Electric Charge

- Electric Charge: property that causes subatomic particles to attract or repel
  - 2 Types: positive and negative
  - Review:
    - Protons are positive
    - Electrons are negative
  - Net charge is caused by an excess or shortage of electrons
- Charge is conserved – the total number of protons equals the total number of electrons

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Electric Force

- Like charges REPEL
- Unlike charges ATTRACT
- Coulomb's Law describes Electric Force
  - Electric force is directly proportional to each of the net charges on the two objects
  - Electric force is inversely proportional to the square of the distance between the two objects

$$F_{electric} = k_C \frac{q_1 q_2}{r^2}$$

where

k_C = Coulomb's Constant,

q_1 = charge on object 1,

q_2 = charge on object 2, and

r = distance between the two objects

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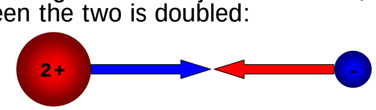
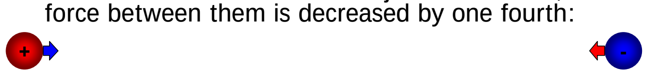
Electric Force (cont'd)

- Opposite charges attract: (The arrows represent the force.)

- If the charge on one object is doubled, the force between the two is doubled:



- If the distance between the objects is doubled, the force between them is decreased by one fourth:



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Electric Fields

- Any charged object has an electric field around it.
- The ***electric field*** is the effect a charge has on other charges in the space around it.
- The field exerts an electric force on any charged object placed in the field.

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Static Electricity

- ***Static electricity***: study of the behavior of electric charges
- Charges are transferred by ***friction***, ***contact*** or ***induction***.
- ***Law of conservation of charge***: the total charge in an isolated system is constant.

How do objects become charged?

- Objects become charged when *electrons move from one object to another*
- ***Charging by Friction***
  - One object transfers electrons to another as they are rubbed together
- ***Charging by Contact***
  - One object gains electrons by contacting (touching) another charged object
- ***Charging by Induction***
  - Charges separate to different parts of a conducting object because another charged object is brought near

Static Discharge

- Static discharge occurs when a pathway through which charges can move forms ***suddenly***.
- Example: Lightning

Electric Current

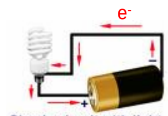
- ***Electric Current:*** continuous flow of electric charge
- Symbol: I
- SI Unit: Ampere (A)
- Two types:
  - Direct Current (DC) – charge flows only one direction
  - Alternating Current – flow of electric charge that regularly reverses direction

Conductors, Insulators and Semiconductors

- Conductors
  - Materials through which charge flows easily
  - Examples: most metals
- Insulators
  - Materials through which charge does NOT flow easily
  - Examples: wood, rubber, plastic and air
- Semiconductors
  - Insulators in their pure state
  - Become good conductors when impurities are added in a controlled way

Electric Circuits

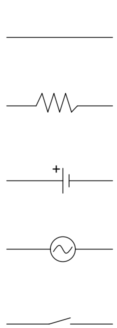
- ***Electric circuit:*** a complete path through which charge (current) can flow
  - Example: a battery powering a light



Simple circuit with light
http://www.energyquest.ca.gov/story/chapter04.html

- ***Circuit diagram:*** uses symbols to represent parts of a circuit

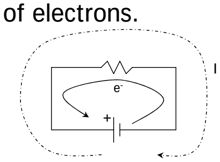
Circuit Diagram Symbols



- Wire
- Resistor (light bulb)
- Battery (DC voltage source)
- AC voltage source
- Switch

More on Electric Current

- Current flows in the OPPOSITE direction to the flow of electrons.



Key:
Direction of electron flow
Direction of current flow

- Batteries provide direct current to a circuit (DC voltage source).
- The outlets in your house usually provide alternating current (AC voltage source).

Resistance

- ***Resistance:*** a material's opposition to flow of charge
  - Materials "resist" the flow of charge because electrons that are moving through the material interact with other electrons and nuclei, which slows them down.
  - Symbol of resistance: R
  - SI Unit: Ohm (Ω)

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Factors Affecting Resistance

- Thickness (or diameter)
  - More electrons can flow through a thicker material.
  - As thickness (or diameter) increases, resistance decreases.
- Length
  - Electrons have to travel farther in a longer wire, so they encounter more opposition.
  - As length increases, resistance increases.
- Temperature
  - Atoms and electrons move more at higher temperatures, so flowing electrons "collide" more often with other electrons and nuclei at higher temperatures.
  - As temperature increases, resistance increases.

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Voltage

- Charges will not flow without a source of energy. (Think of water – it will not flow if sitting in a flat container. However, if you tilt the container and give it gravitational potential energy, the water will flow.)
- ***Voltage:*** electrical potential energy difference between two points in an electric field
  - Symbol: V
  - SI Unit: Volts (V)

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Voltage Sources

- (Review slide 13)
- Batteries
  - Convert chemical energy to electrical energy
  - DC voltage source
- Wall outlets
  - Transmit electrical energy from source to appliances in our homes and offices
  - AC voltage sources

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Ohm's Law

- Current, voltage and resistance are related in a circuit according to ***Ohm's Law:***

$$V = I \times R$$

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

- If the resistance stays the same, what happens if the voltage increases?
  - The current increases.
- If the voltage stays the same, what happens if the resistance increases?
  - The current goes down.

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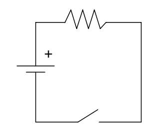
Open Circuit

- ***Open circuit:*** circuit in which a switch is open – a complete loop is NOT made, and current cannot flow



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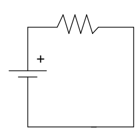
Closed Circuit

- ***Closed circuit:*** circuit in which a switch is closed – a complete loop is made and current flows



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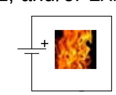
Short Circuit

- ***Short circuit:*** a circuit with abnormally low resistance
  - Example: two ends of a battery connected with a wire only and no resistor (light bulb or other device)
  - BIG DANGER – short circuits can result in CIRCUIT DAMAGE, OVERHEATING, FIRE, and/or EXPLOSIONS

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



If V is constant (like with a battery), and R is very small, then the current, I is going to be VERY LARGE, and it will be more than the battery, wires and/or other connected circuits can handle.

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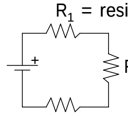
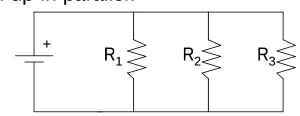
Series Circuits

- Charge has only one path through which to flow
- If one component in a series circuit stops working, they all stop working.
  - It creates an OPEN CIRCUIT.
  - Example: old Christmas tree lights
  - Circuit diagram of 3 resistors powered by a battery and hooked up in series:



Parallel Circuits

- Charge has two or more paths through which to flow
- If one component in a parallel circuit goes out, the others will continue to operate.
  - If one part goes out, there is still one (or more) CLOSED CIRCUIT through other paths.
  - Example: circuits in homes (bathroom vs. kitchen vs. living areas)
  - Circuit diagram of 3 resistors powered by a battery and hooked up in parallel:



Electric Power

- ***Electric power:*** rate at which electric energy is converted to other forms of energy
- SI Unit: Watts
- Electric power is calculated from current and voltage:

$$P = I \times V$$

Electrical Safety

- Safety measures:
  - ***Correct wiring*** (no short circuits, proper diameter wire, etc...)
  - ***Fuses*** (contain a wire that melts if too much current flows through; once the wire melts, it is an OPEN CIRCUIT and the current stops)
  - ***Circuit breakers*** (like a fuse, but has a switch that opens with too much current)
  - ***Insulation*** (prevents people from touching live wires and prevents short circuits)
  - ***Grounded plugs*** (provide an easier path for current to flow than through your body in the event of a short)
  - ***GFCI*** – Ground Fault Circuit Interrupter (opens a circuit if the current flowing to a device doesn't match the current flowing out)