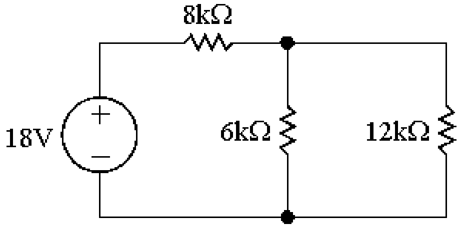
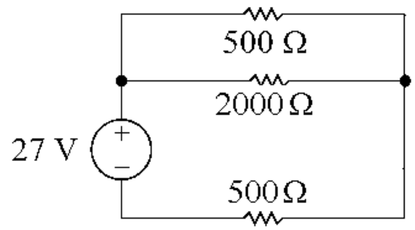
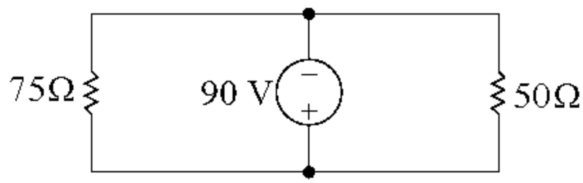
P 3.3 [a] The 5 kΩ and 7 kΩ resistors are in series. The simplified circuit is shown below:



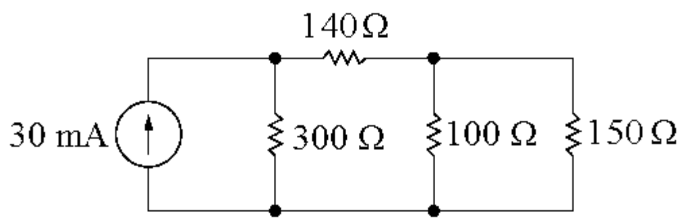
[b] The 800 Ω and 1200 Ω resistors are in series, as are the 300 Ω and 200 Ω resistors. The simplified circuit is shown below:



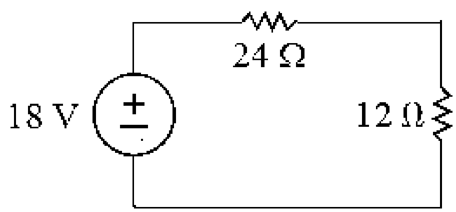
[c] The $35\,\Omega$, $15\,\Omega$, and $25\,\Omega$ resistors are in series. as are the $10\,\Omega$ and $40\,\Omega$ resistors. The simplified circuit is shown below:



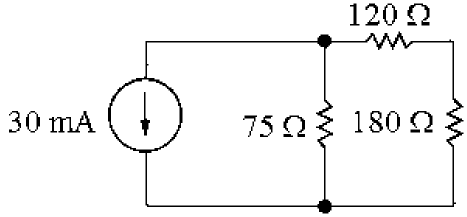
[d] The $50\,\Omega$ and $90\,\Omega$ resistors are in series, as are the $80\,\Omega$ and $70\,\Omega$ resistors. The simplified circuit is shown below:



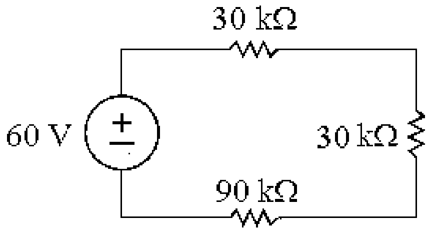
P 3.4 [a] The $36\,\Omega$ and $18\,\Omega$ resistors are in parallel. The simplified circuit is shown below:



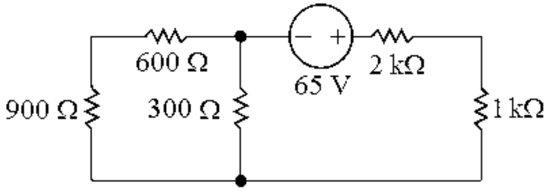
[b] The $200\,\Omega$ and $120\,\Omega$ resistors are in parallel, as are the $210\,\Omega$ and $280\,\Omega$ resistors. The simplified circuit is shown below:



[c] The 100 kΩ, 150 kΩ, and 60 kΩ resistors are in parallel, as are the 75 kΩ and 50 kΩ resistors. The simplified circuit is shown below:



[d] The 750 Ω and 500 Ω resistors are in parallel, as are the 1.5 kΩ and 3 kΩ resistors. The simplified circuit is shown below:



P 3.7 **[a]** Circuit in Fig. P3.7(a):

$$R_{\text{eq}} = ([(15\|60) + (30\|45) + 20]\|50) + 25 + 10 = [(12 + 18 + 20)\|50] + 25 + 10$$
$$= (50\|50) + 25 + 10 = 25 + 25 + 10 = 60\,\Omega$$

Circuit in Fig. P3.7(b) – begin by simplifying the $75\,\Omega$ resistor and all resistors to its right:

$$[(18 + 12)\|60 + 30]\|75 = (30\|60 + 30)\|75 = (20 + 30)\|75 = 50\|75 = 30\,\Omega$$

Now simplify the remainder of the circuit:

$$R_{\text{eq}} = ([(30 + 20)\|50] + (20\|60))\|40 = [(50\|50) + 15]\|40 = (25 + 15)\|40$$
$$= 40\|40 = 20\,\Omega$$

Circuit in Fig. P3.7(c) – begin by simplifying the left and right sides of the circuit:

$$R_{\text{left}} = [(1800 + 1200)\|2000] + 300 = (3000\|2000) + 300 = 1200 + 300 = 1500\,\Omega$$

$$R_{\text{right}} = [(500 + 2500)\|1000] + 750 = (3000\|1000) + 750 = 750 + 750 = 1500\,\Omega$$

Now find the equivalent resistance seen by the source:

$$R_{\text{eq}} = (R_{\text{left}}\|R_{\text{right}}) + 250 + 3000 = (1500\|1500) + 250 + 3000$$
$$= 750 + 250 + 3000 = 4000 = 4\ \text{k}\Omega$$

Circuit in Fig. P3.7(d):

$$R_{\text{eq}} = ([(750 + 250)\|1000] + 100)\|([(150 + 600)\|500] + 300)$$
$$= [(1000\|1000) + 100]\|[(750\|500) + 300] = (500 + 100)\|(300 + 300)$$
$$= 600\|600 = 300\,\Omega$$

[b] Note that in every case, the power delivered by the source must equal the power absorbed by the equivalent resistance in the circuit. For the circuit in Fig. P3.7(a):

$$P = \frac{V_s^2}{R_{\text{eq}}} = \frac{30^2}{60} = 15\ \text{W}$$

For the circuit in Fig. P3.7(b):

$$P = I_s^2(R_{\text{eq}}) = (0.08)^2(20) = 0.128 = 128\ \text{mW}$$

For the circuit in Fig. P3.7(c):

$$P = \frac{V_s^2}{R_{\text{eq}}} = \frac{20^2}{4000} = 0.1 = 100\ \text{mW}$$

For the circuit in Fig. P3.7(d):

$$P = I_s^2(R_{\text{eq}}) = (0.05)^2(300) = 0.75 = 750\ \text{mW}$$

P 3.12 **[a]** $v_o = \dfrac{160(3300)}{(4700+3300)} = 66\text{ V}$

[b] $i = 160/8000 = 20\text{ mA}$

$$P_{R_1} = (400\times10^{-6})(4.7\times10^{3}) = 1.88\text{ W}$$

$$P_{R_2} = (400\times10^{-6})(3.3\times10^{3}) = 1.32\text{ W}$$

[c] Since R_1 and R_2 carry the same current and $R_1 > R_2$ to satisfy the voltage requirement, first pick R_1 to meet the 0.5 W specification

$$i_{R_1} = \frac{160-66}{R_1}, \qquad \text{Therefore, } \left(\frac{94}{R_1}\right)^2 R_1 \le 0.5$$

$$\text{Thus, } R_1 \ge \frac{94^2}{0.5} \qquad \text{or} \qquad R_1 \ge 17{,}672\,\Omega$$

Now use the voltage specification:

$$\frac{R_2}{R_2+17{,}672}(160) = 66$$

Thus, $R_2 = 12{,}408\,\Omega$

P 3.13 $4 = \dfrac{20R_2}{R_2+40} \qquad \text{so} \qquad R_2 = 10\,\Omega$

$$3 = \frac{20R_\text{e}}{40+R_\text{e}} \qquad \text{so} \qquad R_\text{e} = \frac{120}{17}\,\Omega$$

$$\text{Thus, } \quad \frac{120}{17} = \frac{10R_\text{L}}{10+R_\text{L}} \qquad \text{so} \qquad R_\text{L} = 24\,\Omega$$

P 3.16 $R_{\text{eq}} = 10\|[6 + 5\|(8 + 12)] = 10\|(6 + 5\|20) = 10\|(6 + 4) = 5\,\Omega$

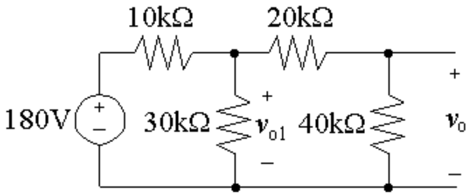
$$v_{10\text{A}} = v_{10\Omega} = (10\ \text{A})(5\,\Omega) = 50\ \text{V}$$

Using voltage division:

$$v_{5\Omega} = \frac{5\|(8+12)}{6 + 5\|(8+12)}(50) = \frac{4}{6+4}(50) = 20\ \text{V}$$

Thus, $p_{5\Omega} = \dfrac{v_{5\Omega}^2}{5} = \dfrac{20^2}{5} = 80\ \text{W}$

P 3.20 [**a**]



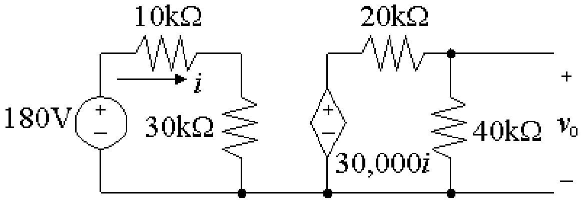
$$20\text{ k}\Omega + 40\text{ k}\Omega = 60\text{ k}\Omega$$

$$30\text{ k}\Omega \| 60\text{ k}\Omega = 20\text{ k}\Omega$$

$$v_{o1} = \frac{20{,}000}{(10{,}000 + 20{,}000)}(180) = 120\text{ V}$$

$$v_o = \frac{40{,}000}{60{,}000}(v_{o1}) = 80\text{ V}$$

[b]



$$i = \frac{180}{40{,}000} = 4.5 \text{ mA}$$

$$30{,}000i = 135 \text{ V}$$

$$v_o = \frac{40{,}000}{60{,}000}(135) = 90 \text{ V}$$

[c] It removes the loading effect of the second voltage divider on the first voltage divider. Observe that the open circuit voltage of the first divider is

$$v'_{o1} = \frac{30{,}000}{40{,}000}(180) = 135 \text{ V}$$

Now note this is the input voltage to the second voltage divider when the current-controlled voltage source is used.

P 3.23 [**a**] The equivalent resistance of the 6 kΩ resistor and the resistors to its right is

$$6\ \text{k}\|(5\ \text{k} + 7\ \text{k}) = 6\ \text{k}\|12\ \text{k} = 4\ \text{k}\Omega$$

Using voltage division,

$$v_{6k} = \frac{4000}{8000 + 4000}(18) = 6 \text{ V}$$

[b] $$v_{5k} = \frac{5000}{5000 + 7000}(6) = 2.5 \text{ V}$$

P 3.24 **[a]** The equivalent resistance of the 100 Ω resistor and the resistors to its right is

$$100\|(80 + 70) = 100\|150 = 60\,\Omega$$

Using current division,

$$i_{50} = \frac{(50 + 90 + 60)\|300}{50 + 90 + 60}(0.03) = \frac{120}{200}(0.03) = 0.018 = 18 \text{ mA}$$

[b] $$v_{70} = \frac{(80 + 70)\|100}{80 + 70}(0.018) = \frac{60}{150}(0.018) = 0.0072 = 7.2 \text{ mA}$$

P 3.28 **[a]** $v_{6\text{k}} = \dfrac{6}{6+2}(18) = 13.5\ \text{V}$

$$v_{3\text{k}} = \frac{3}{3+9}(18) = 4.5\ \text{V}$$

$$v_x = v_{6\text{k}} - v_{3\text{k}} = 13.5 - 4.5 = 9\ \text{V}$$

[b] $v_{6\text{k}} = \dfrac{6}{8}(V_s) = 0.75V_s$

$$v_{3\text{k}} = \frac{3}{12}(V_s) = 0.25V_s$$

$$v_x = (0.75V_s) - (0.25V_s) = 0.5V_s$$

P 3.32 Use current division to find the current in the 8 Ω resistor. Begin by finding the equivalent resistance of the 8 Ω resistor and all resistors to its right:

$$R_{\mathrm{eq}} = ([(20\|80) + 4]\|30) + 8 = 20\,\Omega$$

$$i_8 = \frac{60\|R_{\mathrm{eq}}}{R_{\mathrm{eq}}}(0.25) = \frac{60\|20}{20}(0.25) = 0.1875 = 187.5 \text{ mA}$$

Use current division to find i_1 from i_8:

$$i_1 = \frac{30\|[4 + (80\|20)]}{30}(i_8) = \frac{30\|20}{30}(0.1875) = 0.075 = 75 \text{ mA}$$

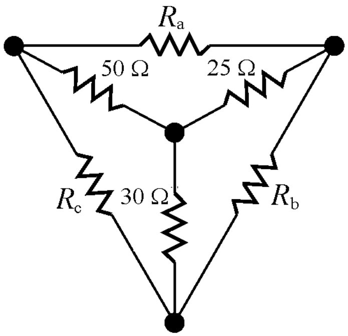
Use current division to find $i_{4\Omega}$ from i_8:

$$i_{4\Omega} = \frac{30\|[4 + (80\|20)]}{4 + (80\|20)}(i_8) = \frac{30\|20}{20}(0.1875) = 0.1125 = 112.5 \text{ mA}$$

Finally, use current division to find i_2 from $i_{4\Omega}$:

$$i_2 = \frac{80\|20}{20}(i_{4\Omega}) = \frac{80\|20}{20}(0.1125) = 0.09 = 90 \text{ mA}$$

P 3.58 [a] Use the figure below to transform the Y to an equivalent Δ:

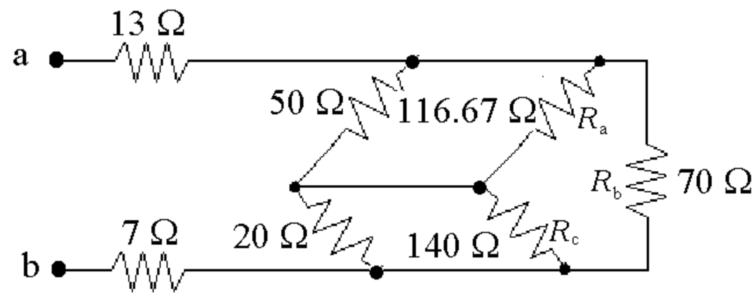


$$R_a = \frac{(25)(30) + (25)(50) + (30)(50)}{30} = \frac{3500}{30} = 116.67\,\Omega$$

$$R_b = \frac{(25)(30) + (25)(50) + (30)(50)}{50} = \frac{3500}{50} = 70\,\Omega$$

$$R_c = \frac{(25)(30) + (25)(50) + (30)(50)}{25} = \frac{3500}{25} = 140\,\Omega$$

Replace the Y with its equivalent Δ in the circuit to get the figure below:



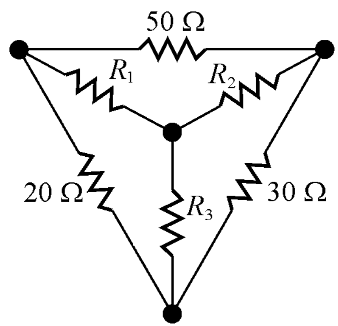
Find the equivalent resistance to the right of the 13 Ω and 7 Ω resistors:

$70\|[(50\|116.67) + (20\|140)] = 30\,\Omega$

Thus, the equivalent resistance seen from the terminals a-b is:

$R_{ab} = 13 + 30 + 7 = 50\,\Omega$

[b] Use the figure below to transform the Δ to an equivalent Y:

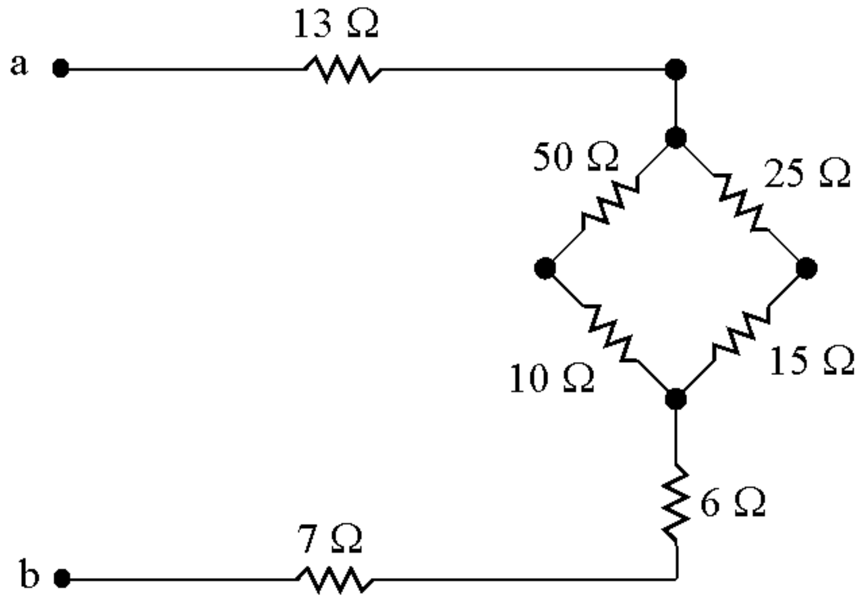


$$R_1 = \frac{(50)(20)}{50 + 20 + 30} = 10\,\Omega$$

$$R_2 = \frac{(50)(30)}{50 + 20 + 30} = 15\,\Omega$$

$$R_3 = \frac{(20)(30)}{50 + 20 + 30} = 6\,\Omega$$

Replace the Δ with its equivalent Y in the circuit to get the figure below:



Find the equivalent resistance to the right of the $13\,\Omega$ and $7\,\Omega$ resistors:

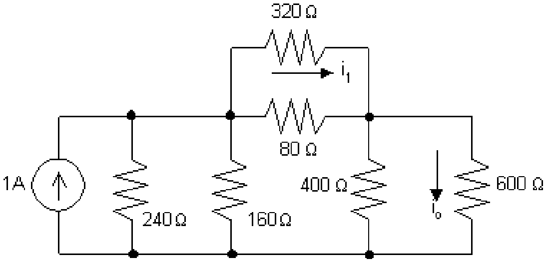
$(50+10)\|(25+15)+6=30\,\Omega$

Thus, the equivalent resistance seen from the terminals a-b is:

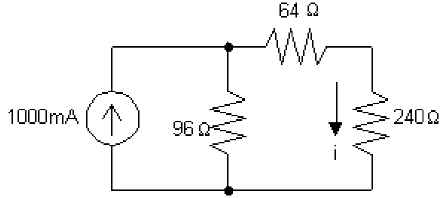
$R_{\text{ab}}=13+30+7=50\,\Omega$

[c] Convert the delta connection R_1—R_2—R_3 to its equivalent wye.
Convert the wye connection R_1—R_3—R_4 to its equivalent delta.

P 3.61 [a] After the 20 Ω—100 Ω—50 Ω wye is replaced by its equivalent delta, the circuit reduces to



Now the circuit can be reduced to

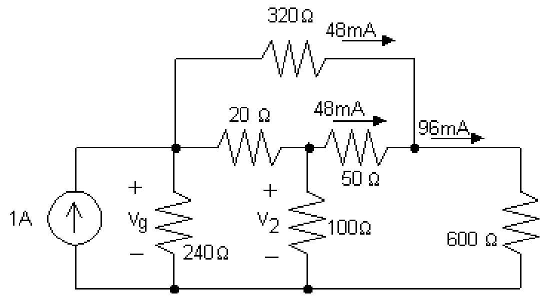


$$i = \frac{96}{400}(1000) = 240 \text{ mA}$$

$$i_o = \frac{400}{1000}(240) = 96 \text{ mA}$$

[b] $i_1 = \dfrac{80}{400}(240) = 48 \text{ mA}$

[c] Now that i_o and i_1 are known return to the original circuit



$$v_2 = (50)(0.048) + (600)(0.096) = 60 \text{ V}$$

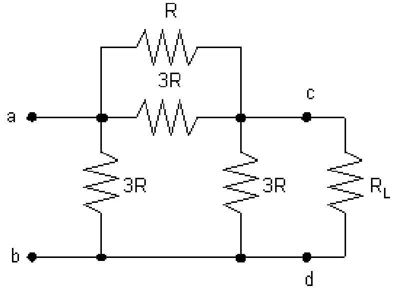
$$i_2 = \frac{v_2}{100} = \frac{60}{100} = 600 \text{ mA}$$

[d] $v_g = v_2 + 20(0.6 + 0.048) = 60 + 12.96 = 72.96 \text{ V}$

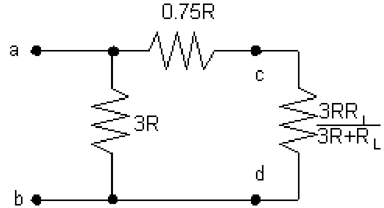
$$p_g = -(v_g)(1) = -72.96 \text{ W}$$

Thus the current source delivers 72.96 W.

P 3.67 **[a]** After making the Y-to-Δ transformation, the circuit reduces to



Combining the parallel resistors reduces the circuit to



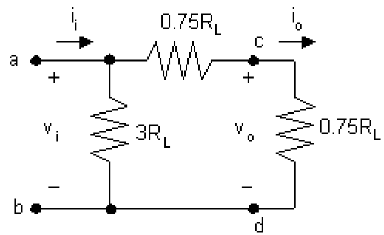
Now note: $$0.75R + \frac{3RR_{\rm L}}{3R+R_{\rm L}} = \frac{2.25R^2 + 3.75RR_{\rm L}}{3R+R_{\rm L}}$$

Therefore $$R_{\rm ab} = \frac{3R\left(\dfrac{2.25R^2+3.75RR_{\rm L}}{3R+R_{\rm L}}\right)}{3R+\left(\dfrac{2.25R^2+3.75RR_{\rm L}}{3R+R_{\rm L}}\right)} = \frac{3R(3R+5R_{\rm L})}{15R+9R_{\rm L}}$$

If $R = R_{\rm L}$, we have $$R_{\rm ab} = \frac{3R_{\rm L}(8R_{\rm L})}{24R_{\rm L}} = R_{\rm L}$$

Therefore $R_{\rm ab} = R_{\rm L}$

[b] When $R = R_{\rm L}$, the circuit reduces to



$$i_o = \frac{i_i(3R_{\rm L})}{4.5R_{\rm L}} = \frac{1}{1.5}i_i = \frac{1}{1.5}\frac{v_i}{R_{\rm L}}, \qquad v_o = 0.75R_{\rm L}i_o = \frac{1}{2}v_i,$$

Therefore $$\frac{v_o}{v_i} = 0.5$$