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

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

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

$n = 8; \quad l = 8; \quad \mathbf{b} = n + l - 1 = \underline{\mathbf{15}}$

Solution 2.7

6 branches and 4 nodes

Solution 2.8

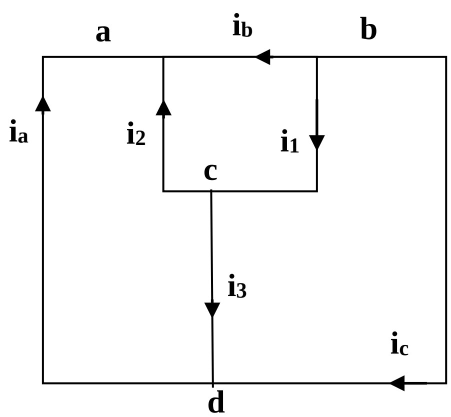
Design a problem, complete with a solution, to help other students to better understand Kirchhoff's Current Law. Design the problem by specifying values of i_a, i_b, and i_c, shown in Fig. 2.72, and asking them to solve for values of i_1, i_2, and i_3. Be careful specify realistic currents.

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.

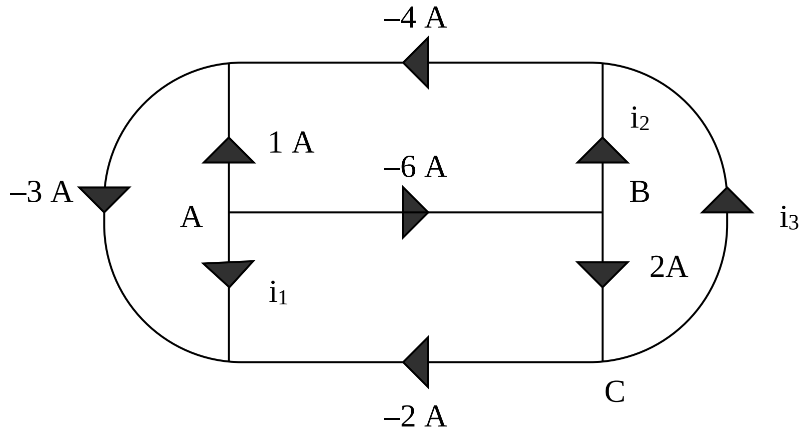


Figure 2.73
For Prob. 2.9.

Solution

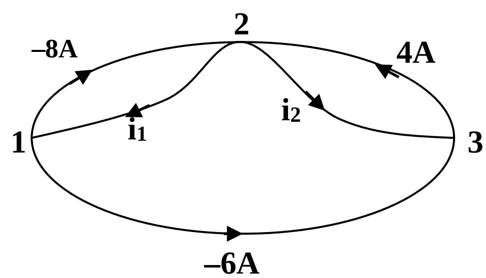
Step 1. We can apply Kirchhoff's current law to solve for the unknown currents.

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



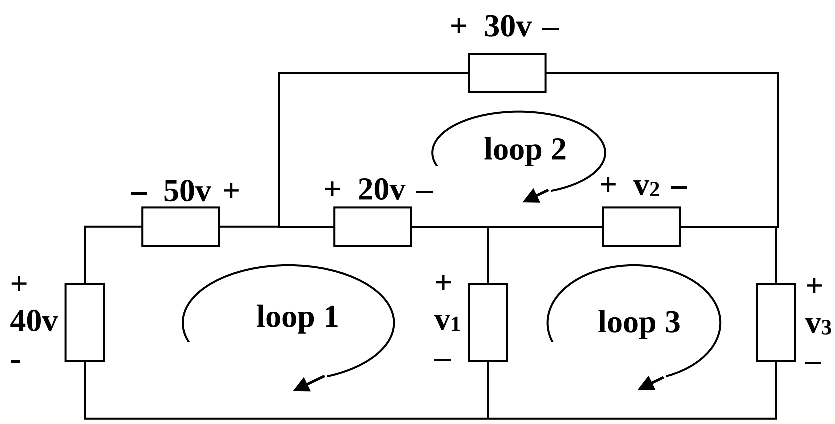
At node 1, $\quad -8-i_1-6 = 0$ or $i_1 = -8-6 =$ **-14 A**

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

Solution 2.11

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

Solution 2.12

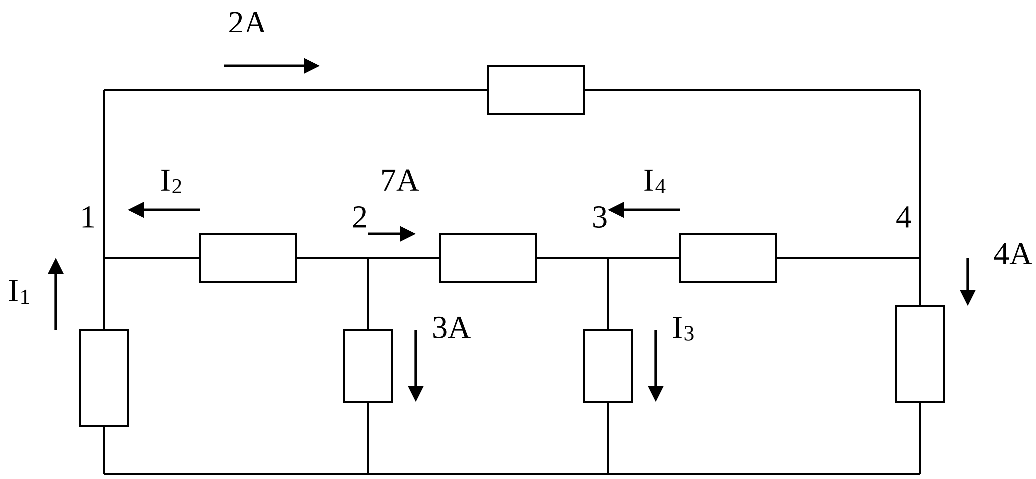


For loop 1, $-40 - 50 + 20 + v_1 = 0$ or $v_1 = 40+50-20 =$ **70 V**

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,

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

At node 1,

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

At node 4,

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

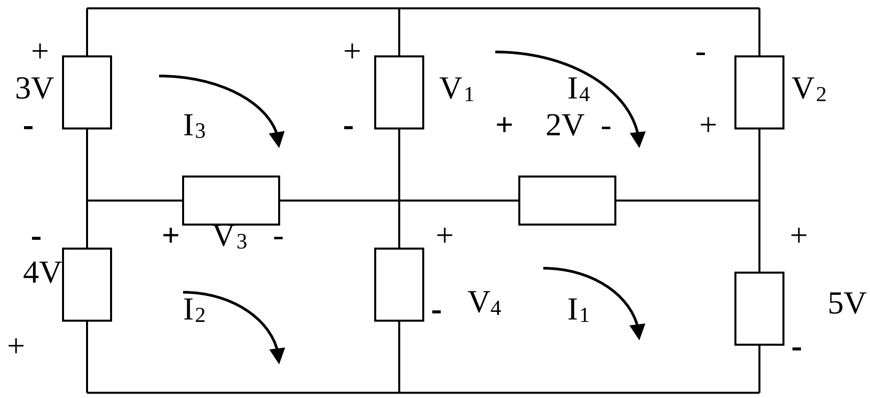
At node 3,

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

Hence,

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

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.

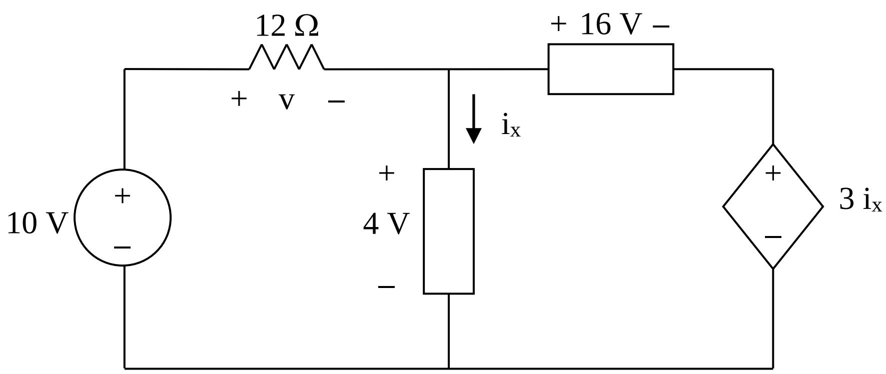


Figure 2.79
For Prob. 2.15.

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 $\boldsymbol{V_o}$ in the circuit in Fig. 2.80.

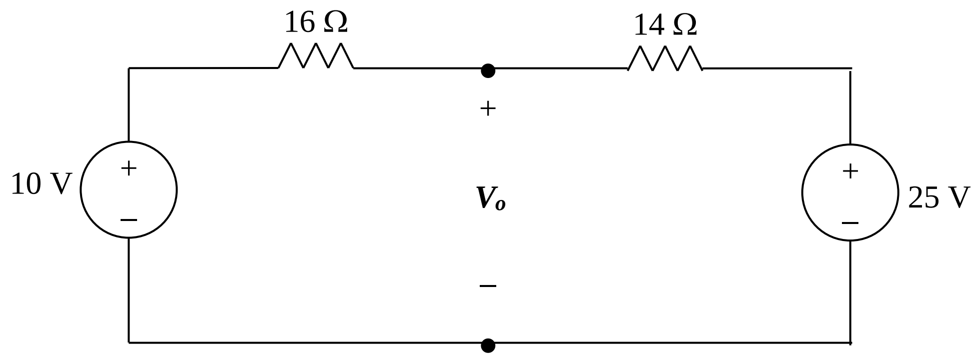


Figure 2.80
For Prob. 2.16.

Solution

Apply KVL,

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

Also,

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

Problem 2.17

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

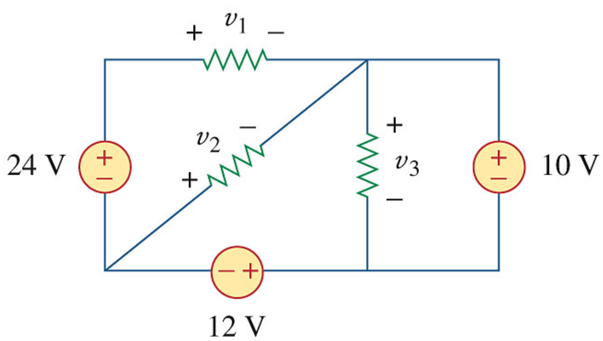


Figure 2.81
For Prob. 2.17.

Solution 2.18

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

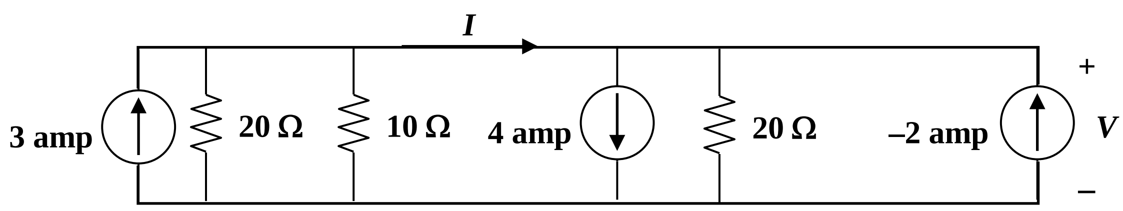


Figure 2.82
For Prob. 2.18.

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.

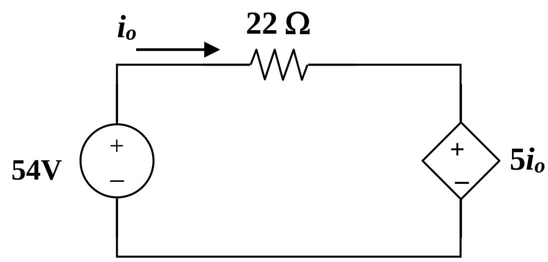


Figure 2.84
For Prob. 2.20

Solution

Applying KVL around the loop,

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

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.

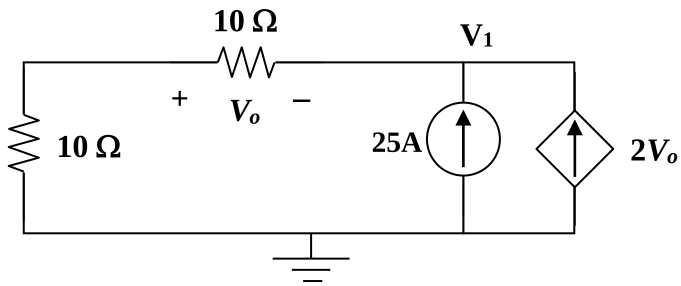


Figure 2.86
For Prob. 2.22

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.

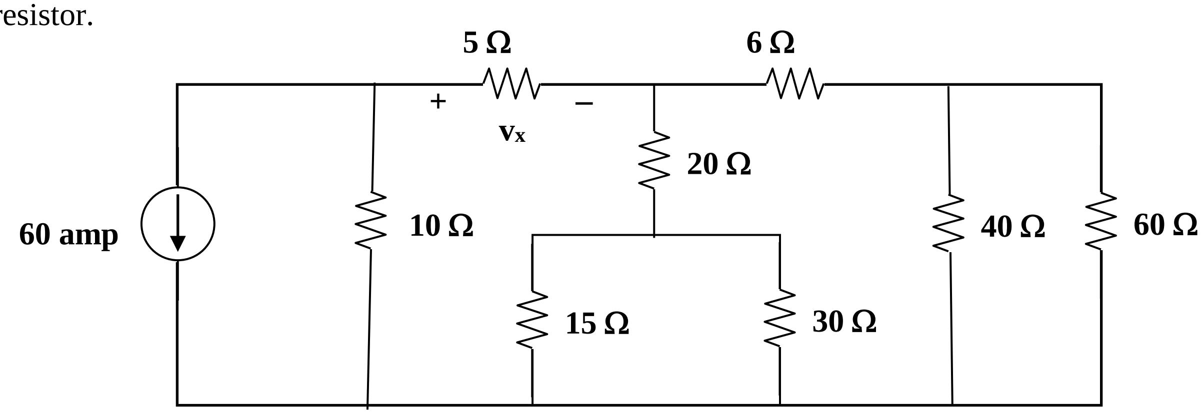
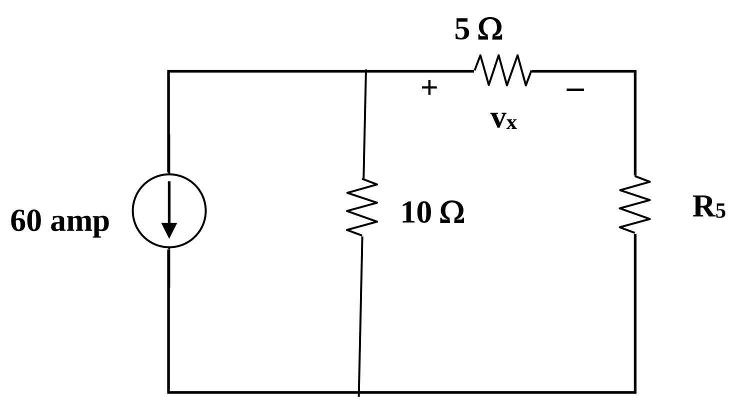


Figure 2.87
For Prob. 2.23.

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,



$R_1 = 40x60/(40+60)$
$R_2 = 6 + R_1$
$R_3 = 15x30/(15+30)$
$R_4 = 20+R_3$
$R_5 = R_2R_4/(R_2+R_4)$

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

$60 + V_{10}/10 + V_{10}/(5+R_5) = 0$
$60 + V_{10}/10 + V_{10}/20 = 0$
$V_{10} = –60x20/3 = –400$ 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) $$I_0 = \frac{V_s}{R_1 + R_2}$$

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

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

(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

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

Using current division,

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

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

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

Solution 2.26

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

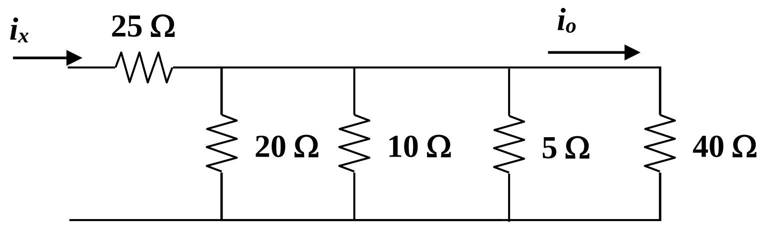


Figure 2.90
For Prob. 2.26.

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. $V_{40} = 40\text{x}5 = 200$ 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.

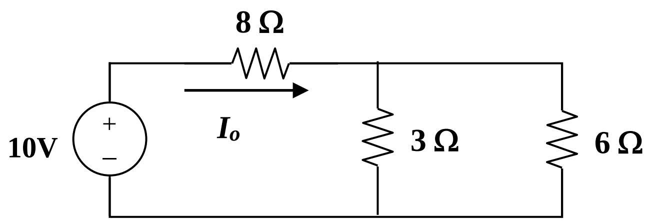


Figure 2.91
For Prob. 2.27.

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**.

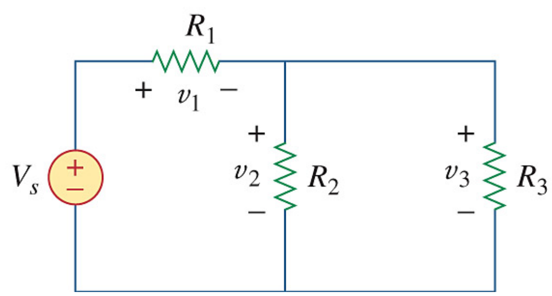
Solution 2.28

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, $v_1 = \mathbf{28\ V}$, $v_2 = \mathbf{12\ V}$, $v_s = \mathbf{12\ V}$

Solution 2.29

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

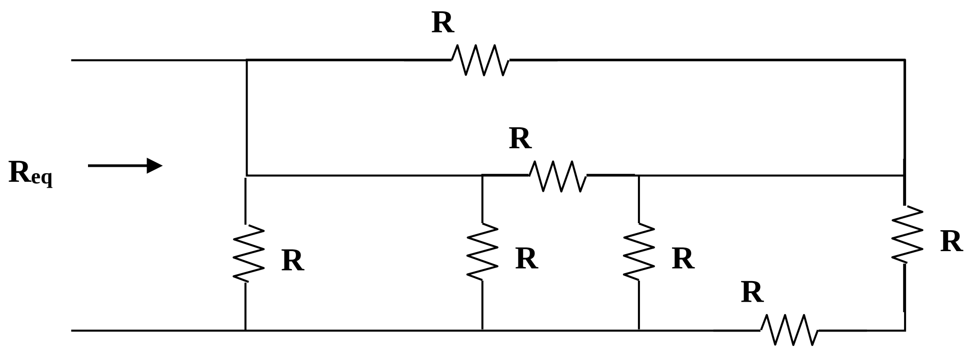


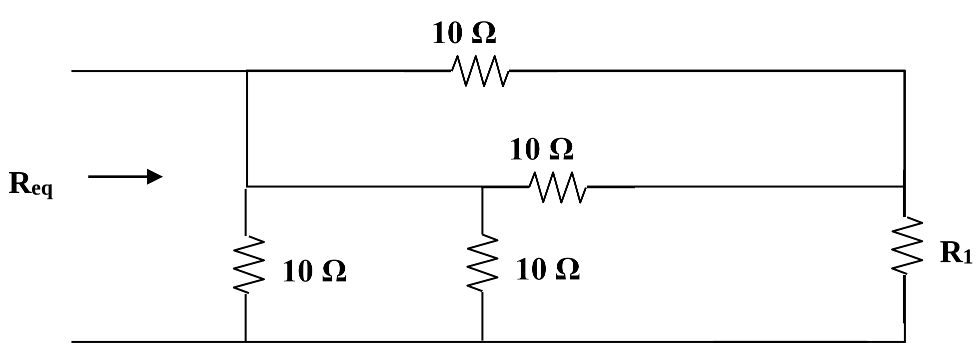
Figure 2.93
For Prob. 2.29.

Solution

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

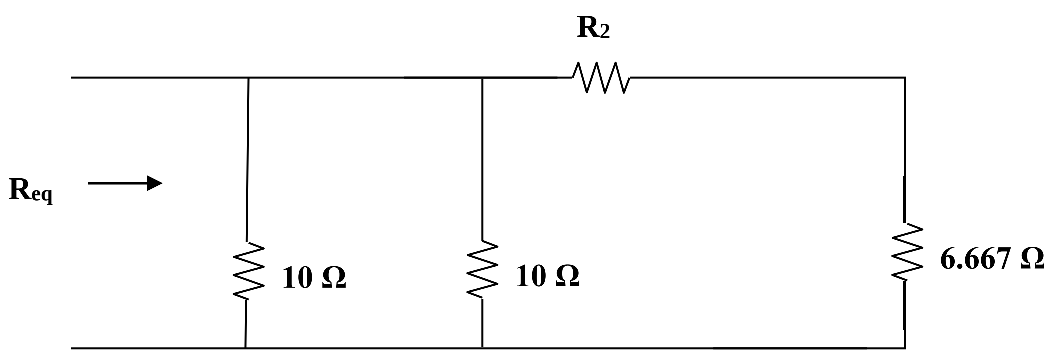
$$R_{eq} = \frac{\left(\frac{R(R)}{R+R}\right)\left(\frac{R(R)}{R+R}+\frac{R(R+R)}{R+R+R}\right)}{\left(\frac{R(R)}{R+R}\right)+\left(\frac{R(R)}{R+R}+\frac{R(R+R)}{R+R+R}\right)}$$ which can be derived by inspection. We will look at a simpler approach after we get the answer.

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

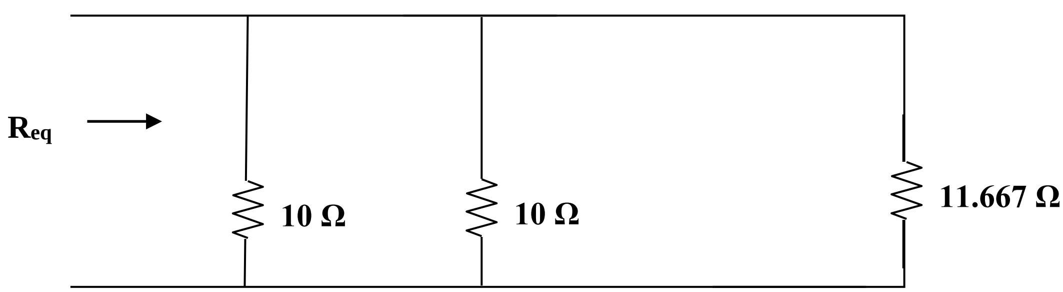


Checking we get,

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



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.

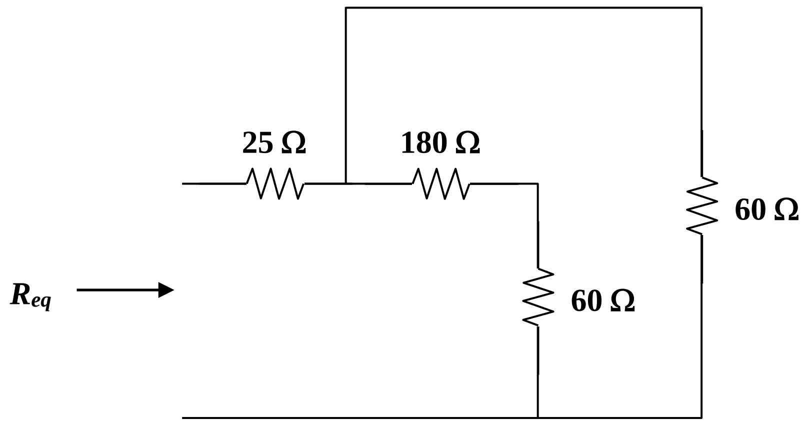


Figure 2.94
For Prob. 2.30.

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 = 0.5714xi_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.

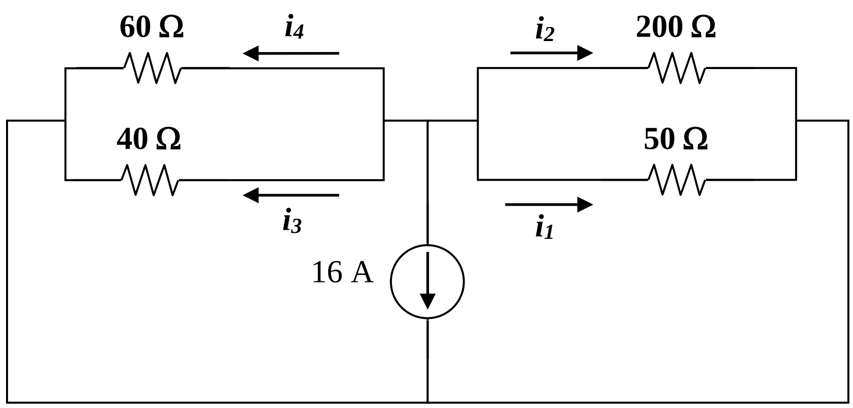


Figure 2.96
For Prob. 2.32.

Solution

We first combine resistors in parallel.

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

Using current division principle,

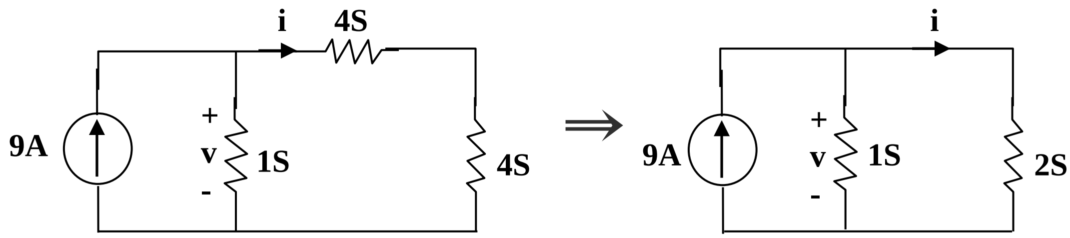
$$i_1 + i_2 = \frac{24}{24+40}(-16) = -6\text{A}, i_3 + i_4 = \frac{40}{64}(-16) = -10\text{A}$$

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

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

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,

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

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.

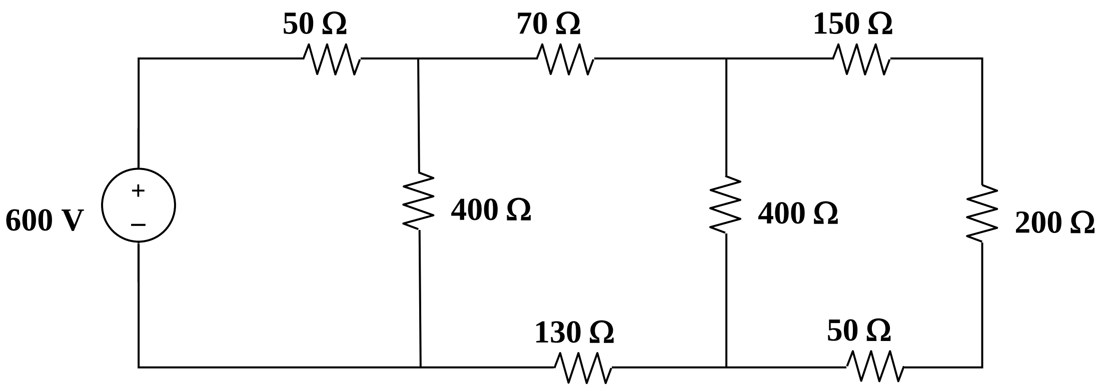


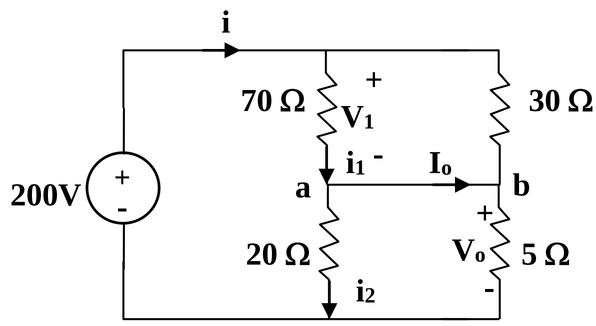
Figure 2.98
For Prob. 2.34.

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. $R_1 = 400\text{x}400/800 = 200$ and $R_2 = 400\text{x}400/800 = 200$ and $R_{eq} = 50+200 =$ **250 Ω**.

$$P = 360{,}000/250 = \mathbf{1.44\ kW}.$$

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

$v_o = 30i_o = 30x0.02 =$ **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.

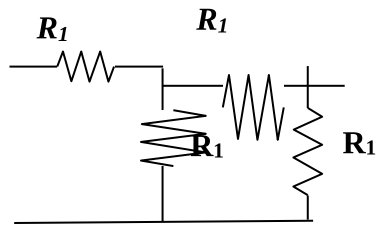


Figure 2.101
For Prob. 2.37.

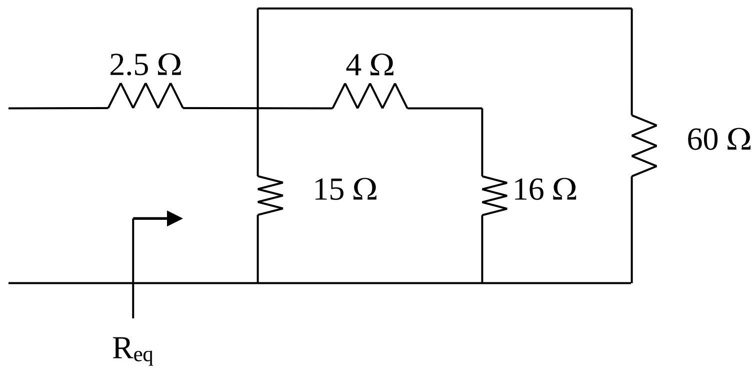
Step 1. First we calculate R_{eq} in terms of R_1. Then we set R_{eq} to 100 ohms and solve for R_1.

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

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.

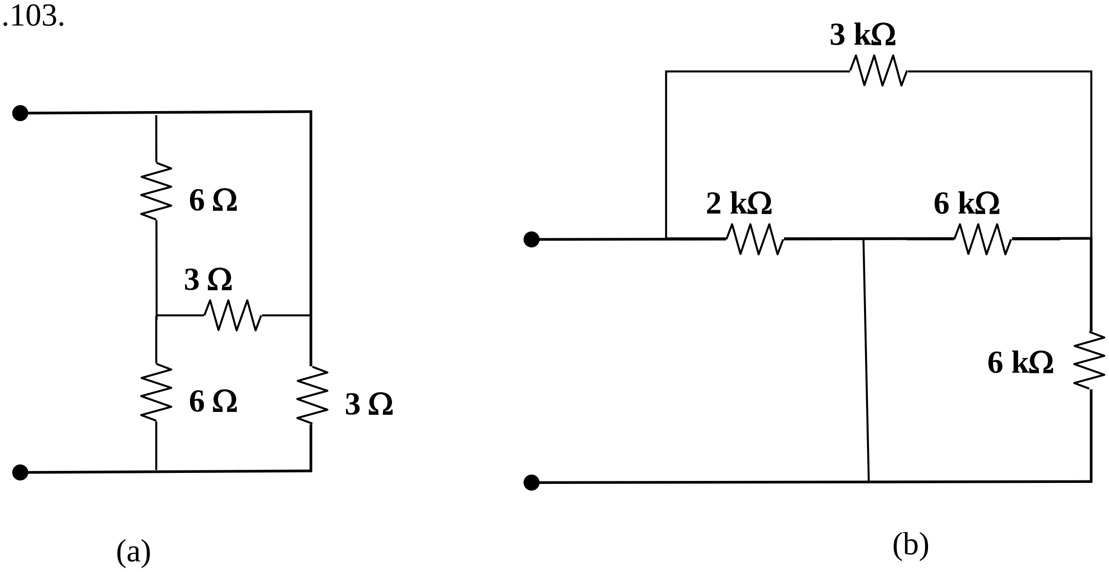


Figure 2.103
For Prob. 2.39.

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 12Ω 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) $\quad R_{ab} = 5 \| 20 + 10 \| 40 = \dfrac{5x20}{25} + \dfrac{400}{50} = 4 + 8 = \mathbf{12\ \Omega}$

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

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

Solution 2.44

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

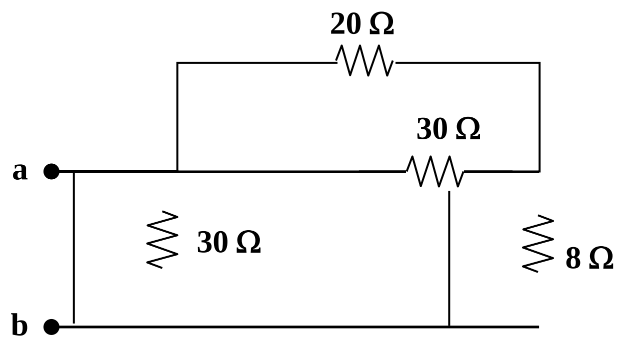


Figure 2.108
For Prob. 2.44

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_1x30)/(R_1+30)].

Step 2. R_1 = (600/50) + 8 = 12 + 8 = 20 Ω and

R_{ab} = 20x30/(20+30) = **12 Ω**.

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.

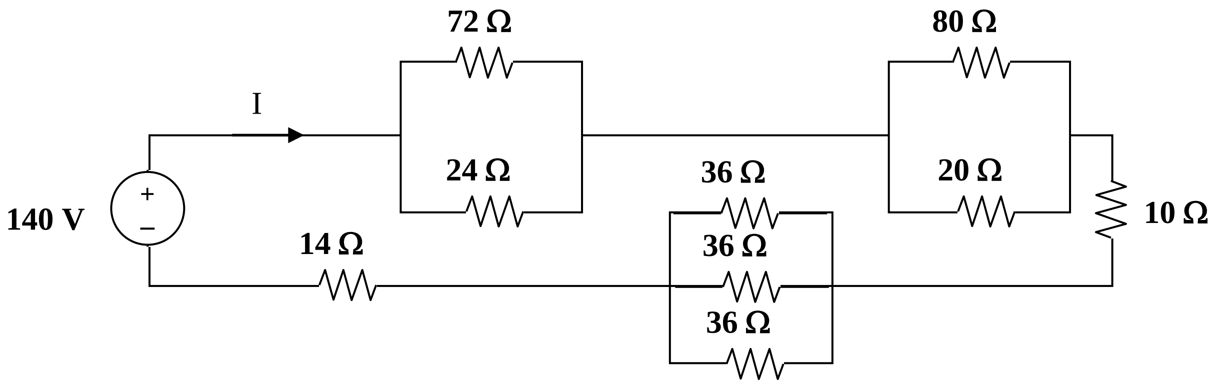


Figure 2.110
For Prob. 2.46.

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**.

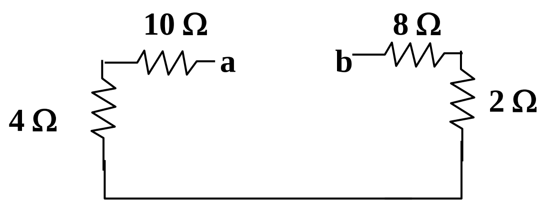
R_{eq} = 12 + 5||20 + [1/((1/15)+(1/15)+(1/15))] + 5 + 24||8
= 12 + 4 + 5 + 5 + 6 = 32 Ω

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 = **24 Ω**

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.

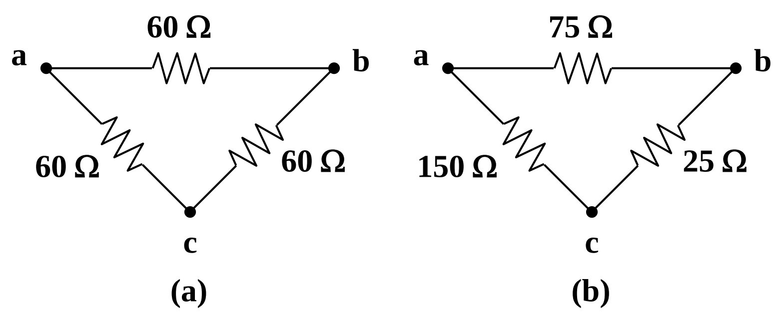


Figure 2.113
For Prob. 2.49.

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.

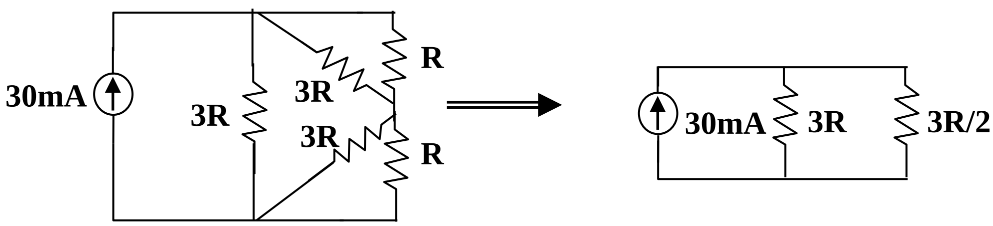
Although there is no correct way to work this problem, this is an example based on the same kind of problem asked in the third edition.

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:



$$3R\|R = \frac{3RxR}{4R} = \frac{3}{4}R$$

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

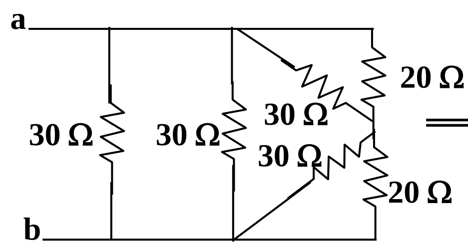
$P = I^2R \longrightarrow 800 \times 10^{-3} = (30 \times 10^{-3})^2 R$

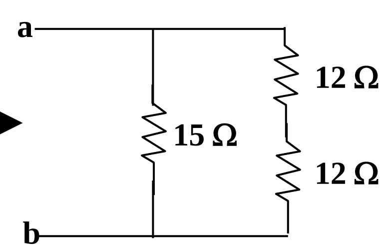
R = **<u>889 Ω</u>**

Solution 2.51

(a) $30 \| 30 = 15\Omega$ and $30 \| 20 = 30\text{x}20/(50) = 12\Omega$

R_{ab} = $15 \| (12+12) = 15\text{x}24/(39) = \mathbf{9.231\ \Omega}$





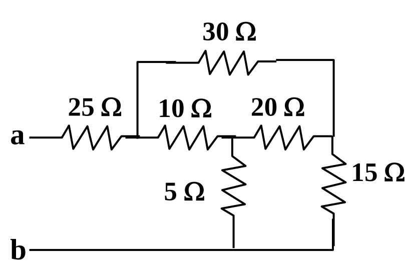
(b) Converting the T-sub network into its equivalent Δ network gives

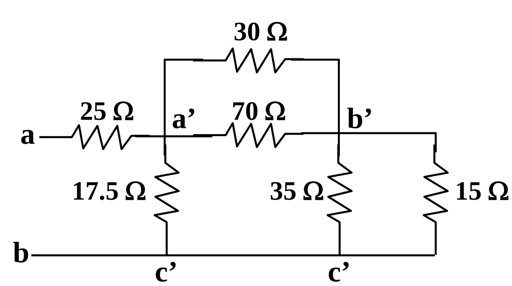
$R_{a'b'}$ = 10x20 + 20x5 + 5x10/(5) = 350/(5) = 70 Ω
$R_{b'c'}$ = 350/(10) = 35Ω, Ra'c' = 350/(20) = 17.5 Ω

Also $30 \| 70 = 30\text{x}70/(100) = 21\Omega$ and 35/(15) = 35x15/(50) = 10.5

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

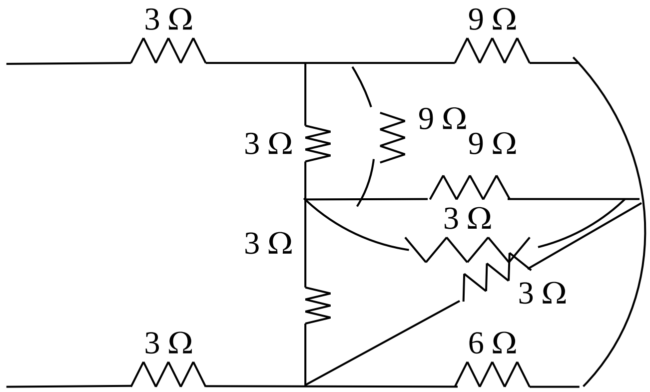
R_{ab} = **36.25 Ω**



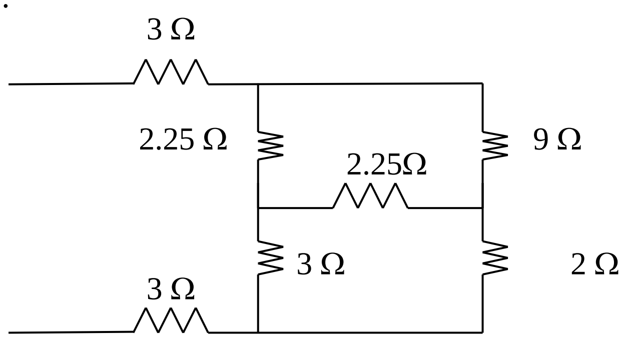


Solution 2.52

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.

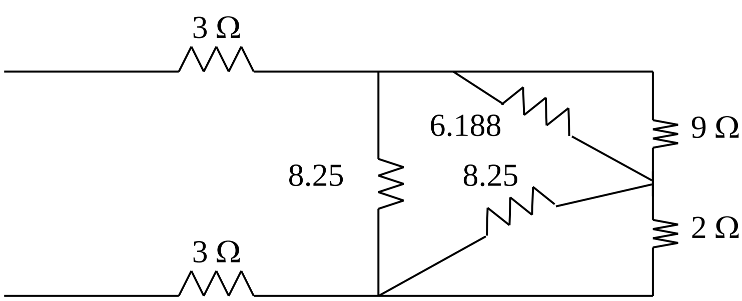


We now convert the wye-subnetwork to the delta-subnetwork.

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.

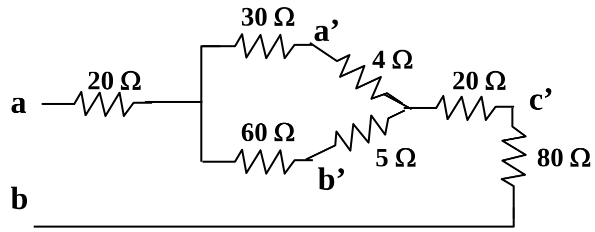


$R = 9||6.188+8.25||2 = 3.667+1.6098 = 5.277$

$R_{eq} = 3+3+8.25||5.277 = \mathbf{9.218\ \Omega}$.

Solution 2.53

(a) Converting one Δ to T yields the equivalent circuit below:



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

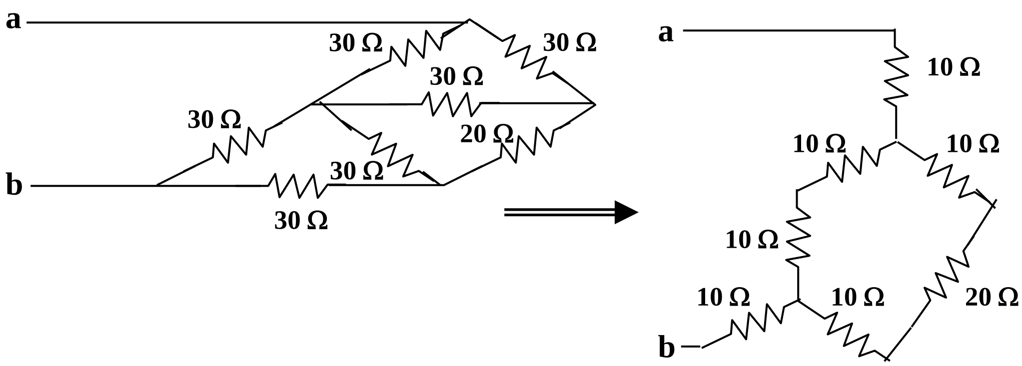
R_{ab} = 20 + 80 + 20 + $(30+4)\|(60+5) = 120+34\|65$

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 Δs 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.

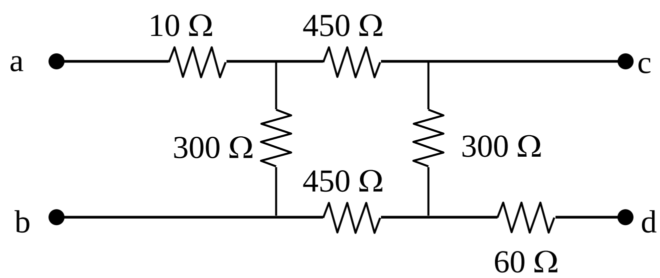


Figure 2.118
For Prob. 2.54.

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.

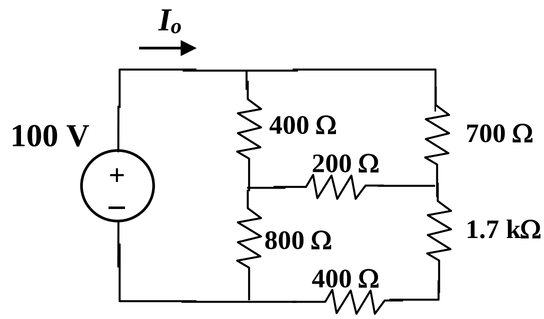
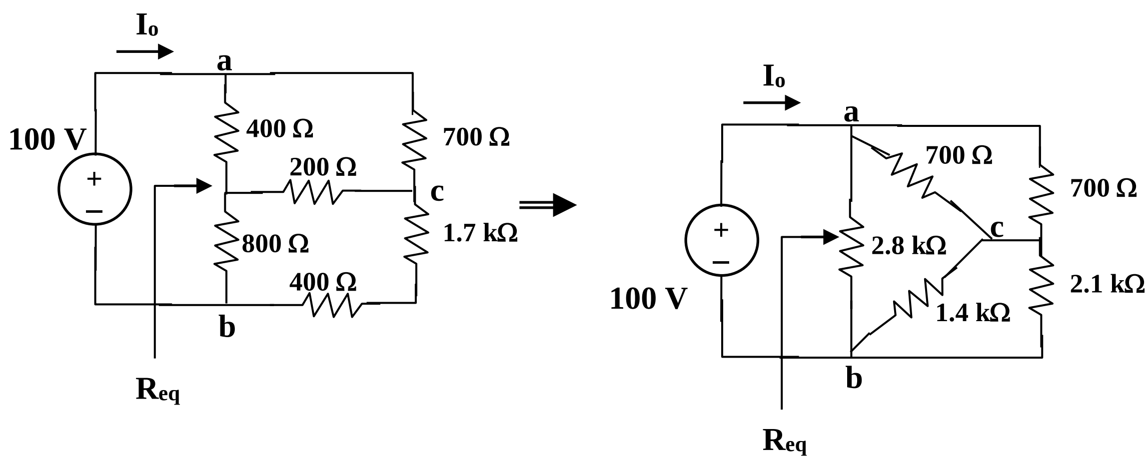


Figure 2.119
For Prob. 2.55.

Solution

Step 1. First we convert the T to Δ.



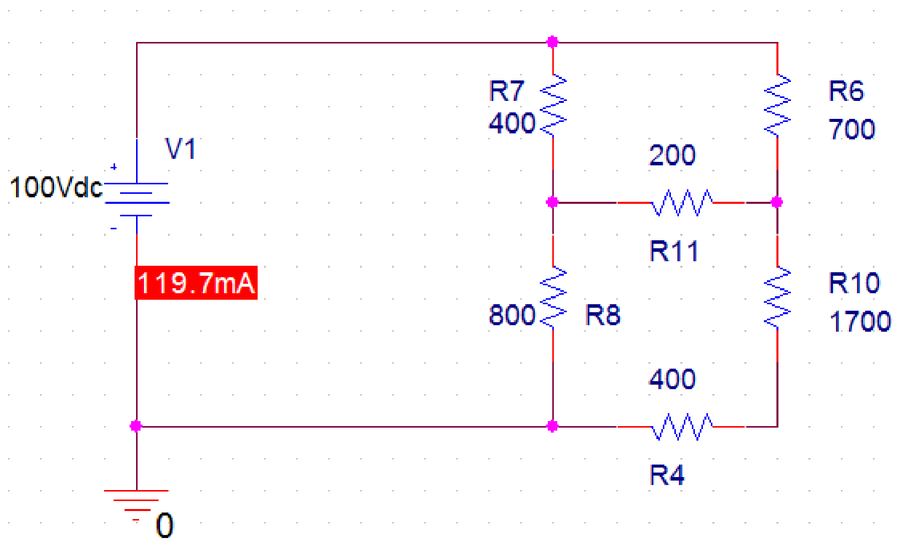
Next we let $R_1 = 400$; $R_2 = 800$; and $R_3 = 200$. Now we can calculate the values of the delta circuit. Let $R_{num} = 400x800+800x200+200x400$ and then we get $R_{ab} = R_{num}/R_3$; $R_{bc} = R_{num}/R_1$; $R_{ac} = R_{num}/R_2$. Finally $R_{eq} = \dfrac{2.8k\left[\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}1.7k}{R_{bc}+1.7k}\right]}{2.8k+\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}1.7k}{R_{bc}+1.7k}}$ 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 $R_{acb} = \left[\frac{R_{ac}700}{R_{ac}+700}+\frac{R_{bc}2.1k}{R_{bc}+2.1k}\right] = \left[\frac{700x700}{700+700}+\frac{1.4k2.1k}{1.4k+2.1k}\right] = 350+840 = 1190.$

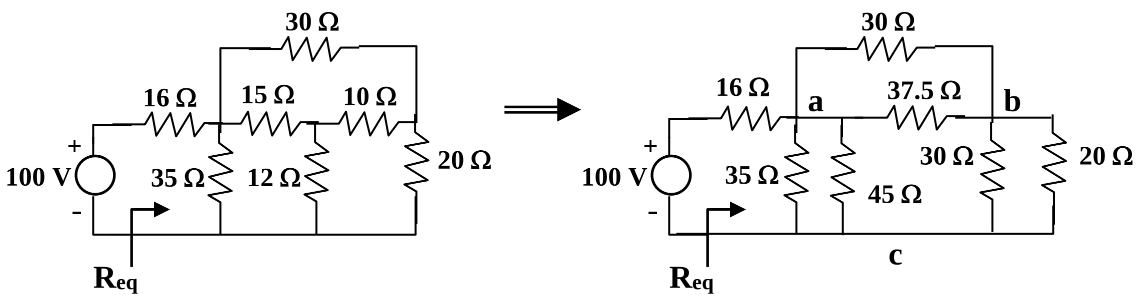
$R_{eq} = \frac{2.8k[1190]}{2.8k+1190} = \frac{3.332k}{3.99} = 835.1\ \Omega$ and $I_o = 100/835.1 =$ **119.75 mA**.

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 Δ.



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

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.

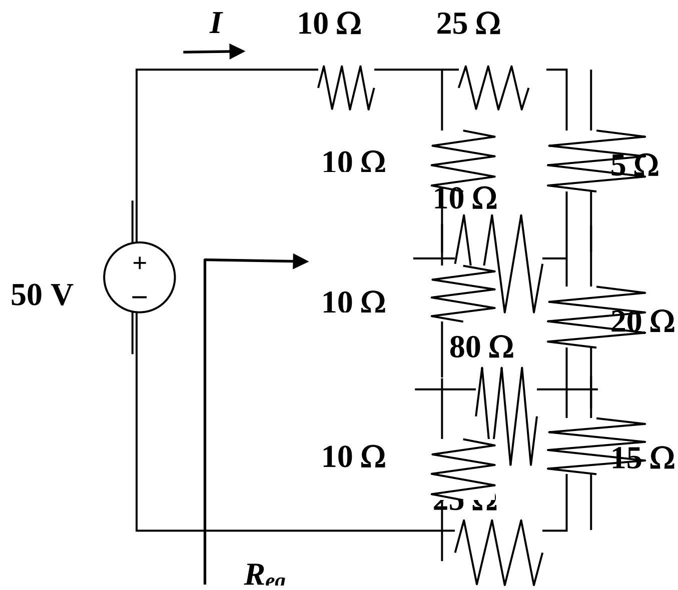
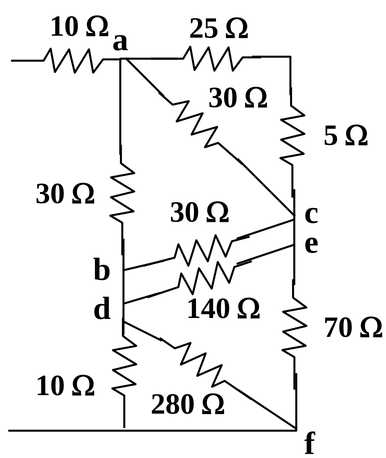


Figure 2.121
For Prob. 2.57.

Solution



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

R_{ac} = 216/(8) = 27Ω, R_{bc} = 36 Ω

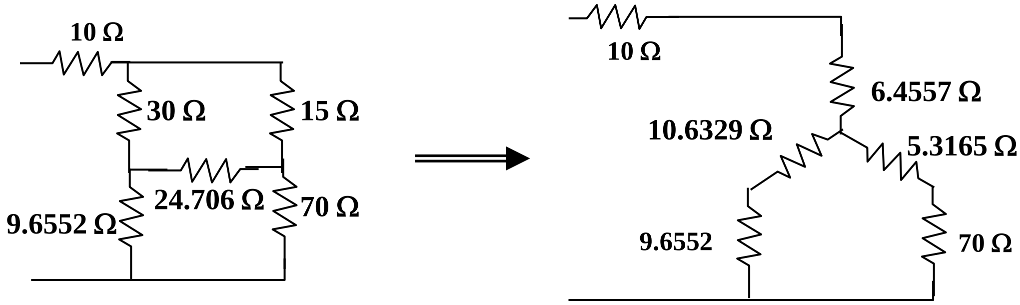
$$R_{de} = \frac{40x20 + 20x80 + 80x40}{40} = \frac{5600}{40} = 140\ \Omega$$

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

Combining resistors in parallel,

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

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



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

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

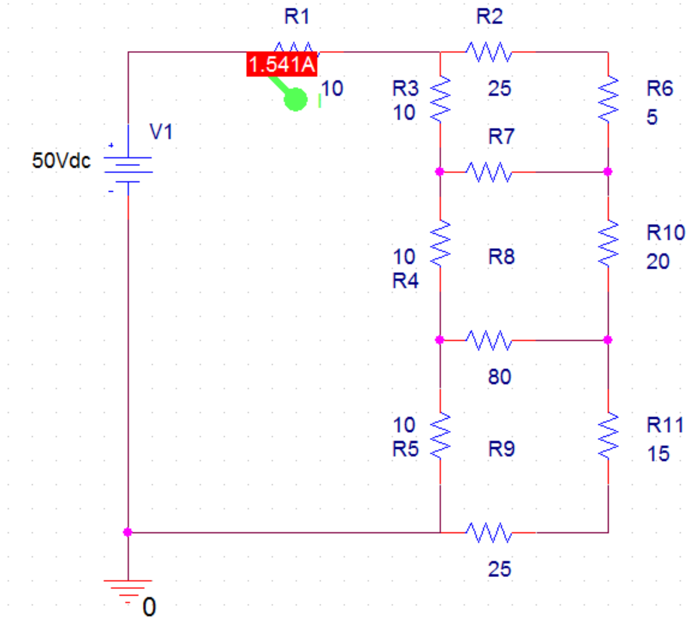
$$R_{cn} = \frac{24.706x15}{69.706} = 5.3165\ \Omega$$

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

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

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.

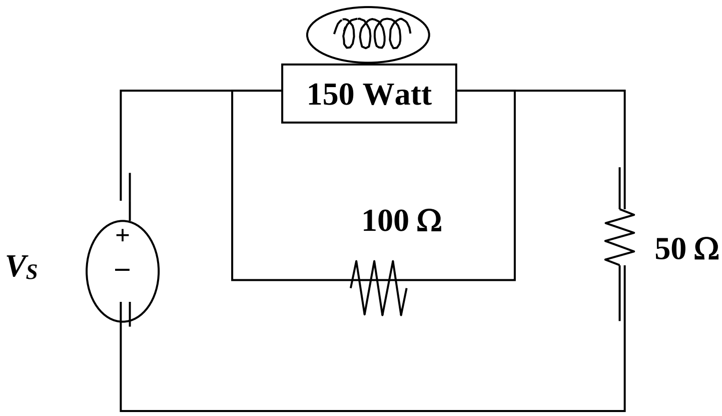
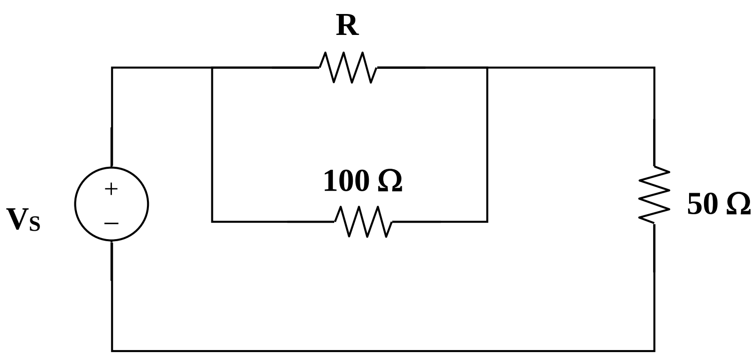


Figure 2.112
For Prob. 2.58.

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?

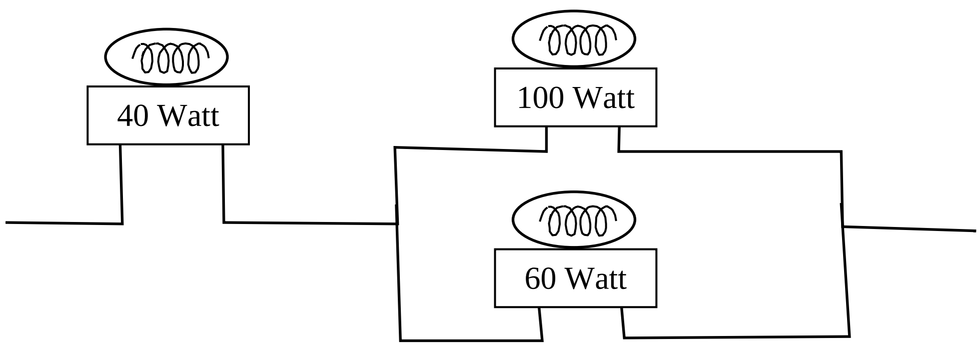


Figure 2.123
For Prob. 2.59.

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

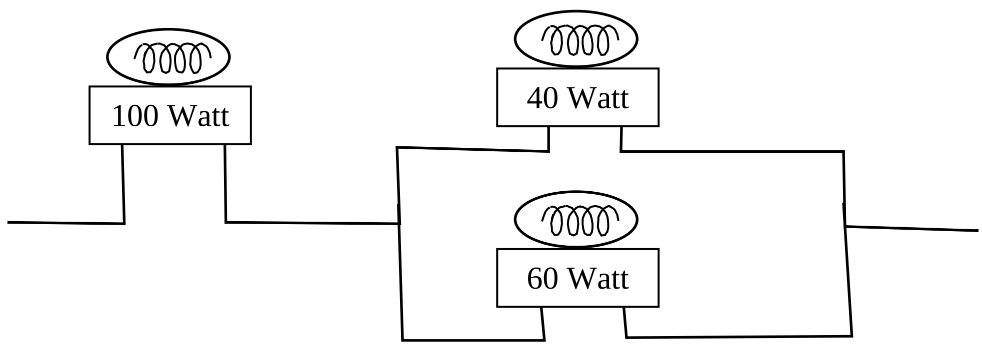
$R_{100W} = (110)^2/100 = 12{,}100/100 = 121\ \Omega$

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

$V_{40W} = (220/R_{Tot})R_{40W} = 0.5819\text{x}302.5 = 176$ 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, $R_{Tot} = 121 + 302.5\text{x}201.7/(302.5+201.7) = 121 + 61{,}014/504.2 = 121+121.01 = 242\ \Omega$. 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.

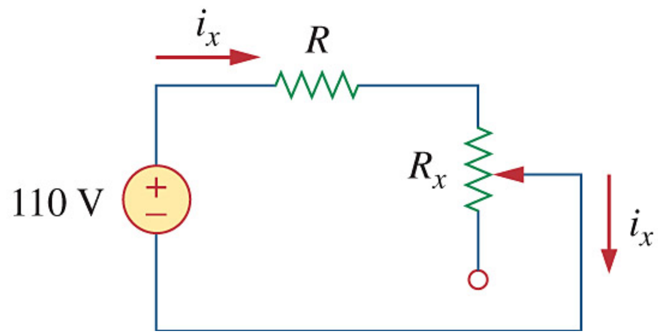


Figure 2.126
For Prob. 2.64.

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

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

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

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

(a) $R_n = \dfrac{V_{fs}}{i_{fs}} - R_m = \dfrac{50\ \text{V}}{50\,\mu\text{A}} - 200\ \text{k}\Omega =$ **800 kΩ**

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

Solution 2.67

(a) By current division,

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

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

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

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

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

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

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

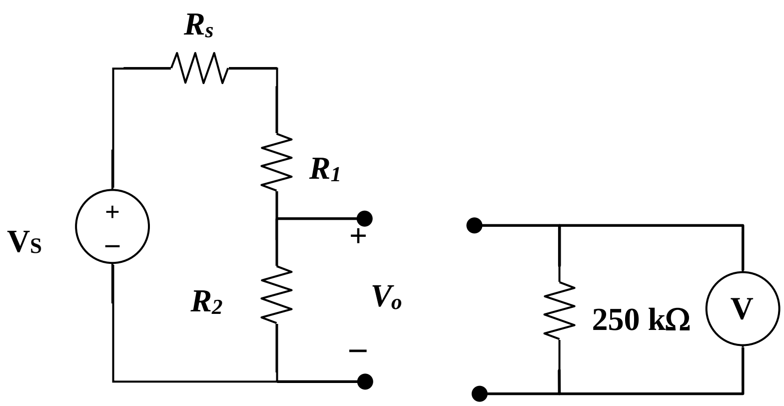


Figure 2.129
For Prob. 2.69

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

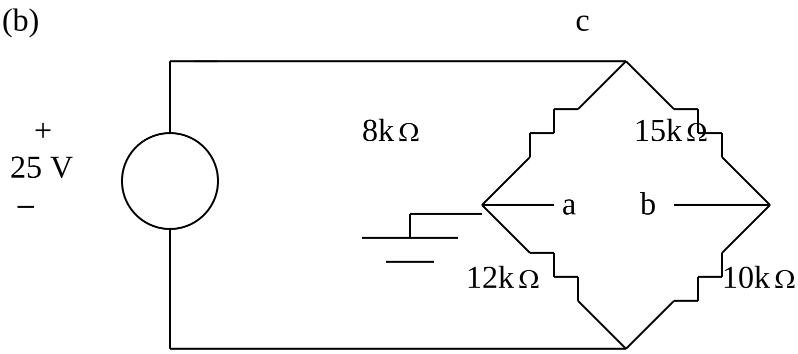
(a) Using voltage division,

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

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

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

(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.

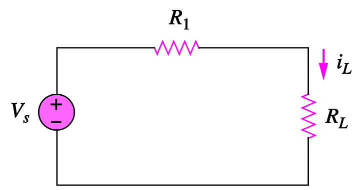


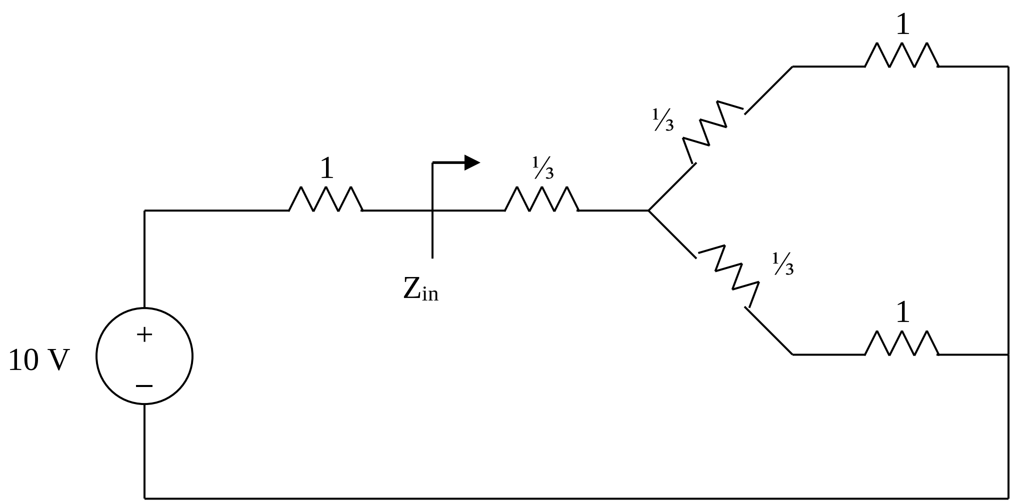
Figure 2.131
For Prob. 2.71.

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

Step 2. $R_L = 47.5 - 25 =$ **22.5 Ω**

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,

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

At the medium position,

$6 = (0.01 + R_2 + R_3 + 0.02) \times 3 \longrightarrow R_2 + R_3 = 1.97$

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

At the low position,

$6 = (0.01 + R_1 + R_2 + R_3 + 0.02) \times 1 \longrightarrow R_1 + R_2 + R_3 = 5.97$
$R_1 = 5.97 - 1.97 = \mathbf{4\ \Omega}$

Solution 2.75

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

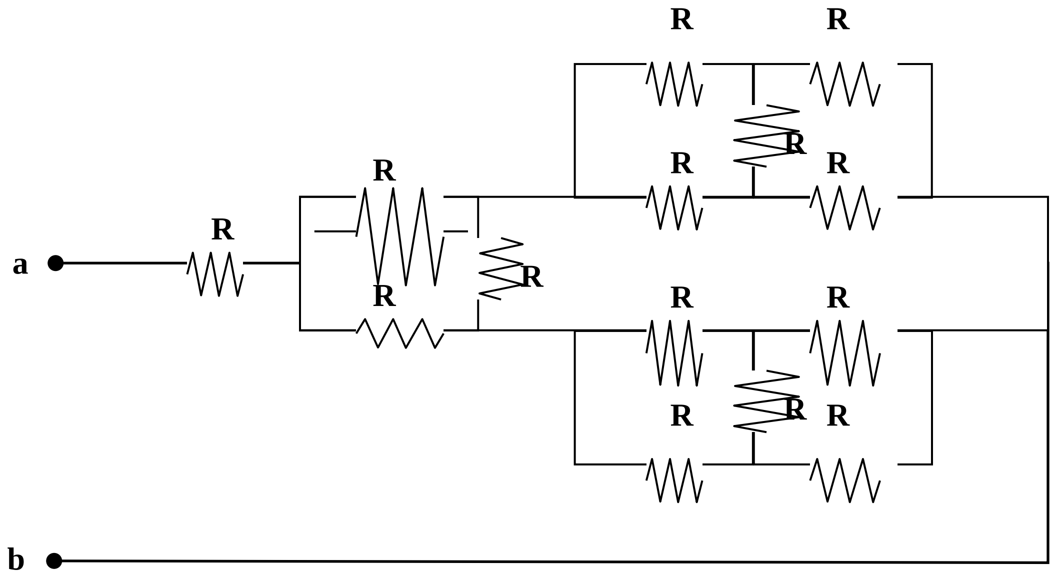
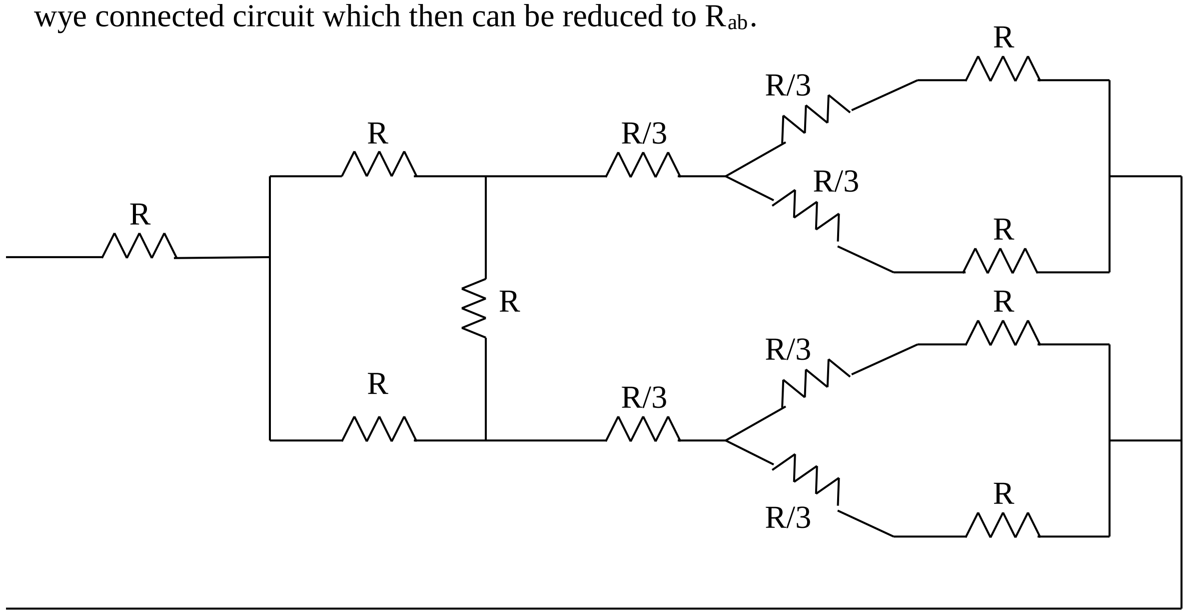


Figure 2.135
For Prob. 2.75.

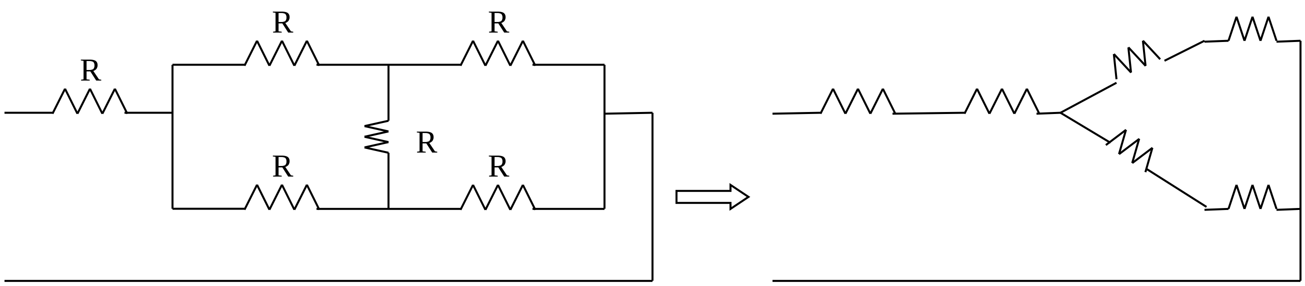
Step 1. There are two delta circuits that can be converted to a wye connected circuit. This then allows us to combine resistances together in series and in parallel. This will yield a new circuit with one remaining delta connected circuit that can be converted to a wye connected circuit which then can 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) $40\text{k}\Omega = 12\text{k}\Omega + 28\text{k}\Omega = (24\|24k) + (56k\|56k)$

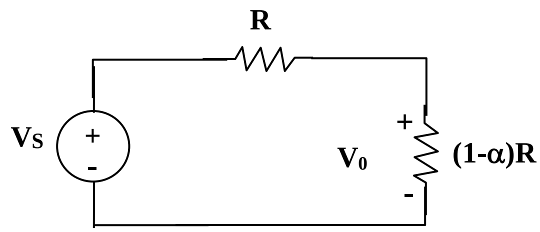
i.e., **Two 24kΩ resistors in parallel connected in series with two 56kΩ resistors in parallel.**

(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

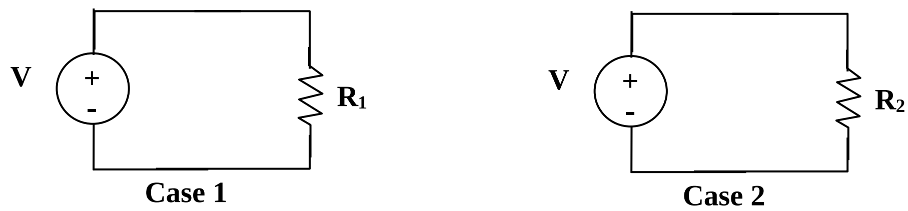
$$R = v^2/(p) = 6^2/(240 \times 10^{-3}) = 150\Omega$$
$$I = p/(v) = 240 \text{ mW}/(6\text{V}) = 40 \text{ mA}$$

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

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?

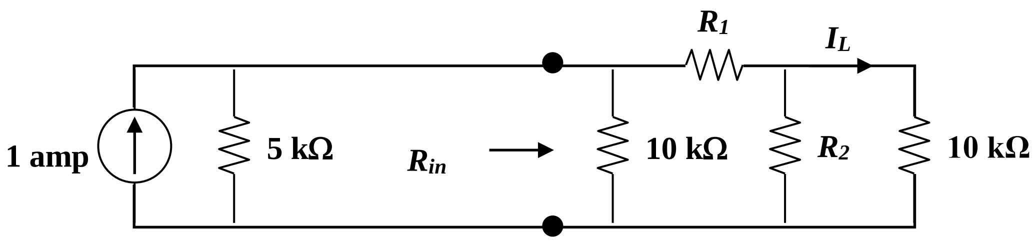


Figure 2.140
For Prob. 2.81.

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

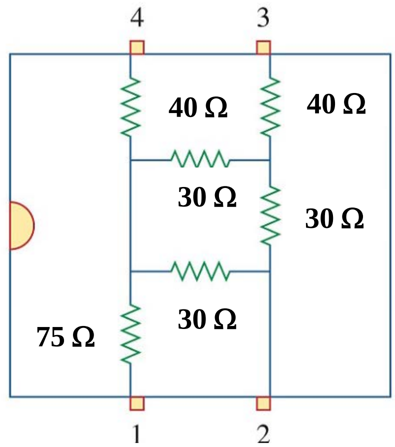
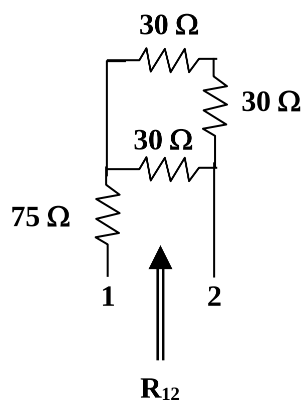


Figure 2.141
For Prob. 2.82.

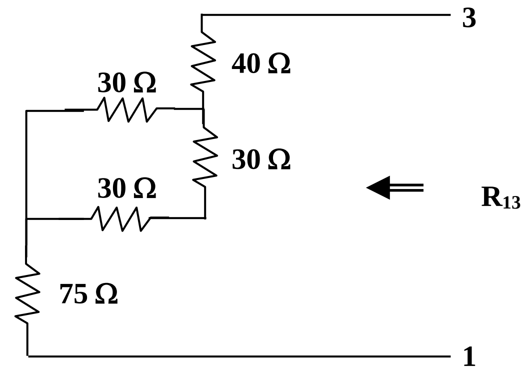
Solution

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.

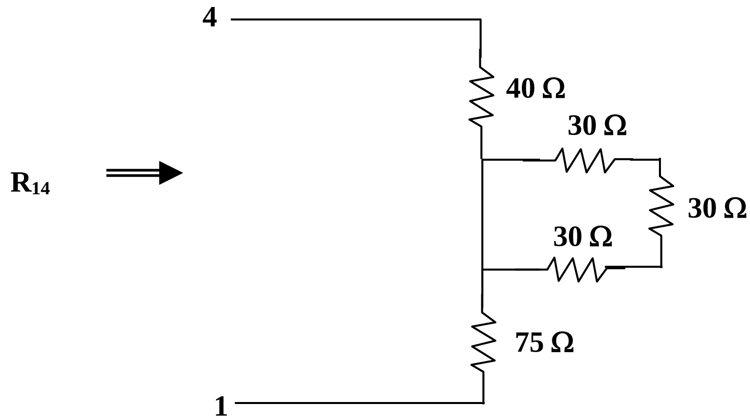
(a)



(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.

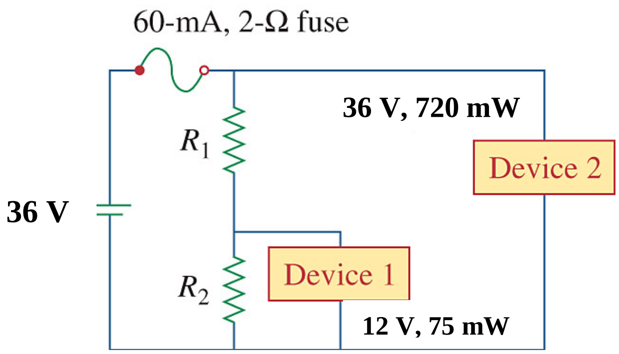


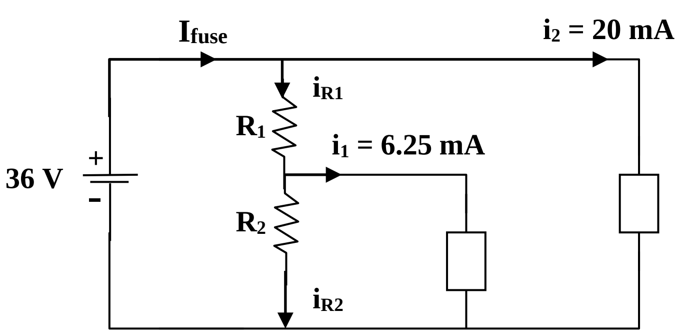
Figure 2.142
For Prob. 2.83.

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.