Section 1: Electric Charge and Force

Preview

Key Ideas

〉 What are the different kinds of electric charge?

〉 How do materials become charged when rubbed together?

〉 What force is responsible for most everyday forces?

Bellringer

1. Name at least five examples of static electricity that occur in everyday life.
2. Fabric softeners are commonly used because they eliminate static cling. Explain why clothes in the dryer get static cling.
3. Why can walking across a carpeted room be a shocking experience.
4. Magnets have both north and south poles. While like poles repel each other, opposite poles attract each other. Explain the parallelism between magnetism and electric charge.

Electric Charge

- What are the different kinds of electric charge?

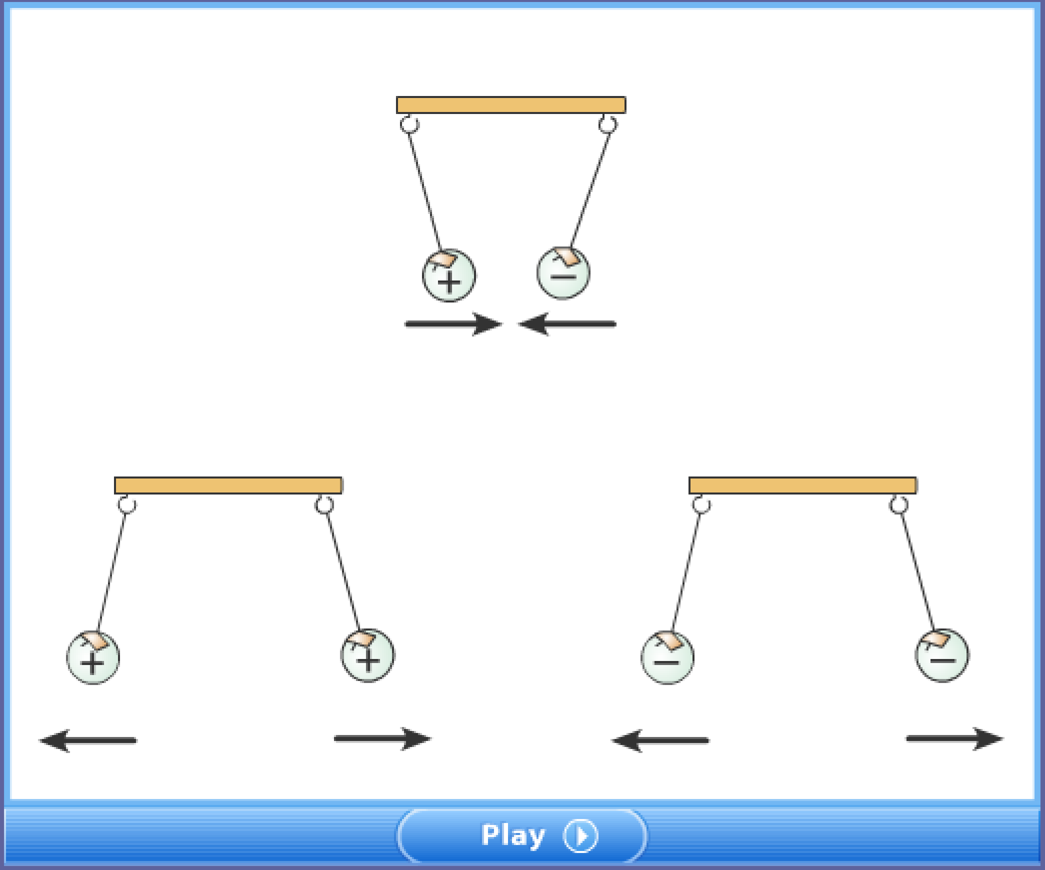
- An object can have a negative charge, a positive charge, or no charge at all.

- **Electric charge:** an electrical property of matter that creates electric and magnetic forces and interactions

Electric Charge, *continued*

- Like energy, electric charge is never created or destroyed.
- Like charges repel, and opposite charges attract.
- Electric charge depends on the imbalance of protons and electrons.
  - Electrons are negatively charged.
  - Protons are positively charged.
  - Neutrons are neutral (no charge).
  - Negatively charged objects have more electrons than protons.
  - Positively charged objects have fewer electrons than protons.

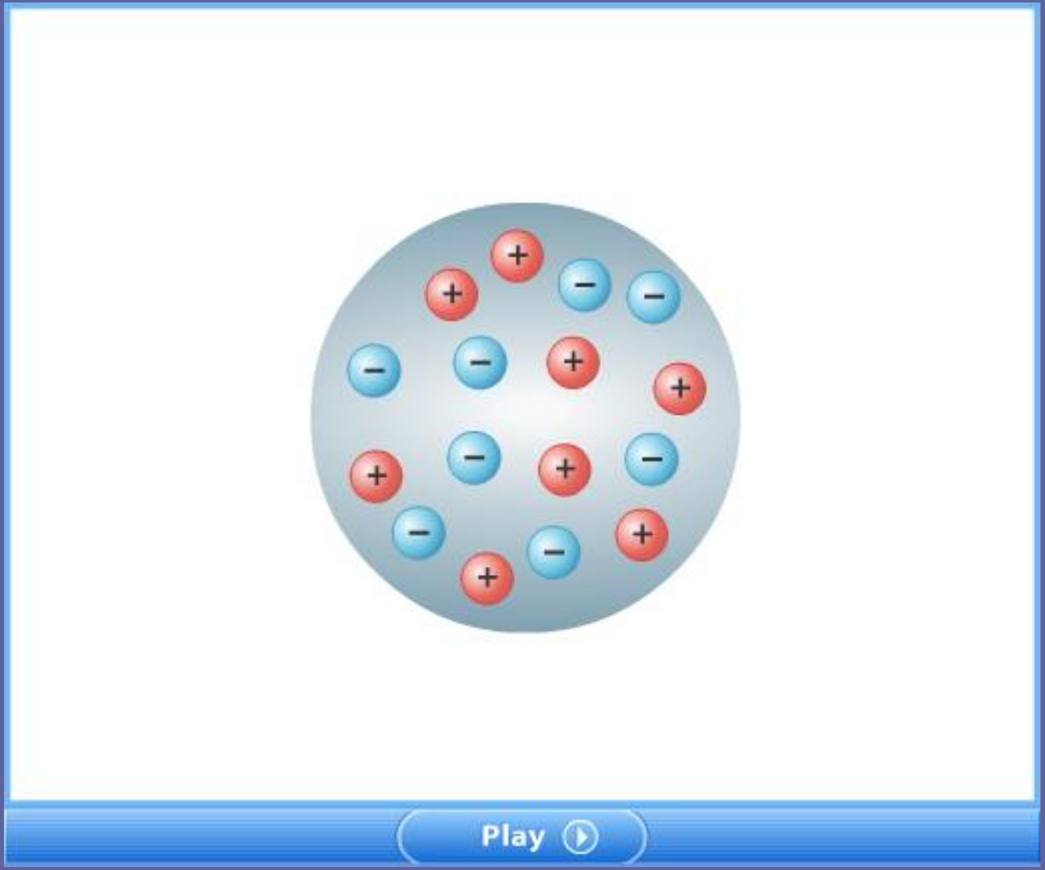
Visual Concept: Electric Charge



Electric Charge, *continued*

- The SI unit of electric charge is the *coulomb,* C.
  - A proton has a charge of $+1.6 \times 10^{-19}$ C.
  - An electron has a charge of -1.6×10^{-19} C.
  - The amount of electric charge on an object depends on the number of protons and electrons.
    - The net electric charge of a charged object is always a multiple of 1.6×10^{-19} C.

Visual Concept: Characteristics of Electric Charge



Transfer of Electric Charge

- How do materials become charged when rubbed together?

- When different materials are rubbed together, electrons can be transferred from one material to the other.

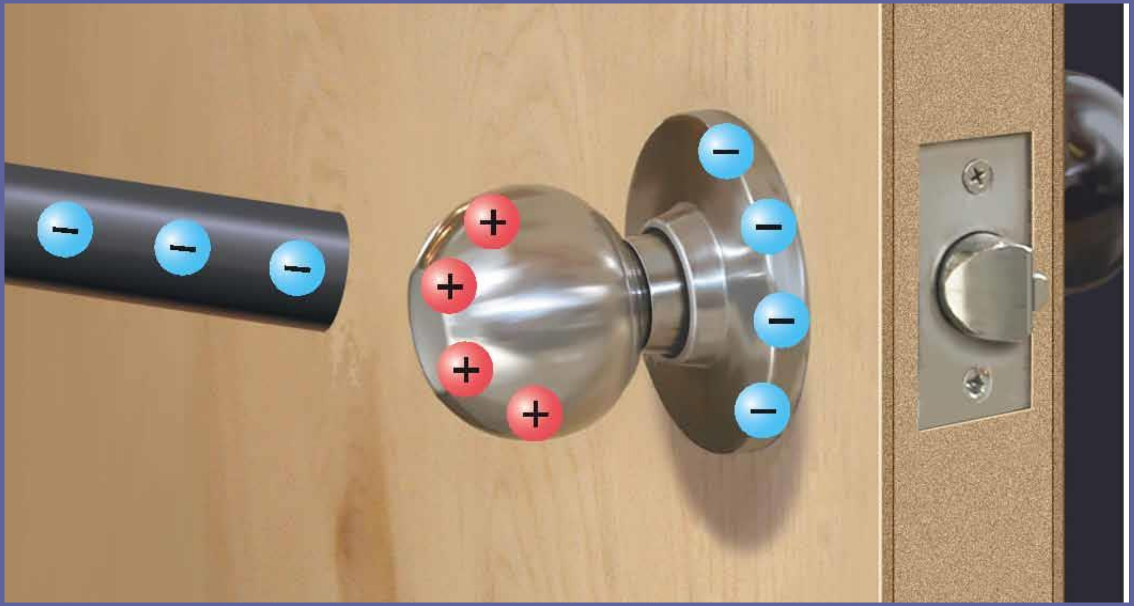
- The direction in which the electrons are transferred depends on the materials.

Transfer of Electric Charge, *continued*

- Conductors allow charges to flow; insulators do not.
  - **electrical conductor:** a material in which charges can move freely
  - **electrical insulator:** a material in which charges cannot move freely
- Charges can move within uncharged objects.
  - The charges in a neutral conductor can be redistributed without changing the overall charge of the object.
  - Although the total charge on the conductor will be zero, the opposite sides can have an *induced* charge.

Visual Concept: Electrical Conductors and Insulators

Induced Charges



A negatively charged rod brought near a metal doorknob induces a positive charge on the side of the doorknob closest to the rod and a negative charge on the side farthest from the rod.

Transfer of Electric Charge, *continued*

- Objects can be charged by contact.
  - The transfer of electrons from one object to another can charge objects.
  - Objects charged by touching a charged object to a neutral object are said to be charged by *contact*.
- Objects can be charged by friction.
  - *Charging by friction* occurs when one material gains electrons and becomes negatively charged, and the other loses electrons and becomes positively charged.
  - Your clothes are charged by friction as they rub against each other inside the dryer, and stick together because of static electricity.

Charging by Contact

When a negative rod touches a neutral doorknob, electrons move from the rod to the doorknob.

The transfer of electrons to the metal doorknob gives the doorknob a net negative charge.

Visual Concept: Charging by Contact

Transfer of Electric Charge, *continued*

- A surface charge can be induced on insulators.
  - When a charged object is brought near an insulator, the positions of the electrons within the individual molecules of the insulator change slightly.
  - One side of a molecule will be slightly more positive or negative than the other side.
    - The molecules are *polarized.*

Electric Force

- What force is responsible for most everyday forces?

- The electric force at the atomic and molecular levels is responsible for most of the everyday forces that we observe, such as the force of a spring and the force of friction.

- **electric force:** the force of attraction or repulsion on a charged particle that is due to an electric field

Electric Force, *continued*

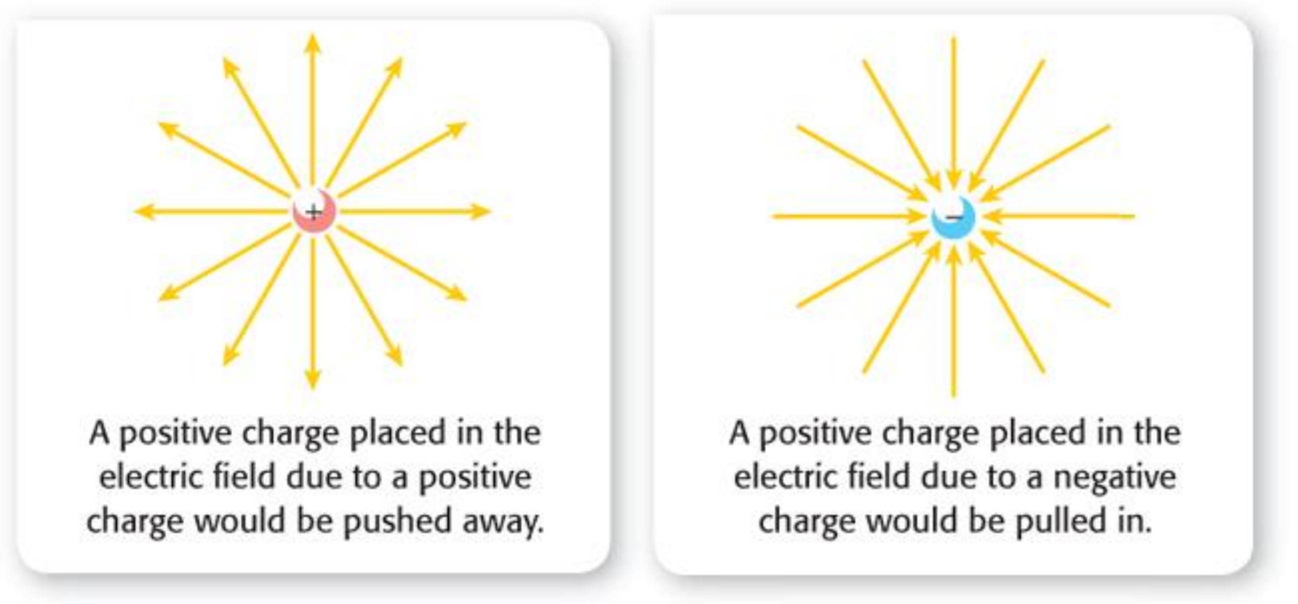
- The electric force is also responsible for effects that we cannot see.
  - Bonding of atoms to form molecules is also due to the electric force.

- Electric force depends on charge and distance.
  - The electric force between two objects is proportional to the product of the charges on the objects.
  - The electric force is inversely proportional to the square of the distance between two objects.

Electric Force, *continued*

- Electric force acts through a field.
  - **electric field:** the space around a charged object in which another charged object experiences an electric force
  - One way to show an electric field is by drawing electric field lines.
  - *Electric field lines* point in the direction of the electric force on a positive charge.

Electric Field Lines



The electric field lines around a positive charge point outward.

The electric field lines around a negative charge point inward.

Electric Force, *continued*

- Electric field lines never cross one another.
- The field lines near two like charges point away from each other, and show that the charges repel each other.
- Field lines show both the direction of an electric field and the relative strength due to a given charge.
  - More lines are drawn for greater charges to indicate greater force.

Electric Field Lines

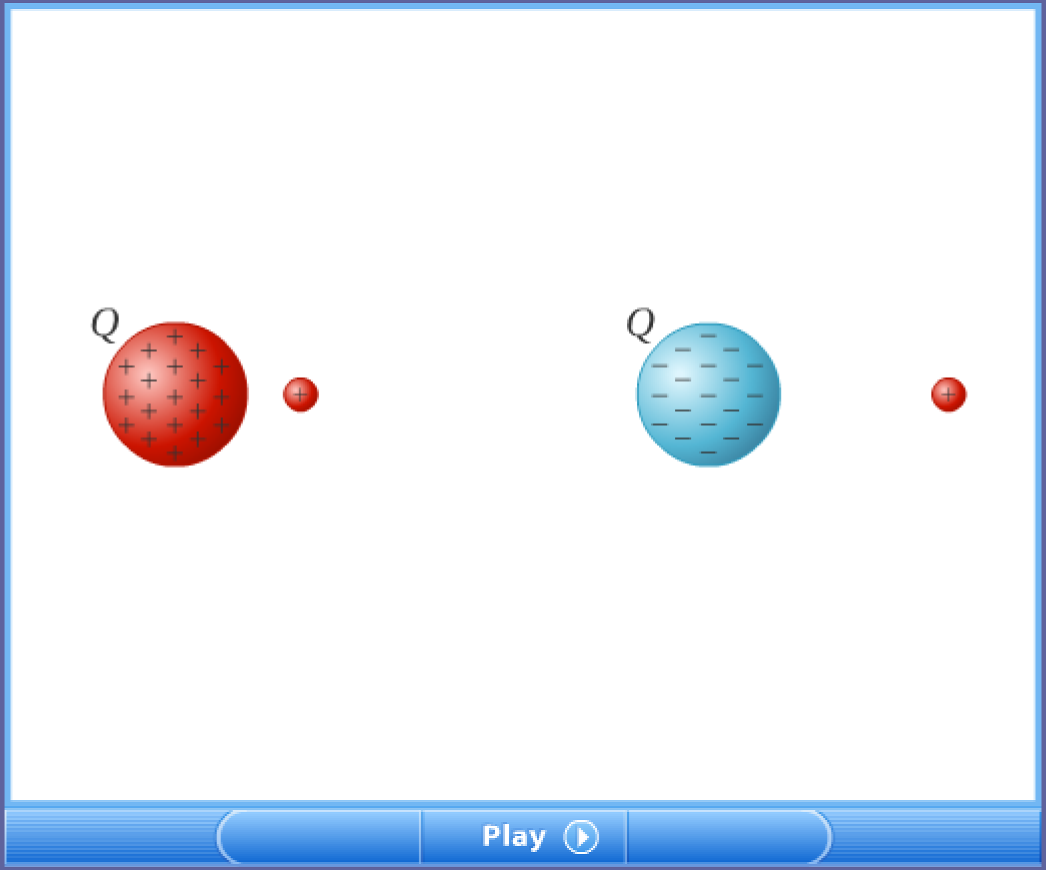
The electric field lines for two positive charges located near each other show the repulsion between the charges.

Half of the field lines starting on the positive charge end on the negative charge because the positive charge is twice as large as the negative charge.

Two positive charges repel each other.

The positive charge is twice as large as the negative charge.

Visual Concept: Electric Fields and Test Charges



Section 2: Current

Preview

Key Ideas

- How are electrical potential energy and gravitational potential energy similar?
- What causes electrical resistance?

Bellringer

1. Dry cell batteries are a source of mobile electrical power. Name five devices that use dry cell batteries.
2. Give reasons why copper is normally used to wire a home for electricity.
3. Why do you think it is important to unplug a device by pulling the plug instead of by yanking the plug out of the socket by pulling on the electrical cord?
4. Why are electrical appliances, such as razors, hair dryers, and curling irons, not to be used in the bathtub or shower?

Voltage and Current

- How are electrical potential energy and gravitational potential energy similar?

- Just as a ball will roll downhill, a negative charge will move away from another negative charge.

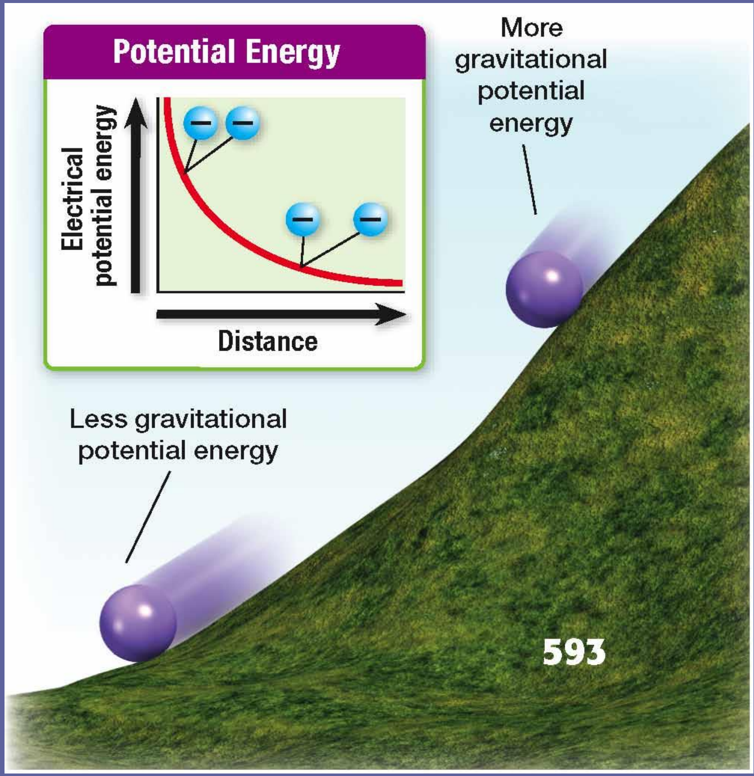
- **electrical potential energy:** the ability to move an electric charge from one point to another

Voltage and Current, *continued*

- The potential energy of an electric charge depends on its position in an electric field.

- The electrical potential energy of a moving charge decreases because the electric field does work on the charge.

Electrical Potential Energy

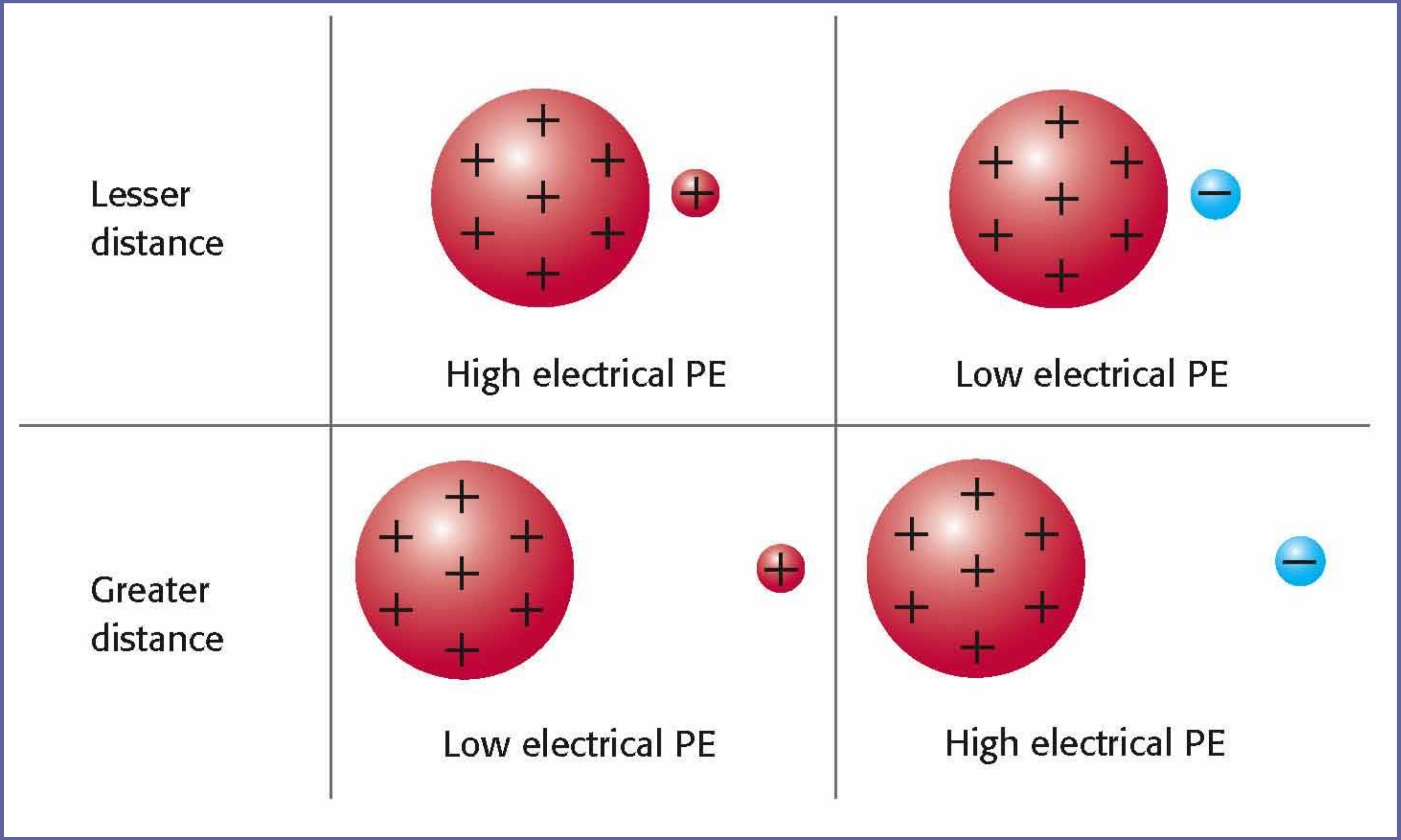


The electrical potential energy between two negative charges decreases as the distance between them increases.

Voltage and Current, *continued*

- Potential difference is measured in volts.
  - **potential difference:** the voltage difference in potential between two points in a circuit
  - For a repulsive force electrical potential energy increases as the charges move closer to each other.
  - The *volt,* V, is equivalent to one joule per coulomb (1 J/C).
  - Potential difference is often called *voltage.*

Electrical Potential Energy and Relative Position



Visual Concept: Electrical Potential Energy

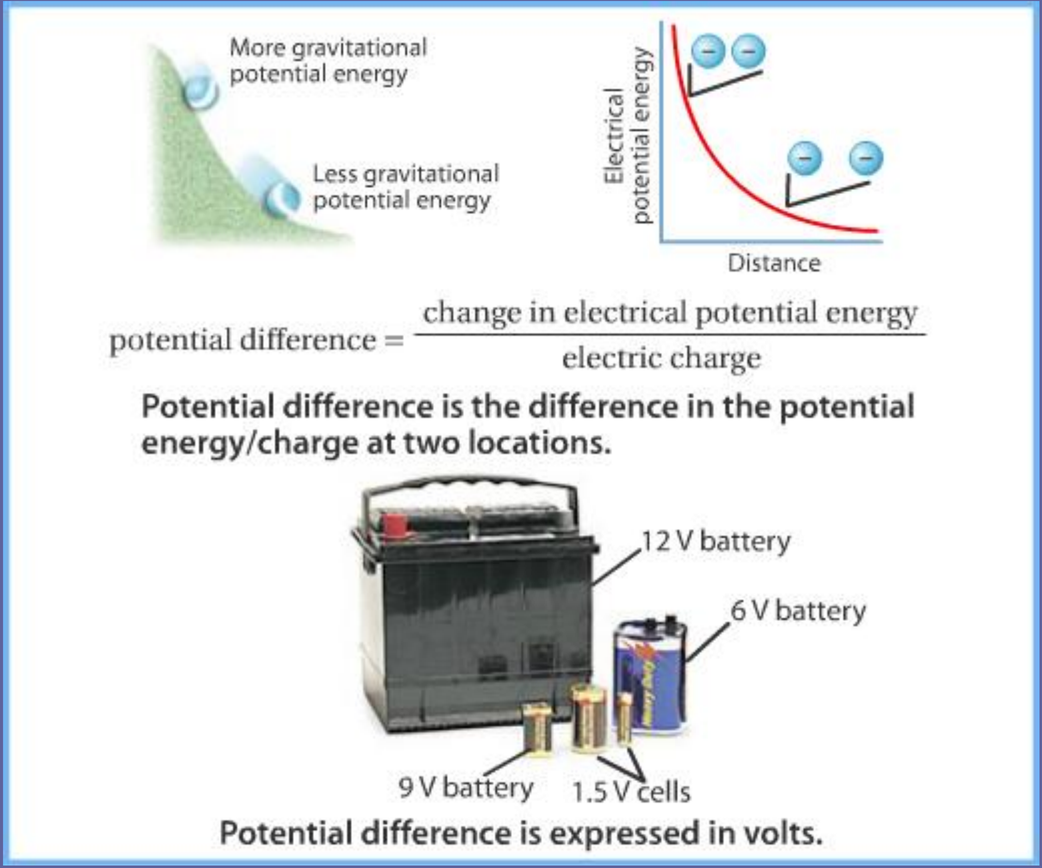
Electrical potential energy for a pair of charges

$$PE_{electric} = k_C \frac{q_1 q_2}{r}$$

$$\text{electrical potential energy} = \text{Coulomb constant} \times \frac{\text{charge 1} \times \text{charge 2}}{\text{distance}}$$

Play

Visual Concept: Potential Difference

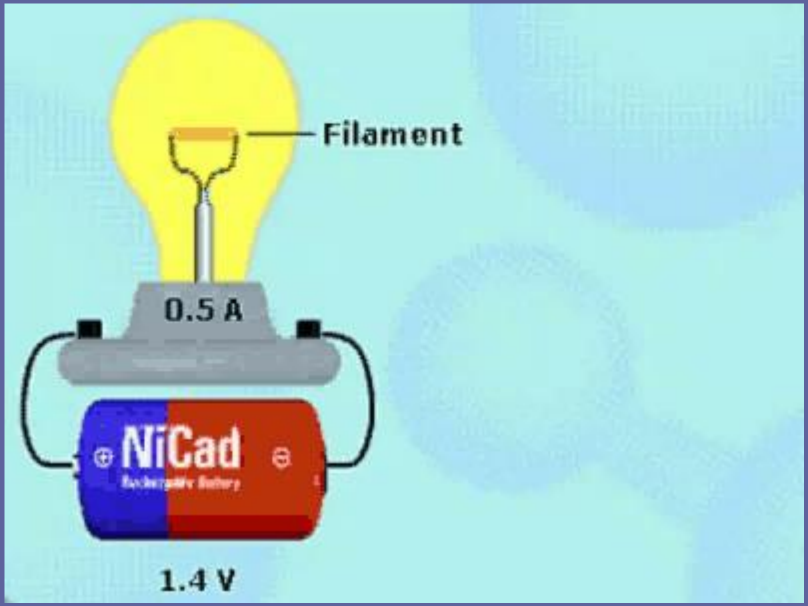


Visual Concept: Voltage

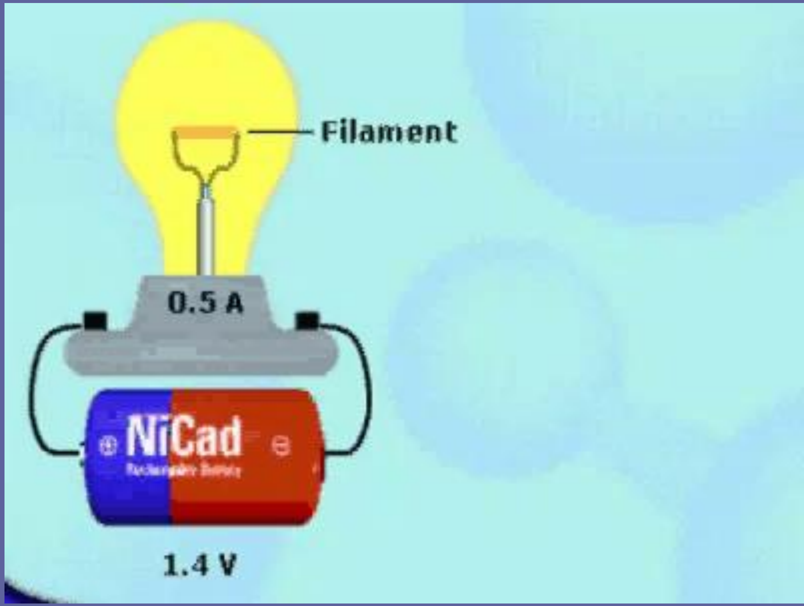
Voltage and Current, *continued*

- There is a voltage across the terminals of a battery.
  - **cell:** a device that produces an electric current by converting chemical or radiant energy into electrical energy
  - One terminal, or end, is positive, and the other is negative.
  - Batteries convert chemical energy into electrical energy.

Battery



Electric Cell



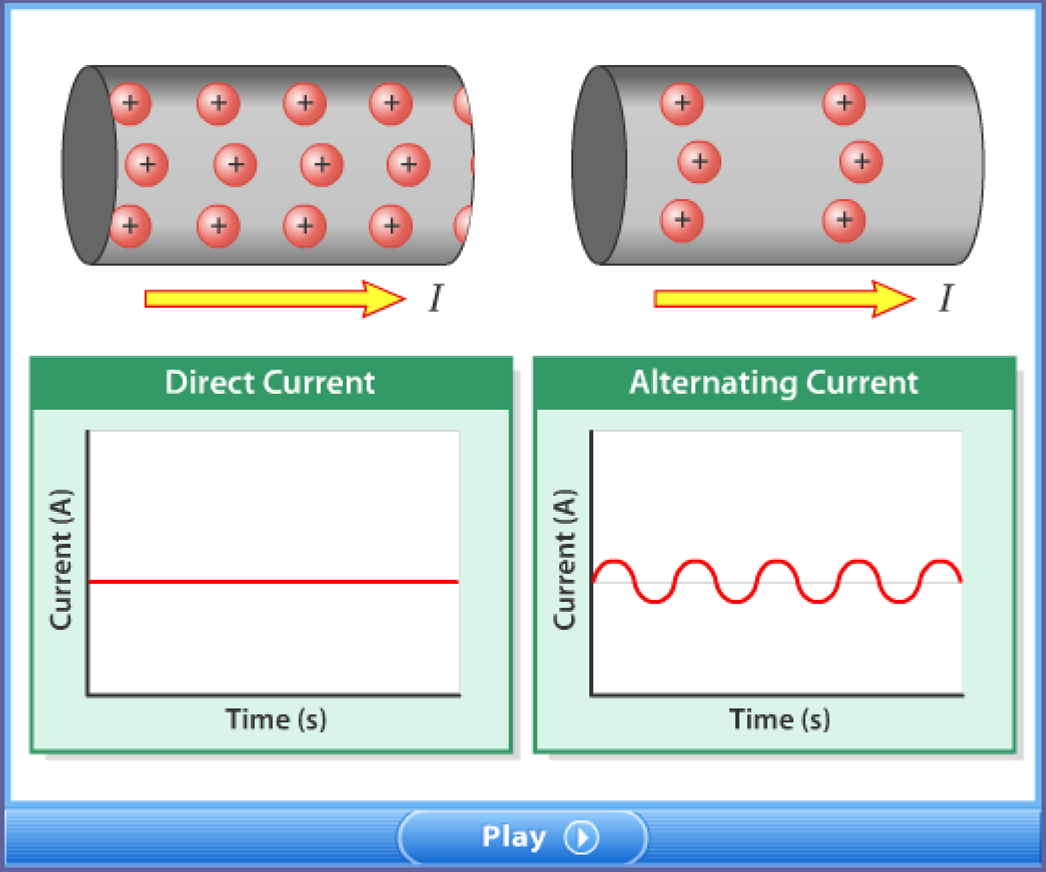
Voltage and Current, *continued*

- A voltage sets charges in motion.
- Current is the rate of charge movement.
  - **electric current:** the rate at which charges pass through a given point
  - The SI unit of current is the *ampere,* A.
    - 1 amp = 1 C/s

Voltage and Current, *continued*

- In a *direct current* source the charges always move from one terminal to the other in the same direction.
  - example: battery
- *Conventional current* is the current made of positive charge that would have the same effect as the actual motion of charge in the material.
  - The direction of current is *opposite* to the direction that electrons move.

Visual Concept: Comparing Direct and Alternating Current



Visual Concept: Conventional Current

Conventional Current

	First case	Second case	Third case
Motion of charge carriers			
Equivalent conventional current			

Play

Electrical Resistance

- What causes electrical resistance?

- Resistance is caused by internal friction, which slows the movement of charges through a conducting material.

- **resistance:** the opposition presented to the current by a material or device

Electrical Resistance, *continued*

- Resistance can be calculated if current and voltage are known.
  - A conductor's resistance indicates how much the motion of charges within it is resisted because of collisions of electrons with atoms.
  - *Ohms' law:*

$$resistance = \frac{voltage}{current} \qquad R = \frac{V}{I}$$

  - The SI unit of resistance is the *ohm* (Ω).
    - 1 Ω = 1 V/A
- A *resistor* is a special type of conductor used to control current.

Math Skills

Resistance

The headlights of a typical car are powered by a 12 V battery. What is the resistance of the headlights if they draw 3.0 A of current when turned on?

1. List the given and unknown values.

Given: *current, I* = 3.0 A

voltage, V = 12 V

Unknown: *resistance, R* = ? Ω

Math Skills, *continued*

2. Write the equation for resistance.

$$resistance = \frac{voltage}{current} \qquad R = \frac{V}{I}$$

3. **Insert the known values into the equation, and solve.**

$$R = \frac{V}{I} = \frac{12\ \text{V}}{3.0\ \text{A}}$$

$$\boxed{R = 4.0\ \Omega}$$

Electrical Resistance, *continued*

- Conductors have low resistances.
- Insulators have high resistances.
- Semiconductors conduct under certain conditions.
  - *semiconductors:* materials that have electrical properties between those of insulators and conductors
- Some materials can become superconductors.
  - Some metals and compounds have zero resistance when their temperature falls below the *critical temperature.*
  - Once a current is established in a superconductor, the current continues even if the applied voltage is removed.

Section 3: Circuits

Preview

Key Ideas

- What is a closed circuit?
- What are the two ways that devices can be connected in a circuit?
- What happens to the energy that charges have in a circuit?
- Why is an overloaded circuit dangerous?

Bellringer

1. Inexpensive electrical power is essential. List at least ten electrical devices that you have used today.
2. In some strings of Christmas lights, none of the lights work if one light is burned out. What is a possible explanation for this?
3. A big feast is being prepared in a home. The cooks are using a turkey roaster, the oven, an electric mixer, a blender, and a toaster. Every light is on and so is the refrigerator. All at once the power in the kitchen goes out. What is an explanation for this, and how can it be corrected?

What Are Circuits?

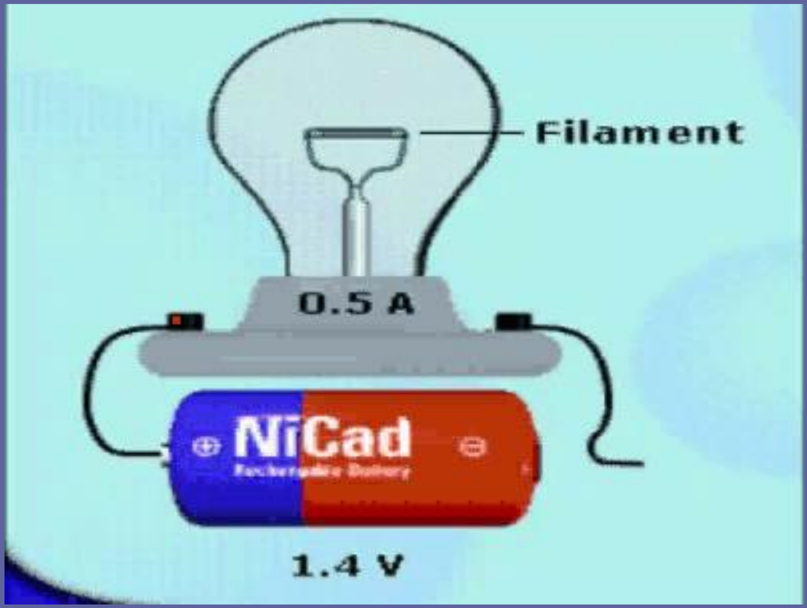
- What is a closed circuit?
- The conducting path produced when a load, such as a string of light bulbs, is connected across a source of voltage is called a *closed circuit.*

- **electric circuit:** a set of electrical components connected such that they provide one or more complete paths for the movement of charges

What Are Circuits?, *continued*

- The voltage source, whether a battery or an outlet, is always part of the conducting path of a closed circuit.
- Without a complete path and a source of voltage, there is no charge flow and therefore no current.
  - This is called an *open circuit.*

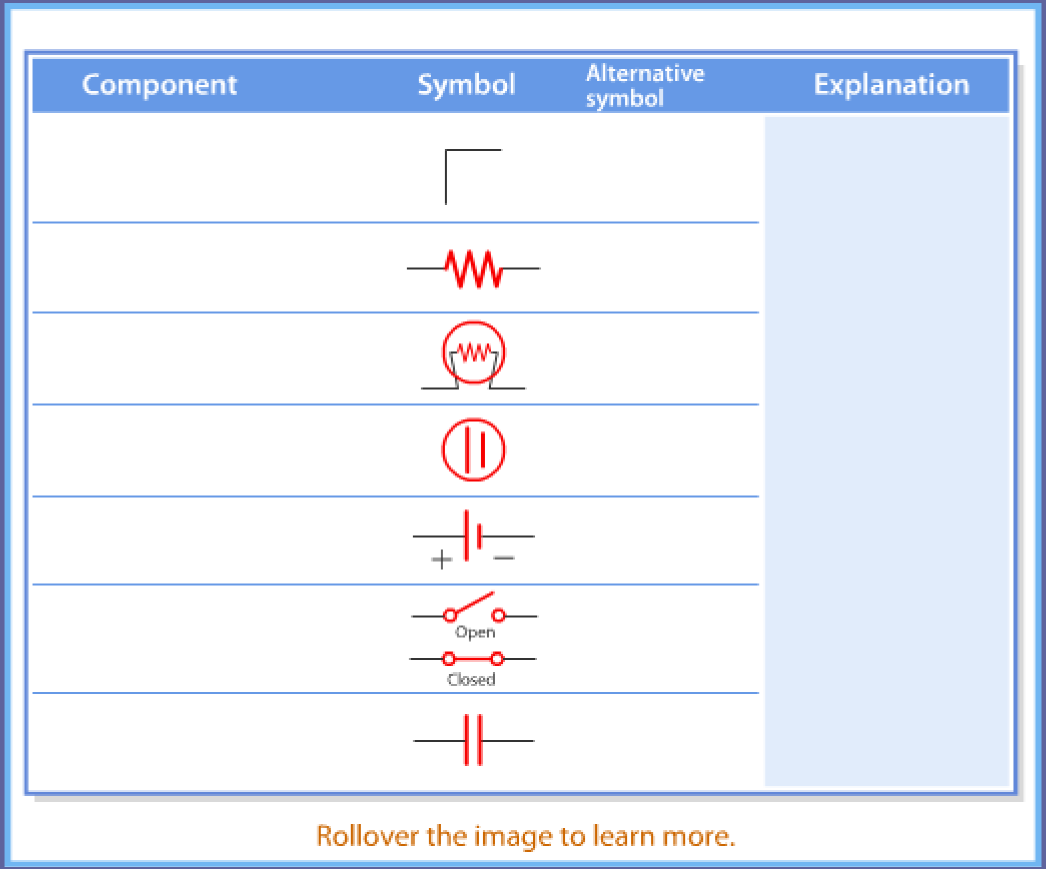
Electric Circuit



What Are Circuits?, *continued*

- Switches interrupt the flow of charges in a circuit.
  - You can use a switch to open and close a circuit.
- Schematic diagrams are used to represent circuits.
  - **schematic diagram:** a graphical representation of a circuit that uses lines to represent wires and different symbols to represent components
  - All electrical devices can be described by schematic diagrams.
  - Schematic diagrams use standard symbols.

Visual Concept: Schematic Diagram and Common Symbols



Series and Parallel Circuits

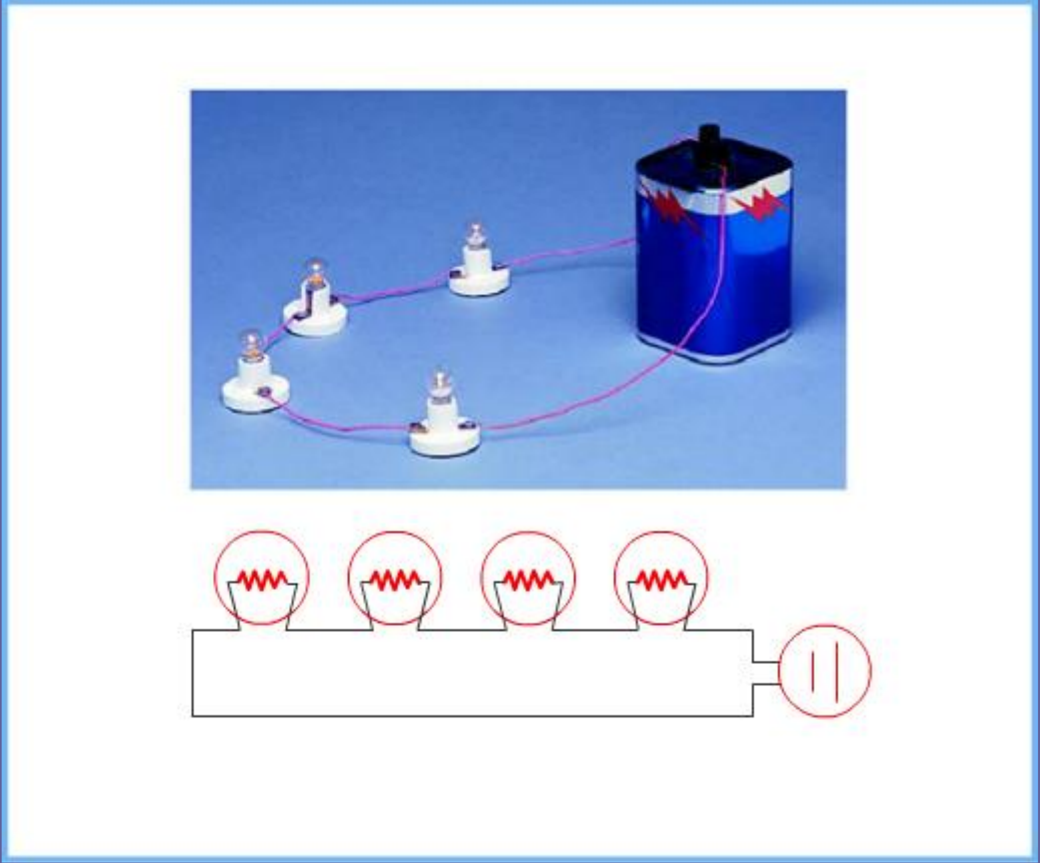
- What are the two ways that devices can be connected in a circuit?
- Electrical devices can be connected as a series circuit so that the voltage is divided among the devices. They can also be connected as a parallel circuit so that the voltage is the same across each device.

- **series circuit:** a circuit in which the parts are joined one after another such that the current in each part is the same
- **parallel circuit:** a circuit in which the parts are joined in branches such that the potential difference across each part is the same

Series and Parallel Circuits, *continued*

- Series circuits have a single path for current.
  - When appliances or other devices are connected in a series circuit, they form a single pathway for charges to flow.
  - The current in each device is the same.
  - The resistances may be different.
    - The voltage across each device in a series circuit can be different.
  - If one element along the path in a series circuit is removed, the circuit will not work.

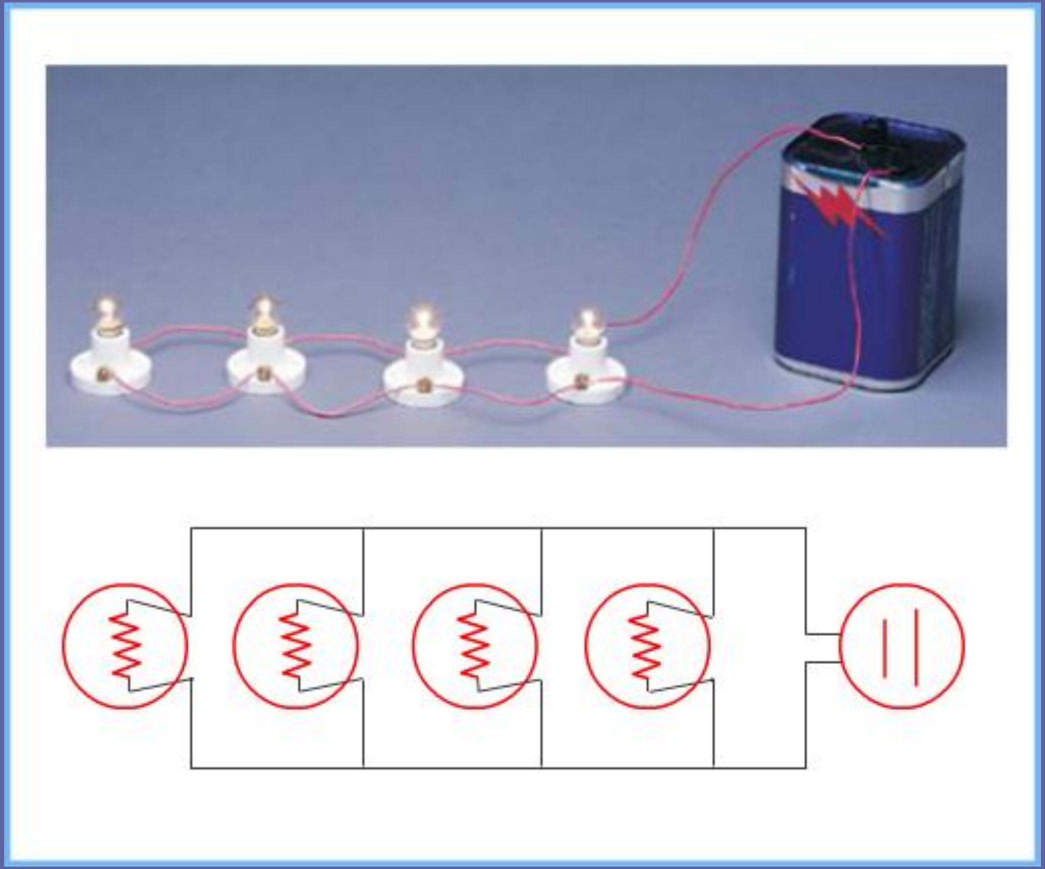
Visual Concept: Resistors in Series



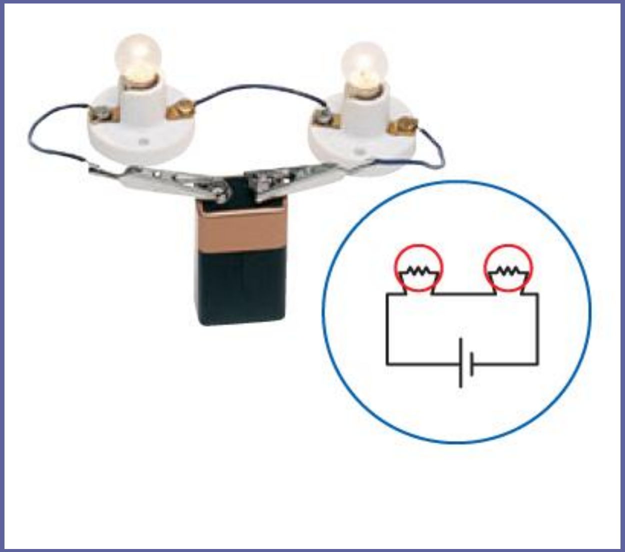
Series and Parallel Circuits, *continued*

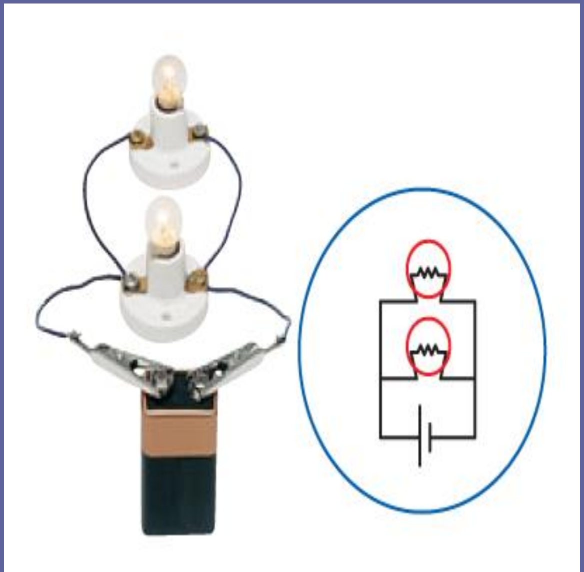
- Parallel circuits have multiple paths for current.
  - The voltage across each device is the same.
  - The current in each device does not have to be the same.
    - The sum of the currents in all of the devices equals the total current.
  - A break in any one path in a parallel circuit does not interrupt the flow of electric charge in the other paths.

Visual Concept: Resistors in Parallel



Series and Parallel





When light bulbs are connected in series, charges must pass through both light bulbs to complete the circuit.

When light bulbs are connected in parallel, charges have more than one path to follow. The circuit can be complete even if one light bulb burns out.

Electric Power and Electrical Energy

- What happens to the energy that charges have in a circuit?
- Some of this energy is transformed into useful work, such as the turning of a motor, and some is lost as heat.

- **electrical power:** the rate at which electrical energy is converted into other forms of energy

Electric Power and Electrical Energy, *continued*

- Electric power is calculated by multiplying the total current, *I*, by the voltage, *V*, in a circuit.

$$power = current \times voltage$$

$$P = IV$$

- The SI unit for power is the watt (W).
- 1 W = 1 A × 1 V

Electric Power and Electrical Energy, *continued*

- If you combine the electric power equation with the resistance equation, *V* = *IR,* you can calculate the power lost, or *dissipated,* by a resistor.

$$P = I^2R = \frac{V^2}{R}$$

- Electric companies measure energy in kilowatt-hours.
  - One kilowatt-hour is the energy delivered in 1 h at the rate of 1 kW.
    - 1 kW•h = 3.6×10^6 J

Equation for Electric Power

$$P = I\Delta V$$

electric power = current x potential difference

Play

Math Skills

Electric Power

When a hair dryer is plugged into a 120 V outlet, the hair dryer has a 9.1 A current in it. What is the hair dryer's power rating?

1.List the given and unknown values.

Given: *voltage, V* = 120 V

current, I = 9.1 A

Unknown: *electric power, P* = ? W

Math Skills, *continued*

2. **Write the equation for electric power.**

$$power = current \times voltage$$

$$P = IV$$

3. **Insert the known values into the equation, and solve.**

$$P = (9.1\ \text{A})(120\ \text{V})$$

$$\boxed{P = 1.1 \times 10^3\ \text{W}}$$

Fuses and Circuit Breakers

- Why is an overloaded circuit dangerous?

- The high currents in overloaded circuits can cause fires.

- When electrical wires carry more than a safe level of current, the circuit is said to be *overloaded.*

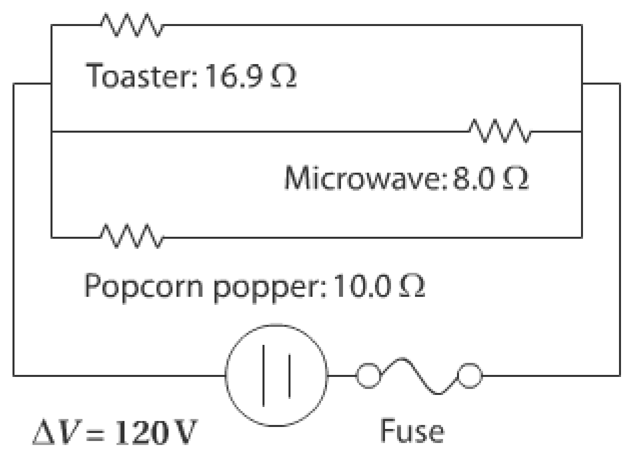
Fuses and Circuit Breakers

- If a wire's insulation wears down, two wires may touch and create an alternative pathway for current, or a *short circuit.*
- Fuses melt to prevent circuit overloads.
  - **fuse:** an electrical device that contains a metal strip that melts when current in the circuit becomes too great

Fuses and Circuit Breakers

- Circuit breakers open circuits with high current.
  - **circuit breaker:** a switch that opens a circuit automatically when the current exceeds a certain value
  - The circuit breaker acts as a switch.
  - Unlike fuses, circuit breakers can be reset by turning the switch back on.

Visual Concept: Fuse



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