Topic one General Physics

Summary Notes

Length and time

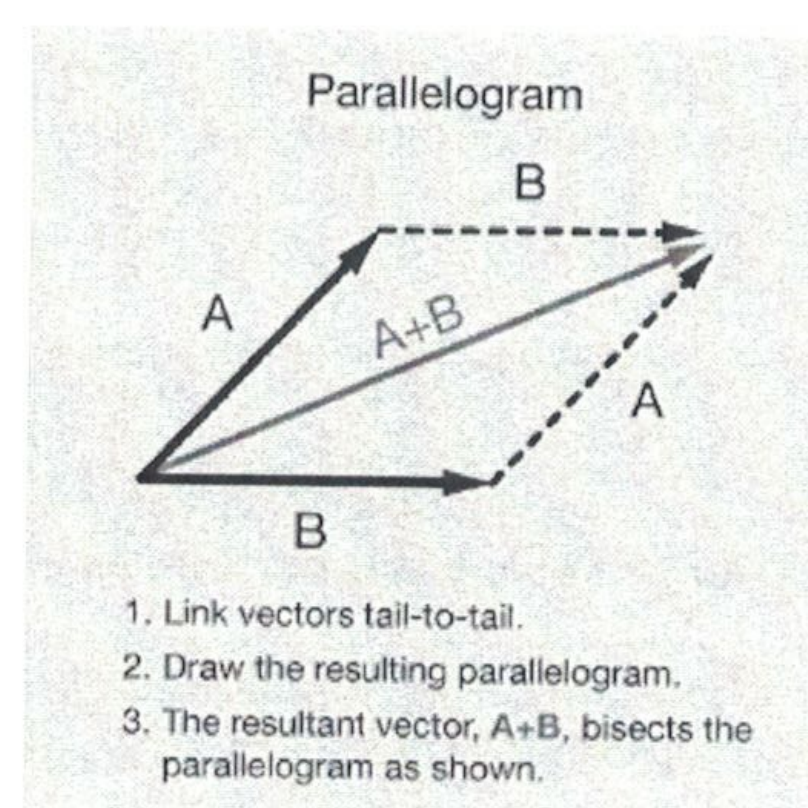
- A ***ruler*** is used to measure the ***length*** of an object between 1mm and 1cm.
- The ***volume*** of an object of ***irregular shape*** can be measured by placing it into a measuring cylinder full of water. This causes the water level to rise, and this rise is equal to the volume of the object.
- ***A micrometer screw gauge*** is used to measure very small ***thickness 0.01 mm*** that a rule cannot measure.
- Analogue and digital ***clocks*** and devices are used to measure ***time*** intervals.
- ***An average*** value for a small distance and for a short time interval can be found by measuring multiples (including the period of a pendulum).

Scalars and vectors

- A ***vector*** has a ***magnitude*** and a ***direction***.
- A ***scalar*** has just a ***magnitude***.

Scalars	Vectors
Distance	Displacement
Speed	Velocity
Time	Acceleration

- ***Vectors*** can be represented by ***arrows***. To determine the ***resultant*** of ***two vectors graphically***, they must be placed head to tail the line between the start and finish is the resultant (***parallelogram method)***



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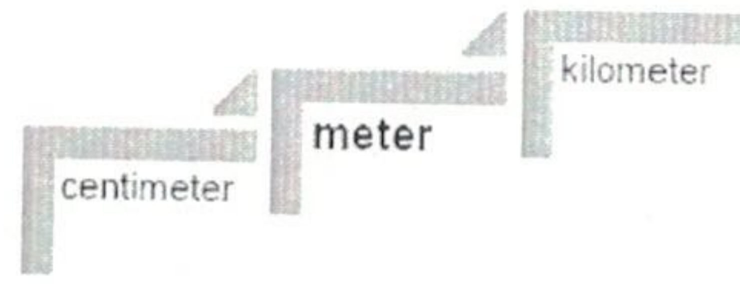
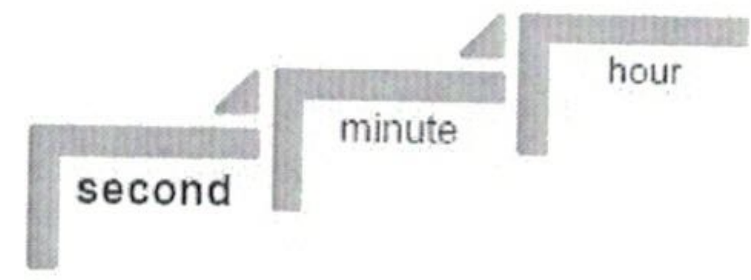
SI Units



- Distance ⟶ meter
- Mass ⟶ kg
- time ⟶ second



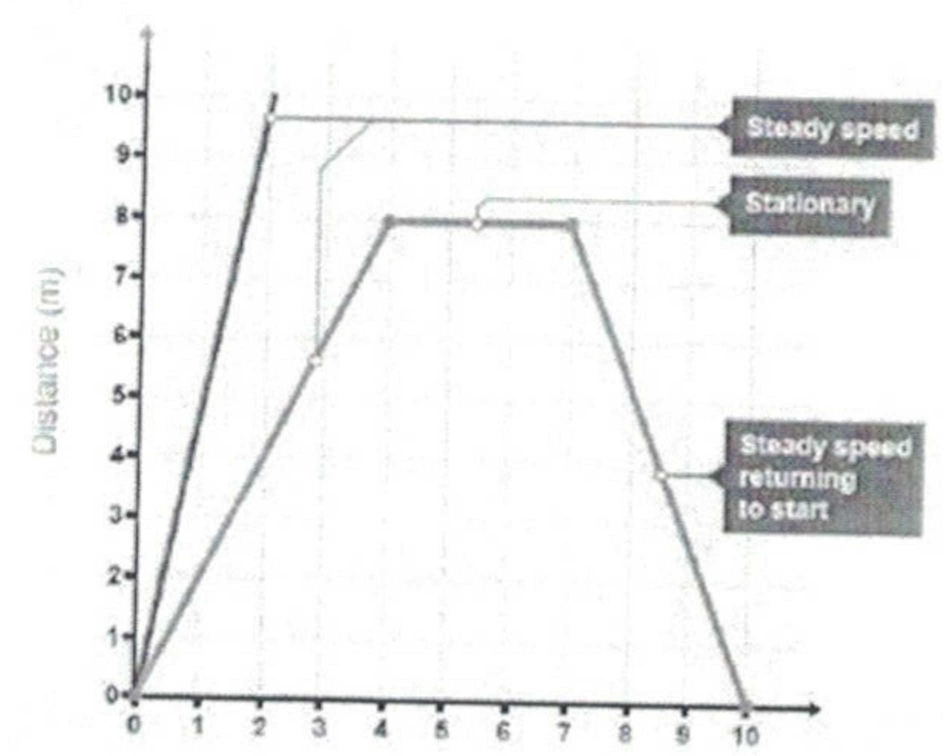
Motion

- ***Speed*** is defined as the ***distance traveled per unit time.***
- ***Velocity*** is the ***speed in a given direction***
- ***Acceleration*** is the ***rate of change of velocity***

$$Speed = \frac{Distance}{Time} \qquad velocity = \frac{Displacement}{Time}$$

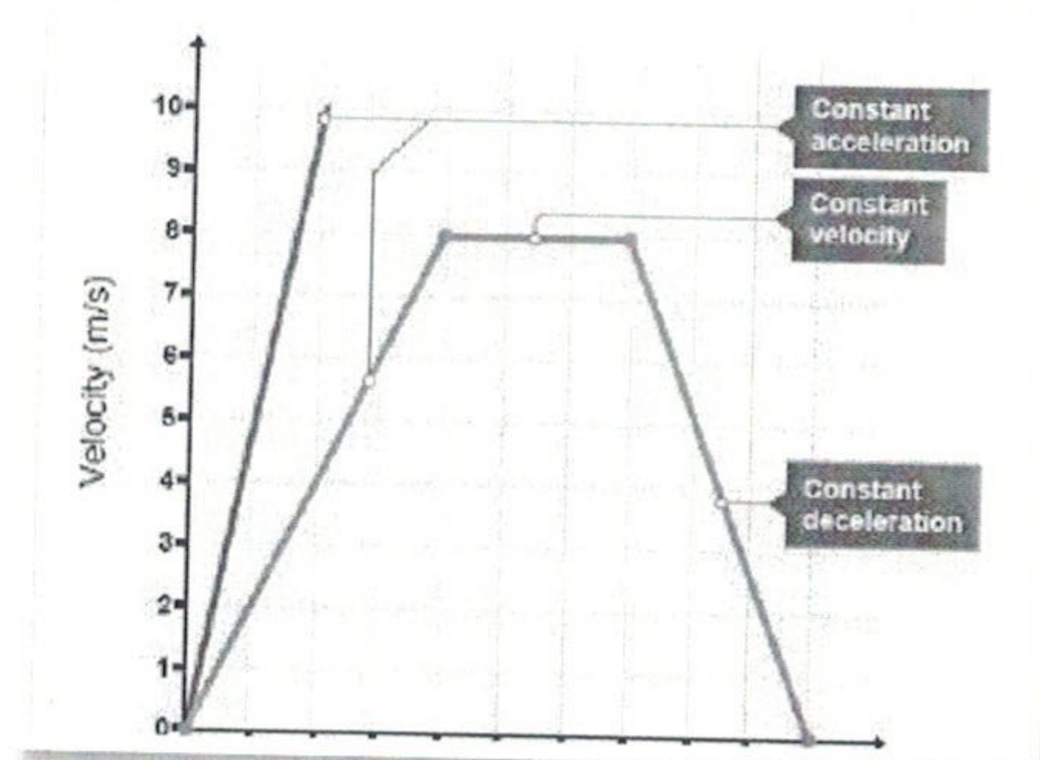
$$acceleration = \frac{final\ velocity - inital\ velocity}{Time}$$

Distance-time graph



- The ***gradient*** is ***velocity***
- ***Negative gradient*** is returning ***back*** to the starting point
- A ***horizontal*** line means it is ***stationary***
- A ***curved line*** means that the velocity is changing and it is ***accelerating***

Speed-time graph



- The ***gradient*** is ***acceleration***
- ***Negative*** gradient is ***deceleration***
- If the speed is ***zero***, it is at ***rest***
- A ***horizontal*** line means ***constant speed***
- The ***area under the line*** is the ***distance*** travelled
- A ***curved line*** means that the ***acceleration is changing.***

Mass

- ***Mass*** is a measure of ***how much matter*** is in an object.

Weight

- ***Weight*** is a ***gravitational force*** (the effect of a gravitational field on a mass) measured in ***Newton***

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- The ***gravitational field strength*** on Earth is 10 N kg^{-1}.
- ***Weights*** (and hence masses) can be compared using a ***balance***

Weight = mass x gravitational field strength

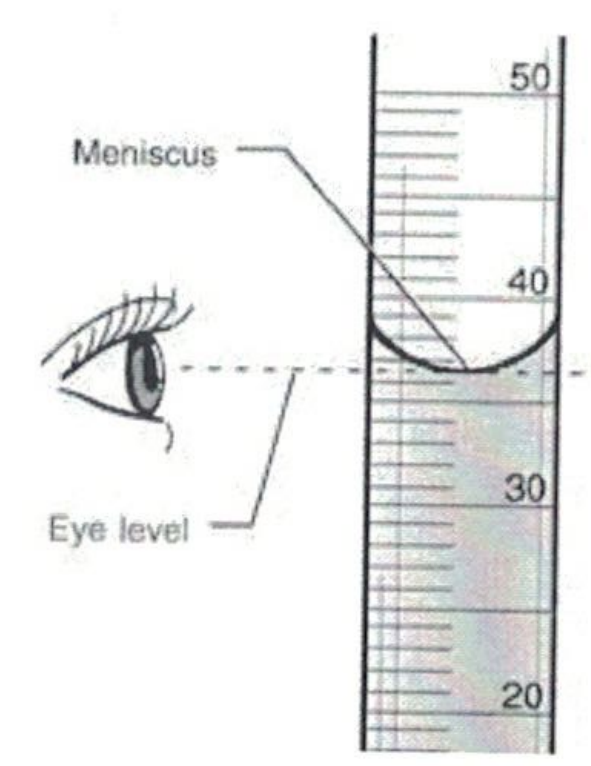
Same object on two different planets

- The ***mass*** is the ***same***
- The ***gravitational field strength*** on the two planets will be ***different*** so the ***weight*** is ***different***.

Density

- The ***density*** is defined as the ***mass per unit volume***
- The ***density*** ρ is in ***kilograms per metre cubed***, kg/m^3, the mass m is in kilograms, kg, and the volume V is in meters cubed, m^3.

To find the density of a liquid



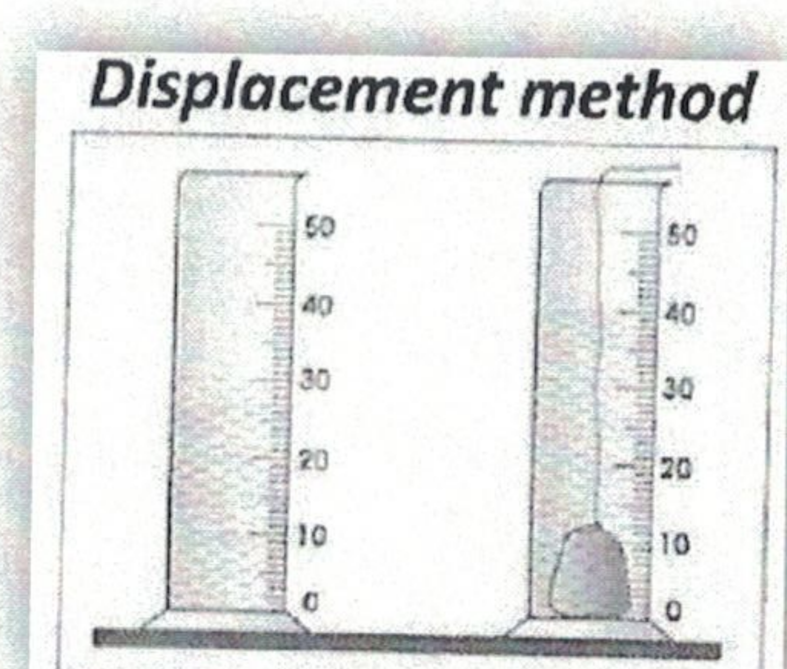
- Find the ***mass*** of the measuring cylinder by placing it on a balance, then fill it with the liquid and measure the ***new mass. The difference in masses is the mass of the liquid.***
- ***The volume*** can be read from the cylinder and the ***density*** calculated using the equation.

$$\text{Density} = \frac{mass}{volume}$$

To find the density of solid

- ***Measure*** the ***mass*** of the ***solid*** by placing it on a ***balance***.
- If the ***solid is regularly shaped, measure*** its ***dimensions*** using a ruler or other measuring tool and then use a ***mathematical formula*** to find the volume.
- If the ***solid*** is ***irregularly shaped, immerse it in water*** and measure the ***volume of the water displaced***. This ***is the volume of the solid***.

$$V = V_2 - V_1$$

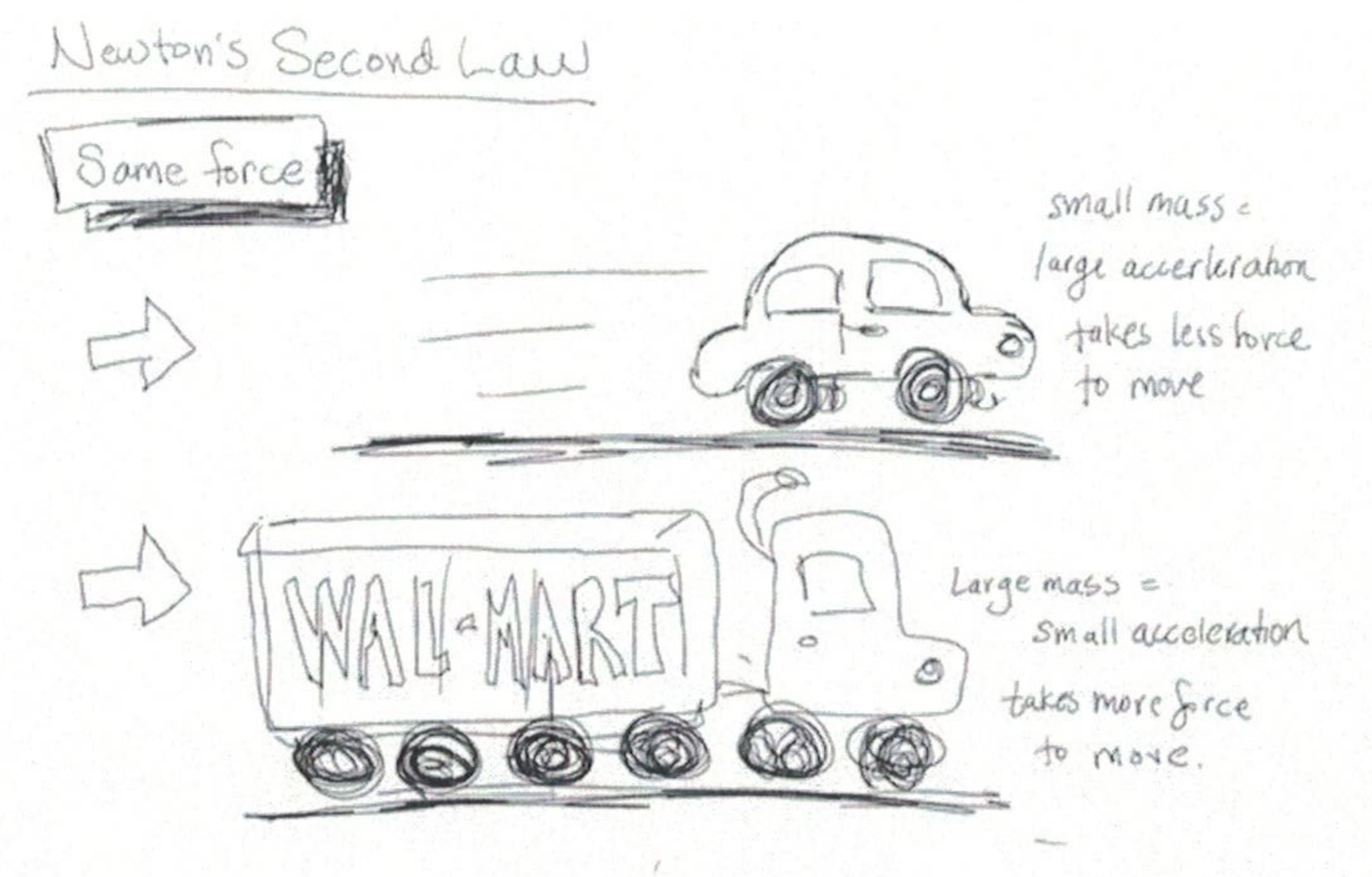


- The ***density*** of ***water*** is $1g/cm^3$
  - ✓ If the density of an object is ***greater than*** this it will ***sink*** in water
  - ✓ If ***less***, it will ***float***

Forces

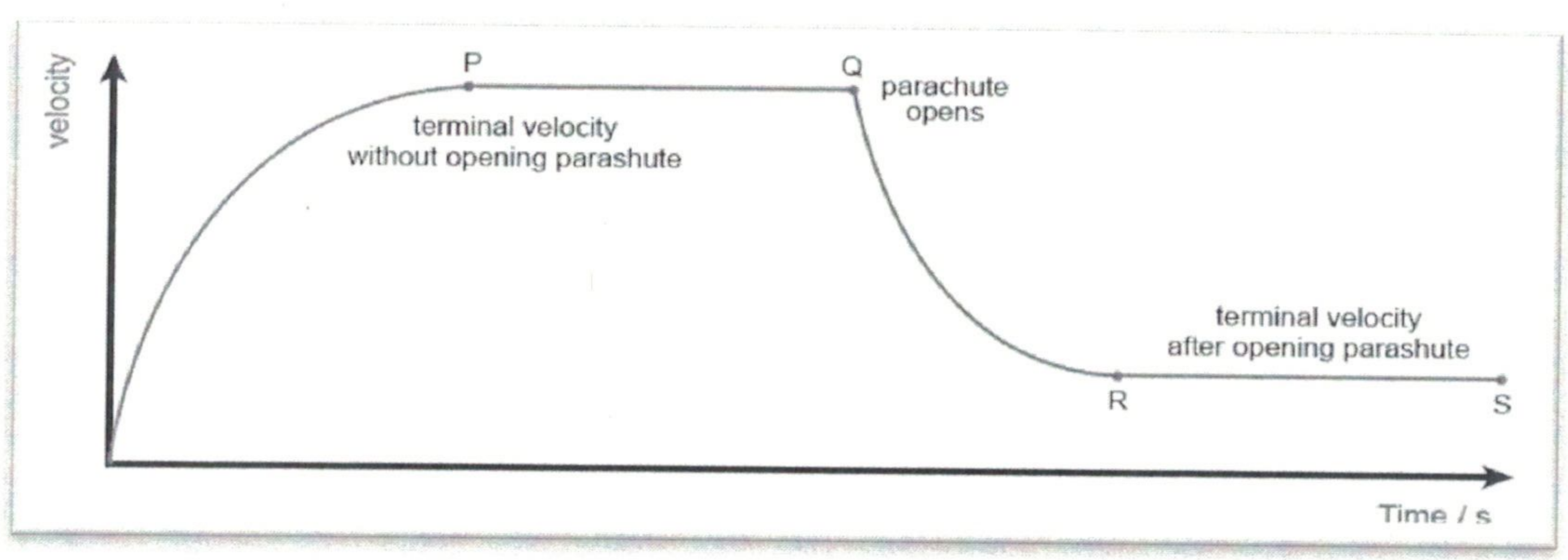
- **Newton's first law** states that an object has a constant velocity unless acted on bya resultant force.
- **Newton's second**

  Force = mass x acceleration
- **Newton's third law** states that ***every action*** force has an ***equal*** and ***opposite reaction force***



Falling object (skydiver)

- ***Initially***, there is ***no air resistance*** and the ***only force acting*** on it is ***weight***
- As it ***falls***, it accelerates which increases its speed and ***hence air resistance***, This causes the ***resultant force downwards to decrease*** so it is ***not speeding up as quickly***
- ***Eventually*** they are ***equal and opposite and balance*** so there is ***no resultant force*** So there is ***no acceleration*** and the ***terminal velocity is reached***
- ***finally*** as ***parachute open*** the upward force ***air resistance greater*** than ***weight*** of the skydiver so speed of sky diver decrease ***deceleration***



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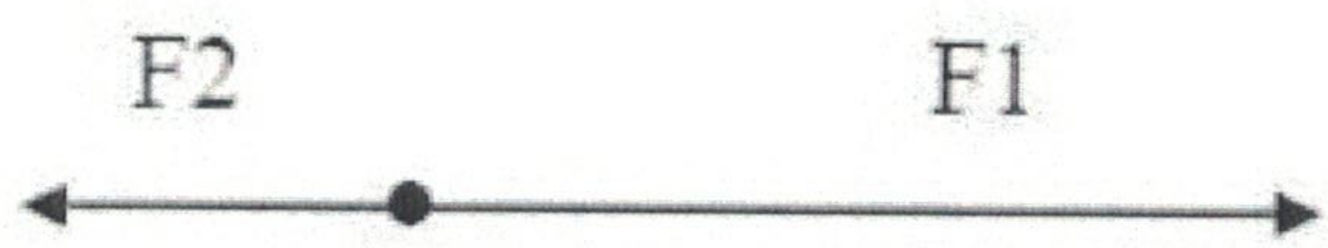
Friction

Is a ***force*** between ***two surfaces*** which ***slide against each other*** and ***results*** in ***heating***

- ✓ Air resistance is a form of friction.

<u>To find the resultant of two or more forces</u> acting along the same line, they ***should be added together*** if in the ***same direction*** and ***subtracted*** if in the ***opposite direction***.

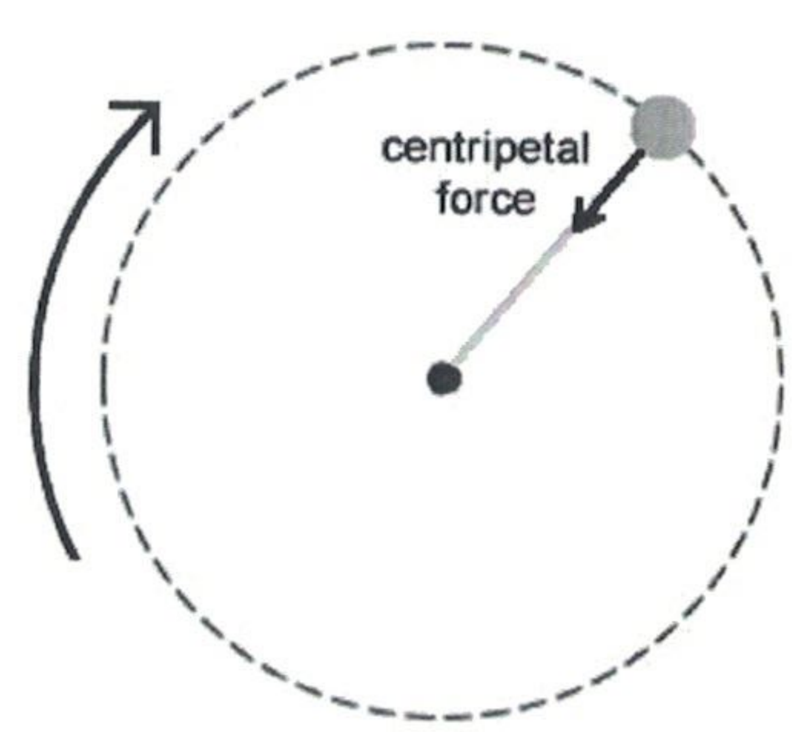
Resultant force= F1+F2



Resultant force = F1 – F2

<u>Object moving in a circle, with constant speed</u>

- The ***speed is constant***, but the ***direction*** is always ***changing*** This means the ***velocity*** is always ***changing***
- Therefore it is ***accelerating*** and there must be a ***force*** perpendicular to its velocity ***towards the center of the circle***



- ✓ **A force may** produce a ***change*** in ***size*** and ***shape*** of a body. This is called deformation , also can change ***speed*** (or direction)

<u>Elastic deformation</u>

- The ***object returns to its original shape*** when the ***load has been removed***, an example being a ***spring*** being stretched under normal usage.

Plastic deformation

- The *object* <u>*does not*</u> *return to its original shape* when the *load has been remove* an example being a *spring* that has been ***stretched too far***.

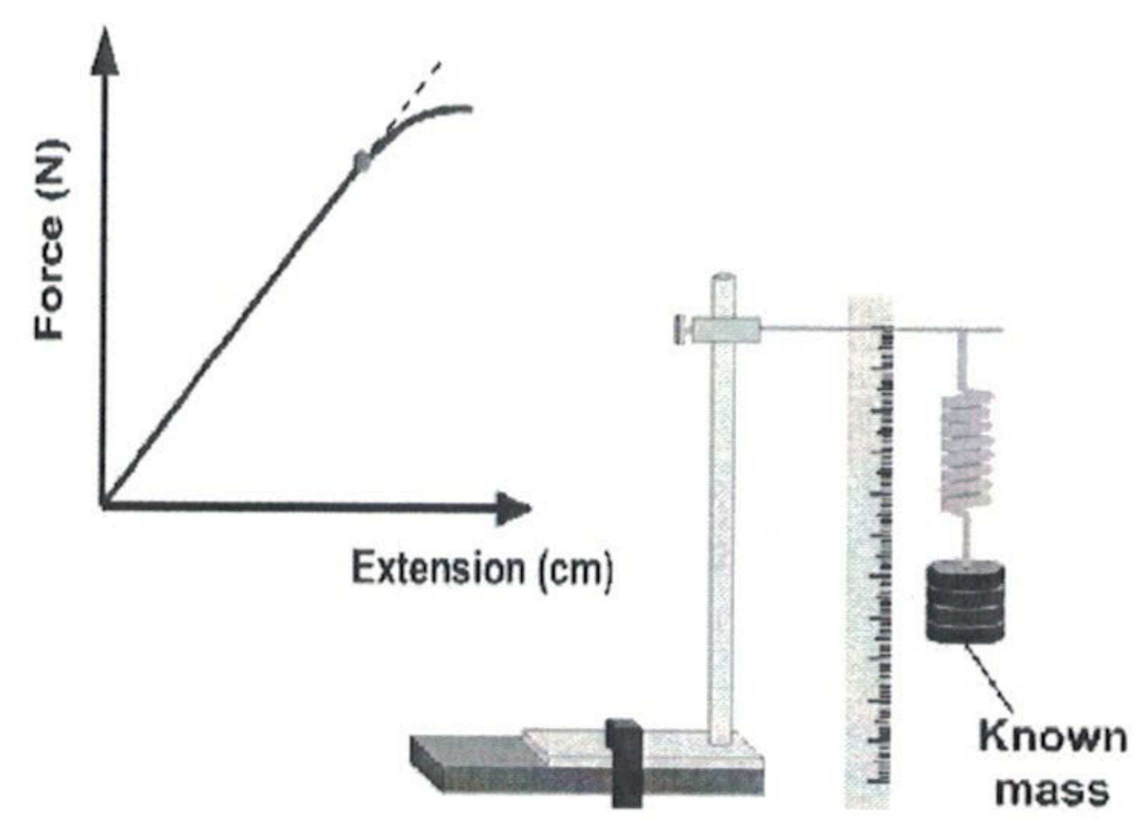
Hook's Law

Stated That's ***Force Is direct proportional with extension*** until elastic limit

$$F = K x$$

<u>**Linear (straight line) force-extension graph**</u>

- ***Elastic deformation*** following Hooke's law
- The point it ***stops being linear*** is called the ***limit of proportionality***. From then, it does not obey Hooke's law.
- ***Gradient*** is the ***spring constant, k***



<u>**Non-linear (curved line) force-extension graph**</u>

- ***Plastic deformation*** not following Hooke's law
- After the plastic region, it will ***fracture***, spring will not go back to it's original shape

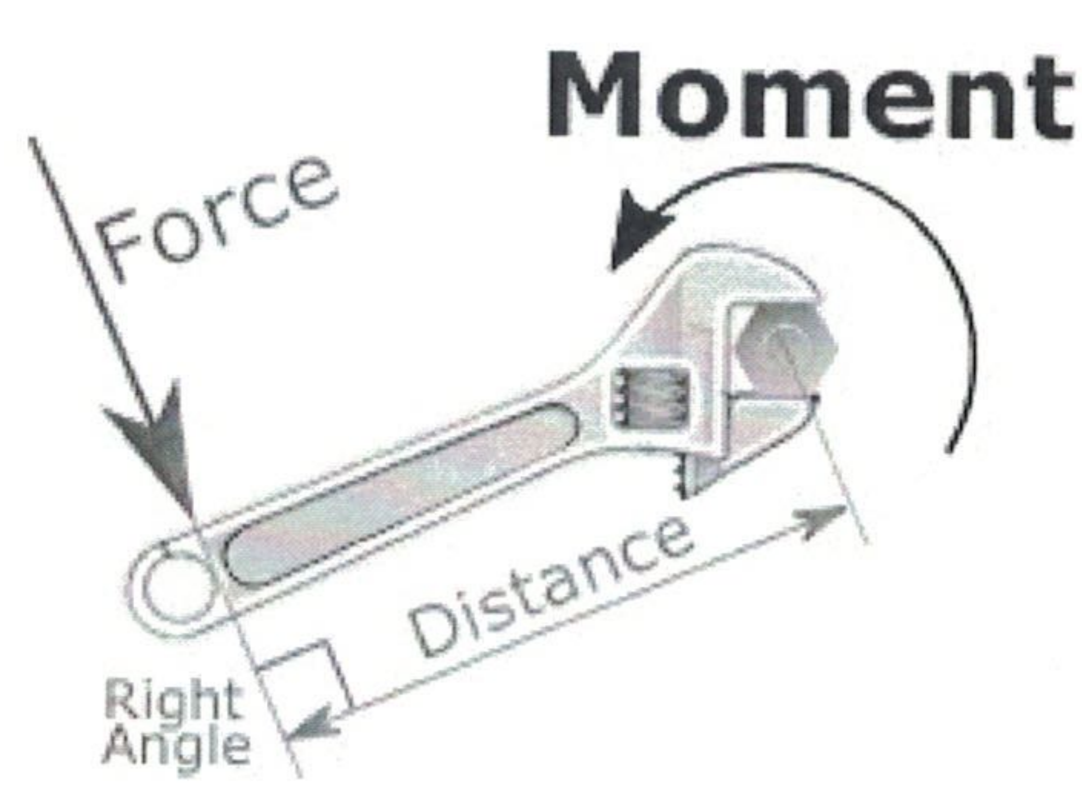
Moment (turning Effect)

For example, when riding a bike, pressing your foot down on the pedal causes a moment about the pivot, turning the pedal arms.

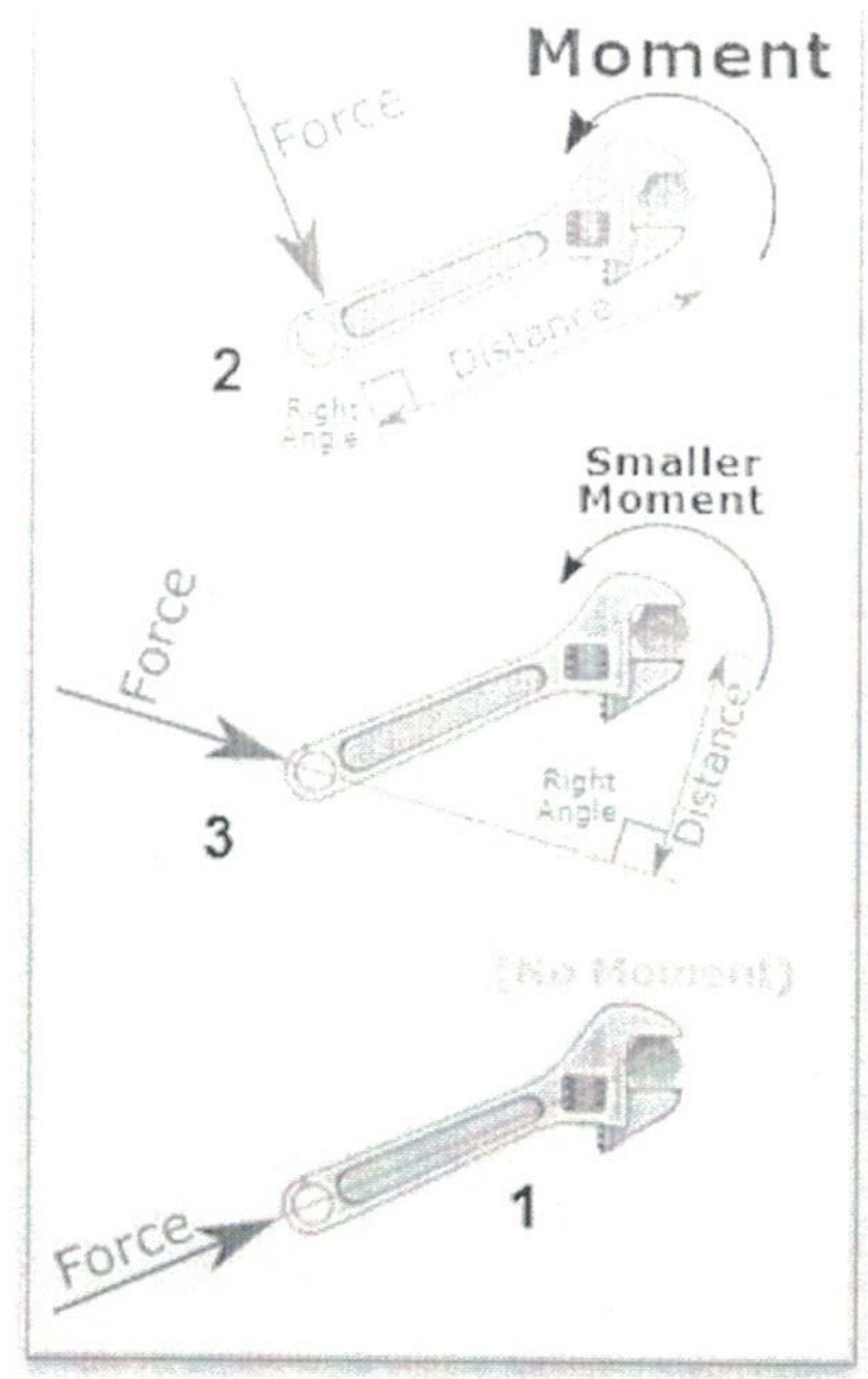
$$Moment\ of\ a\ force = force \times perpendicular\ distance\ from\ the\ pivot$$

$$Moment = F \times d$$

- The ***pivot*** point is the point which the object ***can rotate about.***



- If a ***force is applied in the same line as the pivot*** (see first example in diagram) the object will ***not rotate***, and will ***remain stationary***.
- If the ***force applied is perpendicular to the object***, then the ***perpendicular distance is the length*** of the object (see second example in diagram).
- If the ***force applied is not perpendicular*** to the object, then the ***perpendicular distance to the pivot must be found*** (see third example in diagram).



Conditions for equilibrium

- resultant moment = zero
- resultant force = zero

An object is in equilibrium

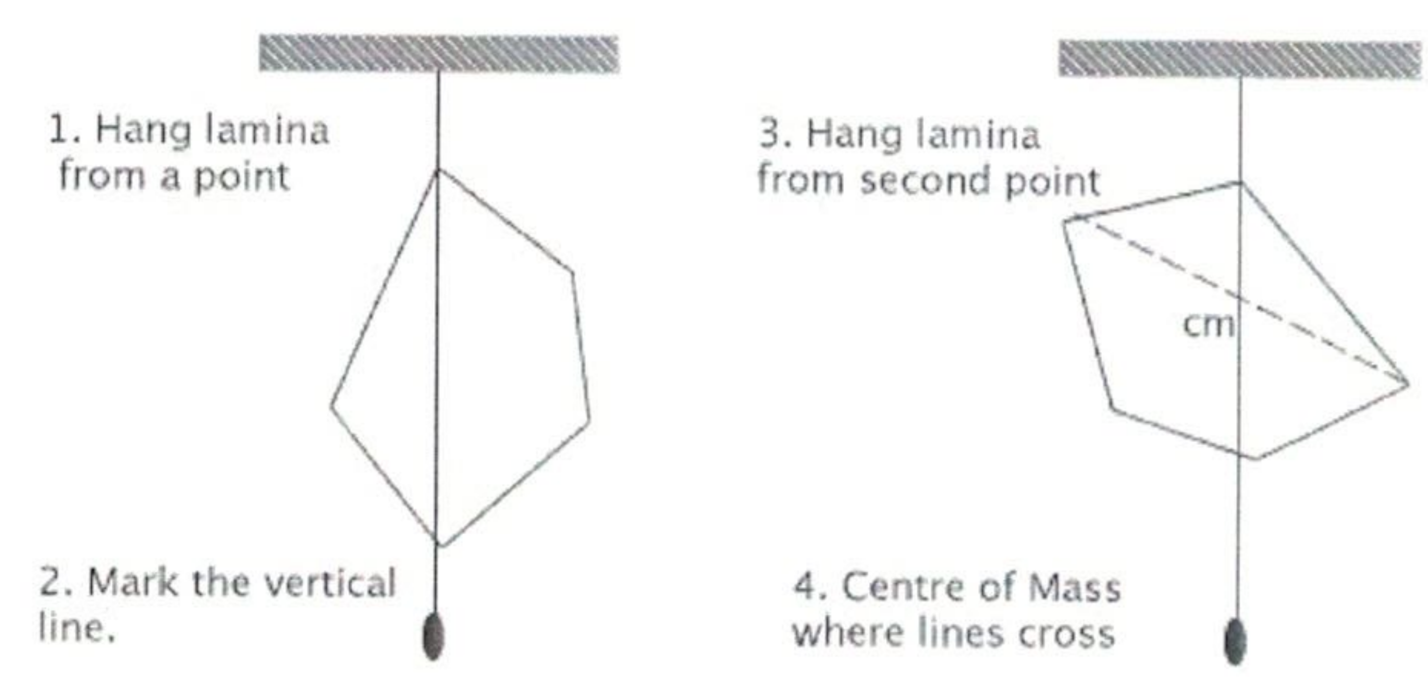
When the ***sum of clockwise moments equals the sum of anticlockwise*** moments (***the principle of moments***) and there is ***no resultant force***

Centre of Mass

The center of mass of a body is the ***point*** at which all of its ***mass can be considered*** to act,

<u>To calculate the center of mass of a card</u>

1. Pin the object from one point so that it rotate freely
2. Draw vertical line once the object reaches equilibrium
3. Repeat step 1 & 2
4. The point of intersection is the center of mass

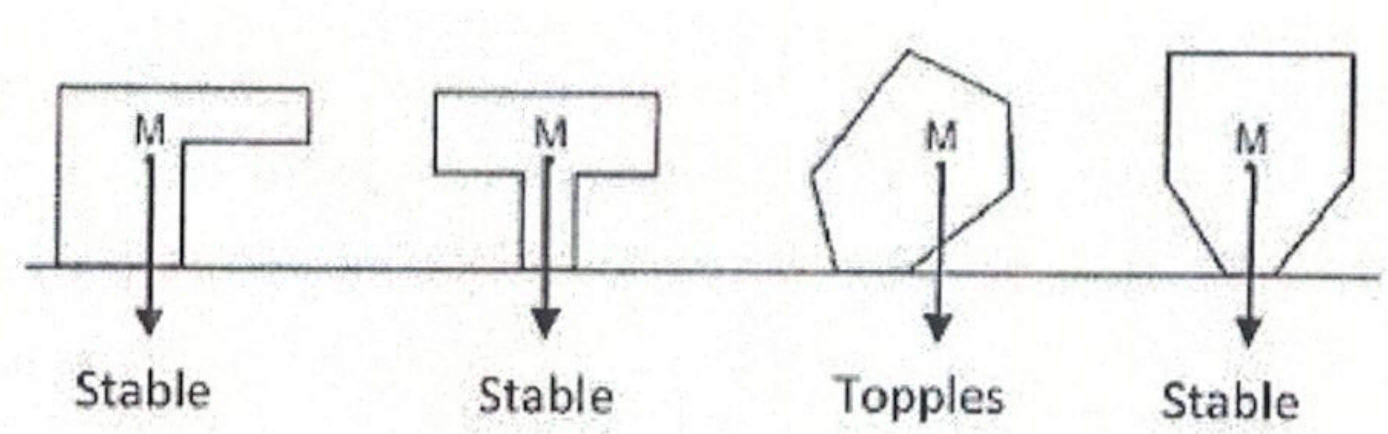


<u>Center of Gravity and Stability</u>

The stability of a body is increased by

1) Lowering its center or mass

2) Increasing the area of its base.



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Momentum

- **Momentum** is the product of mass and velocity
- **Impulse** is the product of force and time

Momentum = mass x velocity   impulse = Force x Time

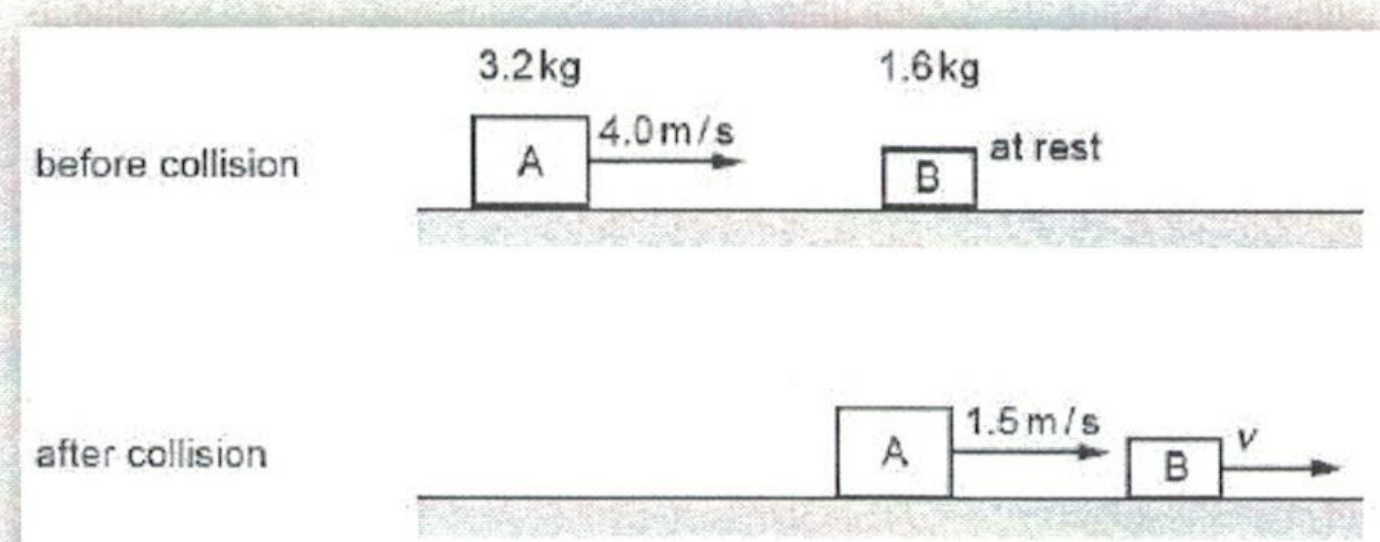
$$\text{Force} = \frac{\text{change in momentum}}{\text{Time}} \qquad \text{Force} = \frac{mv - mu}{t}$$

Principle of conservation of momentum

When two or more objects in a system interact (or collide), ***the total momentum remains constant*** provided that there is no external resultant force acting on the system.

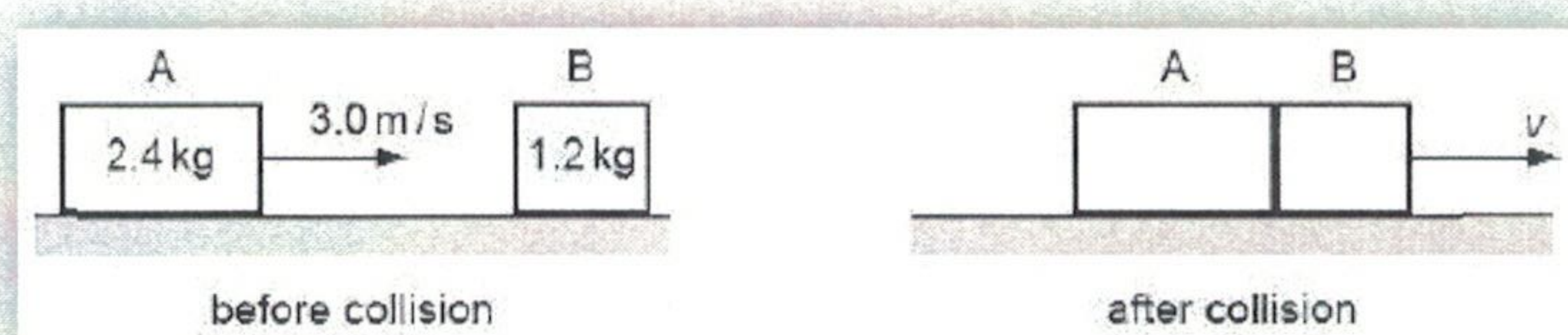
Momentum before collision = momentum after collision

- **Elastic collision (bounce off)**



$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

- **inelastic collision (join together)**



$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

Energy , Work and Power

Energy transfers

Energy can be transferred between ***different forms*** including ***kinetic, gravitational potential, chemical, and elastic potential, nuclear*** and ***internal energy*** as a result of an event or process.

Energy can be transferred in various ways including

- ***Forces*** when gravity accelerates an object downwards and gives it kineticenergy.
- ***Electrical currents*** when a current passes through a lamp and it emits light andheat.
- ***Heating*** when a fire is used to heat up an object.
- ***Waves*** vibrations cause waves to travel through the air as sound.
- ***Work*** is done when a force moves something through a distance

$$Work = F \times d \qquad KE = \frac{1}{2} m v^2 \qquad GPE = m g h$$

- unit is joule (j)

Power

Is the ***rate at which energy is transferred*** or the rate at which work is done. For example, a lamp with a greater power will be brighter because it transfers more energy from electrical energy to light and heat energy in a given time

$$P = \frac{E}{t}$$

- unit is Watt (W)
- ***Energy*** is always ***conserved.*** The total energy ***before*** is ***equal*** to the total energy ***after***.

  For example, when a ball is dropped, ***gravitational potential energy becomes kinetic energy*** as it accelerates downwards. Upon impact with the floor, this kinetic energy will become thermal energy and sound energy.
- In any event or process energy tends to become more spread out among the objects and surroundings (dissipated) ***most common wasted energy heat and sound***

Efficiency

$$Efficiency = \frac{usuful\ energy\ or\ power\ output}{Total\ energy\ or\ power\ input} \times 100\ \%$$

- The efficiency of a system can be increased by:
- ***Reducing waste*** output (***lubrication***, thermal insulation)
- ***Recycling waste*** output (absorbing thermal waste and ***recycling it as input energy***)

Energy sources

It is important to note that apart from ***geothermal***, ***nuclear*** and ***tidal***, the ***sun is the original source*** of all energy on earth, released by nuclear ***fusion***.

- **Renewable** energy is energy which can be replenished as quickly as it is used. Examples include
  - ✓ Biofuel
  - ✓ Wind
  - ✓ Hydro-electricity
  - ✓ Geothermal
  - ✓ Tidal
  - ✓ Solar
  - ✓ Water waves
- It is often more costly and less ***reliable*** (available 24 hour) than non-renewable energy (the wind is intermittent and solar energy relies on good weather).

- **Non-renewable** energy is used more for large-scale energy supplies due to the large energy output per kilogram of fuel. Examples include:
  - ✓ Fossil fuels (coal, oil, gas)
  - ✓ Nuclear fuel
- It is usually ***cheaper than renewable*** energy but is becoming ***less popular because one day it will run out*** and it is ***harmful*** for the environment (burning fossil fuels releases greenhouse gases which cause ***global warming***)

Pressure

in solid	in Fluid (liquid , gas)
$p = \frac{Force}{Area}$	p = Density x gravity x height

✓ **Measured in Pascal**

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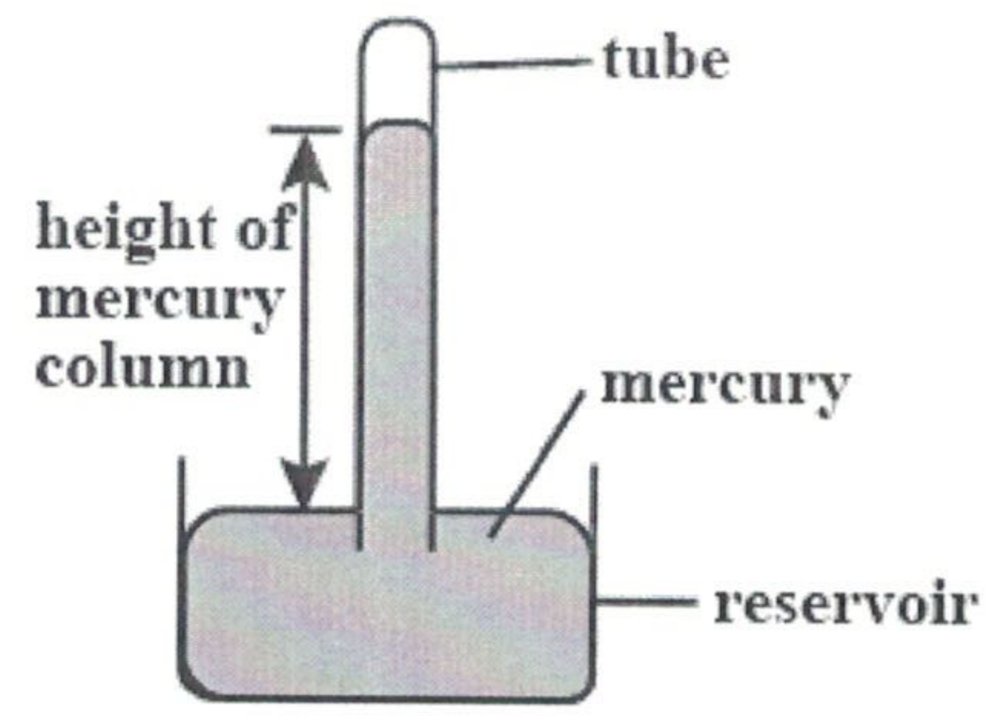
For example, lying down on a bed of nails compared to a single nail

- The force applied is the weight of your body
- The total area is either a single pin point or many points spread out over a largerarea So on a bed of nails, the pressure is lower as the area is greater

Barometer

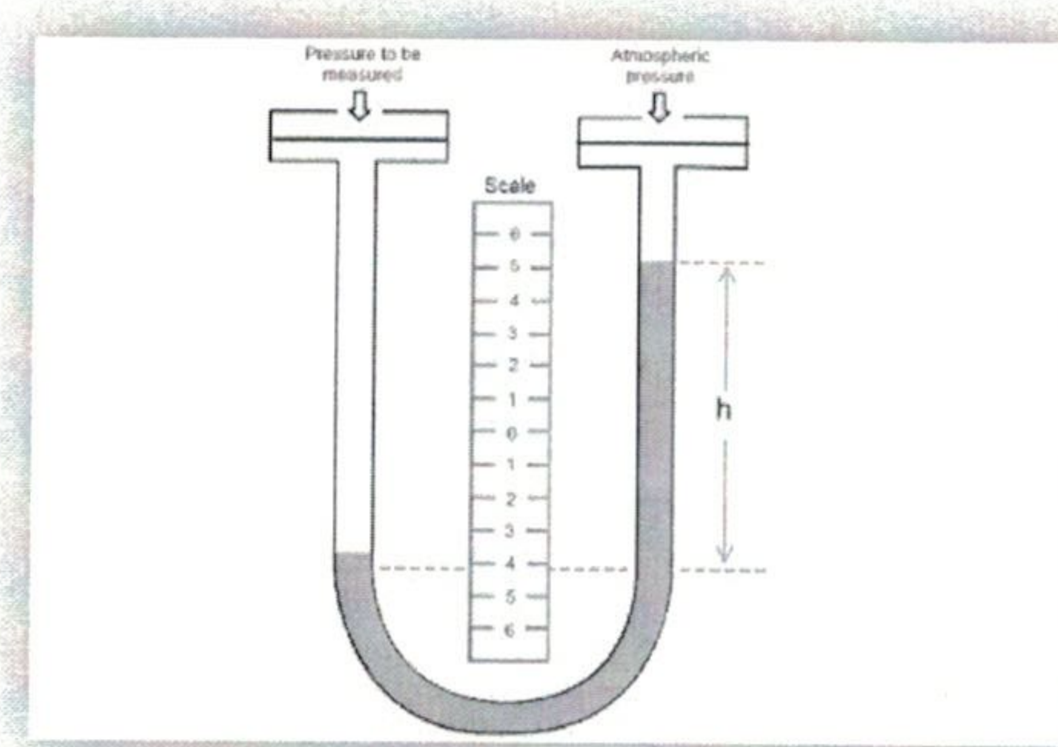


Consists of a ***tube*** filled with ***mercury*** with a ***vacuum*** at the top

Atmospheric pressure pushes down at the sides causing the mercury to rise. The ***height*** of the ***mercury*** is measured to find ***atmospheric pressure***

Manometer

Consists of ***a U-tube*** filled with ***mercury*** and with a gas at either end The ***difference*** in the ***height*** of the mercury on either side can be measured to find the pressure difference between the two ends of the tube



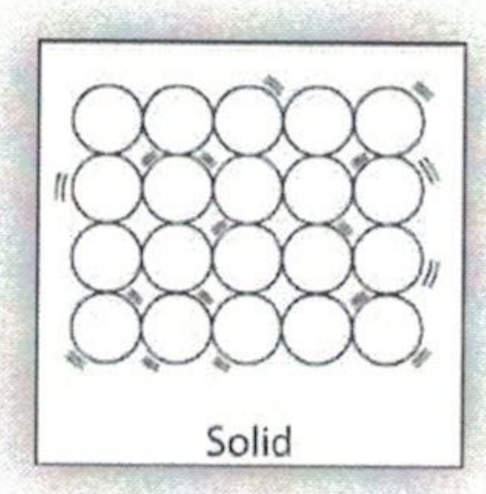
Topic Two Thermal Physics

Summary Notes

Simple kinetic molecular model of matter

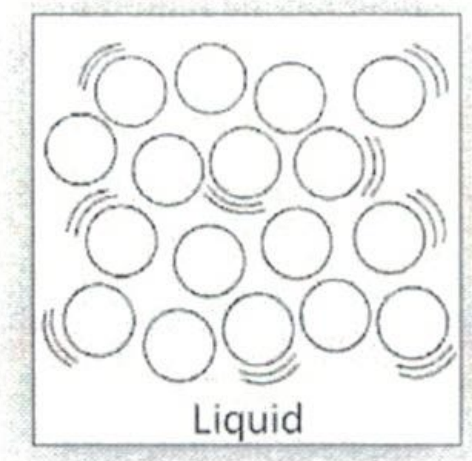
Solids

- Molecules ***close together in regular pattern***
- ***Strong*** intermolecular ***forces*** of attraction
- Molecules ***vibrate*** but can't move about
- ***Cannot flow***, have ***fixed shape*** and ***cannotbe compressed***



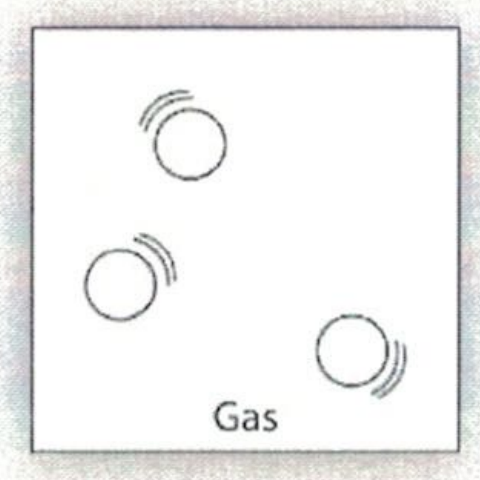
Liquids

- Molecules ***close together in random arrangement***
- ***Weaker*** intermolecular ***forces*** of attraction than solids
- Molecules ***move around each other***
- ***Flow***, take the shape of their container and ***cannotbe compressed***



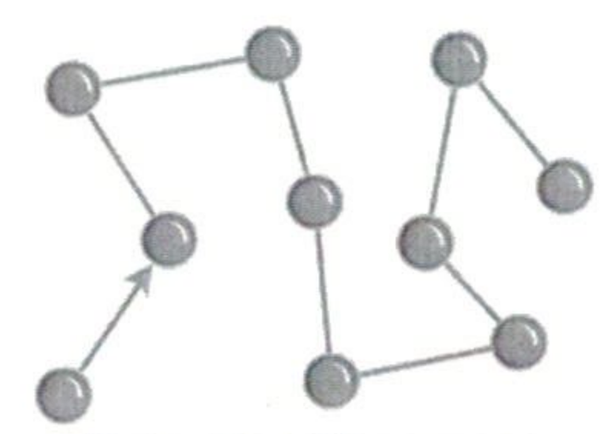
Gases

- Molecules far apart in ***random arrangement***
- Negligible/***very weak*** intermolecular ***forces***
- Molecules ***move quickly in all directions***
- ***Flow***, completely fill their container and ***canbe compressed***



Brownian motion

- Gas molecules ***move rapidly and randomly***
- This is due to ***collisions*** with ***other gas*** molecules
- Massive particles may be ***moved by light, fast-moving molecules***


Brownian Movement of a Particle

Temperature, pressure and volume

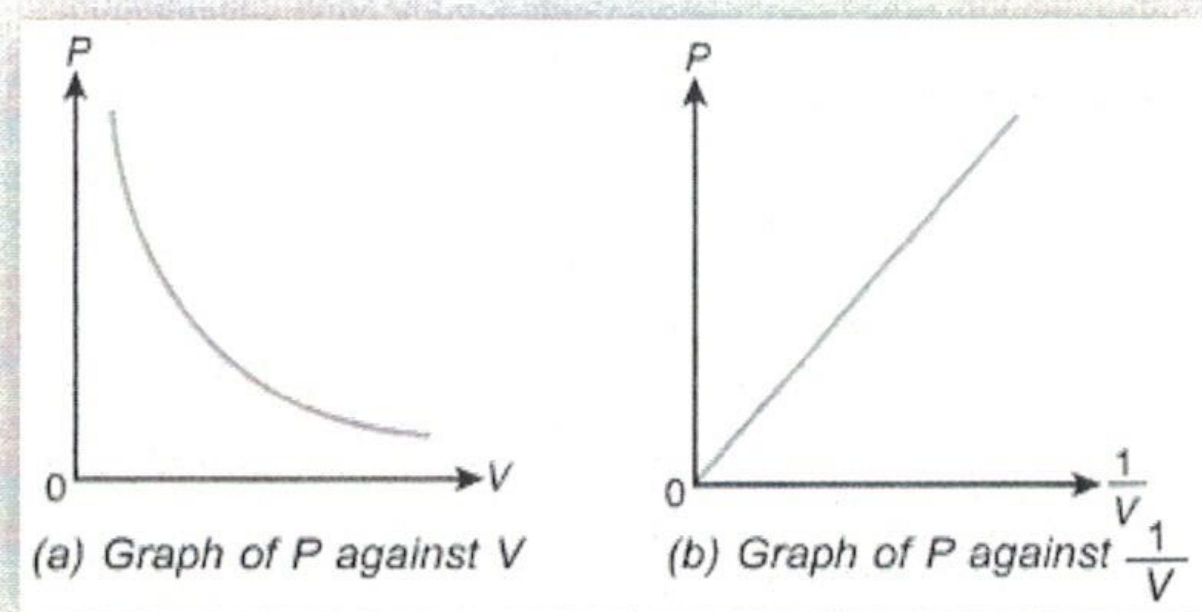
- The ***temperature*** of a gas is related to ***the average kinetic energy of the molecules. The higher the temperature, the greater the average kinetic energy*** and so the faster the average speed of the molecules

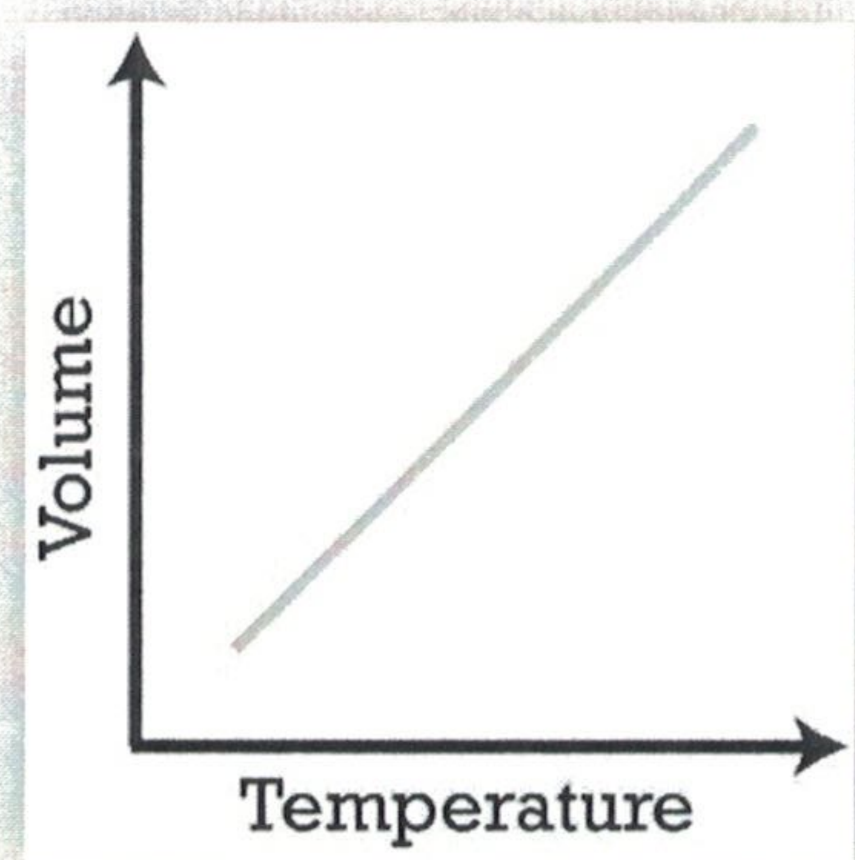
- ***Gases*** exert ***pressure*** on a container due to ***collisions*** between ***gas molecules*** and the ***wall.*** When the molecules rebound off the walls, ***they change direction*** so their **velocity** and therefore **momentum** changes. This means they exert a **force** because force is equal to the change in momentum over time.

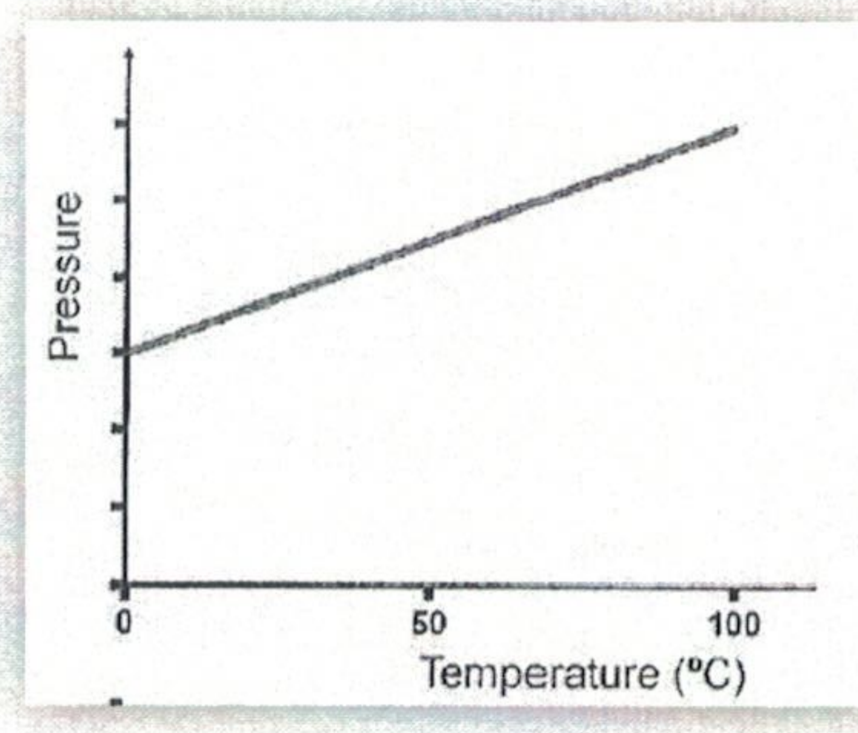
  - At a constant volume, if the ***temperature increases***, the ***pressure increases*** because the ***molecules*** move ***faster*** so they ***collide harder*** and more frequently with the walls

- At a constant temperature, if the ***volume increases***, the ***pressure decreases*** because the molecules **collide less** frequently with the walls.

$$P \propto \frac{1}{V} \qquad P_1V_1=P_2V_2$$

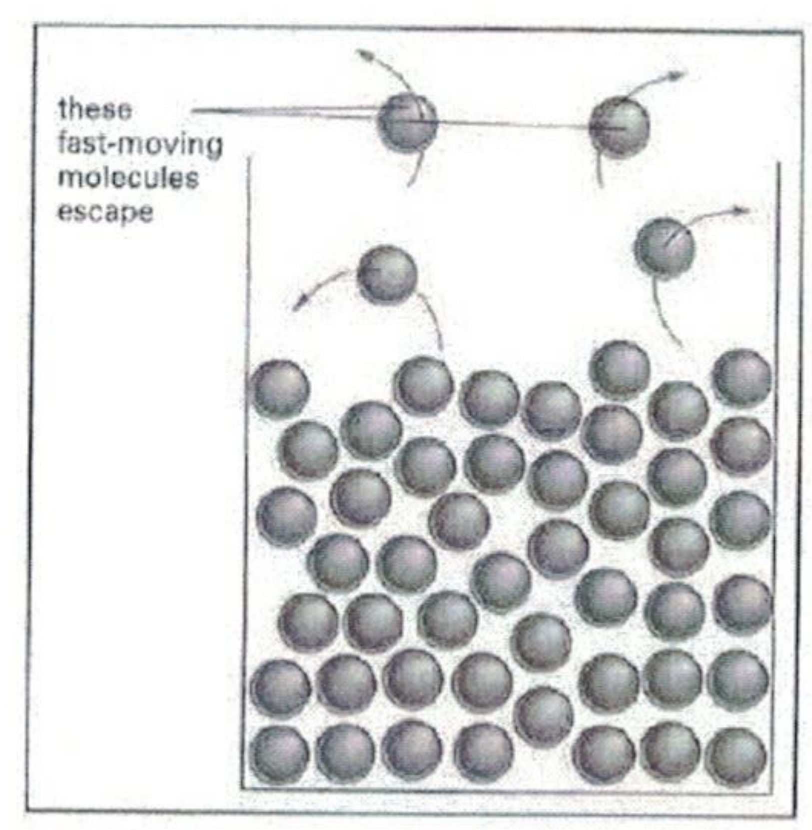






Evaporation

- Evaporation is the ***escape of molecules with higher energy*** from the ***surfaces of liquids***.
- After they escape, the ***remaining molecules have a lower average kinetic*** energy which means ***the temperature is lower***



To increase the rate of evaporation

1. **Increase temperature**: more higher energy molecules
2. **Increase surface area**: more molecules at the surface
3. **Draught**: molecules are removed before returning to the liquid

Evaporation	Boiling
Surface molecule only	Whole the liquid
Any Temperature	Specific Temperature
No Bubbles	Bubbles

Thermal expansion

When something is heated, it ***expands*** because the molecules take up more space

- When a **solid** is **heated**, the molecules **vibrate** more but stay in place, so therelative order of magnitude of the expansion is small.
- When a ***liquid*** is ***heated***, it ***expands*** for the same reason as a solid**, *butthe intermolecular forces are less so it expands more.***
- When a ***gas*** is ***heated***, the ***molecules move faster and further apart***, so the relative order of magnitude of the expansion is the greatest.

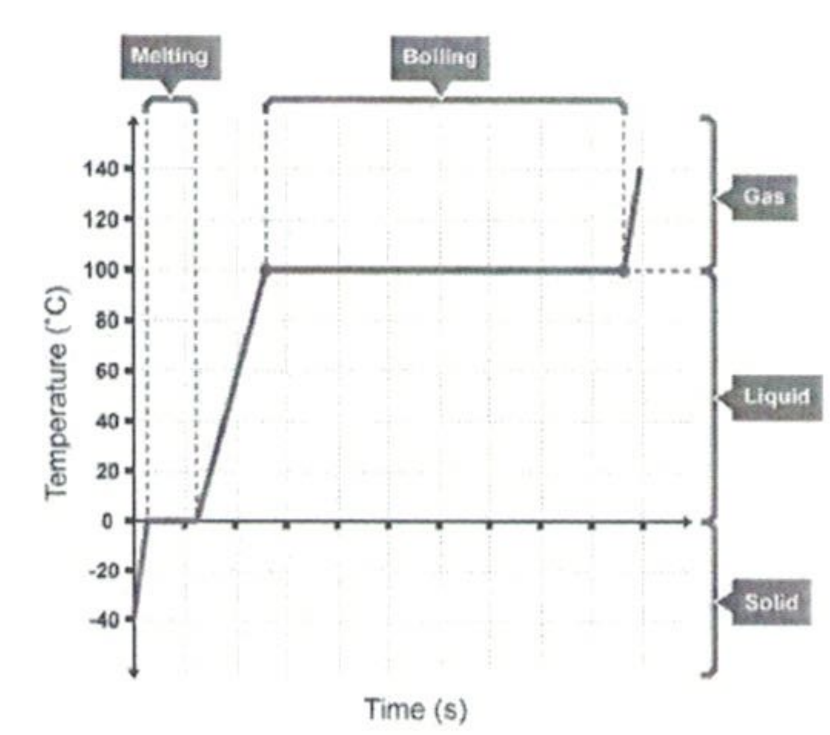
Some applications and consequences of thermal expansion include

- ***Railway tracks*** having small ***gaps*** so that they don't buckle when they***expand***
- The ***liquid in a thermometer expands*** with temperature and rises up theglass
- **Bimetallic strips**: Strips of iron and copper or brass.

brass expands more than the Iron. It is mostly used in fire alarm and thermostat (metal).

Heating curve

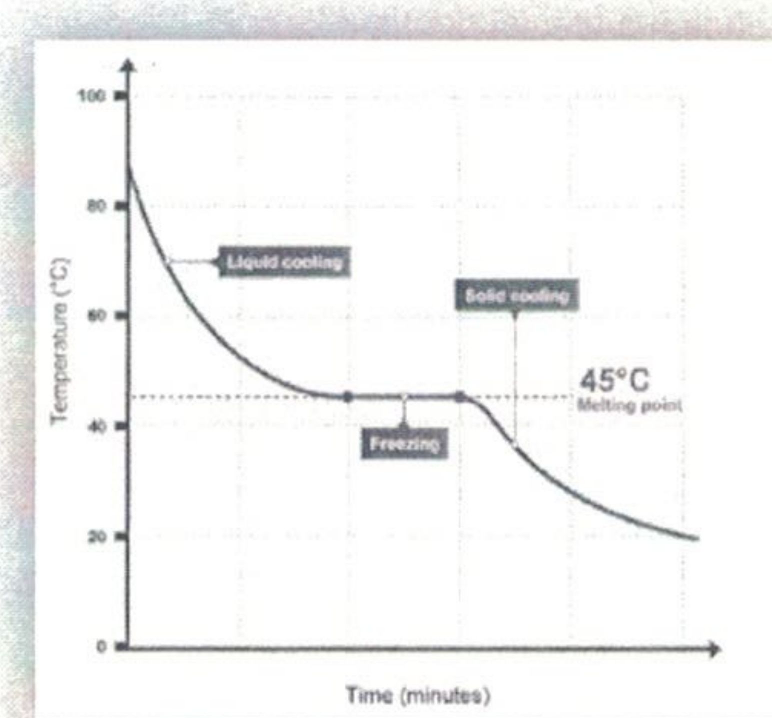
- The graph is **horizontal** at two places. These are where energy is being used to **break the bonds** between the particles to change the state, rather than increase the speed of the particles (and so to increase the temperature).



The **longer the horizontal** line, the more energy has been used to cause the change of state **(boiling)**

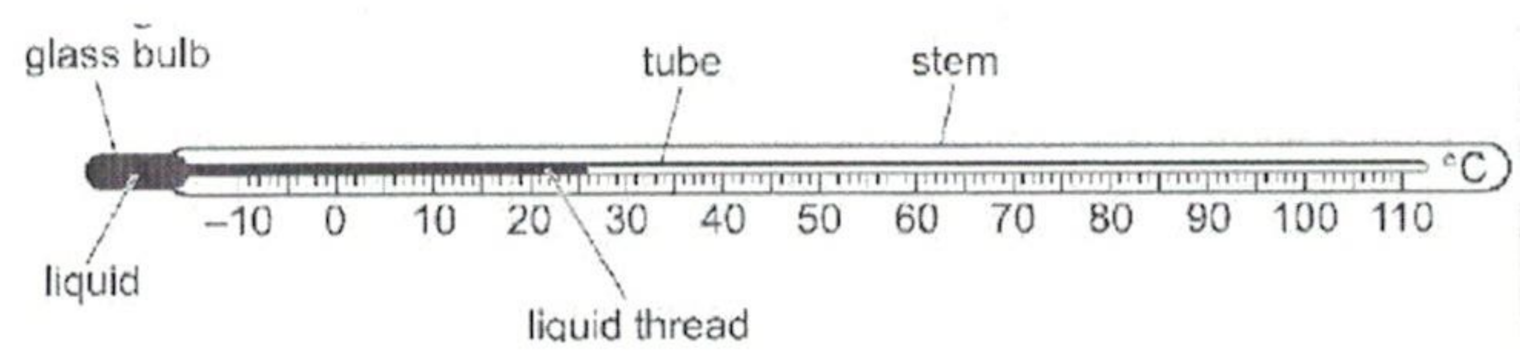
Cooling curve

- during condensing and freezing, internal **energy decreases** as the motion of particles decreases and **new bonds** are formed
- **Horizontal** line Freezing (**Solidifying**)
- The more **stepper** Graph the more **rate** of **cooling**



Liquid-in-glass thermometer

- As temperature ***rises*** or ***falls***, the liquid ***expands*** or ***contracts***.
- Amount of ***expansion*** can be matched to temperature on a ***scale***.



Sensitivity, range and linearity

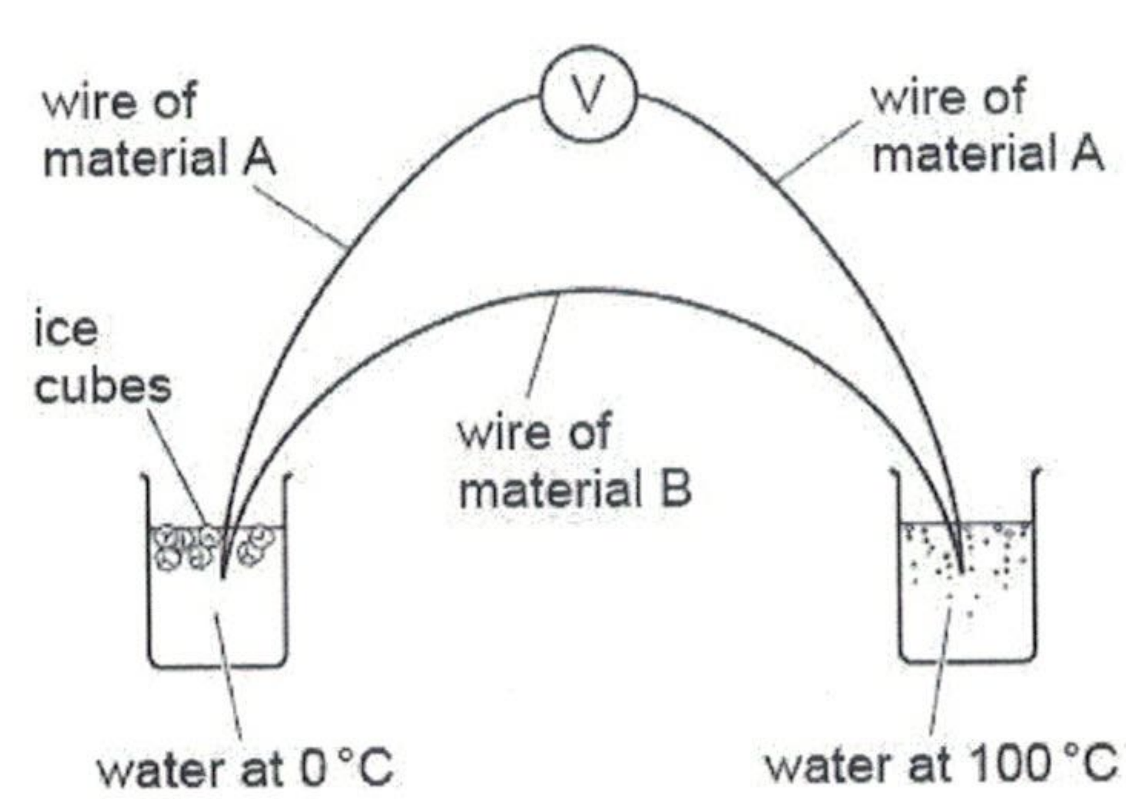
- <u>**Sensitivity**</u> is the change in **length** per change in **temperature**.
  - ✓ To **increase** the **sensitivity** of a thermometer, use a **bigger bulb** or **narrower inner tube.**
- <u>**Range**</u> is **the difference between maximum and minimum temperatures.**
  - ✓ To **increase** the **range** of a thermometer, use **a wider inner tube** or a **longer stem.**
- <u>**Linearity**</u> is when a given **change in temperature** causes the same **change in length.**

Fixed points

Are used to calibrate thermometers For example, the fixed points of the Celsius scale are the ***melting point*** and the ***boiling point*** of water.

Thermocouple

- Contains ***two different metals*** which meet
- The ***temperature difference*** between them causes a tiny ***voltage*** which makes a current flow and reading of voltmeter is ***calibrated***

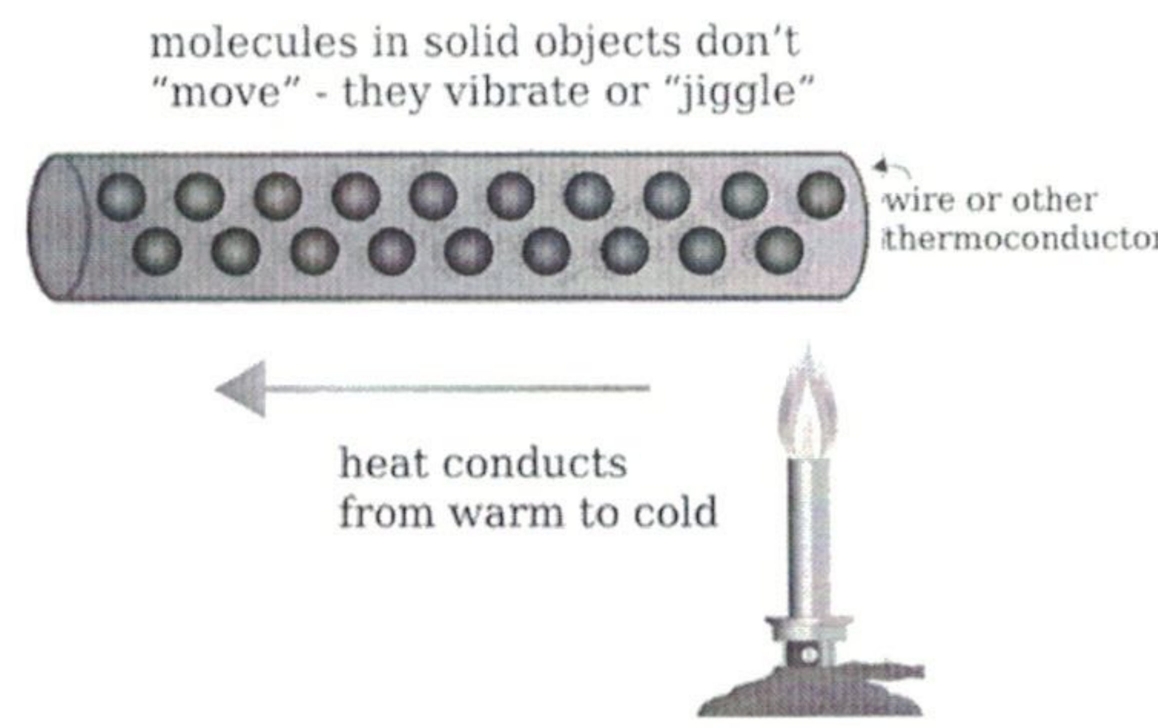


Advantages of a thermocouple

1. High and low temperature (***wide range***)
2. Remote temperature ***sensing***
3. ***Solid surfaces*** temperature measurement
4. ***Rapidly changing*** Temperature

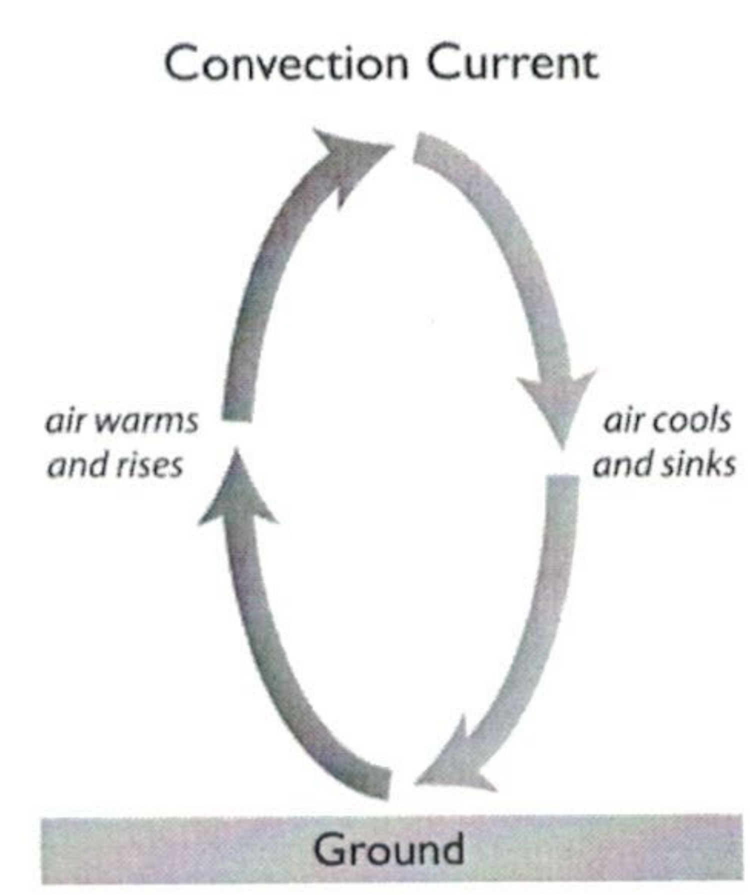
Thermal process

Conduction



- **Thermal energy** in **solids** and **liquids** can be **transferred** by **conduction.**
- **Non-metals** are usually **poor conductors** known as **insulators.** As a non-metal is heated up, the **molecules vibrate** more and cause adjacent molecules to **vibrate** more also, transferring heat energy from **hot** parts to **cooler** parts.
- **Metals** are usually **good conductors.** The **electrons** can leave the atoms and move Freely among positively charged ions As the **metal** is **heated**, the **ions** and **electrons vibrate more.** The free electrons **collide** with **ions** throughout the metal and transfer heat energy from hot parts to cooler parts.

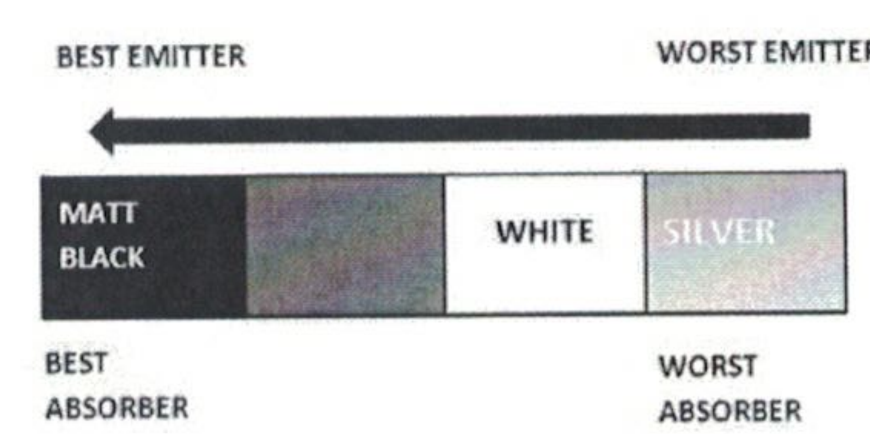
Convection



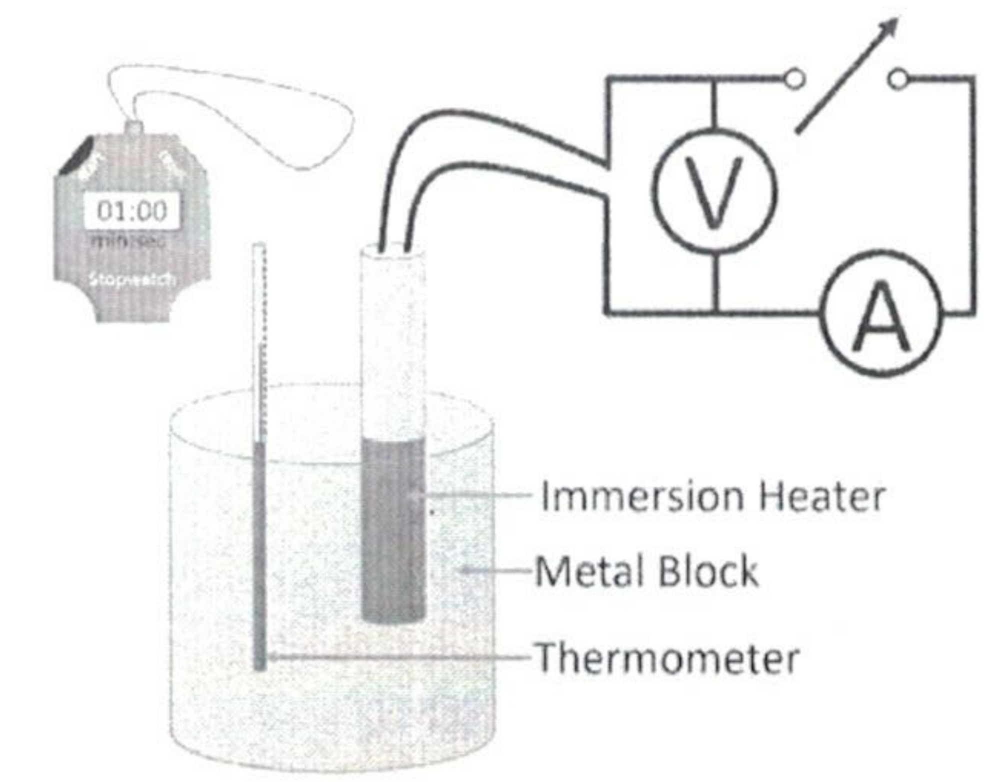
- Thermal energy in **fluids** (liquids and gases) can be transferred by **convection.**
- Convection occurs when molecules in a **fluid with high thermal energy move to an area with low thermal energy.**
- When part of **a fluid is heated, it expands and becomes less dense.** It therefore **rises up** to less dense areas in the **fluid Denser, colder fluid falls down to take its place.**
- Examples of **convection** include **water** boilers and **hot air balloons.**

Radiation

- Thermal energy is also transferred by **infrared radiation** which **does not require a medium (vacuum)**
- **Black** bodies with a dull texture are the **best absorbers and emitters of radiation. White** bodies with a shiny texture are the **best reflectors of radiation.**
- The **higher the temperature** and the greater the surface area of a body the **more infrared radiation emitted.**



Specific heat capacity



- the energy required to **change the temperature** of an object by **one degree Celsius per kilogram** of mass
- It is measured in joules per kilogram per degree Celsius (**J/kg °C**).

Change in thermal energy = mass x S.H.C. x temperature rise

$$\Delta Q = m \times c \times \Delta T$$

- For best results, **insulate** the block to **prevent heat loss** to the surroundings

Heat capacity (Thermal Capacity)

- It is the amount of energy needed to raise the temperature of a *whole body* by 1 Kelvin (or 1 ºC). It is measured in ***J/ºC*** or ***J/K***.

Heat capacity (Thermal Capacity) = m c

Specific latent heat

- It is the amount of heat energy needed to change 1 kg of a substance from ***one state to another*** without any temperature change It is measured in ***J/kg*** or ***J/g***

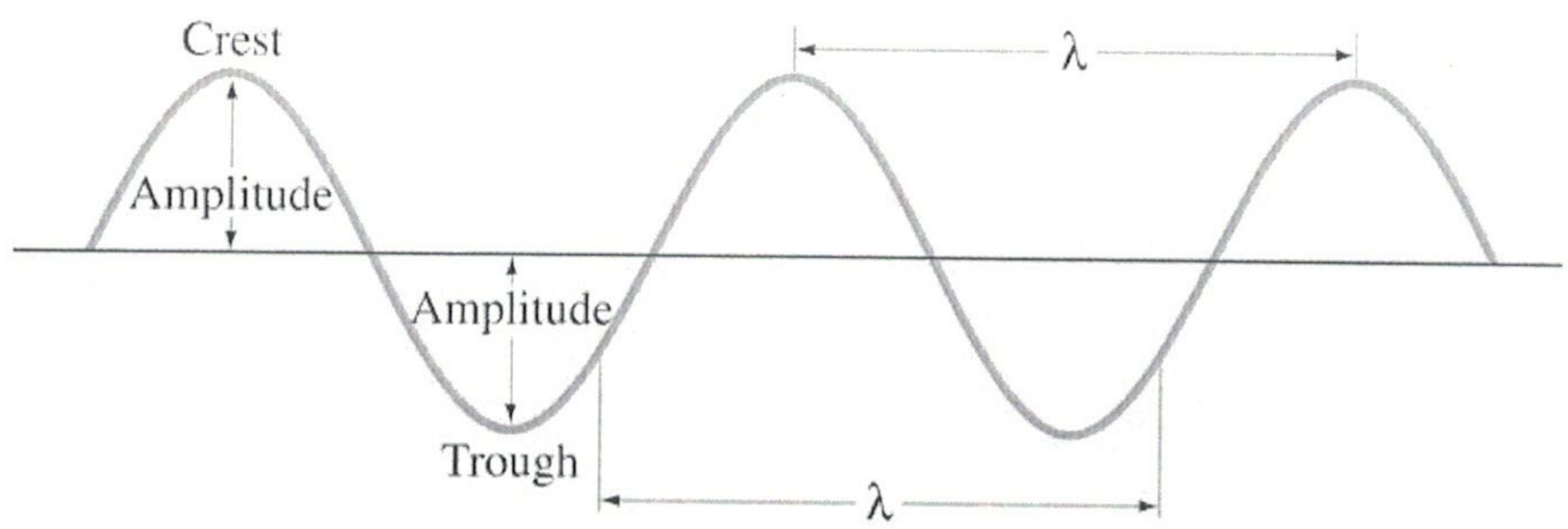
$$E = m\,L$$

Topic three waves
Summary Notes

General wave properties

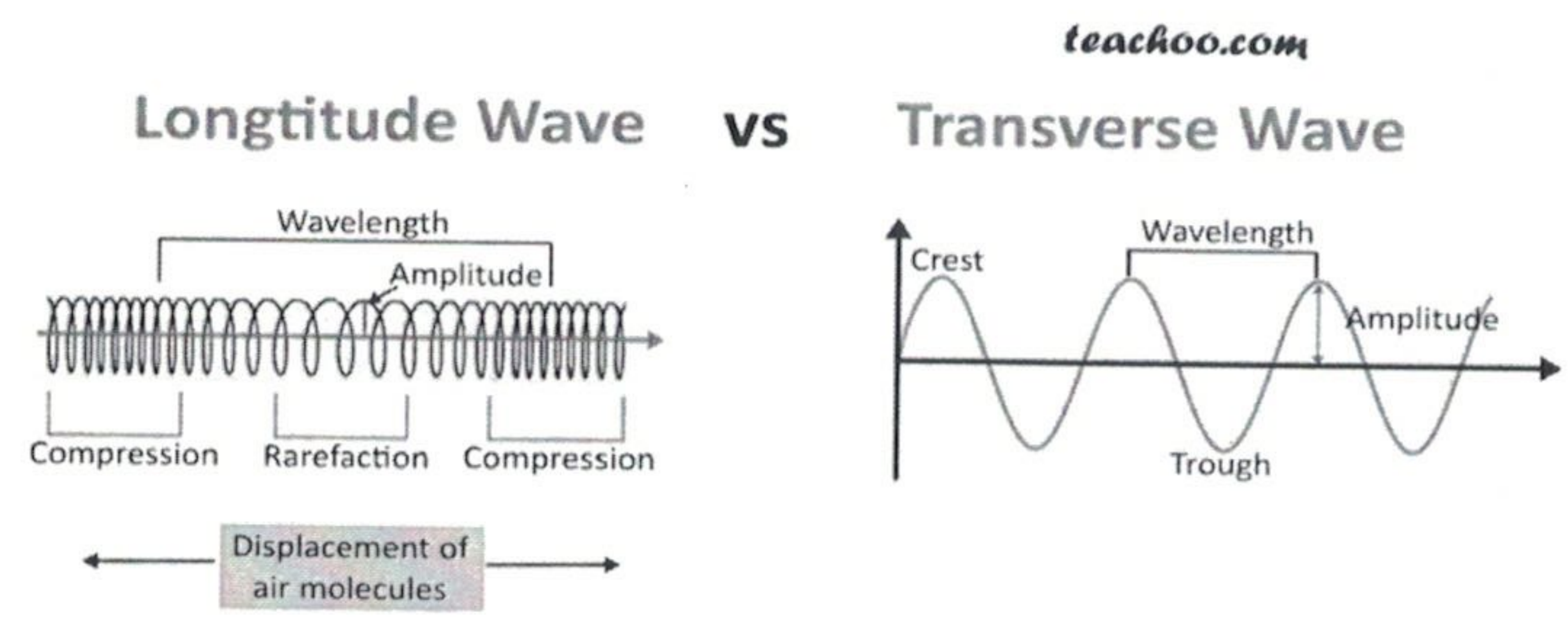
Waves **transfer energy** without transferring matter; particles oscillate about a fixed point.

- **Amplitude** – the distance from the equilibrium position to the maximum displacement
- **Wavelength** – the distance between a point on one wave and the same point on the next wave
- **Frequency** – the number of waves that pass a single point per second
- **Speed** – the distance travelled by a wave each second



- ✓ **Speed is related to frequency and wavelength by:** ***speed=frequency* × *wavelength v=fλ***

Types of waves

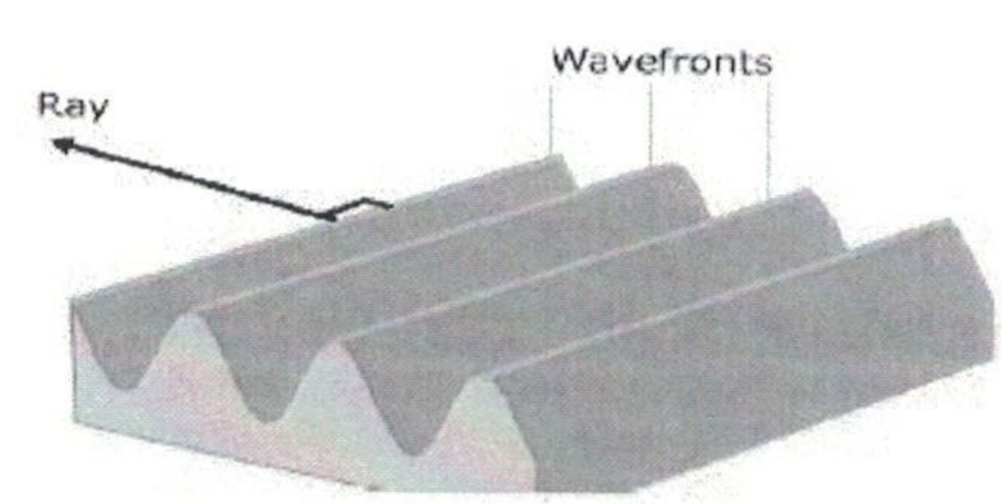


- ✓ **Transverse waves**
  - Has peaks and troughs
  - Vibrations are at **right angles** to the direction of travel
  - An example is **light**

- ✓ **Longitudinal waves**
  - Consists of compressions (particles pushed together) and rarefactions (particles moved apart)
  - Vibrations are in the **same direction(parallel)** the direction of travel
  - An example is **sound**

A wave front

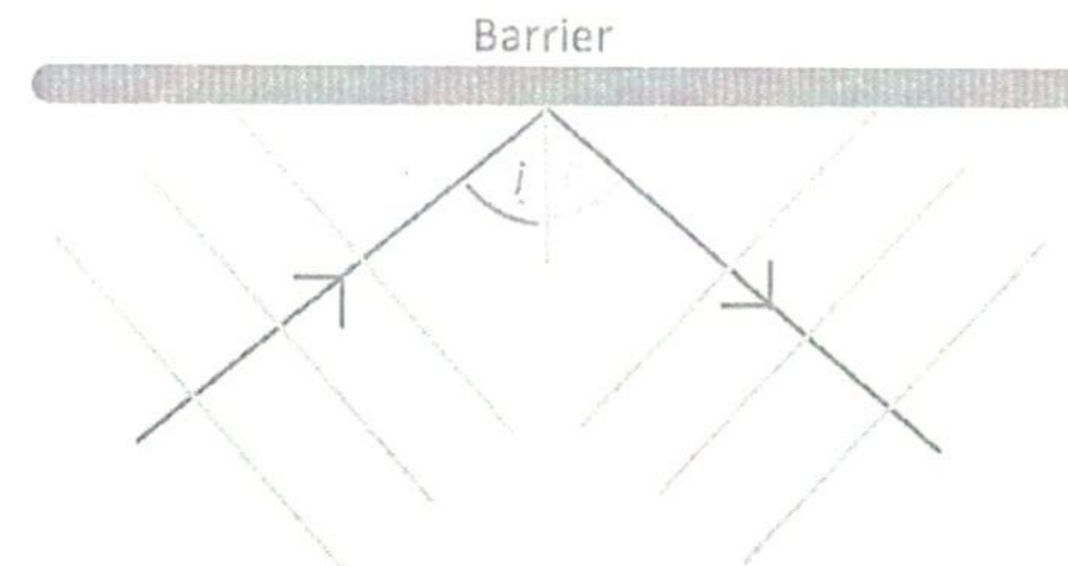
- Is a surface containing points affected in the same way by a wave at a given time such as crests or troughs



Reflection

- Waves reflect off smooth, plane surfaces rather than getting absorbed
- Angle of **incidence =** angle of **reflection**

- Rough surfaces scatter the light in all directions, so they appear matte and unreflective
- Frequency, wavelength, and speed are all **unchanged**



Reflection of Light

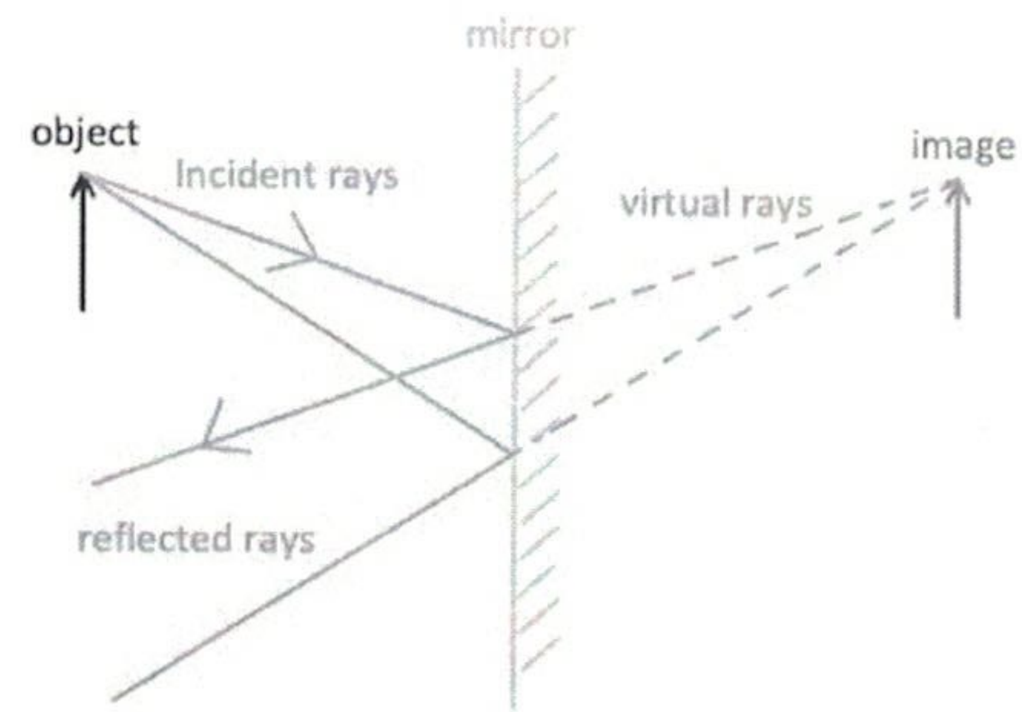
When light is reflected off a plane mirror, it forms an image with these characteristics

✓ ***Upright***

✓ ***Same distance*** from the mirror as the object

✓ ***Same size***

✓ ***Virtual***



Refraction

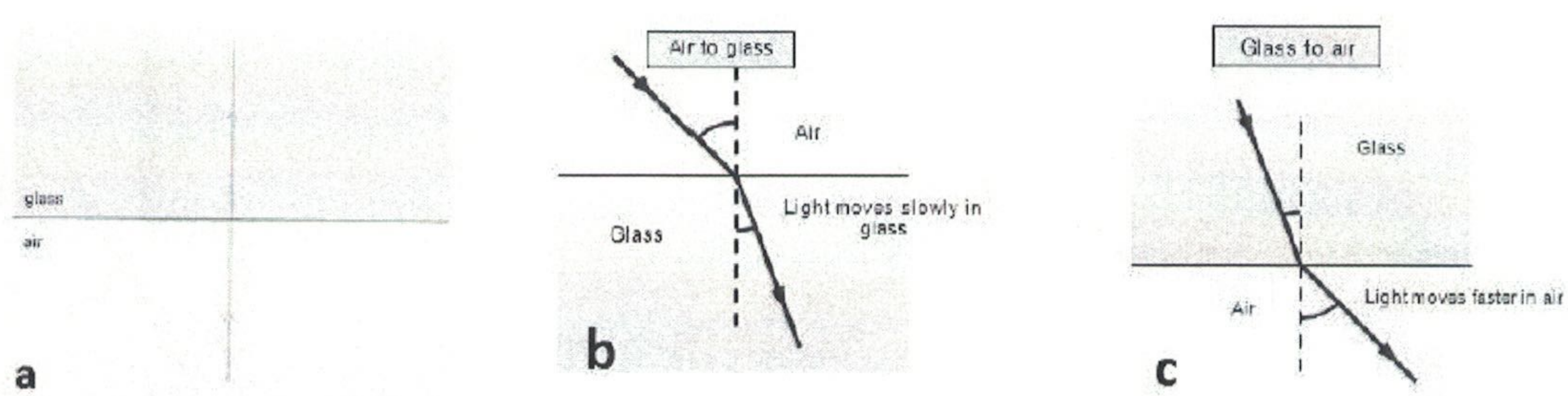
is the ***change*** in both speed and wavelength of a wave as it ***travels from one medium to another***

<u>**Remember**</u>

a) If the ***incident ray is lying along the normal*** (the ray is perpendicular to the boundary or the angle of incidence = zero), then ***no bending occurs***.

b) If the wave comes from a ***less dense medium to a more dense medium***, then its ***speed decreases*** and it ***bends towards the normal*** (i>r).

c) If the wave comes from a ***more dense medium to a less dense medium***, then its ***speed increases*** and it ***bends away from the normal*** (i<r).



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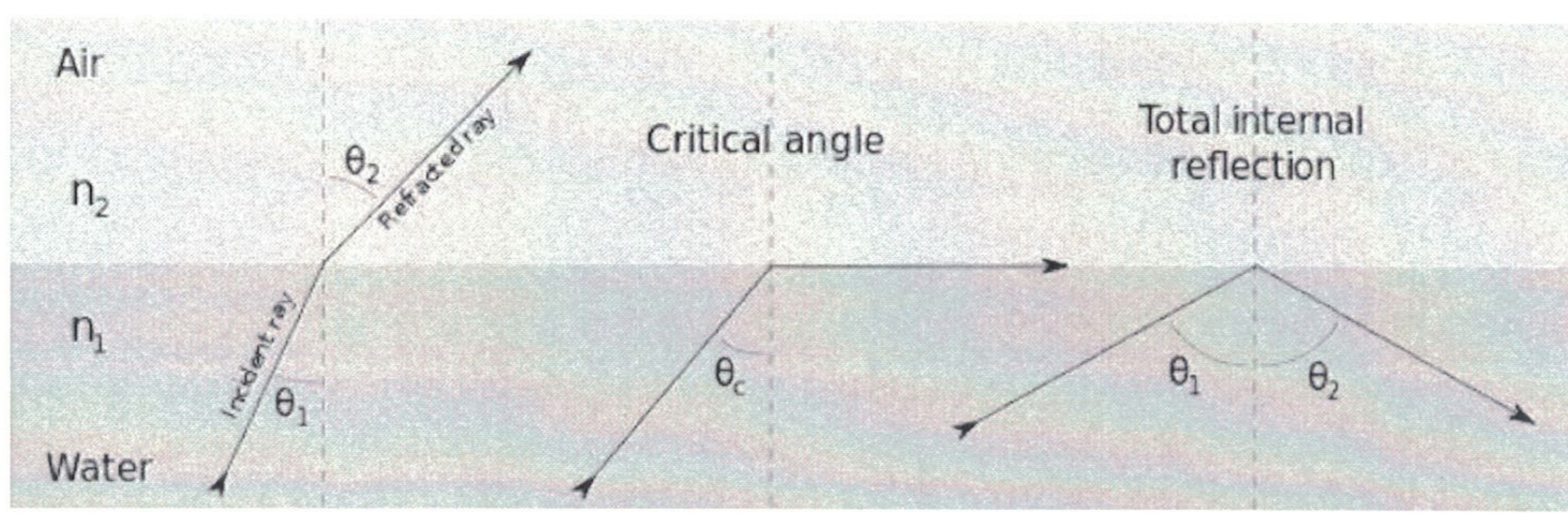
✓ In all cases, the ***frequency*** stays the ***same*** but the ***wavelength changes***.

- **The refractive index** n of a medium is defined as the ratio between the speed of light in a vacuum and the speed of light in the medium
- **Snell's law** relates the angle of incidence and the angle of refraction to the refractive
- The **critical angle** can be related to the refractive

$$n = \frac{1}{\sin c} \qquad n = \frac{\sin i}{\sin r} \qquad n = \frac{C}{V}$$

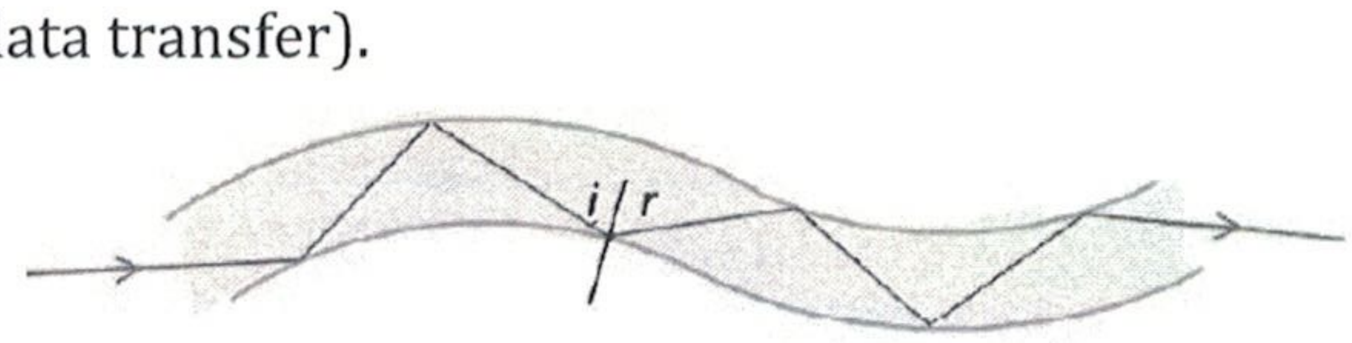
Total internal reflection:

- At a certain **angle of incidence** called the **critical angle**, the light will travel along the boundary between the two media.
- **Total internal reflection** occurs when the angle of incidence is **greater** than the critical angle and the light reflects back into the medium.
- For total internal reflection to occur, **the light must also be travelling from a more optically dense medium** into a less optically dense medium (most common example is glass to air).



Optical fibers

- An optical fibre is a long thin rod of glass surrounded by cladding which uses total internal reflection to transfer information by light, even when bent.
- Extensive use in medicine (**endoscopes**, inside-body flexible cameras) and communications
(high speed data transfer).



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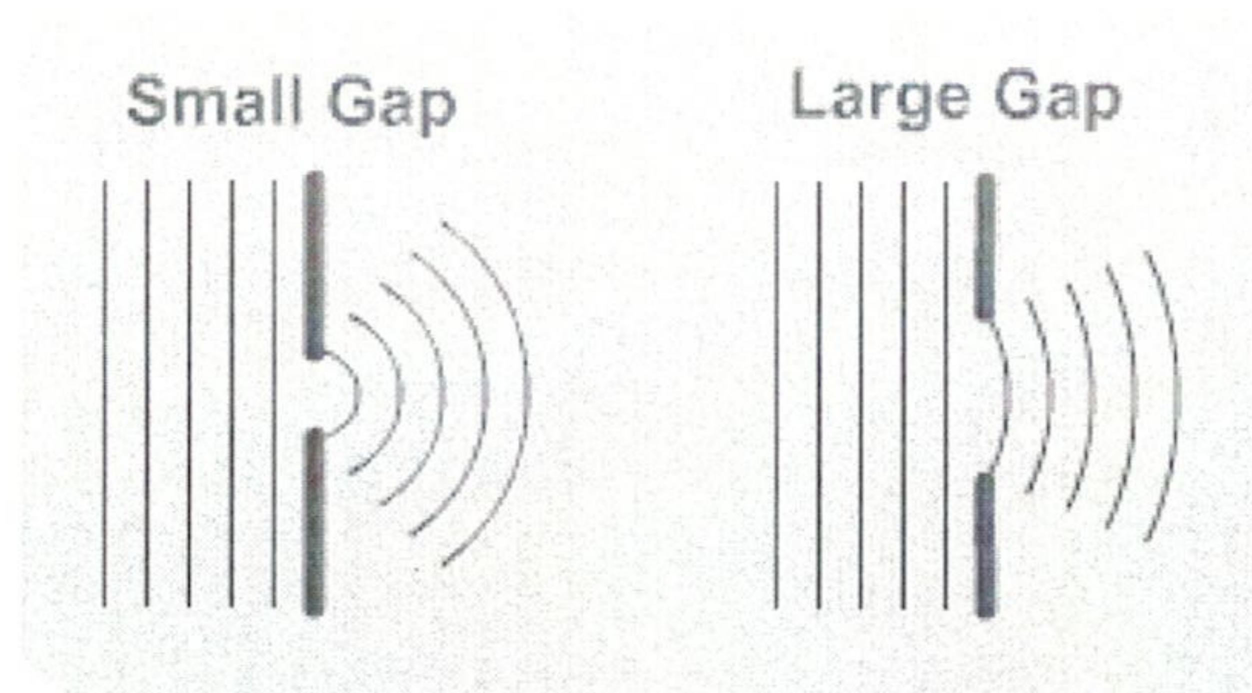
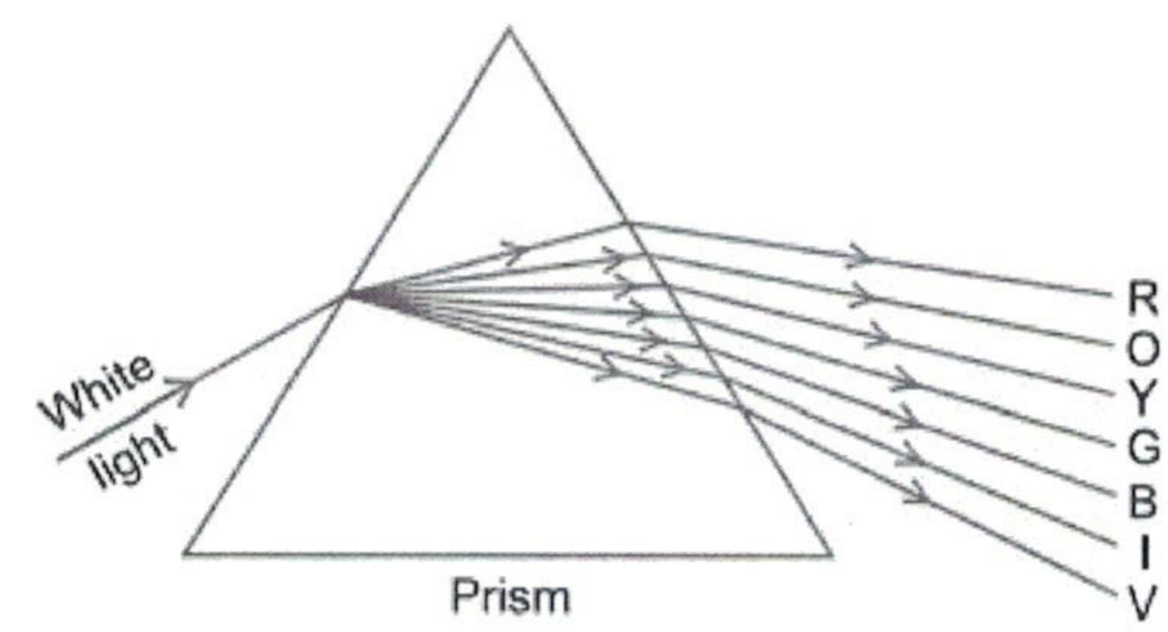
Diffraction



- Waves spread out when they go around the sides of an obstacle or through a **gap**
- The **narrower the gap or the greater the wavelength**, the **more** the **diffraction**
- **Frequency**, **wavelength**, and speed are all **unchanged**

Dispersion of light

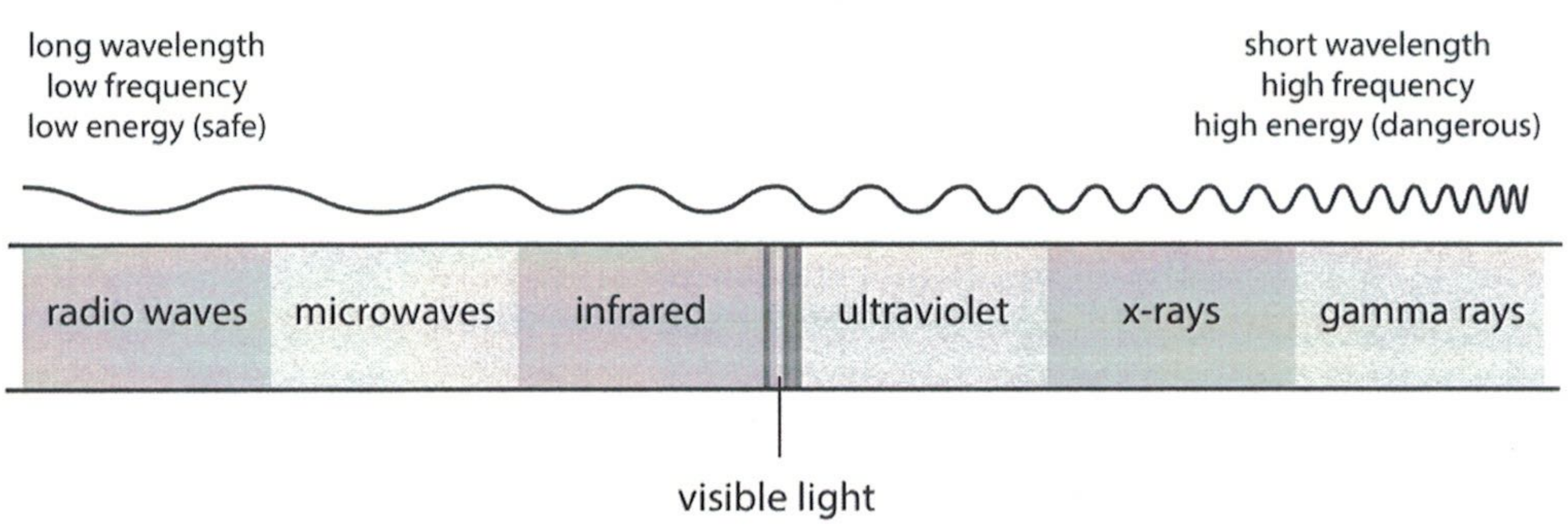
- When **white light** is passed through a **glass prism, it splits up** into its constituent **colors.** This happens **because the different colors travel at different speeds in the glass**, so they refract by different amounts.
- The **seven colors** in order of decreasing wavelength are red, orange, yellow, green, blue, indigo and violet (ROYGBIV).
- **The greater the wavelength, the slower the speed in glass** and the greater the refractive index.
- Light of a single frequency is described as **monochromatic**



Electromagnetic spectrum

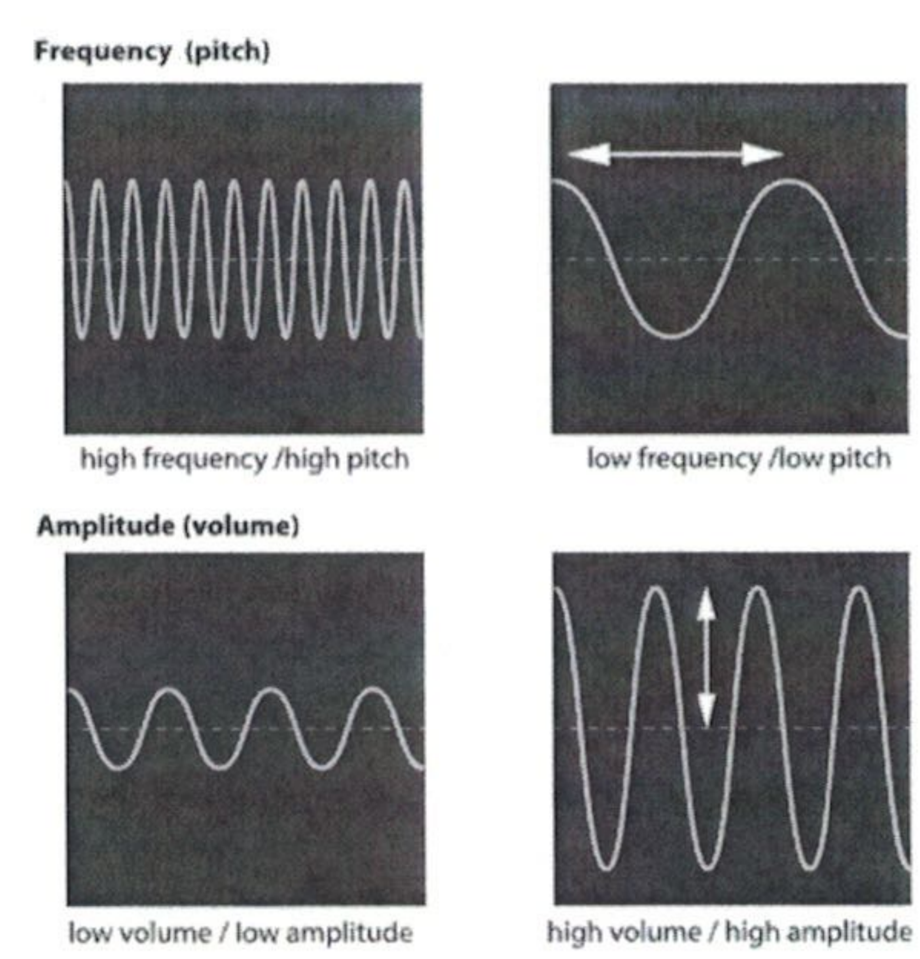
Properties of electromagnetic waves

- **Transverse** waves
- Do not need a medium (travel in **vacuum**)
- All electromagnetic waves travel with the **same speed** of 3.0 x 108 ms-1 in a vacuum and approximately the same speed in air.



Region of E.M. spectrum	Uses	Dangers
radio	broadcasting, communication	-
microwaves	cooking, satellite communication	internal heating of body tissue
infrared	heating, night vision	skin burns
visible	photography, fiber-optic communication	skin burns
ultraviolet	fluorescent lamps and inks	blindness, damage to surface cells
x-rays	observing internal structures, for medicine and materials	damage to internal cells and organs
gamma rays	sterilizing food and medical equipment	mutation of cells, cancer

Sound Waves



Sound waves are **longitudinal** waves created by vibrating sources. A medium is needed to transmit sound waves (such as air).

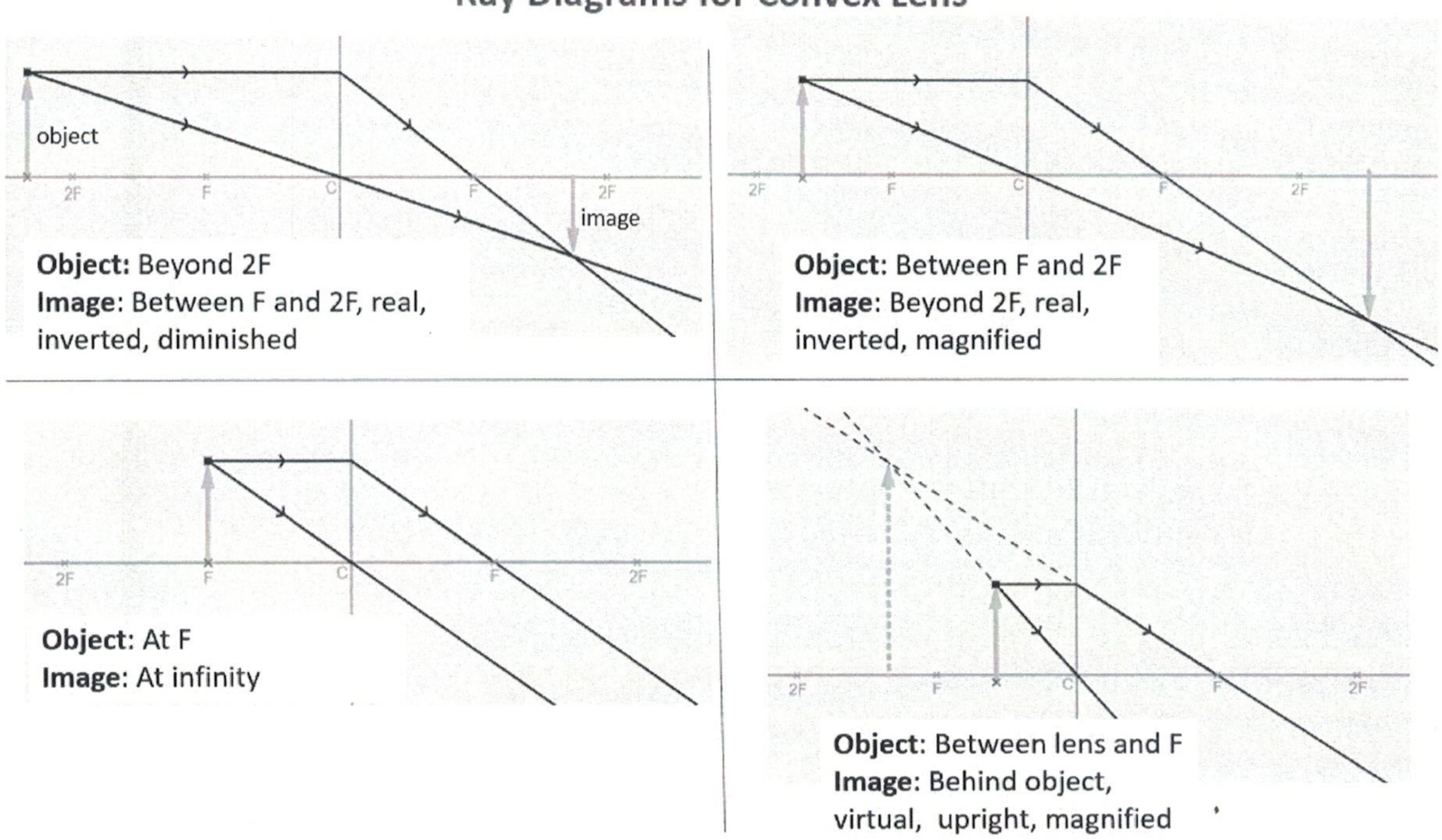
- ✓ The greater the **amplitude** of a sound wave, the **louder** it is.
- ✓ The greater the **frequency** of a sound wave, the higher its **pitch**

- **The range of audible frequencies** for a healthy **human** ear is **20 Hz to 20000 Hz**. Ultrasound is sound with a frequency greater than 20000 Hz
  The speed of sound in **air** is approximately **340 m/s. In liquids 1500 m/s** and **solids 5000 m/s** the particles are much closer together. This means that they are able to transfer sound energy more quickly. So **sound travels faster in solids more than liquids more than gases**

Converging lens

- A converging lens is a transparent block which brings light rays together at a point called the **principal focus** by utilizing refraction.
- The **focal length** is the distance between the center of the lens and the principal focus.
- The **image** formed by a converging lens can be either real or virtual.
- **Real images** are formed when the distance of the object from the center of the lens is greater than the focal length. They are images where light actually converges to a position and can be projected onto a screen.
- **Virtual images** are formed when the distance of the object from the center of the lens is smaller than the focal length. They are images where light only appears to have converged and they cannot be projected onto a screen.

Ray Diagrams for Convex Lens



- The image formed is enlarged/same size/diminished and upright/inverted.
- The image on the left above is diminished and **inverted.**
- The image on the right above is enlarged and **upright.**
- Converging lenses are used in **magnifying glasses** (to enlarge the image).

Topic Four
Electricity and Magnetism
Summary Notes

Magnetism

Magnetic forces are due to **interactions** between magnetic **fields.**

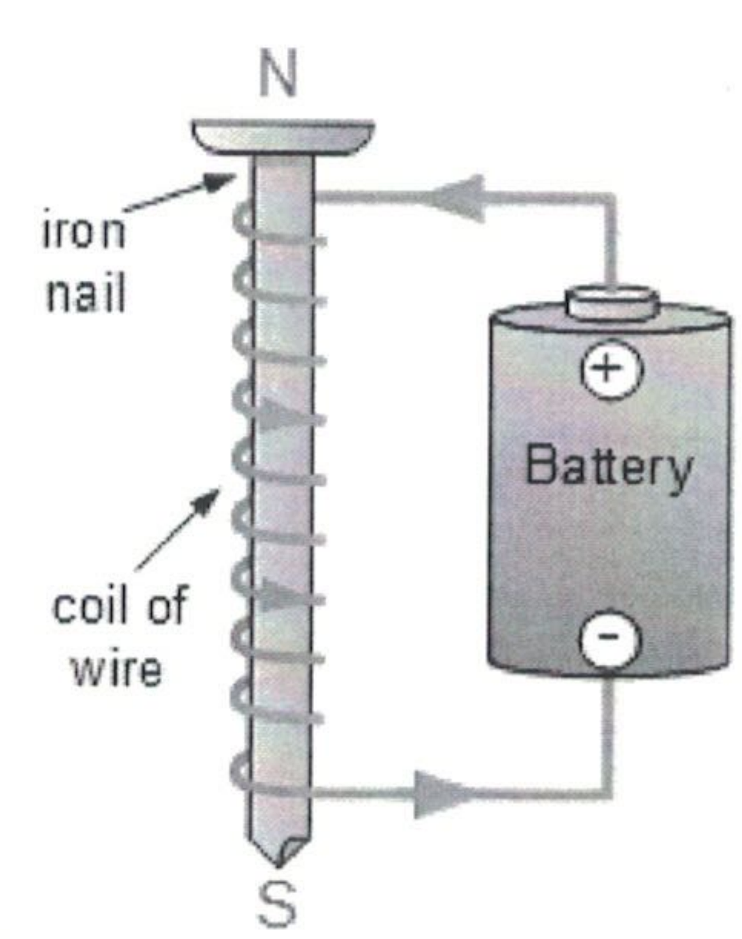
- In a magnet, **like** poles **repel** and **opposite** poles **attract.**
- **Magnetic materials** (ferrous) are materials that are **attracted** to magnets and can **be magnetized**

  (iron , steel, cobalt, nickel)
- **Non-magnetic materials** (non- ferrous) are materials that are **not attracted** to magnets and **cannot** be magnetized (glass, plastic)

  - Magnetic materials can be **magnetized** by **induced magnetism**
- They can be **magnetized** by **stroking** them with a magnet, **hammering** them in a magnetic field, or putting them inside a coil with a **direct current (DC)** through it.
- They can be **demagnetized** by **hammering** them, **heating** them or putting them inside a coil with an **alternating current (AC)** through it.

  - **Magnetic materials** that
- **Permanently** magnetized are described as magnetically **hard** (steel)
- **Temporarily** magnetized are described as magnetically **soft** (soft iron).

Electromagnet



- Consist of a **coil** of wire **wrapped** around a **magnetically soft core** and can be turned **on** and **off.**
- Electromagnets have the ability to be turned on and off so they can be used for situations such as **moving** scrap **metal**

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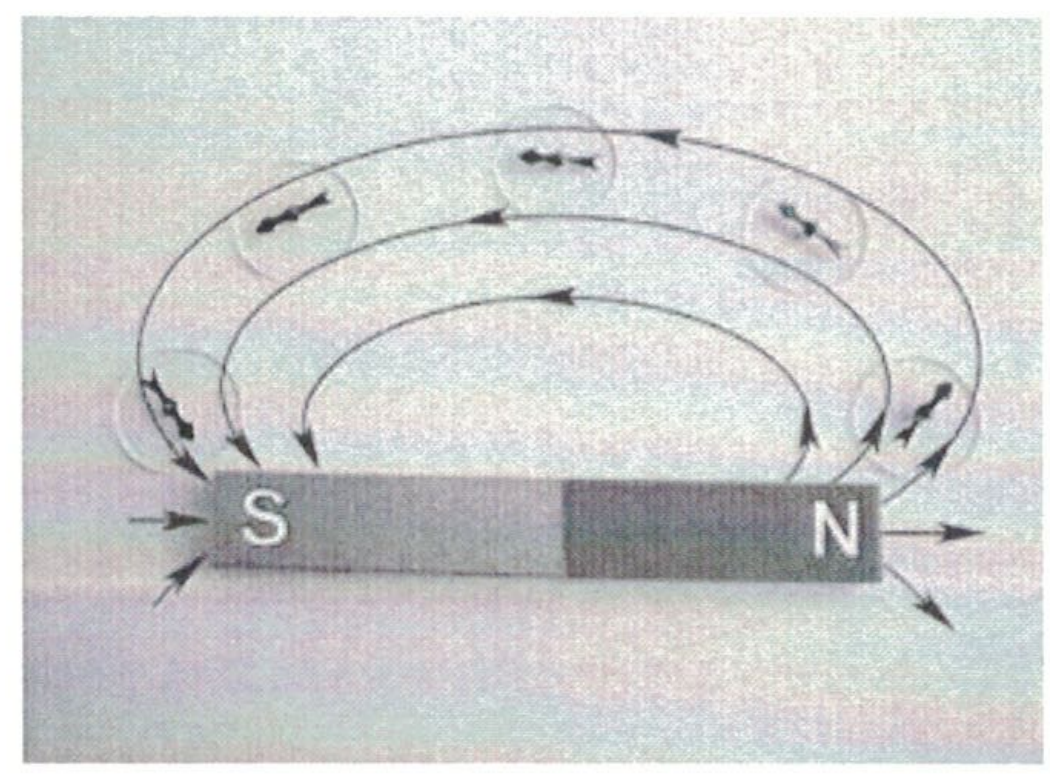
to **increase strength** of electromagnet

- increase **number** of **turn** of coil
- increase **current**
- put **iron** in core of electromagnet

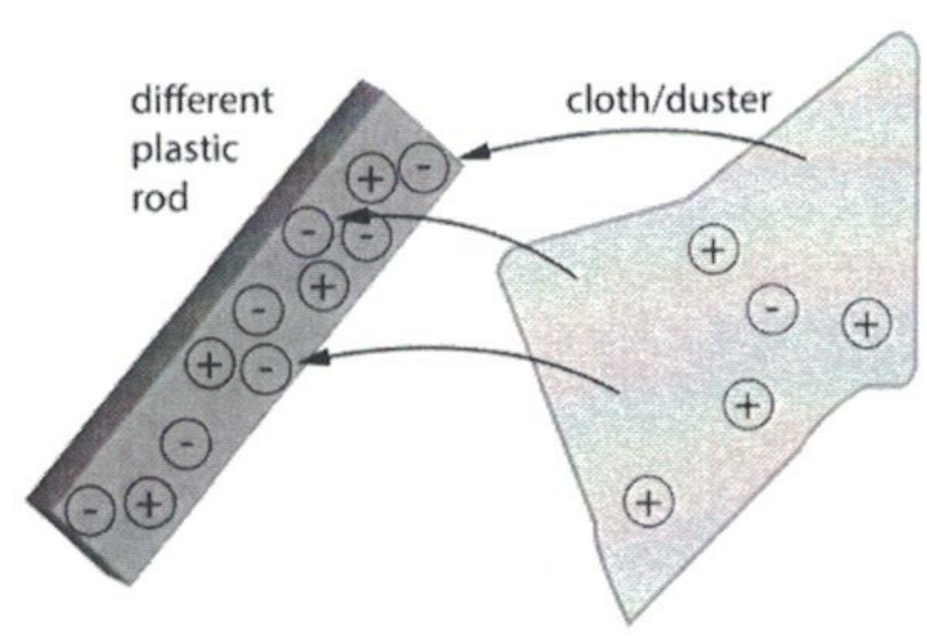
Magnetic fields

- **Field lines** around a bar magnet point from **north** to **south**
- The **direction** of a magnetic **field line** shows the **direction** of the **force** on a north pole at that point.
- Field strength **decreases** with **distance** from the magnet
- Plotting **compasses** are small compasses which **show** the **direction** and shape of a magnetic field.

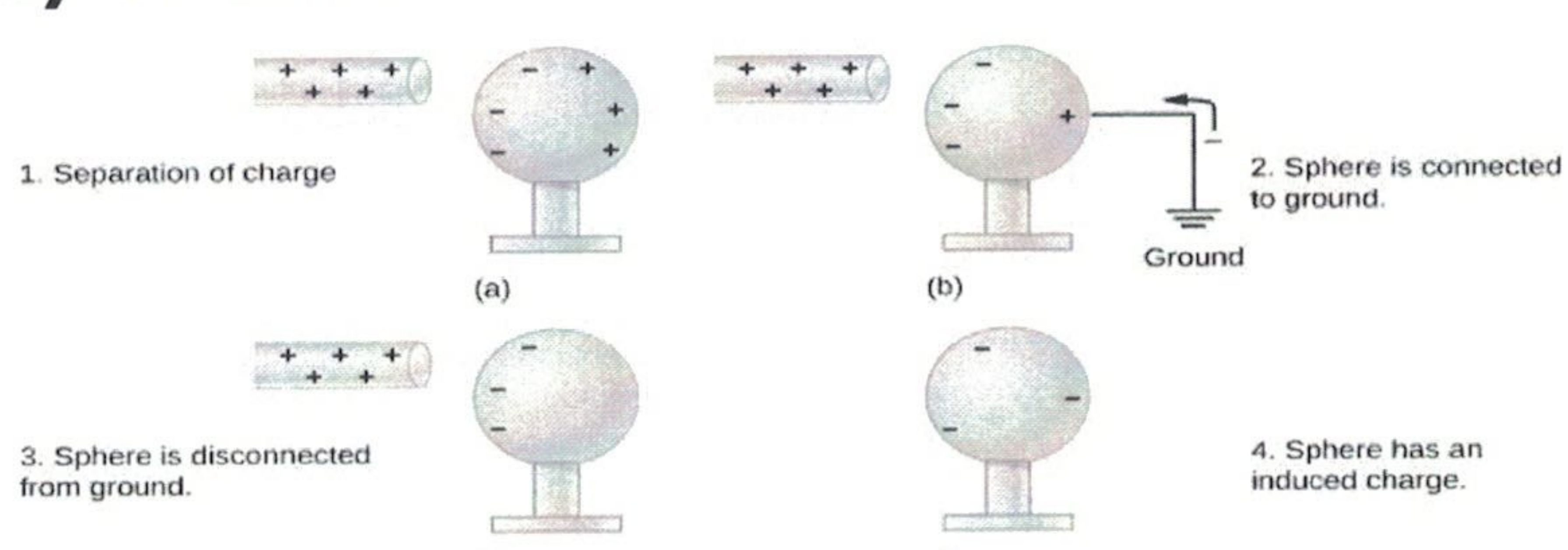


Electric charge

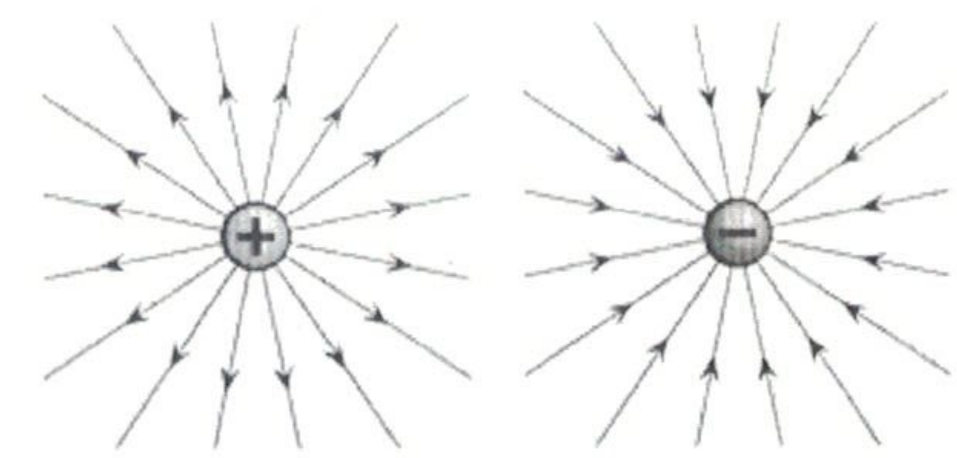
- Charge is measured in **coulombs**. There are **positive** and **negative** charges; **unlike** charges **attract** and **like** charges **repel**.
- Charging a body involves the **addition** or **removal** of **electrons** such (copper)
- **Conductors allow** electrons to **flow** through them
- **insulators** electron **can't** flow through
    - When **two insulators** are **rubbed** together, **electrons move** from one to the other and they become charged. For **example**, when a **rod** is rubbed with a **cloth**, **electrons** are **transferred** from the rod onto the cloth and the rod becomes positively charged



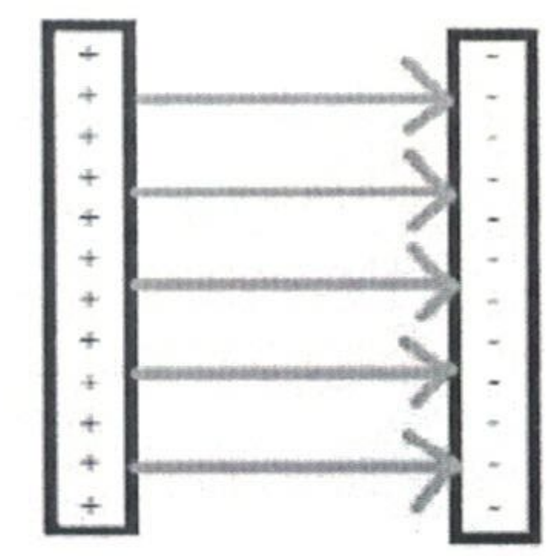
Charging by induction



Electric field



- **Charges** create electric **fields** (regions in which **an electric charge experiences a force**)
- Electric **field** lines point **away** from **positive charges** and **towards negative** charges.
  - The field lines between **two** charged plates go in **straight lines** from the positive plate to the negative plate and are equally spaced apart



Current

- Current **I** is measured in **amps (A)** and is the **rate** of **flow** of **charge** at a point in the circuit.
- The current is given by $I = Q / t$
- It is measured with an **ammeter** placed in **series.**

In metals, current is due to a **flow of electrons.** Because electrons are negatively charged, **conventional** current (which is the rate of flow of positive charge) is in the **opposite** direction to the flow of electrons

Potential difference

- Potential difference **V** is measured in **volts** and is the **work done per unit charge** in moving between two points in a circuit.
- It is measured with a **voltmeter** placed in **parallel**
- The **higher** the **potential difference**, the **greater** the **current**

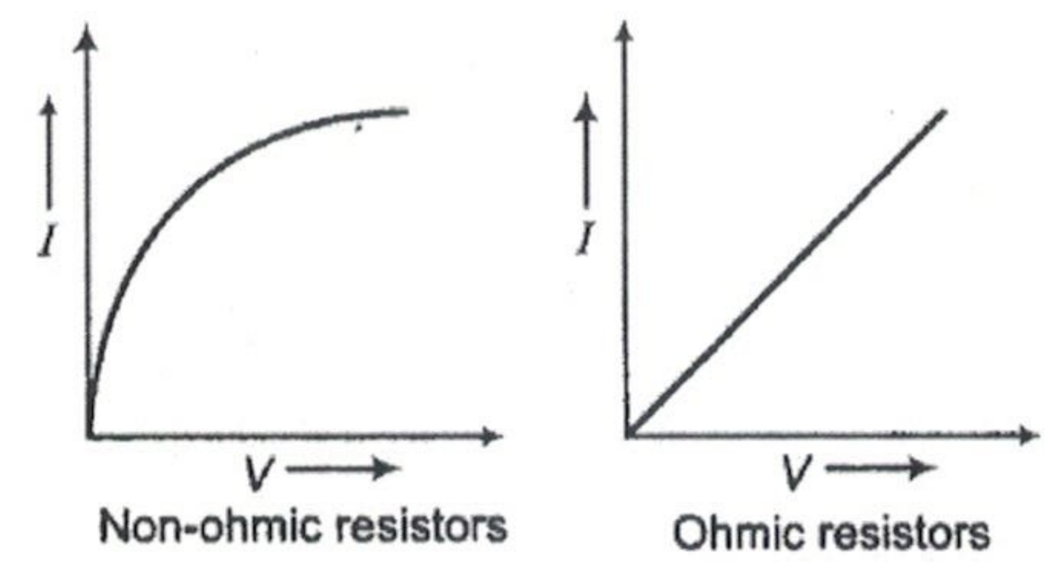
Electromotive force

- **e.m.f** of is the **energy** supplied by the source **per unit charge** in **driving** the charge round a **complete circuit.**

Resistance

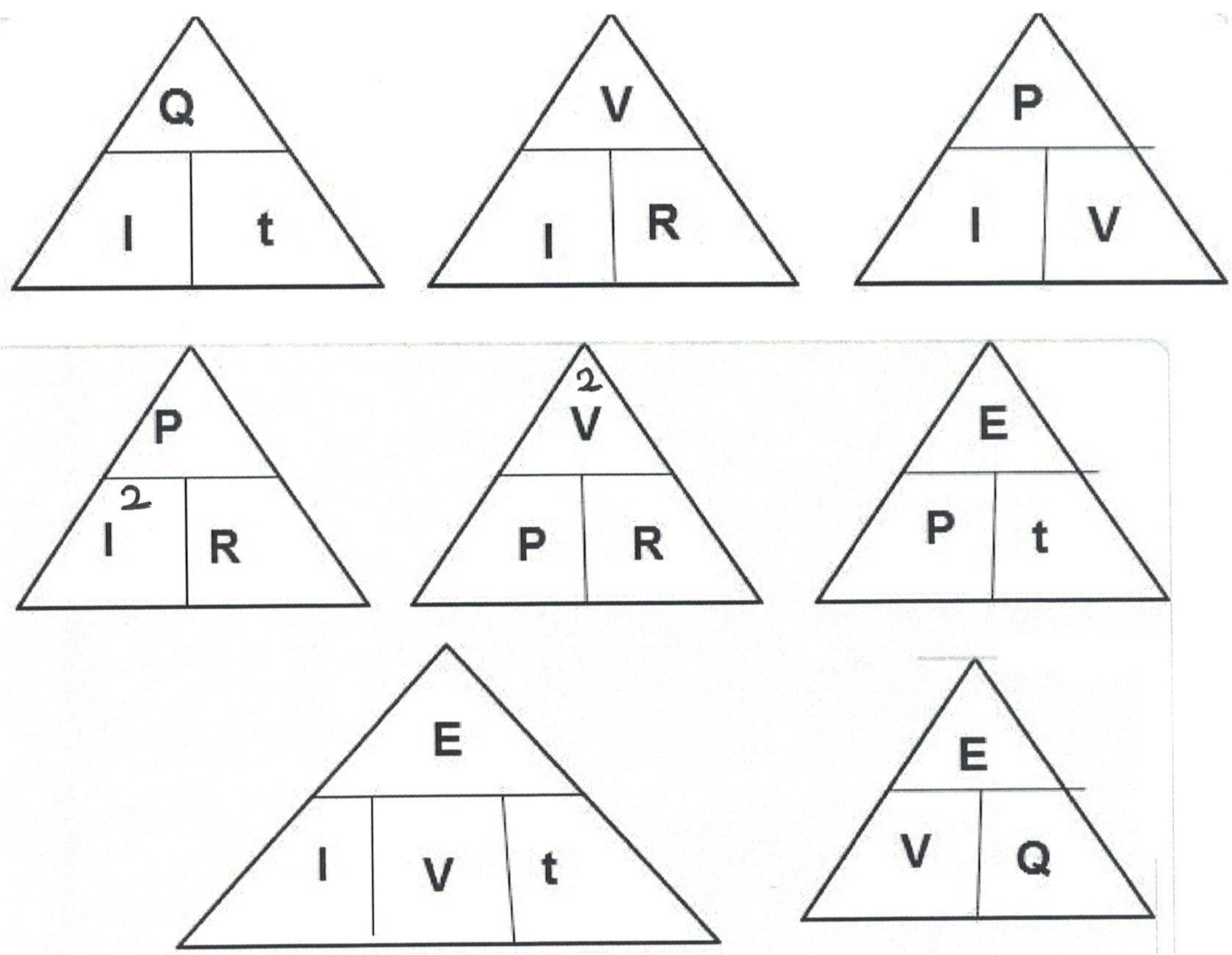
- **Resistance** of a component is given by the **potential difference** across it **divided** by the **current** through it. The **greater** the **resistance**, the **harder** it is for current to **flow** through the component.
- As the **length** of a resistor **increases**, the **resistance increase** (directly proportional)

- As the **diameter** of a resistor **increases**, the **resistance decrease** (inversely proportional to the cross-sectional area)
- In an **ohmic conductor**, the **current** is **directly** proportional to the **voltage** (it has constant resistance).
- In **non-ohmic conductor** (such as a filament lamp), the **resistance changes** as the **voltage** and current **chang**
- As the **current increases** through a **filament lamp**, so **temperature increase** This means **electrons** and ions **vibrate** more and **collide** more, **increasing resistance**



Electrical Energy

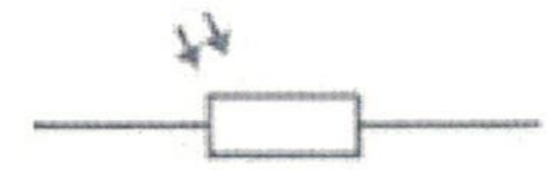
- **Energy** is transferred from **chemical** energy in the **battery** to **electrical** energy used by **circuit** components and then to the surroundings.
- The **power** of a component is given by **P = I V**



Thermistor

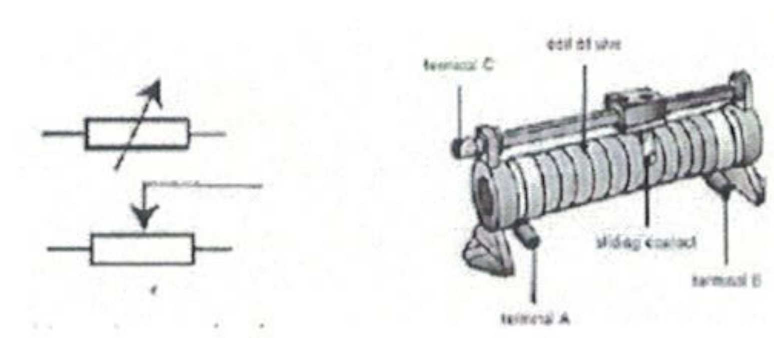
- is a resistor whose **resistance decreases** as the **temperature increases**

Light dependent resistor



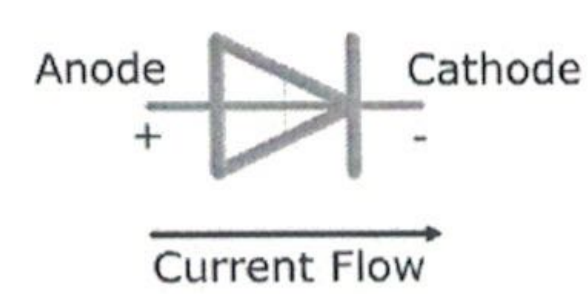
- is a resistor whose **resistance decreases** as **light** intensity **increases**

Variable resistance



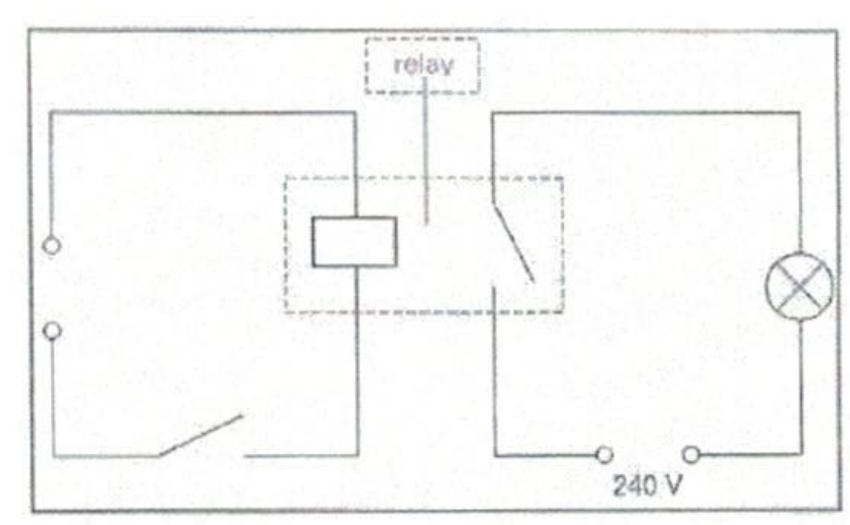
- is a resistance to **adjust current** (increase or decrease) through **difference** in **length**

Diodes



- only allow current to flow in **one direction.** They can be used as a **rectifier** (convert **AC** into **DC**).

Relay

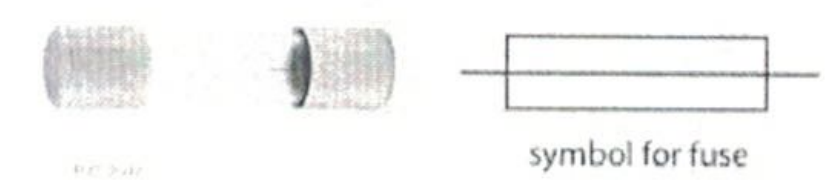


- is an **electromagnetically** operated **switch.** When a **small current** passes through the electromagnet, it **switches on** and **attracts** an iron arm. This arm rotates about a pivot and pushes the contacts in another circuit together. They are used to **switch** on a **circuit** with a **high current** using a circuit with a **small** current

Series connection	Parallel connection
▪ $I_T = I_1 = I_2$	▪ $I_T = I_1 + I_2$
▪ $V_T = v_1 + v_2$	▪ $V_T = v_1 = v_2$
▪ $R_T = R_1 + R_2$	▪ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

Fuses

- A fuse is a **thin** piece of **wire** which overheats and **melts** if the current is **too high, protecting** the circuit.



- Fuses have a current **rating** which should be **slightly higher** than the current used by the device in the circuit. The most common are 3A, 5A and 13A.

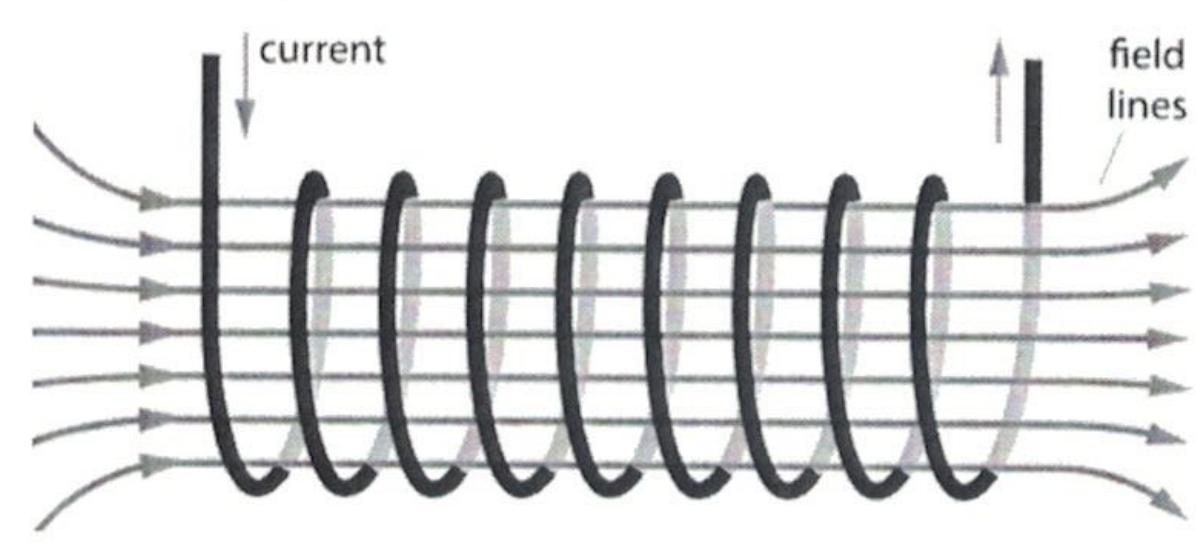
Circuit breakers

- Circuit breakers consist of an automatic **electromagnet** switch which **breaks** the **circuit** if the current **rises** over a **certain value.**

  This is **better** than a **fuse** as it can be **reset** and **used again**, and they operate **faster**

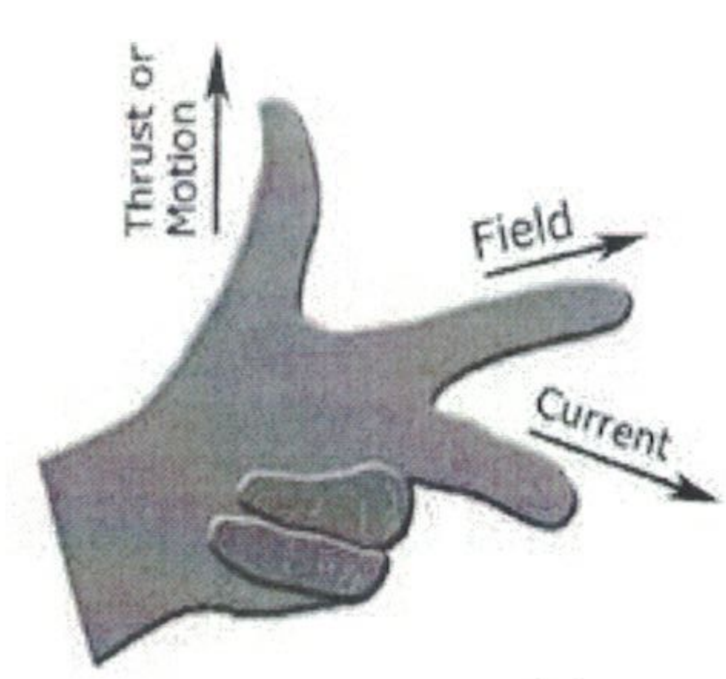
The magnetic effect of a current

- The **magnetic field** created by a **solenoid** is **like** the field produced by a **bar magnet**.
- **Increasing** the **current** through the wire **increases** the strength of the **magnetic field**, and **reversing** the **direction** of the **current** through the wire **reverses** the **direction** of the **magnetic field**

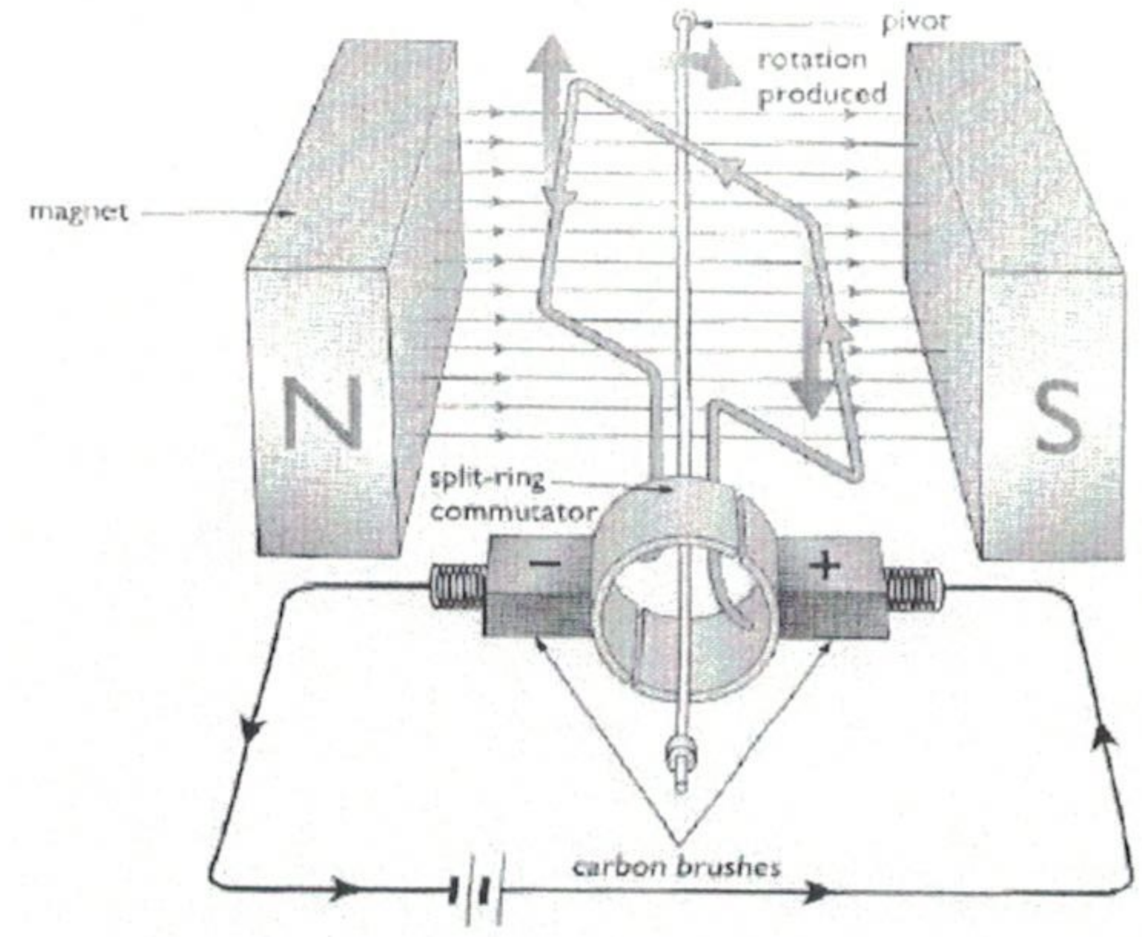


Fleming's left-hand rule

- The **Thumb** indicates **the thrust (a force)** on the current carrying conductor.
- The **First** finger indicates the magnetic **field** (remember field lines go from north to south).
- The **second** finger indicates the **current.**
- The magnetic field is always directed from **north to south.**



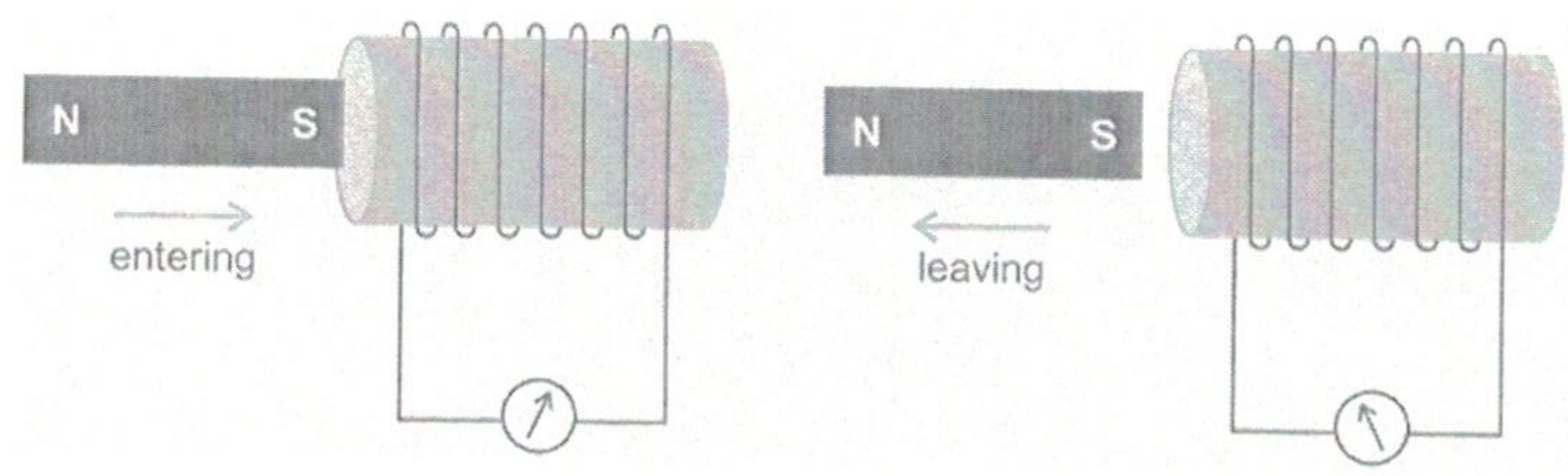
DC motors



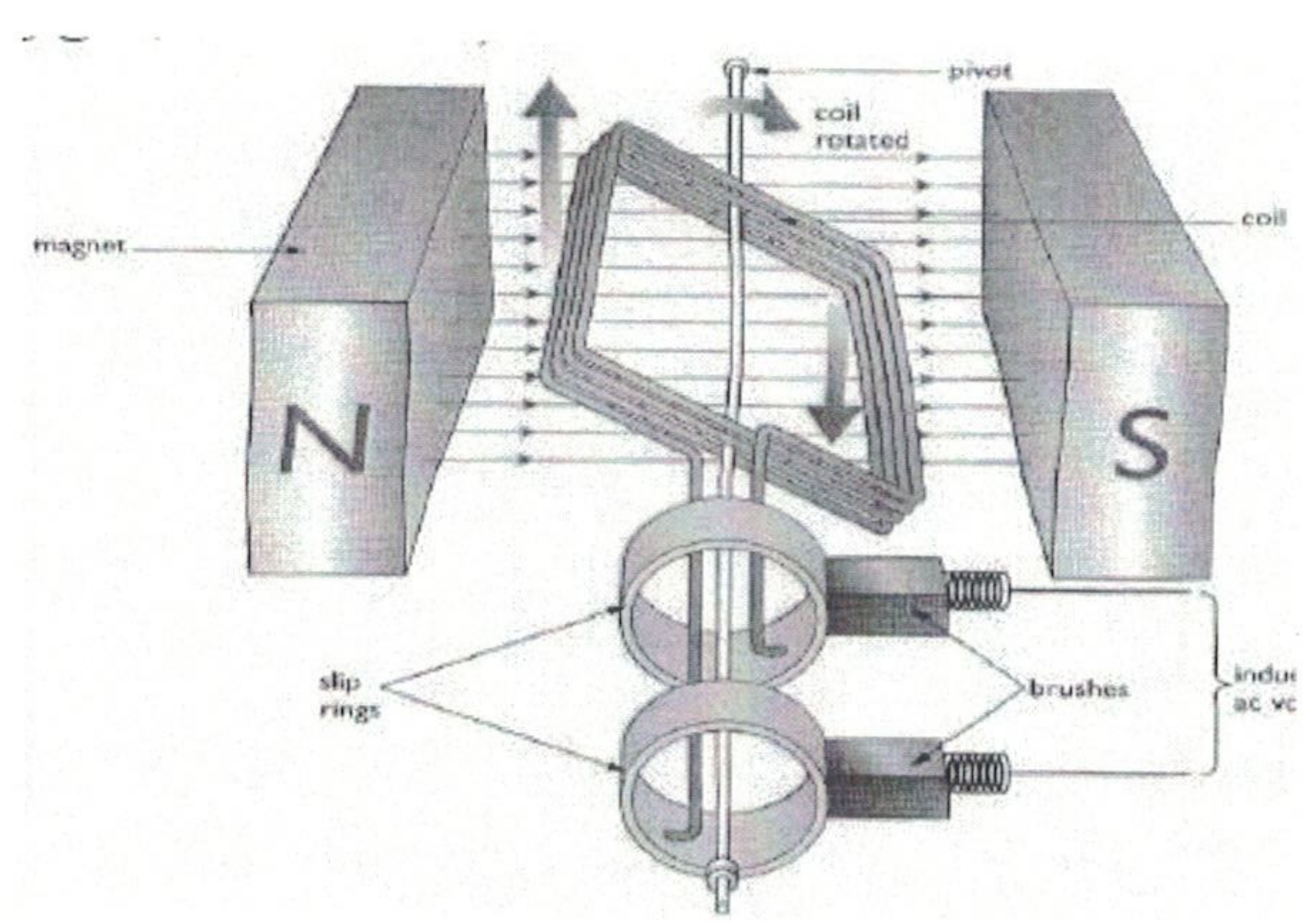
- DC motors consist of a **coil** of **wire** in between two permanent **magnets.**
- **Current flows** through the wire and it experiences a **turning effect** due to the **forces** exerted on it in the magnetic field. The **turning effect** can be **increased** by
  1. **increasing** the **current**
  2. using a **stronger magnetic** field
  3. **Increasing** the number of **turns** on the coil.
- **A split ring commutator** is used to ensure that the direction that the current flows in the coil **reverses** every **half turn.**

Electromagnetic induction

- When a **wire** moves across a **magnetic field**, an e.m.f. is **induced** in it. If it is part of a complete circuit, this **causes** a current to **flow.**
- The induced **current flows** in such a **direction** that it **opposes** the **change** that produced it.
- The **induced** e.m.f. can be **increased** by
  1. moving the wire more **quickly**,
  2. using a **stronger** magnetic field,
  3. **increasing** the **length** of the wire.



AC generator

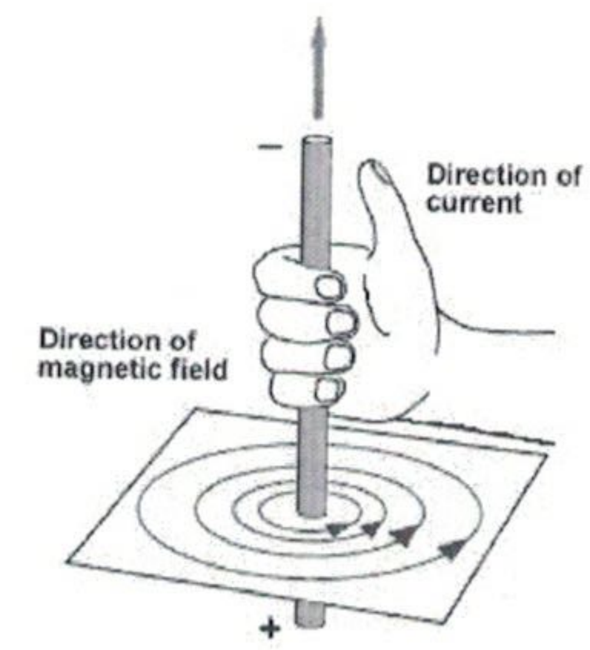


- AC **generator** consists of a **coil** of **wire** between two permanent **magnets.** They generate AC current because a **slip ring** is used.
- As the **coil rotates**, the **magnetic field** through the coil **changes**, which **induces** an e.m.f. in the coil.
- The magnitude of the e.m.f. is **maximum** when the coil is **horizontal** as the field lines are cut the fastest, and **zero** when **vertical** as **no field lines are being cut.**

- The e.m.f. can be **increased** by
  1. increasing the **number** of **turns** on the coil
  2. using a **stronger** magnet
  3. increasing the **speed** of rotation

The right hand grip rule

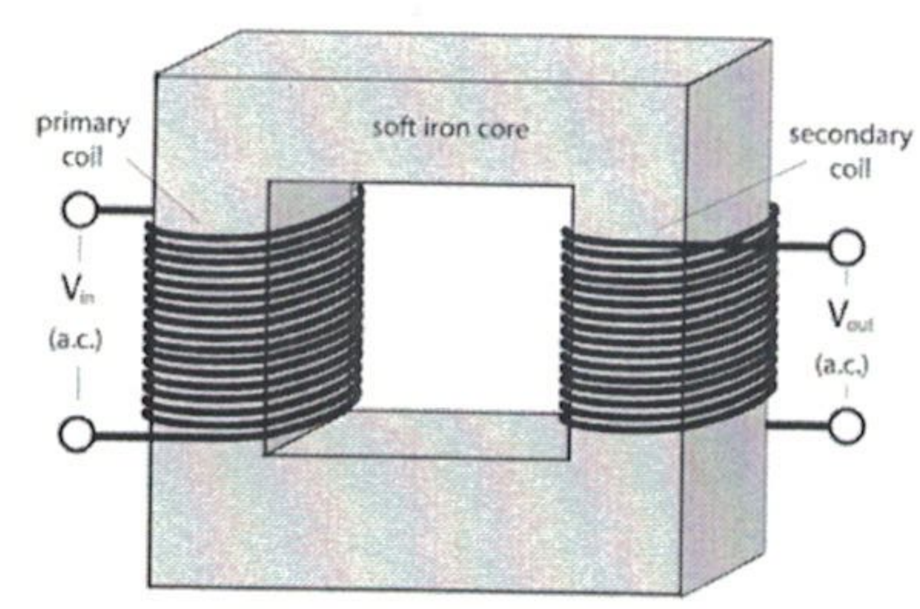
Hold out your right hand with your thumbs tucked in and your thumb pointing upwards:



- the thumb is equal to the direction of current
- the fingers are equal to the magnetic field direction

Transformer

- A transformer consists of **two coils** wrapped around a soft iron core and is used to **transform** voltages.
- An **alternating current** in the **primary coil** creates a **changing magnetic field**; this changing magnetic field links with the **secondary coil** and **induces** an alternating e.m.f. in it.



- A **step up** transformer has **more turns** on the **secondary** which means the **voltage** of the **secondary** is **greater** than that of the **primary**.
- A **step down** transformer has **fewer** turns on the **secondary** which means the **voltage** of the **secondary** is **less** than that of the primary.

$$Vp \times Ip = Vs \times Is$$

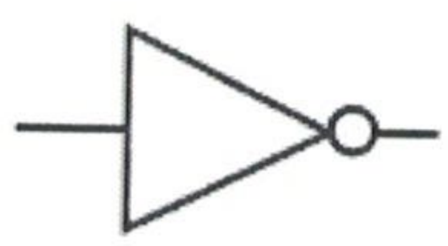
$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

- For a **100% efficient** transformer, because the **power** used is **constant**,
- **Transformers** are used to **step up** the **voltage** in power lines which **reduces power loss.** This is because a **higher voltage** means a **smaller current** and the **loss** of **power**

Digital electronics

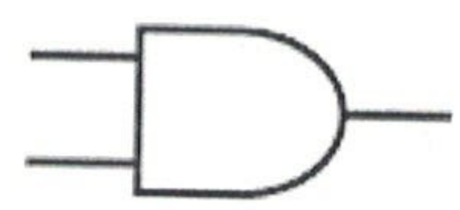
- **Analogue** signals vary **continuously** in amplitude, frequency or both.
- **Digital** signals are a **series** of pulses with **two states**, a **high** state **(1)** and a **low** state **(0)** Digital signals carry **more information** per second and maintain their **quality better**

Logic gates



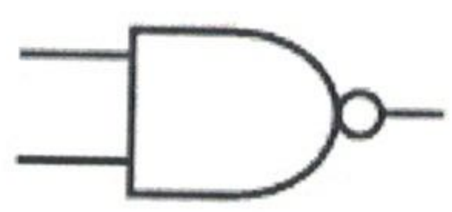
NOT

Input	Output
I	F
0	1
1	0



AND

Inputs		Output
A	B	F
0	0	0
1	0	0
0	1	0
1	1	1



NAND

Inputs		Output
A	B	F
0	0	1
1	0	1
0	1	1
1	1	0

OR

Inputs		Output
A	B	F
0	0	0
1	0	1
0	1	1
1	1	1

NOR

Inputs		Output
A	B	F
0	0	1
1	0	0
0	1	0
1	1	0

Topic five Atomic physics

Summary Notes

The nuclear atom

An atom consists of:

- A positively charged **nucleus** made of:
  - Positive **protons**
  - Neutral **neutrons**
- Surrounded by negatively charged **electrons** which orbit the nucleus

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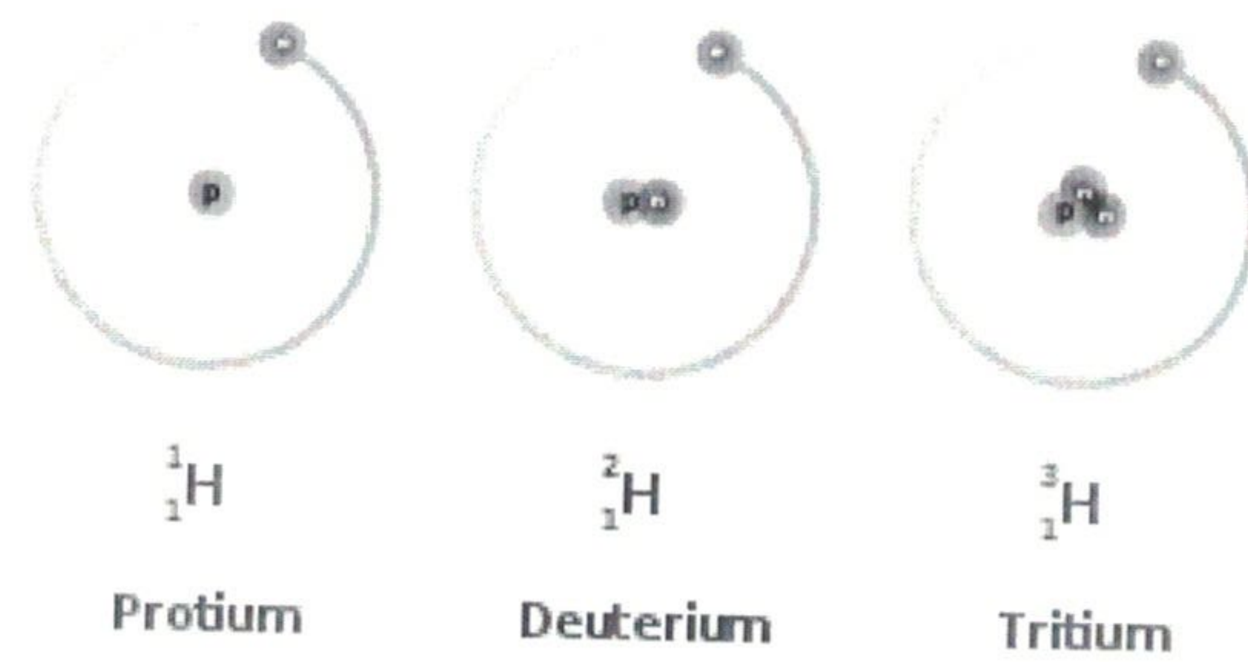
Subatomic particle	Mass	Charge	Location
Proton	1	+1	Nucleus
Neutron	1	Neutral	Nucleus
Electron	1/2000	-1	Outer shell

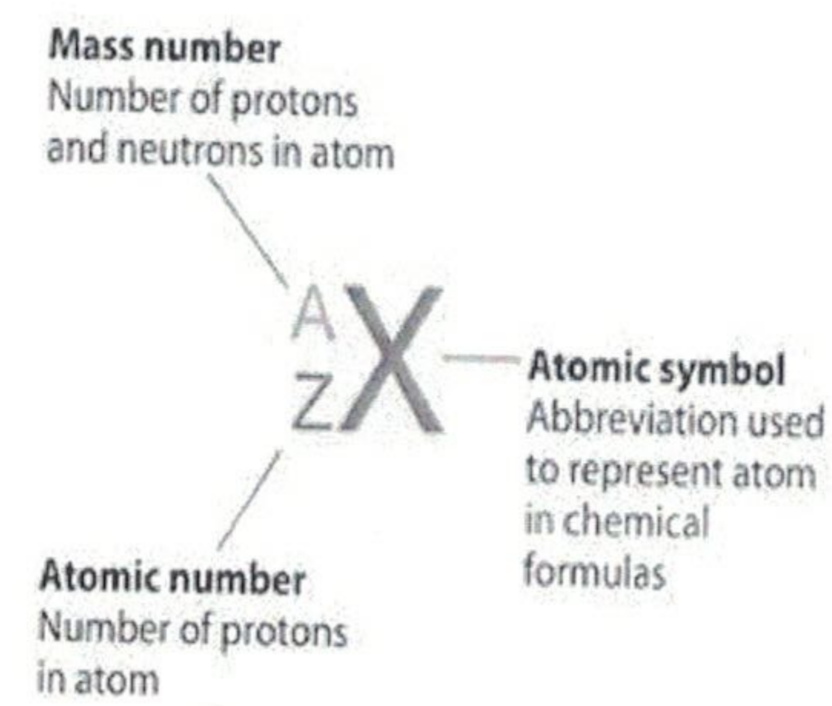
ISOTOPES

Atoms of the **same** element have the **same** number of protons. Isotopes are forms of an element's atom with the same number of protons but a **different** number of neutrons.



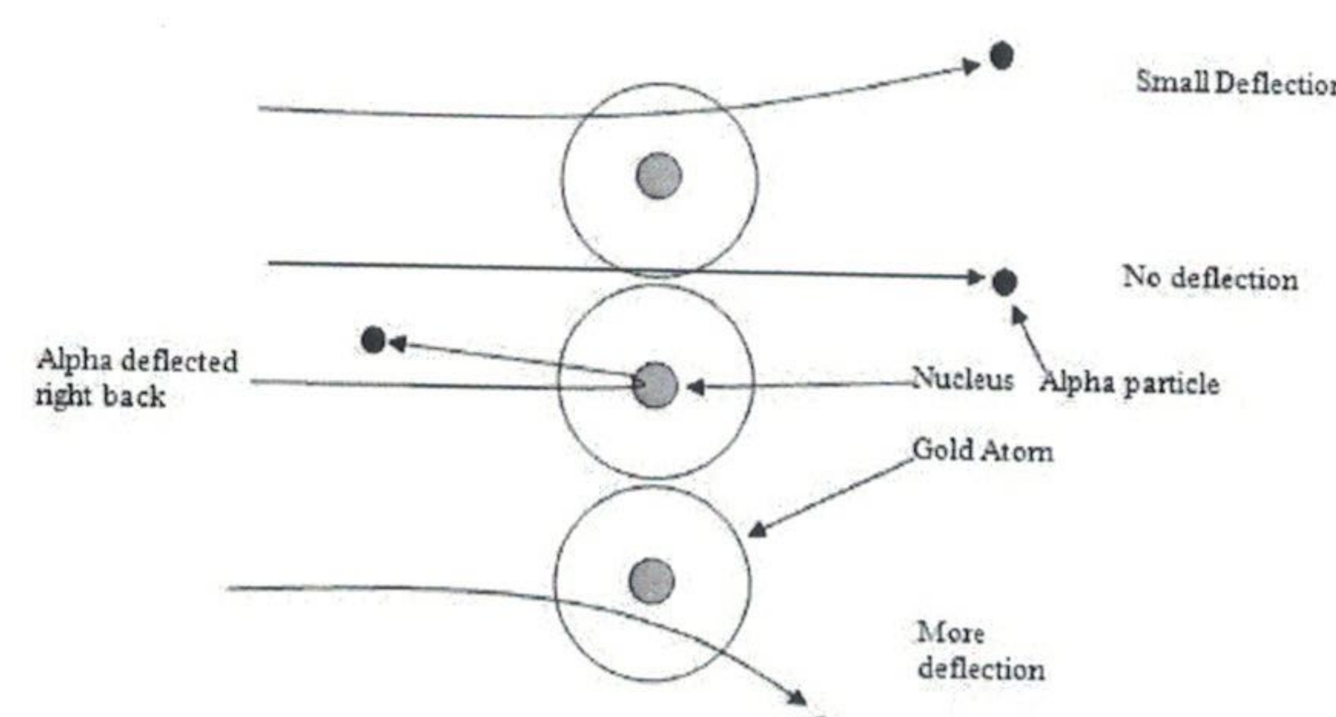
For a given nuclide

- X is the symbol of the element
- A is the nucleon number (number of neutrons and protons)
- Z is the proton number (number of protons)



Alpha particle scattering

- **Alpha** particles (charge +2) were **fired** at a thin sheet of **gold** foil
- **Most** particles went **straight** through
- Some particles were **deflected** by small angles (< 90º)
- A **few** particles were deflected by large angles (> 90º)

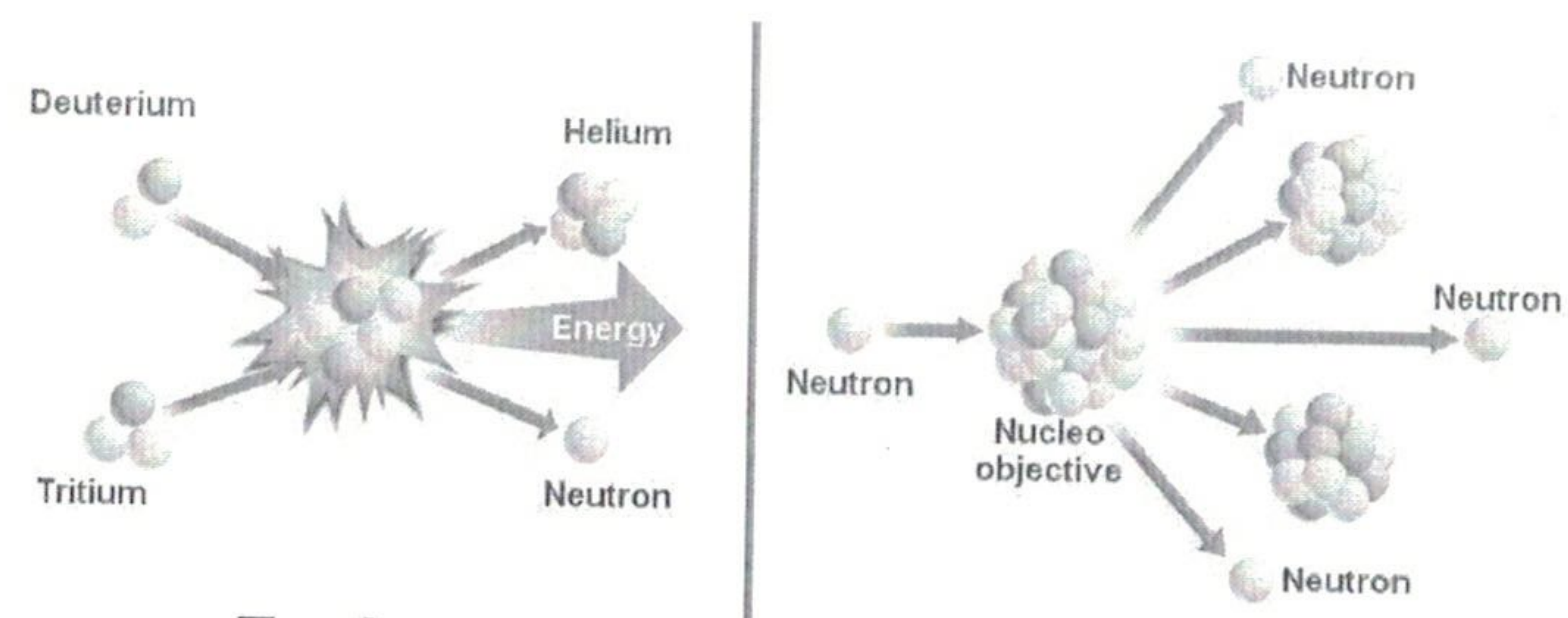


Conclusion

- Most of an atom is **empty space**
- The nucleus has a **positive** charge
- Most of the **mass** is concentrated **in** the **nucleus**

Nuclear fission:

- The process of **splitting** a nucleus is called nuclear **fission**
- **Uranium**-235 is a commonly used isotope as the **fuel** in nuclear **reactors**
- When a Uranium-235 nucleus **absorbs** a **neutron**, it **splits** into **two** daughter nuclei and 2 or 3 neutrons, **releasing** energy in the process



Fusion   Fission

Nuclear fusion:

- The process of **joining two nuclei** to form a **larger nucleus** is called nuclear **fusion**
- Energy is **released** during this process
- Nuclear fusion is how the **sun** and other stars **release** energy

Radioactivity

Radioactive **decay** is the **spontaneous** transformation of an **unstable** nucleus into a more stable one by the **release** of **radiation**. It is a **random** process which means one cannot know what nucleus will decay and when it will decay because it is down to chance.

Alpha

- ✓ A heavy nucleus emits an **alpha** particle (**helium** nucleus).
- ✓ The nucleus changes to that of a **different** element according to the following **equation**
- ✓ They are **highly ionizing** and weakly penetrating. They are **stopped** by a sheet of **paper**.
- ✓ They are slightly **deflected** by **electric** and **magnetic** fields.

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

Beta

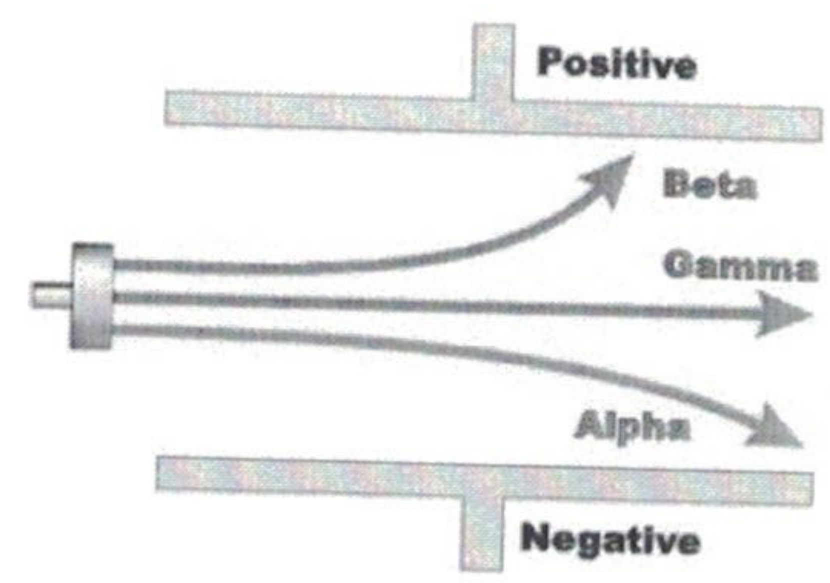
- emits a **beta** particle (**electron**)
- The nucleus changes to that of a **different** element according to the following **equation**
- They are **moderately ionizing** and moderately penetrating. They are **stopped** by a thin sheet of **aluminum**.
  - ✓ They are greatly **deflected** by **electric** and **magnetic** fields

$$^{A}_{Z}x \longrightarrow {}^{A}_{Z+1}y + {}^{0}_{-1}e$$

Gamma

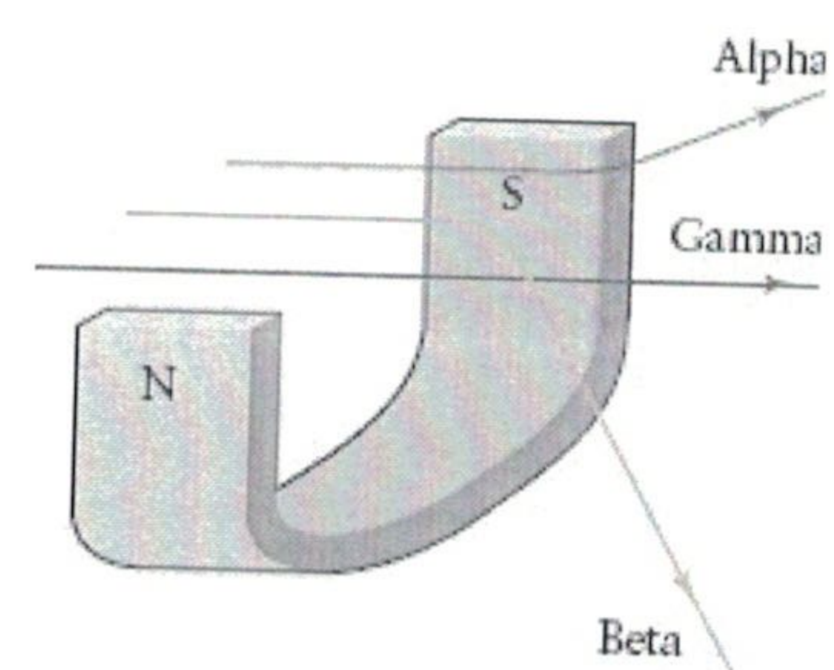
- After a previous decay, a nuclei with excess energy emits a **gamma** radiation
- Gamma particles are a form of **electromagnetic** radiation.
- They are **lowly ionizing** and highly penetrating. They are stopped by many centimeters of **lead.**
  - ✓ They are **not deflected** by electric and magnetic fields

Deflection in electric fields



Electric field lines represent the direction of an electric field which is from the **positive** plate to the **negative** plate. The **positively** charged **alpha particles are attracted to the negative plate** while the **negatively** charged **beta particles are attracted to the positive plate**

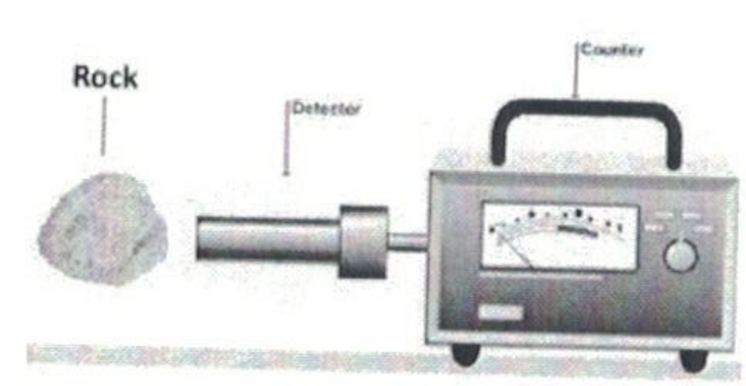
Deflection in magnetic fields



Alpha & beta particles are deflected in directions given ***by Fleming's left hand rule.*** Keep in mind that negative charges traveling to the right counts as a conventional current to the left

Geiger-Muller tube

- A Geiger-Muller tube is a **tube** which can **detect** radiation.
- Each time it **absorbs** radiation, it transmits an electrical **pulse** to the machine, which **produces** a **clicking sound.** The **greater** the **frequency** of clicks, the **more radiation** present.



Background radiation

Weak radiation that can be detected from external sources is called **background radiation. Sources** of background radiation include:

1. Cosmic rays
2. Radiation from underground rocks
3. nuclear fallout
4. Medical rays

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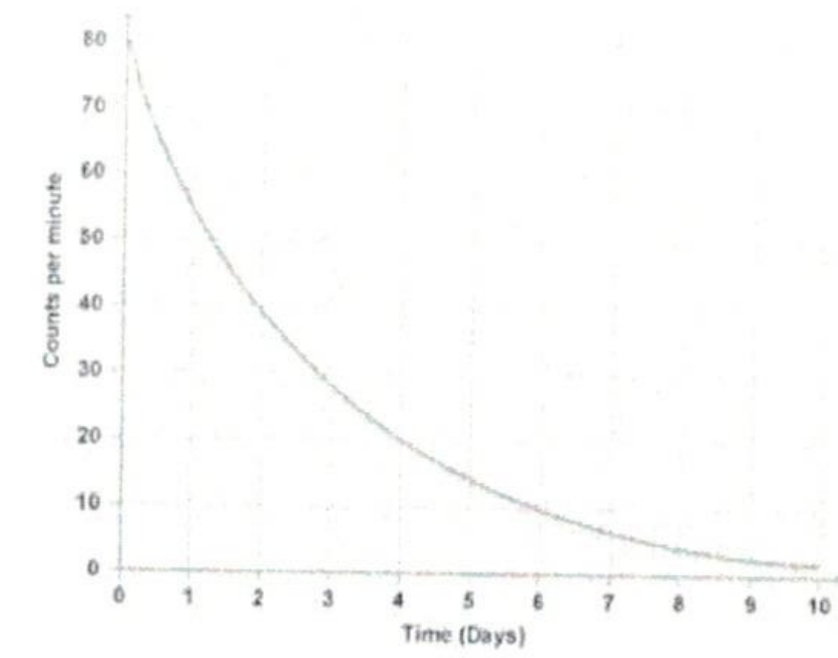
Half-Life Time



The half-life of an isotope is the **time taken** for **half** the **nuclei** to **decay**, or the time taken for the activity to halve.

- In the graph, the count rate drops from 80 to 40 counts per minute in 2 days, which means the half-life is around 2 days.

Background radiation has to be subtracted before attempting to perform half-life calculation

Uses of radioactivity

Smoke detectors

- Long half-life **alpha** emitters are used in **smoke detectors**, Alpha particles **cause a current in the alarm.**

  If smoke enters the detector, **some of the alpha particles are absorbed and the current drops**, triggering the alarm.

Thickness monitoring

- Long half-life **beta** emitters can be used for **thickness** monitoring of **metal sheets** A source and receiver are placed on either side of the sheet during its production. **If there is a drop or rise in the number of beta particles detected**, then the **thickness of the sheet has changed** and needs to be adjusted.

Sterilization of equipment

- **Gamma** emitters are used to **kill bacteria** or parasites on equipment so it is safe for operations.

Diagnosis and treatment

- Short half-life **gamma** emitters such as technetium-99m are used as **tracers** in **medicine** as they concentrate in certain parts of the body

Safety

- **Minimizing** the **time** of exposure to radiation. For example, radioactive tracers with a **short** half-life should be used.
- Keeping as **big** a **distance** from the radioactive source as possible. They should be handled **using tongs** and held **far away** from people.
- Using **shielding** against radiation, such as the **concrete** shielding around a nuclear reactor. Radioactive sources must also be kept in a **lead**-lined **box.**