

Section 2.4 Kirchhoff's Laws

2.8 Design a problem, complete with a solution, to help other students 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.

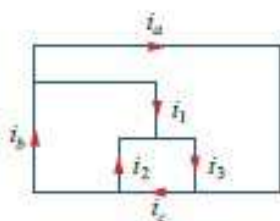


Figure 2.72

For Prob. 2.8.

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

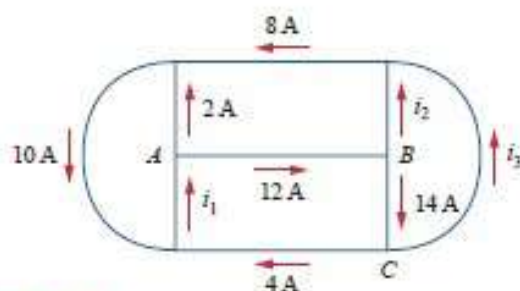


Figure 2.73

For Prob. 2.9.

2.10 Determine i_1 and i_2 in the circuit of Fig. 2.74.

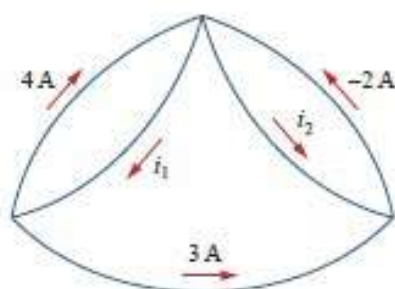


Figure 2.74

For Prob. 2.10.

2.12 In the circuit of Fig. 2.76, obtain v_1 , v_2 , and v_3 .

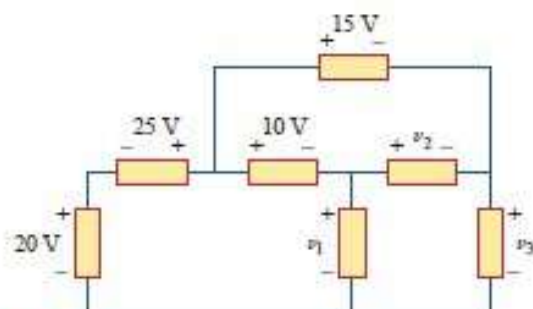


Figure 2.76

For Prob. 2.12.

2.13 For the circuit in Fig. 2.77, use KCL to find the branch currents I_1 to I_4 .

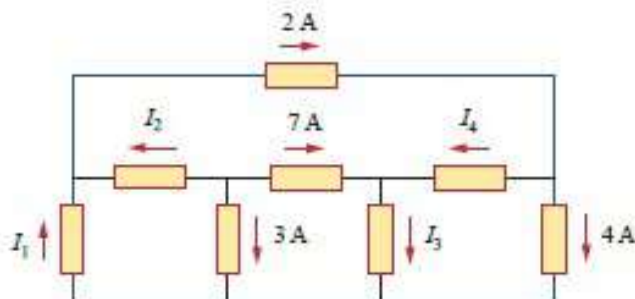


Figure 2.77

For Prob. 2.13.

2.14 Given the circuit in Fig. 2.78, use KVL to find the branch voltages V_1 to V_4 .

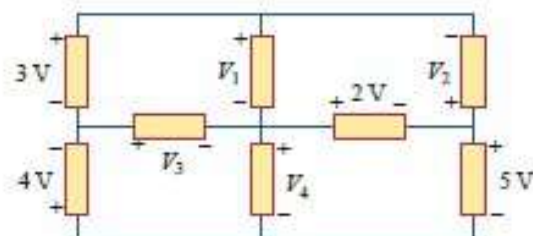


Figure 2.78

For Prob. 2.14.

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

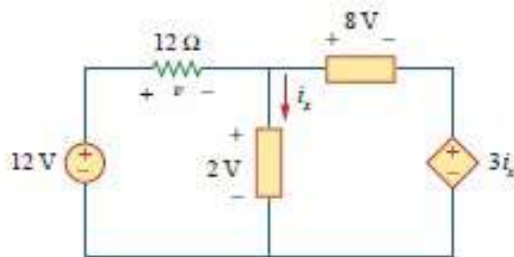


Figure 2.79
For Prob. 2.15.

2.16 Determine V_o in the circuit of Fig. 2.80.

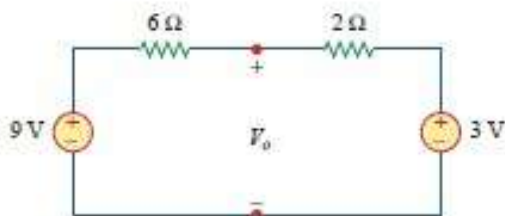


Figure 2.80
For Prob. 2.16.

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

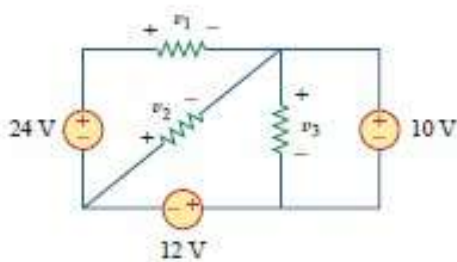


Figure 2.81
For Prob. 2.17.

2.18 Find I and V_{ab} in the circuit of Fig. 2.82.

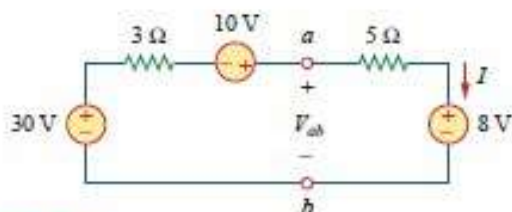


Figure 2.82
For Prob. 2.18.

2.19 From the circuit in Fig. 2.83, find I , the power dissipated by the resistor, and the power absorbed by each source.

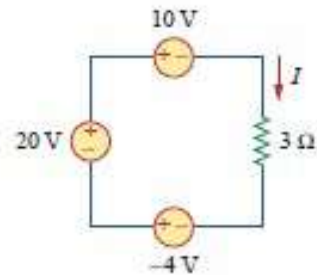


Figure 2.83
For Prob. 2.19.

2.20 Determine i_o in the circuit of Fig. 2.84.

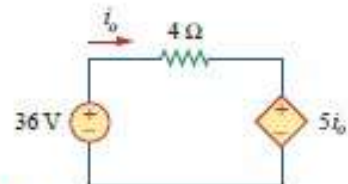


Figure 2.84
For Prob. 2.20.

2.21 Find V_x in the circuit of Fig. 2.85.

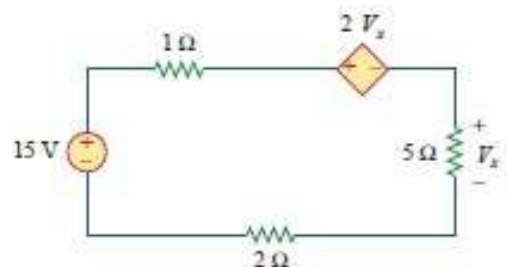


Figure 2.85
For Prob. 2.21.

2.22 Find V_o in the circuit of Fig. 2.86 and the power dissipated by the controlled source.

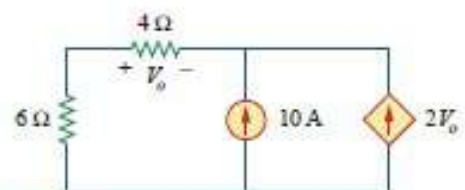


Figure 2.86
For Prob. 2.22.

2.31 For the circuit in Fig. 2.95, determine i_1 to i_5 .

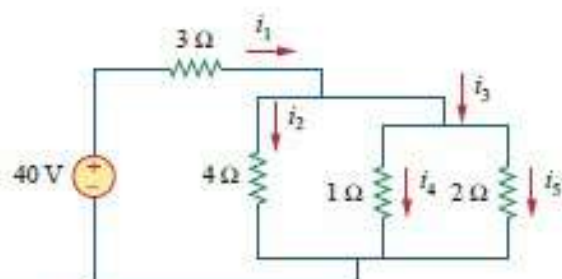


Figure 2.95
For Prob. 2.31.

2.32 Find i_1 through i_4 in the circuit of Fig. 2.96.

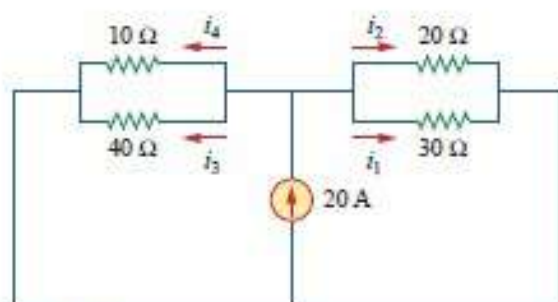


Figure 2.96
For Prob. 2.32.

2.33 Obtain v and i in the circuit of Fig. 2.97.

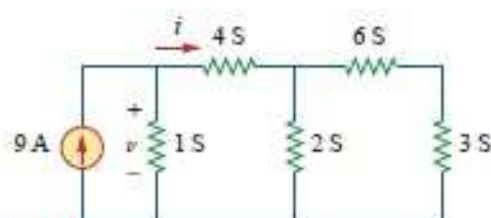


Figure 2.97
For Prob. 2.33.

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 dissipated power.

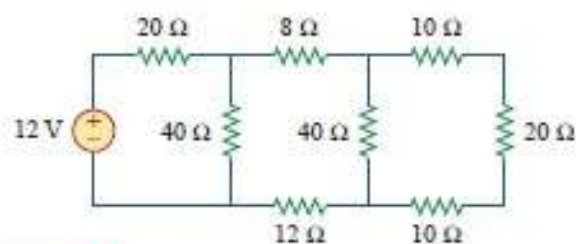


Figure 2.98
For Prob. 2.34.

2.35 Calculate V_o and I_o in the circuit of Fig. 2.99.

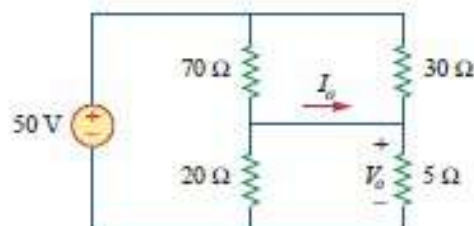


Figure 2.99
For Prob. 2.35.

2.36 Find i and V_o in the circuit of Fig. 2.100.

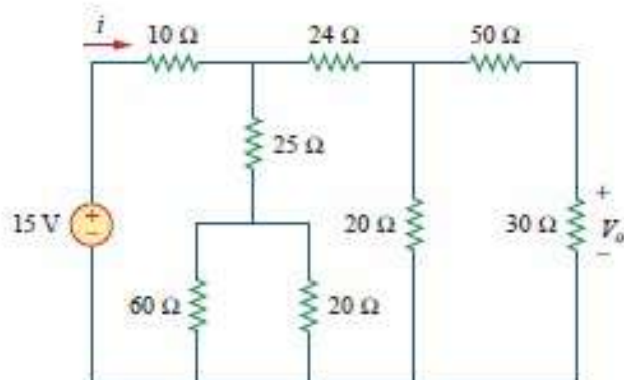


Figure 2.100
For Prob. 2.36.

2.37 Find R for the circuit in Fig. 2.101.

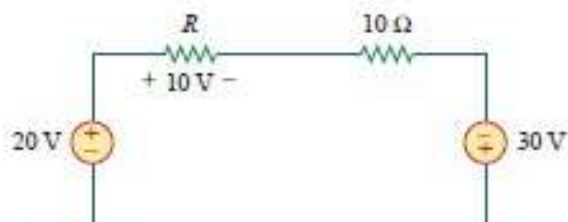


Figure 2.101
For Prob. 2.37.

2.38 Find R_{eq} and i_o in the circuit of Fig. 2.102.

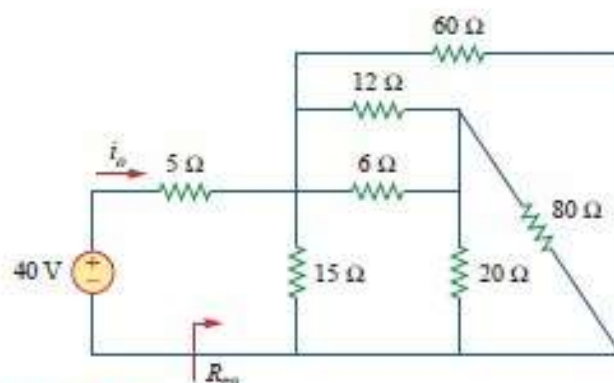


Figure 2.102
For Prob. 2.38.

- 2.39 Evaluate R_{eq} for each of the circuits shown in Fig. 2.103.

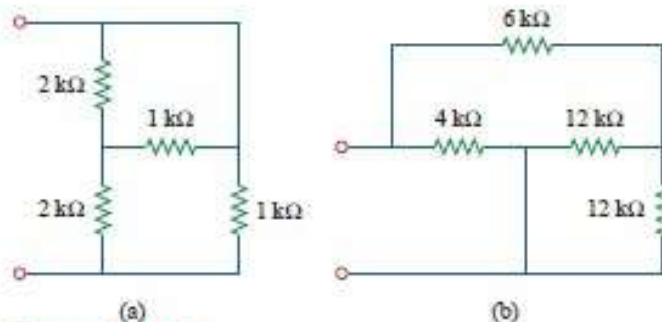


Figure 2.103
For Prob. 2.39.

- 2.40 For the ladder network in Fig. 2.104, find I and R_{eq} .

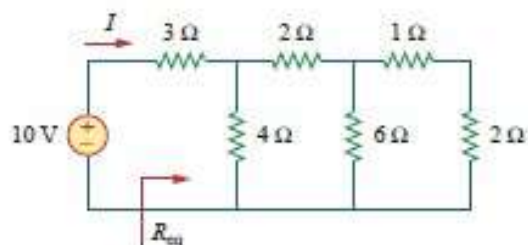


Figure 2.104
For Prob. 2.40.

- 2.41 If $R_{eq} = 50 \Omega$ in the circuit of Fig. 2.105, find R .

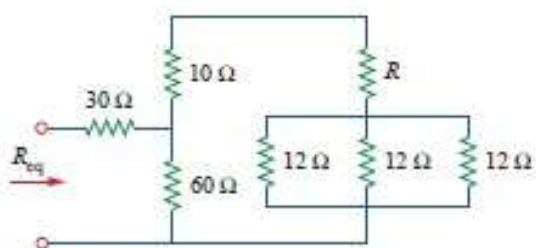


Figure 2.105
For Prob. 2.41.

- 2.42 Reduce each of the circuits in Fig. 2.106 to a single resistor at terminals a - b .

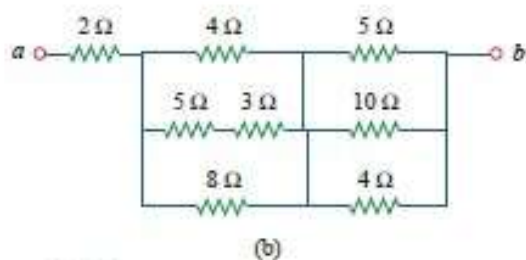
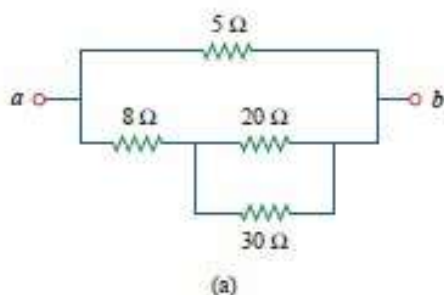


Figure 2.106
For Prob. 2.42.

- 2.43 Calculate the equivalent resistance R_{ab} at terminals a - b for each of the circuits in Fig. 2.107.

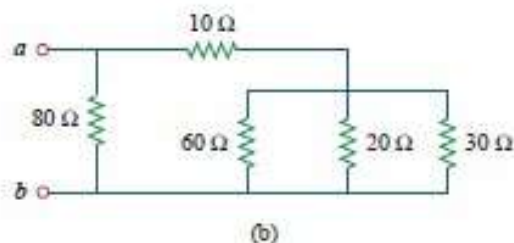
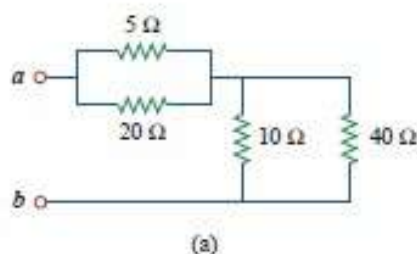


Figure 2.107
For Prob. 2.43.

- 2.44 For the circuit in Fig. 2.108, obtain the equivalent resistance at terminals a - b .

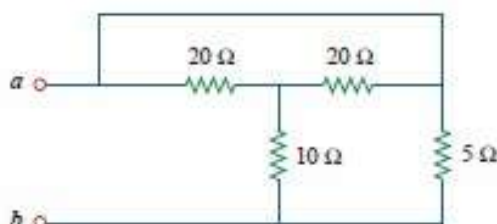


Figure 2.108
For Prob. 2.44.

2.45 Find the equivalent resistance at terminals a - b of each circuit in Fig. 2.109.

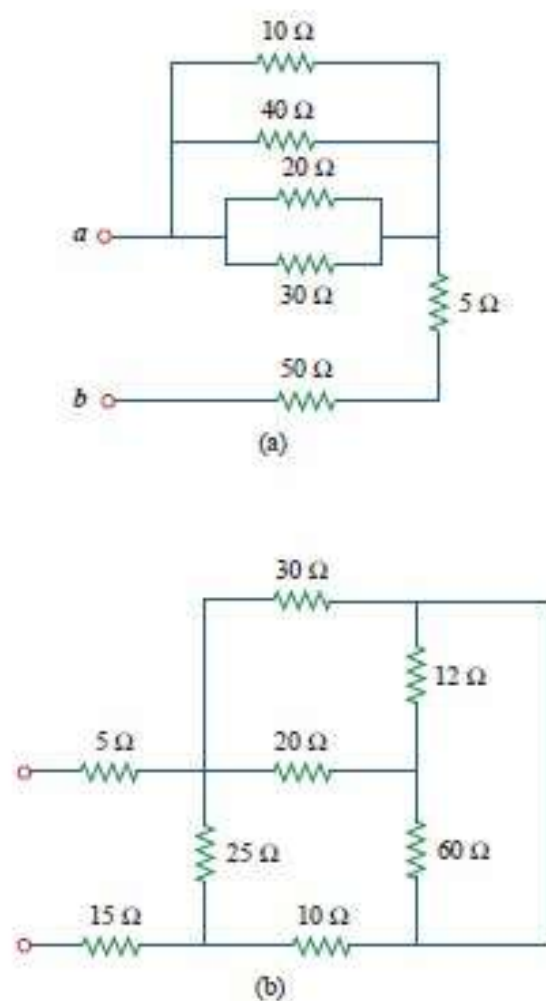


Figure 2.109
For Prob. 2.45.

2.46 Find I in the circuit of Fig. 2.110.

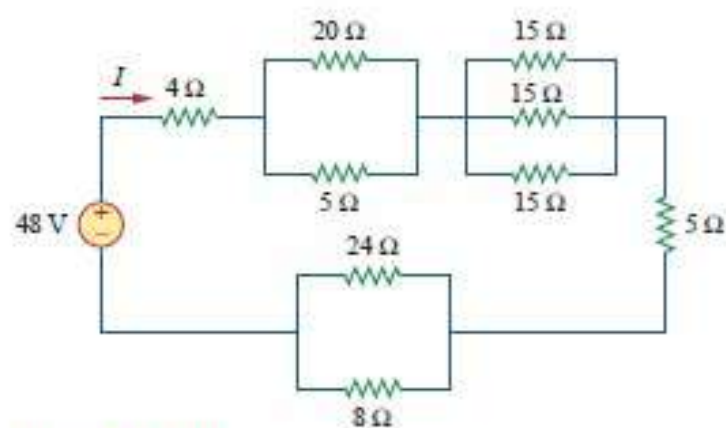
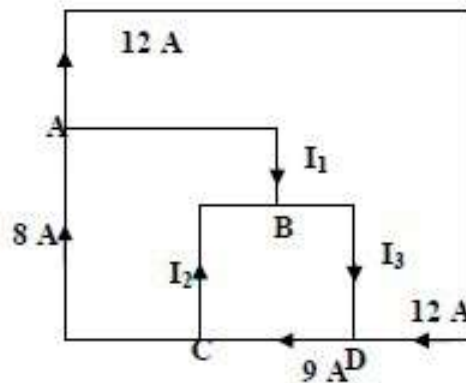


Figure 2.110
For Prob. 2.46.

Chapter 2, Problem 8.

Use KCL to obtain currents i_1 , i_2 , and i_3 in the circuit shown in Fig. 2.72.

Chapter 2, Solution 8



$$\begin{array}{lll} \text{At node a,} & 8 = 12 + i_1 \longrightarrow & \underline{i_1 = -4\text{ A}} \\ \text{At node c,} & 9 = 8 + i_2 \longrightarrow & \underline{i_2 = 1\text{ A}} \\ \text{At node d,} & 9 = 12 + i_3 \longrightarrow & \underline{i_3 = -3\text{ A}} \end{array}$$

Chapter 2, Problem 9.

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

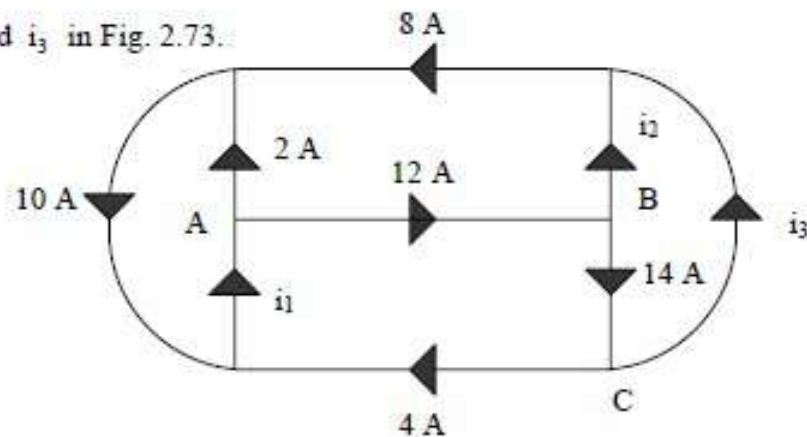


Figure 2.73 For Prob. 2.9.

Chapter 2, Solution 9

$$\text{At A, } 2 + 12 = i_1 \longrightarrow \underline{i_1 = 14\text{ A}}$$

$$\text{At B, } 12 = i_2 + 14 \longrightarrow \underline{i_2 = -2\text{ A}}$$

$$\text{At C, } 14 = 4 + i_3 \longrightarrow \underline{i_3 = 10\text{ A}}$$

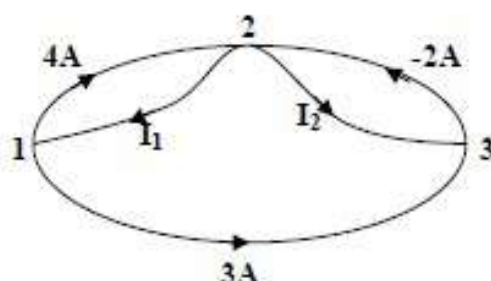
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Chapter 2, Problem 10.

In the circuit in Fig. 2.67 decrease in R_3 leads to a decrease of:

- (a) current through R_3
- (b) voltage through R_3
- (c) voltage across R_1
- (d) power dissipated in R_2
- (e) none of the above

Chapter 2, Solution 10



$$\begin{aligned}\text{At node 1, } 4 + 3 &= i_1 \longrightarrow i_1 = \underline{7A} \\ \text{At node 3, } 3 + i_2 &= -2 \longrightarrow i_2 = \underline{-5A}\end{aligned}$$

Chapter 2, Problem 11.

In the circuit of Fig. 2.75, calculate V_1 and V_2 .

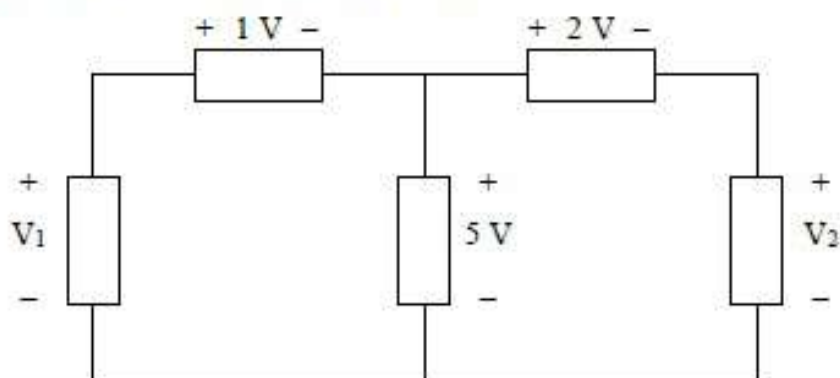
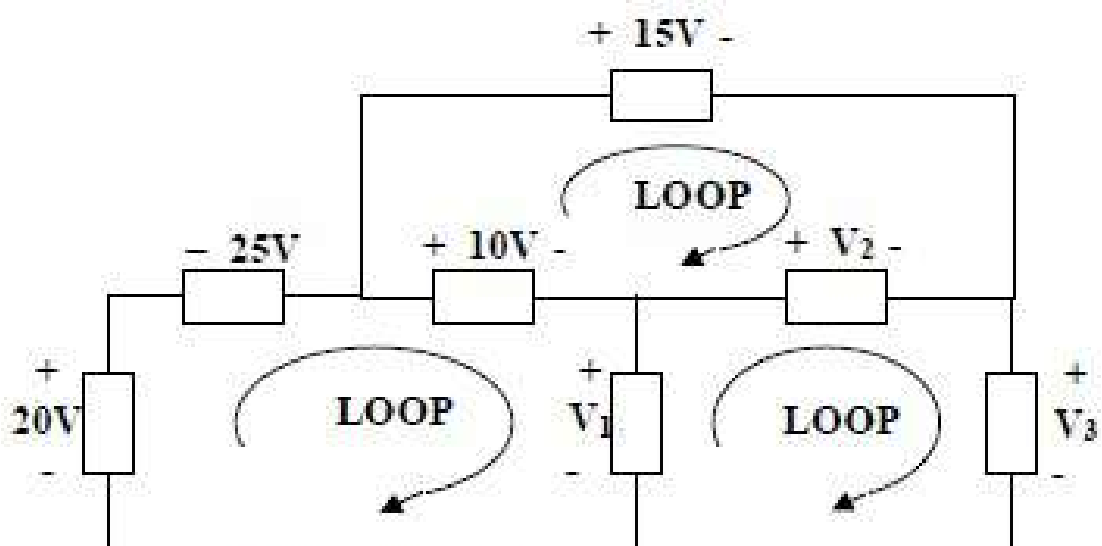


Figure 2.75 For Prob. 2.11.

Chapter 2, Solution 11

$$\begin{aligned}-V_1 + 1 + 5 &= 0 \longrightarrow V_1 = \underline{6V} \\ -5 + 2 + V_2 &= 0 \longrightarrow V_2 = \underline{3V}\end{aligned}$$

Chapter 2, Solution 12



$$\begin{array}{ll}
 \text{For loop 1,} & -20 - 25 + 10 + v_1 = 0 \longrightarrow \underline{v_1 = 35\text{V}} \\
 \text{For loop 2,} & -10 + 15 - v_2 = 0 \longrightarrow \underline{v_2 = 5\text{V}} \\
 \text{For loop 3,} & -V_1 + V_2 + V_3 = 0 \longrightarrow \underline{v_3 = 30\text{V}}
 \end{array}$$

Chapter 2, Problem 13.

For the circuit in Fig. 2.77, use KCL to find the branch currents I_1 to I_4 .

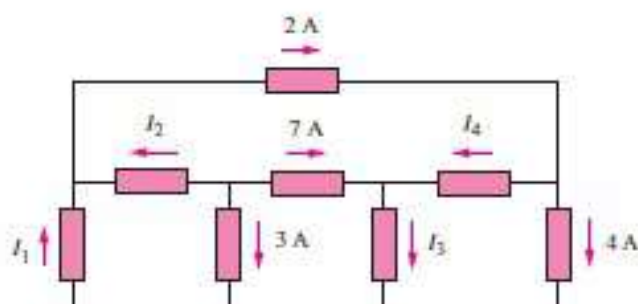
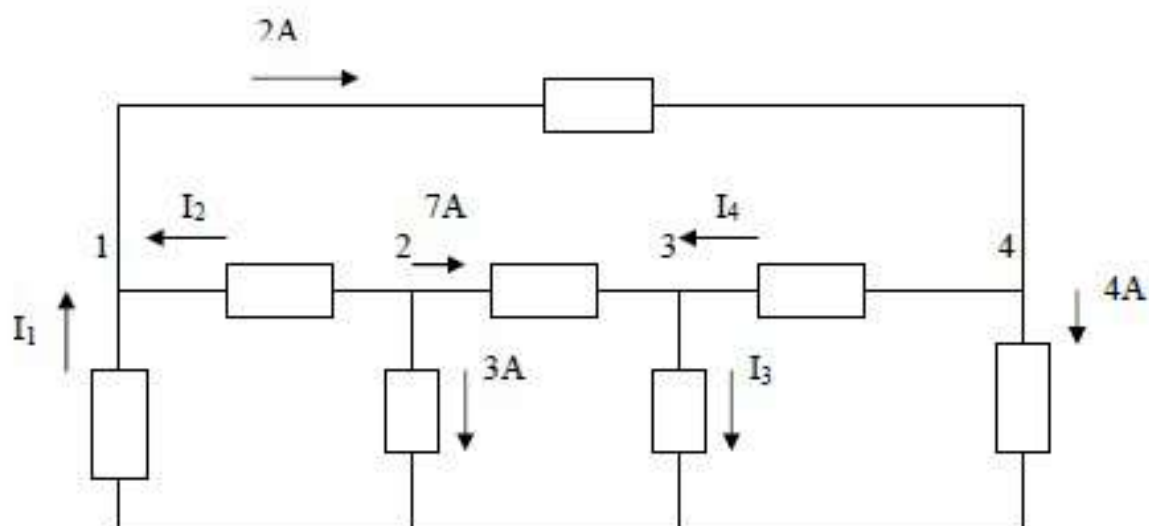


Figure 2.77

Chapter 2, Solution 13



At node 2,

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

At node 1,

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

At node 4,

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

At node 3,

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

Hence,

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

Chapter 2, Problem 14.

Given the circuit in Fig. 2.78, use KVL to find the branch voltages V_1 to V_4 .

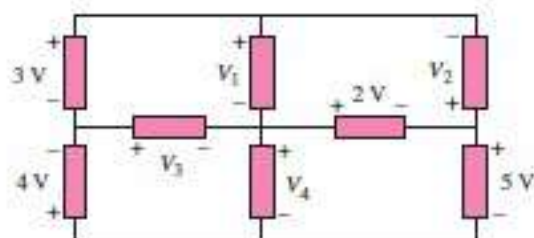
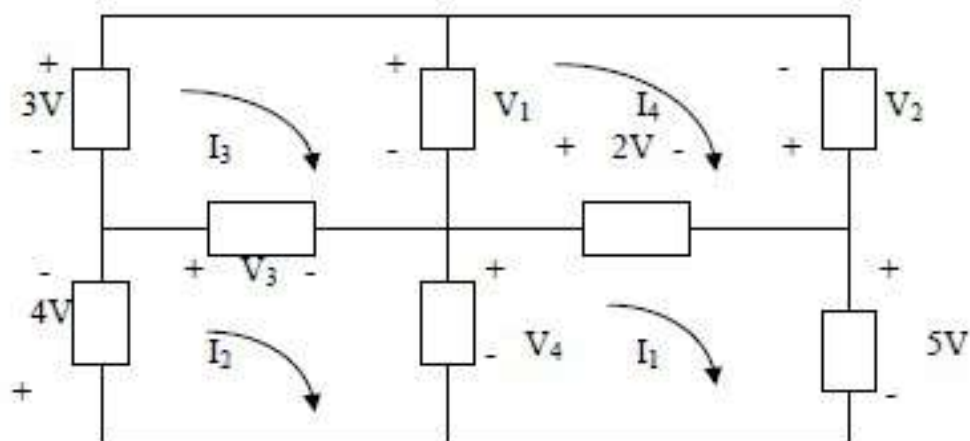


Figure 2.78

Chapter 2, Solution 14



For mesh 1,

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

For mesh 2,

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

For mesh 3,

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

For mesh 4,

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

Thus,

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

Chapter 2, Problem 17.

Obtain v_1 through v_3 in the circuit in Fig. 2.78.

Chapter 2, Solution 17

Applying KVL around the entire outside loop we get,

$$-24 + v_1 + 10 + 12 = 0 \text{ or } v_1 = \underline{2V}$$

Applying KVL around the loop containing v_2 , the 10-volt source, and the 12-volt source we get,

$$v_2 + 10 + 12 = 0 \text{ or } v_2 = \underline{-22V}$$

Applying KVL around the loop containing v_3 and the 10-volt source we get,

$$-v_3 + 10 = 0 \text{ or } v_3 = \underline{10V}$$

Chapter 2, Problem 18.

Find I and V_{ab} in the circuit of Fig. 2.79.

Chapter 2, Solution 18

APPLYING KVL,

$$-30 - 10 + 8 + I(3+5) = 0$$

$$8I = 32 \quad \longrightarrow \quad I = \underline{4A}$$

$$-V_{ab} + 5I + 8 = 0 \quad \longrightarrow \quad V_{ab} = \underline{28V}$$

Chapter 2, Problem 15.

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

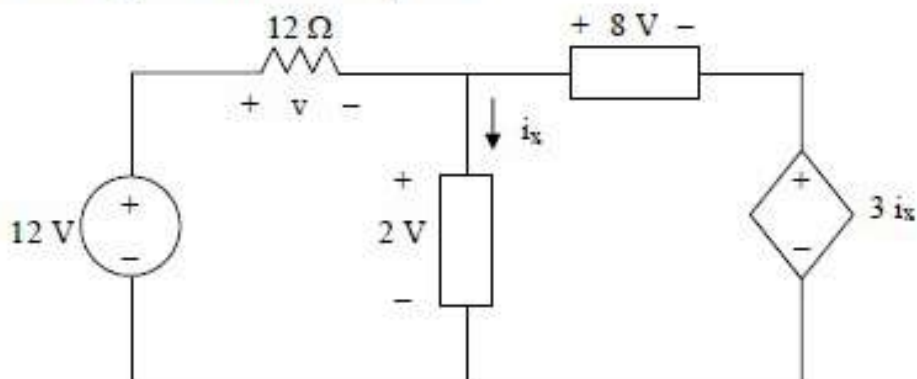


Figure 2.79 For Prob. 2.15.

Chapter 2, Solution 15

For loop 1, $-12 + v + 2 = 0$, $v = \underline{10 \text{ V}}$

For loop 2, $-2 + 8 + 3i_x = 0$, $i_x = \underline{-2 \text{ A}}$

Chapter 2, Problem 16.

Determine V_o in the circuit in Fig. 2.80.

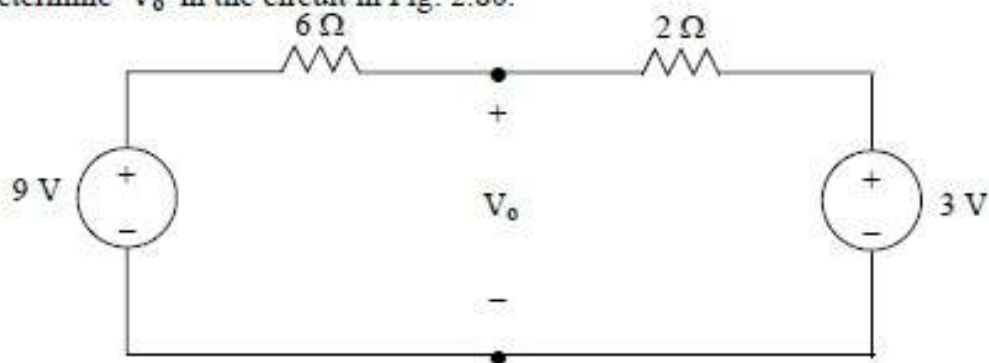


Figure 2.80 For Prob. 2.16.

Chapter 2, Solution 16

Apply KVL,

$$-9 + (6+2)I + 3 = 0, \quad 8I = 9-3=6, \quad I = 6/8$$

Also,

$$-9 + 6I + V_o = 0$$

$$V_o = 9 - 6I = \underline{4.5 \text{ V}}$$

Chapter 2, Problem 19.

From the circuit in Fig. 2.80, find I , the power dissipated by the resistor, and the power supplied by each source.

Chapter 2, Solution 19

APPLYING KVL AROUND THE LOOP, WE OBTAIN

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

Power dissipated by the resistor:

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

Power supplied by the sources:

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

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

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

Chapter 2, Problem 20.

Determine i_o in the circuit of Fig. 2.81.

Chapter 2, Solution 20

APPLYING KVL AROUND THE LOOP,

$$-36 + 4i_o + 5i_o = 0 \longrightarrow \underline{i_o = 4A}$$

Chapter 2, Problem 21.

Find V_x in the circuit of Fig. 2.85.

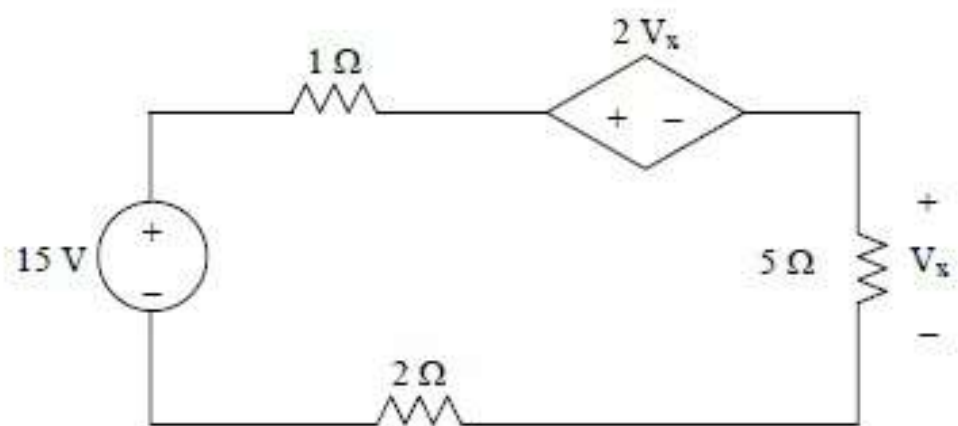


Figure 2.85 For Prob. 2.21.

Chapter 2, Solution 21

Applying KVL,

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

But $V_x = 5I$,

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

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

Chapter 2, Problem 31.

For the circuit in Fig. 2.95, determine i_1 to i_5 .

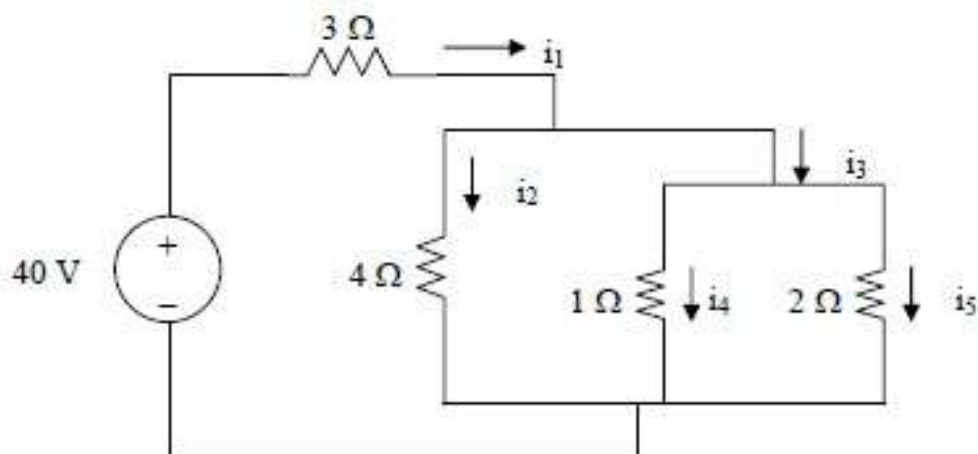


Figure 2.95 For Prob. 2.31.

Chapter 2, Solution 31

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

$$i_1 = \frac{40}{3.5714} = \underline{11.2 \text{ A}}$$

$$v_1 = 0.5714 \times i_1 = 6.4 \text{ V}, \quad i_2 = \frac{v_1}{4} = \underline{1.6 \text{ A}}$$

$$i_4 = \frac{v_1}{1} = \underline{6.4 \text{ A}}, \quad i_5 = \frac{v_1}{2} = \underline{3.2 \text{ A}}, \quad i_3 = i_4 + i_5 = \underline{9.6 \text{ A}}$$

Chapter 2, Problem 32.

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

Chapter 2, Solution 32

We first combine resistors in parallel.

$$20\parallel 30 = \frac{20 \times 30}{50} = 12\ \Omega$$

$$10\parallel 40 = \frac{10 \times 40}{50} = 8\ \Omega$$

Using current division principle,

$$i_1 + i_2 = \frac{8}{8 + 12}(20) = 8\text{A}, i_3 + i_4 = \frac{12}{20}(20) = 12\text{A}$$

$$i_1 = \frac{20}{50}(8) = \underline{3.2\text{ A}}$$

$$i_2 = \frac{30}{50}(8) = \underline{4.8\text{ A}}$$

$$i_3 = \frac{10}{50}(12) = \underline{2.4\text{ A}}$$

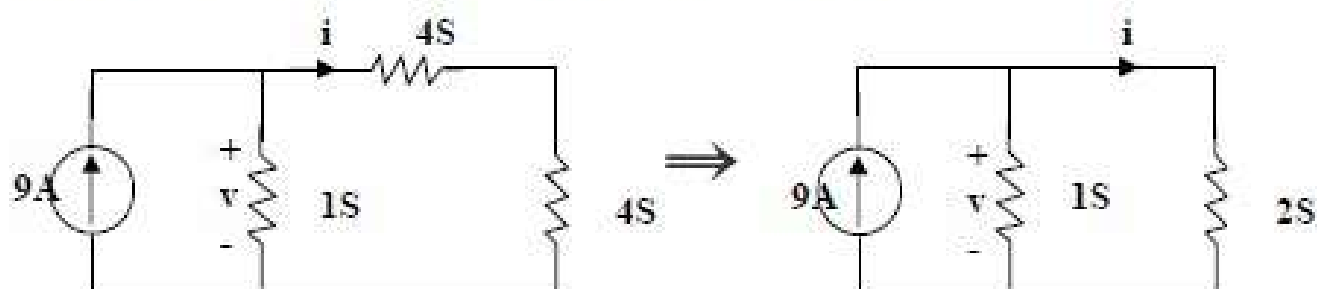
$$i_4 = \frac{40}{50}(12) = \underline{9.6\text{ A}}$$

Chapter 2, Problem 33.

Obtain v and i in the circuit in Fig. 2.97.

Chapter 2, Solution 33

Combining the conductance leads to the equivalent circuit below



$$6S \parallel 3S = \frac{6 \times 3}{9} = 2S \text{ and } 2S + 2S = 4S$$

Using current division,

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

Chapter 2, Problem 34.

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

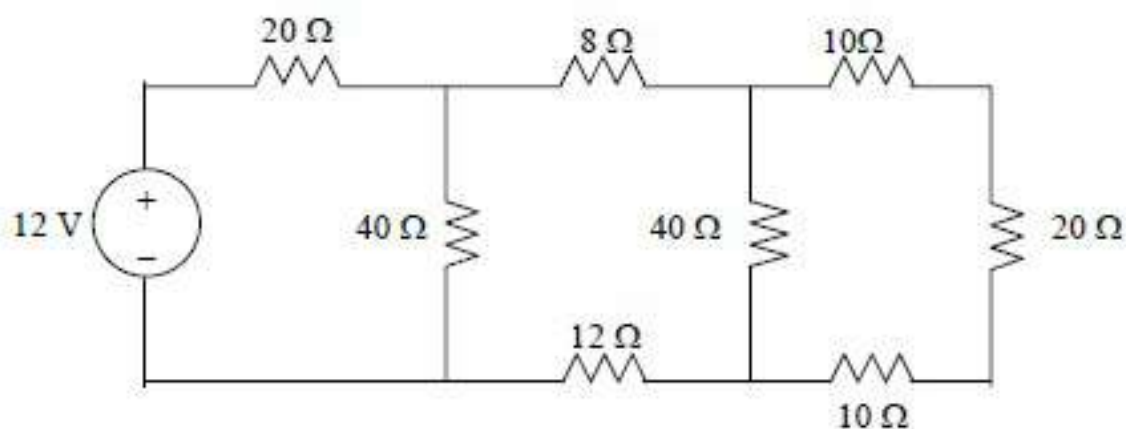


Figure 2.98 For Prob. 2.34.

Chapter 2, Solution 34

$$40 // (10 + 20 + 10) = 20 \, \Omega,$$

$$40 // (8 + 12 + 20) = 20 \, \Omega$$

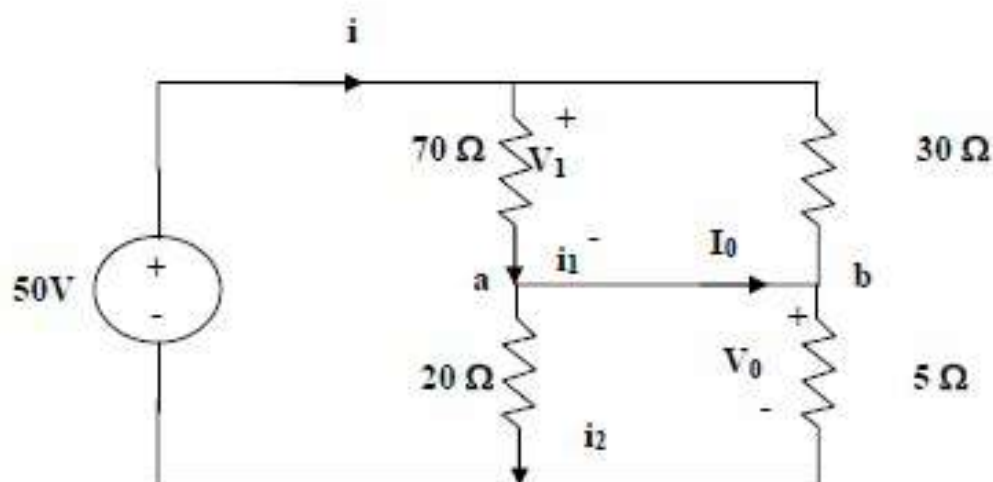
$$R_{eq} = 20 + 20 = \underline{40 \, \Omega}$$

$$I = \frac{V}{R_{eq}} = 12 / 40, \quad P = VI = \frac{12^2}{40} = \underline{3.6 \, W}$$

Chapter 2, Problem 35.

Calculate V_o and I_o in the circuit of Fig. 2.99.

Chapter 2, Solution 35



Combining the versions in parallel,

$$70\parallel 30 = \frac{70 \times 30}{100} = 21\Omega, \quad 20\parallel 5 = \frac{20 \times 5}{25} = 4\Omega$$

$$i = \frac{50}{21 + 4} = 2\text{ A}$$

$$v_1 = 21i = 42\text{ V}, \quad v_0 = 4i = 8\text{ V}$$

$$i_1 = \frac{v_1}{70} = 0.6\text{ A}, \quad i_2 = \frac{v_2}{20} = 0.4\text{ A}$$

At node a, KCL must be satisfied

$$i_1 = i_2 + I_o \longrightarrow 0.6 = 0.4 + I_o \longrightarrow I_o = 0.2\text{ A}$$

Hence $v_0 = \underline{8\text{ V}}$ and $I_o = \underline{0.2\text{ A}}$

Chapter 2, Problem 36.

Find i and V_o in the circuit of Fig. 2.100.

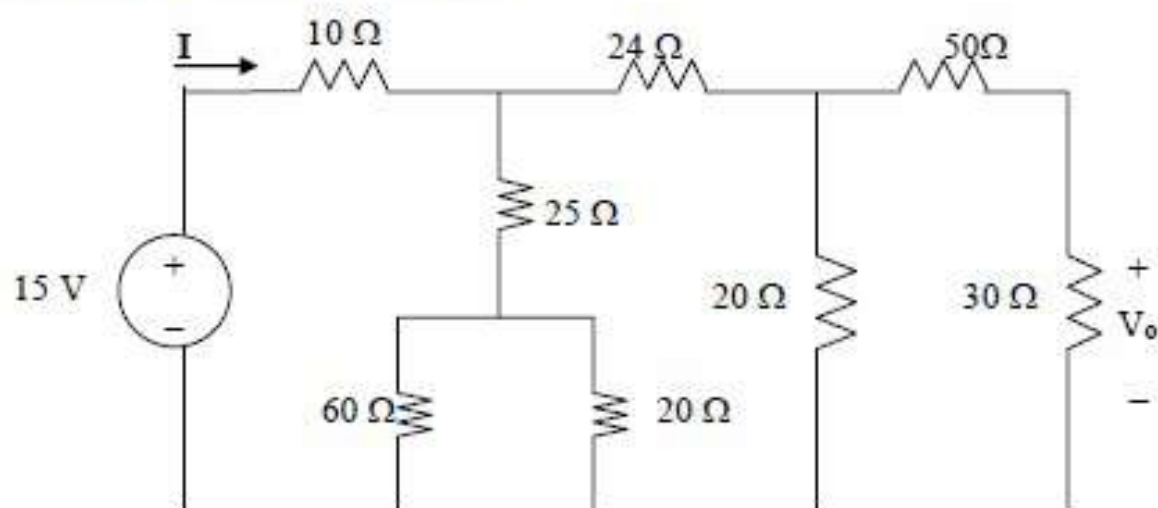


Figure 2.100 For Prob. 2.36.

Chapter 2, Solution 36

$$20 \parallel (30 + 50) = 16, \quad 24 + 16 = 40, \quad 60 \parallel 20 = 15$$

$$R_{eq} = 10 + (15 + 25) \parallel 40 = 10 + 20 = 30$$

$$i = \frac{v_s}{R_{eq}} = \frac{15}{30} = \underline{0.5 \text{ A}}$$

If i_1 is the current through the $24\text{-}\Omega$ resistor and i_o is the current through the $50\text{-}\Omega$ resistor, using current division gives

$$i_1 = \frac{40}{40 + 40} i = 0.25 \text{ A}, \quad i_o = \frac{20}{20 + 80} i_1 = 0.05 \text{ A}$$

$$v_o = 30i_o = 30 \times 0.05 = \underline{1.5 \text{ V}}$$

Chapter 2, Problem 37.

Find R for the circuit in Fig. 2.101.

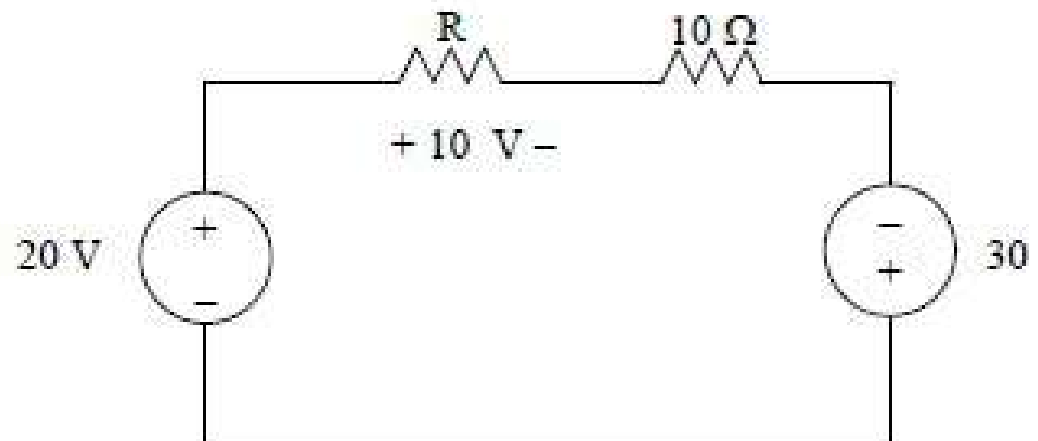


Figure 2.101 For Prob. 2.37.

Chapter 2, Solution 37

Applying KVL,

$$-20 + 10 + 10I - 30 = 0, \quad I = 4$$

$$10 = RI \quad \longrightarrow \quad R = \frac{10}{I} = \underline{2.5\ \Omega}$$

Chapter 2, Problem 38.

Find R_{eq} and i_o in the circuit of Fig. 2.102.

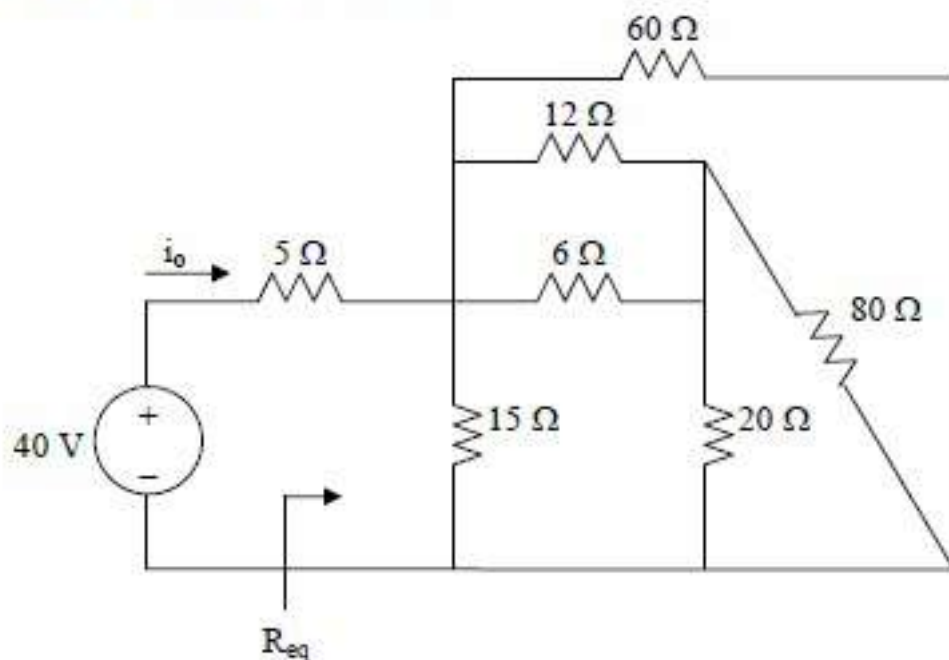
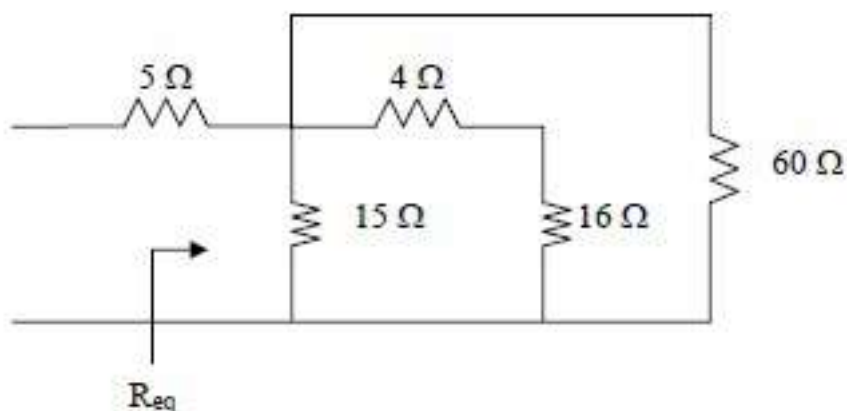


Figure 2.102 For Prob. 2.38

Chapter 2, Solution 38

$$20 // 80 = 80 \times 20 / 100 = 16, \quad 6 // 12 = 6 \times 12 / 18 = 4$$

The circuit is reduced to that shown below.



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

$$R_{eq} = 15 // 15 + 5 = \underline{12.5 \Omega}$$

$$i_o = \frac{40}{R_{eq}} = \underline{3.2 \text{ A}}$$

Chapter 2, Problem 39.

Evaluate R_{eq} for each of the circuits shown in Fig. 2.103.

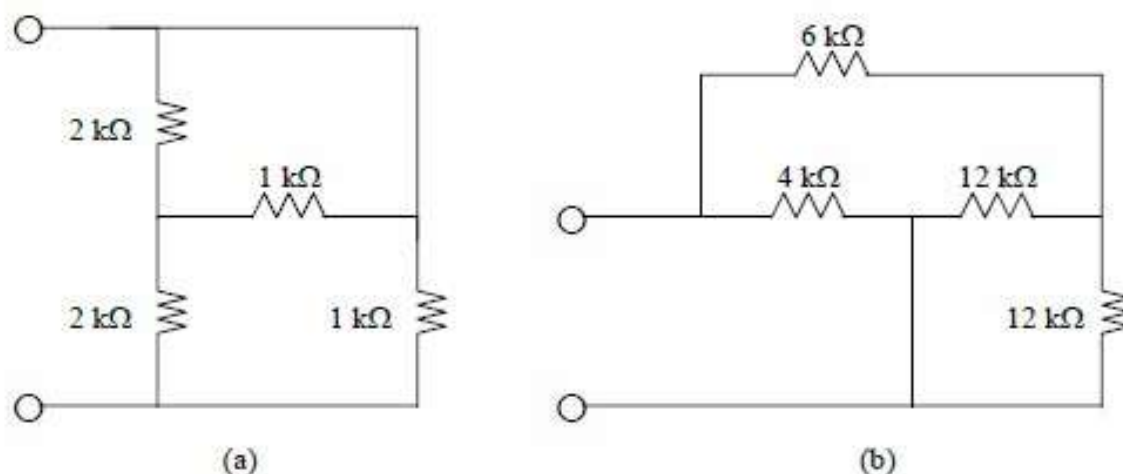


Figure 2.103 For Prob. 2.39.

Chapter 2, Solution 39

(a) We note that the top 2k-ohm resistor is actually in parallel with the first 1k-ohm resistor. This can be replaced (2/3)k-ohm resistor. This is now in series with the second 2k-ohm resistor which produces a 2.667k-ohm resistor which is now in parallel with the second 1k-ohm resistor. This now leads to,

$$R_{eq} = [(1 \times 2.667) / 3.667]k = \underline{727.3 \Omega}.$$

(b) We note that the two 12k-ohm resistors are in parallel producing a 6k-ohm resistor. This is in series with the 6k-ohm resistor which results in a 12k-ohm resistor which is in parallel with the 4k-ohm resistor producing,

$$R_{eq} = [(4 \times 12) / 16]k = \underline{3 k\Omega}.$$

Chapter 2, Problem 40.

For the ladder network in Fig. 2.104, find I and R_{eq} .

Chapter 2, Solution 40

$$R_{eq} = 3 + 4 \parallel (2 + 6 \parallel 3) = 3 + 2 = \underline{5\Omega}$$

$$I = \frac{10}{R_{eq}} = \frac{10}{5} = \underline{2 A}$$

Chapter 2, Problem 41.

If $R_{eq} = 50\ \Omega$ in the circuit in Fig. 2.105, find R .

Chapter 2, Solution 41

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

$$\frac{1}{R_0} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} \longrightarrow R_0 = 4$$

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

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

$$\text{or } R = \underline{16\ \Omega}$$

Chapter 2, Problem 42.

Reduce each of the circuits in Fig. 2.106 to a single resistor at terminals a - b .

Chapter 2, Solution 42

$$(a) \quad R_{ab} = 5 \parallel (8 + 20 \parallel 30) = 5 \parallel (8 + 12) = \frac{5 \times 20}{25} = \underline{4\ \Omega}$$

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

Chapter 2, Problem 43

Calculate the equivalent resistance R_{ab} at terminals a - b for each of the circuits in Fig. 2.107.

Chapter 2, Solution 43

$$(a) \quad R_{ab} = 5 \parallel 20 + 10 \parallel 40 = \frac{5 \times 20}{25} + \frac{400}{50} = 4 + 8 = \underline{12 \, \Omega}$$

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

$$R_{ab} = 80 \parallel (10 + 10) = \frac{80 + 20}{100} = \underline{16 \, \Omega}$$