**Solution 2.1**

Design a problem, complete with a solution, to help students to better understand Ohm's Law. Use at least two resistors and one voltage source. Hint, you could use both resistors at once or one at a time, it is up to you. Be creative.

Although there is no correct way to work this problem, this is an example based on the same kind of problem asked in the third edition.

**Problem**

The voltage across a 5-kΩ resistor is 16 V. Find the current through the resistor.

**Solution**

$v = iR \qquad i = v/R = (16/5) \text{ mA} = \mathbf{3.2\ mA}$

**Solution 2.2**

$p = v^2/R \rightarrow$ $\mathbf{R} = v^2/p = 14400/60 =$ **240 ohms**

**Solution 2.3**

For silicon, $\rho = 6.4x10^2$ Ω-m. $A = \pi r^2$. Hence,

$$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2} \longrightarrow r^2 = \frac{\rho L}{\pi R} = \frac{6.4x10^2 x4x10^{-2}}{\pi x240} = 0.033953$$

r = **184.3 mm**

**Solution 2.4**

(a) $\mathbf{i} = 40/100 = \mathbf{400\ mA}$
(b) $\mathbf{i} = 40/250 = \mathbf{160\ mA}$

**Solution 2.5**

n = **9**; $l$ = **7**; **b** = n + $l$ – 1 = **15**

## Solution 2.6

n = 8; *l* = 8; **b** = n + *l* –1 = <u>**15**</u>

**Solution 2.7**

6 branches and 4 nodes

**Solution 2.8**

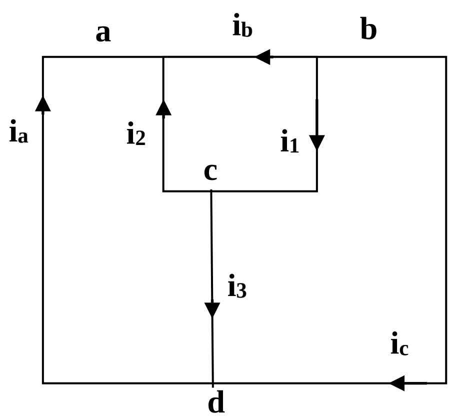
Design a problem, complete with a solution, to help other students to better understand Kirchhoff's Current Law. Design the problem by specifying values of $i_a$, $i_b$, and $i_c$, shown in Fig. 2.72, and asking them to solve for values of $i_1$, $i_2$, and $i_3$. Be careful specify realistic currents.

Although there is no correct way to work this problem, this is one of the many possible solutions. Note that the solution process must follow the same basic steps.

**Problem**

Use KCL to obtain currents $i_1$, $i_2$, and $i_3$ in the circuit shown in Fig. 2.72 given that $i_a$ = 2 amps, $i_b$ = 3 amps, and $i_c$ = 4 amps.

**Solution**




At node a, $-i_a - i_2 - i_b = 0$ or $i_2 = -2 - 3 =$ **−5 amps**
At node b, $i_b + i_1 + i_c = 0$ or $i_1 = -3 - 4 =$ **−7 amps**
At node c, $i_2 + i_3 - i_1 = 0$ or $i_3 = -7 + 5 =$ **−2 amps**

We can use node d as a check, $i_a - i_3 - i_c = 2 + 2 - 4 = 0$ which is as expected.

**Solution 2.9**

Find $i_1$, $i_2$, and $i_3$ in Fig. 2.73.

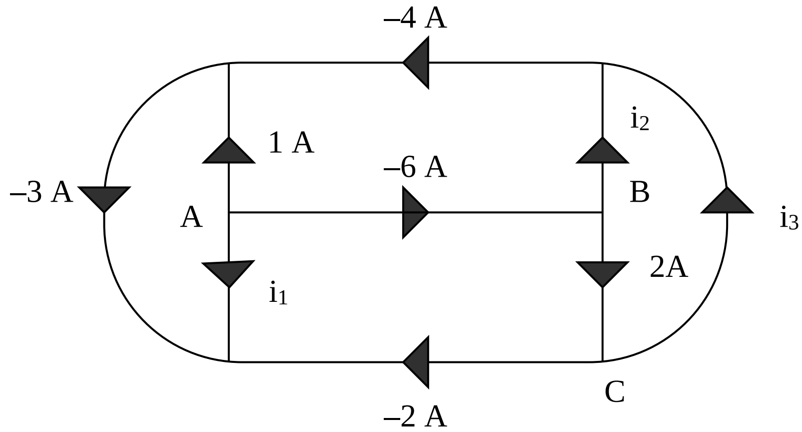



Figure 2.73
For Prob. 2.9.

**Solution**

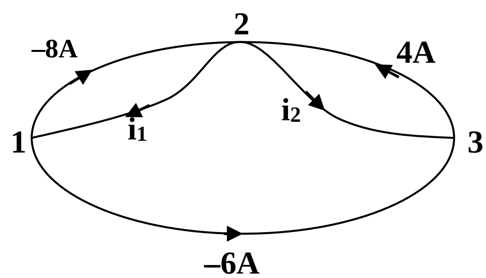
Step 1. We can apply Kirchhoff's current law to solve for the unknown currents.

Summing all of the currents flowing out of nodes A, B, and C we get,

at A, $1 + (-6) + i_1 = 0$;
at B, $-(-6) + i_2 + 2 = 0$; and
at C, $(-2) + i_3 - 2 = 0$.

Step 2. We now can solve for the unknown currents, $i_1 = -1 + 6 =$ **5 amps**; $i_2 = -6 - 2 =$ **–8 amps**; and $i_3 = 2 + 2 =$ **4 amps**.

**Solution 2.10**



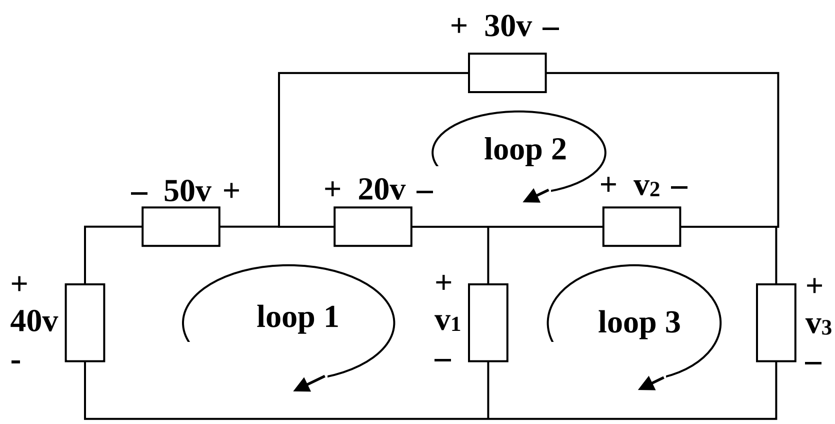

At node 1, $-8 - i_1 - 6 = 0$ or $i_1 = -8 - 6 =$ **$-14$ A**

At node 2, $-(-8) + i_1 + i_2 - 4 = 0$ or $i_2 = -8 - i_1 + 4 = -8 + 14 + 4 =$ **10 A**

**Solution 2.11**

$$-V_1 + 1 + 5 = 0 \longrightarrow V_1 = \underline{6\text{ V}}$$
$$-5 + 2 + V_2 = 0 \longrightarrow V_2 = \underline{3\text{ V}}$$

**Solution 2.12**

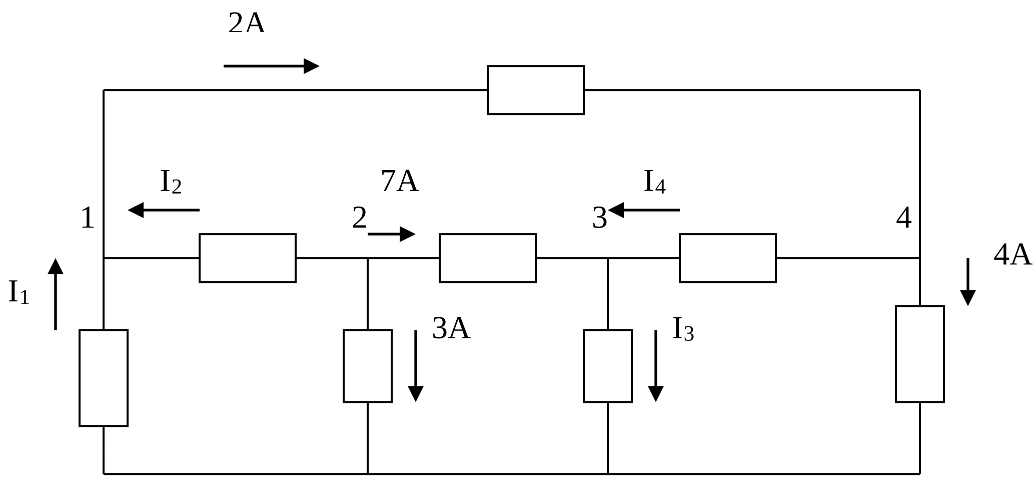



For loop 1, $-40 -50 +20 + v_1 = 0$ or $v_1 = 40+50-20 =$ **70 V**

For loop 2, $-20 +30 -v_2 = 0$ or $v_2 = 30-20 =$ **10 V**

For loop 3, $-v_1 +v_2 +v_3 = 0$ or $v_3 = 70-10 =$ **60 V**

**Solution 2.13**




At node 2,

$$3+7+I_2=0 \quad \longrightarrow \quad I_2=-10\,A$$

At node 1,

$$I_1+I_2=2 \quad \longrightarrow \quad I_1=2-I_2=12\,A$$

At node 4,

$$2=I_4+4 \quad \longrightarrow \quad I_4=2-4=-2\,A$$

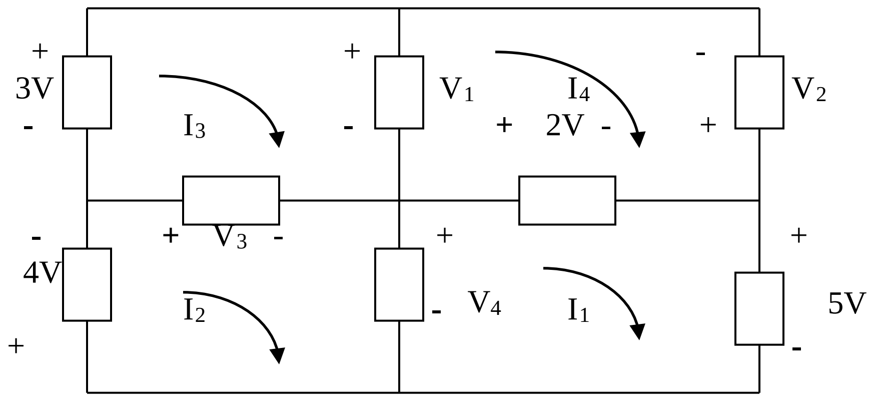
At node 3,

$$7+I_4=I_3 \quad \longrightarrow \quad I_3=7-2=5\,A$$

Hence,

$$\underline{I_1=12\,A, \quad I_2=-10\,A, \quad I_3=5\,A, \quad I_4=-2\,A}$$

**Solution 2.14**




For mesh 1,

$-V_4 + 2 + 5 = 0 \quad \longrightarrow \quad V_4 = 7V$

For mesh 2,

$+4 + V_3 + V_4 = 0 \quad \longrightarrow \quad V_3 = -4 - 7 = -11V$

For mesh 3,

$-3 + V_1 - V_3 = 0 \quad \longrightarrow \quad V_1 = V_3 + 3 = -8V$

For mesh 4,

$-V_1 - V_2 - 2 = 0 \quad \longrightarrow \quad V_2 = -V_1 - 2 = 6V$

Thus,

$\underline{V_1 = -8V, \quad V_2 = 6V, \quad V_3 = -11V, \quad V_4 = 7V}$

**Solution 2.15**

Calculate v and $i_x$ in the circuit of Fig. 2.79.

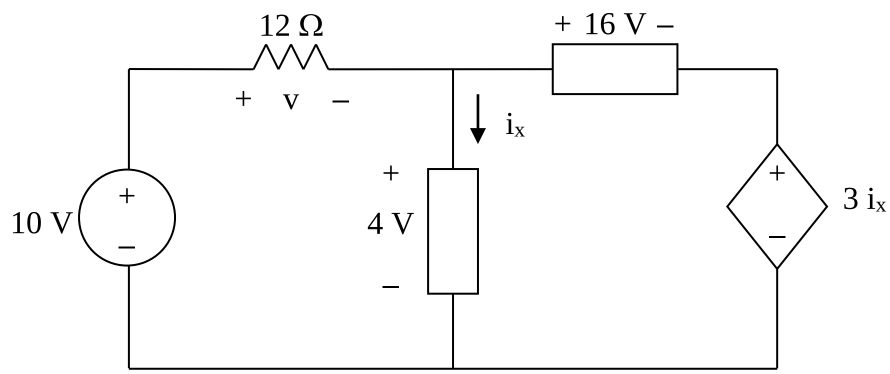



Figure 2.79
For Prob. 2.15.

**Solution**

For loop 1, $-10 + v + 4 = 0$, $v =$ **6 V**

For loop 2, $-4 + 16 + 3i_x = 0$, $i_x =$ **–4 A**

**Solution 2.16**

Determine $V_o$ in the circuit in Fig. 2.80.

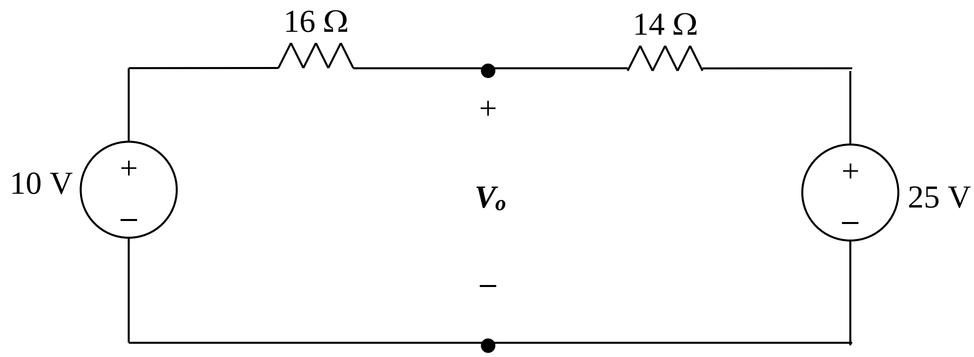



Figure 2.80
For Prob. 2.16.

**Solution**

Apply KVL,

$-10 + (16+14)I + 25 = 0$ or $30I = 10–25 = –$ or $I = –15/30 = –500$ mA

Also,

$-10 + 16I + V_o = 0$ or $V_o = 10 – 16(–0.5) = 10+8 =$ **18 V**

**Problem 2.17**

Obtain $v_1$ through $v_3$ in the circuit in Fig. 2.81.

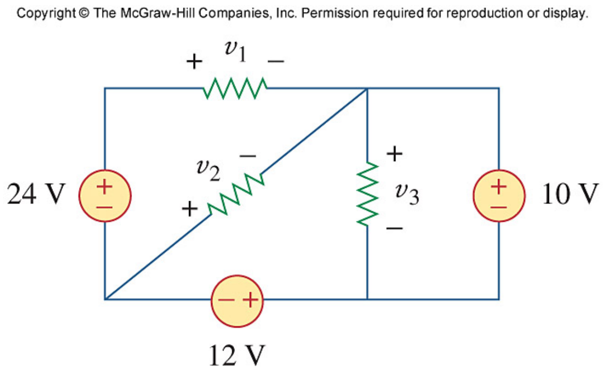



Figure 2.81
For Prob. 2.17.

**Solution 2.18**

Find $I$ and $V$ in the circuit of Fig. 2.82.

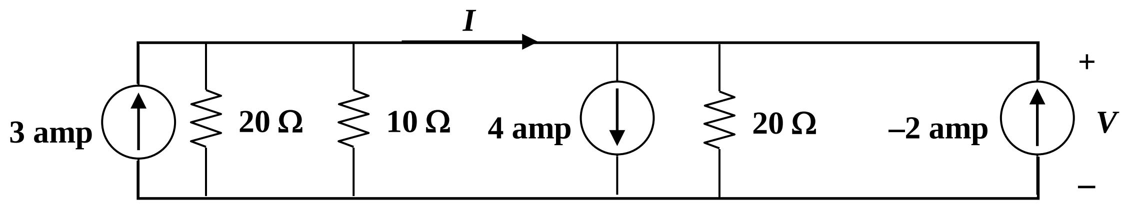



Figure 2.82
For Prob. 2.18.

**Solution.**

Step 1. We can make use of both Kirchhoff's KVL and KCL. KVL tells us that the voltage across all the elements of this circuit is the same in every case. Ohm's Law tells us that the current in each resistor is equal to $V$/R. Finally we can use KCL to find $I$.

Applying KCL and summing all the current flowing out of the top node and setting it to zero we get, $-3 + [V/20] + [V/10] + 4 + [V/20] - [-2] = 0$.

Finally at the node to the left of I we can write the following node equation which will give us $I$, $-3 + [V/20] + [V/10] + I = 0$.

Step 2. $[0.05+0.1+0.05]V = 0.2V = 3-4-2 = -3$ or $V =$ **–15 volts**.

$I = 3-V[0.05+0.1] = 3-[-15]0.15 =$ **5.25 amps**.

**Solution 2.19**

Applying KVL around the loop, we obtain

$$-(-8) - 12 + 10 + 3i = 0 \longrightarrow \mathbf{i = -2A}$$

Power dissipated by the resistor:

$$p_{3\Omega} = i^2R = 4(3) = \mathbf{12W}$$

Power supplied by the sources:

$$p_{12V} = 12\,((-2)) = \mathbf{-24W}$$

$$p_{10V} = 10\,(-(-2)) = \mathbf{20W}$$

$$p_{8V} = (-8)(-2) = \mathbf{16W}$$

**Solution 2.20**

Determine $i_o$ in the circuit of Fig. 2.84.

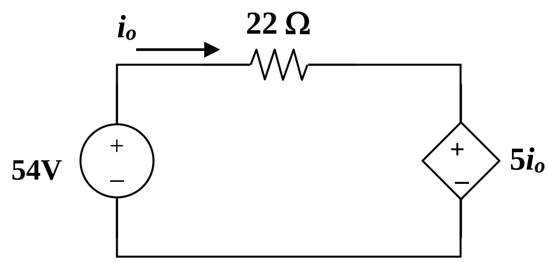



Figure 2.84
For Prob. 2.20

**Solution**

Applying KVL around the loop,

$-54 + 22i_o + 5i_o = 0 \longrightarrow i_o = 4\text{A}$

**Solution 2.21**

Applying KVL,

$$-15 + (1+5+2)I + 2 V_x = 0$$

But $V_x = 5I$,

$$-15 + 8I + 10I = 0, \qquad I = 5/6$$

$$V_x = 5I = 25/6 = \mathbf{4.167\ V}$$

**Solution 2.22**

Find $\boldsymbol{V_o}$ in the circuit in Fig. 2.86 and the power absorbed by the dependent source.

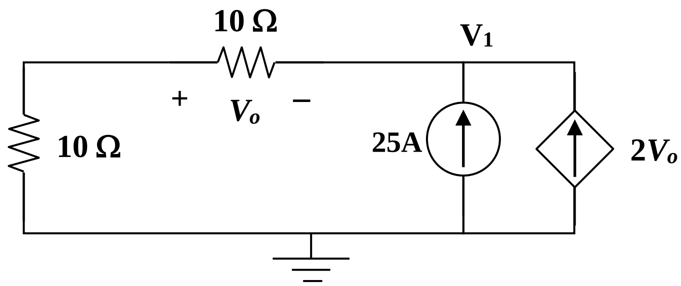



Figure 2.86
For Prob. 2.22

**Solution**

At the node, KCL requires that $[-V_o/10]+[-25]+[-2V_o] = 0$ or $2.1V_o = -25$

or $V_o =$ **–11.905 V**

The current through the controlled source is $i = 2V_0 = -23.81$ A
and the voltage across it is $V_1 = (10+10)\ i_0$ (where $i_0 = -V_0/10) = 20(11.905/10) = 23.81$ V.

Hence,

$p_{\text{dependent source}} = V_1(-i) = 23.81\text{x}(-(-23.81)) =$ **566.9 W**

Checking, $(25-23.81)^2(10+10) + (23.81)(-25) + 566.9 = 28.322 - 595.2 + 566.9 = 0.022$ which is equal zero since we are using four places of accuracy!

**Solution 2.23**

In the circuit shown in Fig. 2.87, determine $v_x$ and the power absorbed by the 60-Ω resistor.

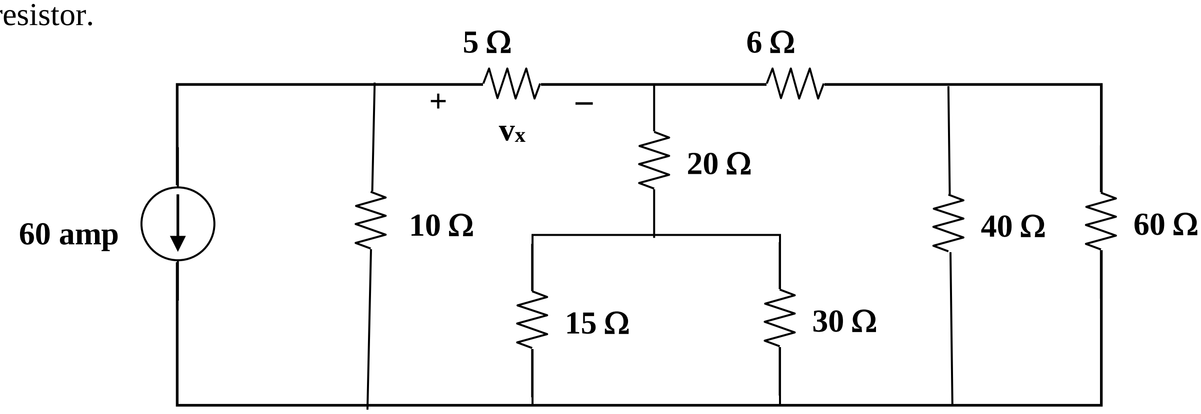
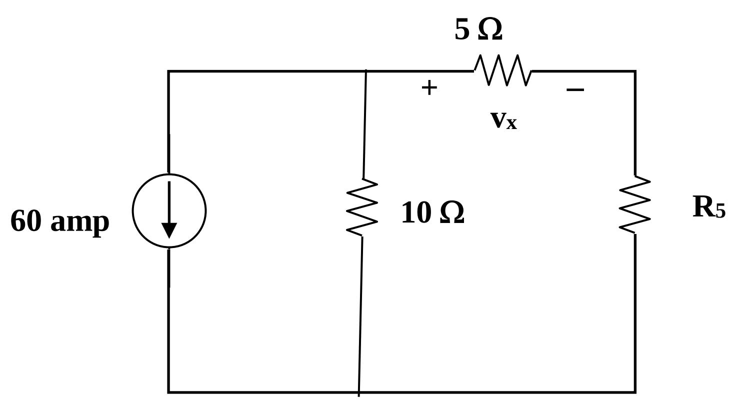



Figure 2.87
For Prob. 2.23.

Step 1. Although we could directly use Kirchhoff's current law to solve this, it will be easier if we reduce the circuit first.

The reduced circuit looks like this,




$R_1 = 40 \text{x} 60/(40+60)$
$R_2 = 6 + R_1$
$R_3 = 15 \text{x} 30/(15+30)$
$R_4 = 20 + R_3$
$R_5 = R_2 R_4/(R_2+R_4)$

Letting $V_{10} = v_x + V_{R5}$ and using Kirchhoff's current law, we get

$60 + V_{10}/10 + V_{10}/(5+R_5) = 0$
$60 + V_{10}/10 + V_{10}/20 = 0$
$V_{10} = -60 \text{x} 20/3 = -400$ volts

We could have also used current division to find the current through the 5 Ω resistor, however, $i_5 = V_{10} /(5+R_5)$ and $v_x = 5i_5$

Calculating the power delivered to the 60-ohm resistor requires that we find the voltage across the resistor. $V_{R5} = V_{10} – v_x$; using voltage division we get $V_{60} = [V_{R5} /(6+R_1)]R_1$. Finally $P_{60} = (V_{60})^2/60$.

Step 2.

$R_1 = 40x60/(40+60) = 2400/100 = 24$;
$R_2 = 6 + R_1 = 6+24 = 30$;
$R_3 = 15x30/(15+30)\ 450/45 = 10$;
$R_4 = 20+R_3 = 20+10 = 30$;
$R_5 = R_2R_4/(R_2+R_4) = 30x30/(30+30) = 15$.

Now, we have $60 + (V_{10}/10) + (V_{10}/(20)) = 0$ or $V_{10} = –60x20/3 = –400$ and $i_{10} = –400/20 = –20$ and

$$v_x = 5i_5 = 5(–20) = \mathbf{–100\ volts}.$$

$V_{R5} = V_{10} – v_x = –400 – (–100) = –300$; using voltage division we get $V_{60} = [V_{R5} /(6+R_1)]R_1. = [–300/30]24 = –240$. Finally,

$$P_{60} = (V_{60})^2/60 = (–240)^2/60 = \mathbf{960\ watts}.$$

**Solution 2.24**

(a) $$I_0 = \frac{V_s}{R_1 + R_2}$$

$$V_0 = -\alpha I_0 \left(R_3 \| R_4\right) = -\frac{\alpha V_s}{R_1 + R_2} \cdot \frac{R_3 R_4}{R_3 + R_4}$$

$$\boldsymbol{\frac{V_0}{Vs} = \frac{-\alpha R_3 R_4}{\left(R_1 + R_2\right)\left(R_3 + R_4\right)}}$$

(b) If $R_1 = R_2 = R_3 = R_4 = R$,

$$\left|\frac{V_0}{V_S}\right| = \frac{\alpha}{2R} \cdot \frac{R}{2} = \frac{\alpha}{4} = 10 \longrightarrow \alpha = \mathbf{40}$$

**Solution 2.25**

$V_0 = 5 \times 10^{-3} \times 10 \times 10^3 = 50V$

Using current division,

$$I_{20} = \frac{5}{5+20}(0.01x50) = \mathbf{0.1\ A}$$

$$V_{20} = 20 \times 0.1 \text{ kV} = \mathbf{2\ kV}$$

$$p_{20} = I_{20} V_{20} = \mathbf{0.2\ kW}$$

**Solution 2.26**

For the circuit in Fig. 2.90, $\boldsymbol{i_o}$ = 5 A. Calculate $\boldsymbol{i_x}$ and the total power absorbed by the entire circuit.

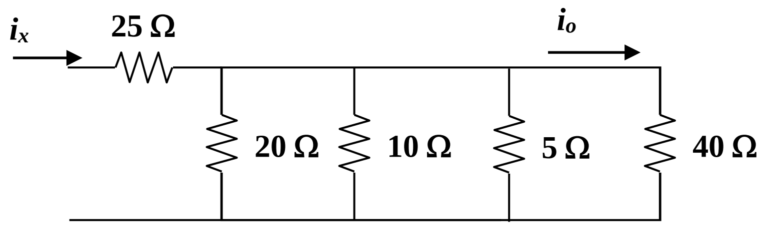



Figure 2.90
For Prob. 2.26.

**Solution**

Step 1. $V_{40} = 40i_o$ and we can combine the four resistors in parallel to find the equivalent resistance and we get $(1/R_{eq}) = (1/20) + (1/10) + (1/5) + (1/40)$.

This leads to $i_x = V_{40}/R_{eq}$ and $P = (i_x)^2(25+R_{eq})$.

Step 2. $V_{40}$ = 40x5 = 200 volts and $(1/R_{eq}) = (1/20) + (1/10) + (1/5) + (1/40) = 0.05 + 0.1 + 0.2 + 0.025 = 0.375$ or $R_{eq} = 2.667\ \Omega$ and $i_x = 200/R_{eq} = 75$ amps.

$$P = (75)^2(25+2.667) = \mathbf{155.62\ kW}.$$

**Solution 2.27**

Calculate $\boldsymbol{I_o}$ in the circuit of Fig. 2.91.

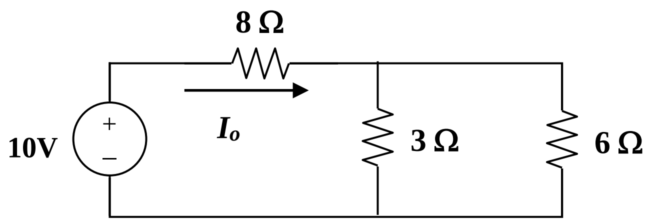



Figure 2.91
For Prob. 2.27.

**Solution**

The 3-ohm resistor is in parallel with the c-ohm resistor and can be replaced by a [(3x6)/(3+6)] = 2-ohm resistor. Therefore,

$\boldsymbol{I_o}$ = 10/(8+2) = **1 A**.

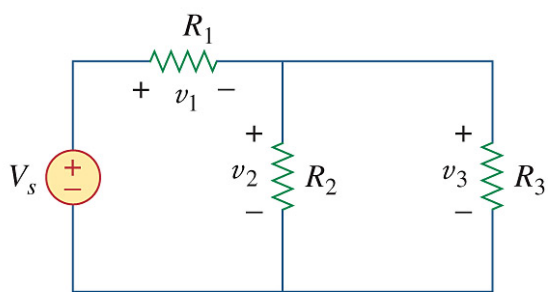
**Solution 2.28**

Design a problem, using Fig. 2.92, to help other students better understand series and parallel circuits.

Although there is no correct way to work this problem, this is an example based on the same kind of problem asked in the third edition.

**Problem**

Find $v_1$, $v_2$, and $v_3$ in the circuit in Fig. 2.92.




**Solution**

We first combine the two resistors in parallel

$$15 \| 10 = 6\ \Omega$$

We now apply voltage division,

$$v_1 = \frac{14}{14+6}(40) = \underline{\mathbf{28\ V}}$$

$$v_2 = v_3 = \frac{6}{14+6}(40) = 12\ \text{V}$$

Hence, $v_1$ = **28 V**, $v_2$ = **12 V,** $v_s$ = **12 V**

**Solution 2.29**

All resistors (R) in Fig. 2.93 are 10 Ω each. Find $R_{eq}$.

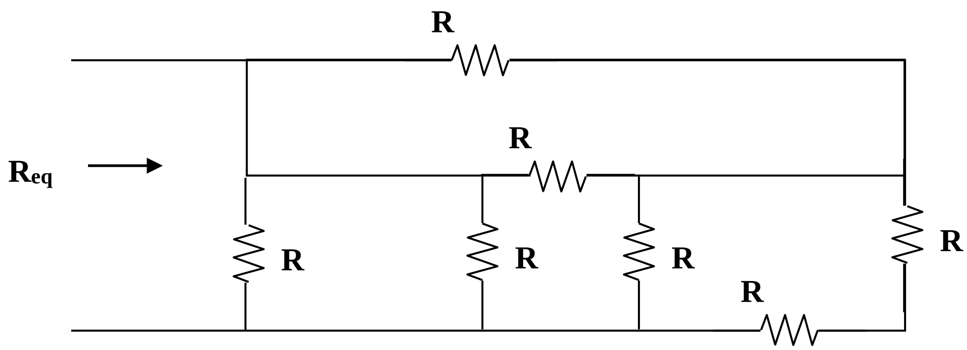


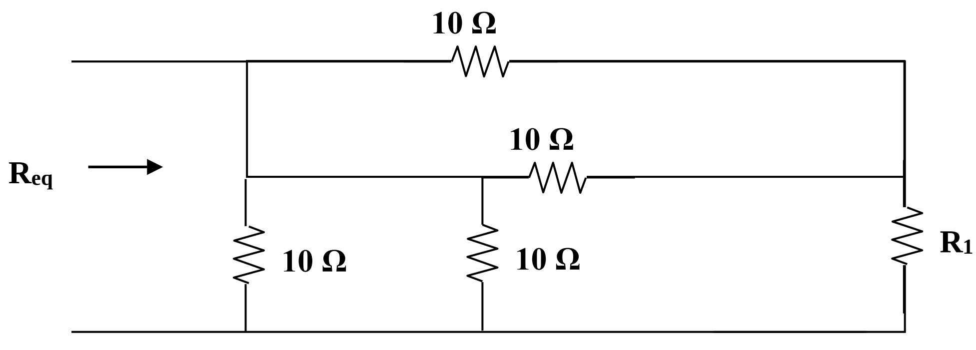

Figure 2.93
For Prob. 2.29.

**Solution**

Step 1. All we need to do is to combine all the resistors in series and in parallel.

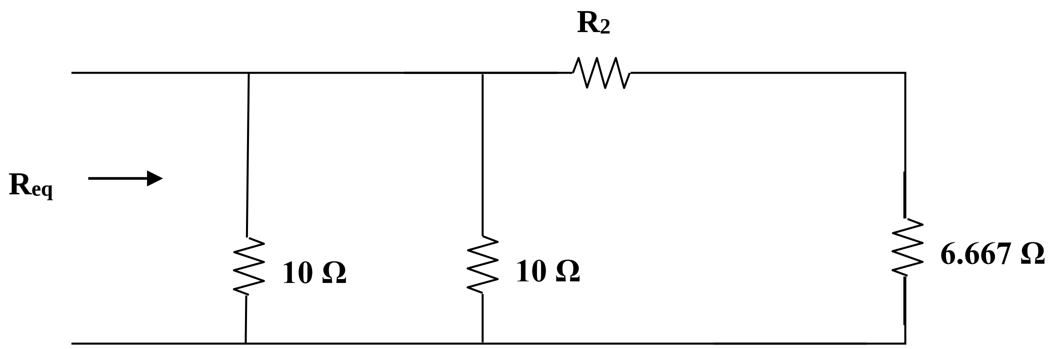
$$R_{eq} = \frac{\left(\frac{R(R)}{R+R}\right)\left(\frac{R(R)}{R+R}+\frac{R(R+R)}{R+R+R}\right)}{\left(\frac{R(R)}{R+R}\right)+\left(\frac{R(R)}{R+R}+\frac{R(R+R)}{R+R+R}\right)}$$ which can be derived by inspection. We will look at a simpler approach after we get the answer.

Step 2. $R_{eq} = \frac{5[(5+6.667)]}{5+5+6.667} = \frac{58.335}{16.667}$ = **3.5 Ω**.

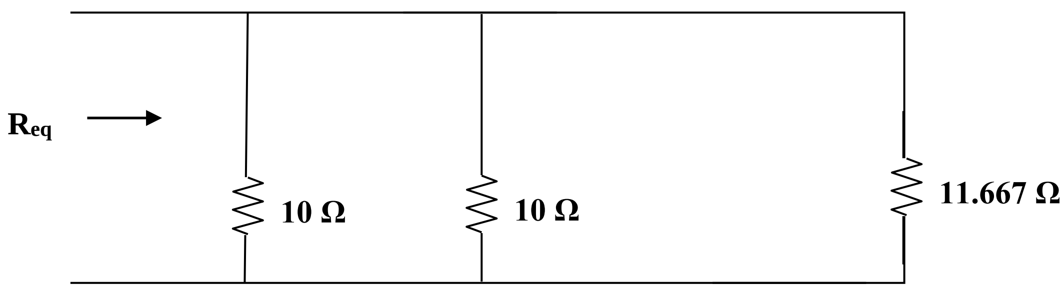


Checking we get,

$R_1 = 10(20)/(10+20) = 6.667\ \Omega$.




We get $R_2 = 10(10)/(10+10) = 5\ \Omega$.




Finally we get (noting that 10 in parallel with 10 gives us 5 Ω,

$R_{eq} = 5(11.667)/(5+11.667) = \mathbf{3.5\ \Omega}$.

**Solution 2.30**

Find $\boldsymbol{R_{eq}}$ for the circuit in Fig. 2.94.

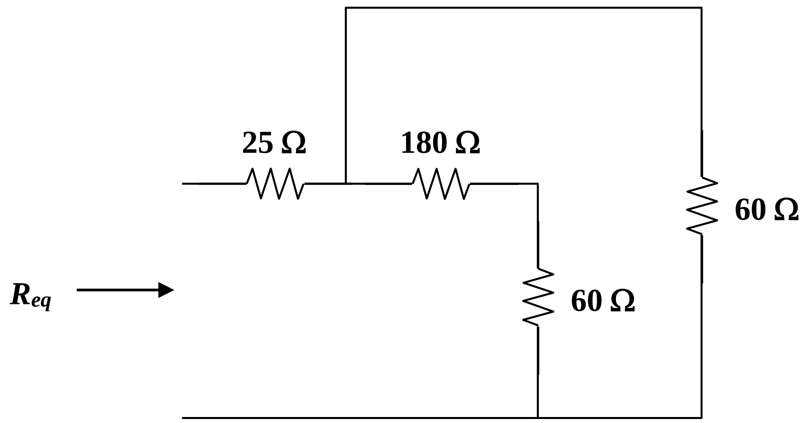



Figure 2.94
For Prob. 2.30.

**Solution**

We start by combining the 180-ohm resistor with the 60-ohm resistor which in turn is in parallel with the 60-ohm resistor or = [60(180+60)/(60+180+60)] = 48.

Thus,
$R_{eq}$ = 25+48 = **73 Ω**.

**Solution 2.31**

$$R_{eq} = 3 + 2 // 4 // 1 = 3 + \frac{1}{1/2 + 1/4 + 1} = 3.5714$$

$i_1$ = 200/3.5714 = **56 A**

$v_1$ = 0.5714x$i_1$ = 32 V and $i_2$ = 32/4 = **8 A**

$i_4$ = 32/1 = **32 A**; $i_5$ = 32/2 = **16 A**; and $i_3$ = 32+16 = **48 A**

**Solution 2.32**

Find $i_1$ through $i_4$ in the circuit in Fig. 2.96.

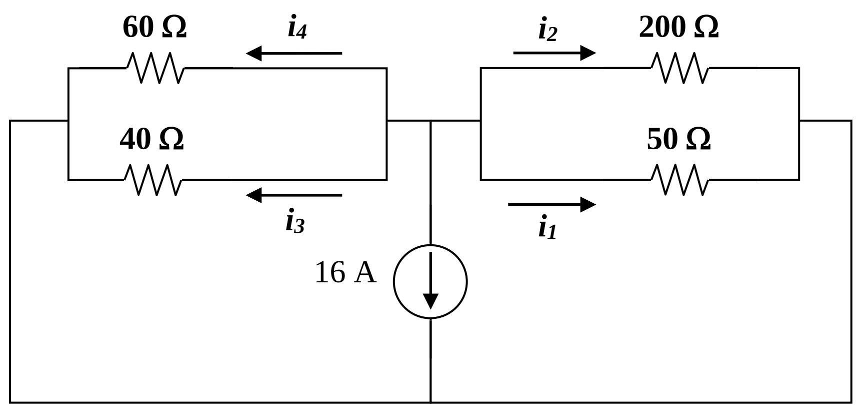



Figure 2.96
For Prob. 2.32.

**Solution**

We first combine resistors in parallel.

$$40\|60 = \frac{40x60}{100} = 24\ \Omega \text{ and } \quad 50\|200 = \frac{50x200}{250} = 40\ \Omega$$

Using current division principle,

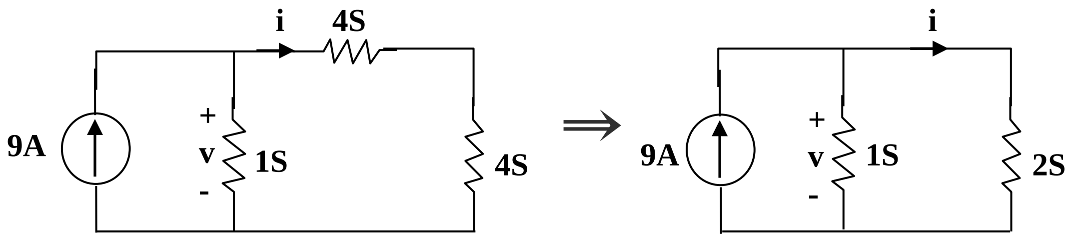
$$i_1 + i_2 = \frac{24}{24+40}(-16) = -6A, i_3 + i_4 = \frac{40}{64}(-16) = -10A$$

$$i_1 = \frac{200}{250}(6) = \mathbf{-4.8\ A} \text{ and } i_2 = \frac{50}{250}(-6) = \mathbf{-1.2\ A}$$

$$i_3 = \frac{60}{100}(-10) = \mathbf{-6\ A} \text{ and } i_4 = \frac{40}{100}(-10) = \mathbf{-4\ A}$$

**Solution 2.33**

Combining the conductance leads to the equivalent circuit below




$$6S \| 3S = \frac{6x3}{9} = 2\text{S} \text{ and } 2\text{S} + 2\text{S} = 4\text{S}$$

Using current division,

$$\text{i} = \frac{1}{1+\frac{1}{2}}(9) = \mathbf{6\ A}, \text{ v} = 3(1) = \mathbf{3\ V}$$

**Solution 2.34**

Using series/parallel resistance combination, find the equivalent resistance seen by the source in the circuit of Fig. 2.98. Find the overall absorbed power by the resistor network.

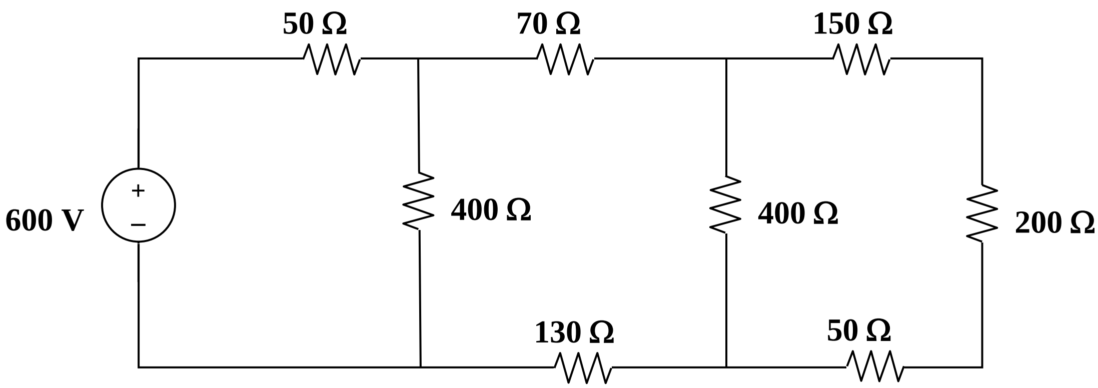


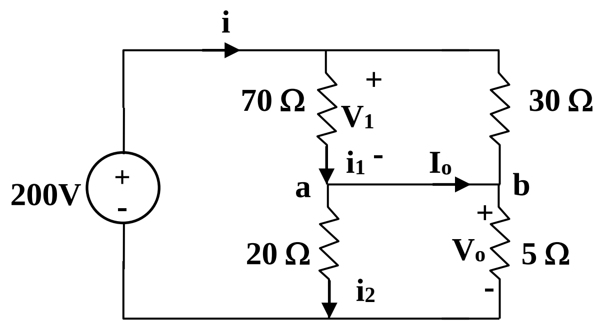

Figure 2.98
For Prob. 2.34.

Step 1. Let $R_1$ = 400(150+200+50)/(400+150+200+50) and $R_2$ = 400(70+$R_1$+130)/(400+70+$R_1$+130). Thus, the resistance seen by the source is equal to $R_{eq}$ = 50+$R_2$ and total power delivered to the circuit = $(600)^2/R_{eq}$.

Step 2. $R_1$ = 400x400/800 = 200 and $R_2$ = 400x400/800 = 200 and $R_{eq}$ = 50+200 = **250 Ω**.

P = 360,000/250 = **1.44 kW**.

**Solution 2.35**




Combining the resistors that are in parallel,

$$70 \| 30 = \frac{70x30}{100} = 21\Omega \ , \qquad 20 \| 5 = \frac{20x5}{25} = 4\ \Omega$$

$$i = \frac{200}{21+4} = 8\ \text{A}$$

$v_1$ = 21i = 168 V, $v_o$ = 4i = 32 V

$$i_1 = \frac{v_1}{70} = 2.4\ \text{A},\ i_2 = \frac{v_o}{20} = 1.6\ \text{A}$$

At node a, KCL must be satisfied

$$i_1 = i_2 + I_o \longrightarrow 2.4 = 1.6 + I_o \longrightarrow I_o = 0.8\ \text{A}$$

Hence,

$v_o$ = **32 V** and $I_o$ = **800 mA**

**Solution 2.36**

$20//(30+50) = 16$, $24 + 16 = 40$, $60//20 = 15$
$R_{eq} = 80+(15+25)40 = 80+20 = 100\ \Omega$

$i = 20/100 = 0.2$ A

If $i_1$ is the current through the 24-Ω resistor and $i_o$ is the current through the 50-Ω resistor, using current division gives

$i_1 = [40/(40+40)]0.2 = 0.1$ and $i_o = [20/(20+80)]0.1 = 0.02$ A or

$v_o = 30i_o = 30\text{x}0.02 =$ **600 mV**.

**Solution 2.37**

Given the circuit in Fig. 2.101 and that the resistance, $R_{eq}$, looking into the circuit from the left is equal to 100 Ω, determine the value of $R_1$.

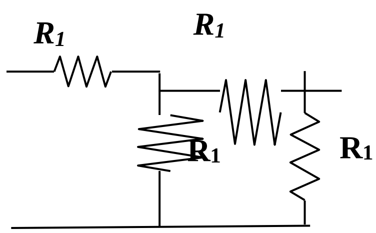



Figure 2.101
For Prob. 2.37.

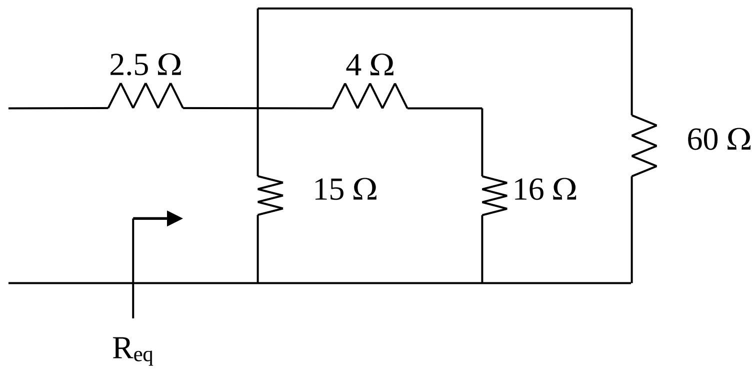
Step 1. First we calculate $R_{eq}$ in terms of $R_1$. Then we set $R_{eq}$ to 100 ohms and solve for $R_1$.

$R_{eq} = R_1 + R_1(R_1+R_1)/(R_1+R_1+R_1) = R_1[1+1(2)/3]$

Step 2. $100 = R_1(3+2)/3$ or $R_1 =$ **60 Ω**.

**Solution 2.38**

$20//80 = 80x20/100 = 16$, $6//12 = 6x12/18 = 4$
The circuit is reduced to that shown below.




$(4 + 16)//60 = 20x60/80 = 15$

$R_{eq} = 2.5+15||15 = 2.5+7.5 =$ **10 Ω** and

$i_o = 35/10 =$ **3.5 A**.

**Solution 2.39**

Evaluate $R_{eq}$ looking into each set of terminals for each of the circuits shown in Fig. 2.103.

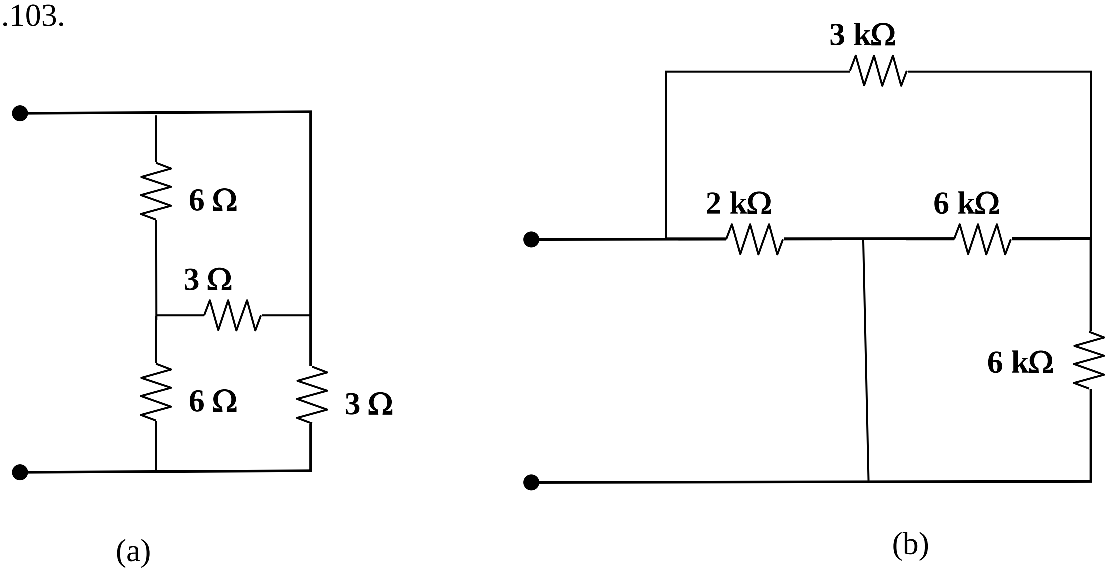



Figure 2.103
For Prob. 2.39.

Step 1. We need to remember that two resistors are in parallel if they are connected together at both the top and bottom and two resistors are connected in series if they are connected only at one end with nothing else connected at that point. With that in mind we can calculate each of the equivalent resistances.

(a) $R_{eqa} = \dfrac{3\left(6+\left(\dfrac{3x6}{(3+6)}\right)\right)}{3+6+\left(\dfrac{3x6}{(3+6)}\right)}$ and (b) $R_{eqb} = \dfrac{2k\left(3k+\left(\dfrac{6kx6k}{(6k+6k)}\right)\right)}{2k+3k+\left(\dfrac{6kx6k}{(6k+6k)}\right)}$.

Step 2. (a) $R_{eqa}$ = 3x8/11 = **2.182 Ω** and (b) $R_{eqb}$ = **1.5 kΩ**.

**Solution 2.40**

Req = $8 + 4 \| (2 + 6 \| 3) = 8 + 2 = \mathbf{10\ \Omega}$

$$I = \frac{15}{R_{eq}} = \frac{15}{10} = \mathbf{1.5\ A}$$

**Solution 2.41**

Let $R_0$ = combination of three $12\Omega$ resistors in parallel

$$\frac{1}{R_o} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} \longrightarrow R_o = 4$$

$$R_{eq} = 30 + 60 \| (10 + R_0 + R) = 30 + 60 \| (14 + R)$$

$$50 = 30 + \frac{60(14 + R)}{74 + R} \longrightarrow 74 + R = 42 + 3R$$

or R = **16 Ω**

**Solution 2.42**

(a) $R_{ab} = 5 \| (8 + 20 \| 30) = 5 \| (8 + 12) = \dfrac{5x20}{25} = \mathbf{4\ \Omega}$

(b) $R_{ab} = 2 + 4 \| (5 + 3) \| 8 + 5 \| 10 \| 4 = 2 + 4 \| 4 + 5 \| 2.857 = 2 + 2 + 1.8181 = \mathbf{5.818\ \Omega}$

**Solution 2.43**

(a) $\mathrm{R_{ab}} = 5 \| 20 + 10 \| 40 = \frac{5x20}{25} + \frac{400}{50} = 4 + 8 = \mathbf{12\ \Omega}$

(b) $60 \| 20 \| 30 = \left(\frac{1}{60} + \frac{1}{20} + \frac{1}{30}\right)^{-1} = \frac{60}{6} = 10\Omega$

$\mathrm{R_{ab}} = 80 \| (10 + 10) = \frac{80 + 20}{100} = \mathbf{16\ \Omega}$

**Solution 2.44**

For the circuits in Fig. 2.108, obtain the equivalent resistance at terminals *a-b*.

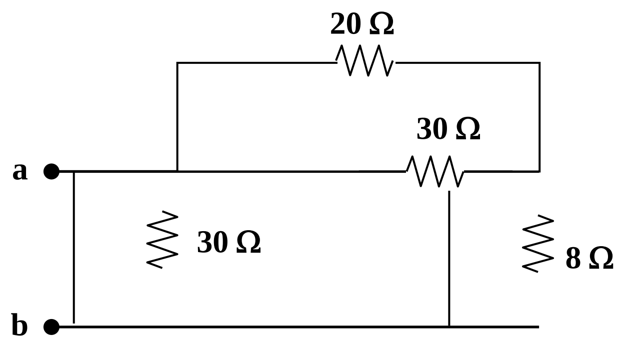



Figure 2.108
For Prob. 2.44

**Solution**

Step 1. First we note that the 20 Ω and 30 Ω resistors are in parallel and can be replaced by a [(20x30)/(20+30)] resistor which in now in series with the 8 Ω resistor which gives $R_1$. Now we $R_1$ in parallel with the 30 Ω which gives us $R_{ab}$ = [($R_1$x30)/($R_1$+30)].

Step 2. $R_1 = (600/50) + 8 = 12 + 8 = 20\ \Omega$ and

$R_{ab} = 20\text{x}30/(20+30) = \mathbf{12\ \Omega}$.

**Solution 2.45**

(a) 10//40 = 8, 20//30 = 12, 8//12 = 4.8

$R_{ab} = 5 + 50 + 4.8 = \underline{59.8\Omega}$

(b) 12 and 60 ohm resistors are in parallel. Hence, 12//60 = 10 ohm. This 10 ohm and 20 ohm are in series to give 30 ohm. This is in parallel with 30 ohm to give 30//30 = 15 ohm. And 25//(15+10) = 12.5. Thus,

$R_{ab} = 5 + 12.8 + 15 = \underline{32.5\Omega}$

**Solution 2.46**

Find I in the circuit of Fig. 2.110.

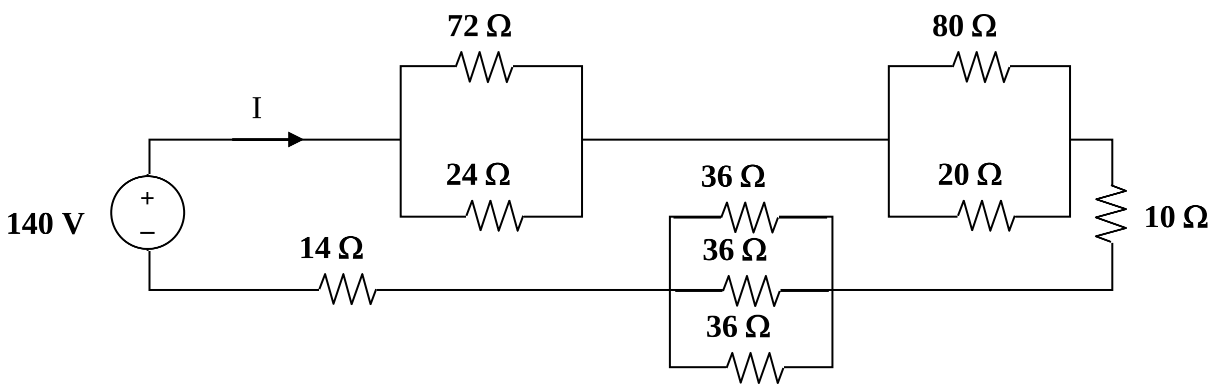



Figure 2.110
For Prob. 2.46.

**Solution**

Step 1. First we need to determine the total resistance that the source sees.

$R_{eq} = \frac{24x72}{24+72} + \frac{20x80}{20+80} + 10 + \frac{1}{\frac{1}{36}+\frac{1}{36}+\frac{1}{36}} + 14$ and I = 140/$R_{eq}$.

Step 2. $R_{eq}$ = 18+16+10+12+14 = 70 Ω and I = 140/70 = **2 amps**.

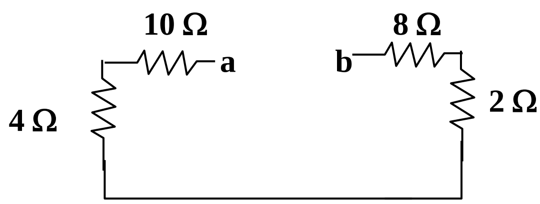
$R_{eq}$ = 12 + 5||20 + [1/((1/15)+(1/15)+(1/15))] + 5 + 24||8
= 12 + 4 + 5 + 5 + 6 = 32 Ω

I = 80/32 = **2.5 A**

**Solution 2.47**

$$5 \| 20 = \frac{5x20}{25} = 4\Omega$$

$$6 \| 3 = \frac{6x3}{9} = 2\Omega$$




$R_{ab} = 10 + 4 + 2 + 8 = \mathbf{24\ \Omega}$

**Solution 2.48**

(a) $R_a = \dfrac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \dfrac{100 + 100 + 100}{10} = 30$

$R_a = R_b = R_c =$ **30 Ω**

(b) $R_a = \dfrac{30x20 + 30x50 + 20x50}{30} = \dfrac{3100}{30} = 103.3\Omega$

$R_b = \dfrac{3100}{20} = 155\Omega, \quad R_c = \dfrac{3100}{50} = 62\Omega$

$R_a =$ **103.3 Ω**, $R_b =$ **155 Ω**, $R_c =$ **62 Ω**

**Solution 2.49**

Transform the circuits in Fig. 2.113 from Δ to Y.

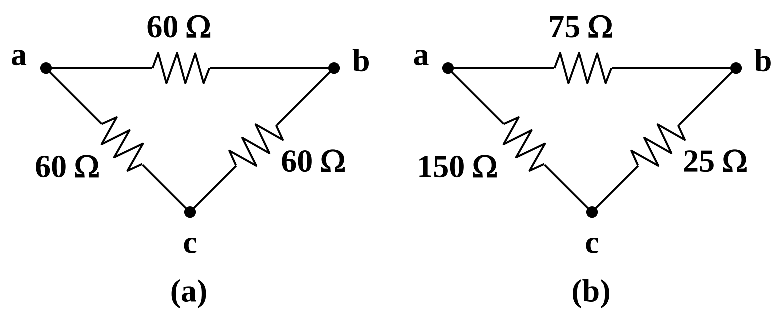



Figure 2.113
For Prob. 2.49.

Step 1. (a) $R_{an} = \frac{60x60}{60+60+60} = R_{bn} = R_{cn}$ and

(b) $R_{an} = \frac{150x75}{150+75+25}$; $R_{bn} = \frac{25x75}{150+75+25}$; $R_{cn} = \frac{150x25}{150+75+25}$.

Step 2. (a) $R_{an}$ = **20 Ω**= $R_{bn} = R_{cn}$ and

(b) $R_{an}$ = 11250/250 = **45 Ω**; $R_{bn}$ = 1875/250 = **7.5 Ω**; and
$R_{cn}$ = 3750/250 = **15 Ω**.

$R_{an}$ $R_{bn}$ $R_{cn}$

**Solution 2.50**

Design a problem to help other students better understand wye-delta transformations using Fig. 2.114.

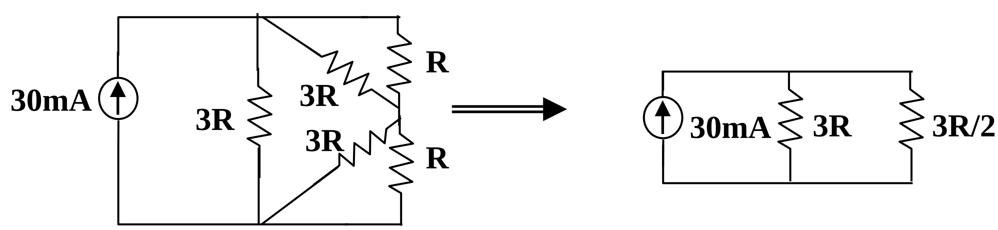
Although there is no correct way to work this problem, this is an example based on the same kind of problem asked in the third edition.

**Problem**

What value of *R* in the circuit of Fig. 2.114 would cause the current source to deliver 800 mW to the resistors.

**Solution**

Using $R_\Delta = 3R_Y = 3R$, we obtain the equivalent circuit shown below:




$$3R \| R = \frac{3R\text{x}R}{4R} = \frac{3}{4}R$$

$$3R \| \left(\frac{3}{4}R + \frac{3}{4}R\right) = 3R \| \frac{3}{2}R = \frac{3R\text{x}\frac{3}{2}R}{3R + \frac{3}{2}R} = R$$

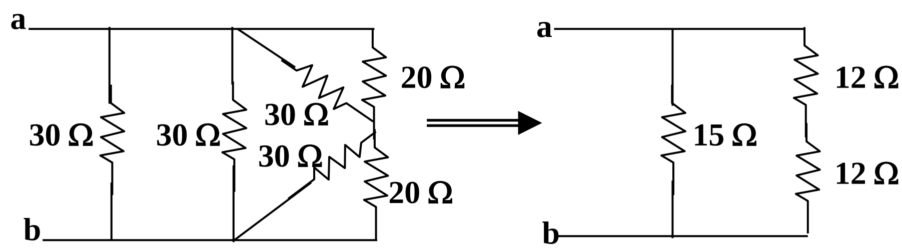
$P = I^2R \longrightarrow 800 \text{ x } 10^{-3} = (30 \text{ x } 10^{-3})^2 R$

R = **889 Ω**

**Solution 2.51**

(a) $30 \| 30 = 15\Omega$ and $30 \| 20 = 30x20/(50) = 12\Omega$

$R_{ab}$ = $15 \| (12+12) = 15x24/(39) = \mathbf{9.231\ \Omega}$



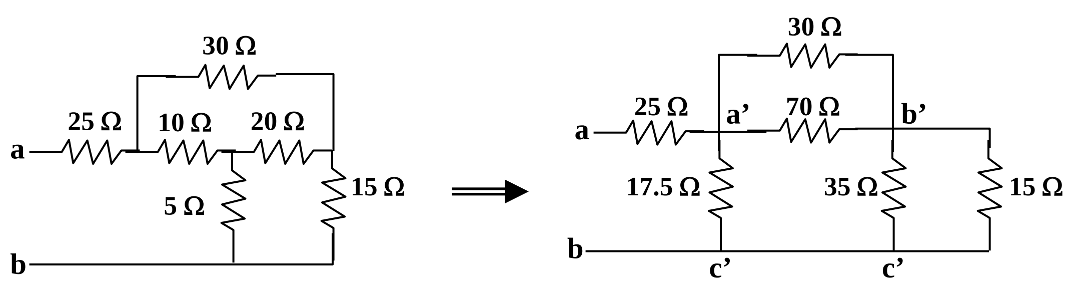

(b) Converting the T-sub network into its equivalent $\Delta$ network gives

$R_{a'b'}$ = 10x20 + 20x5 + 5x10/(5) = 350/(5) = 70 Ω
$R_{b'c'}$ = 350/(10) = 35Ω, Ra'c' = 350/(20) = 17.5 Ω

Also $30 \| 70 = 30x70/(100) = 21\Omega$ and 35/(15) = 35x15/(50) = 10.5

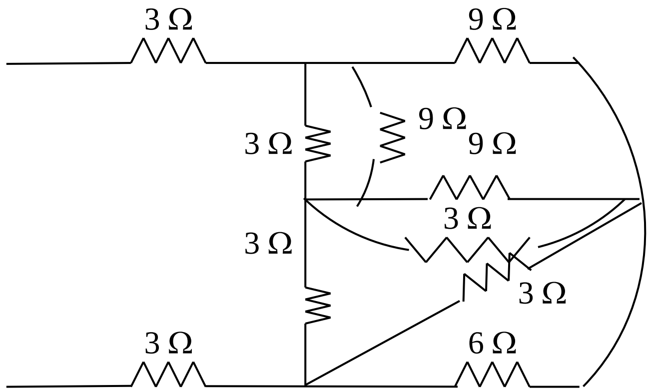
$R_{ab}$ = 25 + $17.5 \| (21+10.5)$ = $25 + 17.5 \| 31.5$

$R_{ab}$ = **36.25 Ω**

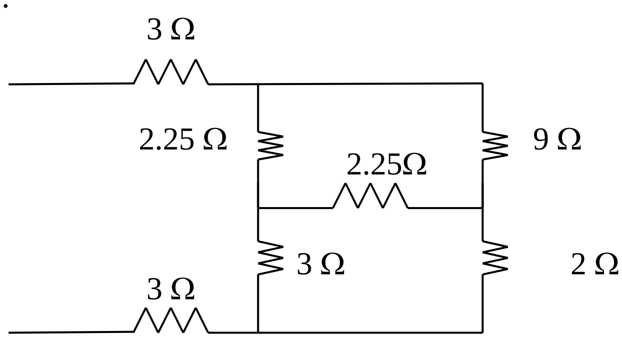


**Solution 2.52**

Converting the wye-subnetwork to delta-subnetwork, we obtain the circuit below.




3//1 = 3x1/4 = 0.75, 2//1 =2x1/3 = 0.6667. Combining these resistances leads to the circuit below.

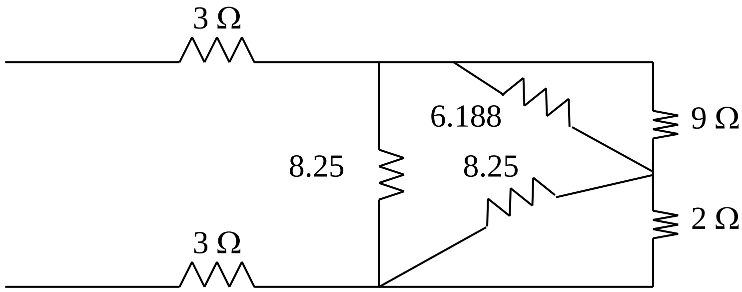



We now convert the wye-subnetwork to the delta-subnetwork.

$R_a$ = [(2.25x3+2.25x3+2.25x2.25)/3] = 6.188 Ω

$R_b$ = $R_c$ = 18.562/2.25 = 8.25 Ω

This leads to the circuit below.

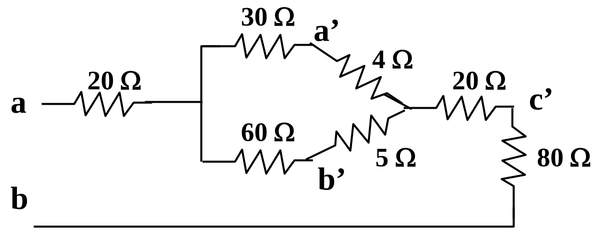


$R = 9||6.188+8.25||2 = 3.667+1.6098 = 5.277$

$R_{eq} = 3+3+8.25||5.277 =$ **9.218 Ω**.

**Solution 2.53**

(a) Converting one $\Delta$ to T yields the equivalent circuit below:




$$R_{a'n} = \frac{40x10}{40+10+50} = 4\Omega,\ \ R_{b'n} = \frac{10x50}{100} = 5\Omega,\ \ R_{c'n} = \frac{40x50}{100} = 20\Omega$$

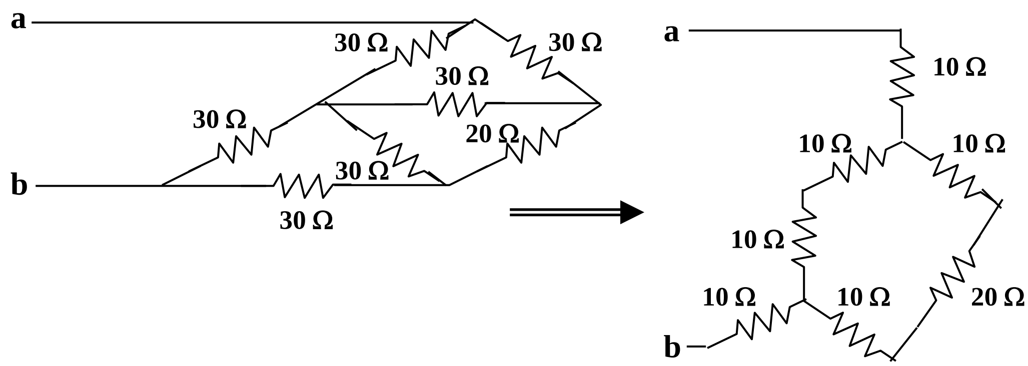
$R_{ab}$ = 20 + 80 + 20 + $(30+4)\|(60+5) = 120 + 34\|65$

$R_{ab}$ = **142.32 Ω**

(b) We combine the resistor in series and in parallel.

$$30\|(30+30) = \frac{30x60}{90} = 20\Omega$$

We convert the balanced $\Delta$s to Ts as shown below:




$R_{ab}$ = 10 + $(10+10)\|(10+20+10)+10 = 20+20\|40$

**$R_{ab}$ = 33.33 Ω**

**Solution 2.54**

Consider the circuit in Fig. 2.118. Find the equivalent resistance at terminals:
(a) a-b, (b) c-d.

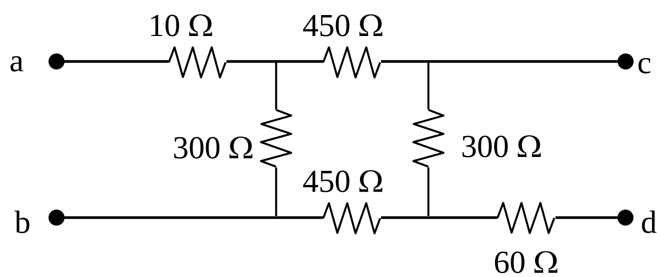



Figure 2.118
For Prob. 2.54.

Step 1. $R_{ab} = 10 + \frac{300x(450+300+450)}{300+450+300+450}$ nd $R_{cd} = \frac{300(450+300+450)}{300+450+300+450}$ 60.

Step 2. $R_{ab}$ = 10+240 = **250 Ω** and $R_{cd}$ = 240+60 = **300 Ω**.

## Solution 2.55

Calculate $I_o$ in the circuit of Fig. 2.119.

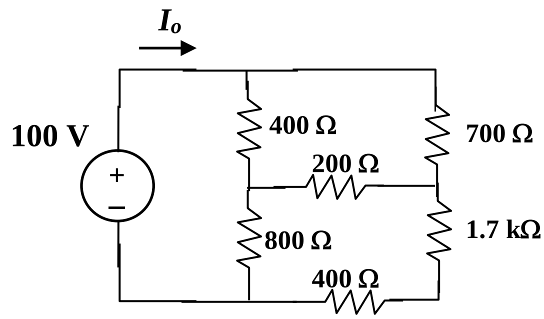
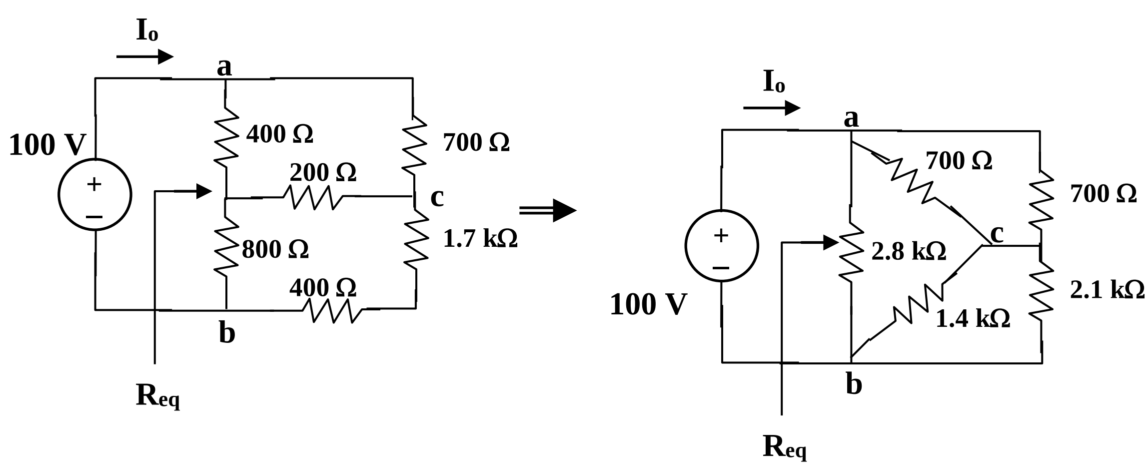



Figure 2.119
For Prob. 2.55.

## Solution

Step 1. First we convert the T to $\Delta$.



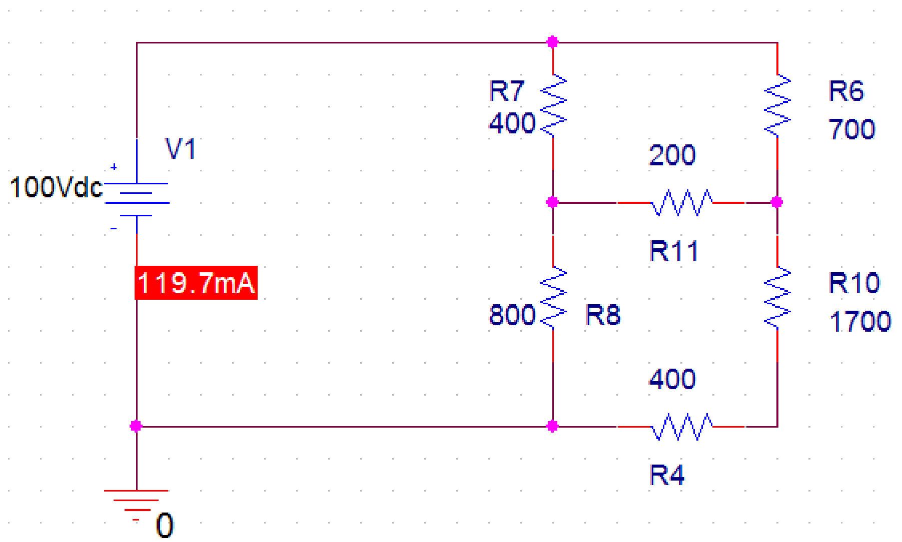

Next we let $R_1 = 400$; $R_2 = 800$; and $R_3 = 200$. Now we can calculate the values of the delta circuit. Let $R_{num} = 400x800+800x200+200x400$ and then we get $R_{ab} = R_{num}/R_3$; $R_{bc} = R_{num}/R_1$; $R_{ac} = R_{num}/R_2$. Finally $R_{eq} = \dfrac{2.8k\left[\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}1.7k}{R_{bc}+1.7k}\right]}{2.8k+\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}1.7k}{R_{bc}+1.7k}}$ and $I_o = 100/R_{eq}$.

Step 2. $R_{num} = 400x800+800x200+200x400 = 560{,}000$ and then we get $R_{ab} = 560{,}000/200 = 2{,}800$; $R_{bc} = 560{,}000/400 = 1{,}400$; $R_{ac} = 560{,}000/800 = 700$.

Let $R_{acb} = \left[\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}2.1k}{R_{bc}+2.1k}\right] = \left[\frac{700x700}{700+700}+\frac{1.4k2.1k}{1.4k+2.1k}\right] = 350+840 = 1190.$

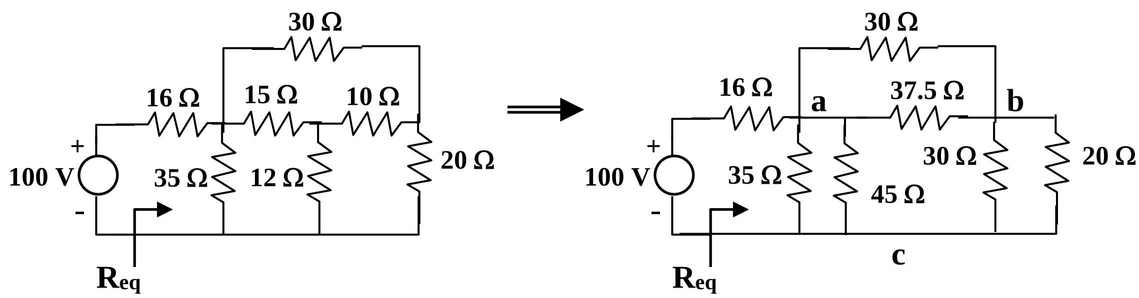
$R_{eq} = \frac{2.8k[1190]}{2.8k+1190} = \frac{3.332k}{3.99} = 835.1\ \Omega$ and $I_o = 100/835.1 =$ **119.75 mA**.

Checking with PSpice we get,



**Solution 2.56**

We need to find $R_{eq}$ and apply voltage division. We first transform the Y network to $\Delta$.




$$R_{ab} = \frac{15x10 + 10x12 + 12x15}{12} = \frac{450}{12} = 37.5\Omega$$

$R_{ac}$ = 450/(10) = 45Ω, $R_{bc}$ = 450/(15) = 30Ω

Combining the resistors in parallel,

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

$$37.5||30 = (37.5x30/67.5) = 16.667\ \Omega$$

$$35||45 = (35x45/80) = 19.688\ \Omega$$

$$R_{eq} = 19.688||(12 + 16.667) = 11.672\Omega$$

By voltage division,

$$v = \frac{11.672}{11.672 + 16}100 = \underline{\mathbf{42.18\ V}}$$

**Solution 2.57**

Find $R_{eq}$ and $I$ in the circuit of Fig. 2.121.

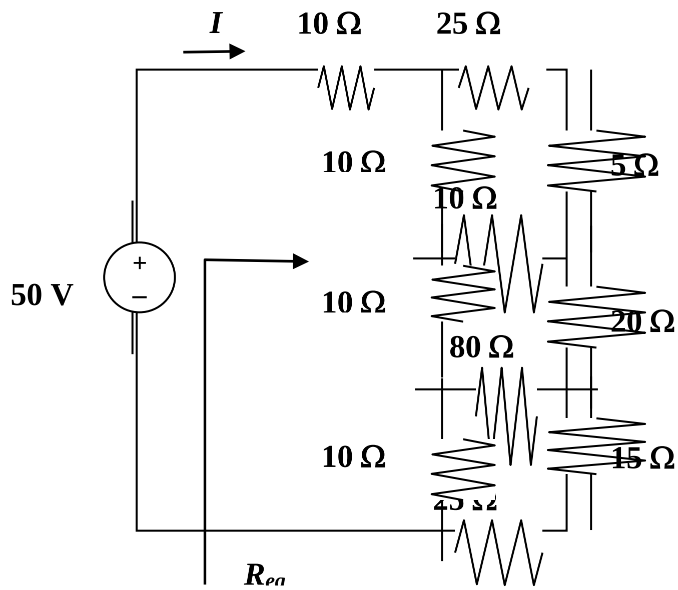
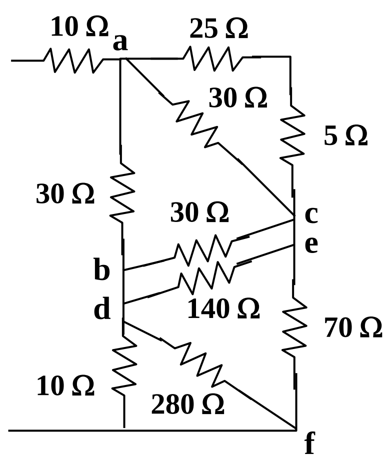



Figure 2.121
For Prob. 2.57.

**Solution**




$$R_{ab} = \frac{10x10+10x10+10x10}{10} = \frac{300}{10} = 30\ \Omega$$

$R_{ac}$ = 216/(8) = 27Ω, $R_{bc}$ = 36 Ω

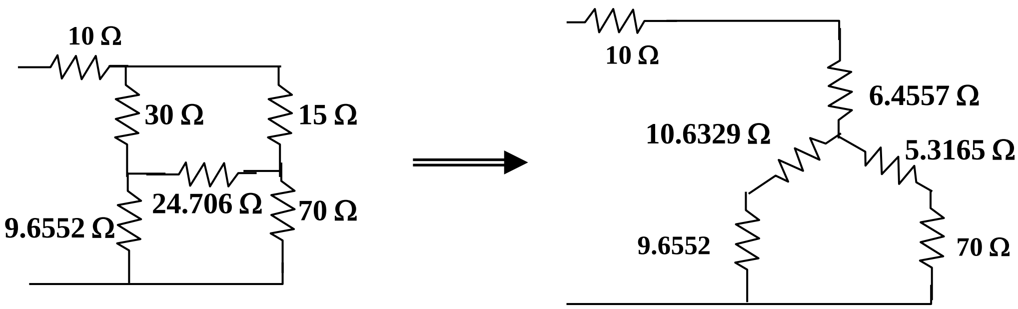
$$R_{de} = \frac{40x20+20x80+80x40}{40} = \frac{5600}{40} = 140\ \Omega$$

$R_{ef}$ = 5600/(80) = 70 Ω, $R_{df}$ = 5600/(20) = 280 Ω

Combining resistors in parallel,

$$30\|30 = \frac{900}{60} = 15\,\Omega,\quad 30\|140 = \frac{4200}{170} = 24.706\,\Omega$$

$$10\|280 = \frac{2800}{290} = 9.6552\,\Omega$$




$$R_{an} = \frac{30x15}{30+15+24.706} = \frac{450}{69.706} = 6.4557\ \Omega$$

$$R_{bn} = \frac{30x24.706}{69.706} = 10.6329\ \Omega$$

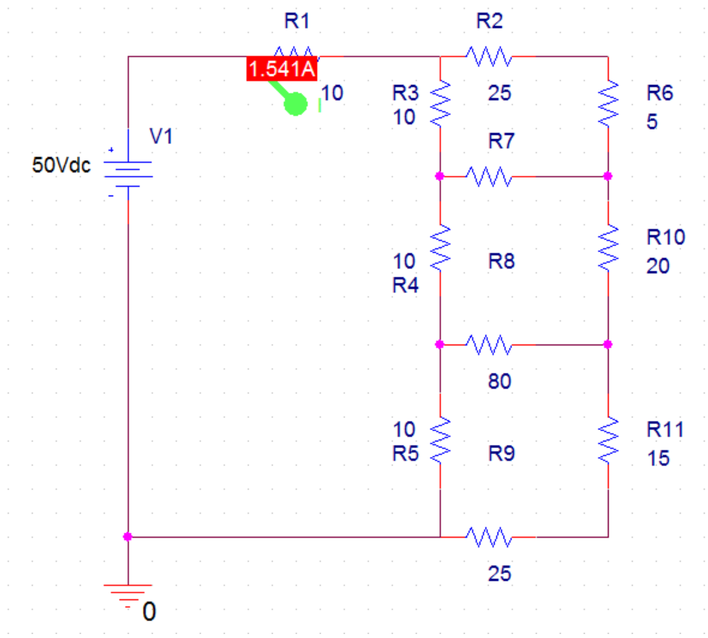
$$R_{cn} = \frac{24.706x15}{69.706} = 5.3165\ \Omega$$

$$R_{eq} = 10 + 6.4557 + (10.6329 + 9.6552)\|(5.3165 + 70)$$

$$= 16.4557 + 20.2881 \,||\, 75.3165 = 16.4557 + 1528.03/95.605$$

$R_{eq}$ = **32.44 Ω** and I = 50/($R_{eq}$) = **1.5413 A**

Checking with PSpice we get,



**Solution 2.58**

The 150 W light bulb in Fig. 2.122 is rated at 110 volts. Calculate the value of $V_s$ to make the light bulb operate at its rated conditions.

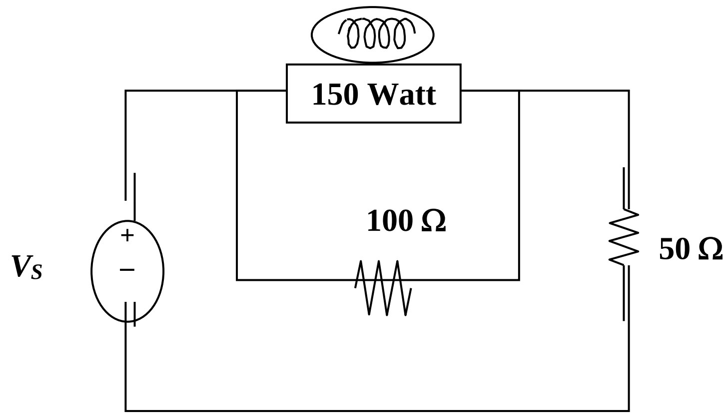
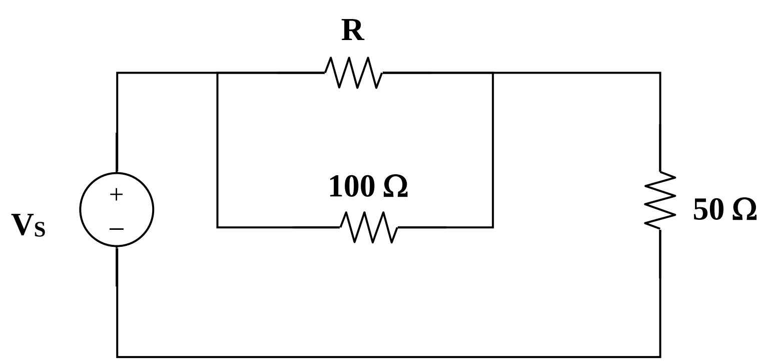



Figure 2.112
For Prob. 2.58.

**Solution**

Step 1. First we need to calculate the value of the resistance of the lightbulb. 150 = $(110)^2/R$ or $R = (110)^2/150$. Now we have an equivalent circuit as shown below.




Next we note that $V_R$ = 110 volts. The equivalent parallel resistance is equal to $100R/(100+R) = R_{eq}$. Now we have a simple voltage divider or $110 = V_s[R_{eq}/(R_{eq}+50)]$ and $V_s = 110(R_{eq}+50)/R_{eq}$.

Step 2. R = 80.667 and $R_{eq}$ = 8066.7/180.667 = 44.65. This leads to,

$V_s$ = 110(94.65)/44.65 = **233.2 volts**.

**Solution 2.59**

An enterprising young man travels to Europe carrying three lightbulbs he had purchased in North America. The lightbulbs he has are a 100 watt lightbulb, a 60 watt lightbulb, and a 40 watt lightbulb. Each lightbulb is rated at 110 volts. He wishes to connect these to a 220 volt system that is found in Europe. For reasons we are not sure of, he connects the 40 watt lightbulb in series with a parallel combination of the 60 watt lightbulb and the 100 watt lightbulb as shown Fig. 2.123. How much power is actually being delivered to each lightbulb? What does he see when he first turns on the lightbulbs?

Is there a better way to connect these lightbulbs in order to have them work more effectively?

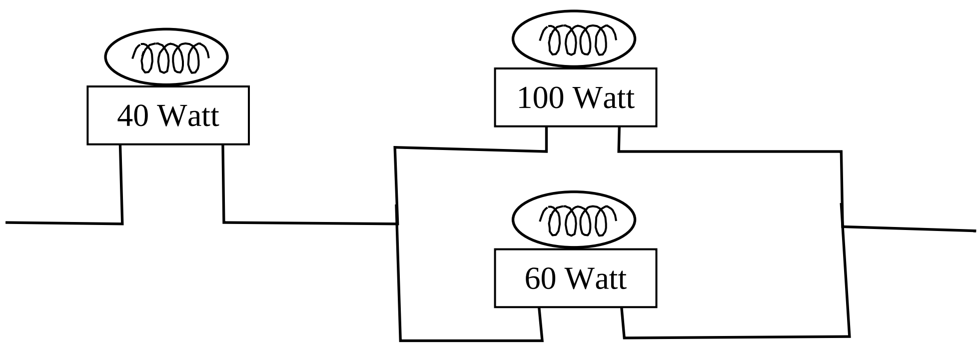



Figure 2.123
For Prob. 2.59.

**Solution**

Step 1. Using $p = v^2/R$, we can calculate the resistance of each bulb.

$R_{40W} = (110)^2/40$
$R_{60W} = (110)^2/60$
$R_{100W} = (110)^2/100$

The total resistance of the series parallel combination of the bulbs is
$R_{Tot} = R_{40W} + R_{100W}R_{60W}/(R_{100W} + R_{60W})$.

We can now calculate the voltage across each bulb and then calculate the power delivered to each. $V_{40W} = (220/R_{Tot})R_{40W}$ and the voltage across the other two, $V_{60||100}$, will equal $220 – V_{40W}$. $P_{40W} = (V_{40W})^2/R_{40W}$, $P_{60W} = (V_{60||100})^2/R_{60W}$, and $P_{100W} = (V_{60||100})^2/R_{100W}$.

Step 2.
$R_{40W} = (110)^2/40 = 12{,}100/40 = 302.5\ \Omega$
$R_{60W} = (110)^2/60 = 12{,}100/60 = 201.7\ \Omega$

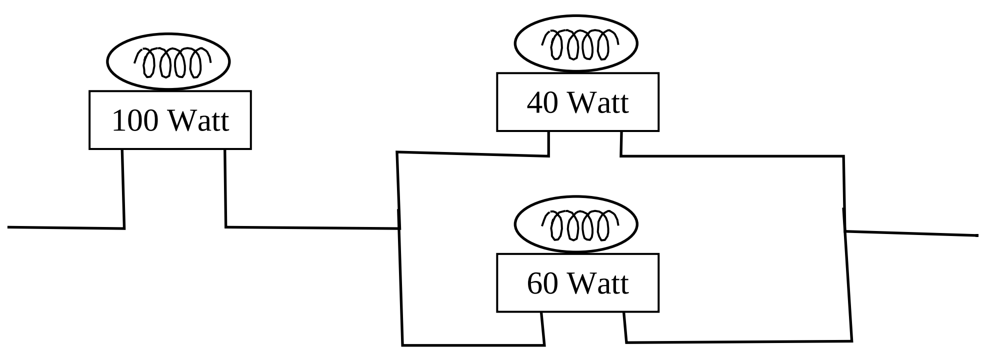
$R_{100W} = (110)^2/100 = 12{,}100/100 = 121\ \Omega$

$R_{Tot} = 302.5 + 121x201.7/(121+201.7) = 302.5 + 24{,}406/322.7 = 302.5+75.63 = 378.1\ \Omega$.

$V_{40W} = (220/R_{Tot})R_{40W} = 0.5819x302.5 = 176$ volts and the voltage across the other two, $V_{100||40}$, will equal $220 - V_{40W} = 44$ volts. $P_{40W} = (V_{40W})^2/R_{40W} = 30976/302.5 =$ **102.4 watts**, $P_{60W} = (V_{60||100})^2/R_{60W} = 1936/201.7 =$ **9.6 watts**, and $P_{100W} = (V_{60||100})^2/R_{100W} = 1936/121 =$ **16 watts**.

Clearly when he flips the switch to light the bulbs the 40 watt bulb will flash bright as it burns out! Not a good thing to do!

Is there a better way to connect them? There are two other possibilities. However what if we place the bulb with the lowest resistance in series with a parallel combination of the other two what happens? Logic would dictate that this might give the best result. So, let us try the 100 watt bulb in series with the parallel combination of the other two as shown below.




Now we get, $R_{Tot} = 121 + 302.5x201.7/(302.5+201.7) = 121 + 61{,}014/504.2 = 121+121.01 = 242\ \Omega$. Without going further we can see that this will work since the resistances are essentially equal which means that each bulb will work as if they were individually connected to a 110 volt system.

$V_{100W} = (220/R_{Tot})121 = 110$ and the voltage across the other two, $V_{60||40}$, will equal $220 - V_{100W} = 110$. $P_{100W} = (V_{100W})^2/121 =$ **100 watts**, $P_{60W} = (V_{60||40})^2/201.7 =$ **60 watts**, and $P_{40W} = (V_{60||40})^2/302.5 =$ **40 watts**. This will work!

Answer: $P_{40W} = 102.4$ W (means that this immediately burns out), $P_{60W} = 9.6$ W, $P_{100W} = 16$ W. The best way to wire the bulbs is to connect the 100 W bulb in series with a parallel combination of the 60 W bulb and the 40 W bulb.

**Solution 2.60**

If the three bulbs of Prob. 2.59 are connected in parallel to the 120-V source, calculate the current through each bulb.

**Solution**

Using $p = v^2/R$, we can calculate the resistance of each bulb.

$R_{30W} = (120)^2/30 = 14{,}400/30 = 480\ \Omega$

$R_{40W} = (120)^2/40 = 14{,}400/40 = 360\ \Omega$

$R_{50W} = (120)^2/50 = 14{,}400/50 = 288\ \Omega$

The current flowing through each bulb is 120/R.

$i_{30} = 120/480 =$ **250 mA**.

$i_{40} = 120/360 =$ **333.3 mA**.

$i_{30} = 120/288 =$ **416.7 mA**.

Unlike the light bulbs in 2.59, the lights will glow brightly!

**Solution 2.61**

There are three possibilities, but they must also satisfy the current range of 1.2 + 0.06 = 1.26 and 1.2 – 0.06 = 1.14.

(a) Use $R_1$ and $R_2$:
$R = R_1 \| R_2 = 80 \| 90 = 42.35\Omega$
$p = i^2R = 70W$
$i^2 = 70/42.35 = 1.6529$ or $i = 1.2857$ (which is outside our range)
cost = \$0.60 + \$0.90 = \$1.50

(b) Use $R_1$ and $R_3$:
$R = R_1 \| R_3 = 80 \| 100 = 44.44\ \Omega$
$i^2 = 70/44.44 = 1.5752$ or $i = 1.2551$ (which is within our range),
cost = \$1.35

(c) Use $R_2$ and $R_3$:
$R = R_2 \| R_3 = 90 \| 100 = 47.37\Omega$
$i^2 = 70/47.37 = 1.4777$ or $i = 1.2156$ (which is within our range),
cost = \$1.65

Note that cases (b) and (c) satisfy the current range criteria and (b) is the cheaper of the two, hence the correct choice is:

**$R_1$ and $R_3$**

**Solution 2.62**

$p_A$ = 110x8 = 880 W,     $p_B$ = 110x2 = 220 W

Energy cost = \$0.06 x 365 x10 x (880 + 220)/1000 = **\$240.90**

**Solution 2.63**

Use eq. (2.61),

$$R_n = \frac{I_m}{I - I_m} R_m = \frac{2x10^{-3} x100}{5 - 2x10^{-3}} = 0.04\Omega$$

$$I_n = I - I_m = 4.998 \text{ A}$$

$$p = I_n^2 R = (4.998)^2 (0.04) = 0.9992 \cong \mathbf{1\ W}$$

**Solution 2.64**

The potentiometer (adjustable resistor) $R_x$ in Fig. 2.126 is to be designed to adjust current $I_x$ from 10 mA to 1 A. Calculate the values of $R$ and $R_x$ to achieve this.

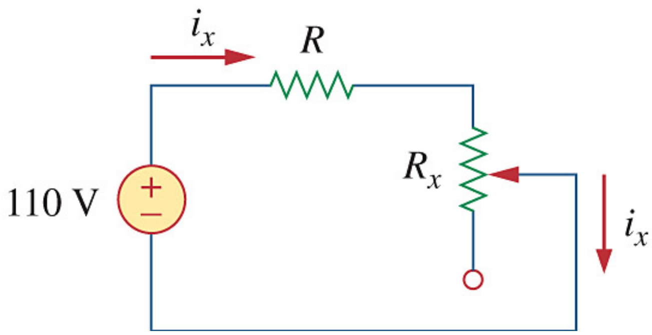



Figure 2.126
For Prob. 2.64.

**Solution**

Step 1. Even though there are an infinite number of combinations that can meet these requirements, we will focus on making the potentiometer the most sensitive.

First we will determine the value of R by setting the potentiometer equal to zero. $i_x = 110/R = 1$ A. Next we set the potentiometer to its maximum value or $0.01 = 110/(R+R_x)$ or $R_x = (110/0.01) - R$. We now have enough equations to solve for R and $R_x$.

Step 2.

$$R = \mathbf{110\ \Omega} \text{ and } R_x = 11{,}000 - 110 = \mathbf{10.89\ k\Omega}.$$

**Solution 2.65**

Design a circuit that uses a d'Arsonval meter (with an internal resistance of 2 kΩ that requires a current of 5 mA to cause the meter to deflect full scale) to build a voltmeter to read values of voltages up to 100 volts.

**Solution.**

Step 1. Since 100 volts across the meter will cause the current through the meter to be 100/2,000 = 0.05 amps, a way must be found to limit the current to 0.005 amps. Clearly adding a resistance in series with the meter will accomplish that. The value of the resistance can be found by solving for $100/R_{Tot} = 0.005$ amps where $R_{Tot} = 2{,}000 + R_s$.

Step 2. $R_{Tot} = 100/0.005 = 20$ kΩ. $R_s = 20{,}000 - 2{,}000 = 18$ kΩ. So, our **circuit consists of the meter in series with an 18 kΩ resistor.**

**Solution 2.66**

$$20\ \mathrm{k\Omega/V} = \text{sensitivity} = \frac{1}{I_{fs}}$$

$$\text{i.e., } I_{fs} = \frac{1}{20}\mathrm{k\Omega/V} = 50\ \mu\mathrm{A}$$

The intended resistance $R_m = \dfrac{V_{fs}}{I_{fs}} = 10(20\mathrm{k\Omega/V}) = 200\mathrm{k\Omega}$

(a) $$R_n = \frac{V_{fs}}{i_{fs}} - R_m = \frac{50\ \mathrm{V}}{50\,\mu\mathrm{A}} - 200\ \mathrm{k\Omega} = \mathbf{800\ k\Omega}$$

(b) $$p = I_{fs}^2 R_n = (50\ \mu\mathrm{A})^2(800\ \mathrm{k\Omega}) = \mathbf{2\ mW}$$

**Solution 2.67**

(a) By current division,

$$i_0 = 5/(5 + 5)\ (2\text{ mA}) = 1\text{ mA}$$
$$V_0 = (4\text{ k}\Omega)\ i_0 = 4 \text{ x } 10^3 \text{ x } 10^{-3} = \mathbf{4\ V}$$

(b) $4\text{k}\| 6\text{k} = 2.4\text{k}\Omega$. By current division,

$$i_0' = \frac{5}{1+2.4+5}(2\text{mA}) = 1.19\text{ mA}$$
$$v_0' = (2.4\text{ k}\Omega)(1.19\text{ mA}) = \mathbf{2.857\ V}$$

(c) $$\%\text{ error} = \left|\frac{v_0 - v_0'}{v_0}\right| \text{ x } 100\% = \frac{1.143}{4}\text{x}100 = \mathbf{28.57\%}$$

(d) $4\text{k}\| 36\text{ k}\Omega = 3.6\text{ k}\Omega$. By current division,

$$i_0' = \frac{5}{1+3.6+5}(2\text{mA}) = 1.042\text{mA}$$
$$v_0'(3.6\,\text{k}\Omega)(1.042\,\text{mA}) = 3.75\text{V}$$
$$\%\text{ error} = \left|\frac{v - v_0'}{v_0}\right|\text{x}100\% = \frac{0.25\text{x}100}{4} = \mathbf{6.25\%}$$

**Solution 2.68**

(a) $40 = 24 \| 60\Omega$

$$i = \frac{4}{16+24} = \mathbf{100\ mA}$$

(b) $$i^{'} = \frac{4}{16+1+24} = \mathbf{97.56\ mA}$$

(c) $$\%\ \text{error} = \frac{0.1-0.09756}{0.1} \text{x}100\% = \mathbf{2.44\%}$$

**Solution 2.69**

A voltmeter is used to measure $V_o$ in the circuit in Fig. 2.129. The voltmeter model consists of an ideal voltmeter in parallel with a 250-kΩ resistor. Let $V_s$ = 95 V, $R_s$ = 25 kΩ, and $R_1$ = 40 kΩ. Calculate $V_o$ with and without the voltmeter when

(a) $R_2$ = 5 kΩ (b) $R_2$ = 25 kΩ

(c) $R_2$ = 250 kΩ

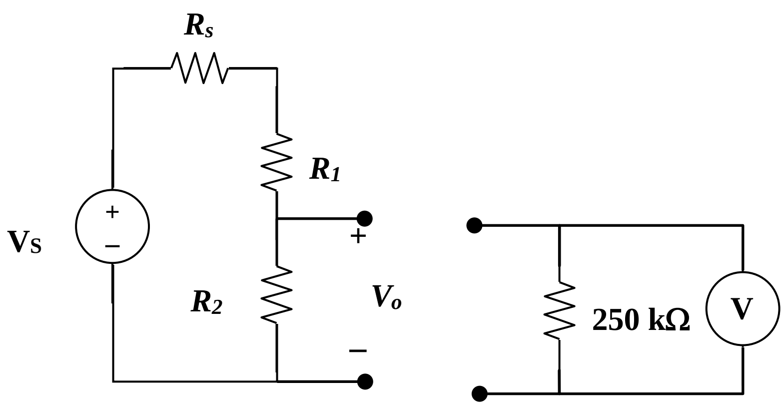



Figure 2.129
For Prob. 2.69

**Solution**

Step 1. $V_o = V_s \dfrac{\left(\frac{250kR_2}{250k+R_2}\right)}{R_s+R_1+\frac{250kR_2}{250k+R_2}} = 95\dfrac{\left(\frac{250kR_2}{250k+R_2}\right)}{65k+\frac{250kR_2}{250k+R_2}}$ and

$V_o = V_s \dfrac{R_2}{R_s+R_1+R_2} = 95\dfrac{R_2}{65k+R_2}$.

Step 2. (a) $V_o = 95\dfrac{\left(\frac{250kR_2}{250k+R_2}\right)}{65k+\frac{250kR_2}{250k+R_2}}$ = 95(4.902/69.902) = **6.662 volts** and

$V_o = 95\dfrac{R_2}{65k+R_2}$ = 95(5k/70k) = **6.786 volts**

(b) $V_o = 95\dfrac{\left(\frac{250kR_2}{250k+R_2}\right)}{65k+\frac{250kR_2}{250k+R_2}}$ = 95(22.727/87.727) = **24.61 volts** and

$V_o = 95\dfrac{R_2}{65k+R_2}$ = 95(25/90) = **26.39 volts**

(c) $V_o = 95\dfrac{\left(\frac{250kR_2}{250k+R_2}\right)}{65k+\frac{250kR_2}{250k+R_2}}$ = 95(125/190) = **62.5 volts** and

$V_o = 95\dfrac{R_2}{65k+R_2}$ = 95(250/315) = **75.4 volts**

**Solution 2.70**

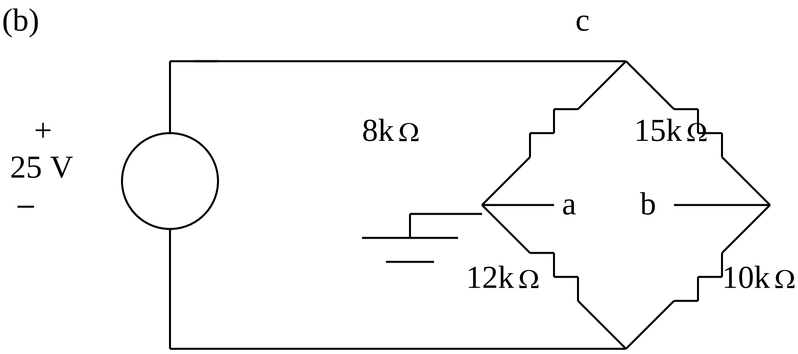
(a) Using voltage division,

$$v_a = \frac{12}{12+8}(25) = \underline{15V}$$

$$v_b = \frac{10}{10+15}(25) = \underline{10V}$$

$$v_{ab} = v_a - v_b = 15 - 10 = \underline{5V}$$

(b)




$v_a$ = $\underline{\mathbf{0}}$; $v_{ac}$ = –(8/(8+12))25 = –10V; $v_{cb}$ = (15/(15+10))25 = 15V.

$v_{ab}$ = $v_{ac}$ + $v_{cb}$ = –10 + 15 = $\underline{\mathbf{5V}}$.

$v_b$ = $-v_{ab}$ = $\underline{\mathbf{-5V}}$.

**Solution 2.71**

Figure 2.131 represents a model of a solar photovoltaic panel. Given that $V_s$ = 95 **V**, $R_1$ = 25 Ω, $i_L$ = 2 **A**, find $R_L$.

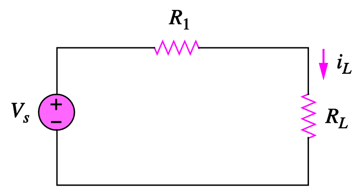


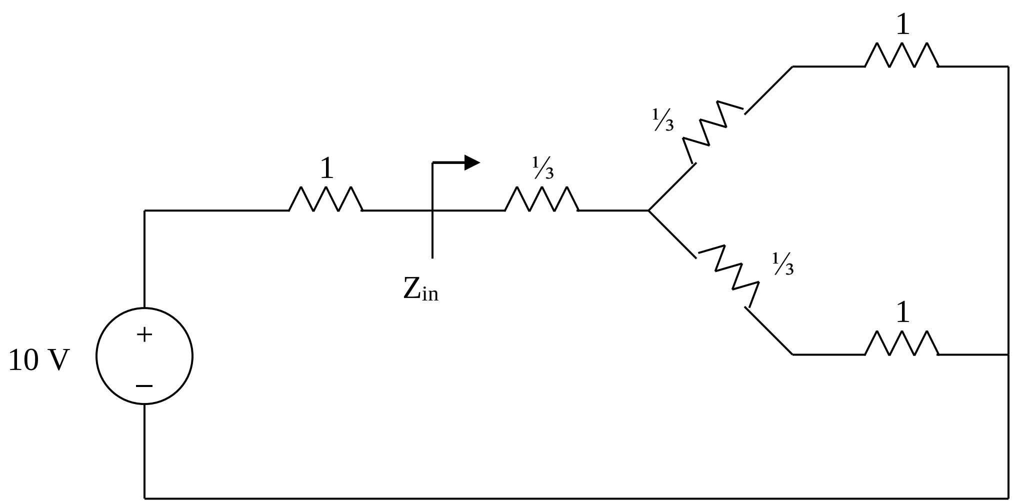

Figure 2.131
For Prob. 2.71.

Step 1. $V_s = i_L(R_1+R_L)$ or $R_L = (95/2) - 25$

Step 2. $R_L = 47.5 - 25 = \mathbf{22.5\ \Omega}$

**Solution 2.72**

Converting the delta subnetwork into wye gives the circuit below.




$$Z_{in} = \frac{1}{3} + (1+\frac{1}{3})//(1+\frac{1}{3}) = \frac{1}{3} + \frac{1}{2}(\frac{4}{3}) = 1\ \Omega$$

$$V_o = \frac{Z_{in}}{1+Z_{in}}(10) = \frac{1}{1+1}(10) = \underline{5\text{ V}}$$

**Solution 2.73**

By the current division principle, the current through the ammeter will be one-half its previous value when

$$R = 20 + R_x$$
$$65 = 20 + R_x \longrightarrow R_x = \mathbf{45\ \Omega}$$

**Solution 2.74**

With the switch in high position,

$$6 = (0.01 + R_3 + 0.02) \text{ x } 5 \longrightarrow \quad R_3 = \mathbf{1.17\ \Omega}$$

At the medium position,

$$6 = (0.01 + R_2 + R_3 + 0.02) \text{ x } 3 \longrightarrow \quad R_2 + R_3 = 1.97$$

or $R_2 = 1.97 - 1.17 = \mathbf{0.8\ \Omega}$

At the low position,

$$6 = (0.01 + R_1 + R_2 + R_3 + 0.02) \text{ x } 1 \longrightarrow \qquad R_1 + R_2 + R_3 = 5.97$$

$R_1 = 5.97 - 1.97 = \mathbf{4\ \Omega}$

**Solution 2.75**

Find $R_{ab}$ in the four-way power divider circuit in Fig. 2.135. Assume each $R = 4\ \Omega$.

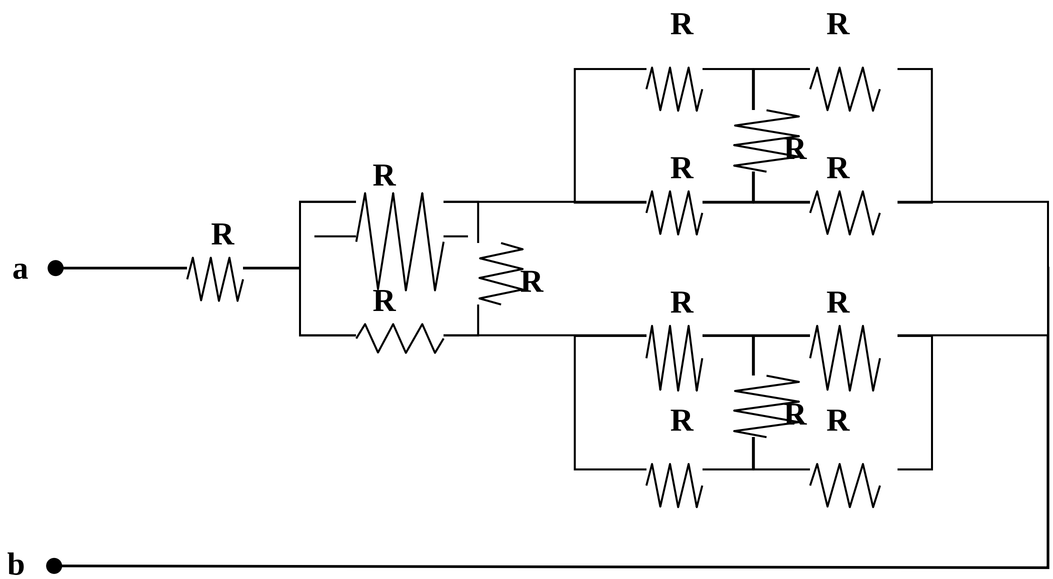
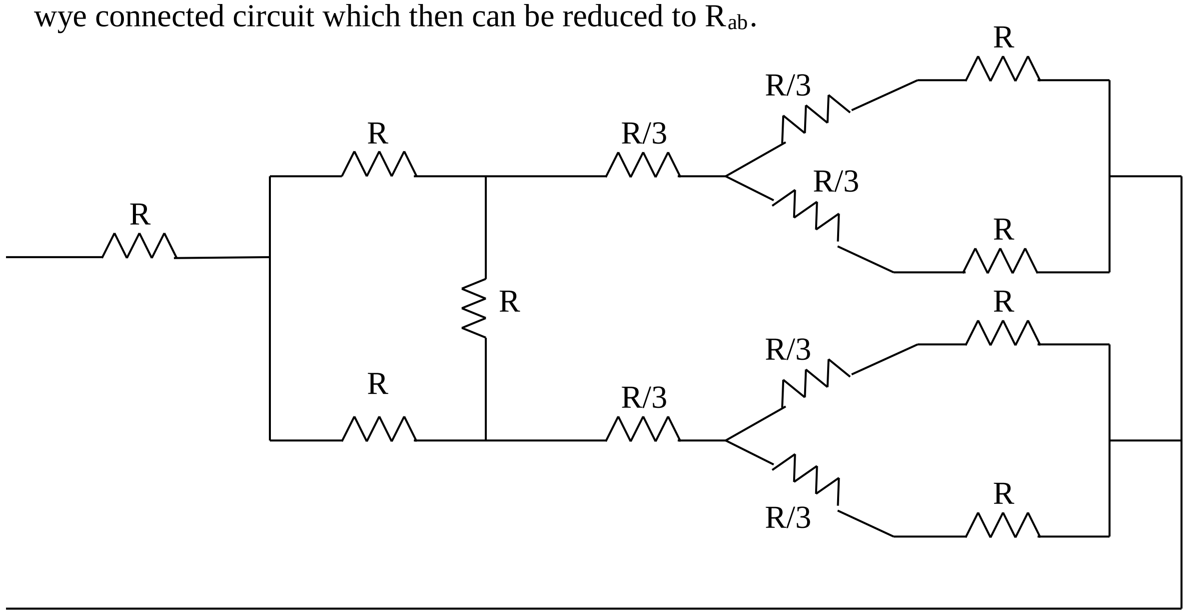



Figure 2.135
For Prob. 2.75.

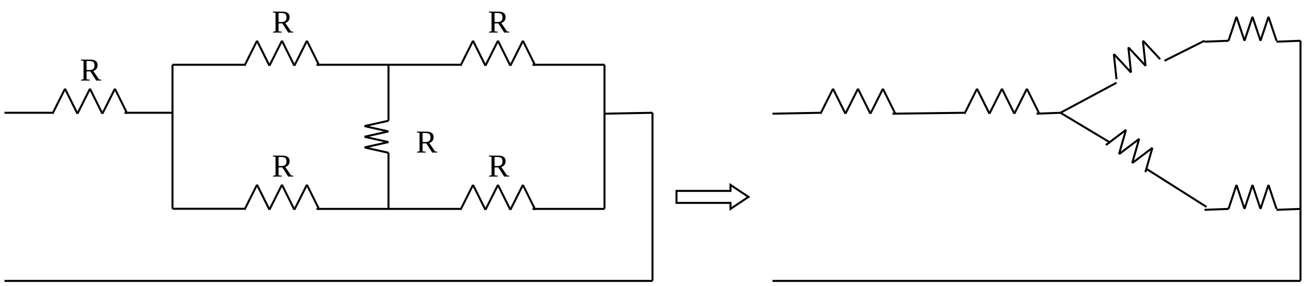
Step 1. There are two delta circuits that can be converted to a wye connected circuit. This then allows us to combine resistances together in series and in parallel. This will yield a new circuit with one remaining delta connected circuit that can be converted to a wye connected circuit which then can be reduced to $R_{ab}$.



Step 2. Converting delta-subnetworks to wye-subnetworks and combining resistances leads to the circuit below.

$$\frac{R}{3}+\frac{(4R/3)(4R/3)}{(4R/3)+(4R/3)}=R\left(\frac{1}{3}+\frac{\frac{16}{9}}{\frac{8}{3}}\right)=R$$

With this combination, the circuit is further reduced to that shown below.




Again we convert the delta to a wye connected circuit and the values of the wye resistances are all equal to R/3 and combining all the series and parallel resistors gives us R in series with R. Thus,

$$R_{ab} = R+R = 4+4 = \mathbf{8\ \Omega}$$

**Solution 2.76**

$Z_{ab} = 1 + 1 = \mathbf{2\ \Omega}$

**Solution 2.77**

(a) $5\ \Omega = 10 \| 10 = 20 \| 20 \| 20 \| 20$

i.e., **four 20 Ω resistors in parallel.**

(b) $311.8 = 300 + 10 + 1.8 = 300 + 20 \| 20 + 1.8$

i.e., **one 300Ω resistor in series with 1.8Ω resistor and a parallel combination of two 20Ω resistors.**

(c) $40\text{k}\Omega = 12\text{k}\Omega + 28\text{k}\Omega = (24 \| 24k) + (56k \| 56k)$

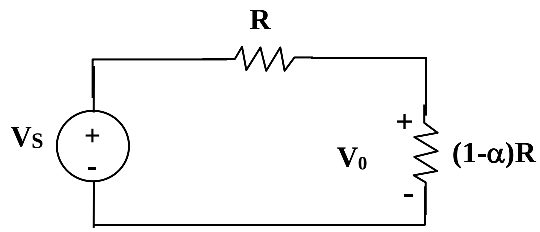
i.e., **Two 24kΩ resistors in parallel connected in series with two 56kΩ resistors in parallel.**

(d) $52.32\text{k}\Omega = 28\text{k}+24\text{k}+300+20 = 56\text{k}||56\text{k}+24\text{k}+300+20$

i.e., **A series combination of a 20Ω resistor, 300Ω resistor, 24kΩ resistor, and a parallel combination of two 56kΩ resistors.**

**Solution 2.78**

The equivalent circuit is shown below:




$$V_0 = \frac{(1-\alpha)R}{R+(1-\alpha)R} V_S = \frac{1-\alpha}{2-\alpha} V_S$$

$$\frac{V_0}{V_S} = \frac{1-\alpha}{2-\alpha}$$

**Solution 2.79**

Since $p = v^2/R$, the resistance of the sharpener is

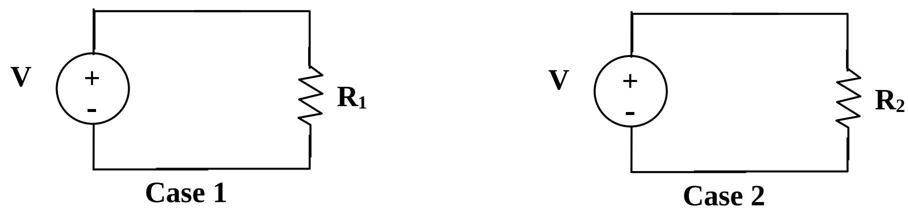
$$R = v^2/(p) = 6^2/(240 \text{ x } 10^{-3}) = 150\Omega$$
$$I = p/(v) = 240 \text{ mW}/(6\text{V}) = 40 \text{ mA}$$

Since R and $R_x$ are in series, I flows through both.

$$IR_x = V_x = 9 - 6 = 3 \text{ V}$$
$$R_x = 3/(I) = 3/(40 \text{ mA}) = 3000/(40) = \mathbf{75\ \Omega}$$

**Solution 2.80**

The amplifier can be modeled as a voltage source and the loudspeaker as a resistor:




Hence $p = \frac{V^2}{R}$, $\frac{p_2}{p_1} = \frac{R_1}{R_2} \longrightarrow p_2 = \frac{R_1}{R_2} p_1 = \frac{10}{4}(12) = \mathbf{30\ W}$

**Solution 2.81**

For a specific application, the circuit shown in Fig. 2.140 was designed so that $I_L$ = 83.33 mA and that $R_{in}$ = 5 kΩ. What are the values of $R_1$ and $R_2$?

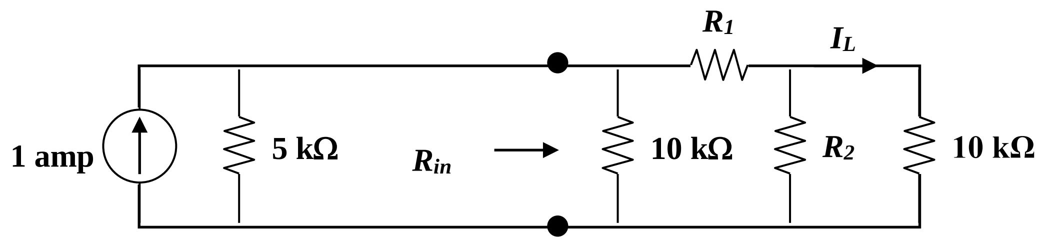



Figure 2.140
For Prob. 2.81.

**Solution**

Step 1. Calculate $R_{in}$ in terms of $R_1$ and $R_2$. Next calculate the value of $I_L$ in terms of $R_1$ and $R_2$.

$$R_{in} = \frac{10k\left(R_1 + \frac{R_2 10k}{R_2 + 10k}\right)}{10k + R_1 + \frac{R_2 10k}{R_2 + 10k}}$$ = 5k and since $R_{in}$ = 5k, the current by current division entering $R_{in}$ has to equal 500 mA. Again using current division, the current through $R_1$ = 250 mA. Finally we can use current division to obtain $I_L$.

$I_L = 0.25xR_2/(R_2+10k) = 0.08333$ A.

Step 2. First we can calculate $R_2$. $0.25R_2 = 0.08333(R_2 + 10{,}000)$ or

$(0.25–0.08333)R_2 = 833.3$ or $R_2 = 833.3/0.16667 = 5{,}000 =$ **5 kΩ**.

$$\text{Next } 5k = \frac{10k\left(R_1 + \frac{5kx10k}{5k + 10k}\right)}{10k + R_1 + \frac{5k10k}{5k + 10k}} = \frac{10k\left(R_1 + 3.3333k\right)}{10k + R_1 + 3.3333k} \text{ or}$$

$5k(R_1+13.3333k) = 10k(R_1+3.3333)$ or $R_1+13.3333 = 2R_1 + 6.6666$ or

$R_1 = 13.3333k–6.6666k = 6.6667k =$ **6.667 kΩ**.

**Solution 2.82**

The pin diagram of a resistance array is shown in Fig. 2.141. Find the equivalent resistance between the following:

(a) 1 and 2 (b) 1 and 3 (c) 1 and 4

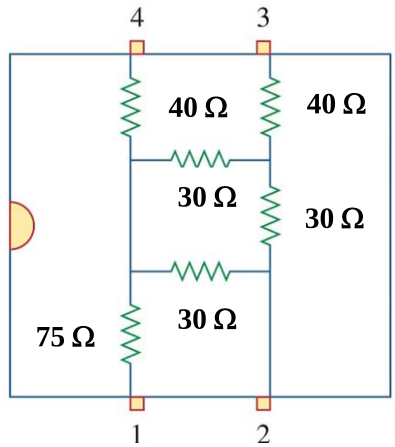
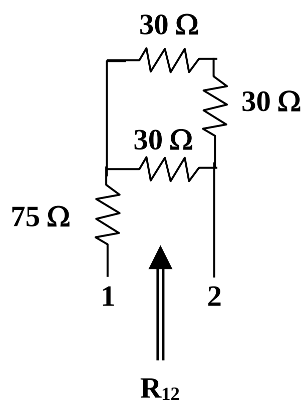



Figure 2.141
For Prob. 2.82.

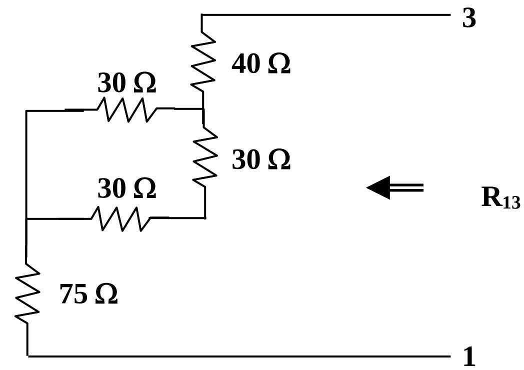
**Solution**

Step 1. Each pair of contacts will connect a specific circuit where we can use the variety of wye-delta, series, and paralleling of resistances to obtain the desired results.

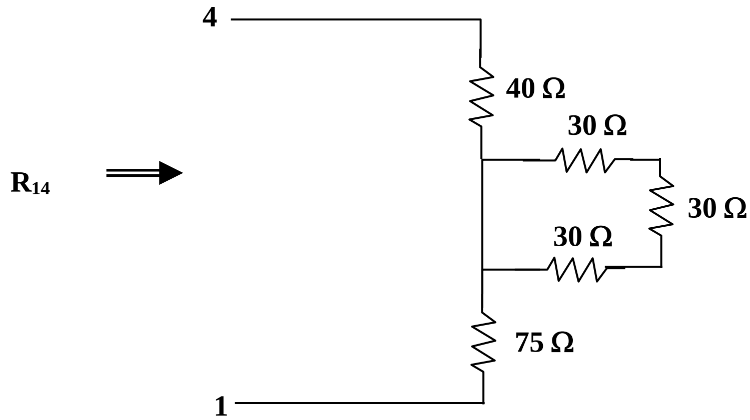
(a)



(b)




(c)




Step 2. (a) $R_{12}$ = 75 + 30x60/(30+60) = 75+20 = **95 Ω**

(b) $R_{13}$ = 75 + [30x60/(30+60)] + 40 = 135 Ω

(c) $R_{14}$ = 40 + 75 = **105 Ω**

**Solution 2.83**

Two delicate devices are rated as shown in Fig. 2.142. Find the values of the resistors $R_1$ and $R_2$ needed to power the devices using a 36-V battery.

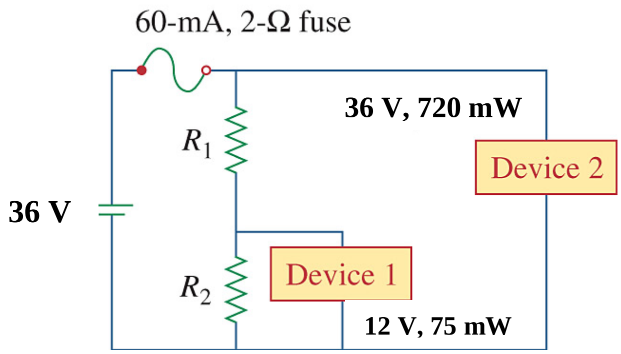


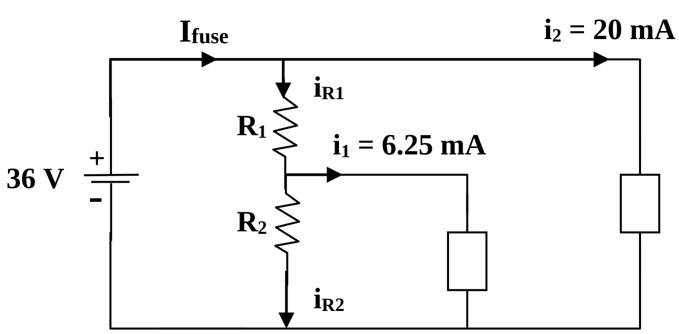

Figure 2.142
For Prob. 2.83.

**Solution**

The voltage across the fuse should be negligible when compared with 24 V (this can be checked later when we check to see if the fuse rating is exceeded in the final circuit). We can calculate the current through the devices.

$$I_1 = \frac{p_1}{V_1} = \frac{75mW}{12V} = 6.25mA$$

$$I_2 = \frac{p_2}{V_2} = \frac{720mW}{36} = 20mA$$




Let $R_3$ represent the resistance of the first device, we can solve for its value from knowing the voltage across it and the current through it.

$$R_3 = 12/0.00625 = 1,920\ \Omega$$

This is an interesting problem in that it essentially has two unknowns, $R_1$ and $R_2$ but only one condition that need to be met and that is that the voltage across $R_3$ must equal 12 volts. Since the circuit is powered by a battery we could choose the value of $R_2$ which draws the least current, $R_2 = \infty$. Thus we can calculate the value of $R_1$ that gives 12 volts across $R_3$.

$$12 = (36/(R_1 + 1920))1920 \text{ or } R_1 = (36/12)1920 - 1920 = \mathbf{3.84\ k\Omega}$$

This value of $R_1$ means that we only have a total of 26.25 mA flowing out of the battery through the fuse which means it will not open and produces a voltage drop across it of 0.0525 mV. This is indeed negligible when compared with the 36-volt source.

# CHAPTER 2

**P.P.2.1** $i = V/R = 110/15 =$ **7.333 A**

**P.P.2.2** (a) $v = iR = 3\ mA[10\ kohms] =$ **30 V**

(b) $G = 1/R = 1/10\ kohms =$ **100 µS**

(c) $p = vi = 30\ volts[3\ mA] =$ **90 mW**

**P.P.2.3** $p = vi$ which leads to $i = p/v = [30\cos^2(t)\ mW]/[15\cos(t)\ mA]$

or $i =$ **2cos(t) mA**

$R = v/i = 15\cos(t)V/2\cos(t)mA =$ **7.5 kΩ**

**P.P.2.4** 5 branches and 3 nodes. The 1 ohm and 2 ohm resistors are in parallel. The 4 ohm resistor and the 10 volt source are also in parallel.

**P.P.2.5** Applying KVL to the loop we get:

$-32 + 4i - (-8) + 2i = 0$ which leads to $i = 24/6 = 4A$

$v_1 = 4i =$ **16 V** and $v_2 = -2i =$ **–8 V**

**P.P.2.6** Applying KVL to the loop we get:

$-70 + 10i + 2v_x + 5i = 0$

But, $v_x = 10i$ and $v_0 = -5i$. Hence,

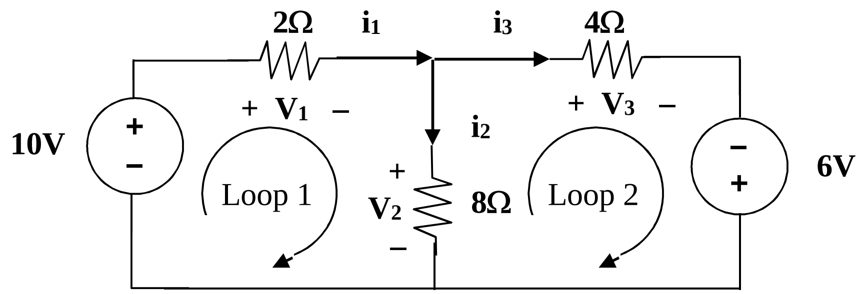
$-70 + 10i + 20i + 5i = 0$ which leads to $i = 2$ A.

Thus, $v_x =$ **20V** and $v_0 =$ **–10 V**

**P.P.2.7** Applying KCL, $0 = -15 + i_0 + [i_0/3] + [v_0/12]$, but $i_0 = v_0/2$

Which leads to: $15 = (v_0/2) + (v_0/6) + (v_0/12) = v_o((6+2+1)/12)$ thus, $v_0 =$ **<u>20 V</u>** and $i_0 =$ **<u>10 A</u>**

**P.P.2.8**




At the top node, $0 = -i_1 + i_2 + i_3$ or $i_1 = i_2 + i_3$ (1)

For loop 1 $-10 + V_1 + V_2 = 0$
or $V_1 = 10 - V_2$ (2)

For loop 2 $-V_2 + V_3 - 6 = 0$
or $V_3 = V_2 + 6$ (3)

Using (1) and Ohm's law, we get

$$(V_1/2) = (V_2/8) + (V_3/4)$$

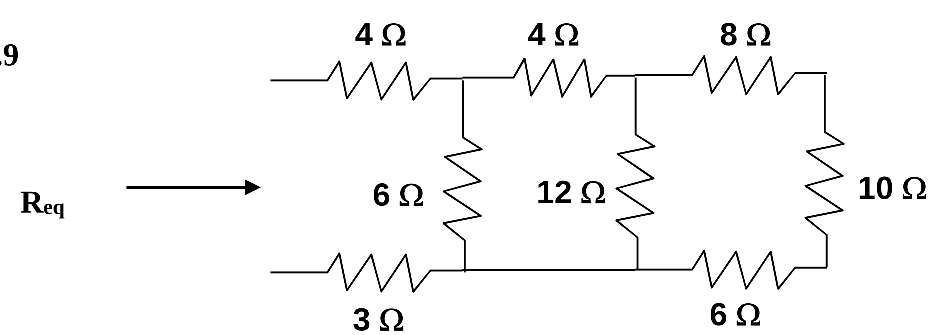
and now using (2) and (3) in the above yields

$$[(10 - V_2)/2] = (V_2/8) + (V_2 + 6)/4$$

or $[7/8]V_2 = 14/4$ or $V_2 =$ **<u>4 V</u>**

$V_1 = 10 - V_2 =$ **<u>6 V</u>**, $V_3 = 4+6 =$ **<u>10 V</u>**, $i_1 = (10-4)/2 =$ **<u>3 A</u>**, $i_2 = 4/8 =$ **<u>500 mA</u>**, $i_3 =$ **<u>2.5 A</u>**

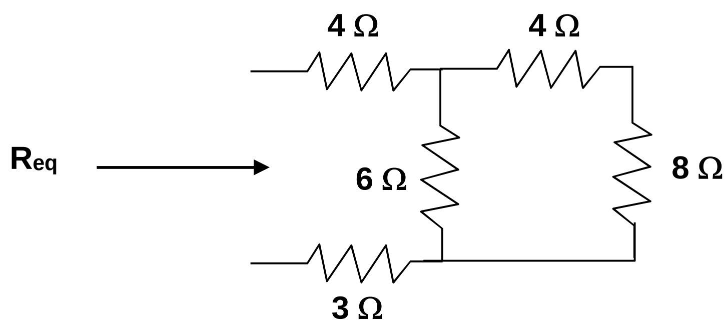
**P.P.2.9**



Combining the 8-ohm, 10-ohm, and 6-ohm resistors in series gives 8+10+6 = 24.

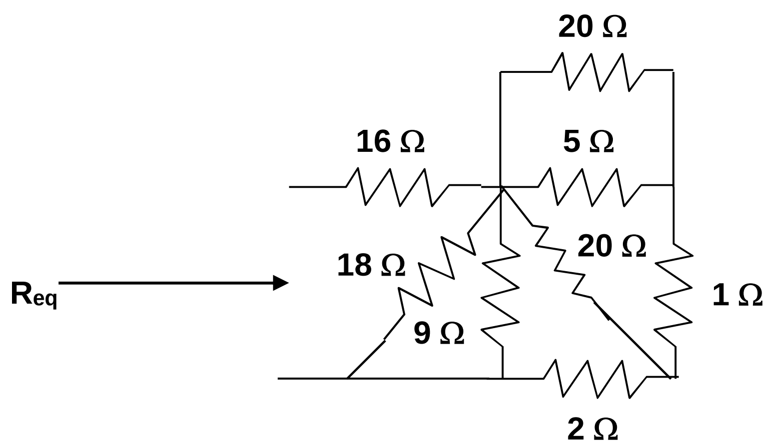
But, 12 in parallel with 24 produces [12x24]/[12+24] = 288/36 = 8 ohms.

So that the equivalent circuit is shown below.



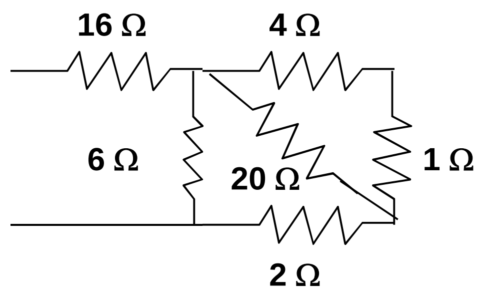

Thus, $\mathbf{R_{eq}}$ = 4 + [6x12]/[6+12] + 3 = **11 Ω**

**P.P.2.10**

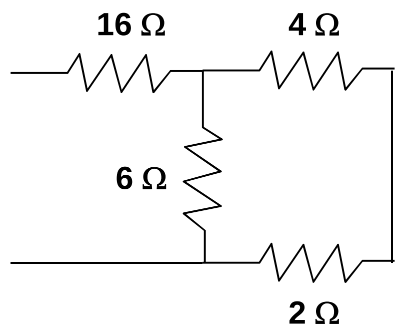



Combining the 9 ohm resistor and the 18 ohm resistor yields [9x18]/[9+18] = 6 ohms.

Combining the 5 ohm and the 20 ohm resistors in parallel produces [5x20/(5+20)] = 4 ohms  We now have the following circuit:



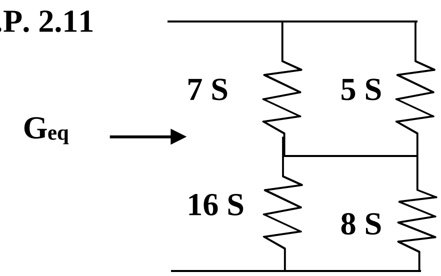

The 4 ohm and 1 ohm resistors can be combined into a 5 ohm resistor in parallel with a 20 ohm resistor.  This will result in [5x20/(5+20)] = 4 ohms and the circuit shown below:




The 4 ohm and 2 ohm resistors are in series and can be replaced by a 6 ohm resistor. This gives a 6 ohm resistor in parallel with a 6 ohm resistor, [6x6/(6+6)] = 3 ohms.  We now have a 3 ohm resistor in series with a 16 ohm resistor or 3 + 16 = 19 ohms. Therefore:

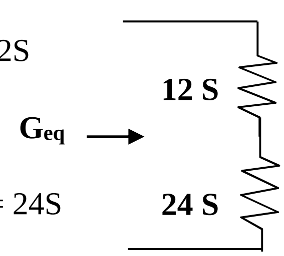
$$\mathbf{R_{eq} = \underline{19\ ohms}}$$

**P.P. 2.11**



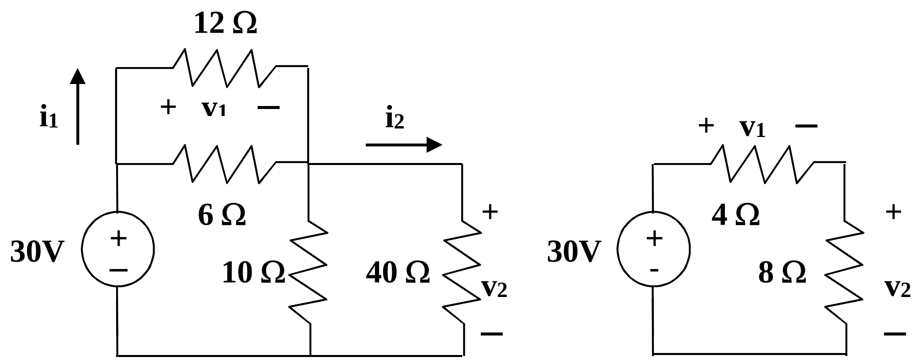

7||5 = 7+5 = 12S

16||8 = 16+8 = 24S




12 S in series with 24 S = {12x24/(12+24)] = 8 or:  $\mathbf{G_{eq} = 8\ S}$

**P.P.2.12**




$6||12 = [6\text{x}12/(6+12)] = 4$ ohm and $10||40 = [10\text{x}40/(10+40)] = 8$ ohm.

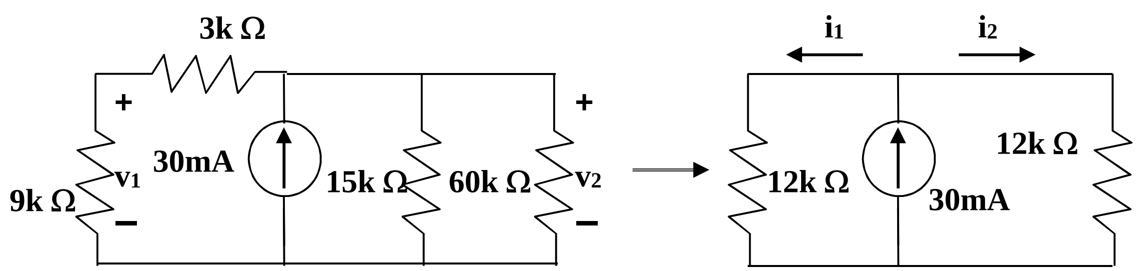
Using voltage division we get:

$\mathbf{v_1} = [4/(4+8)]\ (30) =$ **<u>10 volts</u>**, $\mathbf{v_2} = [8/12]\ (30) =$ **<u>20 volts</u>**

$\mathbf{i_1} = v_1/12 = 10/12 =$ **<u>833.3 mA</u>**, $\mathbf{i_2} = v_2/40 = 20/40 =$ **<u>500 mA</u>**

$\mathbf{P_1} = v_1\ i_1 = 10\text{x}10/12 =$ **<u>8.333 watts</u>**, $\mathbf{P_2} = v_2\ i_2 = 20\text{x}0.5 =$ **<u>10 watts</u>**

**P.P.2.13**




Using current division, $i_1 = i_2 =$ (30 mA)(12 kohm/(12 kohm + 12 kohm)) = 15mA

(a) $\mathbf{v_1}$ = (9 kohm)(15 mA) = **<u>135 volts</u>**
$\mathbf{v_2}$ = (12 kohm)(15 mA) = **<u>180 volts</u>**

(b) For the 9k ohm resistor, $\mathbf{P_1} = v_1 \text{ x } i_1 = 135\text{x}15\text{x}10^{-3} =$ **<u>2.025 w</u>**
For the 60k ohm resistor, $\mathbf{P_2} = (v_2)^2/60\text{k} =$ **<u>540 mw</u>**

(c) The total power supplied by the current source is equal to:
$\mathbf{P} = v_2 \text{ x } 30 \text{ mA} = 180\text{x}30\text{x}10^{-3} =$ **<u>5.4 W</u>**

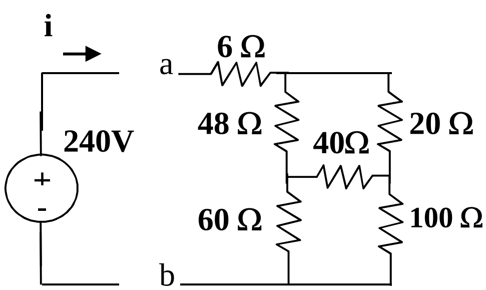
**P.P.2.14**

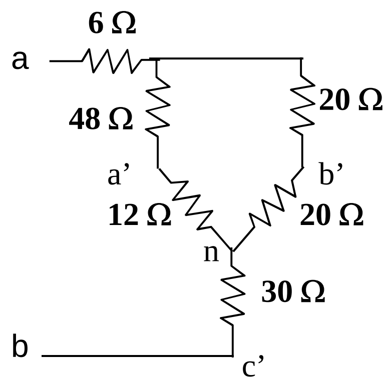
**$R_a$** = $[R_1 R_2 + R_2 R_3 + R_3 R_1]/ R_1$ = $[10x20 + 20x40 + 40x10]/10$ = **<u>140 ohms</u>**

**$R_b$** = $[R_1 R_2 + R_2 R_3 + R_3 R_1]/ R_2$ = $1400/20$ = **<u>70 ohms</u>**

**$R_c$** = $[R_1 R_2 + R_2 R_3 + R_3 R_1]/ R_3$ = $1400/40$ = **<u>35 ohms</u>**

**P.P.2.15** We first find the equivalent resistance, R. We convert the delta sub-network to a wye connected form as shown below:




$R_{a'n}$ = $40x60/[40 + 60 + 100]$ = 12 ohms, $R_{b'n}$ = $40x100/200$ = 20 ohms
$R_{c'n}$ = $60x100/200$ = 30 ohms.

Thus, $R_{ab}$ = $6 + [(48 + 12)||(20 + 20)] + 30$ = $6 + 60x40/(60 + 40) + 30$
$6 + 24 + 30$ = **<u>60 ohms.</u>**

**i** = $240/ R_{ab}$ = $240/60$ = **<u>4 amps</u>**

**P.P.2.16** **For the parallel case, v = $v_0$ = <u>115volts</u>.**
**p = vi ⟹ i = p/v = 40/115 = <u>347.8 mA</u>**

For the series case, v = $v_0/N$ = $115/6$ = **<u>19.167 volts</u>**
**i** = p/v = 40/19.167 = **<u>2.087 amps</u>**

**P.P.2.17** We use equation (2.61)

(a) **$R_1$** = $50x10^{-3}/ (1-10^{-3})$ = $0.05/999$ = **<u>50 mΩ (shunt)</u>**

(b) **$R_2$** = $50x10^{-3}/(100x10^{-3} – 10^{-3})$ = $50/99$ = **<u>505 mΩ (shunt)</u>**

(c) **$R_3$** = $50x10^{-3}/(10x10^{-3}-10^{-3})$ = $50/9$ = **<u>5.556 Ω (shunt)</u>**