Electricity

(Chapter 8)

Student Learning Outcome: Recall properties of charge, recall properties of electricity, and analyze properties of series and parallel circuits.

1. *How do objects become charged?*
1. *How are quantities related in the electric force?*
2. *What is an electric field?*
3. *How is electric potential related to voltage?*
4. *What are the properties of circuits?*

How do objects become charged?

- All matter is composed of atoms which are made up of electrons, protons and neutrons.

	electron	proton	neutron
Charge	**− 1**	**+ 1**	**0**
Mass	9.1×10^{-31} kg	1.67×10^{-27} kg	1.67×10^{-27} kg

Go To: http://www.pond5.com/stock-footage/68580/atom5.html

Question: Why do the electrons stay in orbit around the nucleus?

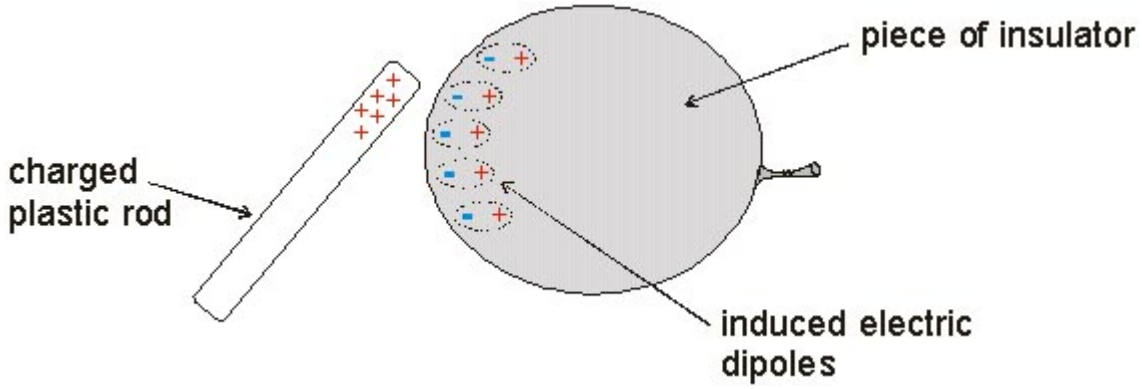
- Neutral atoms have the same number of electrons and protons.
- Objects become charged when they lose or gain electrons.
  - A charged atom is an **ion**.
  - A charged object is **ionized**.

Question: Does an object that has lost electrons have a positive or negative charge? Does it have more or less mass?

- When charges interact they repel or attract each other.

Opposite charges → attract
Like charges → repel

- **Friction charges objects.** Friction causes electrons to be "knocked loose" and transferred from one object to another.
  - Some materials give up electrons easily. (Hair)
  - Some materials have a tendency to accept electrons. (Plastics)
- **Contact charges objects.** Contact allows electrons to be transferred from one object to another.
- **Induction, or polarization, temporarily charges objects.** Charge rearranges itself within an object.



http://www.saburchill.com/physics/chapters/0027.html

- **Law of conservation of charge:** The total amount of electric charge in the universe remains constant. Charge can be transferred or may be broken into smaller units of charge; however, charge is never created or destroyed.

Question: If 10,000 electrons are transferred from your hair to your comb, what is the net charge on your hair? Assume the system is isolated.

- **A net electric charge on an object results in static electricity.**

Examples: Cars, Clothes, & Fabric Softener

Questions:

1. Static electricity on clothes and us is less common on humid days. Why?

2. Why does a plastic slide retain static charge while a metal slide does not?

How are quantities related in the electric force?

- **Coulomb's Law**: the force between charges is directly proportional to the magnitude of each charge and inversely proportional to the square of the distance between the charges.

$$F = \frac{k(q_1)(q_2)}{d^2}$$

- Charges q_1 and q_2 exert forces on each other that are equal in magnitude and opposite in direction.

- The unit of charge is the **Coulomb (C)**.

- The magnitude of charge for one electron *or* one proton is **1.6×10^{-19} C**.

Questions:

1. What is the electric force between the electron and the proton in a hydrogen atom? The average separation between the electron and proton is 5.29×10^{-11} m.

2. After rubbing a balloon on your hair, the balloon has gained 2000 electrons. What is the force between your hair and the balloon if the balloon is 5 cm above your hair?

- The electric force and the gravitational force are both inverse square laws, and both apply mutual forces between two quantities.

$$F = \frac{kq_1q_2}{d^2} \qquad F = \frac{GmM}{d^2}$$

Question: What is the gravitational force between the electron and the proton in a hydrogen atom? The average separation between the electron and proton is 5.29×10^{-11} m.

- The primary difference is the strength of these natural forces.

Electric Force	Gravitational Force
Attract & Repel	**Attract**
Relatively Strong	**Relatively Weak**

What is an electric field?

- An electric field determines the path along which a positive test charge would travel.
  - Every charged object is surrounded by an electric field.
  - Charge modifies the space around itself.

Question: What happens to the electric fields of two objects that are brought together?

Go To: http://www.britannica.com/EBchecked/media/1317/Electric-fields
http://www.physicsclassroom.com/class/estatics/u8l4c.cfm

How is electric potential related to voltage?

- Electric potential is the ratio of electric potential energy per charge.
- Two different electric potentials set up an electric field, which causes existing electrons to flow.

Potential Difference → E Field → Current

- Charges flow from the higher potential to the lower potential.
- EPE is converted into KE as charge is accelerated through the system.
- **Electrons do not come from the wall outlet into your house!** The E Field causes electrons within the system to move.
- **Voltage = Amount of Potential Difference**

$$\text{PD} = \text{Volts} = \frac{\text{Joules}}{\text{Coulomb}}$$

Examples: Wall Outlets, Batteries, Lightening, "Shock War"

- If there is no difference in electric potential, there is no voltage, and no charge will flow!

Questions:

1. How much electric potential energy does 1 coulomb of charge gain from a 12 volt battery? How much work can 1 coulomb of charge do on a system?

2. Why is a bird able to sit on a wire without being shocked?

What are the properties of circuits?

Questions: What is an electric circuit? What are some examples of electric circuits?

- Voltage causes current to flow through circuits, and circuits have resistance to this flow.

- **Voltage is created by a difference in electric potential.** It is the "Energy" of the system.

- **Electric current is the net movement of electrons**.

$$\text{Amperes} = \frac{\text{Coulombs}}{\text{second}}$$

Question: What does the ampere measure?

  - **ac** is alternating current, which means the current continuously changes or alternates direction (Wall outlet)

  - **dc** is direct current, which means the current flows in only one direction (Battery)

- **Electric resistance is a measure how difficult it is for electrons to travel through an electrical system.**

- The amount of resistance depends on 4 properties.

  1. **Conductivity** of material
  2. **Length** of wire or circuit loop
  3. **Diameter** (or thickness) of wire
  4. **Temperature** or wire or circuit loop

❖ **<u>Ohm's Law</u>: Current is directly proportional to the voltage supplied and inversely related to the resistance in the system.**

$$I = \frac{V}{R}$$

❖ The requirements for electric current to flow through a circuit are:

1. Closed circuit loop
2. Potential difference

<u>Questions</u>:

1. A flashlight uses a 1.5 volt battery and has a resistance of 2 ohms. What is the current within the flashlight circuit?

2. A person with dry skin has a maximum resistance of 500,000 Ω. If this person touches the metal prongs of a plug as it is inserted into a 110 volt wall outlet, how much current will pass through the person's body? Is this dangerous? What if the person's skin is moist (R = 1000 Ω)?

0.001 A	**Noticeable**
0.005 A	**Painful**
0.010 A	**Muscle spasms**
0.015 A	**Loss of muscle control**
0.070	**Disrupts heartbeat**

<u>Question</u>: Some strands of Christmas tree lights remain lit if one bulb goes out, some do not. Why?

❖ **A <u>series</u> circuit has all pieces of the circuit connected in a single continuous loop. (one path)**

➢ Voltage is divided among each piece in the single loop. (energy shared)

➢ Resistance is additive; it <u>increases</u> with each added piece.

$$R = R_1 + R_2 + \ldots$$

- **A <u>parallel</u> circuit has the pieces of the circuit connected in multiple, parallel loops. (multiple paths)**
  - Voltage is supplied to each parallel loop. (energy <u>not</u> shared)
  - Resistance of the whole circuit <u>decreases</u> as pieces are added!

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

- Part of the path through current must flow is through the devices.
- **Electrical switches break a circuit loop.**
  - They are connected in series to your household circuits.
  - They open when too much current is drawn.

<u>Questions</u>: Why is too much current in a wire dangerous?

- **Electrical power is the rate at which electrical energy is used.**

$$\boxed{P = IV}$$

<u>Questions</u>:

1. What is the resistance of a standard 60 Watt light bulb? V = 110

2. How much does it cost if you leave a standard 60 Watt light bulb on for 5 hours, and the average rate is 22¢ per kWh?

3. A 2000 Watt hair dryer, a 100 Watt radio, and five 60 Watt light bulbs are being used simultaneously. V = 110

   a. How much total current is drawn by this system?
   b. The safety switch will open at 12 A. Can all of these devices be operated at the same time?