30 Current and Resistance

30.1 The Electron Current

1. A lightbulb is connected with wires to a battery, and the bulb is glowing. Are simple observations and measurements you can make on this circuit able to distinguish a current composed of positive charge carriers from a current composed of negative charge carriers? If so, describe how you can tell which it is. If not, why not?

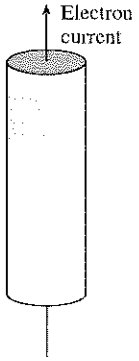
2. One model of current consists of the motion of discrete, charged particles. Another model is that current is the flow of a continuous charged fluid. Do simple experiments provide evidence in favor of either one of these models? Explain.

3. Are the charge carriers always electrons? If so, why is this the case? If not, describe a situation in which a current is due to some other charge carrier.

30.2 Creating a Current

4. The electron drift speed in a wire is exceedingly slow—typically only a fraction of a millimeter per second. Yet when you turn on a light switch, a light bulb several meters away seems to come on instantly. Explain how to resolve this apparent paradox.

5. The figure shows a segment of a current-carrying metal wire.



   a. Is there an electric field inside the wire? If so, draw and label an arrow on the figure to show its direction. If not, why not?

   b. If there is an electric field, draw on the figure a possible arrangement of charges that could be the source charges causing the field.

6. a. If the electrons in a current-carrying wire collide with the positive ions *more* frequently, does their drift speed increase or decrease? Explain.

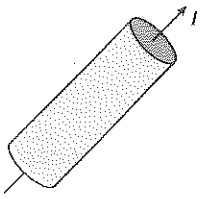
   b. Does an increase in the collision frequency make the wire a better conductor or a worse conductor? Explain.

   c. Would you expect a metal to be a better conductor at high temperature or at low temperature? Explain.

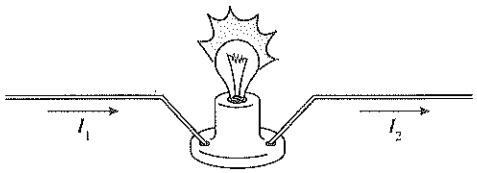
30.3 Current and Current Density

7. What is the difference between current and current density?

8. The figure shows a segment of a current-carrying metal wire.
   a. Draw an arrow on the figure, using a **black** pen or pencil, to show the direction of motion of the charge carriers.
   b. Draw an arrow on the figure, using a **red** pen or pencil, to show the direction of the electric field.



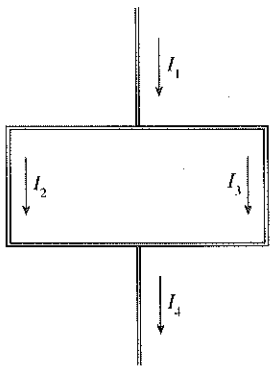
9. Is I_2 greater than, less than, or equal to I_1? Explain.



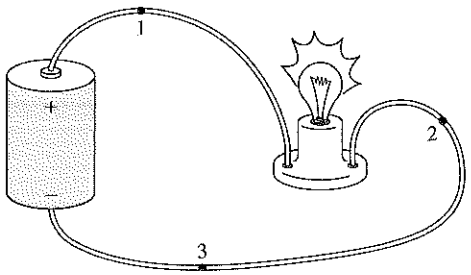
10. All wires in this figure are made of the same material and have the same diameter. Rank in order, from largest to smallest, the currents I_1 to I_4.

Order:

Explanation:



11. A lightbulb is connected to a battery with 1-mm-diameter wires. The bulb is glowing.



   a. Draw arrows at points 1, 2, and 3 to show the direction of the electric field at those points. (The points are *inside* the wire.)

   b. Rank in order, from largest to smallest, the field strengths E_1, E_2, and E_3.

Order:

Explanation:

12. A wire carries a 4 A current. What is the current in a second wire that delivers twice as much charge in half the time?

13. The current density in a wire is 1000 A/m^2. What will the current density be if the current is doubled and the wire's diameter is halved?

30.4 Conductivity and Resistivity

14. Metal 1 and metal 2 are each formed into 1-mm-diameter wires. The electric field needed to cause a 1 A current in metal 1 is larger than the electric field needed to cause a 1 A current in metal 2. Which metal has the larger conductivity? Explain.

15. If a metal is heated, does its conductivity increase, decrease, or stay the same? Explain.

16. Wire 1 and wire 2 are made from the same metal. Wire 1 has twice the diameter and half the electric field of wire 2. What is the ratio I_1/I_2?

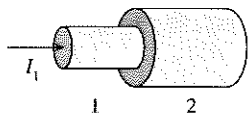
17. Wire 1 and wire 2 are made from the same metal. Wire 2 has a larger diameter than wire 1. The electric field strengths E_1 and E_2 are equal.

    a. Compare the values of the two current densities. Is J_1 greater than, less than, or equal to J_2? Explain.

    b. Compare the values of the currents I_1 and I_2.

    c. Compare the values of the electron drift speeds $(v_d)_1$ and $(v_d)_2$.

18. A wire consists of two segments of different diameters but made from the same metal. The current in segment 1 is I_1.



a. Compare the values of the currents in the two segments. Is I_2 greater than, less than, or equal to I_1? Explain.

b. Compare the values of the current densities J_1 and J_2.

c. Compare the strengths of the electric fields E_1 and E_2 in the two segments.

d. Compare the values of the electron drift speeds $(v_d)_1$ and $(v_d)_2$.

19. A wire consists of two equal-diameter segments. Their conductivities differ, with $\sigma_2 > \sigma_1$. The current in segment 1 is I_1.

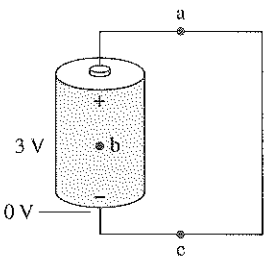
a. Compare the values of the currents in the two segments. Is I_2 greater than, less than, or equal to I_1? Explain.

b. Compare the strengths of the current densities J_1 and J_2.

c. Compare the strengths of the electric fields E_1 and E_2 in the two segments.

30.5 Resistance and Ohm's Law

20. A continuous metal wire connects the two ends of a 3 V battery with a rectangular loop. The negative terminal of the battery has been chosen as the point where $V = 0$ V.



a. Locate and label the approximate points along the wire where $V = 3$ V, $V = 2$ V, and $V = 1$ V.

b. Points a and c are *inside* the wire. Point b is inside the battery. Does the electric field at a, b, and c point left, right, up, or down? Or is $\vec{E} = \vec{0}$?

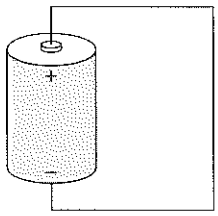
$\vec{E}_a$ ..... $\vec{E}_b$ ..... $\vec{E}_c$ .....

c. In moving through the *wire* from the negative to the positive battery terminal, does the potential increase, decrease, or not change? If the potential changes, by how much does it change?

d. In moving through the *battery* from the negative to the positive battery terminal, does the potential increase, decrease, or not change? If the potential changes, by how much does it change?

e. In moving all the way around the loop in a clockwise direction, is the net change in the potential positive, negative, or zero?

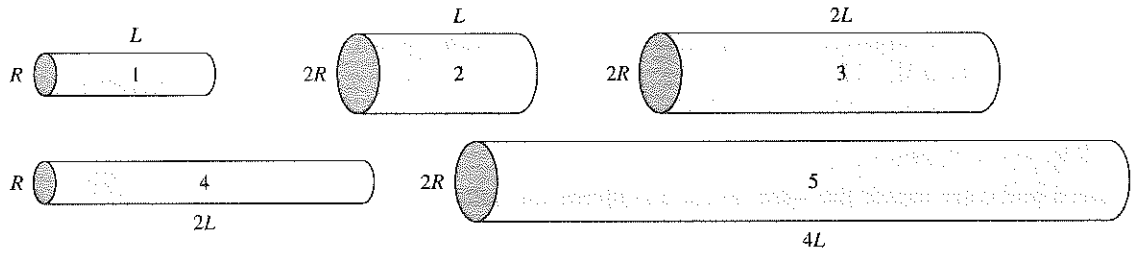
21. a. Which direction—clockwise or counterclockwise—does an electron travel through the wire? Explain.



b. Does an electron's electric potential energy increase, decrease, or stay the same as it moves through the wire? Explain.

c. If you answered "decrease" in part b, where does the energy go? If you answered "increase" in part b, where does the energy come from?

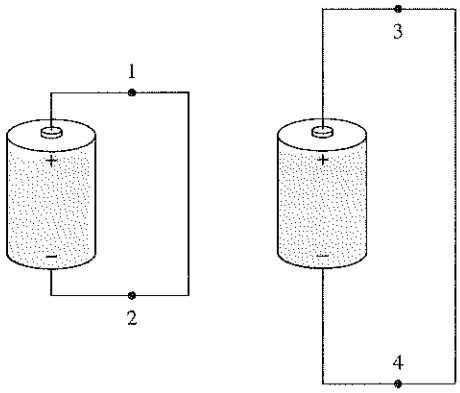
22. The wires below are all made of the same material. Rank in order, from largest to smallest, the resistances R_1 to R_5 of these wires.



Order:

Explanation:

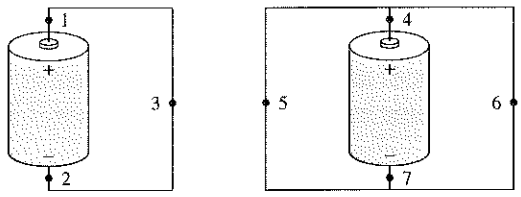
23. The two circuits use identical batteries and wires of equal diameters. Rank in order, from largest to smallest, the currents I_1, I_2, I_3, and I_4 at points 1 to 4.



Order:

Explanation:

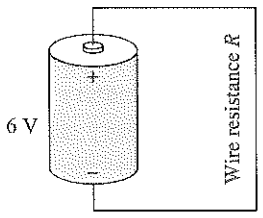
24. The two circuits use identical batteries and wires of equal diameters. Rank in order, from largest to smallest, the currents I_1 to I_7 at points 1 to 7.



Order:

Explanation:

25. A wire is connected to the terminals of a 6 V battery. What is the potential difference ΔV_{wire} between the ends of the wire, and what is the current I through the wire, if the wire has the following resistances:



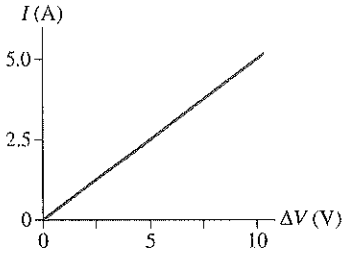
a. $R = 1\ \Omega$ $\Delta V_{wire} =$ _____ $I =$ _____

b. $R = 2\ \Omega$ $\Delta V_{wire} =$ _____ $I =$ _____

c. $R = 3\ \Omega$ $\Delta V_{wire} =$ _____ $I =$ _____

d. $R = 6\ \Omega$ $\Delta V_{wire} =$ _____ $I =$ _____

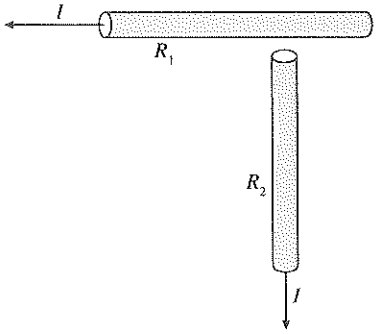
26. The graph shows the current-versus-potential-difference relationship for a resistor R.



a. What is the numerical value of R?

b. Suppose the length of the resistor is doubled. On the figure, draw the current-versus-potential-difference graph for the longer resistor.

27. For resistors R_1 to R_2:



a. Which end (left, right, top, or bottom) is more positive?

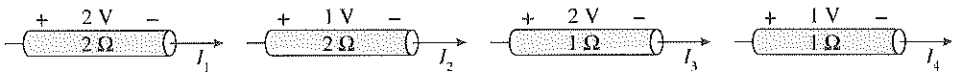
R_1 _____ R_2 _____

b. In which direction (such as left to right or top to bottom) does the potential decrease?

R_1 _____

R_2 _____

28. Rank in order, from largest to smallest, the currents I_1 to I_4 through these four resistors.



Order:

Explanation:

29. Which, if any, of these statements are true? (More than one may be true.)
    i. A battery supplies the energy to a circuit.
    ii. A battery is a source of potential difference. The potential difference between the terminals of the battery is always the same.
    iii. A battery is a source of current. The current leaving the battery is always the same.

    Explain your choice or choices.