EXAMPLE 9–17

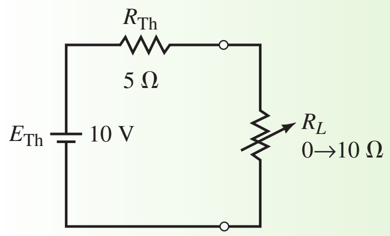

FIGURE 9–72

PSPICE

Use PSpice to input the circuit of Figure 9–72 and use the Probe postprocessor to display output voltage, current, and power as a function of load resistance.

Solution The circuit is constructed as shown in Figure 9–73.

- Double-click on each resistor in the circuit and change the Reference cells to RTH and RL. Click on Apply to accept the changes.
- Double-click on the value for RL and enter **{Rx}.** Place the PARAM part adjacent to RL. Use the *Property Editor* to assign a default value of **10 Ω** to Rx. Click on Apply. Have the display show the name and value and then exit the *Property Editor*. If necessary, refer to Example 7–15 for the complete procedure on how to assign parameters to a circuit component.

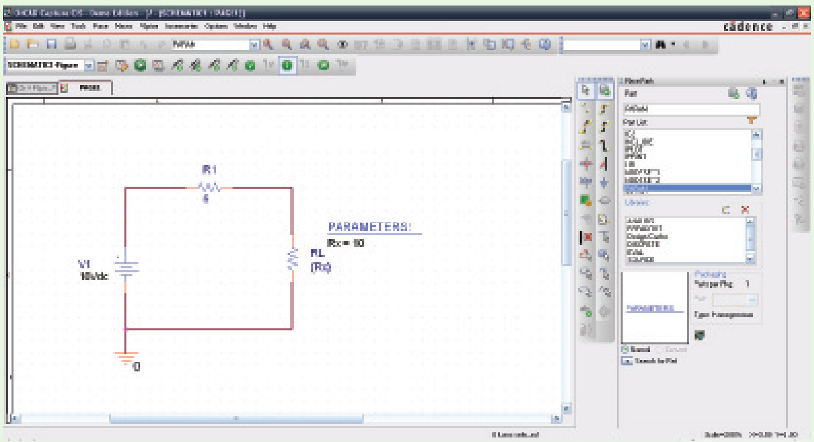

FIGURE 9–73

- Adjust the *Simulation Settings* to result in a dc sweep of the load resistor from **0.1 Ω** to **10 Ω** in **0.1 Ω** increments.
- Click on the *Run* icon once the circuit is complete.
- Once the design is simulated, you will see a blank screen with the abscissa (horizontal axis) showing RX scaled from 0 to 10 Ω.
- Since we would like to have a simultaneous display of voltage, current, and power, it is necessary to do the following:

  To display V_L: Click *Trace* and then *Add Trace*. Select **V(RL:1).** Click *OK* and the load voltage will appear as a function of load resistance.

  To display I_L: First add another axis by clicking on *Plot* and *Add Y Axis*. Next, click *Trace* and then *Add Trace*. Select **I(RL).** Click OK and the load current will appear as a function of load resistance.

  To display P_L: Add another Y axis. Click *Trace* and *Add Trace*. One method of showing power is to enter **W(RL)** and then click *OK*. The display will appear as shown in Figure 9–74. The color and line thickness of a trace can be changed by right-clicking anywhere on the desired trace and selecting *Trace Property*.

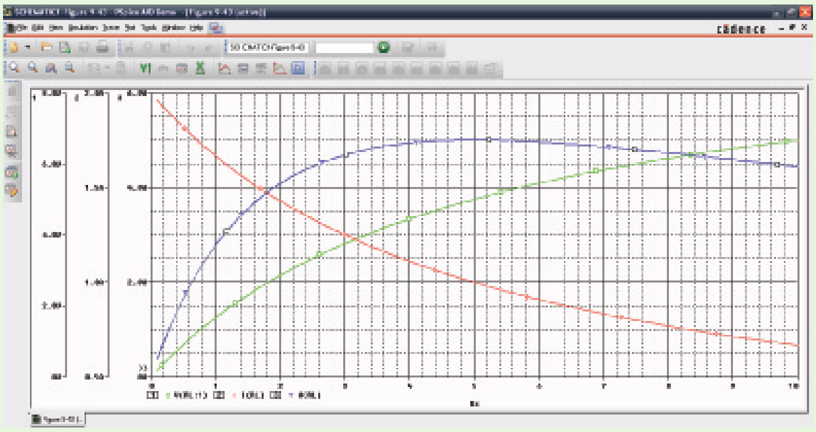

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FIGURE 9–74

PRACTICE PROBLEMS 8

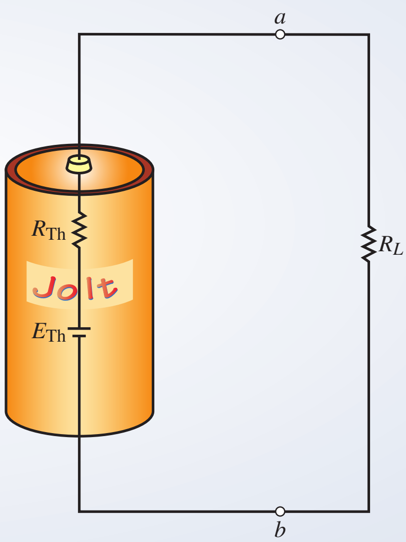
Use PSpice to input the circuit of Figure 9–66. Use the Probe postprocessor to obtain voltage, current, and power for the load resistor as it is varied from 0 to 5 kΩ.

Putting It into Practice

A simple battery cell (such as a D cell) can be represented as a Thévenin equivalent circuit as shown in the accompanying figure.

The Thévenin voltage represents the open-circuit (or unloaded) voltage of the battery cell, while the Thévenin resistance is the internal resistance of the battery. When a load resistance is connected across the terminals of the battery, the voltage V_{ab} will decrease due to the voltage drop across the internal resistor. By taking two measurements, it is possible to find the Thévenin equivalent circuit of the battery.

When no load is connected between the terminals of the battery, the terminal voltage is found to be $V_{ab} = 1.493$ V. When a resistance of $R_L = 10.6\ \Omega$ is connected across the terminals, the voltage is measured to be $V_{ab} = 1.430$ V. Determine the Thévenin equivalent circuit of the battery. Use the measurements to determine the efficiency of the battery for the given load.



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Problems

9.1 Superposition Theorem

1. Given the circuit of Figure 9–75, use superposition to calculate the current through each of the resistors.
2. Use superposition to determine the voltage drop across each of the resistors of the circuit in Figure 9–76.
3. Use superposition to solve for the voltage V_a and the current I in the circuit of Figure 9–77.

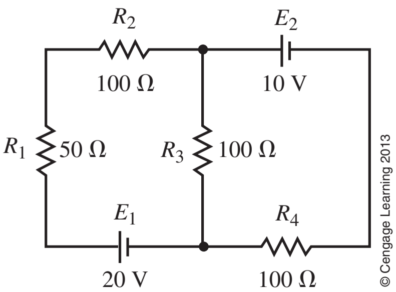

FIGURE 9–75

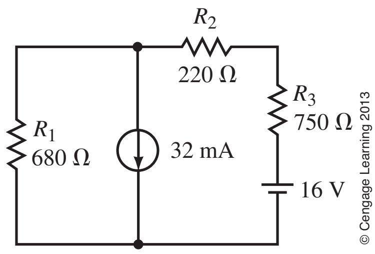

FIGURE 9–76

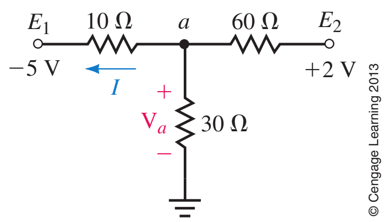

FIGURE 9–77

4. Using superposition, find the current through the 480-Ω resistor in the circuit of Figure 9–78.
5. Given the circuit of Figure 9–79, what must be the value of the unknown voltage source to ensure that the current through the load is $I_L = 5$ mA as shown? Verify the results using superposition.
6. If the load resistor in the circuit of Figure 9–80 is to dissipate 120 W, determine the value of the unknown voltage source. Verify the results using superposition.

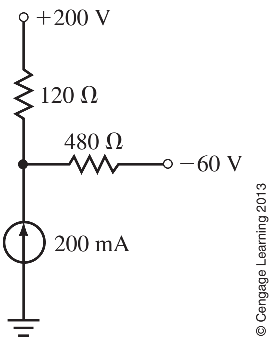

FIGURE 9–78

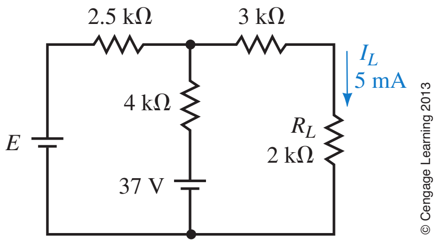

FIGURE 9–79

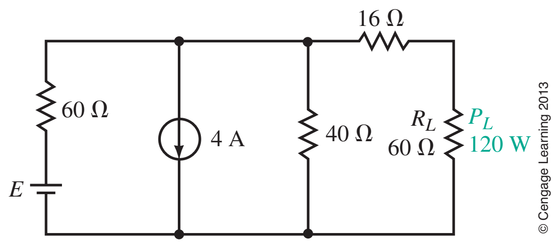

FIGURE 9–80

9.2 Thévenin's Theorem

7. Find the Thévenin equivalent external to R_L in the circuit of Figure 9–81. Use the equivalent circuit to find V_{ab}.
8. Repeat Problem 7 for the circuit of Figure 9–82.
9. Repeat Problem 7 for the circuit of Figure 9–83.
10. Repeat Problem 7 for the circuit of Figure 9–84.
11. Refer to the circuit of Figure 9–85:
    a. Find the Thévenin equivalent circuit external to R_L.
    b. Use the equivalent circuit to determine V_{ab} when $R_L = 20\ \Omega$ and when $R_L = 50\ \Omega$.

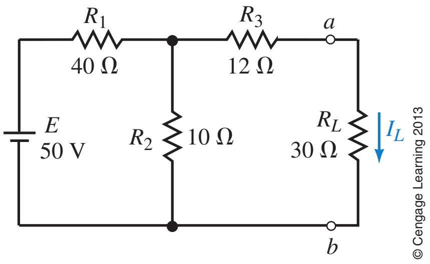

FIGURE 9–81

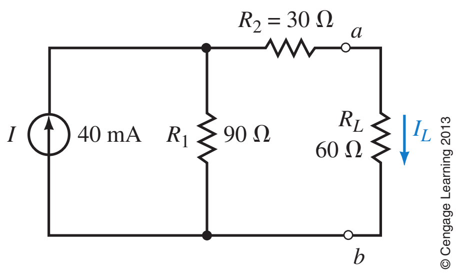

FIGURE 9–82

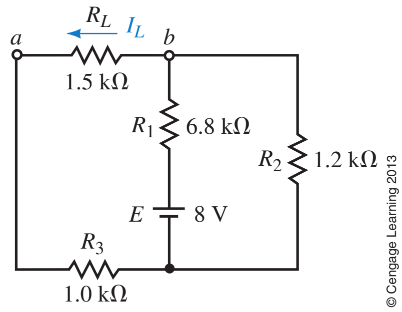

FIGURE 9–83

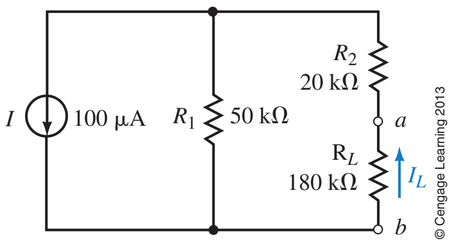

FIGURE 9–84

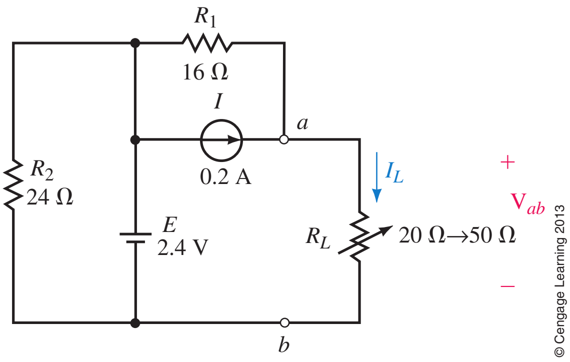

FIGURE 9–85

12. Refer to the circuit of Figure 9–86:
    a. Find the Thévenin equivalent circuit external to R_L.
    b. Use the equivalent circuit to determine V_{ab} when $R_L = 10$ kΩ and when $R_L = 20$ kΩ.
13. Refer to the circuit of Figure 9–87:
    a. Find the Thévenin equivalent circuit external to the indicated terminals.
    b. Use the Thévenin equivalent circuit to determine the current through the indicated branch.

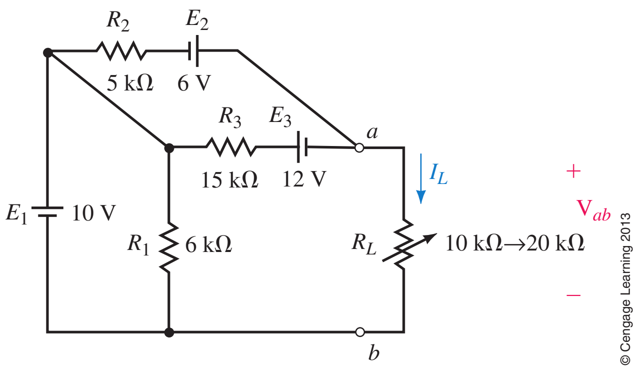

FIGURE 9–86

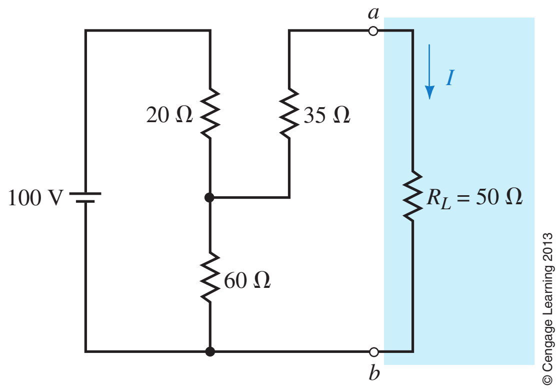

FIGURE 9–87

14. Refer to the circuit of Figure 9–88:
    a. Find the Thévenin equivalent circuit external to R_L.
    b. Use the Thévenin equivalent circuit to find V_L.
15. Refer to the circuit of Figure 9–89:
    a. Find the Thévenin equivalent circuit external to the indicated terminals.
    b. Use the Thévenin equivalent circuit to determine the current through the indicated branch.

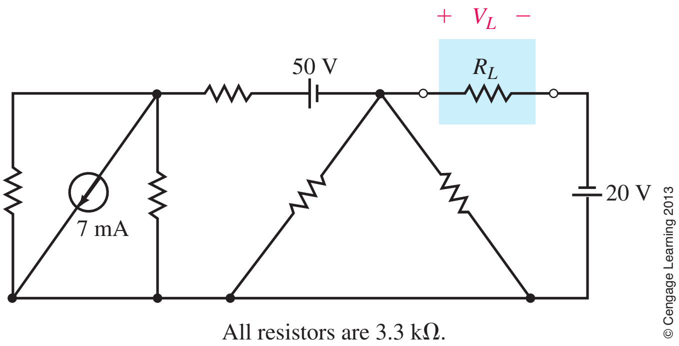

FIGURE 9–88

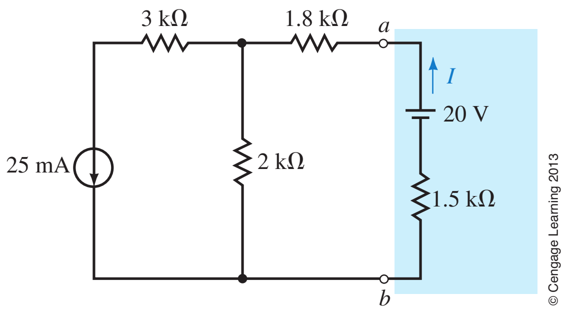

FIGURE 9–89

16. Refer to the circuit of Figure 9–90:
    a. Find the Thévenin equivalent circuit external to the indicated terminals.
    b. If $R_5 = 1$ kΩ, use the Thévenin equivalent circuit to determine the voltage V_{ab} and the current through this resistor.

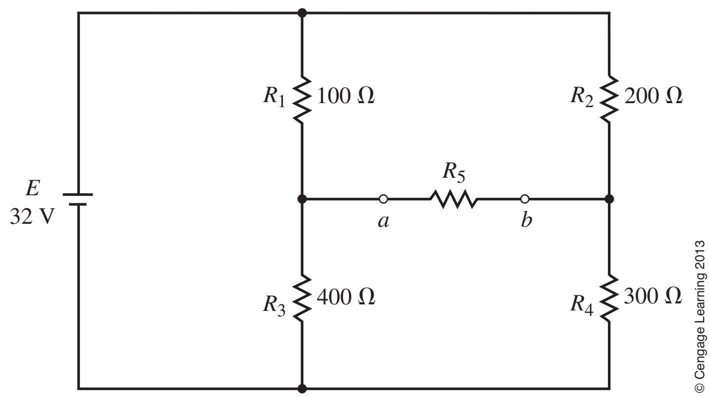

FIGURE 9–90

17. Refer to the circuit of Figure 9–91:
    a. Find the Thévenin equivalent circuit external to R_L.
    b. Use the Thévenin equivalent circuit to find the current I when $R_L = 0$, 10 kΩ, and 50 kΩ.
18. Refer to the circuit of Figure 9–92:
    a. Find the Thévenin equivalent circuit external to R_L.
    b. Use the Thévenin equivalent circuit to find the power dissipated by R_L.

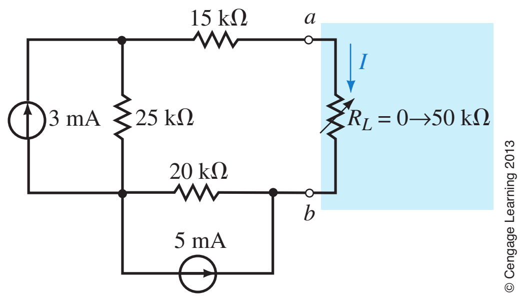

FIGURE 9–91

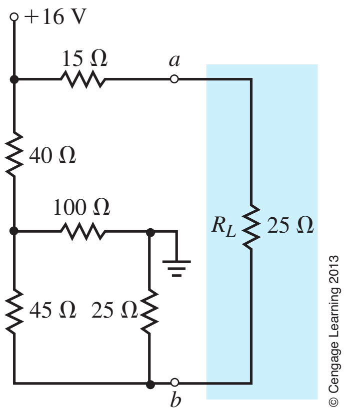

FIGURE 9–92

19. Repeat Problem 17 for the circuit of Figure 9–93.
20. Repeat Problem 17 for the circuit of Figure 9–94.

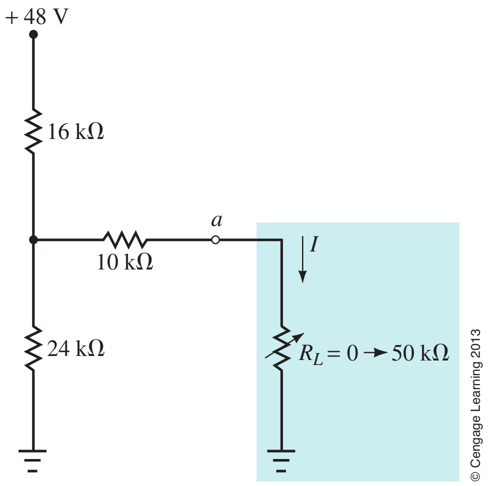

FIGURE 9–93

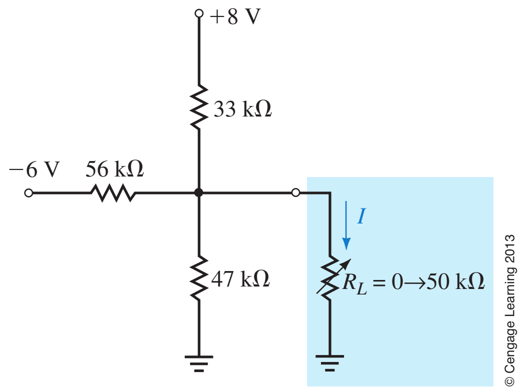

FIGURE 9–94

21. Find the Thévenin equivalent circuit of the network external to the indicated branch as shown in Figure 9–95.
22. Refer to the circuit of Figure 9–96.
    a. Find the Thévenin equivalent circuit external to the indicated terminals.
    b. Use the Thévenin equivalent circuit to determine the current through the indicated branch.
23. Repeat Problem 22 for the circuit of Figure 9–97.

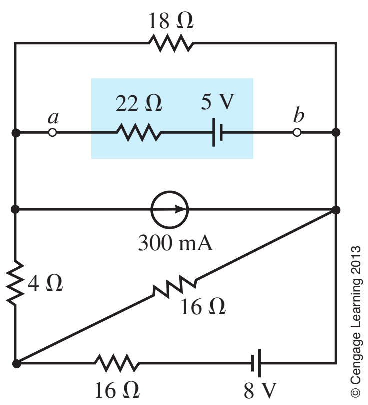

FIGURE 9–95

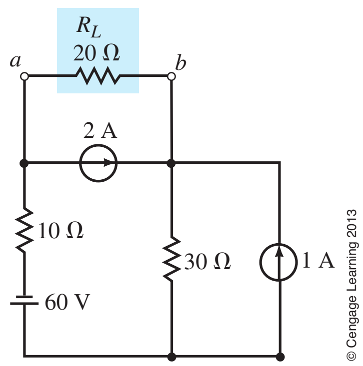

FIGURE 9–96

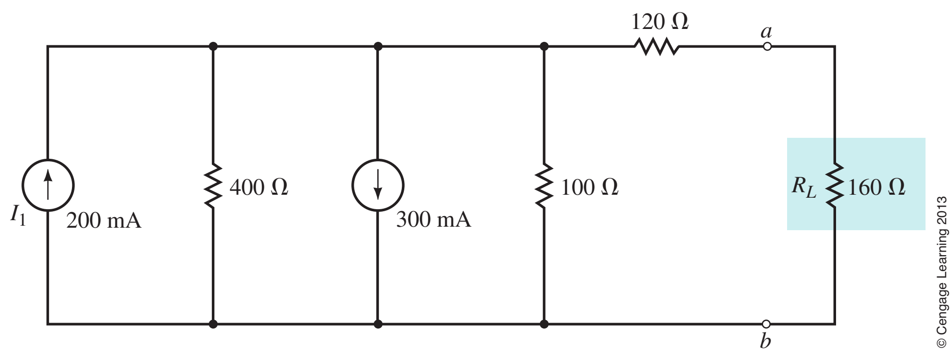

FIGURE 9–97

24. Repeat Problem 22 for the circuit of Figure 9–98.

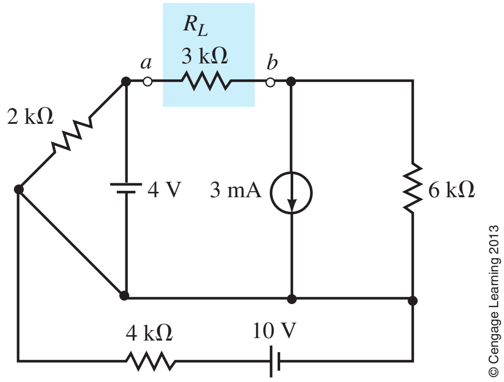

FIGURE 9–98

9.3 Norton's Theorem

25. Find the Norton equivalent circuit external to R_L in the circuit of Figure 9–81. Use the equivalent circuit to find I_L for the circuit.
26. Repeat Problem 25 for the circuit of Figure 9–82.
27. Repeat Problem 25 for the circuit of Figure 9–83.
28. Repeat Problem 25 for the circuit of Figure 9–84.
29. Refer to the circuit of Figure 9–85:
    a. Find the Norton equivalent circuit external to R_L.
    b. Use the equivalent circuit to determine I_L when $R_L = 20\ \Omega$ and when $R_L = 50\ \Omega$.
30. Refer to the circuit of Figure 9–86:
    a. Find the Norton equivalent circuit external to R_L.
    b. Use the equivalent circuit to determine I_L when $R_L = 10\ \text{k}\Omega$ and when $R_L = 20\ \text{k}\Omega$.
31. a. Find the Norton equivalent circuit external to the indicated terminals of Figure 9–87.
    b. Convert the Thévenin equivalent circuit of Problem 13 to its Norton equivalent.
32. a. Find the Norton equivalent circuit external to R_L in the circuit of Figure 9–88.
    b. Convert the Thévenin equivalent circuit of Problem 14 to its Norton equivalent.
33. Repeat Problem 31 for the circuit of Figure 9–91.
34. Repeat Problem 31 for the circuit of Figure 9–92.
35. Repeat Problem 31 for the circuit of Figure 9–95.
36. Repeat Problem 31 for the circuit of Figure 9–96.

9.4 Maximum Power Transfer Theorem

37. a. For the circuit of Figure 9–91, determine the value of R_L so that maximum power is delivered to the load.
    b. Calculate the value of the maximum power which can be delivered to the load.
    c. Sketch the curve of power versus resistance as R_L is adjusted from 0 Ω to 50 kΩ in increments of 5 kΩ.

38. Repeat Problem 37 for the circuit of Figure 9–94.

39. a. For the circuit of Figure 9–99, find the value of R so that $R_L = R_{Th}$.
   b. Calculate the maximum power dissipated by R_L.

40. Repeat Problem 39 for the circuit of Figure 9–100.

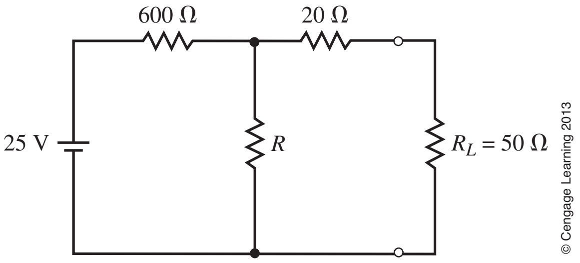

FIGURE 9–99

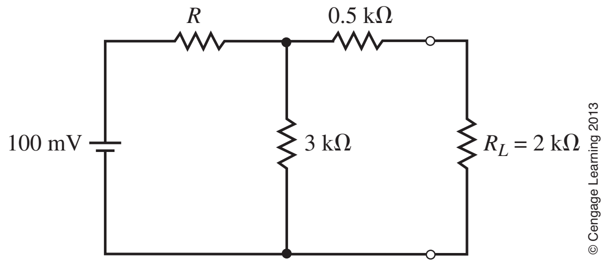

FIGURE 9–100

41. a. For the circuit of Figure 9–101, determine the values of R_1 and R_2 so that the 32-kΩ load receives maximum power.
   b. Calculate the maximum power delivered to R_L.

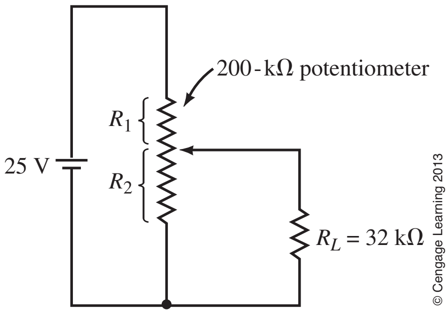

FIGURE 9–101

42. Repeat Problem 41 if the load resistor has a value of $R_L = 25\ \text{k}\Omega$.

9.5 Substitution Theorem

43. If the indicated portion of the circuit in Figure 9–102 is to be replaced with a voltage source and a 50-Ω series resistor, determine the magnitude and polarity of the resulting voltage source.

44. If the indicated portion of the circuit in Figure 9–102 is to be replaced with a current source and a 200-Ω shunt resistor, determine the magnitude and direction of the resulting current source.

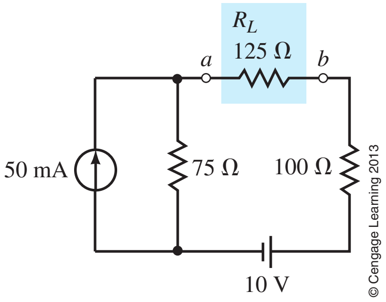

FIGURE 9–102

9.6 Millman's Theorem

45. Use Millman's theorem to find the current through and the power dissipated by R_L in the circuit of Figure 9–103.
46. Repeat Problem 45 for the circuit of Figure 9–104.
47. Repeat Problem 45 for the circuit of Figure 9–105.
48. Repeat Problem 45 for the circuit of Figure 9–106.

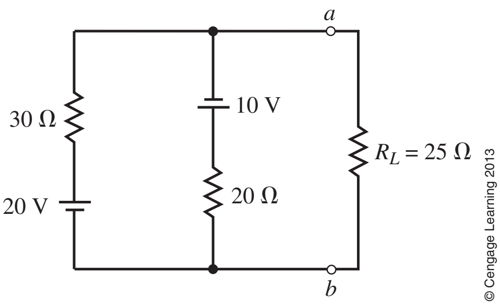

FIGURE 9–103

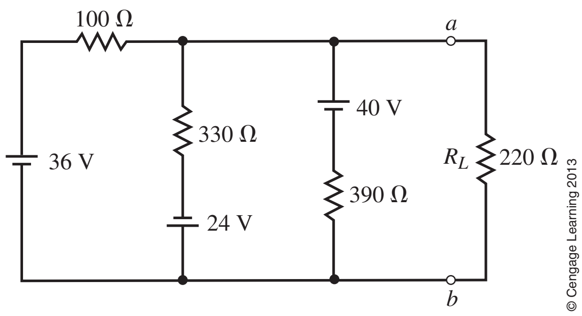

FIGURE 9–104

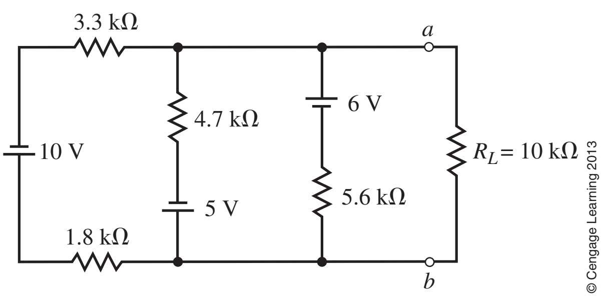

FIGURE 9–105

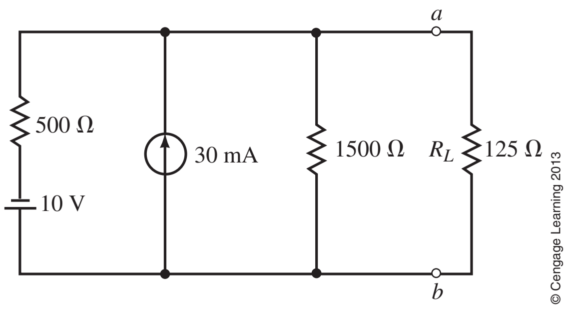

FIGURE 9–106

9.7 Reciprocity Theorem

49. a. Determine the current I in the circuit of Figure 9–107.
    b. Show that reciprocity applies for the given circuit.
50. Repeat Problem 49 for the circuit of Figure 9–108.

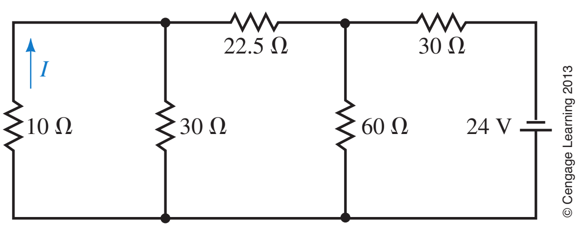

FIGURE 9–107

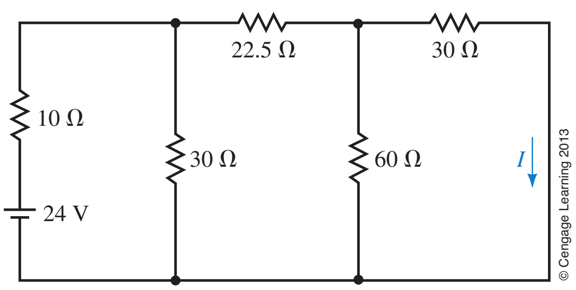

FIGURE 9–108