Questions

1. When an electric cell is connected to a circuit, electrons flow away from the negative terminal in the circuit. But within the cell, electrons flow *to* the negative terminal. Explain. **To keep it negative.**
2. When a flashlight is operated, what is being used up: battery current, battery voltage, battery energy, battery power, or battery resistance? Explain.
3. What quantity is measured by a battery rating given in ampere-hours (A · h)? Explain.
4. Can a copper wire and an aluminum wire of the same length have the same resistance? Explain. **Yes, if Al has a bigger A.**
5. One terminal of a car battery is said to be connected to "ground." Since it is not really connected to the ground, what is meant by this expression?
6. The equation $P = V^2/R$ indicates that the power dissipated in a resistor decreases if the resistance is increased, whereas the equation $P = I^2R$ implies the opposite. Is there a contradiction here? Explain. **Which is fixed, I or V or neither? V=IR**
7. What happens when a lightbulb burns out?
8. If the resistance of a small immersion heater (to heat water for tea or soup, Fig. 18–32) was increased, would it speed up or slow down the heating process? Explain.

Figure 18–32
Question 8.

9. If a rectangular solid made of carbon has sides of lengths *a*, 2*a*, and 3*a*, to which faces would you connect the wires from a battery so as to obtain (*a*) the least resistance, (*b*) the greatest resistance?
10. Explain why lightbulbs almost always burn out just as they are turned on and not after they have been on for some time.
11. Which draws more current, a 100-W lightbulb or a 75-W bulb? Which has the higher resistance?
12. Electric power is transferred over large distances at very high voltages. Explain how the high voltage reduces power losses in the transmission lines.
13. A 15-A fuse blows out repeatedly. Why is it dangerous to replace this fuse with a 25-A fuse?
14. When electric lights are operated on low-frequency ac (say, 5 Hz), they flicker noticeably. Why?
15. Driven by ac power, the same electrons pass back and forth through your reading lamp over and over again. Explain why the light stays lit instead of going out after the first pass of electrons.
16. The heating element in a toaster is made of Nichrome wire. Immediately after the toaster is turned on, is the current magnitude (I_{rms}) in the wire increasing, decreasing, or staying constant? Explain.
17. Is current used up in a resistor? Explain.

18. Why is it more dangerous to turn on an electric appliance when you are standing outside in bare feet than when you are inside wearing shoes with thick soles?
19. * Compare the drift velocities and electric currents in two wires that are geometrically identical and the density of atoms is similar, but the number of free electrons per atom in the material of one wire is twice that in the other.
20. * A voltage V is connected across a wire of length ℓ and radius r. How is the electron drift speed affected if (*a*) ℓ is doubled, (*b*) r is doubled, (*c*) V is doubled, assuming in each case that other quantities stay the same?

MisConceptual Questions

1. When connected to a battery, a lightbulb glows brightly. If the battery is reversed and reconnected to the bulb, the bulb will glow
    a. brighter.
    b. dimmer.
    c. with the same brightness.
    d. not at all.

2. When a battery is connected to a lightbulb properly, current flows through the lightbulb and makes it glow. How much current flows through the battery compared with the lightbulb?
    a. More.
    b. Less.
    c. The same amount.
    d. No current flows through the battery.

3. Which of the following statements about Ohm's law is true?
    a. Ohm's law relates the current through a wire to the voltage across the wire.
    b. Ohm's law holds for all materials.
    c. Any material that obeys Ohm's law does so independently of temperature.
    d. Ohm's law is a fundamental law of physics.
    e. Ohm's law is valid for superconductors.

4. Electrons carry energy from a battery to a lightbulb. What happens to the electrons when they reach the lightbulb?
    a. The electrons are used up.
    b. The electrons stay in the lightbulb.
    c. The electrons are emitted as light.
    d. Fewer electrons leave the bulb than enter it.
    e. None of the above.

5. Where in the circuit of **Fig. 18–33** is the current the largest, (*a*), (*b*), (*c*), or (*d*)? Or (*e*) it is the same at all points?

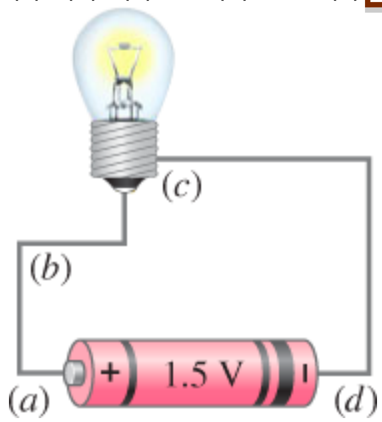

Figure 18–33

MisConceptual Question 5.

6. When you double the *voltage* across a certain material or device, you observe that the *current* increases by a factor of 3. What can you conclude?
   a. Ohm's law is obeyed, because the current increases when *V* increases.
   b. Ohm's law is not obeyed in this case.
   c. This situation has nothing to do with Ohm's law.

7. When current flows through a resistor,
   a. some of the charge is used up by the resistor.
   b. some of the current is used up by the resistor.
   c. Both (*a*) and (*b*) are true.
   d. Neither (*a*) nor (*b*) is true.

8. The unit kilowatt-hour is a measure of
   a. the rate at which energy is transformed.
   b. power.
   c. an amount of energy.
   d. the amount of power used per second.

9. Why might a circuit breaker open if you plug too many electrical devices into a single circuit?

a. The voltage becomes too high.
b. The current becomes too high.
c. The resistance becomes too high.
d. A circuit breaker will not “trip” no matter how many electrical devices you plug into the circuit.

10. Nothing happens when birds land on a power line, yet we are warned not to touch a power line with a ladder. What is the difference?
    a. Birds have extremely high internal resistance compared to humans.
    b. There is little to no voltage drop between a bird's two feet, but there is a significant voltage drop between the top of a ladder touching a power line and the bottom of the ladder on the ground.
    c. Dangerous current comes from the ground only.
    d. Most birds don't understand the situation.

11. When a light switch is turned on, the light comes on immediately because
    a. the electrons coming from the power source move through the initially empty wires very fast.
    b. the electrons already in the wire are instantly “pushed” by a voltage difference.
    c. the lightbulb may be old with low resistance. It would take longer if the bulb were new and had high resistance.
    d. the electricity bill is paid. The electric company can make it take longer when the bill is unpaid.

For assigned homework and other learning materials, go to the MasteringPhysics website.

Problems

18–2 and 18–3 Electric Current, Resistance, Ohm's Law

(*Note*: The charge on one electron is 1.60×10^{-19} C.)

1. (I) A current of 1.60 A flows in a wire. How many electrons are flowing past any point in the wire per second? **10^19**
2. (I) A service station charges a battery using a current of 6.7 A for 5.0 h. How much charge passes through the battery? **1.2X10^5 C**
3. (I) What is the current in amperes if 1200 Na^+ ions flow across a cell membrane in 3.1 μs? The charge on the sodium is the same as on an electron, but positive.
4. (I) What is the resistance of a toaster if 120 V produces a current of 4.6 A? **R=V/I=26.1 Ohm**
5. (I) What voltage will produce 0.25 A of current through a 4800-Ω resistor? **V=IR=1200V**
6. (I) How many coulombs are there in a 75 ampere-hour car battery?
7. (II) (*a*) What is the current in the element of an electric clothes dryer with a resistance of 8.6 Ω when it is connected to 240 V? (*b*) How much charge passes through the element in 50 min? (Assume direct current.) **a) 27.9 A** **b) 8.4 X 10^4 C**
8. (II) A bird stands on a dc electric transmission line carrying 4100 A (**Fig. 18–34**). The line has 2.5×10^{-5} Ω resistance per meter, and the bird's feet are 4.0 cm apart. What is the potential difference between the bird's feet?

   V=4100 X 2.5 X 10^(-5) X .04 = 4.1 X 10^(-3) V

Figure 18–34

Problem 8.

9. (II) A hair dryer draws 13.5 A when plugged into a 120-V line. (*a*) What is its resistance? (*b*) How much charge passes through it in 15 min? (Assume direct current.)
10. (II) A 4.5-V battery is connected to a bulb whose resistance is 1.3 Ω. How many electrons leave the battery per minute?
11. (II) An electric device draws 5.60 A at 240 V. (*a*) If the voltage drops by 15%, what will be the current, assuming nothing else changes? (*b*) If the resistance of the device were reduced by 15%, what current would be drawn at 240 V?

18–4 Resistivity

12. (I) What is the diameter of a 1.00-m length of tungsten wire whose resistance is 0.32 Ω? **4.8 X 10^-4 M**
13. (I) What is the resistance of a 5.4-m length of copper wire 1.5 mm in diameter? **5.1 X 10^-2 ohms**
14. (II) Calculate the ratio of the resistance of 10.0 m of aluminum wire 2.2 mm in diameter, to 24.0 m of copper wire 1.8 mm in diameter.
15. (II) Can a 2.2-mm-diameter copper wire have the same resistance as a tungsten wire of the same length? Give numerical details. **4 mm**
16. (II) A certain copper wire has a resistance of 15.0 Ω. At what point along its length must the wire be cut so that the resistance of one piece is 4.0 times the resistance of the other? What is the resistance of each piece?
17. (II) Compute the voltage drop along a 21-m length of household no. 14 copper wire (used in 15-A circuits). The wire has diameter 1.628 mm and carries a 12-A current.
18. (II) Two aluminum wires have the same resistance. If one has twice the length of the other, what is the ratio of the diameter of the longer wire to the diameter of the shorter wire?
19.

(II) A rectangular solid made of carbon has sides of lengths 1.0 cm, 2.0 cm, and 4.0 cm, lying along the *x, y*, and *z* axes, respectively (**Fig. 18–35**). Determine the resistance for current that passes through the solid in (*a*) the *x* direction, (*b*) the *y* direction, and (*c*) the *z* direction. Assume the resistivity is $\rho = 3.0 \times 10^{-5}\ \Omega \cdot \text{m}$.

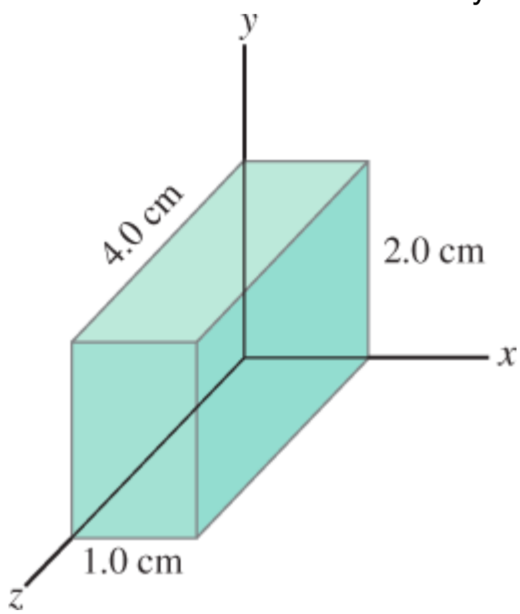

Figure 18–35

Problem 19.

- (II) A length of wire is cut in half and the two lengths are wrapped together side by side to make a thicker wire. How does the resistance of this new combination compare to the resistance of the original wire?

- (II) How much would you have to raise the temperature of a copper wire (originally at 20°C) to increase its resistance by 12%?

- (II) Determine at what temperature aluminum will have the same resistivity as tungsten does at 20°C.

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(II) A 100-W lightbulb has a resistance of about 12 Ω when cold (20°C) and 140 Ω when on (hot). Estimate the temperature of the filament when hot assuming an average temperature coefficient of resistivity $\alpha = 0.0045\ (\mathrm{C}°)^{-1}$.

- (III) A length of aluminum wire is connected to a precision 10.00-V power supply, and a current of 0.4212 A is precisely measured at 23.5°C. The wire is placed in a new environment of unknown temperature where the measured current is 0.3818 A. What is the unknown temperature?

- (III) For some applications, it is important that the value of a resistance not change with temperature. For example, suppose you made a 3.20-kΩ resistor from a carbon resistor and a Nichrome wire-wound resistor connected together so the total resistance is the sum of their separate resistances. What value should each of these resistors have (at 0°C) so that the combination is temperature independent?

- (III) A 10.0-m length of wire consists of 5.0 m of copper followed by 5.0 m of aluminum, both of diameter 1.4 mm. A voltage difference of 95 mV is placed across the composite wire. (*a*) What is the total resistance (sum) of the two wires? (*b*) What is the current through the wire? (*c*) What are the voltages across the aluminum part and across the copper part?

18–5 and 18–6 Electric Power

27. (I) What is the maximum power consumption of a 3.0-V portable CD player that draws a maximum of 240 mA of current? **P=(.24)((3)=.72 W**
28. (I) The heating element of an electric oven is designed to produce 3.3 kW of heat when connected to a 240-V source. What must be the resistance of the element? **R=V^2/P=17.5 Ohms**
29. (I) What is the maximum voltage that can be applied across a

    3.9-kΩ resistor rated at $\frac{1}{4}$ watt?
30. (I) (*a*) Determine the resistance of, and current through, a 75-W lightbulb connected to its proper source voltage of 110 V. (*b*) Repeat for a 250-W bulb.
31. (I) An electric car has a battery that can hold 16 kWh of energy (approximately 6×10^7 J). If the battery is designed to operate at 340 V, how many coulombs of charge would need to leave the battery at 340 V and return at 0 V to equal the stored energy of the battery?
32. (I) An electric car uses a 45-kW (160-hp) motor. If the battery pack is designed for 340 V, what current would the motor need to draw from the battery? Neglect any energy losses in getting energy from the battery to the motor.
33. (II) A 120-V hair dryer has two settings: 950 W and 1450 W (*a*) At which setting do you guess the resistance to be higher? After making a guess, determine the resistance at (*b*) the lower setting, and (*c*) the higher setting.
34. (II) A 12-V battery causes a current of 0.60 A through a resistor. (*a*) What is its resistance, and (*b*) how many joules of energy does the battery lose in a minute?
35. (II) A 120-V fish-tank heater is rated at 130 W. Calculate (*a*) the current through the heater when it is operating, and (*b*) its resistance.
36. (II) You buy a 75-W lightbulb in Europe, where electricity is

delivered at 240 V. If you use the bulb in the United States at 120 V (assume its resistance does not change), how bright will it be relative to 75-W 120-V bulbs? [*Hint*: Assume roughly that brightness is proportional to power consumed.]

37. (II) How many kWh of energy does a 550-W toaster use in the morning if it is in operation for a total of 5.0 min? At a cost of 9.0 cents/kWh, estimate how much this would add to your monthly electric energy bill if you made toast four mornings per week.
38. (II) At $0.095/kWh, what does it cost to leave a 25-W porch light on day and night for a year?
39. (II) What is the total amount of energy stored in a 12-V, 65 A · h car battery when it is fully charged?
40. (II) An ordinary flashlight uses two D-cell 1.5-V batteries connected in series to provide 3.0 V across the bulb, as in **Fig. 18–4b** (**Fig. 18–36**). The bulb draws 380 mA when turned on. (*a*) Calculate the resistance of the bulb and the power dissipated. (*b*) By what factor would the power increase if four D-cells in series (total 6.0 V) were used with the same bulb? (Neglect heating effects of the filament.) Why shouldn't you try this?

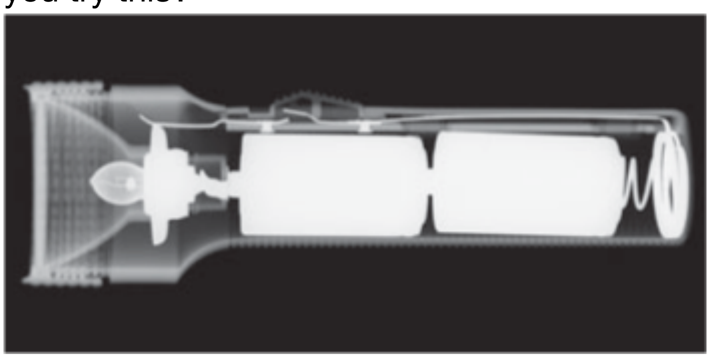

Figure 18–36

Problem 40 (X-ray of a flashlight).

41. (II) How many 75-W lightbulbs, connected to 120 V as in **Fig. 18–20**, can be used without blowing a 15-A fuse?
42. (II) An extension cord made of two wires of diameter 0.129 cm (no. 16 copper wire) and of length 2.7 m (9 ft) is connected to

an electric heater which draws 18.0 A on a 120-V line. How much power is dissipated in the cord?

43. (II) You want to design a portable electric blanket that runs on a 1.5-V battery. If you use a 0.50-mm-diameter copper wire as the heating element, how long should the wire be if you want to generate 18 W of heating power? What happens if you accidentally connect the blanket to a 9.0-V battery?

44.

1) $I = \Delta Q/\Delta t$. So $\Delta Q = I\Delta t = (1.6)(1) = 1.6\,\text{C}$.

   # of electrons is $\dfrac{1.6}{1.6 \times 10^{-19}} = 10^{19}$.

2) $\Delta Q = (6.7)(5 \times 60 \times 60) = 1.2 \times 10^5\,\text{C}$.

4) $V = IR$, so $R = V/I = 120/4.6 = 26.1\,\Omega$.

5) $V = 0.25 \times 4800 = 1.2 \times 10^3\,\text{V}$.

7) a) $I = V/R = 240/8.6 = 27.9\,\text{A}$.

   b) $\Delta Q = I\Delta t = (27.9)(50 \times 60) = 8.4 \times 10^4\,\text{C}$.

8) $V = IR = (4100)\big((2.5 \times 10^{-5}) \cdot (4 \times 10^{-2})\big)$

   $= 4.1 \times 10^{-3}\,\text{V}$.

12) $R = \rho\dfrac{\ell}{A}$.

   So $A = \dfrac{\rho\ell}{R} = \dfrac{(5.6 \times 10^{-8})(1)}{0.32} = 1.75 \times 10^{-7}\,\text{m}^2$.

   $A = \pi r^2$; $r = \sqrt{\dfrac{A}{\pi}} = \sqrt{\dfrac{1.75 \times 10^{-7}}{\pi}} = 2.4{\times}10^{-4}\,\text{m}$.

13) $R = 1.68 \times 10^{-8}\dfrac{5.4}{\pi(0.75 \times 10^{-3})^2} = 5.1 \times 10^{-2}\,\Omega$.

15) We need $\rho_\text{t}\dfrac{\ell}{A_\text{t}} = \rho_\text{c}\dfrac{\ell}{A_\text{c}}$. Cancel ℓ and solve for A_t:

   $A_\text{t} = \dfrac{\rho_\text{t}}{\rho_\text{c}}A_\text{c} = \dfrac{5.6}{1.68}(\pi \times 1.1^2) = 4\pi\,\text{mm}^2$.

   So $\pi r_\text{t}^2 = 4\pi \quad \Rightarrow \quad r_\text{t} = 2 \quad \Rightarrow \quad d_\text{t} = 4\,\text{mm}$.

27) $P = IV = (0.24)(3) = 0.72\,\text{W}$.

28) $P = IV$, $V = IR$, so $P = V^2/R$.

   So $R = V^2/P = 240^2/(3.3 \times 10^3) = 17.5\,\Omega$.