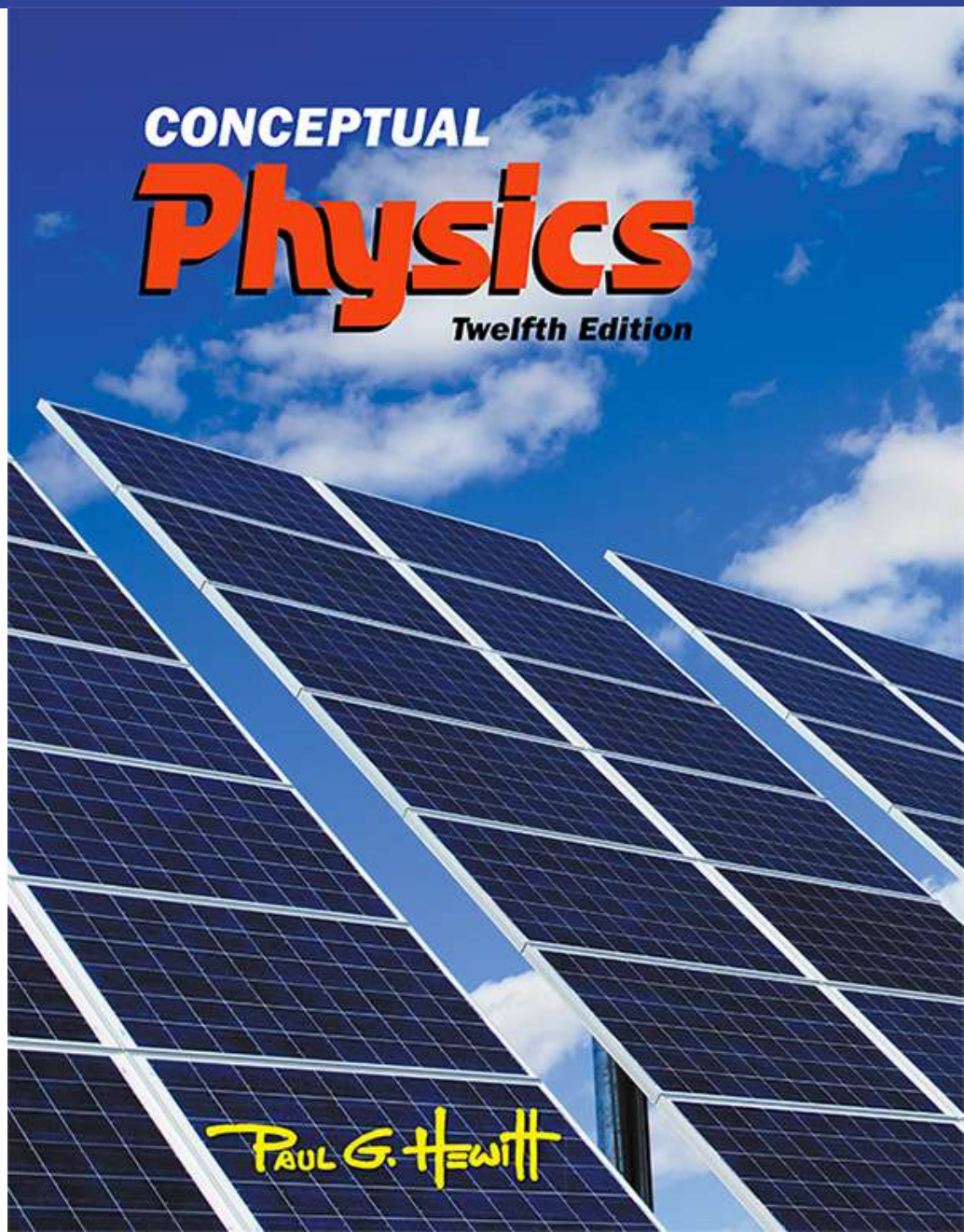
Lecture Outline

Chapter 23: Electric Current

Sections 4-6:

- Ohm's Law
- Direct Current and Alternating Current
- Speed and Source of Electrons in a Circuit



Ohm's Law

- Ohm's law
  - Relationship between voltage, current, and resistance
  - States that the current in a circuit varies in direct proportion to the potential difference, or voltage, and inversely with the resistance

$$\text{Current} = \frac{voltage}{resistance}$$

$$\text{units:} \quad \text{amperes} = \frac{volts}{ohms}$$

Ohm's Law, Continued

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

-cause currents
-produced by batteries or generator

-resist currents
-can be a resistor or lamps or you!

- Example:
  - For a constant resistance, current will be twice as much for twice the voltage.
  - For twice the resistance and twice the voltage, current will be unchanged.
  - For a constant voltage, reducing resistance increases current.

Ohm's Law
CHECK YOUR NEIGHBOR

When you double the voltage in a simple electric circuit, you double the

A. current.
B. resistance.
C. Both A and B.
D. Neither A nor B.

Ohm's Law
CHECK YOUR ANSWER

When you double the voltage in a simple electric circuit, you double the

A. current.

Explanation:

This is a straightforward application of Ohm's law.

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

1. How much current is drawn by a 60-Ω resistor when a voltage of 12 V is impressed across it?

$$\text{Current} = \frac{voltage}{resistance}$$

$$= \frac{12\ V}{60\ \Omega}$$

$$= 0.2\ \text{A}$$

2. What Is the resIstance of an electrIc fryIng pan that draws 12 A when connected to a 120-V cIrcuIt?

$$\text{Current} = \frac{voltage}{resistance}$$

$$12\ \text{A} = \frac{120\ V}{resistance}$$

$$\text{resistance} = \frac{120\ V}{12\ A}$$

$$= 10\ \Omega$$

Electric Shock

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

Water on your skin decreases resistance
less resistance → more current

TABLE 23.1 EFFECTS OF ELECTRIC CURRENTS ON THE BODY

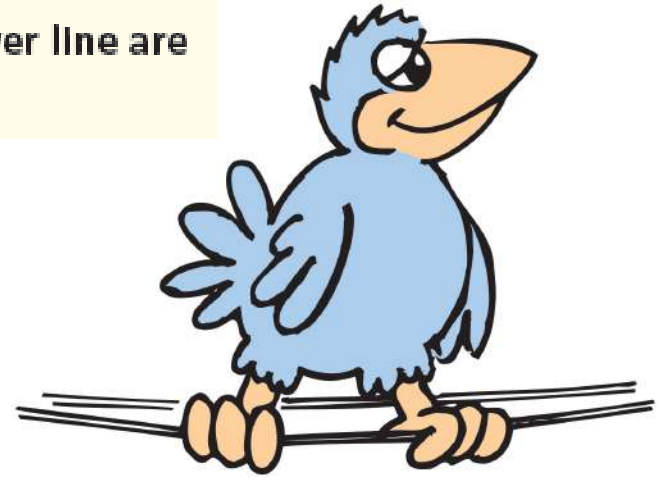
Current (A)	Effect
0.001	Can be felt
0.005	Is painful
0.010	Causes involuntary muscle contractions (spasms)
0.015	Causes loss of muscle control
0.070	If through the heart, causes serious disruption; probably fatal if current lasts longer than 1 s

Your muscles function on natural, tiny electrical impulses…and these currents can be fatal.

Ohm's Law, Continued-1

- Electric shock
  - Damaging effects of shock result from current passing through the body.
  - Electric potential difference between one part of your body and another part depends on body condition and resistance, which can range from 100 ohms to 500,000 ohms.

If the two feet of a bird on the high-potential wire of a power line are widely spaced, won't it get a shock?

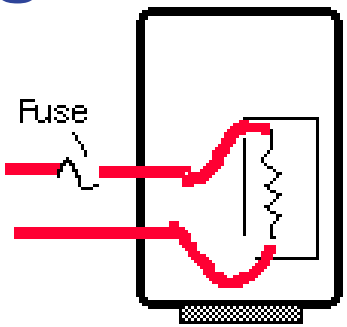


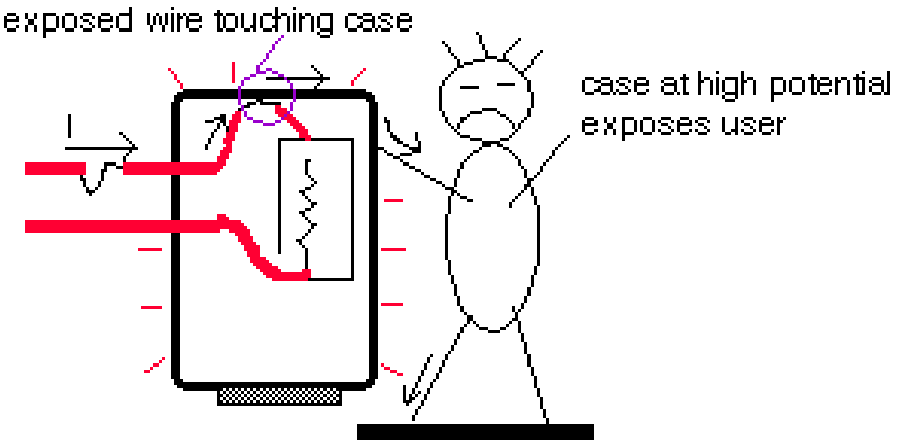
No. The feet are at the same potential because they are on the same line. No potential difference…no current.

→ Not true if it grabs the other line.

The 3rd prong:

no prong:





prong:

The prong provides safe path for excess charge to get to ground instead of through you.

1. If your body resistance is 100,000 Ω, how much current will you experience if you touch the terminals of a 12-V battery?

$$\text{Current} = \frac{\textit{voltage}}{\textit{resistance}}$$

$$= \frac{12\ V}{}$$

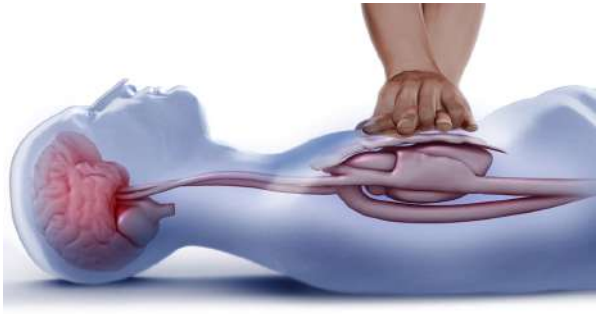
2. If your skin is very moist, so that your resistance is only 1000 Ω, and you again touch the battery terminals, how much current will you experience?

$$\text{Current} = \frac{\textit{voltage}}{\textit{resistance}}$$

$$\frac{12\ V}{}$$

If shock occurs:

- Locate power source. Turn it off.
- Administer CPR until help arrives.



11. If the voltage impressed across a circuit is held constant while the resistance doubles, what change occurs in the current?

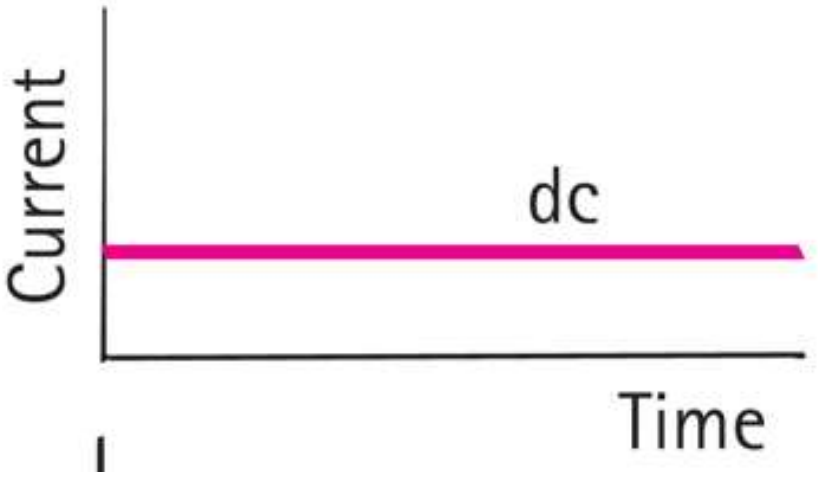
12. If the resistance of a circuit remains constant while the voltage across the circuit decreases to half its former value, what change occurs in the current?

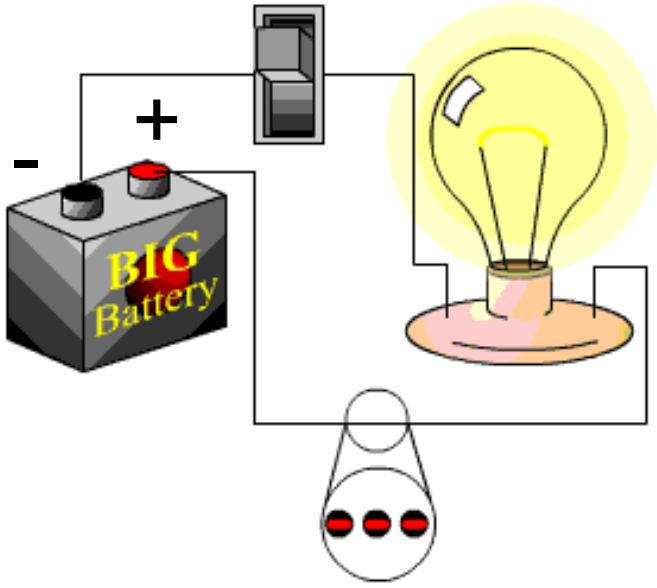
13. How does wetness affect the resistance of your body?

14. What is the function of the round third prong in a modern household electrical plug?

Direct and Alternating Current

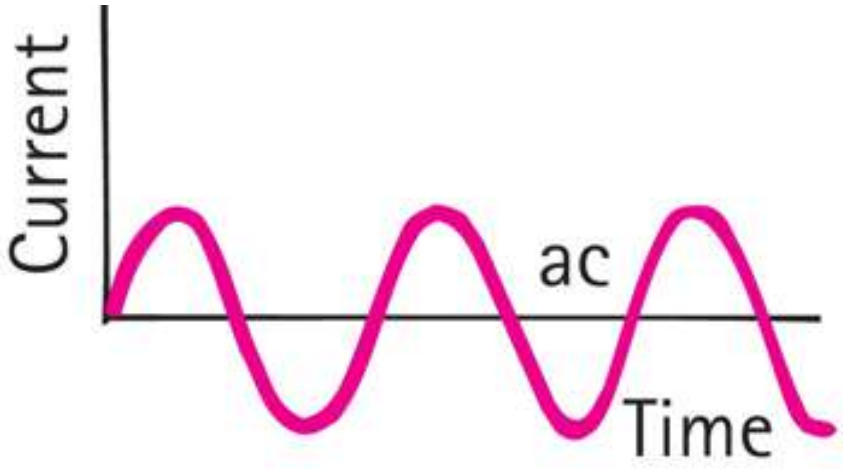
- **Direct current (dc)**
  - Flows in one direction only.
  - Electrons move from negative terminal to positive terminal.
  - Batteries cause DC current.

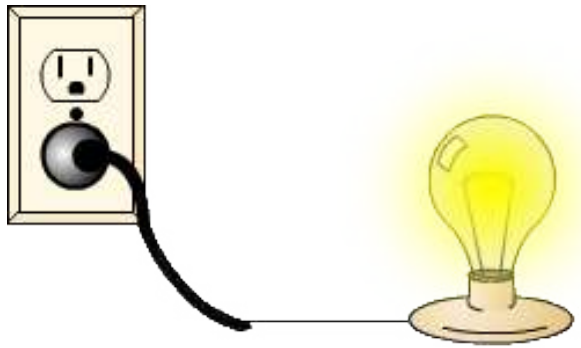




Direct and Alternating Current

- **Alternating Current (ac)**
  - Electrons are moved first in 1 direction and then in the opposite direction, alternating to and fro
  - This is accomplished by alternating the polarity of voltage at the generator or other voltage source.
  - The outlets in your house or apartment provided ac





Direct and Alternating Current, Continued

- Commercial electricity in North America
  - Alternating current (ac)
  - 60 cycles per second
  - current switches direction 60x per second
  - Voltage is 120 V
- Power transmission is more efficient at higher voltages.
  - Europe adopted 220 V as its standard.
  - U.S. continued with 120 V because so much equipment was already installed.

- Converting from ac to dc

  Household current is ac, but current in cellphones and laptops is dc. So ac must be converted to dc.

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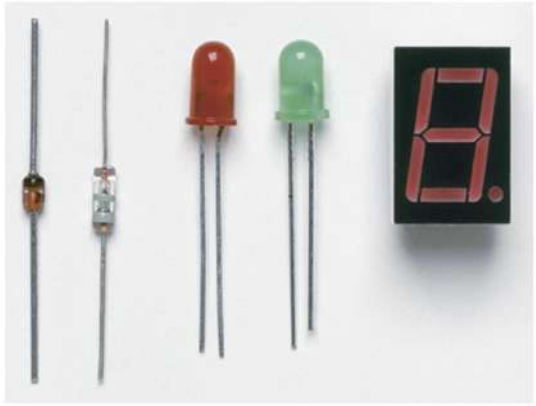
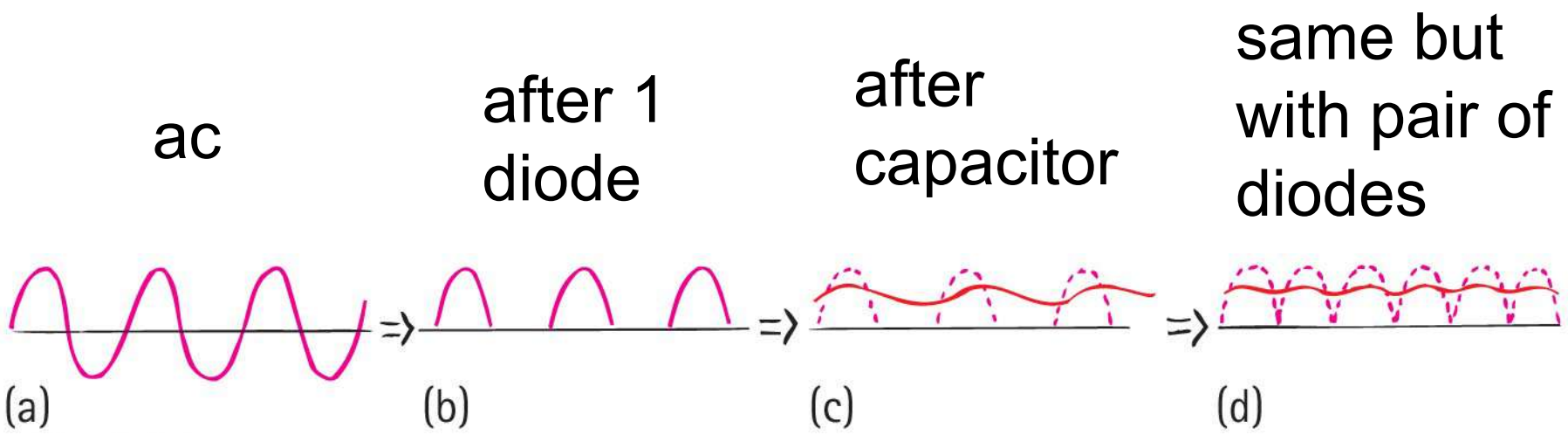
  - The converter uses a *diode*, a tiny electronic device that acts as a one-way valve to allow electron flow in one direction only.



  - It also uses a *capacitor*, which stores charge up and releases it gradually. This smooths out the current.

FIGURE 23.12
Water input to the reservoir may be in repeated spurts or pulses, but the output is a fairly smooth stream. Likewise with a capacitor.

- Converting from ac to dc
  a. When input to a *diode* is ac, output is pulsating dc because the diode **only allows one way current**
  b. Slow charging and discharging of a *capacitor* provides continuous and **smoother** current.
  c. A pair of diodes is used, so there are no gaps in current output. The pair of diodes reverses the polarity of alternate half-cycles instead of eliminating them.



15. Does a battery produce dc or ac? Does the generator at a power station produce dc or ac?

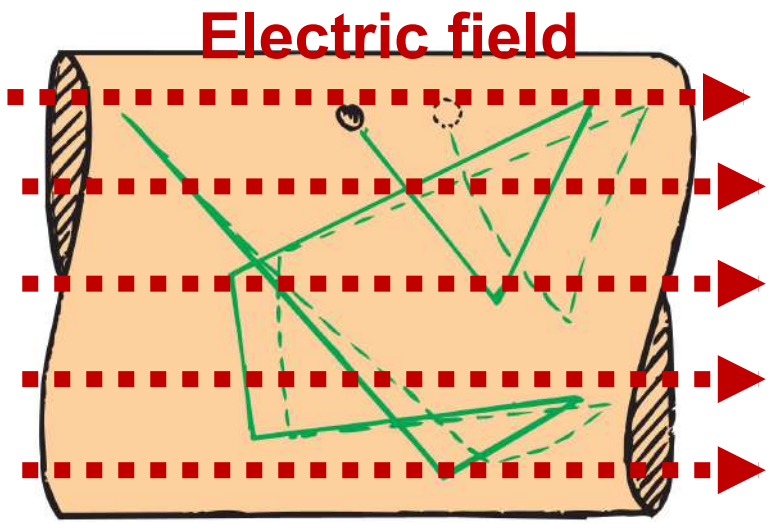
16. What does it mean to say that a certain current is 60 Hz?

17. What property of a diode enables it to convert ac to pulsed dc?

18. A diode converts ac to pulsed dc. What electrical device smoothes the pulsed dc to a smoother dc?

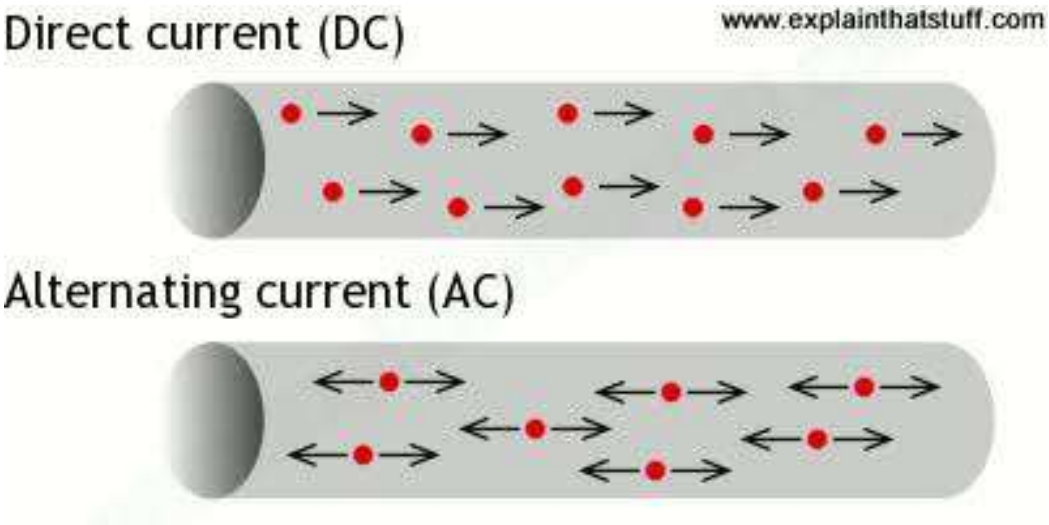
Speed and Source of Electrons in a Circuit

- When we flip the light switch on a wall and the circuit, an electric field is established inside the conductor.
  - The electrons continue their random motions while simultaneously being nudged by the electric field.
  - They bump into the metal
  - This changes their kinetic energy into heat.



  - **The electric field can travel through a circuit at nearly the speed of light.**
  - It is *not* the electrons that move at this speed.
  - The electrons “drift” through the wire
  - It takes about 3 hours to go 1 meter!

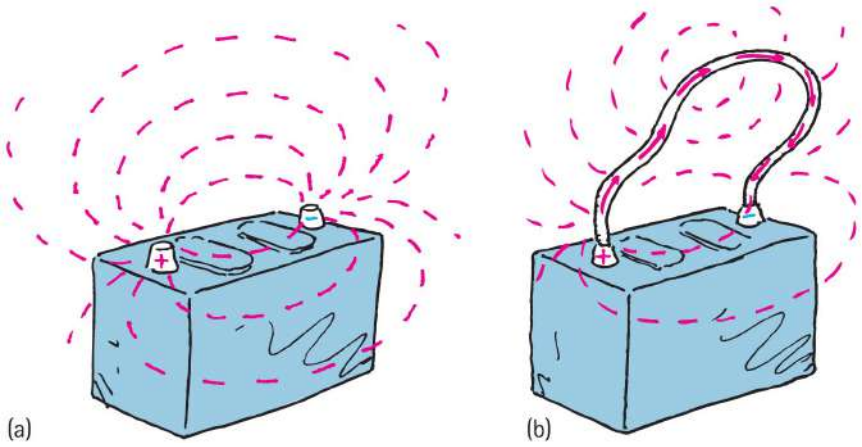
- Alternating current (ac)
  - Electrons oscillate to and fro around fixed positions.



  - Movement is produced by a generator or an alternator that **switches the signs of charge periodically**.

Speed and Source of Electrons in a Circuit

- If the voltage source is **dc**, like the battery, electric field lines are maintained **in one direction** in the conductor.
- Conduction electrons are accelerated by the field in a direction parallel to the field lines.
- Before they gain appreciable speed, they "bump into" the anchored metallic ions in their paths and transfer some of their kinetic energy to them. **This heats the wire.**
- **Bumping slows them. It does not cause them to move!**



- Misconceptions about electric current:
  - **"Current is propagated through the conducting wires by electrons bumping into one another."**
    - NOT true: Electrons that are free to move in a conductor are accelerated by the electric field impressed upon them.
    - True, they do bump into one another and other atoms, but this slows them down and offers resistance to their motion.
    - Electrons throughout the entire closed path of a circuit all react simultaneously to the electric field.

- Misconceptions about electric current:
  - "**Electrical outlets in the walls of the homes are a source of electrons**."
    - NOT true: The outlets in homes are ac. Electrons make no net migration through a wire in an ac circuit.
    - When you plug a lamp into an outlet, *energy* flows from the outlet into the lamp, not electrons. Energy is carried by the pulsating electric field and causes vibratory motion.
    - Electrical utility companies sell *energy*. You provide the electrons.

19. What is the error in saying that electrons in a common battery-driven circuit travel at about the speed of light?

20. Why does a wire that carries electric current become hot?