frac{35}{6}\right) \left(\frac{132}{13}\right) = \frac{770}{13} \text{ V}$$

4 A source acting alone:

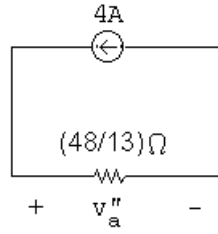


$$5 \Omega \parallel 10 \Omega = 50/15 = 10/3 \Omega$$

$$10/3 + 2 = 16/3 \Omega$$

$$16/3 \parallel 12 = 48/13 \Omega$$

Hence our circuit reduces to:



It follows that

$$v''_a = 4(48/13) = (192/13) \text{ V}$$

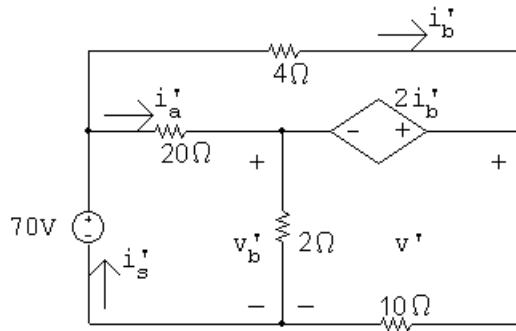
and

$$v''_o = \frac{-v''_a}{(16/3)}(10/3) = -\frac{5}{8}v''_a = -(120/13) \text{ V}$$

$$\therefore v_o = v'_o + v''_o = \frac{770}{13} - \frac{120}{13} = 50 \text{ V}$$

$$[\mathbf{b}] \quad p = \frac{v_o^2}{10} = 250 \text{ W}$$

DE 2.6 70-V source acting alone:



$$v' = 70 - 4i'_b$$

$$i'_s = \frac{v'_b}{2} + \frac{v'}{10} = i'_a + i'_b$$

$$70 = 20i'_a + v'_b$$

$$i'_a = \frac{70 - v'_b}{20}$$

$$\therefore i'_b = \frac{v'_b}{2} + \frac{v'}{10} - \frac{70 - v'_b}{20} = \frac{11}{20}v'_b + \frac{v'}{10} - 3.5$$

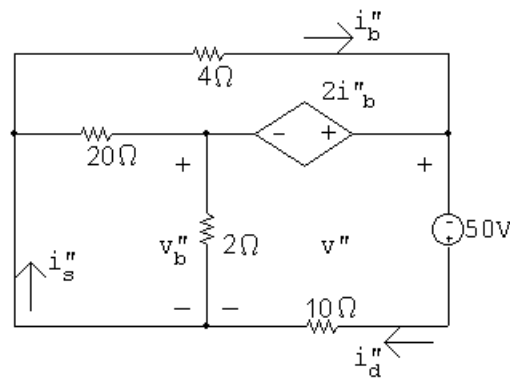
$$v' = v'_b + 2i'_b$$

$$\therefore v'_b = v' - 2i'_b$$

$$\therefore i'_b = \frac{11}{20}(v' - 2i'_b) + \frac{v'}{10} - 3.5 \quad \text{or} \quad i'_b = \frac{13}{42}v' - \frac{70}{42}$$

$$\therefore v' = 70 - 4\left(\frac{13}{42}v' - \frac{70}{42}\right) \quad \text{or} \quad v' = \frac{3220}{94} = \frac{1610}{47} \text{ V}$$

50-V source acting alone:



$$v'' = -4i''_b$$

$$v'' = v''_b + 2i''_b$$

$$v'' = -50 + 10i''_d$$

$$\therefore i''_d = \frac{v'' + 50}{10}$$

$$i''_s = \frac{v''_b}{2} + \frac{v'' + 50}{10}$$

$$i''_b = \frac{v''_b}{20} + i''_s = \frac{v''_b}{20} + \frac{v''_b}{2} + \frac{v'' + 50}{10} = \frac{11}{20}v''_b + \frac{v'' + 50}{10}$$

$$v''_b = v'' - 2i''_b$$

$$\therefore i''_b = \frac{11}{20}(v'' - 2i''_b) + \frac{v'' + 50}{10} \quad \text{or} \quad i''_b = \frac{13}{42}v'' + \frac{100}{42}$$

$$\text{Thus, } v'' = -4\left(\frac{13}{42}v'' + \frac{100}{42}\right) \quad \text{or} \quad v'' = -\frac{200}{47} \text{ V}$$

$$\text{Hence, } v = v' + v'' = \frac{1610}{47} - \frac{200}{47} = \frac{1410}{47} = 30 \text{ V}$$

Problems

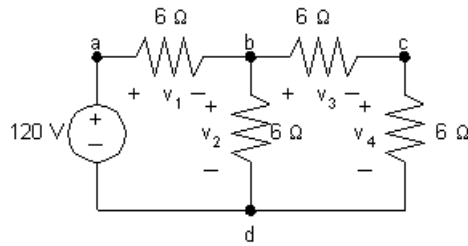
P 2.1 [a] $p_{4\Omega} = i_s^2 4 = (12)^2 4 = 576 \text{ W}$ $p_{18\Omega} = (4)^2 18 = 288 \text{ W}$

$p_{3\Omega} = (8)^2 3 = 192 \text{ W}$ $p_{6\Omega} = (8)^2 6 = 384 \text{ W}$

[b] $p_{120\text{V}}(\text{delivered}) = 120i_s = 120(12) = 1440 \text{ W}$

[c] $p_{\text{diss}} = 576 + 288 + 192 + 384 = 1440 \text{ W}$

P 2.2 [a] From Ex. 3-1: $i_1 = 4 \text{ A}$, $i_2 = 8 \text{ A}$, $i_s = 12 \text{ A}$
 at node x: $-12 + 4 + 8 = 0$, at node y: $12 - 4 - 8 = 0$



[b] $v_1 = 4i_s = 48 \text{ V}$ $v_3 = 3i_2 = 24 \text{ V}$

$v_2 = 18i_1 = 72 \text{ V}$ $v_4 = 6i_2 = 48 \text{ V}$

loop abda: $-120 + 48 + 72 = 0$,

loop bcd b: $-72 + 24 + 48 = 0$,

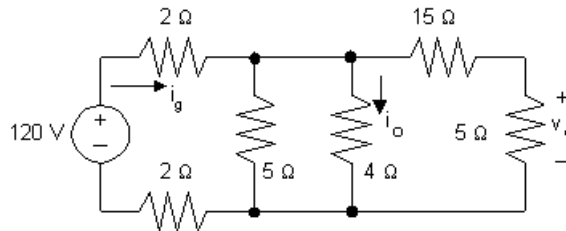
loop abcda: $-120 + 48 + 24 + 48 = 0$

P 2.3 $\frac{1}{R_{\text{eq}}} = \frac{1}{6} + \frac{1}{10} + \frac{1}{15} = \frac{10}{30} = \frac{1}{3}$; $R_{\text{eq}} = 3 \Omega$

$v_{(2+8+5)\Omega} = (20)(3) = 60 \text{ V}$, $i_{(2+8+5)\Omega} = 60/15 = 4 \text{ A}$

$P_{5\Omega} = (4)^2(5) = 80 \text{ W}$

P 2.4 [a]



$R_{\text{eq}} = 2 + 2 + (1/4 + 1/5 + 1/20)^{-1} = 6 \Omega$

$i_g = 120/6 = 20 \text{ A}$

$v_{4\Omega} = 120 - (2 + 2)20 = 40 \text{ V}$

$i_o = 40/4 = 10 \text{ A}$

$$i_{(15+5)\Omega} = 40/(15+5) = 2 \text{ A}$$

$$v_o = (5)(2) = 10 \text{ V}$$

[b] $i_{15\Omega} = 2 \text{ A}; \quad P_{15\Omega} = (2)^2(15) = 60 \text{ W}$

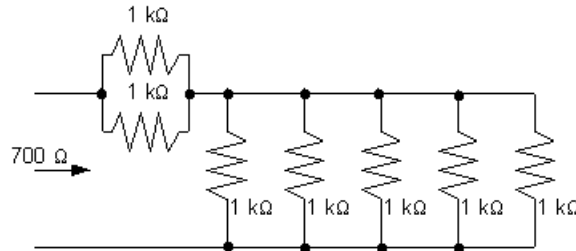
[c] $P_{120\text{V}} = (120)(20) = 2.4 \text{ kW}$

P 2.5 [a] $R_{\text{eq}} = R \parallel R = \frac{R^2}{2R} = \frac{R}{2}$

[b]
$$\begin{aligned} R_{\text{eq}} &= R \parallel R \parallel R \parallel \cdots \parallel R \quad (n \text{ } R\text{'s}) \\ &= R \parallel \frac{R}{n-1} \\ &= \frac{R^2/(n-1)}{R + R/(n-1)} = \frac{R^2}{nR} = \frac{R}{n} \end{aligned}$$

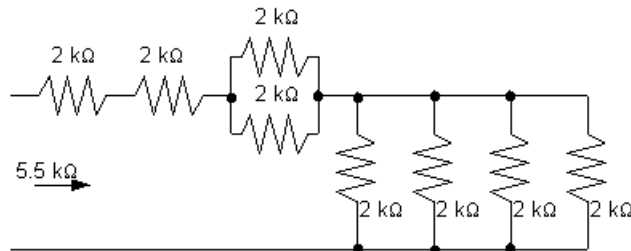
[c] One solution:

$$\begin{aligned} 700 \Omega &= 200 \Omega + 500 \Omega \\ &= 1000/5 + 1000/2 \\ &= 1 \text{ k}\Omega \parallel 1 \text{ k}\Omega \parallel 1 \text{ k}\Omega \parallel 1 \text{ k}\Omega \parallel 1 \text{ k}\Omega + 1 \text{ k}\Omega \parallel 1 \text{ k}\Omega \end{aligned}$$



[d] One solution:

$$\begin{aligned} 5.5 \text{ k}\Omega &= 5 \text{ k}\Omega + 0.5 \text{ k}\Omega \\ &= 2 \text{ k}\Omega + 2 \text{ k}\Omega + 1 \text{ k}\Omega + 0.5 \text{ k}\Omega \\ &= 2 \text{ k}\Omega + 2 \text{ k}\Omega + \frac{2 \text{ k}\Omega}{2} + \frac{2 \text{ k}\Omega}{4} \\ &= 2 \text{ k}\Omega + 2 \text{ k}\Omega + 2 \text{ k}\Omega \parallel 2 \text{ k}\Omega + 2 \text{ k}\Omega \parallel 2 \text{ k}\Omega \parallel 2 \text{ k}\Omega \end{aligned}$$



P 2.6 [a] $12\ \Omega \parallel 24\ \Omega = 8\ \Omega$ Therefore, $R_{ab} = 8 + 2 + 6 = 16\ \Omega$

$$[b] \frac{1}{R_{eq}} = \frac{1}{24\ \text{k}\Omega} + \frac{1}{30\ \text{k}\Omega} + \frac{1}{20\ \text{k}\Omega} = \frac{15}{120\ \text{k}\Omega} = \frac{1}{8\ \text{k}\Omega}$$

$$R_{eq} = 8\ \text{k}\Omega; \quad R_{eq} + 7 = 15\ \text{k}\Omega$$

$$\frac{1}{R_{ab}} = \frac{1}{15\ \text{k}\Omega} + \frac{1}{30\ \text{k}\Omega} + \frac{1}{15\ \text{k}\Omega} = \frac{5}{30\ \text{k}\Omega} = \frac{1}{6\ \text{k}\Omega}$$

$$R_{ab} = 6\ \text{k}\Omega$$

P 2.7 [a] For circuit (a)

$$R_{ab} = 15 \parallel (18 + 48 \parallel 16) = 10\ \Omega$$

For circuit (b)

$$\frac{1}{R_e} = \frac{1}{20} + \frac{1}{15} + \frac{1}{20} + \frac{1}{4} + \frac{1}{12} = \frac{30}{60} = \frac{1}{2}$$

$$R_e = 2\ \Omega$$

$$R_e + 16 = 18\ \Omega$$

$$18 \parallel 18 = 9\ \Omega$$

$$R_{ab} = 10 + 8 + 9 = 27\ \Omega$$

For circuit (c)

$$48 \parallel 16 = 12\ \Omega$$

$$12 + 8 = 20\ \Omega$$

$$20 \parallel 30 = 12\ \Omega$$

$$12 + 18 = 30\ \Omega$$

$$30 \parallel 15 = 10\ \Omega$$

$$10 + 10 + 20 = 40\ \Omega$$

$$R_{ab} = 40 \parallel 60 = 24\ \Omega$$

$$[b] P_a = \frac{20^2}{10} = 40\ \text{W}$$

$$P_b = \frac{144^2}{27} = 768\ \text{W}$$

$$P_c = 6^2(24) = 864\ \text{W}$$

P 2.8 [a] $5\parallel 20 = 100/25 = 4\ \Omega$ $5\parallel 20 + 9\parallel 18 + 10 = 20\ \Omega$
 $9\parallel 18 = 162/27 = 6\ \Omega$ $20\parallel 30 = 600/50 = 12\ \Omega$
 $R_{ab} = 5 + 12 + 3 = 20\ \Omega$

[b] $5 + 15 = 20\ \Omega$ $30\parallel 20 = 600/50 = 12\ \Omega$
 $20\parallel 60 = 1200/80 = 15\ \Omega$ $3\parallel 6 = 18/9 = 2\ \Omega$
 $15 + 10 = 25\ \Omega$ $3\parallel 6 + 30\parallel 20 = 2 + 12 = 14\ \Omega$
 $25\parallel 75 = 1875/100 = 18.75\ \Omega$ $26\parallel 14 = 364/40 = 9.1\ \Omega$
 $18.75 + 11.25 = 30\ \Omega$ $R_{ab} = 2.5 + 9.1 + 3.4 = 15\ \Omega$

[c] $3 + 5 = 8\ \Omega$ $60\parallel 40 = 2400/100 = 24\ \Omega$
 $8\parallel 12 = 96/20 = 4.8\ \Omega$ $24 + 6 = 30\ \Omega$
 $4.8 + 5.2 = 10\ \Omega$ $30\parallel 10 = 300/40 = 7.5\ \Omega$
 $45 + 15 = 60\ \Omega$ $R_{ab} = 1.5 + 7.5 + 1.0 = 10\ \Omega$

P 2.9 [a] $R_{\text{cond}} = 845(0.0397) = 33.5465\ \Omega$

$$R_{\text{total}} = 2(1/2)R_{\text{cond}} = 33.5465\ \Omega$$

$$P_{\text{loss}} = (2000)^2(33.5465) = 134.186\ \text{MW}$$

$$P_{\text{calif}} = 800(2) - 134.186 = 1465.814\ \text{MW}$$

$$\text{Efficiency} = (1465.814/1600) \times 100 = 91.61\%$$

[b] $P_{\text{calif}} = 2000 - 134.86 = 1865.814\ \text{MW}$

$$\text{Efficiency} = 93.29\%$$

[c] $P_{\text{loss}} = (3000)^2 \cdot 2 \cdot (1/3) \cdot 845 \cdot (0.0397) = 201.279\ \text{MW}$

$$P_{\text{oregon}} = 3000\ \text{MW}, \quad P_{\text{calif}} = 3000 - 201.279 = 2798.7\ \text{MW}$$

$$\text{Efficiency} = (2798.70/3000) \times 100 = 93.29\%$$

P 2.10 $i_{10k} = \frac{(18)(15)}{40} = 6.75\ \text{mA}$

$$v_{15k} = -(6.75)(15) = -101.25\ \text{V}$$

$$i_{3k} = 18 - 6.75 = 11.25\ \text{mA}$$

$$v_{12k} = -(12)(11.25) = -135\ \text{V}$$

$$v_o = -101.25 - (-135) = 33.75\ \text{V}$$

P 2.11 [a] $v_{1k} = \frac{1}{1+5}(30) = 5 \text{ V}$

$$v_{15k} = \frac{15}{15+60}(30) = 6 \text{ V}$$

$$v_x = v_{15k} - v_{1k} = 6 - 5 = 1 \text{ V}$$

[b] $v_{1k} = \frac{v_s}{6}(1) = v_s/6$

$$v_{15k} = \frac{v_s}{75}(15) = v_s/5$$

$$v_x = (v_s/5) - (v_s/6) = v_s/30$$

P 2.12 $60 \parallel 30 = 20 \Omega$

$$i_{30\Omega} = \frac{(25)(75)}{125} = 15 \text{ A}$$

$$v_o = (15)(20) = 300 \text{ V}$$

$$v_o + 30i_{30} = 750 \text{ V}$$

$$v_g - 12(25) = 750$$

$$v_g = 1050 \text{ V}$$

P 2.13 $5 \Omega \parallel 20 \Omega = 4 \Omega; \quad 4 \Omega + 6 \Omega = 10 \Omega; \quad 10 \parallel 40 = 8 \Omega;$

Therefore, $i_g = \frac{125}{8+2} = 12.5 \text{ A}$

$$i_{6\Omega} = \frac{(40)(12.5)}{50} = 10 \text{ A}; \quad i_o = \frac{(5)(10)}{25} = 2 \text{ A}$$

P 2.14 [a] $40 \parallel 10 = 8 \Omega \quad i_{75V} = \frac{75}{10} = 7.5 \text{ A}$

$$8 + 7 = 15 \Omega \quad i_{4+3\Omega} = 7.5 \left(\frac{30}{45} \right) = 5 \text{ A}$$

$$15 \parallel 30 = 10 \Omega \quad i_o = -5 \left(\frac{10}{50} \right) = -1 \text{ A}$$

[b] $i_{10\Omega} = i_{4+3\Omega} + i_o = 5 - 1 = 4 \text{ A}$

$$P_{10\Omega} = (4)^2(10) = 160 \text{ W}$$

P 2.15 [a] $v_{9\Omega} = (1)(9) = 9 \text{ V}$

$$i_{2\Omega} = 9/(2 + 1) = 3 \text{ A}$$

$$i_{4\Omega} = 1 + 3 = 4 \text{ A};$$

$$v_{25\Omega} = (4)(4) + 9 = 25 \text{ V}$$

$$i_{25\Omega} = 25/25 = 1 \text{ A};$$

$$i_{3\Omega} = i_{25\Omega} + i_{9\Omega} + i_{2\Omega} = 1 + 1 + 3 = 5 \text{ A};$$

$$v_{40\Omega} = v_{25\Omega} - v_{3\Omega} = 25 - (-5)(3) = 40 \text{ V}$$

$$i_{40\Omega} = 40/40 = 1 \text{ A}$$

$$i_{5\parallel 20\Omega} = i_{40\Omega} + i_{25\Omega} + i_{4\Omega} = 1 + 1 + 4 = 6 \text{ A}$$

$$v_{5\parallel 20\Omega} = (4)(6) = 24 \text{ V}$$

$$v_{32\Omega} = v_{40\Omega} + v_{5\parallel 20\Omega} = 40 + 24 = 64 \text{ V}$$

$$i_{32\Omega} = 64/32 = 2 \text{ A};$$

$$i_{10\Omega} = i_{32\Omega} + i_{5\parallel 20\Omega} = 2 + 6 = 8 \text{ A}$$

$$v_g = 10(8) + v_{32\Omega} = 80 + 64 = 144 \text{ V}.$$

[b] $P_{20\Omega} = \frac{(v_{5\parallel 20\Omega})^2}{20} = \frac{24^2}{20} = 28.8 \text{ W}$

P 2.16 [a] Let i_s be the current oriented down through the resistors. Then,

$$i_s = \frac{V_s}{R_1 + R_2 + \cdots + R_k + \cdots + R_n}$$

and

$$v_k = R_k i_s = \frac{R_k}{R_1 + R_2 + \cdots + R_k + \cdots + R_n} V_s$$

[b] $i_s = \frac{200}{5 + 15 + 30 + 10 + 40} = 2 \text{ A}$

$$v_1 = 2(5) = 10 \text{ V}$$

$$v_2 = 2(15) = 30 \text{ V}$$

$$v_3 = 2(30) = 60 \text{ V}$$

$$v_4 = 2(10) = 20 \text{ V}$$

$$v_5 = 2(40) = 80 \text{ V}$$

P 2.17 [a] $v_o = \frac{25}{25}(20) = 20 \text{ V}$

[b] $v_o = \frac{25}{5 + R_e} R_e$

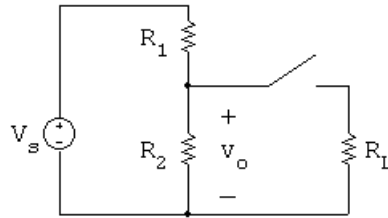
$$R_e = \frac{(20)(12)}{32} = 7.5 \text{ k}\Omega$$

$$v_o = \frac{25}{12.5}(7.5) = 15 \text{ V}$$

[c] $\frac{v_o}{25} = \frac{20}{25} = 0.80$

[d] $\frac{v_o}{25} = \frac{15}{25} = 0.60$

P 2.18 [a]



No load:

$$v_o = \frac{R_2}{R_1 + R_2} V_s = \sigma V_s$$

$$\therefore \sigma = \frac{R_2}{R_1 + R_2}$$

Load:

$$v_o = \frac{R_e}{R_1 + R_e} V_s = \beta V_s$$

$$\therefore \beta = \frac{R_e}{R_e + R_1} \quad R_e = \frac{R_2 R_L}{R_2 + R_L}$$

$$\therefore \beta = \frac{R_2 R_L}{R_1 R_2 + R_L (R_1 + R_2)}$$

$$\text{But } R_1 + R_2 = \frac{R_2}{\sigma} \quad \therefore R_1 = \frac{R_2}{\sigma} - R_2$$

$$\therefore \beta = \frac{R_2 R_L}{R_2 \left(\frac{R_2}{\sigma} - R_2 \right) + \frac{R_L R_2}{\sigma}}$$

$$\beta = \frac{R_L}{R_2 \left(\frac{1}{\sigma} - 1 \right) + \frac{R_L}{\sigma}}$$

or

$$\beta R_2 \left(\frac{1}{\sigma} - 1 \right) + \frac{\beta R_L}{\sigma} = R_L$$

$$\beta R_2 \left(\frac{1}{\sigma} - 1 \right) = R_L \left(1 - \frac{\beta}{\sigma} \right)$$

$$\therefore R_2 = \frac{(\sigma - \beta)}{\beta(1 - \sigma)} R_L$$

$$R_1 = \frac{(1 - \sigma)}{\sigma} R_2 = \left(\frac{\sigma - \beta}{\sigma \beta} \right) R_L$$

$$[\mathbf{b}] \quad R_1 = \frac{(0.9 - 0.7)}{0.63} (126) \text{ k}\Omega = 40 \text{ k}\Omega$$

$$R_2 = \frac{(0.9 - 0.7)}{(0.7)(0.1)} (126) \text{ k}\Omega = 360 \text{ k}\Omega$$

P 2.19 **[a]** Let v_o be the voltage across the parallel branches, positive at the upper terminal, then

$$i_g = v_o G_1 + v_o G_2 + \cdots + v_o G_N = v_o (G_1 + G_2 + \cdots + G_N)$$

$$\text{It follows that} \quad v_o = \frac{i_g}{(G_1 + G_2 + \cdots + G_N)}$$

The current in the k^{th} branch is $i_k = v_o G_k$; Thus,

$$i_k = \frac{i_g G_k}{[G_1 + G_2 + \cdots + G_N]}$$

$$[\mathbf{b}] \quad i_{6.25} = \frac{1142(0.16)}{[4 + 0.4 + 1 + 0.16 + 0.1 + 0.05]} = 32 \text{ mA}$$

$$\text{P 2.20} \quad R_e = \frac{4}{8} \times 10^3 = 500 \Omega$$

$$\therefore \sum G = \frac{1}{500} = 2 \text{ mS}$$

$$i_1 = 2i_2 = 2(10i_3) = 20i_4$$

$$i_2 = 10i_3 = 10i_4$$

$$i_3 = i_4$$

$$8 = 20i_4 + 10i_4 + i_4 + i_4 = 32i_4$$

$$\therefore i_4 = \frac{8}{32} = 0.25 \text{ mA}$$

$$R_4 = \frac{v_g}{i_4} = \frac{4}{0.25 \times 10^{-3}} = 16 \text{ k}\Omega$$

$$i_3 = i_4 = 0.25 \text{ mA}$$

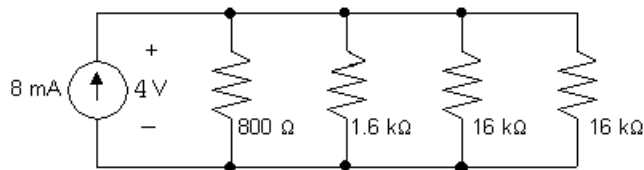
$$\therefore R_3 = 16 \text{ k}\Omega$$

$$i_2 = 10i_4 = 2.5 \text{ mA}$$

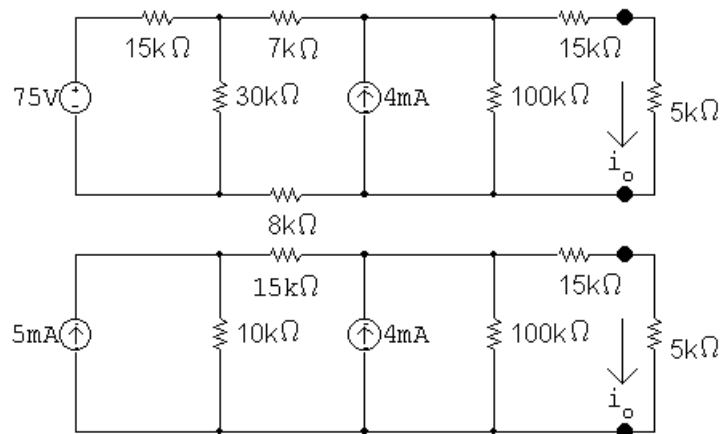
$$R_2 = \frac{v_g}{i_2} = \frac{4}{2.5 \times 10^{-3}} = 1.6 \text{ k}\Omega$$

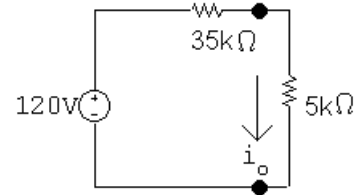
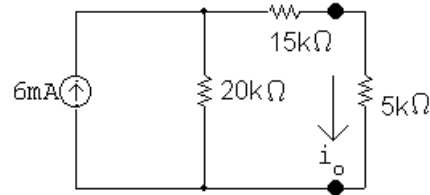
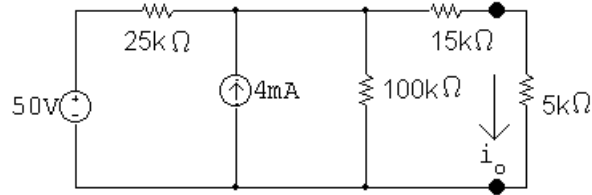
$$i_1 = 20i_4 = 5 \text{ mA}$$

$$R_1 = \frac{v_g}{i_1} = \frac{4}{5 \times 10^{-3}} = 800 \Omega$$



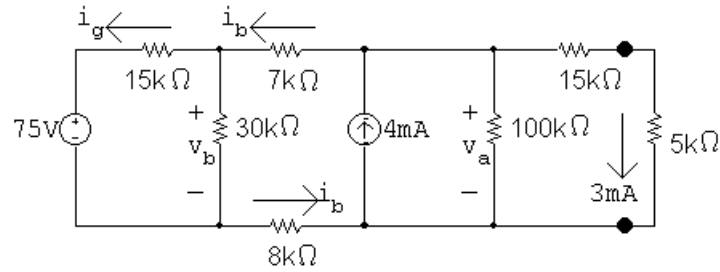
P 2.21 [a]





$$i_o = 120/40 \text{ k}\Omega = 3 \text{ mA}$$

[b]



$$v_a = (3)(20) = 60 \text{ V}$$

$$i_a = \frac{v_a}{100} = 0.6 \text{ mA}$$

$$i_b = 4 - 3.6 = 0.4 \text{ mA}$$

$$v_b = 60 - (0.4)(15) = 54 \text{ V}$$

$$i_g = 0.4 - 54/30 = -1.4 \text{ mA}$$

$$p_{75V} \text{ (developed)} = (75)(1.4) = 105 \text{ mW}$$

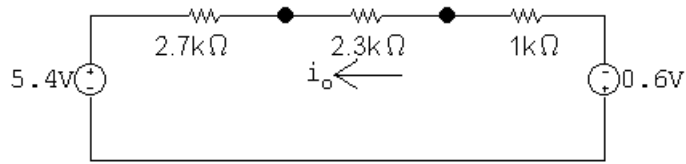
Check:

$$p_{4mA} \text{ (developed)} = (60)(4) = 240 \text{ mW}$$

$$\sum P_{\text{dev}} = 105 + 240 = 345 \text{ mW}$$

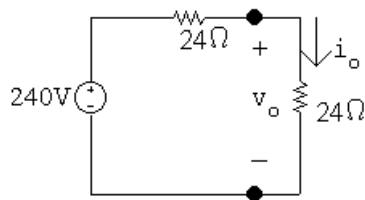
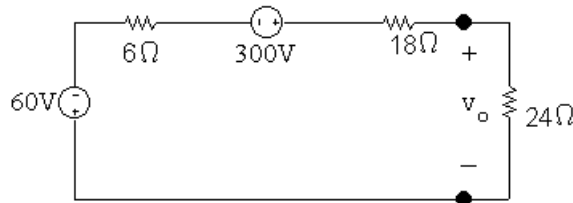
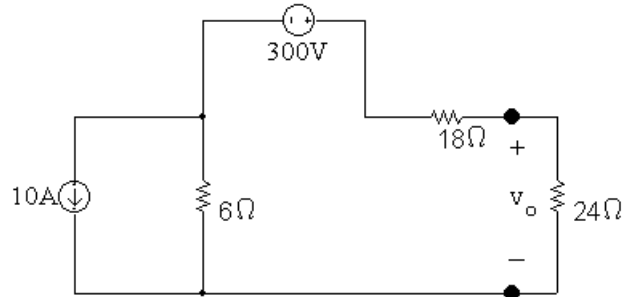
$$\begin{aligned} \sum P_{\text{dis}} &= (-1.4)^2(15) + (1.8)^2(30) + (0.4)^2(15) + (0.6)^2(100) + \\ &\quad (3)^2(20) \\ &= 345 \text{ mW} \end{aligned}$$

P 2.22 Apply source transformations to both current sources to get



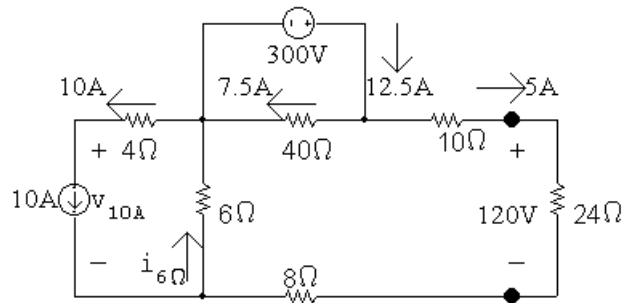
$$i_o = \frac{-6}{6} = -1 \text{ mA}$$

P 2.23 [a]



$$\therefore v_o = \frac{1}{2}(240) = 120 \text{ V}; \quad i_o = 120/24 = 5 \text{ A}$$

[b]



$$p_{300\text{V}} = -12.5(300) = -3750 \text{ W}$$

Therefore, the 300 V source is developing 3.75 kW.

$$[c] -10 + i_{6\Omega} + 7.5 - 12.5 = 0; \quad \therefore i_{6\Omega} = 15 \text{ A}$$

$$v_{10A} + 4(10) + 6(15) = 0; \quad \therefore v_{10A} = -130 \text{ V}$$

$$p_{10A} = 10v_{10A} = -1300 \text{ W}$$

Therefore the 10 A source is developing 1300 W.

$$[d] \sum p_{\text{dev}} = 3750 + 1300 = 5050 \text{ W}$$

$$p_{4\Omega} = 100(4) = 400 \text{ W}$$

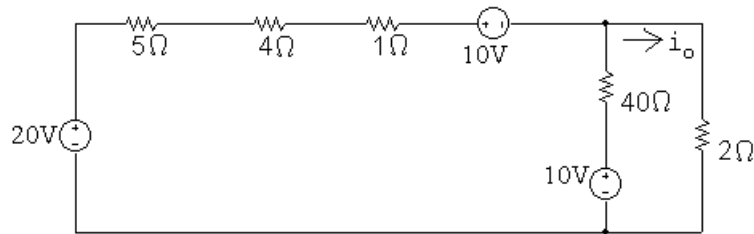
$$p_{40\Omega} = (7.5)^2(40) = 2250 \text{ W}$$

$$p_{6\Omega} = (15)^2(6) = 1350 \text{ W}$$

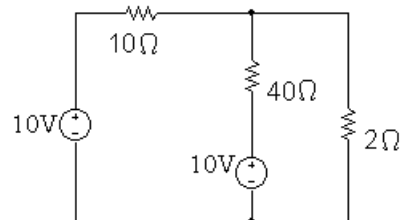
$$p_{42\Omega} = (5)^2(42) = 1050 \text{ W}$$

$$\sum p_{\text{diss}} = 400 + 1350 + 2250 + 1050 = 5050 \text{ W (CHECKS)}$$

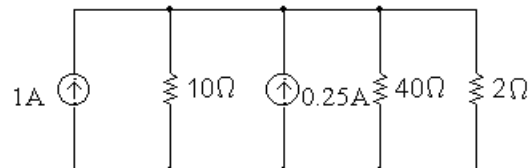
P 2.24 Applying a source transformation to each current source yields



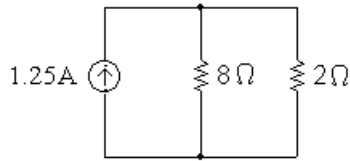
Now combine the 20 V and 10 V sources into a single voltage source and the 5 Ω, 4 Ω and 1 Ω resistors into a single resistor to get



Now use a source transformation on each voltage source, thus

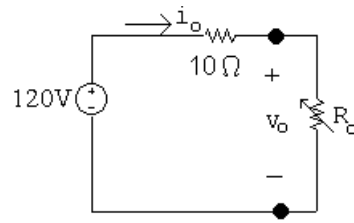
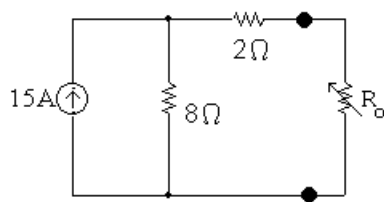
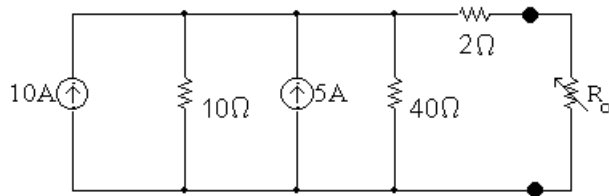


which can be reduced to



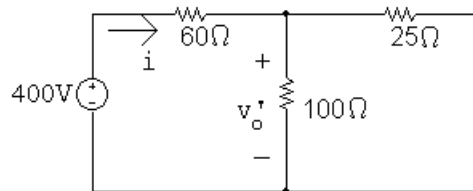
$$\therefore i_o = \frac{(1.25)(8)}{10} = 1 \text{ A}$$

P 2.25 First, find the Thévenin equivalent with respect to R_o .



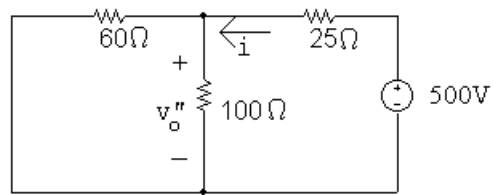
R_o	i_o	v_o	R_o	i_o	v_o
0	12	0	20	4	80
2	10	20	30	3	90
6	7.5	45	40	2.4	96
10	6	60	50	2	100
15	4.8	72	70	1.5	105

P 2.26



$$100 \Omega \parallel 25 \Omega = 20 \Omega \quad \therefore i = \frac{400}{60 + 20} = 5 \text{ A}$$

$$v'_o = 20i = 100 \text{ V}$$



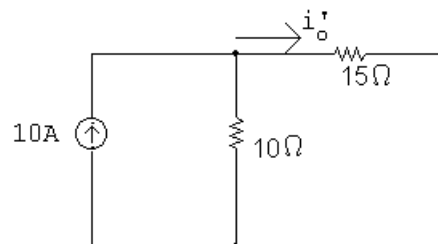
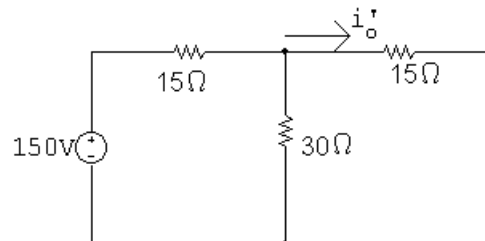
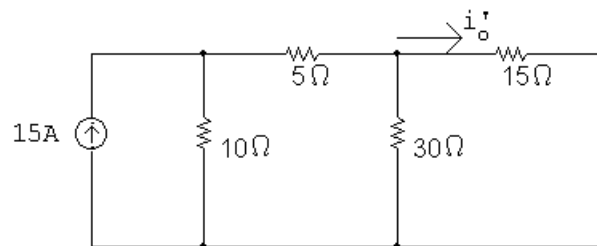
$$100\Omega \parallel 60\Omega = 37.5\Omega$$

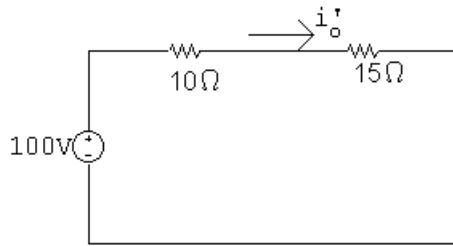
$$i = \frac{500}{25 + 37.5} = 8 \text{ A}$$

$$v''_o = 37.5i = 300 \text{ V}$$

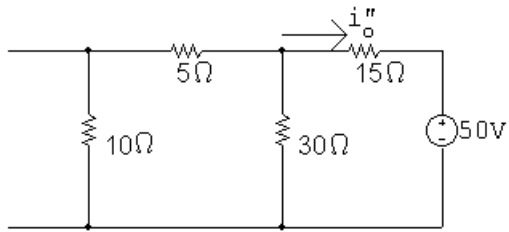
$$v_o = v'_o + v''_o = 100 + 300 = 400 \text{ V}$$

P 2.27

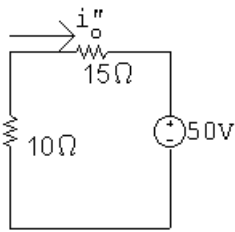




$$i'_o = \frac{100}{25} = 4 \text{ A}$$



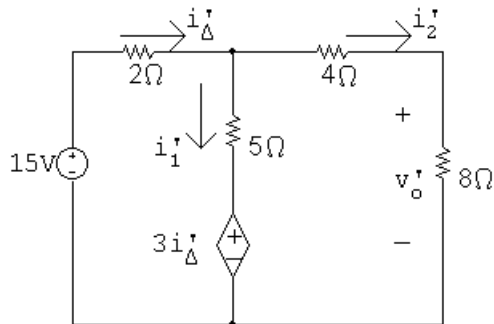
$$15\Omega \parallel 30\Omega = 10\Omega$$



$$i''_o = \frac{-50}{25} = -2 \text{ A}$$

$$\therefore i_o = i'_o + i''_o = 4 - 2 = 2 \text{ A}$$

P 2.28

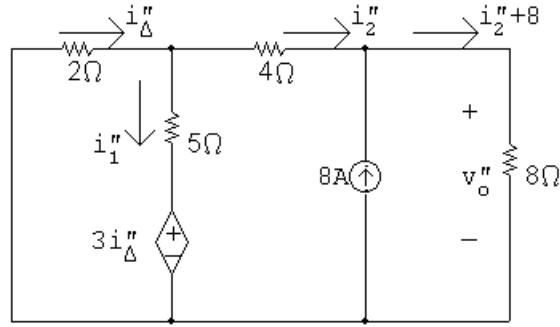


$$15 = 2i'_\Delta + 5i'_1 + 3i'_\Delta$$

$$15 = 2i'_{\Delta} + 12i'_2$$

$$i'_{\Delta} = i'_1 + i'_2, \quad i'_1 = 27/26 \text{ A}; \quad i'_{\Delta} = 51/26 \text{ A}$$

$$\therefore i'_2 = \frac{12}{13} \text{ A}; \quad v'_o = \frac{96}{13} \text{ V}$$



$$-2i''_{\Delta} = 5i''_1 + 3i''_{\Delta} \quad \therefore i''_{\Delta} = -i''_1$$

$$i''_2 = i''_{\Delta} - i''_1 = 2i''_{\Delta}$$

$$4i''_2 + (8 + i''_2)8 = -2i''_{\Delta}$$

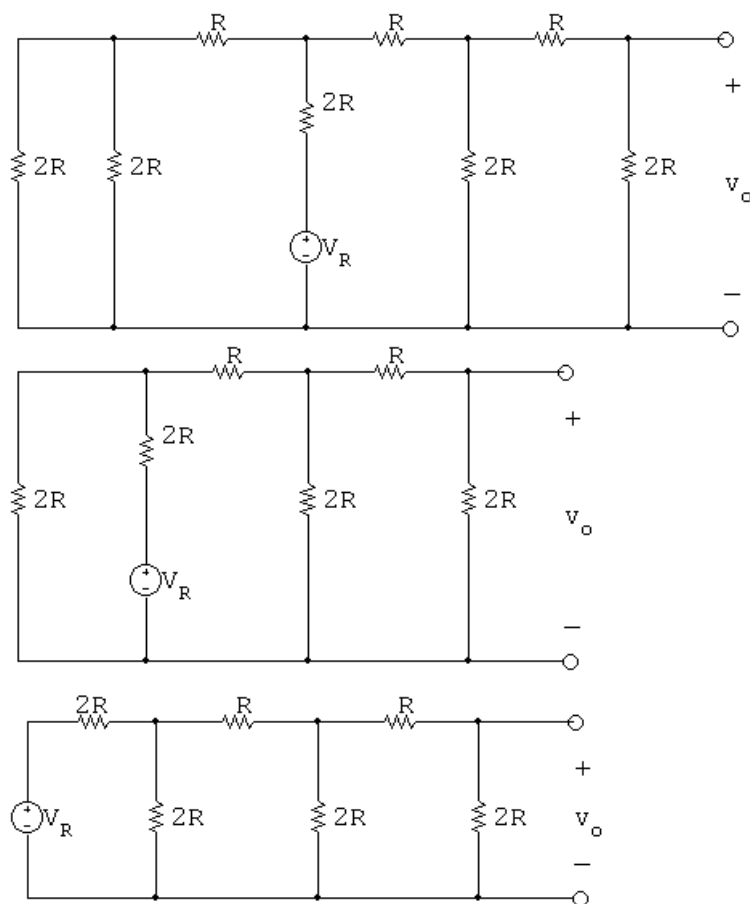
$$\therefore i''_2 = -\frac{64}{13} \text{ A}; \quad i''_1 = \frac{32}{13} \text{ A}; \quad i''_{\Delta} = -\frac{32}{13} \text{ A}$$

$$\therefore 8 + i''_2 = \frac{40}{13} \text{ A}$$

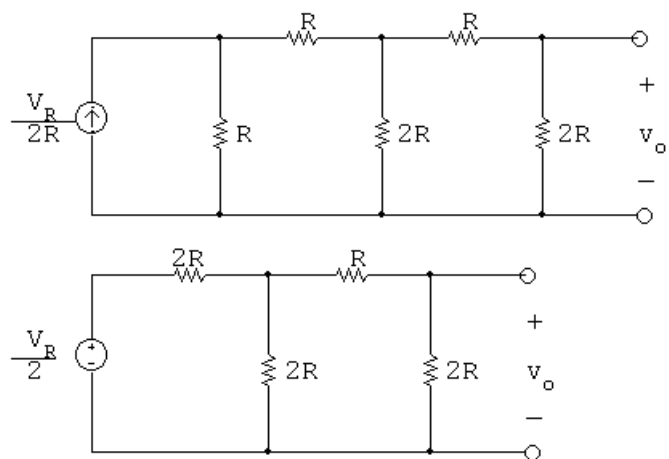
$$\therefore v''_o = 8 \left(\frac{40}{13} \right) = \frac{320}{13} \text{ V}$$

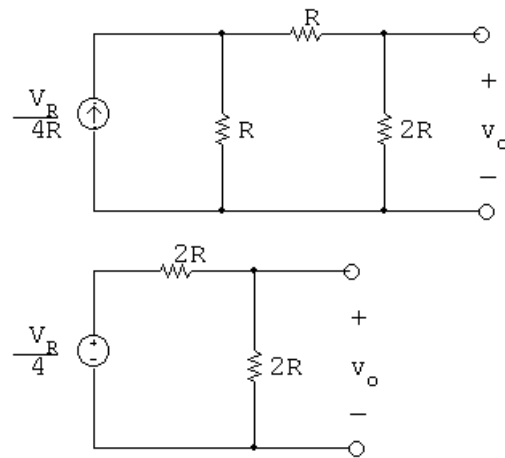
$$\therefore v_o = v'_o + v''_o = \frac{96}{13} + \frac{320}{13} = 32 \text{ V}$$

P 2.29 [a] The evolution of the circuit shown in Fig. P2.29 is illustrated in the following steps:



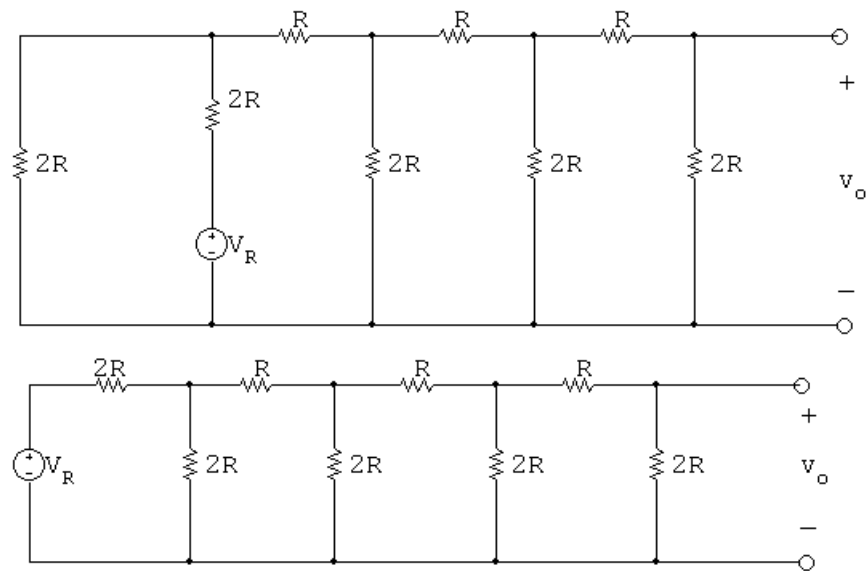
[b] Starting at the left end of the circuit and working toward the right end, a series of source transformations yields:



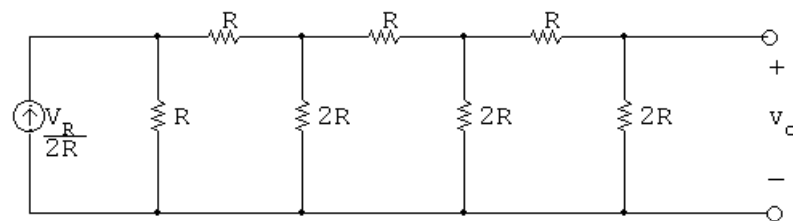


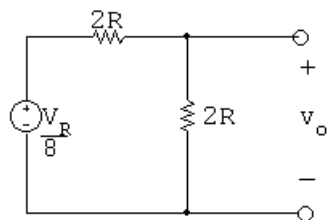
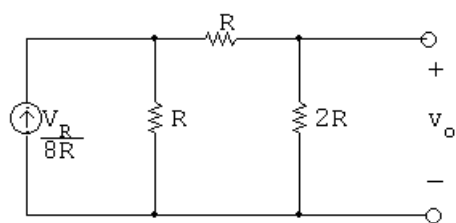
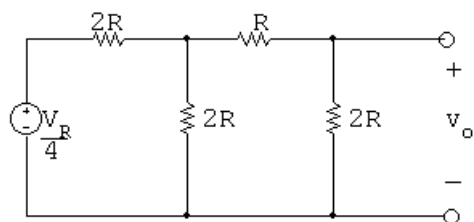
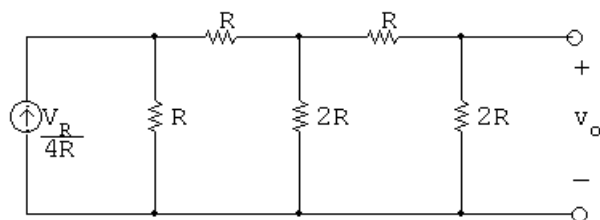
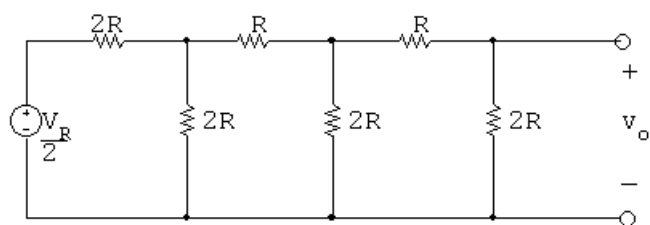
$$\frac{V_R/4}{4R}(2R) = \frac{V_R}{8}$$

P 2.30 [a] The evolution of the circuit in Fig. P2.30 can be shown in two steps, thus:



[b] Moving from left to right, a series of source transformations yields:





$$v_o = \frac{V_R/8}{4R}(2R) = \frac{V_R}{16}$$

P 2.31

$$\text{Eq. (2.34)} \quad v_o = \frac{1}{2}V_R \quad (\text{Switch 1})$$

$$\text{Eq. (2.35)} \quad v_o = \frac{1}{4}V_R \quad (\text{Switch 2})$$

$$\text{Eq. (2.36)} \quad v_o = \frac{1}{8}V_R \quad (\text{Switch 3})$$

$$\text{Eq. (2.37)} \quad v_o = \frac{1}{16}V_R \quad (\text{Switch 4})$$

Given $V_R = 16$ V:

Switch Position				v_o
1	2	3	4	
0	0	0	0	$v_o = 0$ V
0	0	0	V_R	$v_o = \frac{1}{16}V_R = 1$ V
0	0	V_R	0	$v_o = \frac{1}{8}V_R = 2$ V
0	0	V_R	V_R	$v_o = \frac{1}{16}V_R + \frac{1}{8}V_R = 3$ V
0	V_R	0	0	$v_o = \frac{1}{4}V_R = 4$ V
0	V_R	0	V_R	$v_o = \frac{1}{4}V_R + \frac{1}{16}V_R = 5$ V
0	V_R	V_R	0	$v_o = \frac{1}{4}V_R + \frac{1}{8}V_R = 6$ V
0	V_R	V_R	V_R	$v_o = \frac{1}{4}V_R + \frac{1}{8}V_R + \frac{1}{16}V_R = 7$ V
V_R	0	0	0	$v_o = \frac{1}{2}V_R = 8$ V
V_R	0	0	V_R	$v_o = \frac{1}{2}V_R + \frac{1}{16}V_R = 9$ V
V_R	0	V_R	0	$v_o = \frac{1}{2}V_R + \frac{1}{8}V_R = 10$ V
V_R	0	V_R	V_R	$v_o = \frac{1}{2}V_R + \frac{1}{8}V_R + \frac{1}{16}V_R = 11$ V
V_R	V_R	0	0	$v_o = \frac{1}{2}V_R + \frac{1}{4}V_R = 12$ V
V_R	V_R	0	V_R	$v_o = \frac{1}{2}V_R + \frac{1}{4}V_R + \frac{1}{16}V_R = 13$ V
V_R	V_R	V_R	0	$v_o = \frac{1}{2}V_R + \frac{1}{4}V_R + \frac{1}{8}V_R = 14$ V
V_R	V_R	V_R	V_R	$v_o = \frac{1}{2}V_R + \frac{1}{4}V_R + \frac{1}{8}V_R + \frac{1}{16}V_R = 15$ V

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