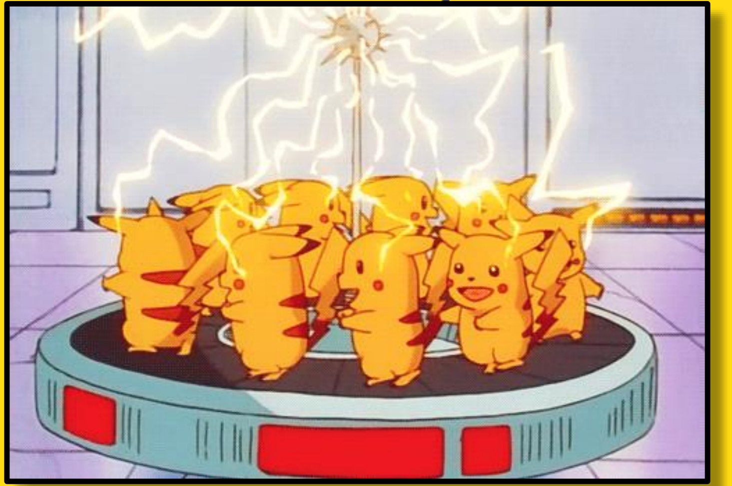


Part 4: Electricity & Magnetism

Notes: Magnetism

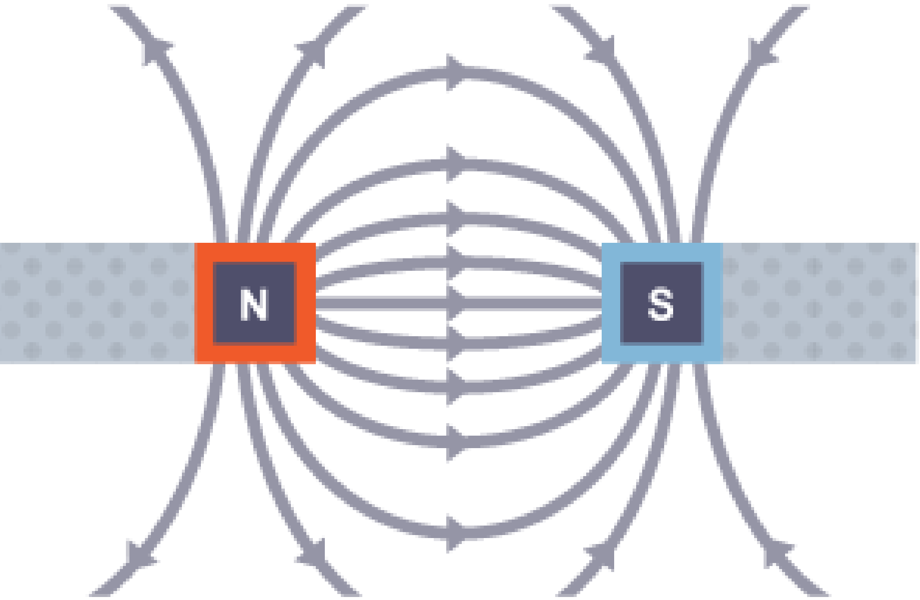
Magnetism

Magnets:

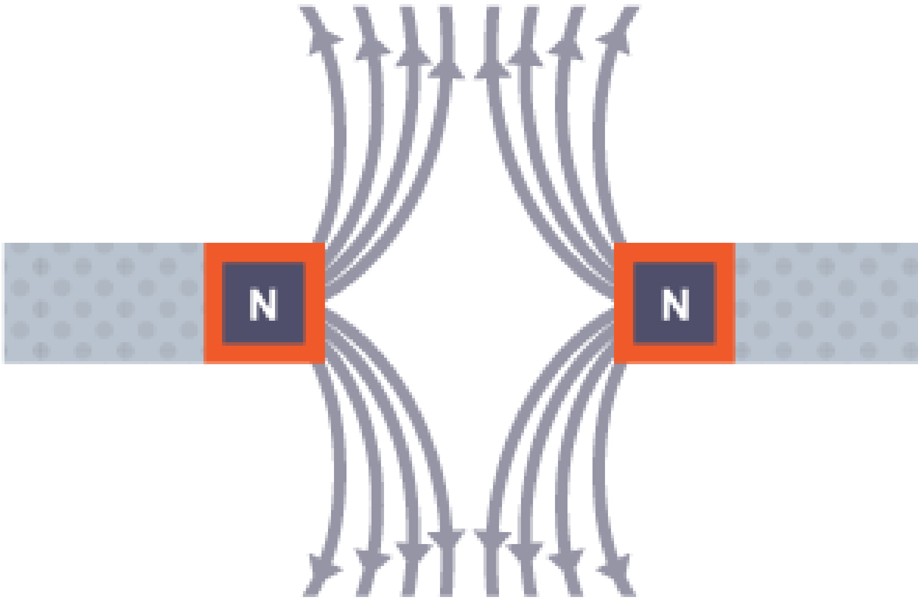
1. Have a **north and south pole**
2. **Like** poles **repel**; **opposite** poles **attract**

   - The larger the distance between the magnets, the weaker the force of attraction or repulsion will be

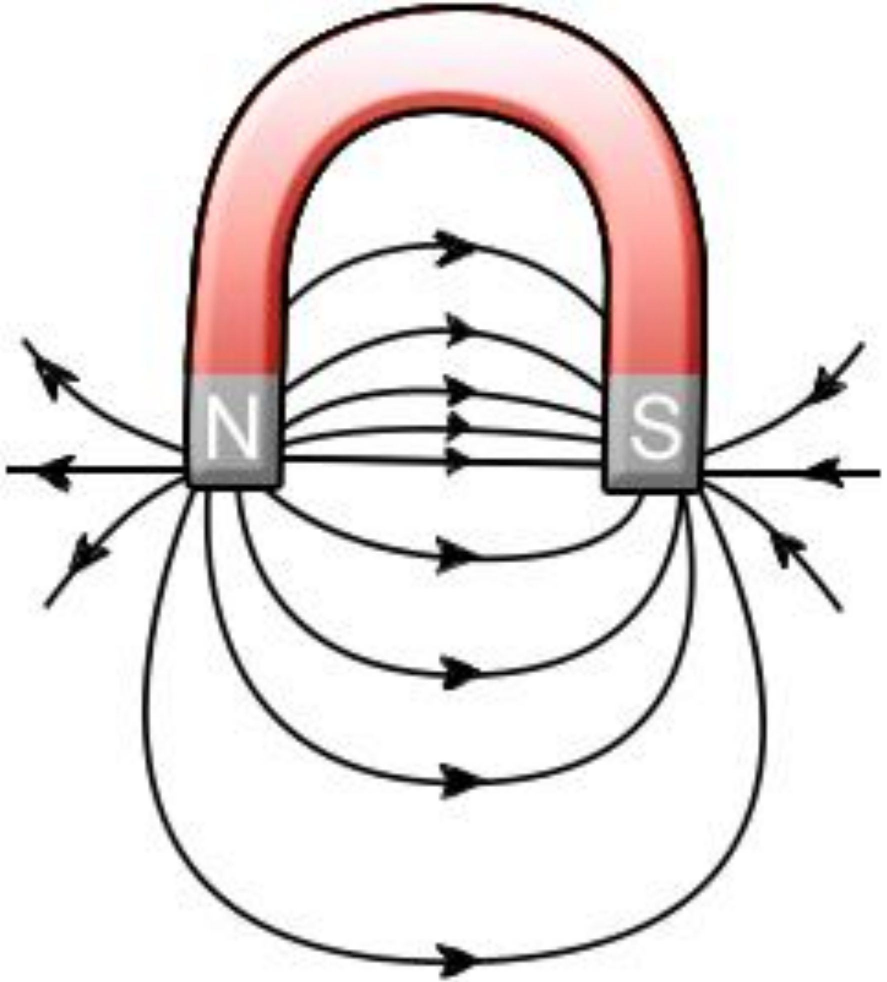
3. If you cut a magnet in half; it will still have a north and south pole



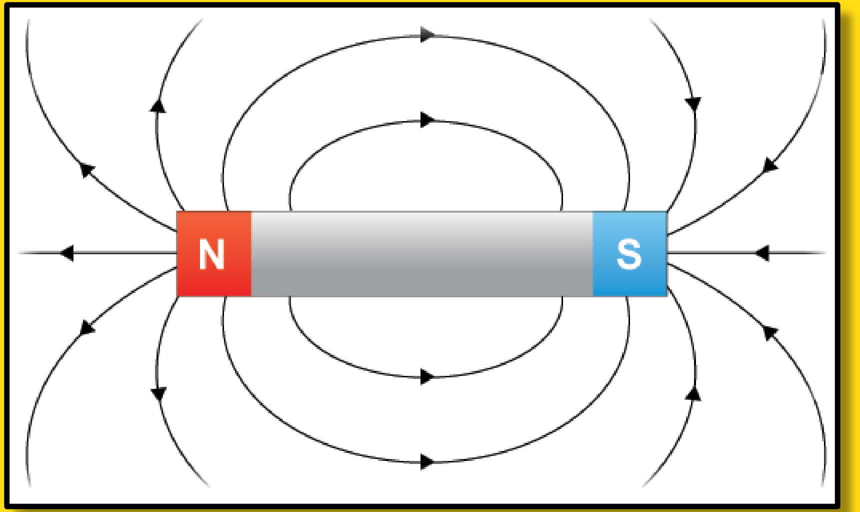
B Unlike pole attraction



C Like pole repulsion


N
S

Magnetism



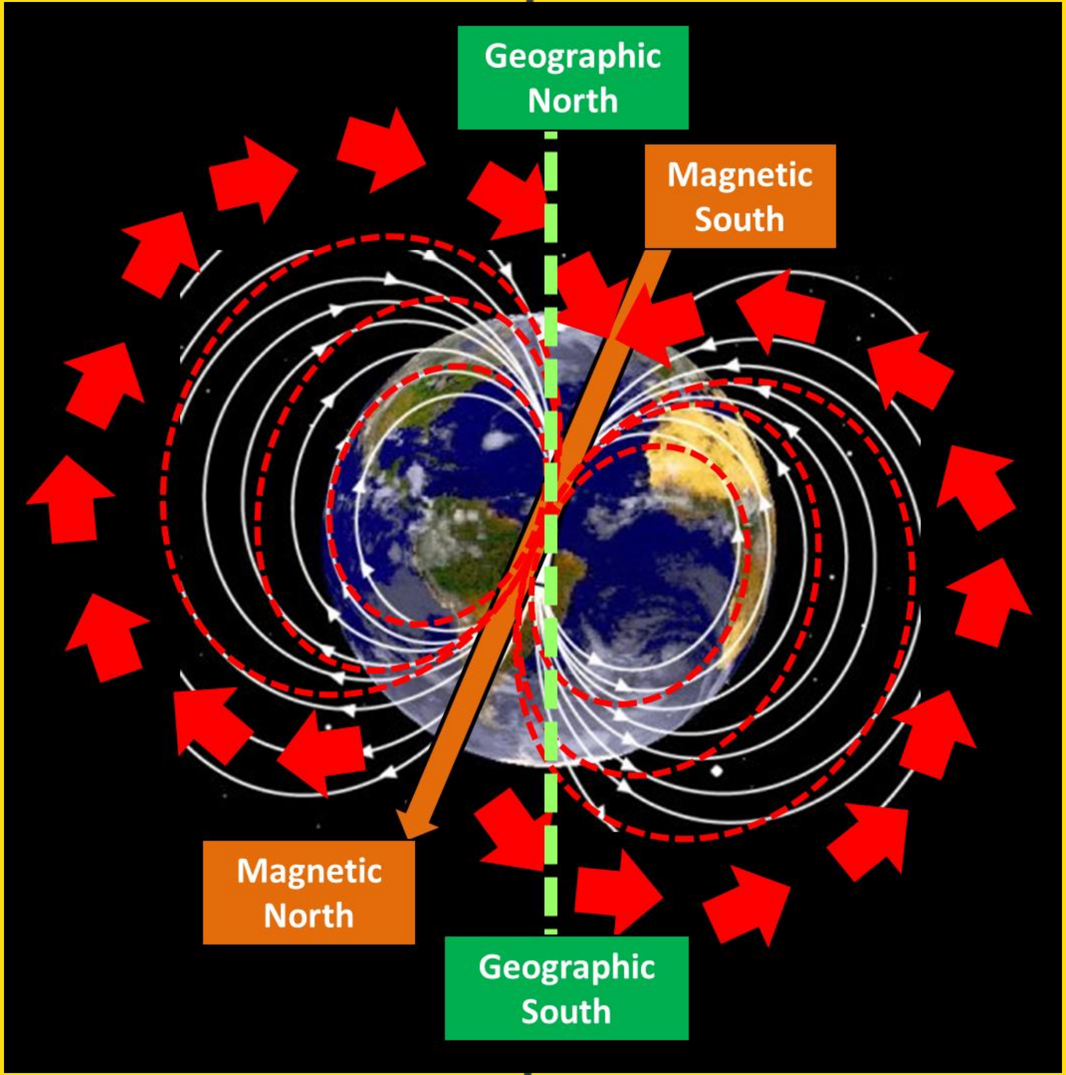
Magnetic fields:

- The area around a magnet where the attraction or repulsion are felt by another magnet
- The field is always **N** → **S**

Magnetism

Earth’s Magnetic field:

- In the Earth’s core there is a bunch of liquid iron and other ferromagnetic substances sloshing around
    - This produces a massive magnetic field around the whole planet


Geographic North
Magnetic South
Magnetic North
Geographic South

Magnetism

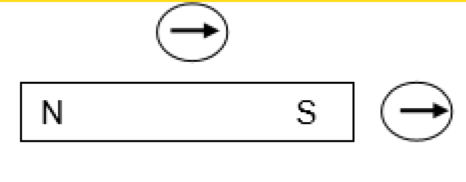
How does a compass work?

- The North arrow on the compass will point to **geographic north** because that is a **magnetic south pole**

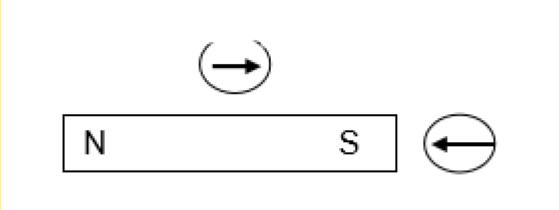
Example

Which of the following correctly illustrates the behavior of a compass in the magnetic field of a bar magnet?

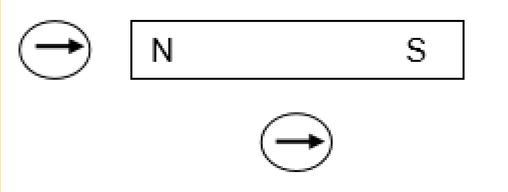
A



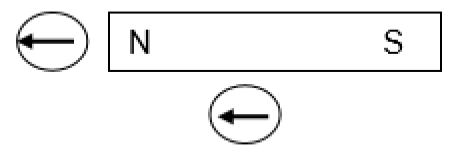
B



C



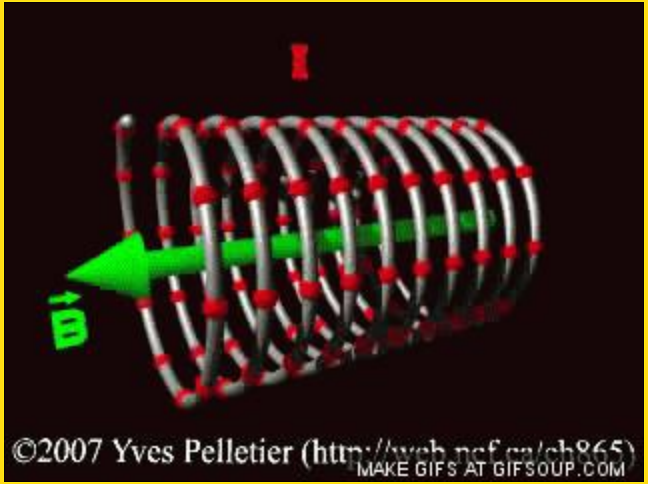
D



Magnetism

Electromagnetism

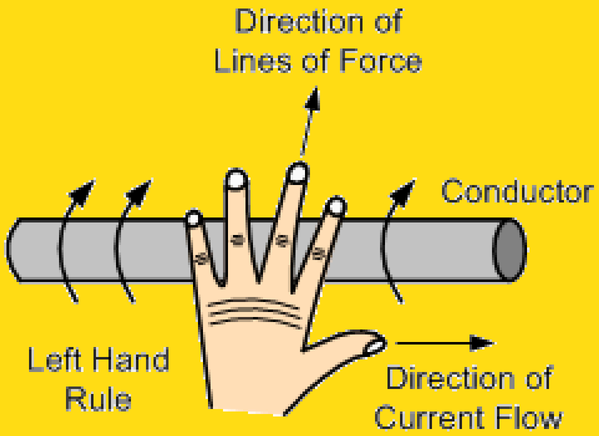
- When current is passed through a wire, a **magnetic field around the wire** is created



Magnetism

Electromagnetism

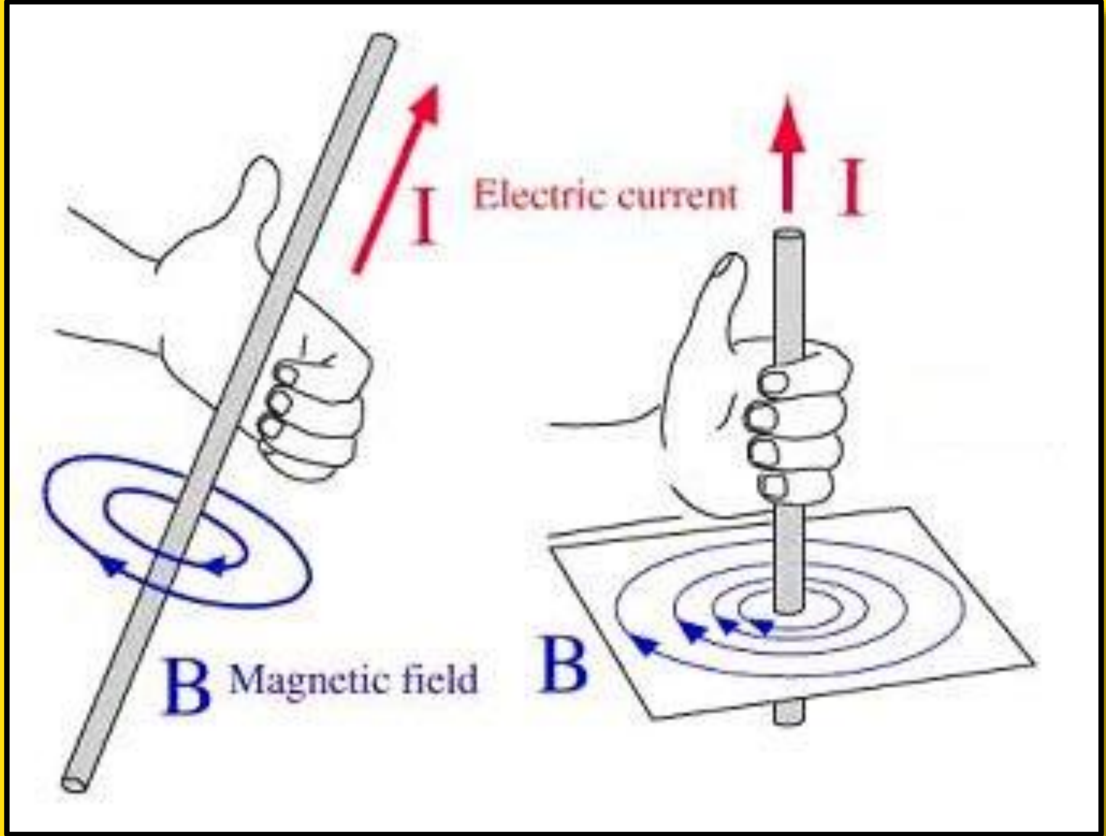
- How do we determine the direction of the magnetic field?
- **Left hand rule!**



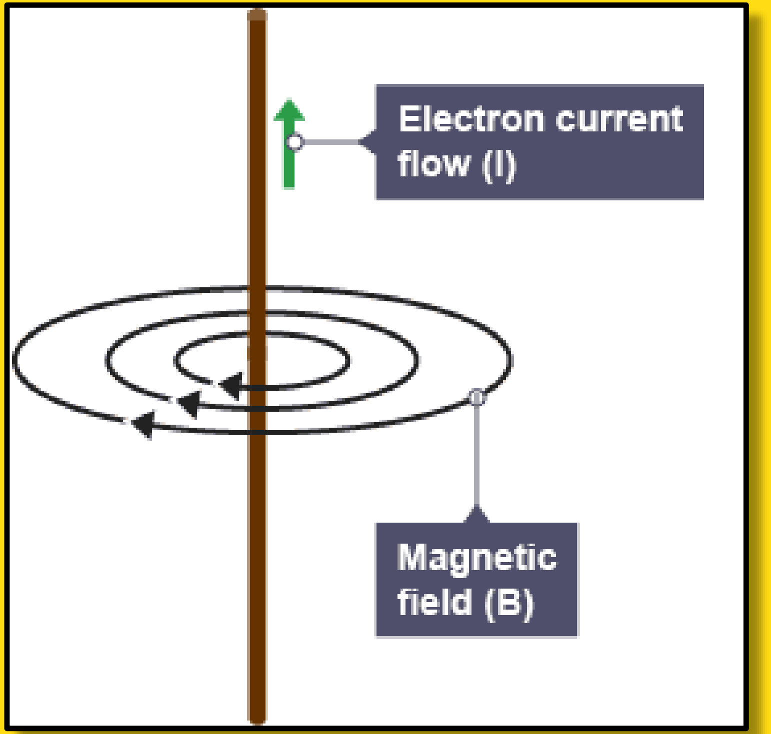
Magnetism

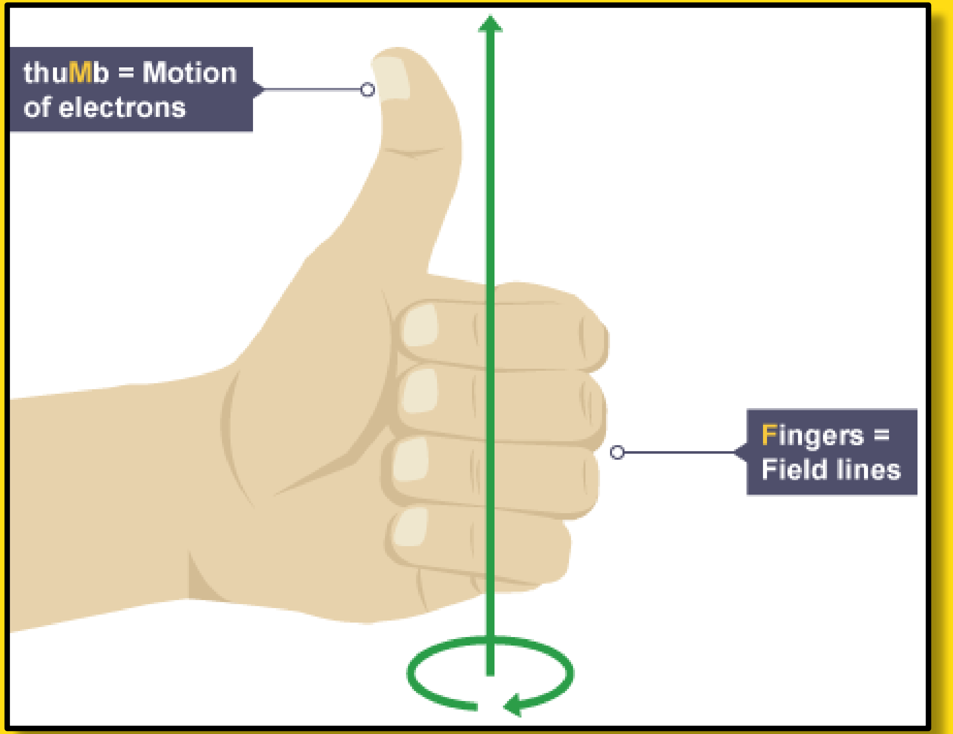
Left Hand Rule

- **Thumb:** in direction of **current** (negative to positive terminal; electron flow)
- **Fingers:** indicate **magnetic field** direction



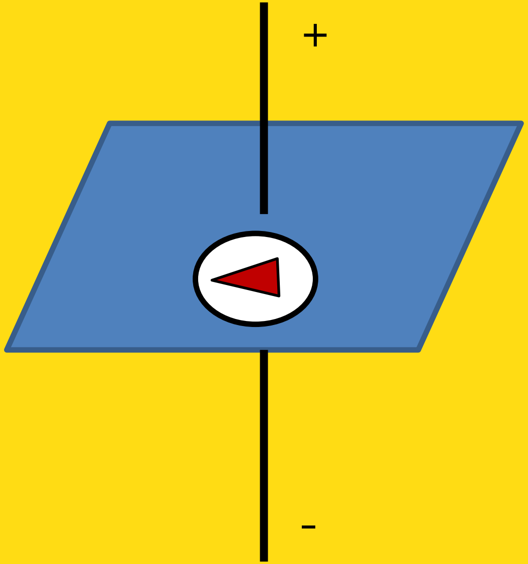
I
Electric current
I
B
Magnetic field
B


Electron current flow (I)
Magnetic field (B)


thuMb = Motion of electrons
Fingers = Field lines

Examples

Which way will the arrow of the compass point?



Notes: Static Electricity

Electricity

Electricity

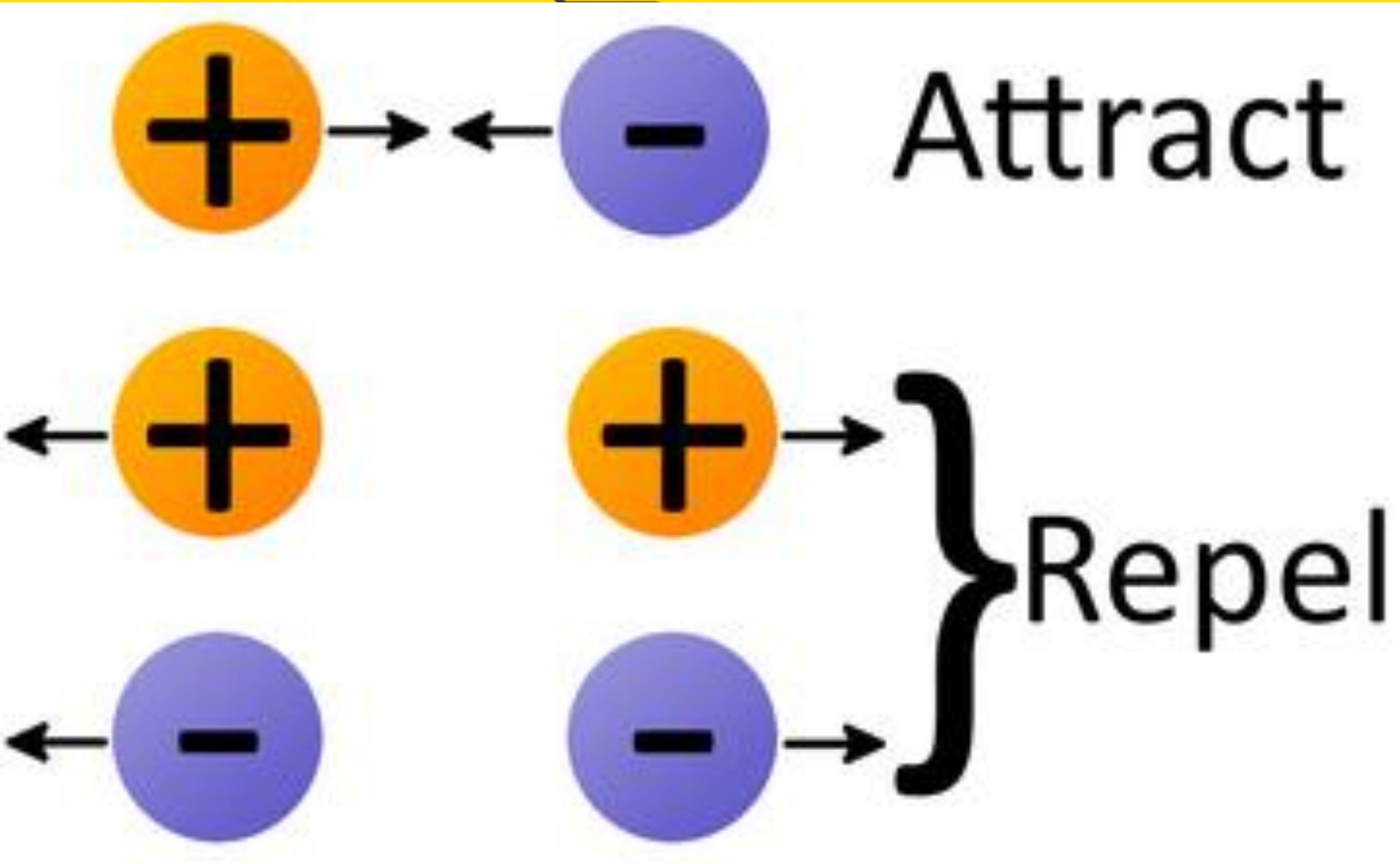
- Phenomena caused by positive and negative charges
    - **Remember:**
        - Protons = + charge
        - Electrons = - charge
        - So if an object has a charge it's because it has an imbalance of protons and electrons

Electricity

Electricity

- Similar to magnets:
  - **Like charges repel**

  - **Opposite charges attract**


Attract
Repel

Electricity

Remember

- Charges are neither created nor destroyed; they are **transferred** from one body to another
- You charge an object by creating an imbalance in the number of positive and negative charges
  - **Only electrons move**!

Electricity

Properties of materials:

- **Conductor:** allows for electrons to flow (*usually metals and electrolytic solutions)*
- **Insulator:** prevents electrons from flowing (*usually non-metals and plastics)*
- **Semi-conductor:** sometimes allows for electrons to flow, depending on the factors (*usually metalloids; carbon and silicon are common semi-conductors)*

Static Electricity

- Electric charges at **REST**
  - The electrons have moved from one substance to another and now are no longer moving
- Charging can happen in different ways:
  - 1) Friction
  - 2) Conduction
  - 3) Induction

Static Electricity

Friction

Two neutral objects are rubbed against each other

One object **takes electrons from the other**

Result:

- Material taking electrons = **becomes negative**
- Material giving up electrons = **becomes positive**

Tendency for materials to give/take electrons → See *triboelectric series*

Static Electricity

Conduction

One charged object **touches** a neutral object

Result:

- Charged object gives half its charge to neutral object
- Both objects now share **the same charge**
- The charge on both **is weaker than the original object's charge**

Static Electricity

Induction

One charged object comes close (but **doesn’t touch**) a neutral object

Result:

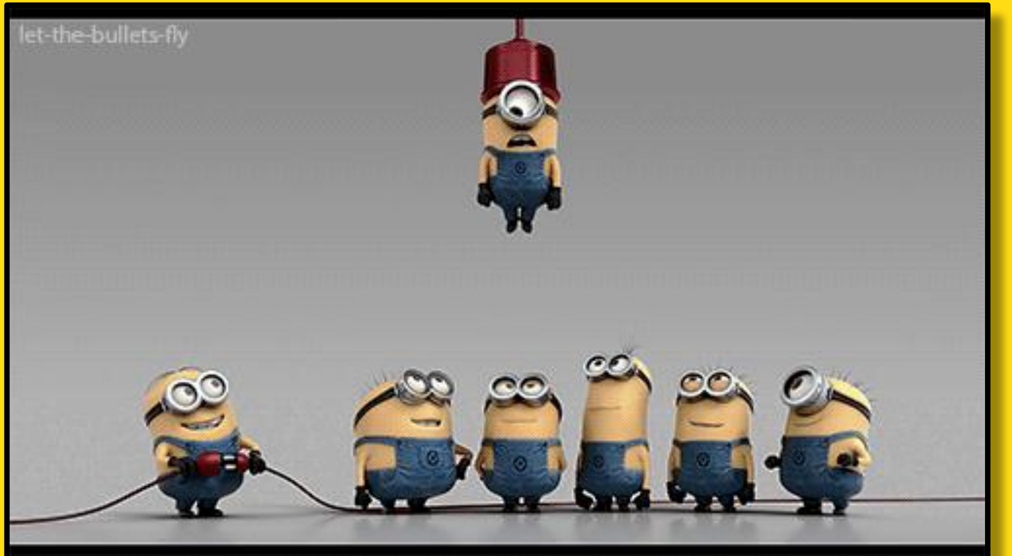
- Charged object causes **charges to re-arrange** in neutral object
- This causes the creation of a positive and negative pole in the “neutral object”
  - Yet, the **net charge is still zero (no charge)**

Method	Before Charging	Charging Process	Result
Friction	Both objects are **neutral**	Objects are **rubbed** on one another	Objects take on **opposite charges** (one is +, other is –)
Conduction	Object "A" is charged Object "B: is neutral	Charged object **touches** neutral object	Objects take on **same charge**, which is **weaker than original charge**.
Induction	Object "A" is charged Object "B: is neutral	Charged object is **brought close** to neutral object	Object "B"'s charges are **re-arranged.** Object "A" stays charged

Examples

Friction? Induction? Conduction?

Notes: Dynamic Electricity



Dynamic Electricity

Dynamic electricity:

- Electricity caused by the **movement of electrons**
  - Like in a circuit

Dynamic Electricity

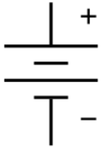
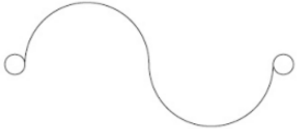
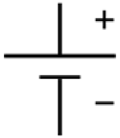
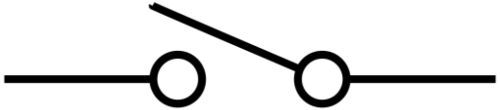
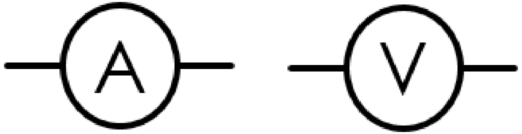
Good conductors:

1. Short
2. Fat
3. Cold
4. Gold/Copper

Dynamic Electricity

Elements of a circuit:

- Power supply
- Wires
- Various objects:
    - Light bulbs, resistors, switches, etc

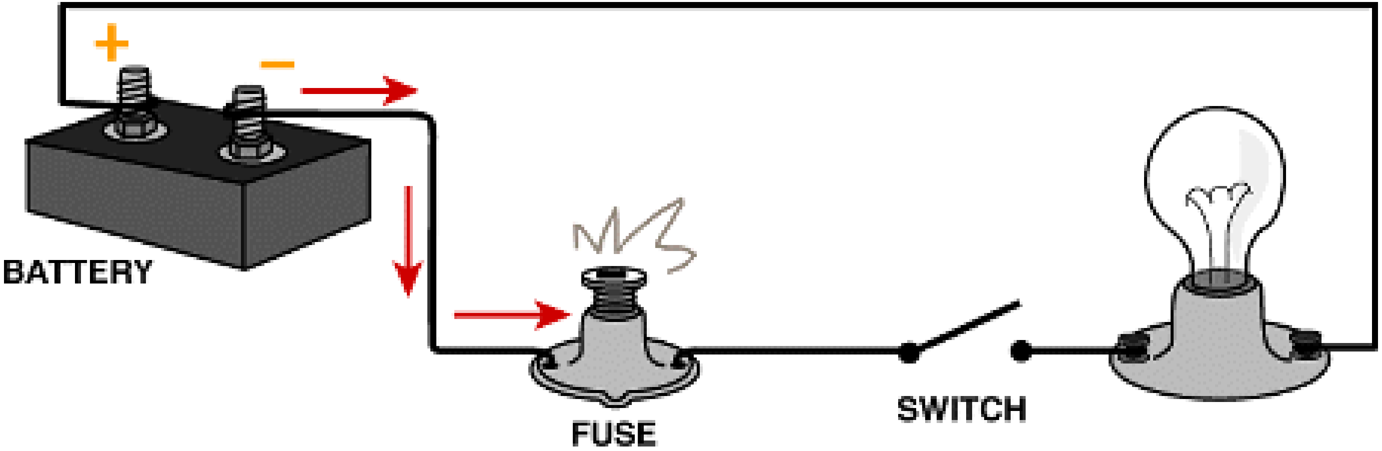
Wires	Battery	Fuse
		
Power supply	Switch	Motor
		
Light bulb	Resistor	Ammeter & Voltmeter
		

Dynamic Electricity

Types of circuits:

- Open:
  - The circuit is **not complete**; current **cannot flow** through
- Closed:
  - The circuit is **complete**; **current can flow** through

Open or closed?



Open

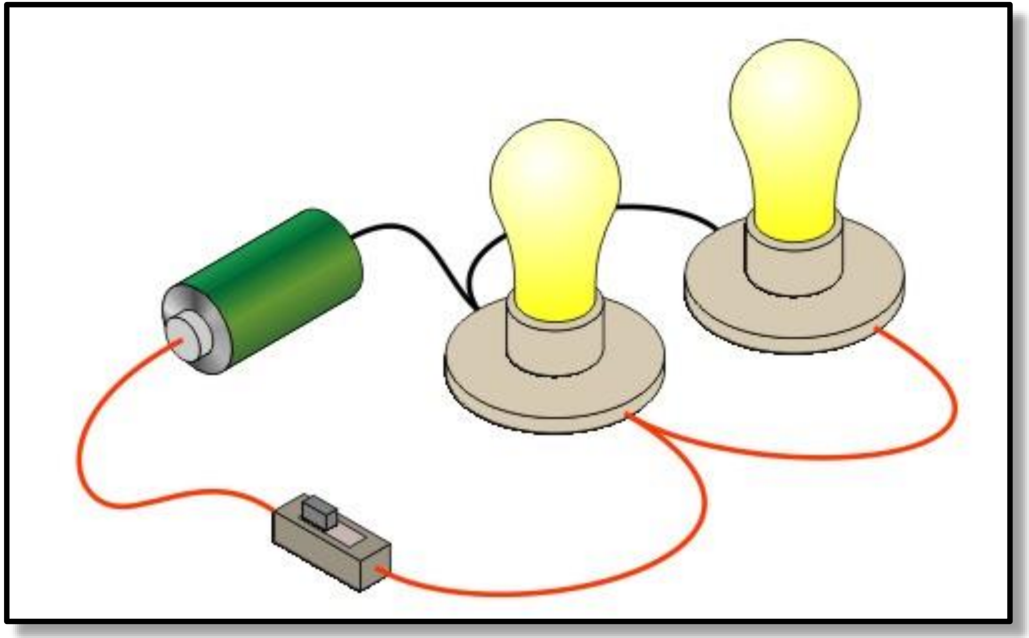
Dynamic Electricity

Types of circuits:

- Series:
- All elements are connected in a **row**
- Current only has one path

- Parallel:
- Elements in circuit are connected so that **multiple paths** are possible for the current to follow

Series or Parallel? Parallel



Dynamic Electricity

Current direction:

- Direction of movement of the electrons
  - Move from - to +
    - **Electrons are what's moving!**

Dynamic Electricity

Current intensity:

- **Definition:** the number of charges that pass a given point in an electrical circuit every second
    - Basically: the speed of the electrons
- **Symbol:** I
- **Unit:** A (amperes)
- **Device used to measure**: Ammeter

Dynamic Electricity

Current intensity:

- **Remember:** Ammeters are connected in **series**
    - Counting electron flow, so need to have electrons flow through them

Dynamic Electricity

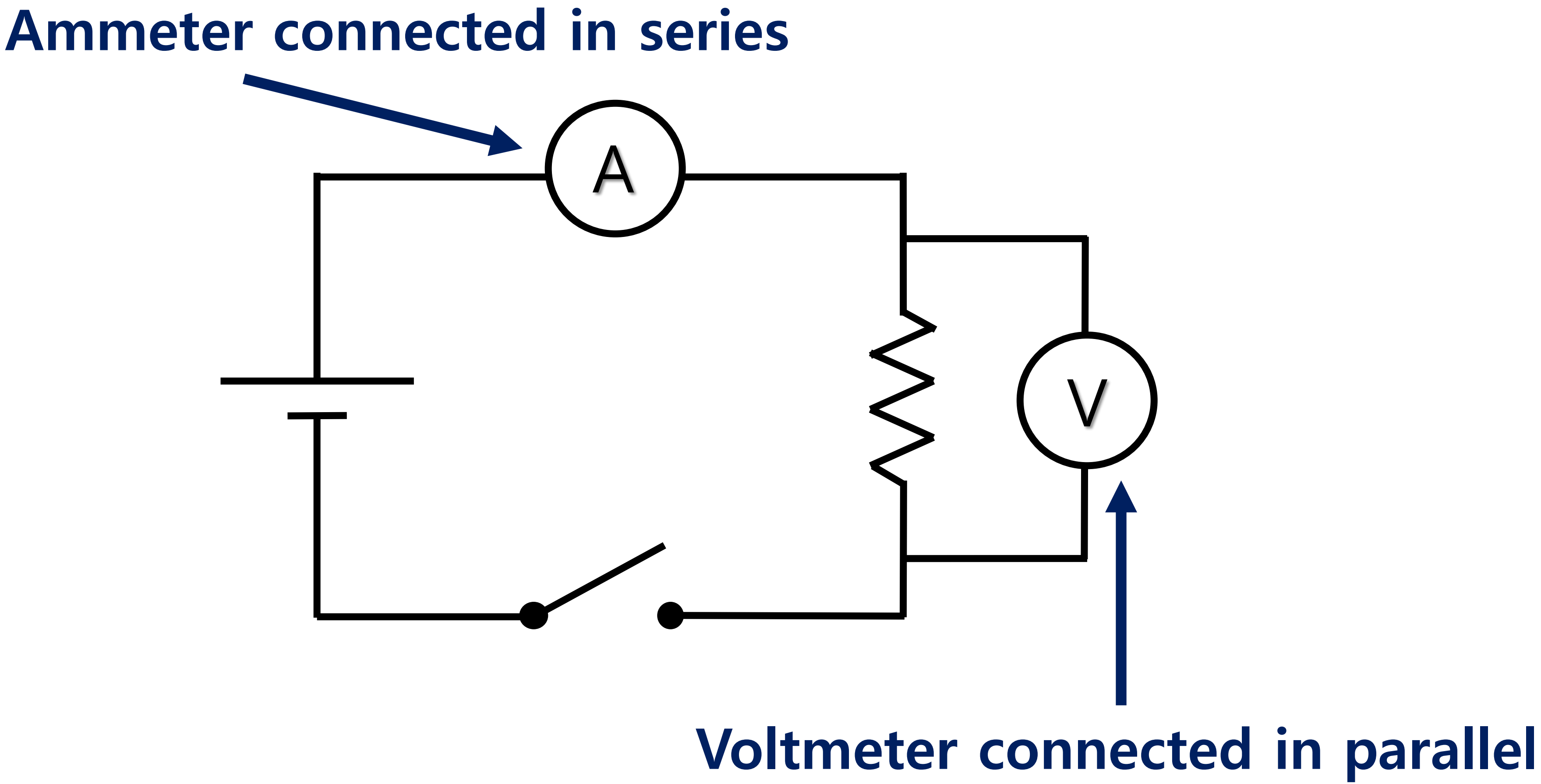
Potential Difference (voltage):

- **Definition:** amount of energy transferred between two points
- **Symbol:** V
- **Unit:** V (volts)
- **Device used to measure**: Voltmeter

Dynamic Electricity

Potential Difference:

- **Remember:** Voltmeters are connected in **parallel**


Ammeter connected in series
A
V
Voltmeter connected in parallel

Dynamic Electricity

Resistance:

- **Definition:** ability of a material to hinder the flow of electrons (slows them down)
  - Think of traffic congestion
- **Symbol:** R
- **Unit:** Ω (ohms)
- **Device used to measure**: none
  - Calculated from V and I

Ohm’s Law

$$\boldsymbol{V = RI}$$

Examples

What is the applied voltage of a telephone circuit that draws 0.017A through a resistance of 15,000Ω?

$$\mathrm{V} = IR$$

$$V = (0.017A)(15000\Omega)$$

$$V = 255V$$

Examples

What is the total resistance of a circuit that draws 0.06A with 12V?

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

$$R = \frac{12V}{0.06A}$$

$$R = 200\Omega$$

Examples

A circuit has 1200 Ω of total resistance with 12 V as the power supply. What is the total current of this circuit?

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

$$I = \frac{12V}{1200\Omega} = 0.01A$$

Electrical Functions

- Each component in a circuit plays a **particular role**
  - In other words, it has a **function**, a **job within the circuit**

Electrical Functions

1) **Power Supply**

- Energy is needed for the current to flow in a circuit
  - **Components:** batteries, outlets, power supplies

Electrical Functions

2) **Conduction**

- In order for the electrons to get to the different components, they need a **pathway made of conductive materials that will transmit the current**
  - **Components:** wires, jumpers

Electrical Functions

3) Insulation

- Since electricity can be **harmful** (both to living things and components of a circuit) we often **want to isolate the current to particular areas** (ex: in the wires); **prevent it from flowing**
  - **Components: rubber casing around wires, plastic wire connectors**

Electrical Functions

4) **Protection**

- Since electricity can be **harmful** if there is a **short circuit** or an **overload on the system**, we need devices that can help **protect** us and the circuit its elf by **cutting the flow of current**
  - **Components:** breakers, fuses

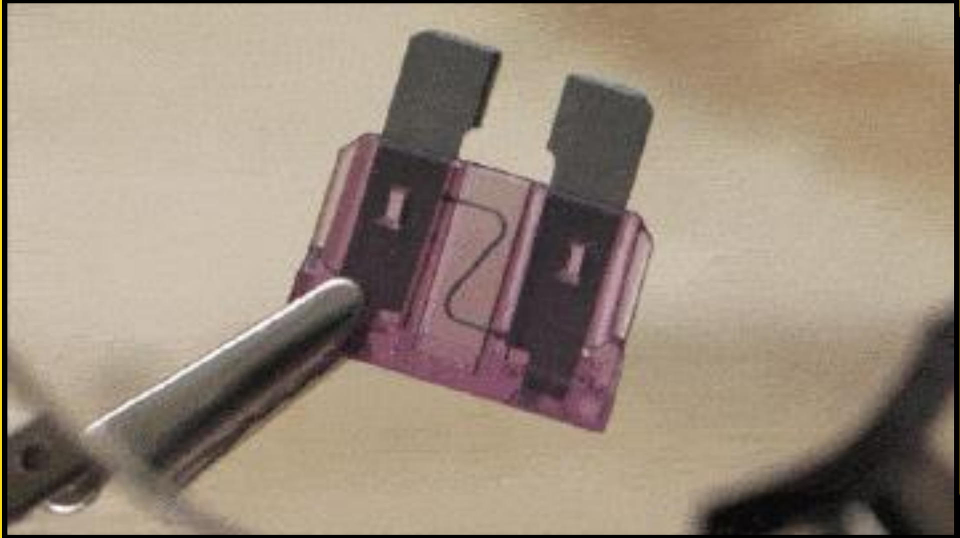
Dynamic Electricity

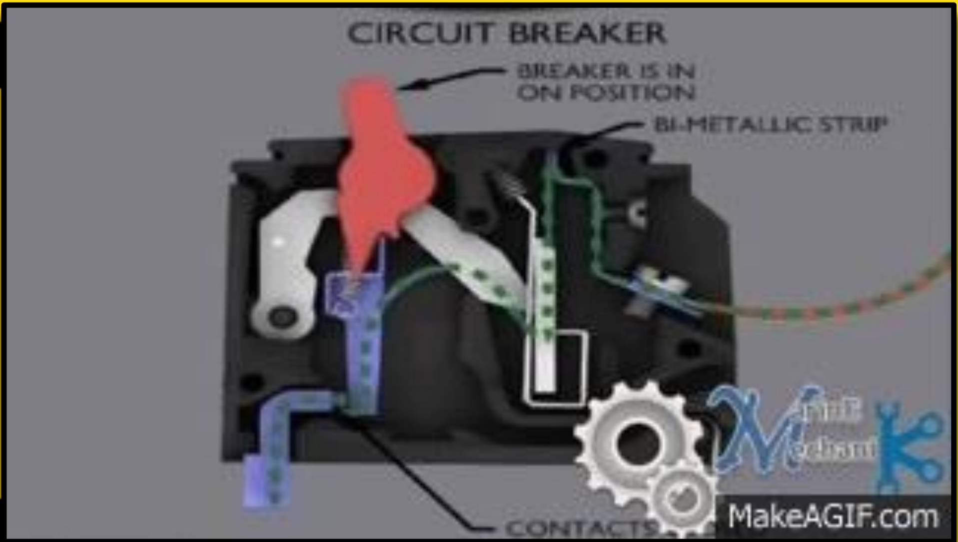
Protection in circuits:

1. **Fuse:** Contains conductive filament that "melts" if current exceeds a certain level
2. **Breakers:** Strip bends when current exceeds a certain level and opens the circuit

Fuse

Circuit Breaker





Electrical Functions

5) Control

- We don't necessarily **always want a current** to be flowing through a circuit (think of the lights in your room) so we ne ed a way **to be able to open and close a circuit at will**
  - **Components:** switches

Electrical Functions

6) **Energy Transformation**

- The role of many components in a circuit is to **transform electrical energy into some other form of energy** (heat, sound, light, mechanical, etc)
  - **Components:** lights, speakers, heating elements, electromagnet, buzzer, motors, resistors, etc.

Examples

What is the electrical function of:

1) A light bulb Energy transformation
2) A resistor Energy transformation
3) A battery Power supply
4) The plastic covering on wires Insulation
5) The metal in wires Conduction

Dynamic Electricity

Electrical Power:

- **Definition:** the rate of energy transfer in an electrical device
    - Amount of energy it can transform
- **Symbol: P**
- **Unit:** W (Watts)
- **Device used to measure**: none
    - Calculated using V and I

$$P = VI$$

Examples

If a blender is plugged into a 110 V outlet that supplies 2.7 A of current, what amount of power is used by the blender?

$V = 110V$

$I = 2.7A$

P=?

$$P = IV = (2.7A)(110V)$$

$$= 297W$$

Examples

If a clock expends 2W of power from a 1.5V battery, what amount of current is passing through the clock?

$$V = 1.5V$$

$$I = ?$$

$$P = 2W$$

$$P = IV$$

$$I = \frac{P}{V} = \frac{2W}{1.5V} = 1.33A$$

Dynamic Electricity

Electrical Energy:

- **Definition:** ability to do work
- **Symbol:** E
- **Unit:** J (Joules) when using Watts and s econds
    - Can also use KWh if power is in kW and time is in hours
- **Device used to measure**: none
    - Calculated using power and time

Energy Measured in **J**

Power Measured in **W**

$$E = P\Delta t$$

Time (measured in **s**)

Examples

What is the energy consumed by a 2.5 kW toy car after 3 hours of use?

$$P = 2.5kW$$

$$\Delta t = 3h$$

E=?

$$E = P\Delta t$$

$$E = (2.5kW)(3h)$$

$$E = 7.5kWh$$

Examples

How much energy will a blender have consumed after 15 mins of use if the current flowing through it has an intensity of 15 A and the potential difference is 120 V?

$$I = 15A$$

$$V = 120V$$

$$\Delta t = 15mins$$

E=?

$$E = P\Delta t \qquad P = IV$$

$$E = IV\Delta t$$

900s

$$E = (15A)(120V)(\cancel{15mins})$$

$$E = 1620000J = 1620kJ$$

Law of Conservation of Energy

Law:

- Energy is never created nor destroyed, but **transformed from one form to another**

- Main forms of energy:
  - **Kinetic**
    - Radiation
    - Magnetic
    - Electrical
    - Thermal
    - Acoustic (sound)
    - Wind
    - Hydro
  - **Potential**
    - Chemical
    - Nuclear
    - Elastic

Energy Efficiency

Energy Efficiency:

- How well a system converts energy from one form into another
- Can be calculated mathematically using the following formula:

$$\boxed{Efficiency(\%) = \frac{useful\ energy\ (J)}{Total\ energy\ \ consumed(J)} x100}$$

Alternative

$$\frac{Efficiency(\%)}{100} = \frac{useful\ energy\ (J)}{Total\ energy\ \ consumed(J)}$$

Examples

What is the energy efficiency of an iPod that has 5200 J of total energy and produces 1800 J of sound?

$$E_{tot} = 5200J$$
$$E_{use} = 1800J$$
$$\mathrm{E}_{eff} = ?$$

$$Eeff.(\%) = \frac{E_{use}(J)}{E_{tot}(J)} x100$$

$$Eeff.(\%) = \frac{1800J}{5200J} x100$$

$$Eeff.(\%) = 34.6\%$$

Examples

A technician examines different electrical devices to determine the one that is the most energy efficient. While conducting a test, he notes that one of these devices consumes 550 000 J of energy and loses 315 000 J at the same time. What is the energy efficiency of this device?

$$E_{tot} = 550\,000 J$$

$$E_{lost} = 315\,000 J$$

$$E_{eff} = ?$$

$$E_{use}(J) = E_{tot}(J) - E_{lost}(J)$$

$$E_{use}(J) = 235\,000\,J$$

$$E_{eff.}(\%) = \frac{E_{use}(J)}{E_{tot}(J)} x100$$

$$E_{eff.}(\%) = \frac{235000 J}{550000 J} x100$$

$$E_{eff.}(\%) = 42.7\%$$