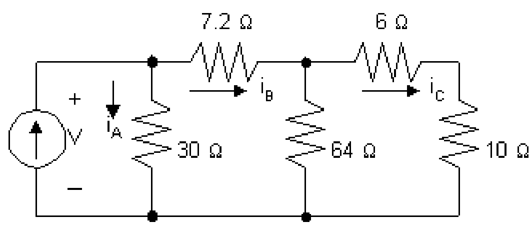
2

Some Circuit Simplification Techniques

Drill Exercises

DE 2.1



$16\|64 = 12.8\,\Omega, \qquad 12.8 + 7.2 = 20\,\Omega, \qquad 20\|30 = 12\,\Omega$

[a] $v = 5(12) = 60$ V

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

[c]
$$i_\text{A} = 60/30 = 2 \text{ A} \qquad i_\text{C} = 3(64)/(80) = 2.4 \text{ A}$$
$$i_\text{B} = 5 - 2 = 3 \text{ A} \qquad p_{10\Omega} = (2.4)^2 10 = 57.6 \text{ W}$$

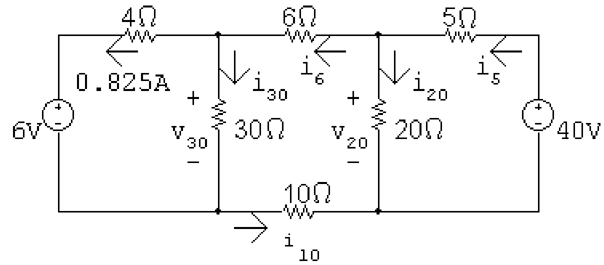
DE 2.2 **[a]** $v_o(\text{no load}) = 200(75)/100 = 150$ V

[b] $75\|150 = 50$ kΩ, therefore $v_o = 200(50)/75 = 133.3$ V

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

[d] Maximum dissipation at no load since v_o is maximum
$$p = \frac{v_o^2}{75{,}000} = 0.3 \text{ W}$$

DE 2.3



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

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

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

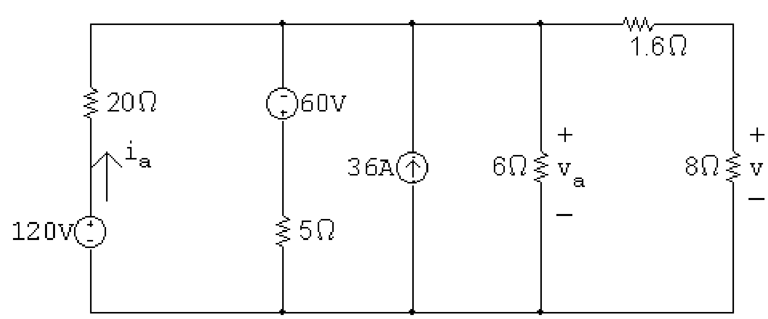
$$\therefore \quad v_{20} = 9.3 + 16(1.135) = 27.46 \text{ V}$$

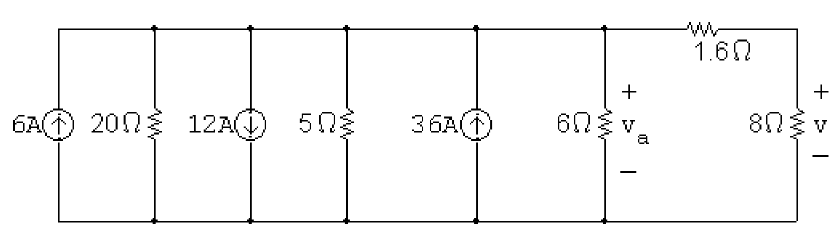
$$i_{20} = \frac{27.46}{20} = 1.373 \text{ A}; \qquad i_5 = i_6 + i_{20} = 2.508 \text{ A}$$

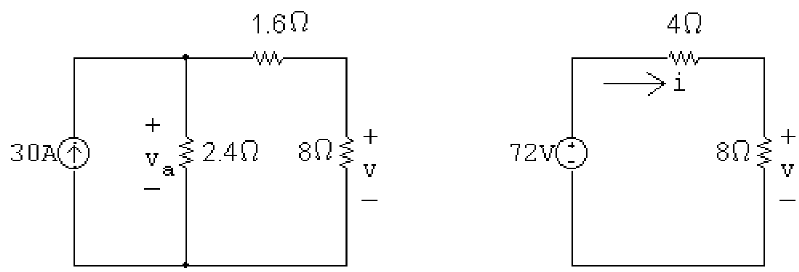
$$i_{30} = 0.31 \text{ A}; \qquad i_6 = 1.135 \text{ A}; \qquad i_{10} = 1.135 \text{ A};$$

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

DE 2.4





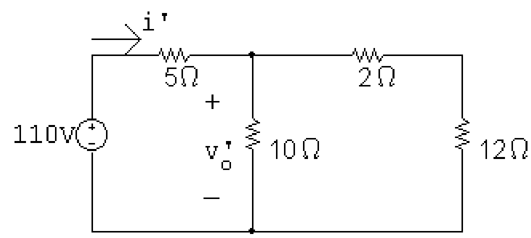


$$i = \frac{72}{12} = 6 \text{ A}$$

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

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

2.3 DE 2.5 [a] 110 V source acting alone:

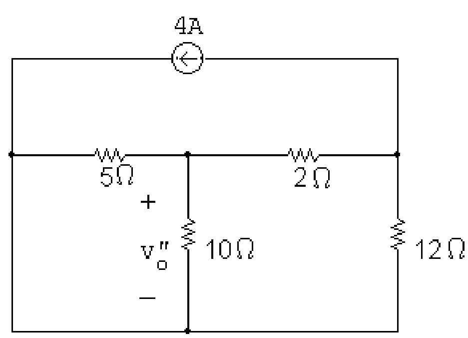


$$R_e = \frac{10(14)}{24} = \frac{35}{6}\,\Omega$$

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

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

4 A source acting alone:

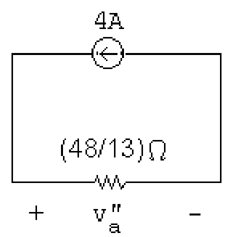


$$5\,\Omega \| 10\,\Omega = 50/15 = 10/3\,\Omega$$

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

$16/3\|12 = 48/13\,\Omega$

Hence our circuit reduces to:



It follows that

$v_a'' = 4(48/13) = (192/13)$ V

and

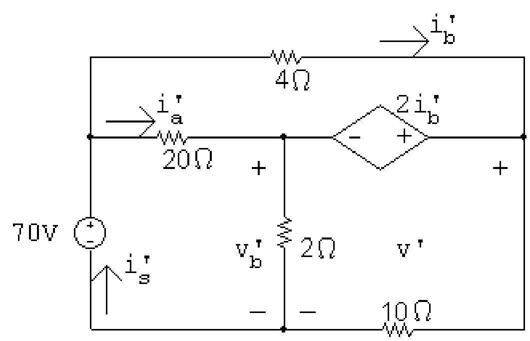
$$v_o'' = \frac{-v_a''}{(16/3)}(10/3) = -\frac{5}{8}v_a'' = -(120/13) \text{ V}$$

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

[b] $p = \dfrac{v_o^2}{10} = 250$ W

DE 2.6 70-V source acting alone:

2.4



$v' = 70 - 4i_b'$

$$i_s' = \frac{v_b'}{2} + \frac{v'}{10} = i_a' + i_b'$$

$70 = 20i_a' + v_b'$

$$i_a' = \frac{70 - v_b'}{20}$$

$$\therefore \quad i_b' = \frac{v_b'}{2} + \frac{v'}{10} - \frac{70 - v_b'}{20} = \frac{11}{20}v_b' + \frac{v'}{10} - 3.5$$

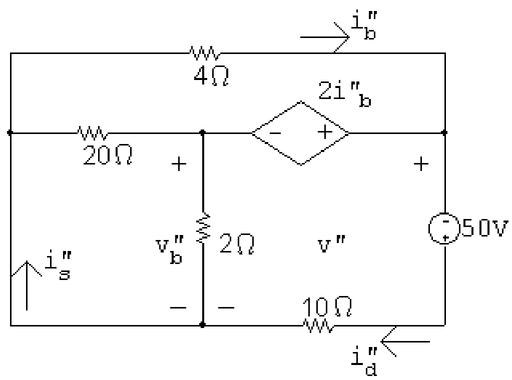
$$v' = v_b' + 2i_b'$$

$$\therefore \quad v_b' = v' - 2i_b'$$

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

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

50-V source acting alone:



$$v'' = -4i_b''$$

$$v'' = v_b'' + 2i_b''$$

$$v'' = -50 + 10i_d''$$

$$\therefore \quad i_d'' = \frac{v'' + 50}{10}$$

$$i_s'' = \frac{v_b''}{2} + \frac{v'' + 50}{10}$$

$$i_b'' = \frac{v_b''}{20} + i_s'' = \frac{v_b''}{20} + \frac{v_b''}{2} + \frac{v'' + 50}{10} = \frac{11}{20}v_b'' + \frac{v'' + 50}{10}$$

$$v_b'' = v'' - 2i_b''$$

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

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

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

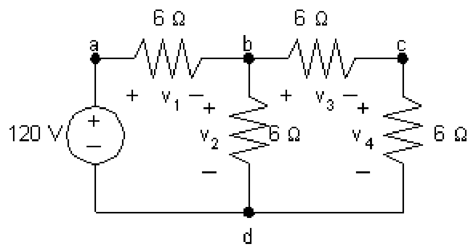
Problems

P 2.1 **[a]**
$$p_{4\Omega} = i_s^2 4 = (12)^2 4 = 576 \text{ W} \qquad p_{18\Omega} = (4)^2 18 = 288 \text{ W}$$
$$p_{3\Omega} = (8)^2 3 = 192 \text{ W} \qquad p_{6\Omega} = (8)^2 6 = 384 \text{ W}$$

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

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

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



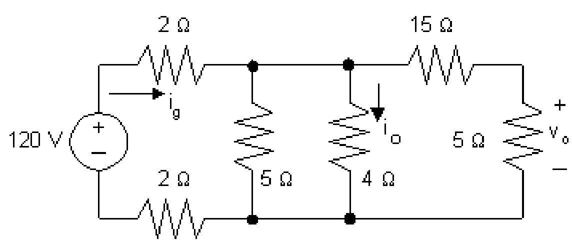
[b]
$$v_1 = 4i_s = 48 \text{ V} \qquad v_3 = 3i_2 = 24 \text{ V}$$
$$v_2 = 18i_1 = 72 \text{ V} \qquad v_4 = 6i_2 = 48 \text{ V}$$
loop abda: $-120 + 48 + 72 = 0$,
loop bcdb: $-72 + 24 + 48 = 0$,
loop abcda: $-120 + 48 + 24 + 48 = 0$

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

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

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

P 2.4 **[a]**



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

$i_g = 120/6 = 20$ A

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

$i_o = 40/4 = 10$ A

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

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

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

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

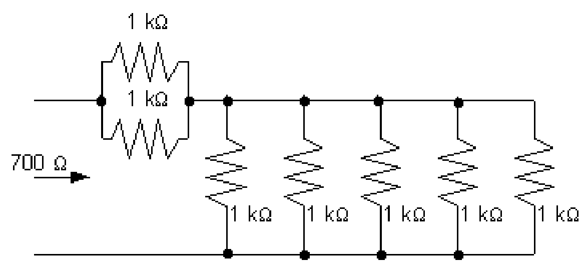
P 2.5 **[a]** $R_{\text{eq}} = R\|R = \dfrac{R^2}{2R} = \dfrac{R}{2}$

[b]

$$\begin{aligned} R_{\text{eq}} &= R\|R\|R\|\cdots\|R \qquad (n\ R\text{'s}) \\ &= R\|\frac{R}{n-1} \\ &= \frac{R^2/(n-1)}{R+R/(n-1)} = \frac{R^2}{nR} = \frac{R}{n} \end{aligned}$$

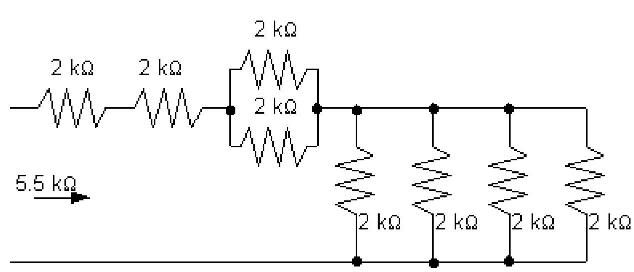
[c] One solution:

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



[d] One solution:

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



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

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

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

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

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

P 2.7 **[a]** For circuit (a)

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

For circuit (b)

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

$$R_e = 2\,\Omega$$

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

$$18\|18 = 9\,\Omega$$

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

For circuit (c)

$$48\|16 = 12\,\Omega$$

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

$$20\|30 = 12\,\Omega$$

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

$$30\|15 = 10\,\Omega$$

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

$$R_{\rm ab} = 40\|60 = 24\,\Omega$$

[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]** $5\|20 = 100/25 = 4\,\Omega$

$9\|18 = 162/27 = 6\,\Omega$

$R_{\rm ab} = 5 + 12 + 3 = 20\,\Omega$

$5\|20 + 9\|18 + 10 = 20\,\Omega$

$20\|30 = 600/50 = 12\,\Omega$

[b] $5 + 15 = 20\,\Omega$

$20\|60 = 1200/80 = 15\,\Omega$

$15 + 10 = 25\,\Omega$

$25\|75 = 1875/100 = 18.75\,\Omega$

$18.75 + 11.25 = 30\,\Omega$

$30\|20 = 600/50 = 12\,\Omega$

$3\|6 = 18/9 = 2\,\Omega$

$3\|6 + 30\|20 = 2 + 12 = 14\,\Omega$

$26\|14 = 364/40 = 9.1\,\Omega$

$R_{\rm ab} = 2.5 + 9.1 + 3.4 = 15\,\Omega$

[c] $3 + 5 = 8\,\Omega$

$8\|12 = 96/20 = 4.8\,\Omega$

$4.8 + 5.2 = 10\,\Omega$

$45 + 15 = 60\,\Omega$

$60\|40 = 2400/100 = 24\,\Omega$

$24 + 6 = 30\,\Omega$

$30\|10 = 300/40 = 7.5\,\Omega$

$R_{\rm ab} = 1.5 + 7.5 + 1.0 = 10\,\Omega$

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

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

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

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

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

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

Efficiency $= 93.29\%$

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

$P_{\rm oregon} = 3000$ MW, $\qquad P_{\rm calif} = 3000 - 201.279 = 2798.7$ MW

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

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

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

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

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

$v_o = -101.25 - (-135) = 33.75$ V

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

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

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

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

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

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

P 2.12 $60\|30 = 20\,\Omega$

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

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

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

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

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

P 2.13 $5\,\Omega\|20\,\Omega = 4\,\Omega; \qquad 4\,\Omega + 6\,\Omega = 10\,\Omega; \qquad 10\|40 = 8\,\Omega;$

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

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

P 2.14 **[a]** $40\|10 = 8\,\Omega \qquad i_{75\text{V}} = \dfrac{75}{10} = 7.5 \text{ A}$

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

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

[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]** $v_{9\Omega} = (1)(9) = 9$ V

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

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

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

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

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

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

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

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

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

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

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

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

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

[b] $P_{20\Omega} = \dfrac{(v_{5\|20\Omega})^2}{20} = \dfrac{24^2}{20} = 28.8$ 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] $i_s = \dfrac{200}{5 + 15 + 30 + 10 + 40} = 2$ A

$v_1 = 2(5) = 10$ V

$v_2 = 2(15) = 30$ V

$v_3 = 2(30) = 60$ V

$v_4 = 2(10) = 20$ V

$v_5 = 2(40) = 80$ V

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

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

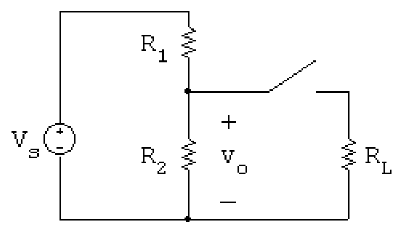
$$R_e = \frac{(20)(12)}{32} = 7.5\ \text{k}\Omega$$

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

[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:

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

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

Load:

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

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

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

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

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

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

or

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

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

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

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

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

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

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

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

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

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

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

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

P 2.20 $R_e = \dfrac{4}{8} \times 10^3 = 500\,\Omega$

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

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

$$i_2 = 10i_3 = 10i_4$$

$$i_3 = i_4$$

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

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

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

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

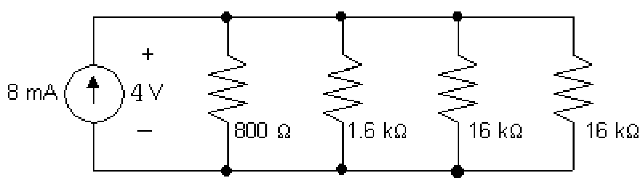
$$\therefore \quad R_3 = 16 \text{ k}\Omega$$

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

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

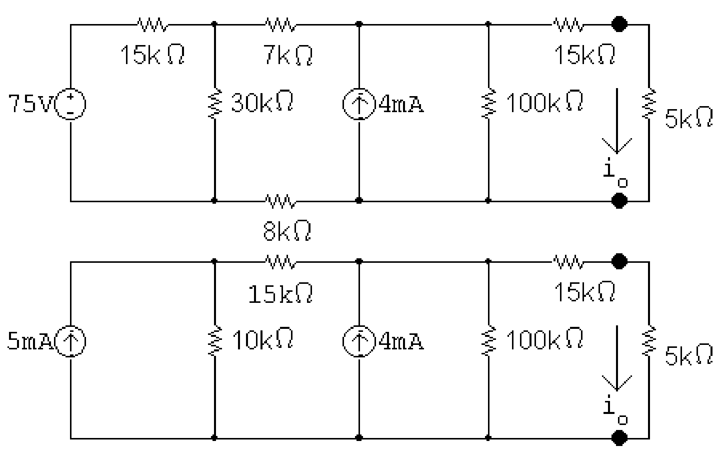
$$i_1 = 20i_4 = 5 \text{ mA}$$

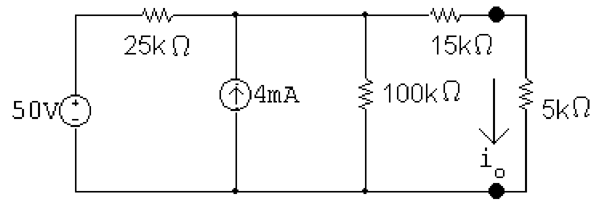
$$R_1 = \frac{v_g}{i_1} = \frac{4}{5 \times 10^{-3}} = 800\,\Omega$$

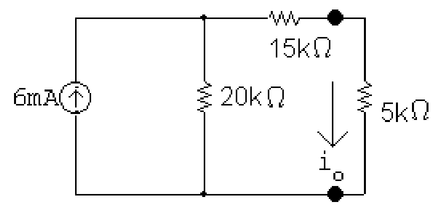


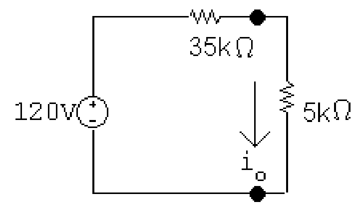
2.1

P 2.21 [a]



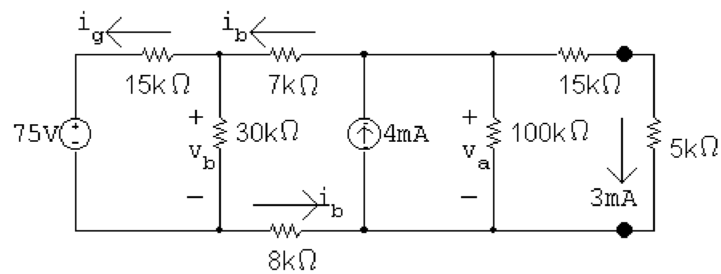






$i_o = 120/40\ \text{k}\Omega = 3\ \text{mA}$

[b]



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

$i_\text{a} = \dfrac{v_\text{a}}{100} = 0.6\ \text{mA}$

$i_\text{b} = 4 - 3.6 = 0.4\ \text{mA}$

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

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

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

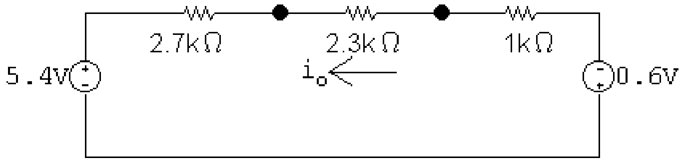
Check:

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

$$\begin{aligned}
\sum P_\text{dev} &= 105 + 240 = 345\ \text{mW} \\
\sum P_\text{dis} &= (-1.4)^2(15) + (1.8)^2(30) + (0.4)^2(15) + (0.6)^2(100) + \\
&\quad (3)^2(20) \\
&= 345\ \text{mW}
\end{aligned}$$

P 2.2

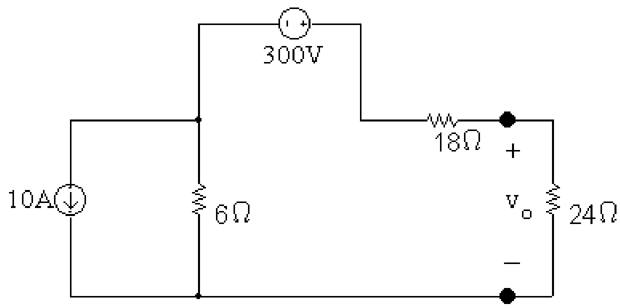
P 2.22 Apply source transformations to both current sources to get

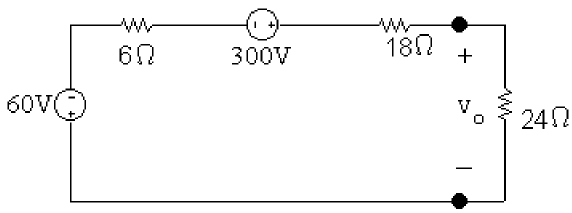


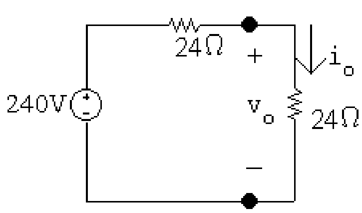
$$i_o = \frac{-6}{6} = -1 \text{ mA}$$

P 2.3

P 2.23 **[a]**

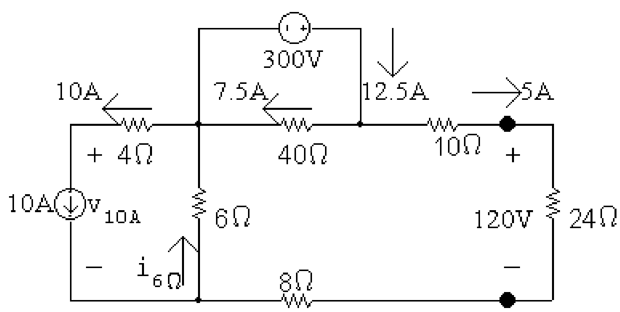






$$\therefore \quad v_o = \frac{1}{2}(240) = 120 \text{ V}; \qquad i_o = 120/24 = 5 \text{ A}$$

[b]



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

Therefore, the 300 V source is developing 3.75 kW.

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

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

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

Therefore the 10 A source is developing 1300 W.

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

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

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

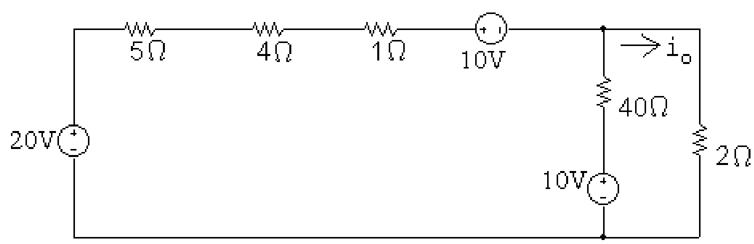
$p_{6\Omega} = (15)^2(6) = 1350$ W

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

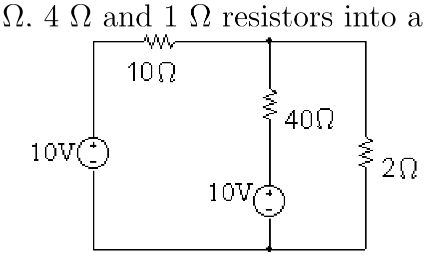
$\sum p_{\text{diss}} = 400 + 1350 + 2250 + 1050 = 5050$ W (CHECKS)

P2.4

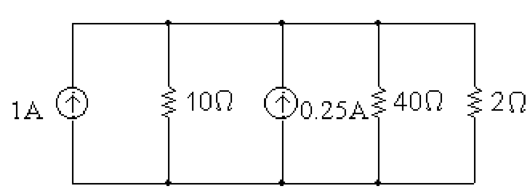
P 2.24 Applying a source transformation to each current source yields



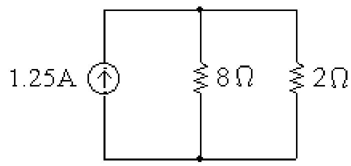
Now combine the 20 V and 10 V sources into a single voltage source and the 5 Ω. 4 Ω and 1 Ω resistors into a single resistor to get



Now use a source transformation on each voltage source, thus

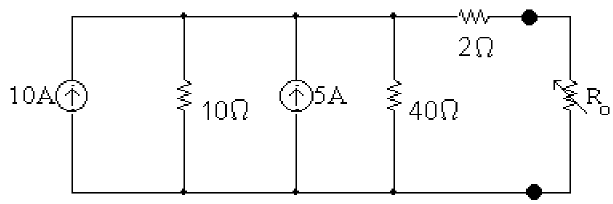


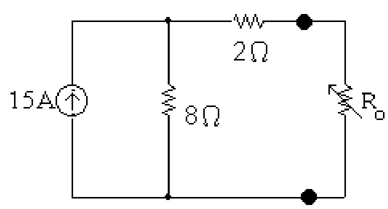
which can be reduced to

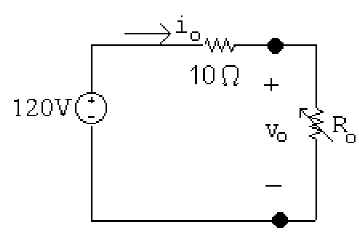


$$\therefore \quad i_o = \frac{(1.25)(8)}{10} = 1 \text{ A}$$

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

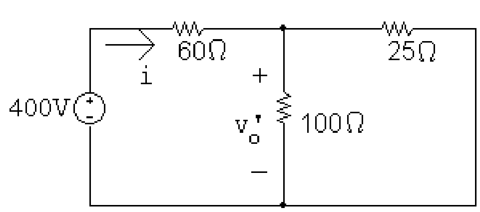






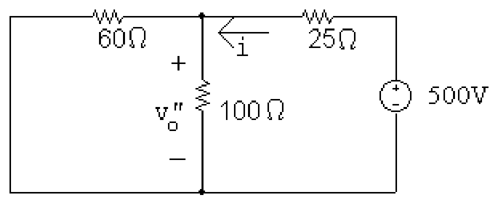
R_o	i_o	v_o	R_o	i_o	v_o
0	12	0	20	4	80
2	10	20	30	3	90
6	7.5	45	40	2.4	96
10	6	60	50	2	100
15	4.8	72	70	1.5	105

P 2.26



$100\,\Omega \| 25\,\Omega = 20\,\Omega \qquad\qquad \therefore \quad i = \dfrac{400}{60+20} = 5 \text{ A}$

$v_o' = 20i = 100$ V



$100\,\Omega \| 60\,\Omega = 37.5\,\Omega$

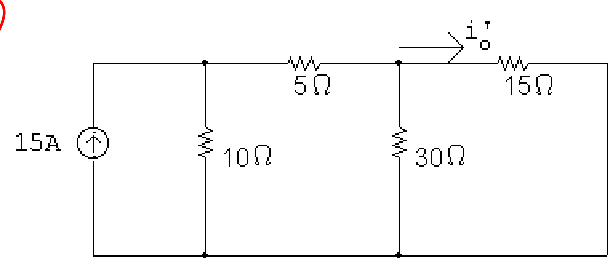
$$i = \frac{500}{25 + 37.5} = 8 \text{ A}$$

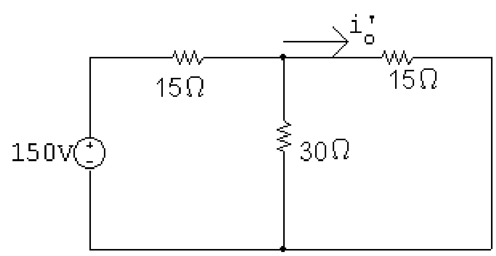
$v_o'' = 37.5i = 300$ V

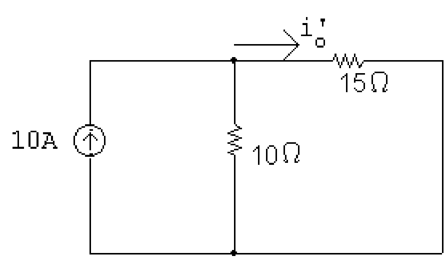
$v_o = v_o' + v_o'' = 100 + 300 = 400$ V

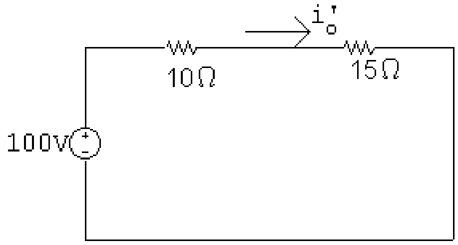
P 2.27

P2.7

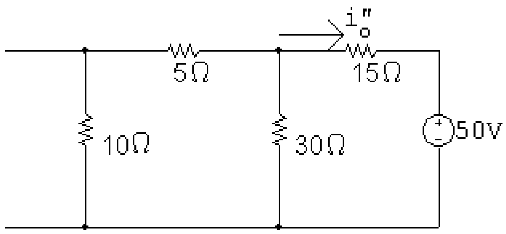




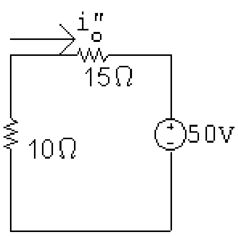




$$i_o' = \frac{100}{25} = 4 \text{ A}$$



$$15\,\Omega \| 30\,\Omega = 10\,\Omega$$

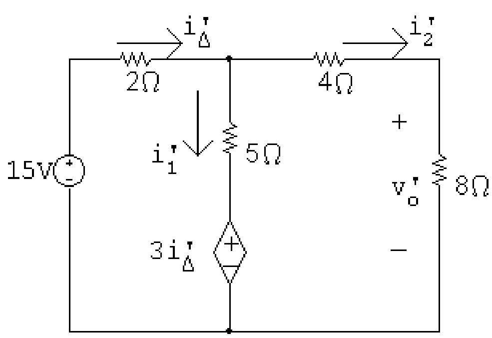


$$i_o'' = \frac{-50}{25} = -2 \text{ A}$$

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

P 2.28

P2.8

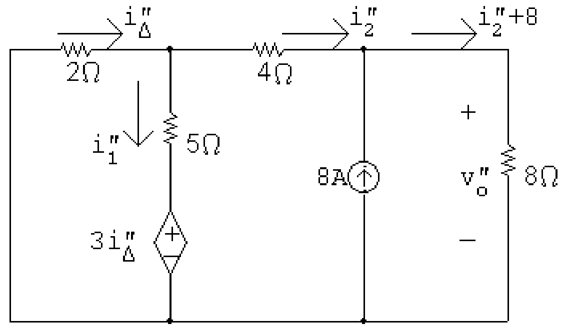


$$15 = 2i_\Delta' + 5'i_1 + 3i_\Delta'$$

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

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

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



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

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

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

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

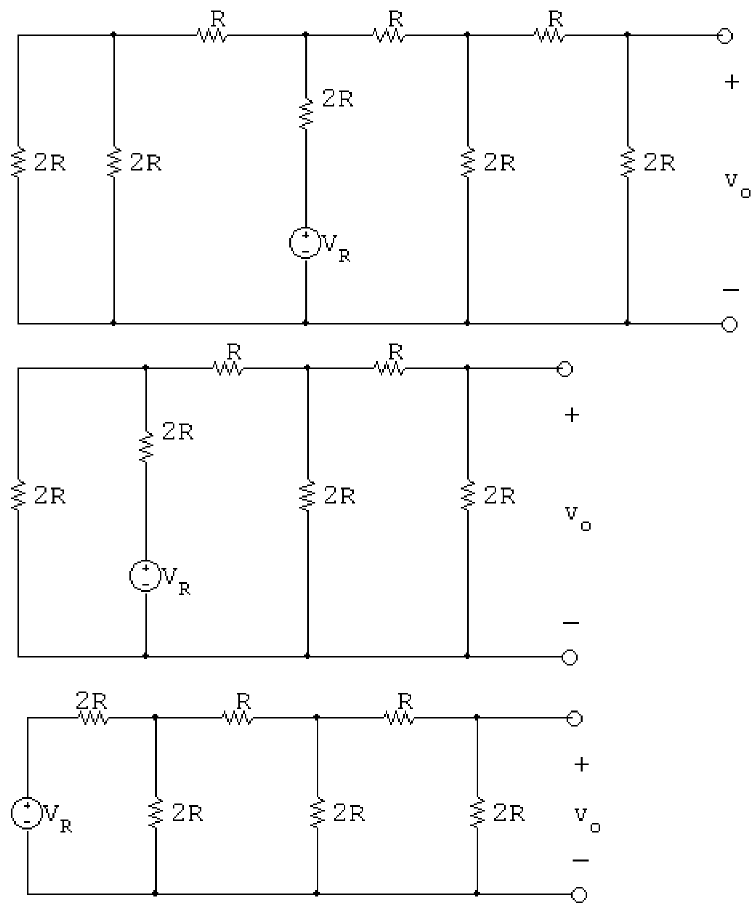
$$\therefore \quad 8 + i''_2 = \frac{40}{13} \text{ A}$$

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

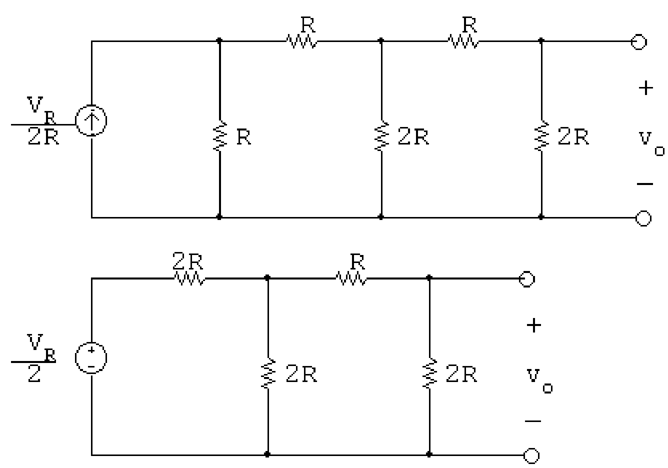
$$\therefore \quad v_o = v'_o + v''_o = \frac{96}{13} + \frac{320}{13} = 32 \text{ V}$$

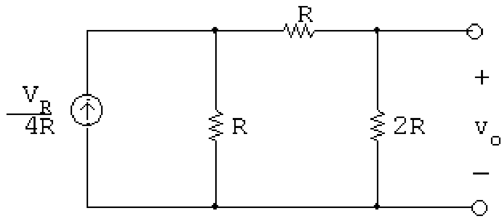
P 2.29 [a] The evolution of the circuit shown in Fig. P2.29 is illustrated in the following steps:

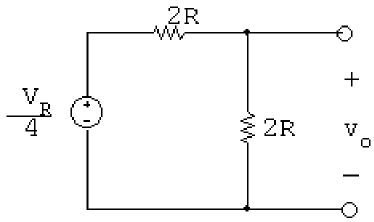
P 2.10



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

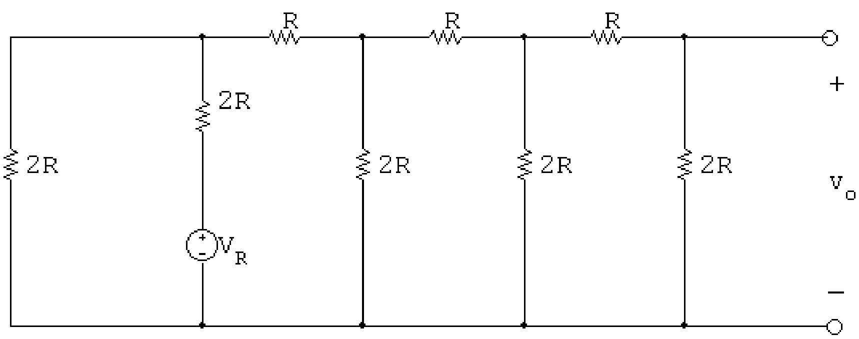


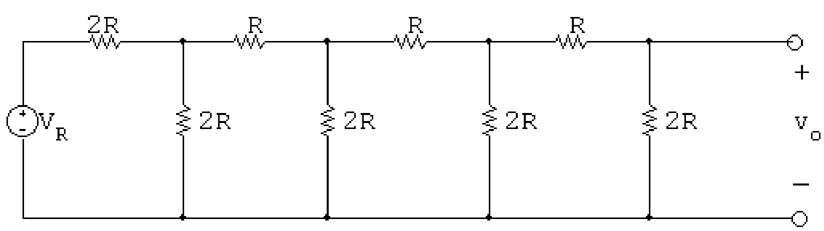




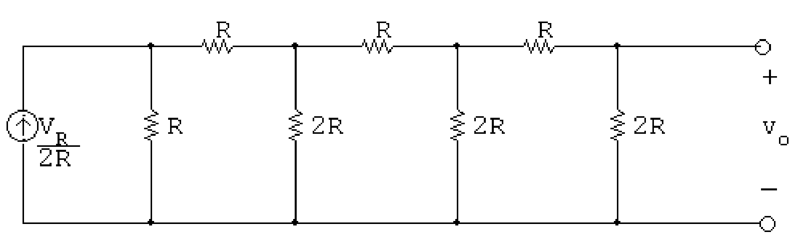
$$\frac{V_R/4}{4R}(2R) = \frac{V_R}{8}$$

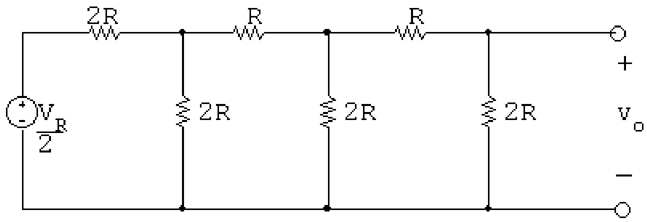
P 2.30 **[a]** The evolution of the circuit in Fig. P2.30 can be shown in two steps, thus:

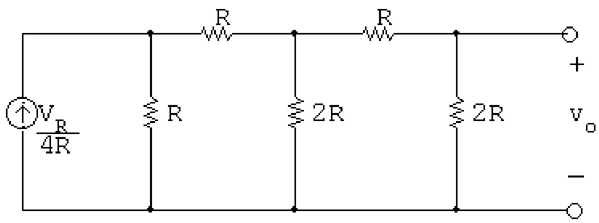


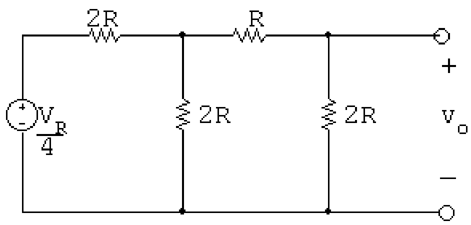


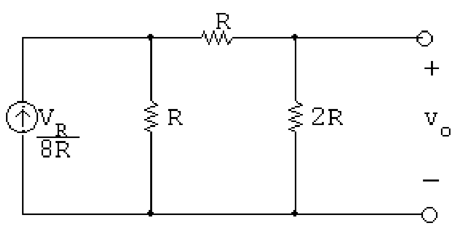
[b] Moving from left to right, a series of source transformations yields:

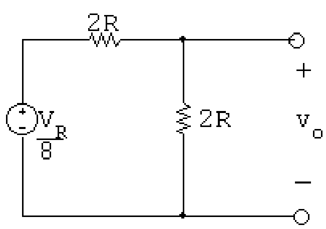












$$v_o = \frac{V_R/8}{4R}(2R) = \frac{V_R}{16}$$

P 2.31

Eq.(2.34)	$v_o = \frac{1}{2}V_R$	(Switch 1)
Eq.(2.35)	$v_o = \frac{1}{4}V_R$	(Switch 2)
Eq.(2.36)	$v_o = \frac{1}{8}V_R$	(Switch 3)
Eq.(2.37)	$v_o = \frac{1}{16}V_R$	(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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