PROBLEMS

1, 2, 3 = straightforward, intermediate, challenging ☐ = full solution available in Student Solutions Manual/Study Guide [icon] = biomedical application

Section 18.1 Sources of emf

Section 18.2 Resistors in Series

Section 18.3 Resistors in Parallel

1. A battery having an emf of 9.00 V delivers 117 mA when connected to a 72.0-**Ω** load. Determine the internal resistance of the battery.

2. A 4.0-**Ω** resistor, an 8.0-**Ω** resistor, and a 12-Ω resistor are connected in series with a 24-V battery. What are (a) the equivalent resistance and (b) the current in each resistor? (c) Repeat for the case in which all three resistors are connected in parallel across the battery.

3. A lightbulb marked "75 W [at] 120 V" is screwed into a socket at one end of a long extension cord in which each of the two conductors has a resistance of 0.800 **Ω.** The other end of the extension cord is plugged into a 120-V outlet. Draw a circuit diagram, and find the actual power of the bulb in this circuit.

4. A 9.0-**Ω** resistor and a 6.0-**Ω** resistor are connected in series with a power supply. (a) The voltage drop across the 6.0-**Ω** resistor is measured to be 12 V. Find the voltage output of the power supply. (b) The two resistors are connected in parallel across a power supply, and the current through the 9.0-**Ω** resistor is found to be 0.25 A. Find the voltage setting of the power supply.

5. (a) Find the equivalent resistance between points *a* and *b* in Figure P18.5. (b) Calculate the current in each resistor if a potential difference of 34.0 V is applied between points *a* and *b*.

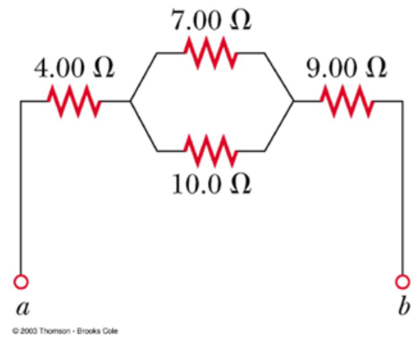

Figure P18.5

6. Find the equivalent resistance of the circuit in Figure P18.6.

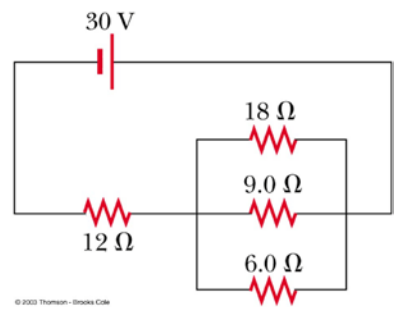

Figure P18.6

7. Find the equivalent resistance of the circuit in Figure P18.7.

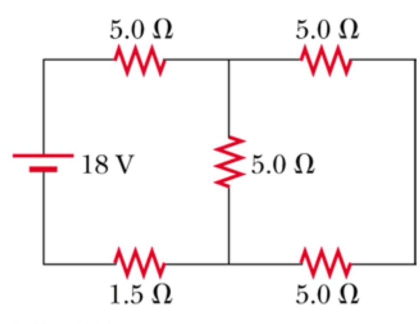

Figure P18.7

8. (a) Find the equivalent resistance of the circuit in Figure P18.8. (b) If the total power supplied to the circuit is 4.00 W, find the emf of the battery.

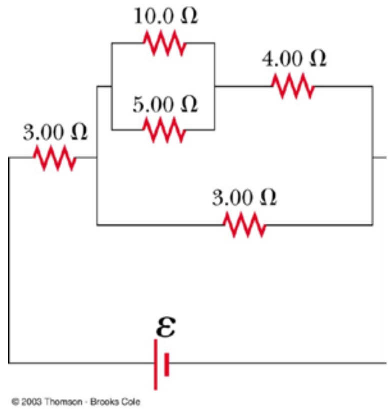

Figure P18.8

9. Consider the circuit shown in Figure P18.9. Find (a) the current in the 20.0-**Ω** resistor and (b) the potential difference between points *a* and *b*.

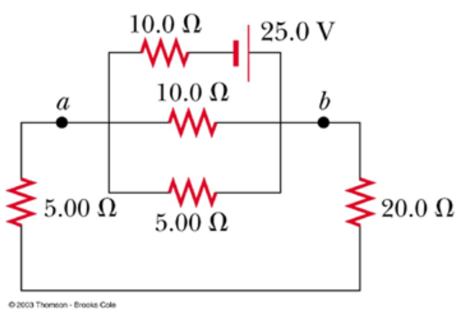

Figure P18.9

10. Two resistors, *A* and *B*, are connected in parallel across a 6.0-V battery. The current through *B* is found to be 2.0 A. When the two resistors are connected in series to the 6.0-V battery, a voltmeter connected across resistor *A* measures a voltage of 4.0 V. Find the resistances of *A* and *B*.

11. The resistance between terminals *a* and *b* in Figure P18.11 is 75 **Ω.** If the resistors labeled *R* have the same value, determine *R*.

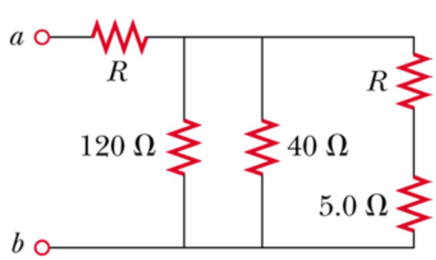

Figure P18.11

12. Three 100-**Ω** resistors are connected as shown in Figure P18.12. The maximum power that can safely be delivered to any one resistor is 25.0 W. (a) What is the maximum voltage that can be applied to the terminals *a* and *b*?

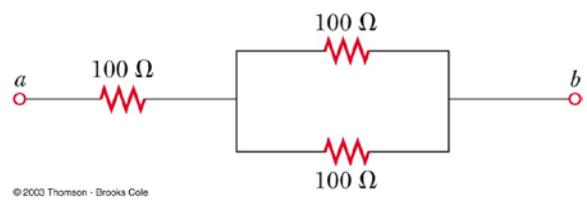

Figure P18.12

(b) For the voltage determined in part (a), what is the power delivered to each resistor? What is the total power delivered?

13. Find the current in the 12-**Ω** resistor in Figure P18.13.

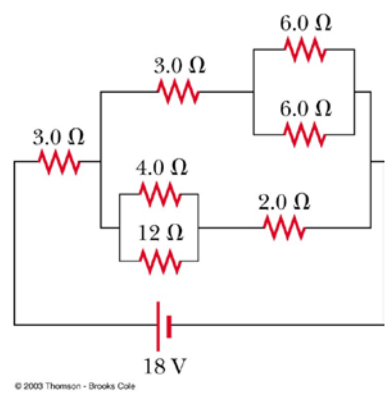

Figure P18.13

14. Calculate the power delivered to each resistor in the circuit shown in Figure P18.14.

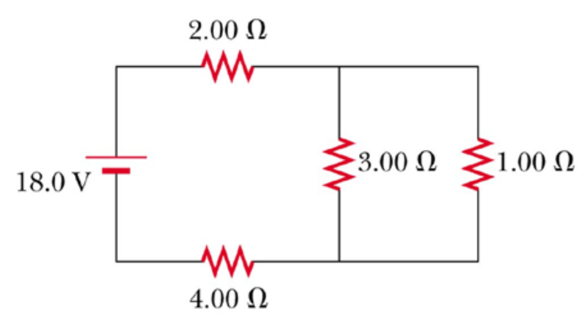

Figure P18.14

Section 18.4 Kirchhoff's Rules and Complex DC Circuits

Note: The currents are not necessarily in the direction shown for some circuits.

15. (a) You need a 45-**Ω** resistor, but the stockroom has only 20-**Ω** and 50-**Ω** resistors. How can the desired resistance be achieved under these circumstances? (b) What can you do if you need a 35-**Ω** resistor?

16. The ammeter shown in Figure P18.16 reads 2.00 A. Find I_1, I_2, and ε.

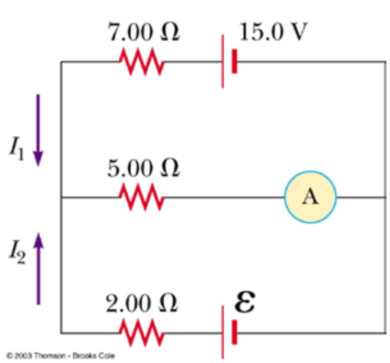

Figure P18.16

17. Determine the current in each branch of the circuit shown in Figure P18.17.

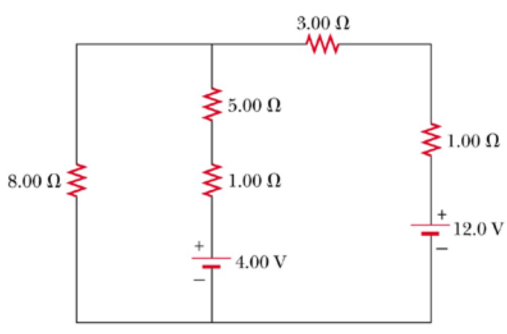

Figure P18.17

18. In Figure P18.17, show how to add just enough ammeters to measure every different current in the circuit. Show how to add just enough voltmeters to measure the potential difference across each resistor and across each battery.

19. Figure P18.19 shows a circuit diagram. Determine (a) the current, (b) the potential of wire *A* relative to ground, and (c) the voltage drop across the 1 500-**Ω** resistor.

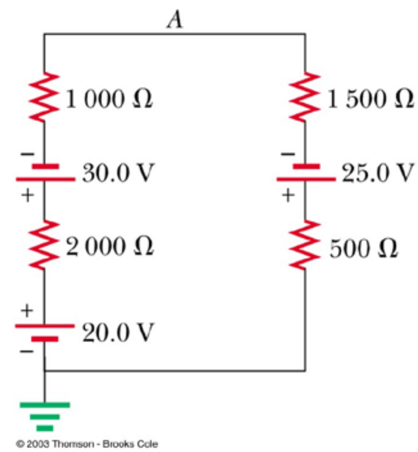

Figure P18.19

20. In the circuit of Figure P18.20, the current I_1 is 3.0 A and the values of ε and *R* are unknown. What are the currents I_2 and I_3?

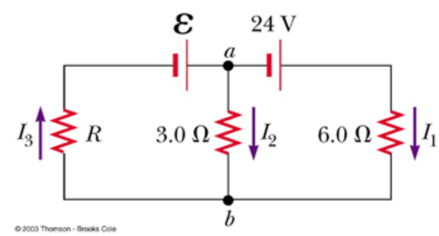

Figure P18.20

21. What is the emf ε of the battery in the circuit of Figure P18.21?

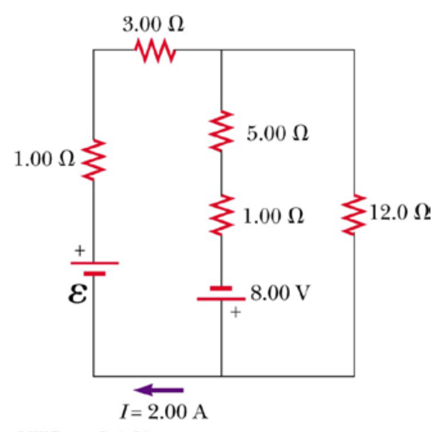

Figure P18.21

22. Find the current in each of the three resistors of Figure P18.22 (a) by the rules for resistors in series and parallel and (b) by the use of Kirchhoff's rules.

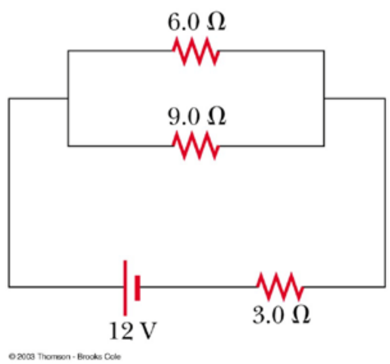

Figure P18.22

23. (a) Using Kirchhoff's rules, find the current in each resistor shown in Figure P18.23 and (b) find the potential difference between points *c* and *f*.

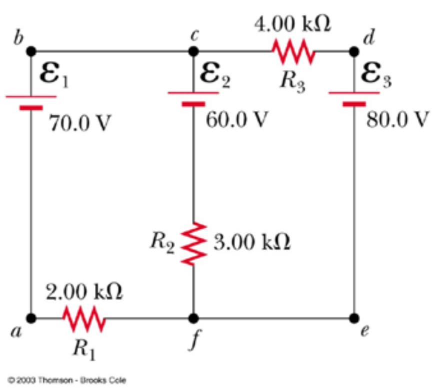

Figure P18.23

24. Two 1.50-V batteries—with their positive terminals in the same direction—are inserted in series into the barrel of a flashlight. One battery has an internal resistance of 0.255 **Ω,** the other an internal resistance of 0.153 **Ω.** When the switch is closed, a current of 0.600 A passes through the lamp. (a) What is the lamp's resistance? (b) What fraction of the power dissipated is dissipated in the batteries?

25. Calculate each of the unknown currents I_1, I_2, and I_3 for the circuit of Figure P18.25.

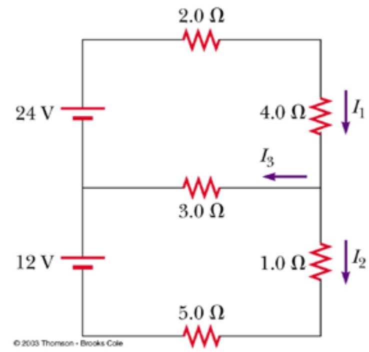

Figure P18.25

26. A dead battery is charged by connecting it to the live battery of another car with jumper cables (Fig. P18.26). Determine the current in the starter and in the dead battery.

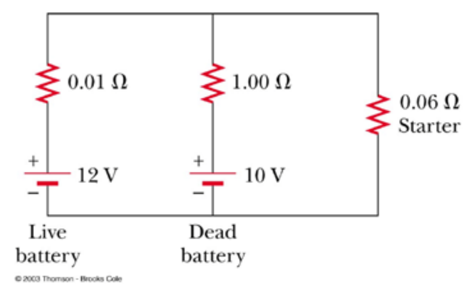

Figure P18.26

27. Find the current in each resistor in Figure P18.27.

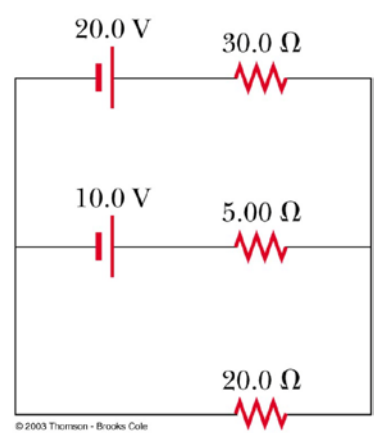

Figure P18.27

28. (a) Determine the potential difference ΔV_{ab} for the circuit in Figure P18.28. Note that each battery has an internal resistance as indicated in the figure. (b) If points *a* and *b* are connected by a 7.0-**Ω** resistor, what is the current through this resistor?

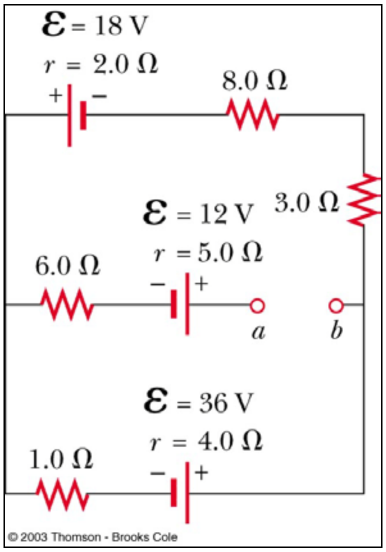

Figure P18.28

29. Find the potential difference across each resistor in Figure P18.29.

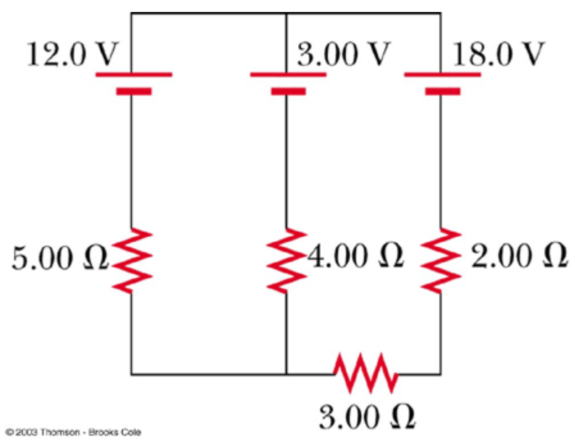

Figure P18.29

Section 18.5 *RC* Circuits

30. Show that $\tau = RC$ has units of time.

31. Consider a series *RC* circuit for which $C = 6.0\ \mu\text{F}$, $R = 2.0 \times 10^6\ \Omega$, and $\varepsilon = 20$ V. Find (a) the time constant of the circuit and (b) the maximum charge on the capacitor after a switch in the circuit is closed.

32. An uncharged capacitor and a resistor are connected in series to a source of emf. If $\boldsymbol{\varepsilon} = 9.00$ V, $C = 20.0$ **μF,** and $R = 100$ **Ω,** find (a) the time constant of the circuit, (b) the maximum charge on the capacitor, and (c) the charge on the capacitor after one time constant.

33. Consider a series *RC* circuit for which $R = 1.0$ M **Ω,** $C = 5.0\ \mu\text{F}$, and $\boldsymbol{\varepsilon} = 30$ V. The capacitor is initially uncharged when the switch is open. Find the charge on the capacitor 10 s after the switch is closed.

34. A series combination of a 12-k**Ω** resistor and an unknown capacitor is connected to a 12-V battery. One second after the circuit is completed, the voltage across the capacitor is 10 V. Determine the capacitance.

35. A capacitor in an *RC* circuit is charged to 60.0% of its maximum value in 0.900 s. What is the time constant of the circuit?

36. A series *RC* circuit has a time constant of 0.960 s. The battery has an emf of 48.0 V, and the maximum current in the circuit is 0.500 mA. What are (a) the value of the capacitance and (b) the charge stored in the capacitor 1.92 s after the switch is closed?

Section 18.6 Household Circuits

37. An electric heater is rated at 1 300 W, a toaster is rated at 1 000 W, and an electric grill is rated at 1 500 W. The three appliances are connected in parallel to a common 120-V circuit. (a) How much current does each appliance draw? (b) Is a 30.0-A circuit breaker sufficient in this situation? Explain.

38. A lamp ($R = 150$ **Ω**), an electric heater ($R = 25$ **Ω**), and a fan ($R = 50$ **Ω**) are connected in parallel across a 120-V line. (a) What total current is supplied to the circuit? (b) What is the voltage across the fan? (c) What is the current in the lamp? (d) What power is expended in the heater?

39. A heating element in a stove is designed to dissipate 3 000 W when connected to 240 V. (a) Assuming that the resistance is constant, calculate the current in this element if it is connected to 120 V. (b) Calculate the power it dissipates at this voltage.

40. Your toaster oven and coffeemaker each dissipate 1 200 W of power. Can you operate them together if the 120-V line that feeds them has a circuit breaker rated at 15 A? Explain.

Section 18.8 Conduction of Electrical Signals by Neurons

41. Assume that a length of axon membrane of about 10 cm is excited by an action potential. (Length excited = nerve speed × pulse duration = 50 m/s × 2.0 ms = 10 cm.) In the resting state, the outer surface of the axon wall is charged positively with K^+ ions and the inner wall has an equal and opposite charge of negative organic ions as shown in Figure P18.41. Model the axon as a parallel plate capacitor and use C **κ™**$_0A/d$ and $Q = C\Delta V$ to investigate the charge as follows. Use typical values for a cylindrical axon of cell wall thickness $d = 1.0 \times 10^{-8}$ m, axon radius r = 10 μm, and cell wall dielectric constant **κ** = 3.0. (a) Calculate the positive charge on the outside of a 10-cm piece of axon when it is not conducting an electric pulse. How many K^+ ions are on the outside of the axon? Is this a large charge per unit area? [*Hint:* Calculate the charge per unit area in terms of the number of square angstroms ($Å^2$) per electronic charge. An atom has a cross section of about 1 $Å^2$ (1 Å = 10^{-10} m).] (b) How much positive charge must flow through the cell membrane to reach the excited state of +30 mV from the resting state of –70 mV? How many sodium ions is this? (c) If it takes 2.0 ms for the Na^+ ions to enter the axon, what is the average current in the axon wall in this process? (d) How much energy does it take to raise the potential of the inner axon wall to +30 mV starting from the resting potential of –70 mV?

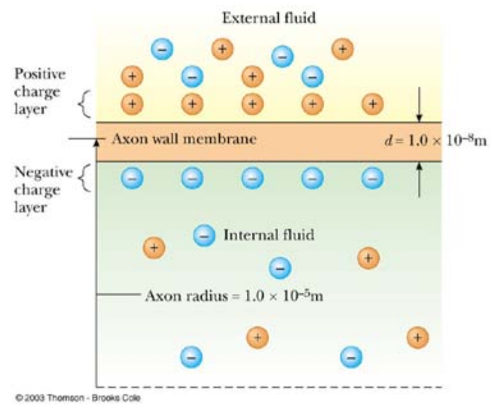

Figure P18.41

42. Continuing with the model of the axon as a capacitor from Problem 41 and Figure P18.41, (a) how much energy does it take to restore the inner wall of the axon to –70 mV starting from +30 mV? (b) Find the average current in the axon wall during this process, if it takes 3.0 ms.

43. Using Figure 18.27b and the results of Problem 18.41d and Problem 18.42a, find the average power supplied by the axon during firing and recovery.

ADDITIONAL PROBLEMS

44. Consider an *RC* circuit in which the capacitor is being charged by a battery connected in the circuit. After a time equal to two time constants, what percent of the *final* charge is present on the capacitor?

45. Find the equivalent resistance between points *a* and *b* in Figure P18.45.

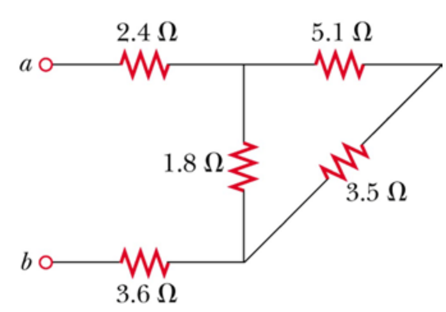

Figure P18.45

46. For the circuit in Figure P18.46, calculate (a) the equivalent resistance of the circuit and (b) the power dissipated by the entire circuit. (c) Find the current in the 5.0-**Ω** resistor.

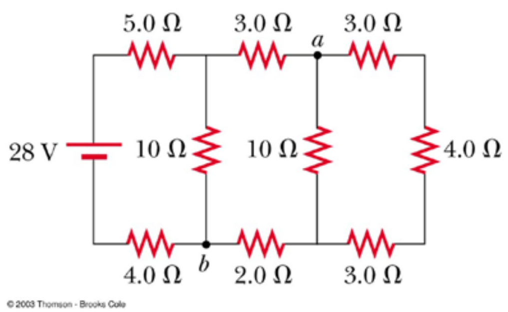

Figure P18.46

47. Find (a) the equivalent resistance of the circuit in Figure P18.47, (b) each current in the circuit, (c) the potential difference across each resistor, and (d) the power dissipated by each resistor.

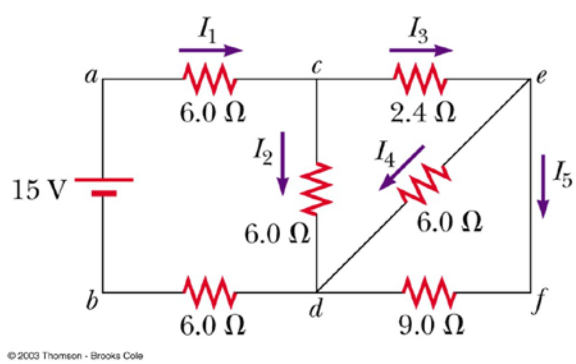

Figure P18.47

48. Three 60.0-W, 120-V lightbulbs are connected across a 120-V power source, as shown in Figure P18.48. Find (a) the total power delivered to the three bulbs and (b) the potential difference across each. Assume that the resistance of each bulb is constant (even though in reality the resistance increases markedly with current).

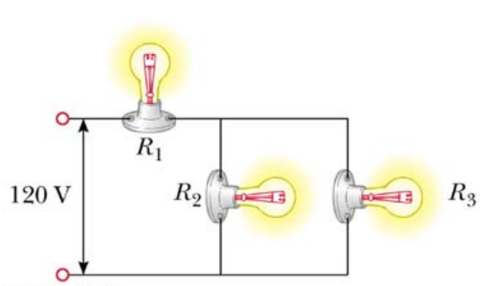

Figure P18.48

49. An automobile battery has an emf of 12.6 V and an internal resistance of 0.080 **Ω**. The headlights have total resistance of 5.00 **Ω** (assumed constant). What is the potential difference across the headlight bulbs (a) when they are the only load on the battery and (b) when the starter motor is operated, taking an additional 35.0 A from the battery?

50. In Figure P18.50, suppose that the switch has been closed for a length of time sufficiently long for the capacitor to become fully charged. (a) Find the steady-state current in each resistor and (b) find the charge on the capacitor.

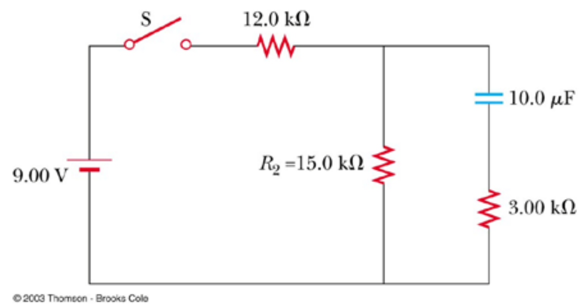

Figure P18.50

51. Find the values of I_1, I_2, and I_3 for the circuit in Figure P18.51.

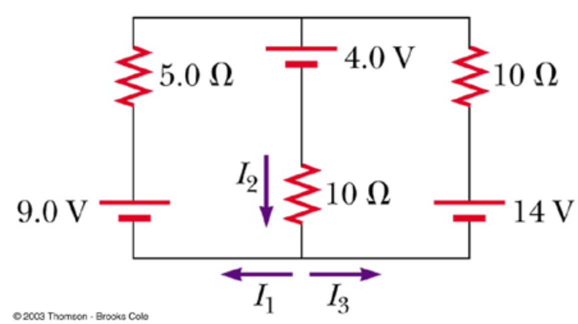

Figure P18.51

52. The resistance between points *a* and *b* in Figure P18.52 drops to one half its original value when switch S is closed. Determine the value of *R*.

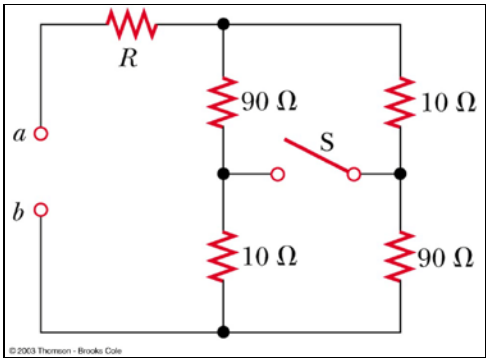

Figure P18.52

53. A generator has a terminal voltage of 110 V when it delivers 10.0 A, and 106 V when it delivers 30.0 A. Calculate the emf and the internal resistance of the generator.

54. An emf of 10 V is connected to a series *RC* circuit consisting of a resistor of 2.0×10^6 **Ω** and a capacitor of 3.0 μF. Find the time required for the charge on the capacitor to reach 90% of its final value.

55. The student engineer of a campus radio station wishes to verify the effectiveness of the lightning rod on the antenna mast (Fig. P18.55). The unknown resistance R_x is between points *C* and *E*. Point *E* is a "true ground" but is inaccessible for direct measurement since this stratum is several meters below the Earth's surface. Two identical rods are driven into the ground at *A* and *B*, introducing an unknown resistance R_y. The procedure is as follows: measure resistance R_1 between points *A* and *B*, then connect *A* and *B* with a heavy conducting wire and measure resistance R_2 between points *A* and *C*. (a) Derive a formula for R_x in terms of the observable resistances R_1 and R_2. (b) A satisfactory ground resistance would be $R_x < 2.0$ **Ω**. Is the grounding of the station adequate if measurements give $R_1 = 13$ **Ω** and $R_2 = 6.0$ Ω?

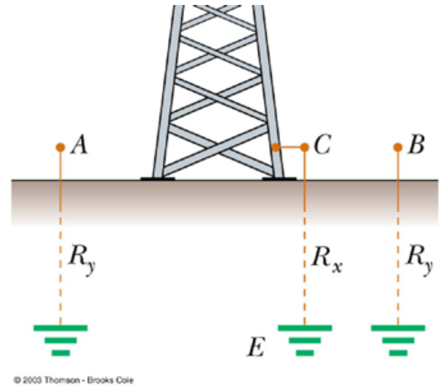

Figure P18.55

56. The resistor *R* in Figure P18.56 dissipates 20 W of power. Determine the value of *R*.

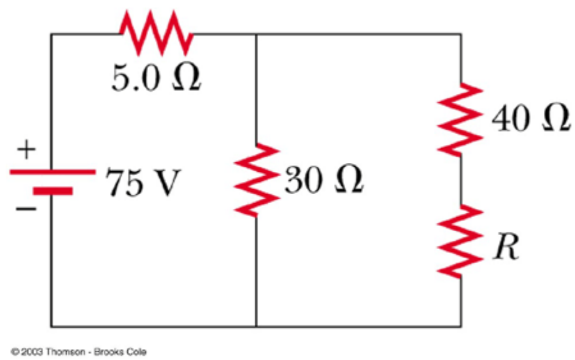

Figure P18.56

57. A voltage **Δ***V* is applied to a series configuration of *n* resistors, each of value *R*. The circuit components are reconnected in a parallel configuration, and voltage **Δ***V* is again applied. Show that the power consumed by the series configuration is $1/n^2$ times the power consumed by the parallel configuration.

58. For the network in Figure P18.58, show that the resistance between points *a* and *b* is $R_{ab} = \frac{27}{17}$ **Ω**. (*Hint:* Connect a battery with emf **ε** across points *a* and *b* and determine **ε** /*I*, where *I* is the current in the battery.)

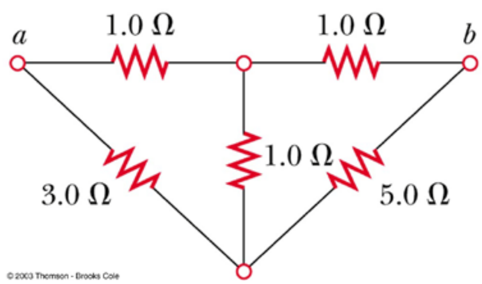

Figure P18.58

59. A battery with an internal resistance of 10.0 **Ω** produces an open-circuit voltage of 12.0 V. A variable load resistance with a range of 0 to 30.0 **Ω** is connected across the battery. (*Note:* A battery has a resistance that depends on the condition of its chemicals and increases as the battery ages. This internal resistance can be represented in a simple circuit diagram as a resistor in series with the battery.) (a) Graph the power dissipated in the load resistor as a function of the load resistance. (b) With your graph, demonstrate the following important theorem: *the power delivered to a load is a maximum if the load resistance equals the internal resistance of the source.*

60. The circuit in Figure P18.60 contains two resistors, R_1 = 2.0 k**Ω** and R_2 = 3.0 k**Ω**, and two capacitors, C_1 = 2.0 μF and C_2 = 3.0 μF, connected to a battery with emf **ε** = 120 V. If there are no charges on the capacitors before switch S is closed, determine as functions of time the charges q_1 and q_2 on capacitors C_1 and C_2, respectively, after the switch is closed. (*Hint:* First reconstruct the circuit so that it becomes a simple *RC* circuit containing a single resistor and single capacitor in series, connected to the battery, and then determine the total charge *q* stored in the circuit.)

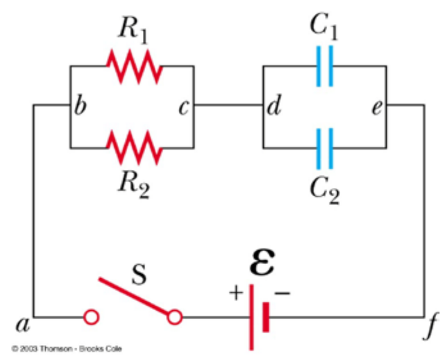

Figure P18.60