voltage for a given current (d) the resistance stays constant, but the current decreases (e) none of these.

19. A copper wire has a resistance of 10 Ω. What will be its new resistance if the wire is shortened by cutting it in half? (a) 20 Ω (b) 10 Ω (c) 5 Ω (d) 1 Ω (e) none of these.

20. When the temperature of a length of aluminum wire is lowered, itsresistance (a) increases slightly (b) decreases correspondingly (c) stays the same (d) increases as ΔT (e) none of these.

21. If a potential difference of 12 V across a resistor results in a current of $\frac{1}{2}$ A, how much power is dissipated? (a) 48 W (b) 12 W (c) 4 W (d) 6 W (e) none of these.

22. Imagine a length of ordinary insulated hookup wire. The wire's resistance is not dependent on (a) the conductor's length (b) the conductor's radius (c) the material making up the insulator (d) the material making up the conductor (e) none of these.

23. The units of $\Omega \cdot A^2$ correspond to (a) current (b) energy (c) power (d) voltage (e) none of these.

24. One microvolt (1 μV) corresponds to (a) 10^6 V (b) 10^{-6} V (c) 1000 V (d) 1/1000 V (e) none of these.

25. A resistor operating at 100 V generates joule heat at a rate of 20 W. When placed across a 50-V source, it will draw (a) 0.10 A (b) 5 A (c) 20 A (d) 4.0 A (e) none of these.

For more Multiple Choice Questions with answers click on WARM-UPS in CHAPTER 17 on the CD.

Suggestions on Problem Solving

1. An important type of derivation involves determining the current, given a flow of charge or vice versa. For example, a detector measures N particles, each carrying a charge q, arriving *per second per unit of its surface area*—what current strikes the instrument if its area is A? The basic definition is $I = \Delta q/\Delta t$, but to use this equation you must first find Δq, the amount of charge that strikes the detector during the time Δt. We are given N, and so Nq is the amount of charge arriving *per second* per unit of surface area. Consequently, NqA is the total amount of charge arriving on the detector per second and is equal to I. We obtained I without finding Δq explicitly because N had the time built into it to begin with. This kind of analysis of flow is very important in physics—we've seen it before and we'll see it again

2. Remember that all parts of an ideal hookup wire in a circuit are at the same potential. Drops or rises in potential occur only across circuit elements (resistors, batteries, etc.); and in the case of a resistor, that means only when a current is passing through it (take a look at Multiple Choice Question 16). **A steady-state current cannot exist in a length of conductor unless it forms part of a closed path.**

3. Whenever you have a circuit diagram with a battery in it, place + and − signs at the appropriate terminals. Current, being imagined as composed of positive charge, always emerges from the positive terminal (provided there are no other batteries bucking it) and reenters at the negative one. In a simple circuit where you know the direction of the current, follow it around, labeling all the resistors with + signs where current enters and − signs where it leaves. This will show the voltage drops and rises, something that will be explored further in Chapter 18.

4. The voltage of any point in a circuit is only known relative to some other point in that circuit. Thus, one side of a battery might be 12 V higher than the other side (though it could be 10000 V higher than your nose). For example, the entire chassis of an automobile serves as a common conductor called "ground" in the trade, though it isn't usually grounded and so actually floats—the + terminal of the battery is 12 V higher than the engine block. Often a point in a circuit is grounded, as is done with stereo systems and computers. Its potential is then taken as zero, and all voltage drops or rises are referenced with respect to it.

Problems + Coordinated Problems + Progressive Problems + Solutions

STUDY GUIDE **1. Coordinated Problems:** The three problems within each magenta-colored grouping are solvable in similar ways. Note that the first of these always has a hint; moreover, its solution is provided in the back of the book. *Work out each of these sets; they'll strengthen technique and build confidence.* **2. Progressive Problems:** The problems introduced in blue unfold step-by-step carrying along the analysis in a more suggestive way than is customary. *Work out all of these; they'll guide you through the analytic process and help develop problem-solving skills.* **3. Worked-Out Solutions:** Studying worked-out solutions is an important part of learning how to solve problems. Accordingly, additional ***solutions*** to a number of model problems are given below. *Make sure you understand each of them before you go on to the next problem.* **4.** Also provided in the back of the book are the ***Answers*** to all odd-numbered problems, as well as worked-out ***solutions*** to those with boldface numbers. Problem numbers in italic indicate that a solution appears in the Student Solutions Manual.

SECTION 17.1: ELECTRIC CURRENT

1. [I] The moving nonconducting belt of a Van de Graaff generator carries 10 μC of charge up to the metal sphere (Fig. Q14, Chapter 15) each second. Determine the corresponding current.

2. [I] THIS PROBLEM EXPLORES THE BASIC NATURE OF CURRENT. A small motor is attached to a 12-V battery, and 0.48 millicoulombs of charge are supplied during a period of 10 milliseconds. (a) How much charge in coulombs are we talking about? (b) How much time in seconds did the charge transfer take? (c) What is the definition of current? (d) How much current flows through the motor?

3. [I] A 1.5-V D-cell has a rating of 3.0 amp-hours. How many coulombs of charge can it provide before running down?

SOLUTION: The cell can provide 3 A for 1 h, where 1 A = 1 C/s. That's 3 C/s for 3600 s or (3 C/s)(3600 s) = 10800 C = 0.011 MC.

4. [I] A beam of positrons carries 1.4 C past a point in space in 2.0 s. To what current does that correspond?

5. [I] If a quantity of singly ionized sodium ions (Na^+) equal to Avogadro's number streams past a point in 1000 s, what is the current?

6. [I] The photo on p. 608 shows an electron beam representing a current of 60 kA. How many electrons flow out of the device per second?

7. [I] The starter motor in an automobile is a small but powerful electrical device that "turns over" the main gasoline engine, moving it through a cycle to get it started. Typically, it will draw about 180 A from the battery for perhaps 2.0 s. How much charge flows through the circuit?

8. [I] A particle accelerator contains two beams flowing side-by-side in opposite directions; the beams will ultimately be made to collide. One is a stream of protons (each with a charge of $+1.60 \times 10^{-19}$ C), the other a stream of antiprotons (each with a charge of -1.60×10^{-19} C). Given that either beam can deliver 1.0×10^{14} particles per second to the colliding region, what is the net current in the machine as the two streams race past each other?

9. [I] A synchrotron accelerates protons up to nearly the speed of light, imparting energies to them of 500 MeV. If the beam current is 1.0 mA, how many protons will hit a target in 0.10 s?

10. [I] With the previous problem in mind, how many protons are there in each 1.0-cm-long segment of the beam? Assume a uniform particle density throughout the beam.

11. [I] A wire is connected across the terminals of a battery for precisely 60.0 s during which time a constant current of 2.00 A circulates around the loop. What was the net charge that flowed past any point on the wire?

12. [I] A portable tape recorder is powered by six 1.5-V AA-cells in series. What is its operating voltage?

13. [I] A torpedo, a giant saltwater ray that can develop a voltage of 220 V, is covered with cells known as electroplaques, each of which produces a potential difference of about 0.15 V. Several thousand rows (each made up of a series-connected array of cells) are then connected in parallel to build up a sizable current. How many cells would you guess form each row? Why do freshwater electric fish in general develop higher voltages than saltwater ones?

14. [I] A NiCd-cell has a voltage of 1.2 V and an amp-hour rating of 34. It is a sealed storage cell with a nickel anode and a cadmium cathode immersed in an alkaline electrolyte. How long can it operate when providing 2.0 A to some load?

15. [I] A battery is rated at 10 amp-hours. How much charge does that correspond to?

16. [I] The positive terminal of a 1.5-V dry cell is attached to ground via a length of heavy hookup wire. The negative terminal is then connected, via the same kind of wire, to a neutral brass ball. What is the potential of the ball? Describe its state of charge. What is the potential of the central carbon electrode?

17. [I] THIS PROBLEM EXPLORES THE VOLTAGES IN A CIRCUIT. Consider Fig. P17. (a) What is the voltage of point-A with respect to ground? (b) What is the voltage of point-D with respect to ground? (c) What is the voltage of point-B with respect to ground? (d) What, if anything, is the value of the voltage (V) across the load? (e) Which point B or C, is at a higher potential? (f) Is there a current in the circuit, and if so, in which direction does it flow?

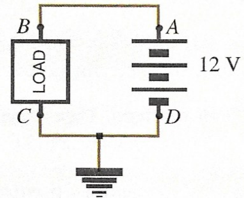

Figure P17

18. [II] Consider a 1.0-A current flowing in a long wire. Roughly 10^{22} electrons move in each meter-long segment of the wire. (a) How much charge moves along each meter of wire? (b) What is the average speed of the electrons?

SOLUTION: The definition of current is $I = Q/t$ where a charge Q is transported in a time t. In that time t, traveling at an average speed v_{av}, charge moves a distance l where $l = v_{av}t$. (a) Recall that if 10^{22} electrons move, a charge of $q_e 10^{22}$ moves. (b) Hence $I = Q/t = Qv_{av}/l$ and the moving charge per meter $Q/l = q_e 10^{22} = 1.6 \times 10^3$ C. $v_{av} = (1.0$ A$)/(1.6 \times 10^3$ C$) = 6 \times 10^{-4}$ m/s.

19. [II] A pure gold wire with a 1.00-mm $\times$ 1.00-mm cross section carries a flow of electrons having a current density (I/A) equal to 1.0 MA/m^2. How long will it take for an amount of electrons equal to Avogadro's number to pass a point on the wire?

20. [II] An ion generator used to clean room air puts out a stream of negatively charged molecules that attach themselves to airborne pollutants, which are then collected electrostatically. Oxygen molecules tend to pick up electrons, thereby becoming negative oxygen ions. According to one company's literature, at 1.0 m from a particular generator, a detector would record the arrival of "168 million ions/sec./cm^2." Assuming that each ion is singly charged, what current impinges on a 10.0-cm^2 target at 1.0 m from the device?

21. [II] Figure P21 is a diagram of a portion of the electrical system of an automobile. List which switches—A, B, C, D, E, and F—must be closed in order to (a) blow the horn; (b) turn on the headlights; (c) turn on the tail lights; (d) turn on only the parking lights; (e) activate the inside dome light. When do the side marker lights go on? *Note that the whole body of the car, including the engine block, is generally wired together as a common "ground."*

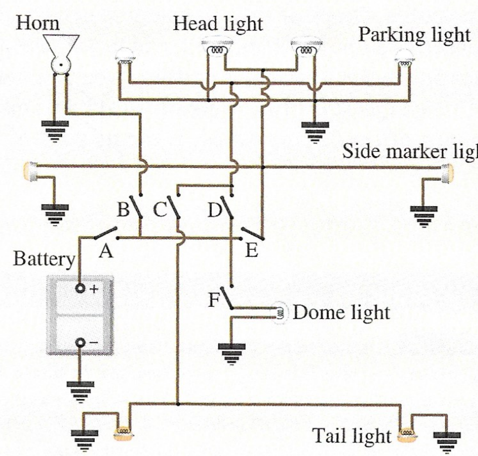

Figure P21

22. [II] A particular model of automobile battery, when fully charged, can deliver roughly 4.0×10^5 C before becoming completely run down. What is the amp-hour rating of such a battery?

23. [II] We wish to make up a panel of silicon solar cells that will provide at least 440 mA at 9.0 V when placed in an appropriately illuminated region. Given that each cell has an output of 22 mA at 0.45 V, design the panel. [*Hint: First deal with the voltage.*]

24. [II] A small cell has an emf of 0.80 V and can supply 10.0 mA under normal operating conditions. How should a battery be con-

V=IR

structed if it is to have an emf of 12.0 V and an operating current of 30.0 mA? How many cells will be needed?

25. [II] Suppose you have two different kinds of cells: four large 1.5-V cells that can operate at 4.0 A and ten small 1.5-V cells that can operate at 1.0 A. Design a 4.5-V battery that can supply 8.0 A and, moreover, use all the large cells. How many of the small size will you need?

26. [II] Show that the battery in Fig 17.11*b* is equivalent to having five rows in parallel each with three cells in series.

27. [III] In the process of recharging a rundown automobile battery, it's attached to an electronic 12-V charger. As soon as the device is turned on, an ammeter shows that the battery draws 7.0 A; but as it revives, the current slowly drops until after 6.0 hours it's down to 3.0 A. Assuming the current decreased linearly with time, how much charge passed through the battery?

SECTION 17.2: OHM'S LAW

28. [I] A 6.0-Ω resistor is placed across the terminals of a 12.0-V battery. How much current flows through the resistor?

29. [I] Consider an ordinary light bulb which has a resistance of 100 Ω when illuminated. What is the value of the current drawn by the bulb while 110 V are across it? When measured fresh out of the box the bulb had a resistance of around 20 Ω; explain this difference.

SOLUTION: We have a 100-Ω resistance with 110 V across it. Using Ohm's Law, $V = IR$, $I = (110\ \text{V})/(100\ \Omega) = 1.10\ \text{A}$. The resistance increases with temperature.

30. [I] A piece of wire at a constant temperature is placed across a variable voltage source, and the current through it is measured. If the wire is ohmic, which part of Fig. P30 best represents its behavior as the voltage is increased?

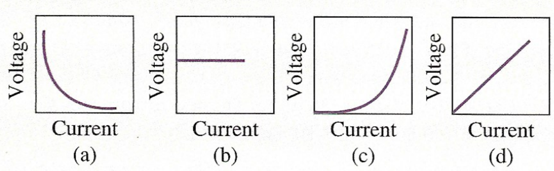

Figure P30

31. [I] THIS PROBLEM EXPLORES THE VOLTAGES AND CURRENT IN A CIRCUIT. Consider Fig. P31. (a) What is the voltage of point-*C* with respect to ground? (b) What is the voltage of point-*D* with respect to ground? (c) What is the voltage of point-*A* with respect to ground? (d) What, if anything, is the value of the voltage (V) across the resistor R? (e) Which point, *A* or *B*, is at a higher potential? (f) Write an expression relating R and V. (g) What is the value of the resistance R?

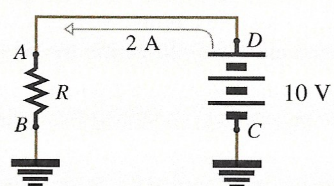

Figure P31

32. [I] Determine the current, if there is any, in the circuit in Fig. P32.

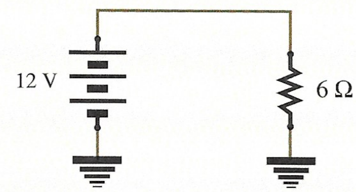

Figure P32

33. [I] A length of wire with a resistance of 150 Ω is placed across the terminals of a battery comprised of six 1.5-V cells in series. How much current will it draw from the battery? [*Hint: The total voltage of the battery is across the wire.*]

34. [I] Three 1.5-V cells are connected in series, and the combination is attached across a resistor. If 3.0 A flows through the resistor, what is its resistance?

35. [I] What voltage will be measured across a 1000-Ω resistor in a circuit if we determine that there is a current of 2.50 mA flowing through it?

36. [I] The two electric probes of an ohmmeter touching damp skin measure a resistance of 120 kΩ. If a voltage of 200 V is now put across these probes, what current will flow through that region of the skin?

37. [I] THIS PROBLEM EXPLORES RESISTANCE IN A CIRCUIT. Considering Fig. P37 where the colors on the resistor are green-blue-black-silver, (a) what is its resistance? Suppose that the red and yellow leads clipped to the resistor are attached to the two terminals of a 1.5-V cell. (b) What is the voltage across the the resistor? (c) Write a mathematical expression for the relationship between that voltage, the resistance, and the resulting current. (d) Determine the current flowing through the resistor.

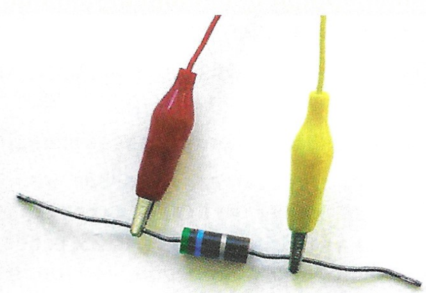

Figure P37

38. [I] A small high-torque variable-speed dc motor requires an input of 10 mA at 3.0 V. Determine the electrical resistance of the motor.

39. [I] A 100-V electric heater draws 10 A. What is its resistance?

40. [I] If electric contacts are placed on the scalp, time-varying differences in potential will be observed. These can be recorded by an electroencephalograph. Voltage differences of ≈0.5 mV will appear across resistances of ≈10 kΩ. What size currents are involved?

41. [I] A wooden stick in contact with the metal sphere of a 100-kV Van de Graaff generator carries a current of 2.0 μA down to ground. Calculate the stick's resistance.

$R = \rho \frac{L}{A}$

42. [I] If the current in a 10-Ω resistor is 500 mA, what is the voltage across its terminals?

43. [II] Six 1.5-V cells are connected in two strings, each of which has three cells in series. These two are then attached to each other in parallel and put across a 90.0-Ω resistor. How much current flows through the resistor?

44. [II] Figure P44 shows a variable resistance (total 100 Ω) across which is a voltage drop of 12 V supplied by a battery. What must be the resistance of that portion of the resistor between A and B (namely, R_{AB}) if the voltage V_{AB} is to be (a) 12 V; (b) 6.0 V; (c) 3.0 V?

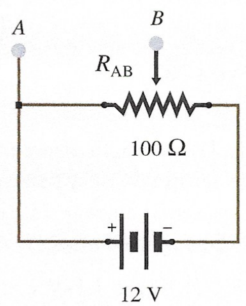

Figure P44

45. [II] Two 1.0-MΩ resistors in series form a closed circuit with a 200-V source. What is the voltage drop across each resistor? What is the current through each resistor?

46. [II] A variable slidewire resistor with a total of 50 Ω is made by wrapping a single layer of 200 turns of varnished copper wire around an insulating cylindrical core. When it carries a current of 3.0 A, what is the voltage drop across each turn of wire?

47. [II] Three identical resistors are wired one-to-the-next in series, and the string of them is then placed across the two terminals of a 300-V power source, thereby forming a closed circuit. If 4.0 A flows around the circuit, what is the voltage drop across each resistor? What is the resistance of each resistor?

48. [II] Two 12-V batteries are connected with the positive terminal of one attached to the negative terminal of the other. The two remaining terminals are then each attached to one of the terminals of a 600-Ω resistor, thereby forming a closed circuit. How much current passes through each battery?

SECTION 17.3: RESISTIVITY

49. [I] Given a solid cube of metal, under what circumstances, if any, will $R = \rho$?

50. [I] Prove that the correct units for resistivity are Ω·m.

51. [I] THIS PROBLEM EXAMINES THE IDEAS OF RESISTIVITY AND RESISTANCE. Earlier we looked at the way a voltage spike propagates along a nerve cell (see Fig. P123, p. 606) . There is something called the *cable model* of the nerve axon. It assumes currents are parallel to the axis of the axon, which is taken to be a fluid cylinder. Axoplasm fills the axon and has a resistivity of ≈0.5 Ω·m. The axon (see Fig. P83, p. 603) is a thin, ≈10 mm long, cylinder having a diameter of ≈10 μm. From that we want to compute the axon's resistance per unit length. (a) What physical characteristics of the axon determine its resistance. (b) What are its dimensions in meters? (c) What is the cross-sectional area of the axon in meters squared? (d) Now that we have everything in proper units, approximate the resistance of the axon. (e) Why is the resistance so high? (f) What is the resistance per unit length of the axon?

52. [I] A 1.0-m-long wire of pure silver at 20 °C is to have a resistance of 0.10 Ω. What should be its diameter?

53. [I] Considering a length of metal wire, show that Ohm's Law can be written as

$$I = \frac{E}{\rho/A}$$

54. [I] A nichrome wire with a cross-sectional area of 1.5×10^{-6} m² is to be used in a heater. If the design calls for a 3.0-Ω coil, what length of wire will be needed?

55. [I] A 5.0-m-long wire has a cross-sectional area of 2.0 mm² and a resistance of 40 mΩ. What is the resistivity of the material constituting the wire?

56. [I] According to the American Wire Gauge system, No. 0000 wire, which is the heaviest, has a diameter of 11.7 mm. What would be the resistance of 100 m of copper AWG No. 0000 at 20 °C?

57. [I] Copper telegraph wire has a resistance of about 10 Ω per mile. What's its diameter in millimeters?

58. [I] A wire of pure gold is drawn through a die so that it is stretched out to twice its original length. Given that its volume is unchanged in the process and its new cross-sectional area is constant, compare the new with the original resistance.

59. [I] A narrow rod of pure iron has a resistance of 0.10 Ω at 20 °C. What is its resistance at 50 °C? [*Hint: Reexamine Example 17.6.*]

60. [I] A carbon rod used to generate the bright light in a movie-theater projector has a resistance of 110 Ω at 20.0 °C. What will be its resistance at 520 °C? (Incidentally, the hottest point on a functioning carbon arc, and the point of greatest luminosity, is typically at about 3500 °C.)

61. [I] A narrow rod of manganin has a resistance of 0.10 Ω at 20 °C. What is its resistance at 50 °C?

62. [II] At room temperature the resistance of a length of aluminum rod is 250 mΩ. (a) If the rod has a cross-sectional area of 0.025 cm², how long is it? (b) How much current will it draw when 9.0 V are put across its ends? (c) How much current would it draw if the rod was shortened by 20%?

SOLUTION: (a) We want to find the length, and that's a physical characteristic of the rod. That calls to mind $R = \rho L/A$; using Table 17.2, $L = RA/\rho = (0.250\ \Omega)(0.025 \times 10^{-4}\ \text{m}^2)/(2.8 \times 10^{-8}\ \Omega\cdot\text{m}) = 22$ m. (b) We have a 0.250-Ω resistance with 9.0 V across it. Using Ohm's Law, $V = IR$, $I = (9.0\ \text{V})/(0.250\ \Omega) = 36$ A. (c) The new resistance is $R' = 80\%R$; therefore $I' = I/0.80 = (36\ \text{A})/0.80 = 45$ A.

63. [II] THIS PROBLEM EXAMINES THE IDEAS OF RESISTIVITY AND RESISTANCE. A piece of copper wire 210 cm long has a cross-sectional area of 1.00×10^{-4} m². We want to know how much current it will draw from a 12-V battery. (a) First put everything in proper units. (b) What physical characteristics of the wire determine its resistance? (c) Write an expression for the resistance of the wire. (d) Compute the resistance of the wire. (e) If we attach each end of the wire to one of the terminals of a 12-V battery, what potential difference will exist across the length of the wire? (f) How much current will pass through the wire? (g) Is shorting a battery a good idea?

64. [II] A length of copper wire 1.0-m long with a cross-sectional area of 1.0 mm² is part of a circuit carrying 1.0 A. What is the value of the steady-state electric field within the wire?

65. [II] It is said that the carbon filaments in the early incandescent light bulbs that Edison produced lost more than two-thirds of their resistance soon after they were turned on. Explain this occurrence and compute their approximate operating temperature. The latter was actually about 1900 °C.

66. [II] Imagine that you are going to connect a remote speaker to your stereo system. The speaker has a resistance of 4.0 Ω, and so

P=IV

you want to use hookup wire whose total resistance is small by comparison, say, 0.25 Ω. If the speaker is to be 15 m away, what diameter copper wire should be used? [*Hint: You'll need two leads.*]

67. [II] A platinum resistance thermometer made up of a coil of wire with a resistance of 10 Ω at 20 °C is placed in a chamber at 420 °C. What will be its new resistance if α_0 is fairly constant at 0.003 9 K^{-1}?

68. [II] Show that if a conductor has its temperature changed, it will experience a fractional change in its resistivity given by

$$\frac{\Delta\rho}{\rho_0} = \alpha_0 \Delta T$$

What assumption must be made here?

69. [II] An iron wire at 20 °C is heated until its resistance doubles. At what temperature will that occur? Assume the temperature coefficient is constant over that temperature range.

70. [II] When currents are transported at very high voltages, it's desirable to keep the electric fields surrounding the conductors down to levels that will not break down the surrounding air, thereby controlling sparking. Accordingly, conductors at power plants and high-voltage laboratories are often large-diameter pipes. What is the resistance per meter of a copper pipe 2.5-cm thick with an inside diameter of 15.0 cm?

71. [III] A modern incandescent lamp has a tungsten filament with a melting point of 3400 °C. Ordinarily, with the bulb evacuated, it's operated at about 2200 °C. The efficiency can be improved almost threefold by raising the temperature to 2800 °C, but that causes the tungsten to evaporate and shortens the life appreciably. The alternative (an idea introduced by Langmuir) is to fill the bulb with nitrogen or argon to suppress evaporation of the tungsten. What is the fractional change in the resistance of the filament when raised from 2200 °C to 2800 °C? Use the value of α_0 found in Table 17.3. Given the following values of α_0 for tungsten (from the *Handbook of Chemistry and Physics*)—0.004 5 at 18 °C, 0.005 7 at 500 °C, 0.008 9 at 1000 °C— how good was the calculation you just made? Discuss your answer and make a very rough estimate of α_0 at 2500 °C. Now estimate the fractional change in resistance using this new value.

72. [III] Figure 17.19 shows how the resistivities of various pure metals each seem to be heading toward zero at some Celsius temperature $-T'$. Make a plot of R versus T (in °C), assuming it to be a straight line. Is that reasonable? Taking $T = 0$ °C as the reference (that is, the line crosses the R-axis at $R = R_0$ and $T = 0$), show that for any point (T, R) on the line

$$R = R_0 \frac{T' + T}{T'}$$

and that $\alpha_0 = 1/T'$. How does this result compare with the values of resistivity given in Table 17.3? Notice how most values approximate $1/273 = 3.7 \times 10^{-3}$.

SECTION 17.5: ENERGY AND POWER

73. [I] A portable tape recorder has a plate on its underside indicating that it uses 1 W at 9 V dc. What net current does it draw from its battery?

74. [I] Referring to Problem 73, what is the net resistance of the tape recorder?

75. [I] A high-torque dc motor designed to drive cassette decks has a no-load speed of 7400 rpm at 9 V with a torque of 9.6 in.·oz and a no-load current of 16 mA. How much power will it draw from a 9-V battery when turning freely? [*Hint: At what voltage is it operating and how much current does it draw?*]

76. [I] A tiny motor mounted on a toy car operates across two D-cells in series. If it draws 0.15 A, how much power does it drain from the battery pack?

77. [I] Six D-cells in series power a tape recorder. If the device dissipates 15 W, how much current does it require?

78. [I] What is the maximum current that should be passed through a 100-Ω, 10-W resistor?

79. [I] The little speaker in a portable radio is labeled 8 Ω, 0.2 W. To what current does that correspond?

80. [I] A windmill with 6-ft propellers generates dc at 12 V. In a strong wind it will produce up to 200 W of electrical power, which is fed to a 230-amp-hour battery. What's the maximum current the windmill will deliver?

81. [I] An automobile starter motor will draw about 180 A from the 12-V battery of a car for perhaps 2.0 s in the process of starting the gasoline engine. How much power does it use?

82. [I] A light bulb operating at 110 V draws 1.82 A. Determine its resistance and the amount of power it draws.

83. [II] THIS PROBLEM EXAMINES THE CONCEPT OF ELECTRIC POWER. Operating at 110 V a light bulb draws 0.50 A. The bulb converts electrical energy into thermal energy and electromagnetic radiant energy. (a) How much charge passes through the bulb in 10 minutes? (b) Making use of part (a), how much energy does that charge deliver in the process of descending 110 V? (c) Using these results determine the power rating of the light bulb. (d) Check your answer using $P = IV$. (e) What is the resistance of the bulb?

84. [II] THIS PROBLEM DEALS WITH THE CONCEPT OF ELECTRIC POWER. The resistor in Fig. P84 has a power rating of 2.0 W, and we want to determine the limitations that places on voltage and current in the circuit. (a) In terms of the voltage of the battery, what is the potential difference across the resistor? (b) Write an expression for the power dissipated by the resistor in terms of the voltage across it. (c) What is the maximum voltage the battery can have if the resistor is not to be damaged? (d) Write an expression for the power dissipated by the resistor in terms of the current through it. (e) What is the maximum current the resistor can handle?

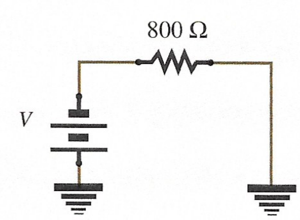

Figure P84

85. [II] A powerhouse near a waterfall has a large dc generator that produces electricity for a factory 0.50 mile away. The energy is transmitted over two cables each with a resistance of 0.25 Ω/mile. Given that the factory requires 45 kW at a voltage of 110 V to run its equipment, what must be the output of the powerhouse?

86. [II] A 0.8-in.-square silicon solar cell delivers 90 mA at 0.45 V

when illuminated by sunlight (at 100 mW/cm^2). Suppose 10 such cells are connected in series; how much power could the panel deliver?

87. [II] For greater flexibility, electrical wires often consist of several fine strands twisted together rather than being constructed of one thick lead. A copper wire is made up of 10 fine fibers, each with a resistance of 2.0 mΩ. When placed across a voltage difference, a total current of 0.12 A traverses the wire. (a) What is the net resistance of the length of wire? (b) What voltage exists across it? (c) How much power is dissipated by each strand? [*Hint: How much current does each strand carry?*]

88. [II] A credit card–sized calculator uses two tiny 1.5-V cells in series that provide a normal operating power of 0.000 18 W. Determine the current passing through each cell when the device is in use.

89. [II] An old-fashioned trolley car draws 12 A from an overhead wire at +500 V (the rails are grounded). What power is delivered to the motor? If the motor is 86% efficient, what power does it develop in propelling the car?

90. [II] When put across the terminals of two D-cells in series, a small flashlight bulb draws 330 mA. How much power does it consume? How much energy does it take from the cells in 1.0 minute of operation?

91. [II] The moving nonconducting belt of a Van de Graaff generator carries 10 μC of charge up to the metal sphere (Fig. Q14, Chapter 15) each second. The steady-state potential difference between the sphere and the grounded source of charge is 3 MV. What minimum power must be supplied to the generator to sustain its operation?

92. [II] A stereo tuner-amplifier with a maximum power output of 50 W per channel (that is, 50 W to each of two speakers) has its right channel connected as shown in Fig. P92. Since the speaker will be destroyed if it receives more than 36 W, a fuse is installed to limit the current entering it. What should be the rated maximum current of the fuse?

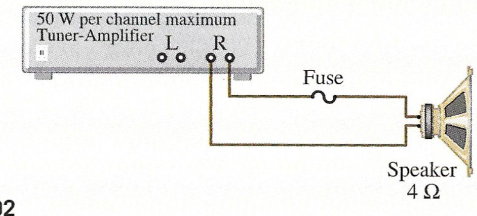

Figure P92

93. [II] When turned on, a flashlight bulb draws 1/3 A at 3.9 V. How much power does it require? Incidentally, more than 95% of that power appears in the form of thermal energy and not light. What is the resistance of the filament in the lamp?

94. [II] How much current does an ideal 1.00-hp dc electric motor draw when operating off a portable 100-V generator?

95. [II] A NiCd battery has an amp-hour rating of 10 and consists of five cells connected in series. What is the maximum power the battery will deliver if it is to operate for 5.0 h?

96. [III] A silicon solar cell 5 mm $\times$ 4 mm produces a current of 5 mA at 0.45 V under sunlight illumination of 100 mW/cm^2. Determine its efficiency.

97. [III] Determine the power rating in kilowatts of an electric heater that will raise the temperature of 10 liters of water from 25 °C to 85 °C in 15 minutes, assuming no loss of thermal energy. Given that the heater coil has a resistance of 10 Ω, how much current does it draw?