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UPDATED TO 2019 SYLLABUS

CAIE IGCSE
PHYSICS (0625)

SUMMARIZED NOTES ON THE THEORY SYLLABUS

1. General Physics

1.1. Length and Time

LENGTH

- A rule (ruler) is used to measure length for distances between 1mm and 1meter.
- For even smaller lengths, use a micrometer screw gauge.
- SI unit for length is the meter (m)
- To find out volume of regular object, use mathematical formula

- To find out volume of irregular object, put object into measuring cylinder with water. When object added, it displaces water, making water level rise. Measure this rise. This is the volume.

TIME

- Interval of time is measured using clocks or a stopwatch
- SI unit for time is the second(s)
- To find the amount of time it takes a pendulum to make a spin, time ~25 circles and then divide by the same number as the number of circles.

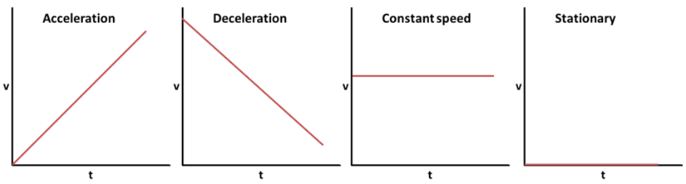
1.2. Motion

- Speed is the distance an object moves in a time frame. It is measured in meters/second (m/s) or kilometers/hour (km/h).

$$\therefore \text{ Speed}_{\text{average}} = \frac{\text{Total Distance}}{\text{Total Time}}$$

- Speed is a scalar quantity as it only shows magnitude.
- Speed in a specified direction is velocity, which is a vector

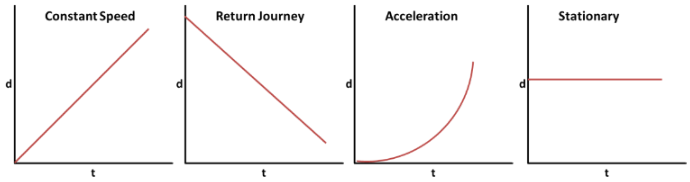
SPEED TIME GRAPHS



- Area under the line equals to the distance travelled
- $Gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta v}{t}$ = Acceleration (m/s)^2
- Positive acceleration means the velocity of a body is increasing
- Deceleration or negative acceleration means the velocity of a body is decreasing

- A curved speed time graph means changing acceleration.
- Acceleration is the rate of change in velocity per unit of time, and a vector as it's direction is specified

DISTANCE TIME GRAPHS



- $Gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta d}{t}$ = Speed (m/s)

- Therefore, distance:
  - With constant speed: $Speed \times Time$
  - With constant acceleration[1]: $\frac{Final\ Speed + Initial\ Speed}{2} \times Time$

ACCELERATION BY GRAVITY

- An object in free-fall near to the Earth has a constant acceleration caused by gravity due to the Earth's uniform gravitational field
- Objects are slowed down by air resistance. When deceleration caused by air resistance = acceleration by gravity, i.e. no net force acting on a body in free fall, the body reached terminal velocity

1.3. Mass and Weight

- Mass: A measure of matter in a body and the body's resistance to motion.
- Weight is the force of gravity on a body as a result of its mass.

$$\textbf{Weight} = \textbf{Mass} \times \textbf{G}$$

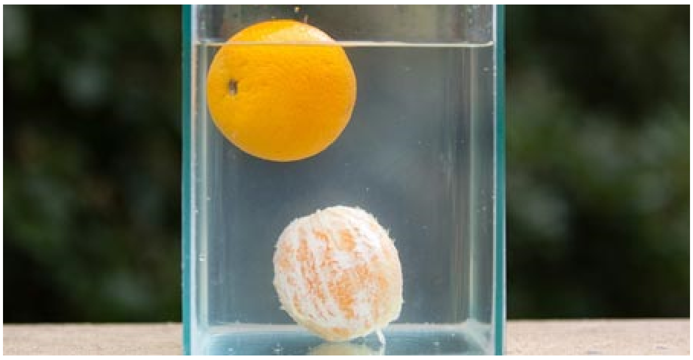
- Weights (and hence masses) may be compared using a balance

1.4. Density

$$\textbf{Density } (\rho) = \frac{\textbf{Mass (m)}}{\textbf{Volume (V)}}$$

- Density of a liquid: Place measuring cylinder on balance. Add liquid. Reading on measuring cylinder = V, change in mass on balance = m. Use formula.
- Density of solid:
  - Finding the volume: To find out volume of a regular object, use mathematical formula. To find out volume of an irregular object, put object into a measuring

cylinder with water and the rise of water is the volume of the object.
  - Finding the mass: Use balance
- An object will float in a fluid if it's density is lesser than the density of the liquid, i.e. The volume of fluid displaced has a greater mass than the object itself.
- **Example:** an orange with its peel has a density of 0.84g/cm^3, we can predict that it will float in water because it is less than 1 g/cm^3 (density of water). We can also say, that an orange without its peel, which has a density of 1.16g/cm^3, will sink because it is greater than 1g/cm^3.



1.5. Forces

- Force is measured in Newtons

$$\textbf{Force} = \textbf{Mass} \times \textbf{Acceleration}$$

- 1 Newton is the amount of force needed to give 1kg an acceleration of 1m/s^2
- A force may produce a change in size and shape of a body, give an acceleration or deceleration or a change in direction depending on the direction of the force.
- The resultant of forces acting in the same dimension will be their sum, provided a convention for directions is set. Therefore, the resultant of 2 forces acting in the same dimension, in the opposite direction will be the difference in their magnitude in the direction of the greatest.
- If there is no resultant force acting on a body, it either remains at rest or continues at constant speed in a straight line

RESISTIVE FORCES

- **Friction:** the force between two surfaces which impedes motion and results in heating
- Air resistance is a form of friction

NEWTON'S LAWS OF MOTION

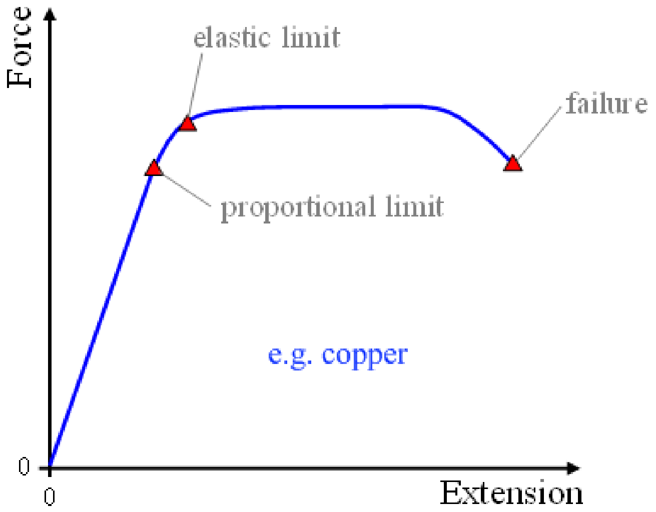
- First law of motion: If no external force is acting on it, an object will, if stationary, remain stationary, and if moving, keep moving at a steady speed in the same straight line.
- Second law of motion: $\mathbf{F} = \mathbf{ma}$
- Third law of motion: if object A exerts a force on object B, then object B will exert an equal but opposite force on object A

HOOKE'S LAW

- Springs extend in proportion to load, as long as they are under their proportional limit.
- Limit of proportionality: point at which load and extension are no longer proportional
- Elastic limit: point at which the spring will not return to its original shape after being stretched

$$\text{Load (In Newtons)} = \textit{Spring Constant} \times \textit{extension}$$

$$\mathbf{F} = \mathbf{kx}$$



CIRCULAR MOTION

- An object at steady speed in circular orbit is always accelerating as its direction is changing, but it gets no closer to the center. The speed of the ball stays constant.
- Centripetal force is the force acting towards the center of a circle. It is a force that is needed, not caused, by circular motion,
- For example, when you swing a ball on a string round in a circle, the tension of the string is the centripetal force. If the string is cut then the ball will travel in a straight line at a tangent to the circle at the point where the string was cut.
- Centrifugal force is the force acting away from the center of a circle. This is what makes a slingshot go outwards as you spin it. The centrifugal force is the reaction to the centripetal force. It has the same magnitude but opposite direction to centripetal force.

1.6. Moments

- A moment is the measure of the turning effect on a body and is defined as:

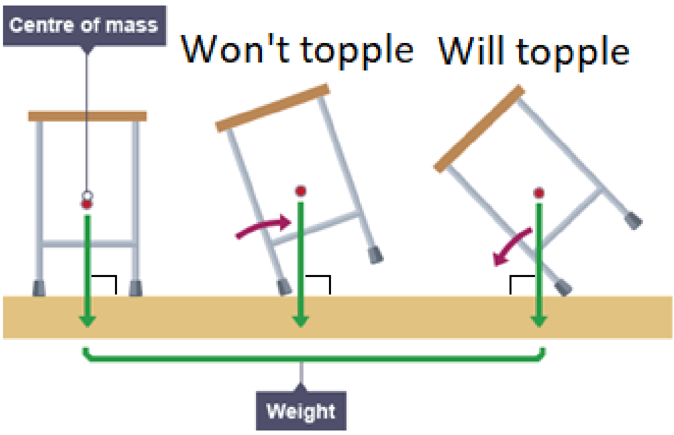
$$Moment\ (Nm) = Force\ (N) \times\ Perpendicular$$

$distance\ from\ Pivot\ (m)$

- Therefore, increasing force or distance from the pivot increases the moment of a force
- This explains why levers are force magnifiers
  - Turning a bolt is far easier with a wrench because the perpendicular distance from pivot is massively increased, and so is the turning effect.
- In equilibrium, clockwise moment = anticlockwise moment there is no resultant force acting on the body.
  - This can be proven by hanging masses of the same weight on opposite sides of a meter rule on a pivot at equal distances from the pivot showing that the meter rule in stationary.

1.7. Centre of Mass

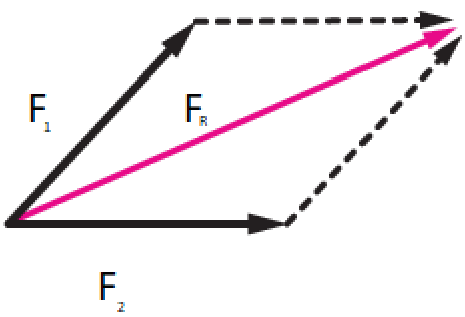
- Centre of mass: imaginary point in a body where total mass of body seems to be acting.
- An object will be in stable equilibrium when it returns to its original position given a small displacement.
- For an object that is displaced, it will stabilize only if the force caused by it's weight is within it's base.



- For an object to start rotating it needs to have an unbalanced moment acting on it

1.8. Scalars and Vectors

- A scalar is a quantity that only has a magnitude (so it can only be positive) for example speed.
- A vector quantity has a direction as well as a magnitude, for example velocity, which can be negative.
- Calculating resultant force:



- A parallelogram has to be made with the acting forces (F_1 and F_2). The resultant force will be the diagonal. Make sure the same scale is used to convert between length and forces. Measure length of diagonal and use scale to convert value into force (F_R).

1.9. Momentum

- **Momentum:** product of mass and velocity

$$\mathbf{p = mv}$$

- **Principle of conservation of linear momentum:** when bodies in a system interact, total momentum remains constant provided no external force acts on the system.

$$\mathbf{m_A u_A + m_B u_B = m_A v_A + m_B v_B}$$

- **Impulse:** product of force and time for which it acts

$$\mathbf{Ft = mv - mu}$$

1.10. Energy

- **Energy:** amount of work and its measured in Joules (J)
- An object may have energy due to its motion or its position
- Conservation of energy: energy cannot be created or destroyed, when work is done, energy is changed from one form to another.
- Energy can be stored

Energy type	What it is	Example
Kinetic	Due to motion	Car moving
Gravitational	From potential to fall	Book on shelf
Chemical	In chemical bonds	Bonds in starch (food)
Strain	Compress/stretch	Stretched elastic band
Nuclear	Atoms rearranged/split	Released in nuclear plant
Internal	Motion of molecules	In a glass of water
Electrical	Carried by electrons	Battery to bulb
Light	Carried in light waves	From sun
Sound	Carried in sound waves	From speaker

$$Kinetic\ energy = \frac{1}{2} \times Mass \times \text{Velocity}^2$$

$$\mathbf{K.E. = \frac{1}{2} mv^2}$$

$$Graviational\ Potential\ Energy = Mass \times Gravity \times Height$$

$$\mathbf{G.P.E. = mgh}$$

- Example of conversion of energy: A book on a shelf has g.p.e , if it falls of the shelf it will have k.e

- Due to the processes through which energy transfers take place not being 100% efficient, energy is lost to the surrounding and therefore energy gets more spread out (dissipated)
- Efficiency: how much useful work is done with energy supplied

$$Efficiency = \frac{Useful\ Energy\ Output}{Energy\ input} \times 100$$
$$Efficiency = \frac{Useful\ Power\ Output}{Power\ input} \times 100$$

1.11. Energy Resources

- Renewable sources are not exhaustible
- Non-renewable sources of energy are exhaustible

Type	Advantages	Disadvantages
Fuel: burnt to make thermal energy, makes steam, turns turbine	Cheap, Plentiful, Low-tech	Harmful wastes: (Greenhouse/ pollutant gas, Radiation)
Wave energy: generators driven by up and down motion of waves at sea.	No greenhouse gases produced	Difficult to build
Tidal energy: dam built where river meets sea, lake fills when tides comes in & empties when tide goes out; water flow runs generator	No greenhouse gases produced	Expensive Can't be built everywhere
Hydroelectric: river & rain fill up lake behind dam, water released, turns turbine ∴ generator	Low impact on environment Energy produced at constant rate	Few areas of the world suitable
Geothermal: water pumped down to hot rocks rising as steam	No CO_2 produced	Deep drilling difficult and expensive
Nuclear fission: uranium atoms split by shooting neutrons at them	Produces a lot of energy with very little resources	Produces radioactive waste
Wind: windmills are moved by the breeze. They generate electricity from kinetic energy.	No CO_2/ Greenhouse gasses produced	Few areas of the world suitable.

Type	Advantages	Disadvantages
Solar cells/ photovoltaic cells: made of materials that deliver electrical current when it absorbs light	No CO_2 produced	Variable amount of sunshine in some countries
Solar panels: absorbs energy and use it to heat water		

1.12. Work and Power

- Work is done whenever a force makes something move.

$$W = \Delta E$$

- The unit for work is the Joule (J).
- 1 joule of work = force of 1 Newton moves an object by 1 meter

$$\text{Work done (J)} = \mathbf{Force\ (N)} \times \mathbf{Distance\ (m)}$$
$$\mathbf{W = FD}$$

- Power is the rate of work
- The unit for power is Watts (W)
- 1W = 1J/s

$$\mathbf{Power\ (W)} = \frac{\mathbf{Work\ Done\ (J)}}{\mathbf{Time\ Taken\ (s)}}$$

1.13. Pressure

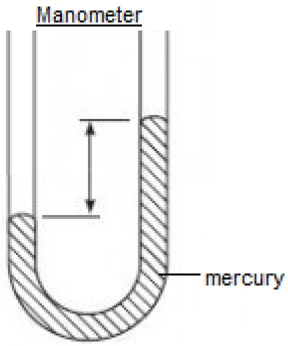
- Pressure is the force per unit area.

$$\text{Pressure (Pa)} = \frac{\mathbf{Force\ (N)}}{\mathbf{Area\ (m^2)}}$$
$$\mathbf{P} = \frac{\mathbf{F}}{\mathbf{A}}$$

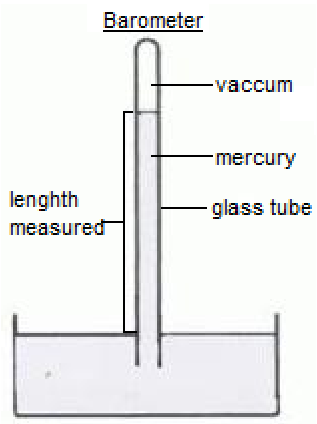
- Unit: Pascals (Pa) = N/m^2
- In Liquids

$$\text{Pressure (Pa)} = \mathbf{Density (kg/m^3)} \times \mathbf{Gravity (m/s^2)} \times$$
$$\mathbf{P = h\rho g}$$

- Therefore, as the depth of a fluid increases, the pressure caused by the whole liquid increases.
- **Measuring Pressure:** Manometer
  - Measures the pressure difference
  - The height difference shows the excess pressure in addition to the atmospheric pressure.

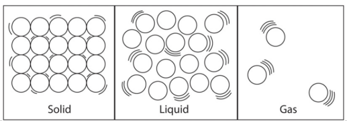


- **Measuring Pressure:** Barometer
    - Tube with vacuum at the top and mercury filling the rest.
    - Pressure of the air pushes down on reservoir, forcing mercury up the tube.
    - Measure height of mercury
    - ~760 mm of mercury is 1 atm.



2. Thermal Physics

2.1. Simple Kinetic Molecular Model of Matter

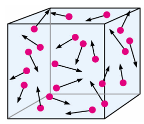


Solid	Liquid	Gas
Fixed shape and volume	Fixed volume but changes shape depending on its container	No fixed shape or volume, gases fill up containers
Strong forces of attraction between particles- particles close to each other.	Weaker attractive forces than solids- medium distances between particles	Almost no intermolecular forces- large distances between particles
Fixed pattern (lattice)	No fixed pattern, liquids take shape of their container	Particles far apart, and move quickly
Atoms vibrate but can't change position ∴ fixed volume and shape	Particles slide past each other.	Collide with each other and bounce in all directions

- The more the kinetic energy in a gas, the faster it's particles move and therefore the gas is at a higher temperature.
- The pressure gases exert on a container is due to the particles colliding on the container walls.
- The greater the kinetic energy in gasses the faster they move and the more often they collide on the container's walls.
- Therefore, the volume is constant, then increasing the temperature will increase the pressure.
- Thus, if there is a change in momentum of the particles, the kinetic energy decreases, decreasing the collisions on the container walls and thus the pressure.

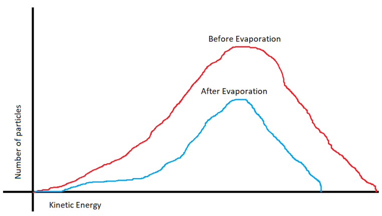
BROWNIAN MOTION

- Gas molecules move randomly. This is because of repeated random collisions with other gas molecules, which constantly change the direction they move in.
- Small molecules move much faster and have higher energy than larger molecules. They can effectively move large molecules due to repeated random bombardment- this can be seen by larger smoke particles moving.
- Therefore, the random motion of particles in a suspension is evidence for the kinetic molecular model of matter.



2.2. Evaporation

- It is the escape of more energetic particles from the surface of a liquid.
- If more energetic particles escape, the liquid contains few high energy particles and more low energy particles so the average temperature decreases.



- In the above graph, the number of particles with higher kinetic energies has gone down.'

- Therefore a body in contact with an evaporating liquid with subsequently cool.

- Evaporation can be accelerated by:
  - Increasing temperature: more particles have energy to escape
  - Increasing surface area: more molecules are close to the surface
  - Reduce humidity level in air (draught): if the air is less humid, fewer particles are condensing.

2.3. Pressure Changes in Gases

- Pressure is inversely proportional to the volume given a constant temperature.
- If the volume increases and the temperature stays constant, the particles hit the surface less often, thus decreasing the pressure.

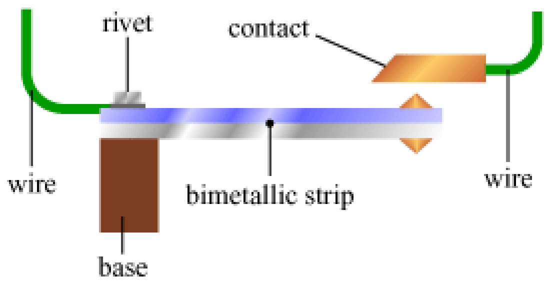
$$\mathbf{P_1V_1 = P_2V_2}$$

$$\mathbf{PV = constant}$$

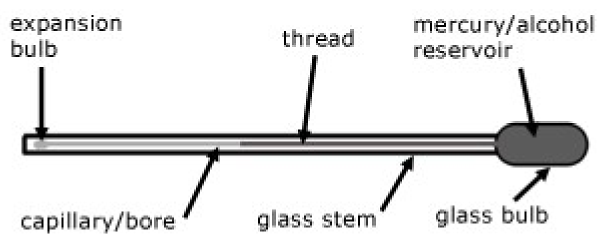
- The constant is valid at a fixed mass of gas at a constant temperature.
- As the temperature increases of a fixed mass of gas, the pressure increases as the average kinetic energy increases... Refer card 'Simple Kinetic Molecular Model of Matter' for more detail.

2.4. Thermal properties and temperature

- Solids, liquids and gasses expand when they are heated as atoms vibrate more and this causes them to become further apart, taking up a greater volume.
- Due to differences in molecular structure of the different states of matter, expansion is greatest in gases, less so in liquids and lowest in solids
- Applications and consequences of thermal expansion:
  - Overhead cables have to be slack so that on cold days, when they contract, they don't snap or detach.
  - Gaps have to be left in bridge to allow for expansion
  - Bimetal thermostat: when temperature gets too high, bimetal strip bends, to make contacts separate until temperature falls enough, then metal strip will become straight again and contacts touch, to maintain a steady temperature

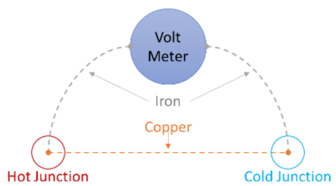


- Temperature can be measured by observing a physical property that changes with temperature. Examples include alcohol and mercury - used in thermometers.
- **Fixed points** are definite temperatures at which something happens and are used to calibrate a thermometer. For example, melting and boiling point of water
- **Sensitivity:** Change in length or volume per degree
- **Range:** The values which can be measured using the thermometer
- **Linearity:** Uniform changes in the physical property with a change in temperature over the measured temperature values.
- **Responsiveness:** How long it takes for the thermometer to react to a change in temperature
- **Calibrating a thermometer:**
  - Place thermometer in pure water.
  - Place the thermometer above the steam of the pure boiling water, this is 100 °C.
- **Liquid-in-glass thermometer:**



- As temperature rises or falls, the liquid (mercury or alcohol) expands or contracts.
- Amount of expansion can be matched to temperature on a scale.
- **To increase sensitivity:**
  - Thinner capillary
  - Less dense liquid
  - Bigger bulb
- Depending on the melting and boiling point of the liquid being used, the range is defined.
- The linearity depends on the liquid being used

- **Thermocouple thermometer:**



- The probe contains 2 different metals joined to form 2 junctions.
- The temperature difference causes a tiny voltage which makes a current flow.
- A greater temp. difference gives a greater current.
- Thermocouple thermometers are used for high temperatures which change rapidly and have a large range (-200C° to 1100°C)

2.5. Thermal Capacity

- The rise in temperature of a body is an increase in the internal energy of that body. The **average kinetic energy** of a gas particle is directly proportional to the **temperature**. When of that gas particle. particles move faster due to greater kinetic energy, they collide more often, which is felt by heat
- All gases at the same temperature have the same average kinetic energy.
- Specific Heat capacity (c) is the amount of energy required to raise the temperature of 1 kg of a certain substance by 1° C.

c = $\frac{Q}{m\Delta T}$

- Thermal Capacity (Q) is the amount of energy required to raise the temperature of an object by 1°C.

$$Q = mc$$

IMPORTANT: The Q's in both equations are NOT the same, however the c's are.

2.6. Melting and Boiling

- Melting is when a solid turns into a liquid.
- The temperature increases thus kinetic energy in solid increases and particles vibrate more rapidly.
- When melting starts there is no increase in temperature of the substance because thermal energy supplied is being used to break bonds between particles of the solid thus making it into a liquid.
- The latent heat of fusion is the amount of energy needed to melt 1Kg of a substance
- The melting point is the temp. at which a substance liquefy
- Boiling is when a liquid turns into a gas
- The temperature increases thus kinetic energy in liquid increases and particles vibrate more rapidly.
- When boiling starts, there is no increase in temperature of the substance because the thermal energy supplied is being used to break bonds between particles of the liquid thus making it into a gas.
- The latent heat of vaporization is the amount of energy needed to boil 1Kg of a substance
- The boiling point is the temp. at which a substance boils

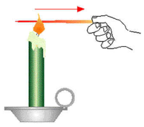
$$\text{Specific latent heat of fusion vaporization} = \frac{\text{Energy Transferred}}{\text{Mass}}$$

$$\mathbf{L_f / L_v = \frac{E}{m}}$$

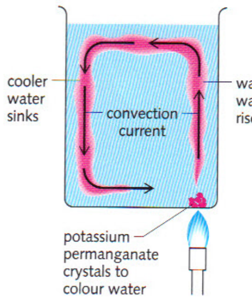
- The difference between boiling and evaporation is that:
  - Boiling occurs at a fixed temperature and throughout the liquid
  - Evaporation occurs at any temperature and only on the surface
- Condensation is when a gas turns back into a liquid.
- When a gas is cooled, the particles lose energy. They move more and more slowly. When they bump into each other, they do not have enough energy to bounce away again so they stay close together, and a liquid forms.
- When a liquid cools, the particles slow down even more. Eventually they stop moving except for vibrations and a solid forms.

2.7. Thermal Properties

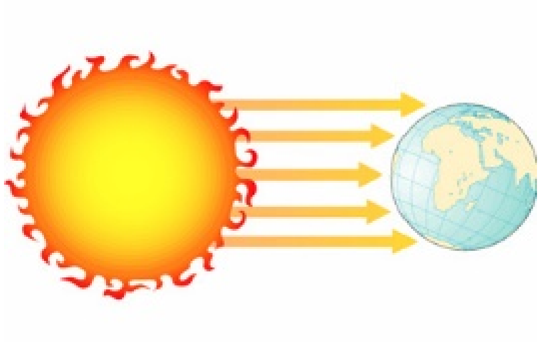
- *Conduction* is the flow of heat through matter from places of higher temperature to places of lower temperature without movement of the matter as a whole



- In non-metals - when heat is supplied to something, its atoms vibrate faster and pass on their vibrations to the adjacent atoms.
- In metals – conduction happens in the previous way and in a quicker way –electrons are free to move, they travel randomly in the metal and collide with atoms and pass on the vibrations Good conductors are used whenever heat is required to travel quickly through something
- Bad conductors (insulators) are used to reduce the amount of heat lost to the surroundings
- *Convection* is the flow of heat through a fluid from places of higher temperature in places of lower temperature by movement of the fluid itself.
- As a fluid (liquid or gas) warms up, the particles which are warmer become less dense and rise.
- They then cool and fall back to the heat source, creating a cycle called convection current.
- As particles circulate they transfer energy to other particles. If a cooling object is above a fluid it will create a convection current as well.



- **Radiation** is the flow of heat from one place to another by means of electromagnetic waves. It does **not** require a medium.
- Thermal radiation is mainly infra-red waves, but very hot objects also give out light waves. Infra-red radiation is part of the electromagnetic spectrum.



	Matt Black	White	Silver
Emitter	Best	→	Worst
Reflector	Worst	→	Best
Absorber	Best	→	Worst

- An emitter sends out thermal radiation.
- A reflector reflects thermal radiation, therefore is a bad absorber.
- An emitter will cool down quickly, an absorber will heat up more quickly and a reflector will not heat up quickly.
- The amount of radiation also depends on the surface temperature and surface area of a body.
- Consequences of energy transfer include:
  - Metal spoon in a hot drink will warm up because it conducts heat
  - Convection currents create sea breezes. During the day the land is warmer and acts as heat source. During the night the sea acts as the heat source.
  - A black saucepan cools better than a white one, white houses stay cooler than dark ones.

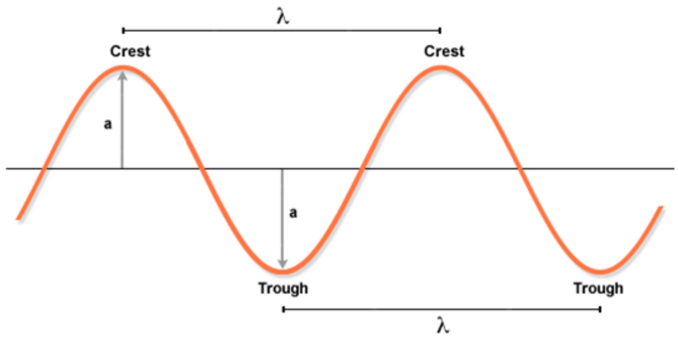
3. Properties of Waves, Including Light and Sound

3.1. General Wave Properties

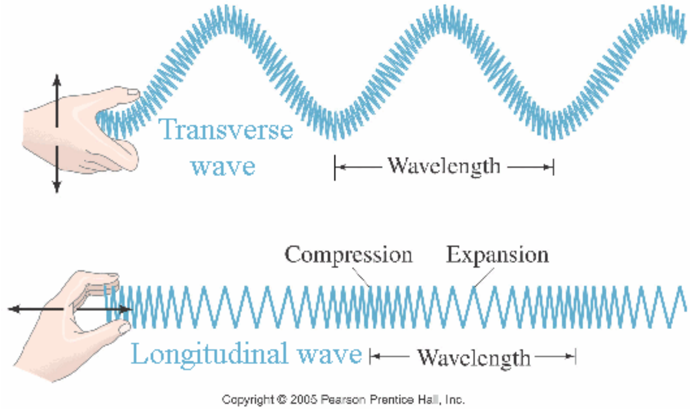
- Waves transfer energy without transferring matter.
- Examples of wave motion include:
  - Water Waves
  - Ropes
  - Springs
- **Frequency:** the number of waves passing any point per second measured in hertz (Hz)

$$\textbf{Frequency} = \frac{\textbf{1}}{\text{Period}}$$

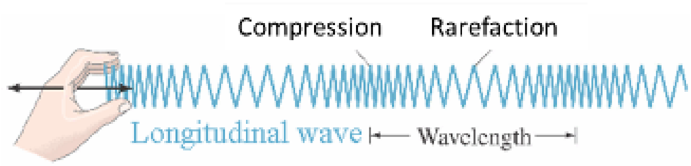
- **Period:** time taken for one oscillation in seconds
- **Wavefront:** the peak of a transverse wave or the compression of a longitudinal wave
- **Speed:** how fast the wave travels measured in m/s
- **Wavelength:** distance between a point on one wave to the corresponding point on the next wave in length
- **Amplitude:** maximum displacement of a wave from its undisturbed point.



- Transverse Waves
  - Travelling waves in which oscillation is perpendicular to direction of travel
  - Has crests and troughs
  - For example, light, water waves and vibrating string



- Longitudinal Waves
  - Travelling waves in which oscillation is parallel to direction of travel.
  - Has compressions and rarefactions
  - For example, sound waves

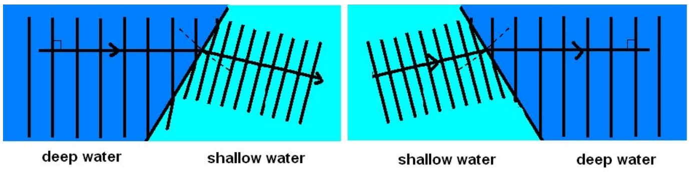


$$Speed\ (m/s) = Frequncy(Hz) \times Wavelength(m)$$

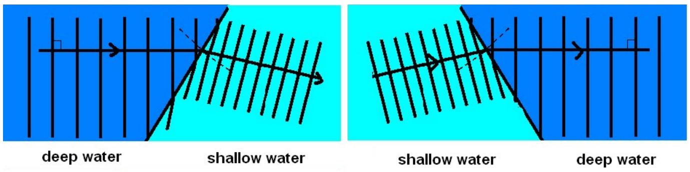
$$\mathbf{V = F\lambda}$$

- Refraction:
  - Speed and wave length is reduced but frequency stays the same and the wave changes direction
  - Mechanical waves slow down when they pass from a rarer to a denser material and vice versa
  - Note: Electromagnetic waves like light increase in speed from an optically denser to a rarer medium.
  - When wave is slowed down, it is refracted towards normal (i > r)
  - When wave is sped up, it is refracted away from normal (i < r)
  - Deep water is denser than shallow water

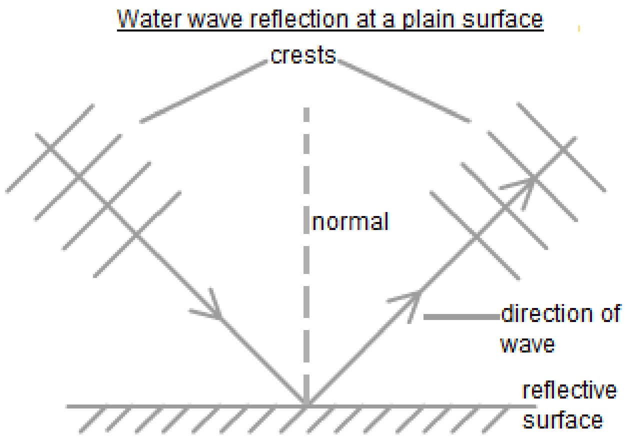
- **Deep water to shallow water:** speed decreases, wavelength decreases, and frequency remains constant



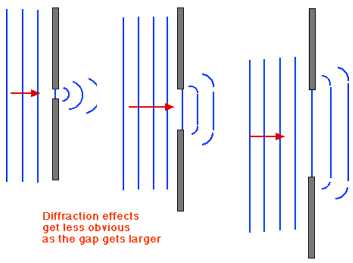
- **Shallow water to deep water:** speed increases wavelength increases, and frequency remains constant



- Reflection:
  - Waves bounce away from surface at same angle they strike it
  - Angle of incidence = angle of reflection
  - The incident ray, normal and reflected ray all lie on the same plane.
  - Speed, wavelength and frequency are unchanged by reflection

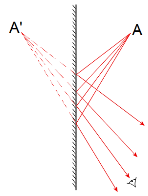


- Diffraction:
  - Waves bend round the sides of an obstacle or spread out as they pass through a gap.
  - Wider gaps produce less diffraction.
  - When the gap size is equal to the wavelength, maximum diffraction occurs

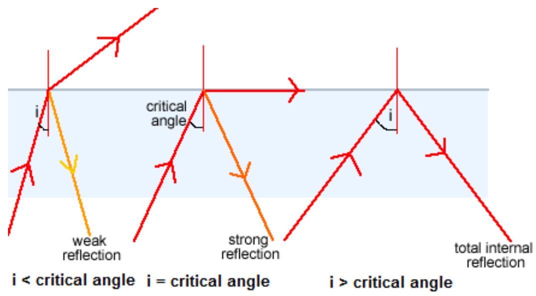


3.2. Reflection of Light

- Plane (flat) mirrors produce a reflection.
- Rays from an object reflect off the mirror into our eyes, but we see them behind the mirror.
- The image has these properties:
  - Image is the same size as the object
  - Image is the same distance from the mirror as object
  - A line joining corresponding points of the image and object meet the mirror at a right angle
  - Image is virtual: no rays actually pass through the image and the image cannot be formed on a screen



- Laws of reflection:
  - **Angle of incidence = angle of reflection**
  - **The incident ray, reflected ray and normal are always on the same plane (side of mirror)**
- **Critical angle**: an angle at which the r = 90 degrees, where the reflected ray bends at a 90 degree angle
- If the angle of incidence is greater than the critical angle there is no refracted ray, there is total internal reflection.
- If the angle of incidence is less than the critical angle the incidence ray will split into a refracted ray and a weaker reflected ray.



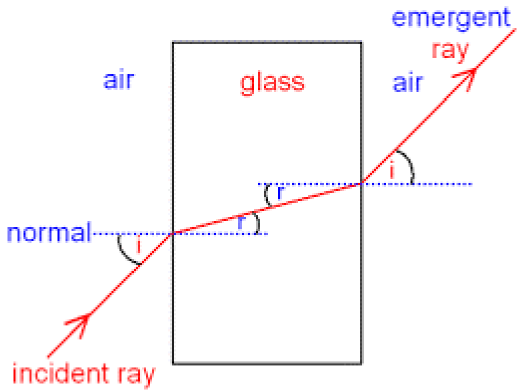
$$\textbf{Refractive Index} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in a medium}}$$

$$\textbf{Refractive Index} = \frac{\sin i}{\sin r}$$

$$\textbf{Critical angle} = \sin^{-1}\frac{\mathbf{1}}{\mathbf{n}}$$

3.3. Refraction of Light

- Refraction is the bending when light travels from one medium to another due to the change in speed of the ray of light.



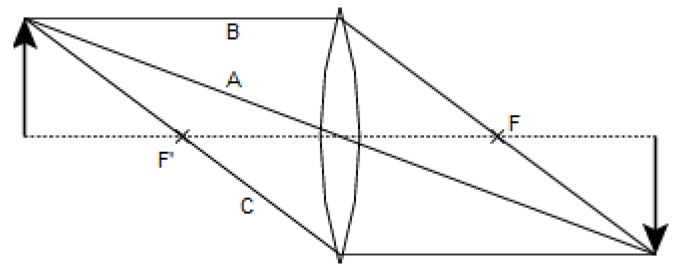
- Note:
  - The emergent ray is parallel to the incident ray only if the sides of the glass are parallel)
  - i = angle of incidence, r = angle of refraction
- Light put in at one end is totally internally reflected until it comes out the other end.
- **Application**: Optical Fibres
  - Used in communications: signals are coded and sent along the fiber as pulses of laser light
  - Used in medicine: an endoscope, an instrument used by surgeons to look inside the body; contains a long bundle of optic fibers.

3.4. Thin Converging Lens

- **Principal focus:** the point where rays parallel to the principal axis converge with a converging lens.
- **Focal length:** distance from principle focus and the optical center.
- **Principal axis:** line that goes through optical center, and the 2 foci.
- **Optical center:** the center of the lens
- **Real:** image can be caught on a screen
- **Virtual:** image cannot be caught on a screen

Real Image

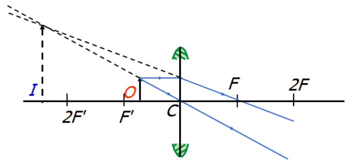
- When object is further away from the optical centre than F' is



A) A ray through centre of the lens passes straight through the lens.
B) A ray parallel to the principal axis passes through the focus on the other side of the lens
C) A ray through F' will leave the lens parallel to the principal axis

Virtual Image

- When the object is closer to the optical centre than F' is

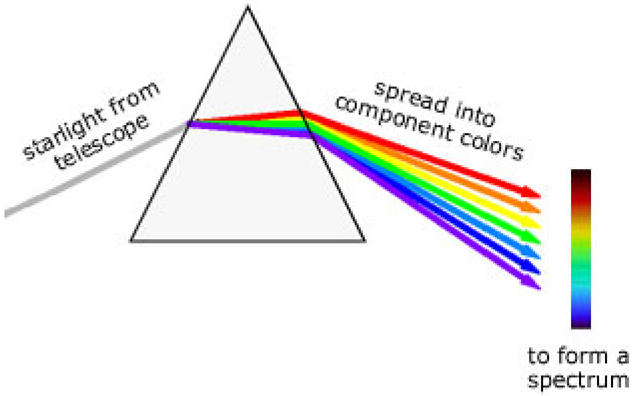


- Magnifying glass: when a convex lens is used like this - an object is closer to a convex (converging) lens than the principal focus (like the diagram above), the rays never converge. Instead, they appear to come from a position behind the lens. The image is upright and magnified, it is a virtual image.
- Images can be:
  - Enlarged: The image is larger than the object.
  - Same size: The image is the same size as the object.
  - Diminished: The image is smaller than the object.
  - Upright: The image is in the same vertical orientation as the object.

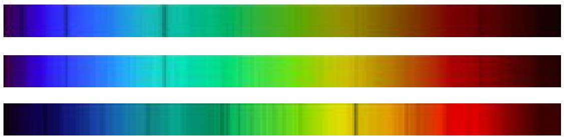
3.5. Dispersion of Light

Refraction by a prism:

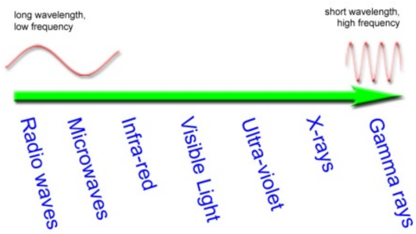
- When light is refracted by a prism, the incidence ray is not parallel to the emergent ray, since the prism's sides are not parallel.
- If a beam of white light is passed through a prism it is dispersed into a spectrum.
- White light is a mixture of colors, and the prism refracts each color by a different amount – red is deviated least & violet most
- Monochromatic light is that of a single frequency and colour.
- The visible spectrum of light is acronymed as ROYGBIV



Examples of stellar spectra



3.6. Electromagnetic Spectrum

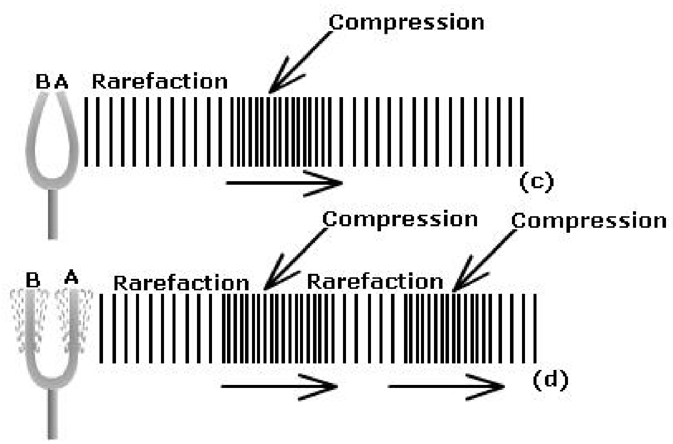


- ROMAN MEN INVENTED VERY UNUSUAL XRAY GUNS

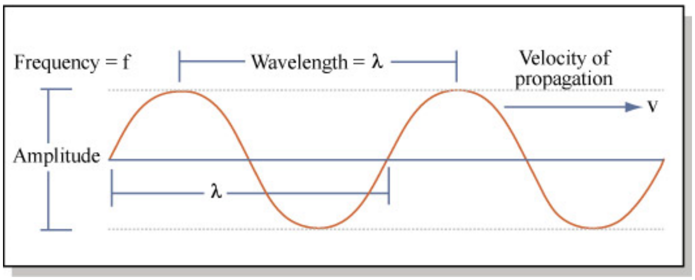
- All electromagnetic waves:
  - Travel at the speed of light: approximately $3 \times 10^8 m/s$.
  - They travel at around the same speed in air too.
  - Don't need a medium to travel through (travel through a vacuum)
  - Can transfer energy
  - Are produced by particles oscillating or losing energy in some way
  - Are transverse waves
- Applications:
  - Radio waves: radio and television communications
  - Microwaves: satellite television and telephones
  - Safety issue: cause internal heating of body tissues
  - Infrared: electrical appliances (radiant heaters and grills), remote controllers for televisions and intruder alarms
  - X-rays: medicine (x-ray photography and killing cancer cells) and security
  - Safety issue: is a mutagen, it cause cancer (mutations)
  - Monochromatic: light of a single wavelength and color (used in lasers)

3.7. Sound

- Sound is a mechanical wave.
- Sound waves come from a vibrating source e.g. loudspeaker
- As the loudspeaker cone vibrates, it moves forwards and backwards, which squashes & stretches the air in front.
- As a result, a series of compressions (squashes) and rarefactions (stretches) travel out through the air, these are sound waves
- Humans can hear frequencies between 20 and 20 000Hz.
- Properties:
  - Sound waves are **longitudinal**: they have compressions and rarefactions and oscillate backwards and forwards.
  - Sound waves need a medium to travel through as it moves due to oscillating particles.
- Ultrasound Waves: high frequency sound waves, medically used to look at structures and organs inside the human body, i.e. to form an image of a fetus in a pregnancy



- **Compression:** High pressure section of a longitudinal wave
- **Rarefaction:** Low pressure section of a longitudinal wave



- The higher the frequency, the higher the pitch.
- The higher the amplitude, the louder the sound
- If a sound is repeated 0.1 seconds or more after it is first heard, the brain senses it again.
- Therefore, given the adequate distance, if sound reflects off a surface, and comes back, an echo is produced.

Speed of sound in various media		
Medium	**State**	**Speed**
Concrete	Solid	5000 m/s
Pure Water	Liquid	1400 m/s
Air	Gas	330 m/s
V in Gas <V in Liquid <V in solid		

- Remember to take into account that sound has

4. Electricity and Magnetism

4.1. Simple phenomena of magnetism

MAGNETS:

- Magnets have a magnetic field around them
- They have 2 opposite poles (North and South) which exert forces on other magnets. Like poles repel and unlike poles attract. This is caused by the interaction of magnetic fields.
  - Therefore, if magnets are facing each other with opposite poles, they will come together given a small

space between them

- They attract magnetic materials by inducing (permanent or temporary) magnetism in them.
- Will exert little or no force on a non-magnetic material
- The direction of an electric field at a point is the direction of the force on a positive charge at that point
- **Induced Magnetism:**
  - Magnets attract materials by inducing magnetism in them; the material becomes a magnet as well.
  - The side of the material facing the magnet will become the opposite pole as the magnet.

Ferrous/Magnetic materials	Non-ferrous/Non-magnetic materials
Iron	Plastic
Nickel	Wood
Cobalt	Rubber

- Methods of inducing magnetism:

- A piece of steel becomes permanently magnetized when placed near a magnet, but its magnetism is usually weak.
- It can be magnetized more strongly by stroking it with one end of a magnet
- *Most effective method: place it in a solenoid and pass a large, direct current (d.c.) through the coil.*

- Methods of demagnetisation:
  - If a magnet is hammered, its atomic magnets are thrown out of line and it becomes demagnetized.
  - Heating a magnet to a high temperature also demagnetize it.
  - Stroking with another magnet to destroy the alignment of poles
  - Place magnet with poles opposite to that which is induced by a d.c. current and insert into coil with d.c. current
  - Most efficient method: place magnet inside a solenoid connected to an alternating current (a.c.) supply.
- Soft Iron vs. Steel

Soft iron	Steel
Gets magnetized faster but loses its magnetism as soon as inducing magnet is removed.	Slow to be magnetized but retains acquired magnetism for a long time.
High susceptibility but low retentivity	Low susceptibility but high retentivity.
Use: core in the transformer	**Use:** making magnets.

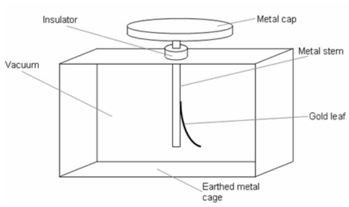
- Permanent Magnet vs. Electromagnet

Permanent Magnet	Electromagnet
Design: hard magnetic material	**Design:** Uses a solenoid to create magnetic field

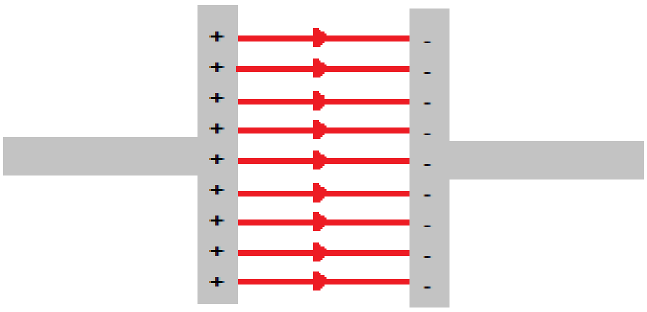
Permanent Magnet	Electromagnet
Use: for applications where magnetism is needed over long periods – fridge doors	**Use:** For applications where magnetic field needs to be turned on & off - scrap metal moving

4.2. Electric Charge

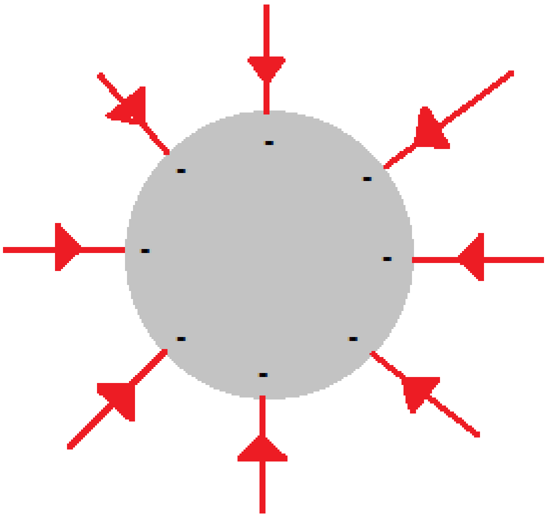
- There are 2 types of charges: positive and negative.
- Unlike charges attract and like charges repel.
- The SI unit of charge is the Coulomb (C).
- The presence of an electrostatic charge can be detected using a leaf electroscope.
  - If a charged object is placed near the cap, charges are induced.
  - The metal cap gets one type of charge (positive or negative) and the metal stem and gold leaf get the other type of charge so they repel each other.



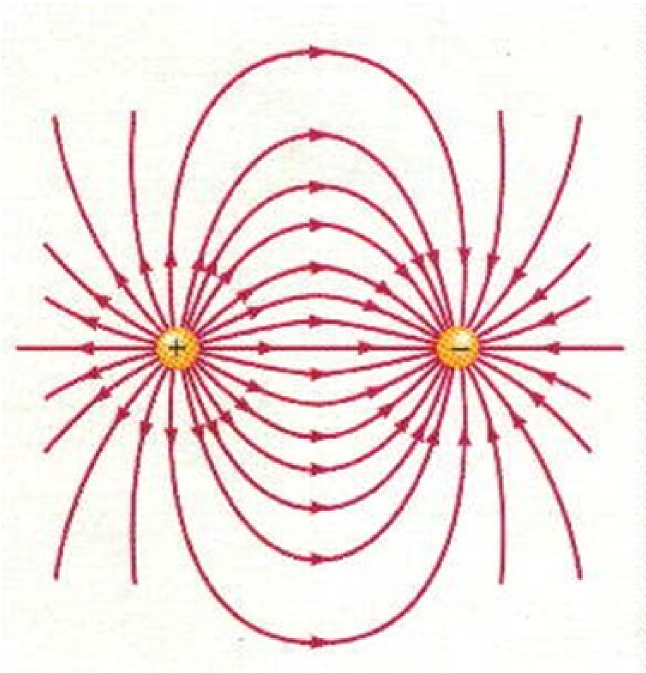
- **Electric field:** region in which electric charge experiences a force.
- The direction of an electric field at a point is the direction of the force on a positive charge at that point
- **Conductors:** materials that let electrons pass through them. Metals are the best electrical conductors as they have free electrons. E.g. copper
- **Insulators:** materials that hardly conduct at all. Their electrons are tightly held to atoms and hardly move, but they can be transferred by rubbing. E.g. Rubber
- **Simple Field Patterns:**
  - Parallel plates



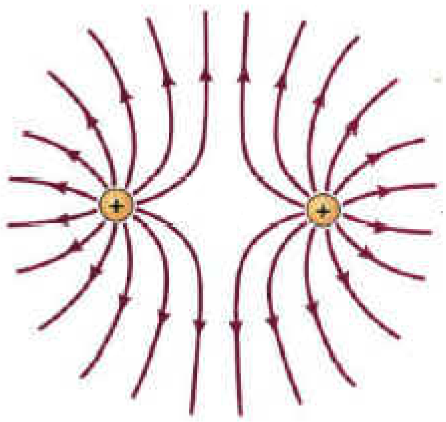
  - Point charge



- +ve and -ve



- +ve and +ve



- **Induced charges:**
  - Charging a body involves the addition or removal of electrons.
  - A charge that "appears" on an uncharged object because of a charged object nearby
  - For example if a positively charged rod is brought near a small piece of aluminum foil, electrons in foil are pulled towards rod, which leaves the bottom of the foil with a net positive charge.
  - The attraction is stronger than repulsion because the attracting charges are closer than the repelling ones.

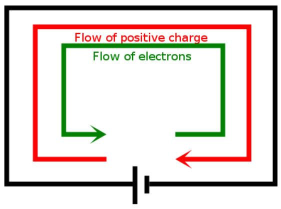
4.3. Current

- Current: a flow of charge, the SI unit is the Ampere (A).
- An ammeter measures the current in a circuit and is connected in series
- Current is a rate of flow of charge.
- In metals, current is caused by a flow of electrons

$$\text{Current } (A) = \frac{Charge\ (C)}{Time\ (s)}$$

$$I = Q/t$$

- Current follows path of least resistance
- Conventional current flows in the direction opposite to that which electrons flow in.
- Red = Conventional Current
- Green = flow of electrons



- $1\overline{e} = 1.6 \times 10^{-19} C$
- $1C = 6.25 \times 10^{18} \overline{e}$

4.4. Electromotive Force (EMF)

- The energy supplied by the source in driving a unit charge around a circuit.

- The maximum voltage a cell can produce is called the electromotive force (EMF), measured in volts.
- When a current is being supplied, the voltage is lower because of the energy wastage inside the cell.
- A cell produces its maximum PD when not in a circuit and not supplying current.

4.5. Potential Difference (P.D)

- Potential difference, or PD for short, is also known as voltage.
- Voltage is the amount of energy the cell gives the electrons it pushes out. Voltage is measured in volts (V) and is measured by a voltmeter (connected in parallel). If a cell has 1 Volt, it delivers 1 Joule of energy to each coulomb of charge (J/C).

$$\textbf{Voltage } = \frac{\text{Energy}}{\text{Charge}}$$

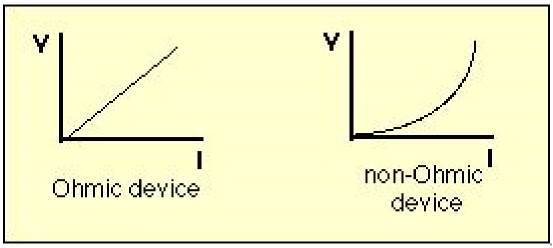
$$V = \frac{E}{C}$$

4.6. Resistance

$$\text{Resistance } (\Omega) = \frac{\text{Voltage}}{\text{Current}} = \frac{V}{I}$$

Factors affecting resistance:

- Length
  - $\Omega \propto L$
  - The electrons have to travel a longer length and thus encounter more resistance.
- Cross-sectional area
  - $\Omega \propto \frac{1}{A}$
  - More electrons can flow per unit time, increasing the current and therefore decreasing the resistance.
- Material
  - Better conductor = less resistance
- Current Voltage Character of an Ohmic Resistor and a Filament Lamp:



- Ohm's law states that voltage across a resistor is directly proportional to the current through it. This is only true if the temperature of the resistor or lamp remains constant

4.7. Electrical Energy

- Electrical energy is transferred from the battery or power source to the circuit components then into the surroundings
- 1 Watt is 1J/s

$$Electrical\ power = Voltage\ (V) \times Current\ (A)$$

$$P = VI$$

$$Electrical\ energy = Voltage\ (V) \times Current \times Time$$

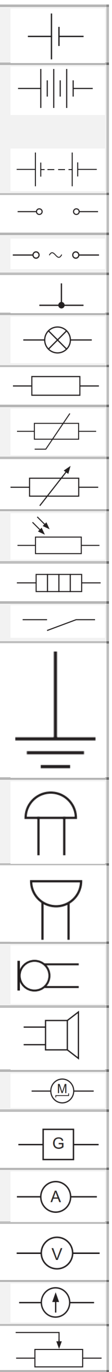
$$E = VIt$$

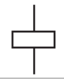
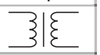
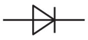
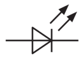
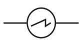
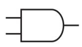
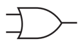
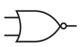
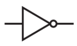
4.8. Series and Parallel Circuits

- The current at any point in a series circuit is the same
- The current splits at each branch in a parallel circuit so the total current is always greater than the current in one branch
- Combining resistors
  - In Series: $R_{Total} = R_1 + R_2$
  - In Parallel: $R_{Total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$
  - The combined resistance of 2 resistors in parallel is less than that of either resistor by itself and the current in the two resistors in greater in the source than in the individual resistors and is equal to the sum of the currents in all the resistors connected in parallel.
- Advantages of putting lamps in parallel are:
  - If one lamp breaks, the other still works
  - Each lamp gets maximum PD
- In series: PD across the supply = PD across all the components combined
- In parallel: Current across the source = sum of currents in the separate branches

4.9. Circuit Diagrams

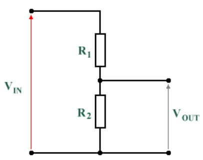
Cell		
Battery of cells	Or	
Power supply		
a.c. power supply		
Junction of conductors		
Lamp		
Fixed resistor		
Thermistor		
Variable Resistor		
Light dependent resistor		
Heater		
Switch		
Earth or Ground		
Electric Bell		
Buzzer		
Microphone		
Loudspeaker		
Motor		
Generator		
Ammeter		
Voltmeter		
Galvanometer		
Potential Divider		
Relay Coil		



		
Transformer		
Diode		
Light- emitting diode		
Fuse		
Oscilloscope		
AND gate		
OR gate		
NAND gate		
NOR gate		
NOT gate		

4.10. Action and Use of Circuit Components

- A potential divider divides the voltage into smaller parts.

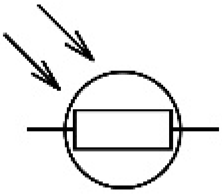


- To find the voltage (at V_{OUT}) we use the following formula:

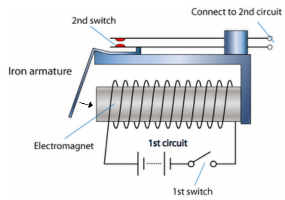
$$V_{OUT} = V_{IN} \times \left(\frac{R_2}{R_{Total}}\right)$$

- A variable potential divider (potentiometer) is the same as the one above but using a variable resistor; it acts like a potential divider, but you can change output voltage.
- Input Transducers:
  - **Thermistor:** input sensor and a transducer. It is a temperature-dependent resistor. At higher temperature there is less resistance.

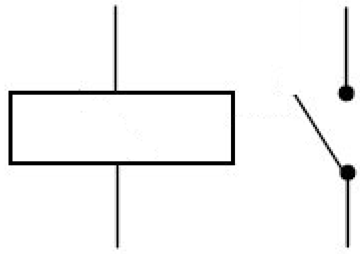
* **Light dependent resistor (LDR):** input sensor and a transducer. When light intensity increases, resistance decreases.



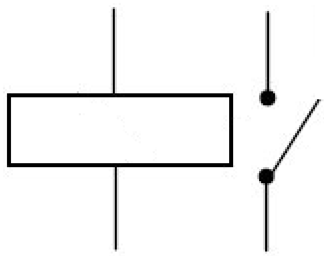
- Relays:
  - A switch operated by an electromagnet



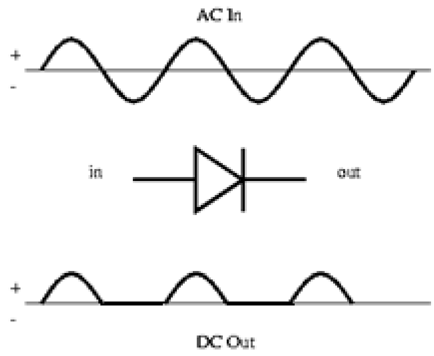
- **Normally closed relay:** when coil *not energized*, switch is closed, completing circuit



- **Normally open relay:** when coil *energized*, switch is closed, breaking circuit



- Diodes:
  - A device that has an extremely high resistance in one direction and a low resistance in the other, therefore it effectively only allows current to flow in one direction
  - Forward bias is when the diode is pointing in the direction of the conventional current and reverse bias is the opposite
  - It can be used in a rectifier; turns AC current into DC current.



4.11. Digital Electronics

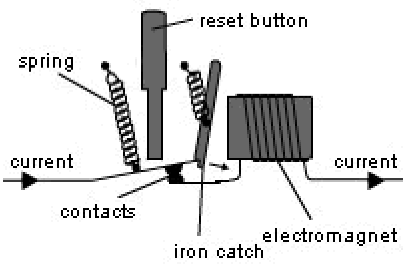
- Analogue uses a whole range of continuous variations to transmit a signal that include variations of high and low states.
- Digital signals use only 2 states, on and off.
- Logic gates are processors that are circuits containing transistors and other components. Their function is shown by the truth table below (3 columns from the right)

Gate	Symbol	Input A	Input B	Output
NOT Gate		0 1	None	1 0
AND Gate		0 0 1 1	0 1 0 1	0 0 0 1
OR Gate		0 0 1 1	0 1 0 1	0 1 1 1
NAND Gate		0 0 1 1	0 1 0 1	1 1 1 0
NOR Gate		0 0 1 1	0 1 0 1	1 0 0 0

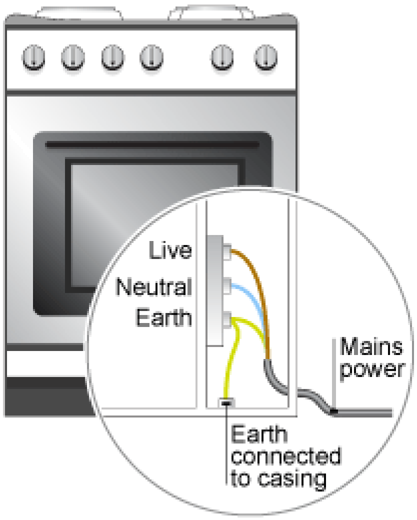
4.12. Dangers of Electricity

- Hazards:
  - **Damaged insulation:** contact with the wire (live wire especially) due to gap in the insulation causes electric shock which can cause serious injury or shock.
  - **Overheating of cables:** when long extension leads are coiled up, they may overheat. The current warms the wire, but the heat has less area to escape from a tight bundle. This might cause a fire.
  - **Damp conditions:** water can conduct a current, so if electrical equipment is wet someone might get electrocuted
- Fuse:
  - A fuse protects a circuit.
  - Thin piece of wire which overheats and melts if current is too high.
  - It is placed on the live wire before the switch.
  - This prevents overheating and catching fire.
  - A fuse will have a specific current value (e.g. 13 Amps.) so when choosing a suitable fuse, you must use the one above minimum value but less than maximum value

- Circuit Breaker:
  - An automatic switch which if current rises over a specified value, the electromagnet pulls the contacts apart, breaking the circuit.
  - The reset button is to rest everything.
  - It works like a fuse but is better because it can be reset.

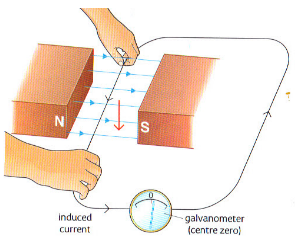


- **Benefits of Earthing a Metal Case:**
  - Many electrical appliances, have metal cases, the earth wire creates a safe route for current to flow through if the live wire touches the casing
  - Earth terminal connected to metal casing, so in such a case, the current goes through earth wire instead of causing an electric shock.
  - A strong current surges through earth wire because it has very low resistance
  - This breaks the fuse and disconnects the appliance



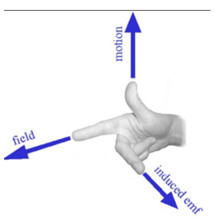
4.13. Electromagnetic Effects

- Electromagnetic Induction: If a wire is passed across a magnetic field/changing magnetic field, a small EMF is induced and can be detected by a galvanometer.

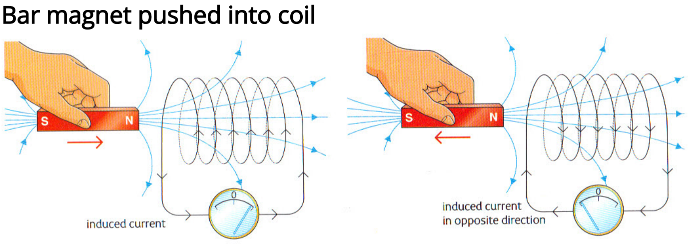


- The direction of an induced EMF opposes the change causing it.

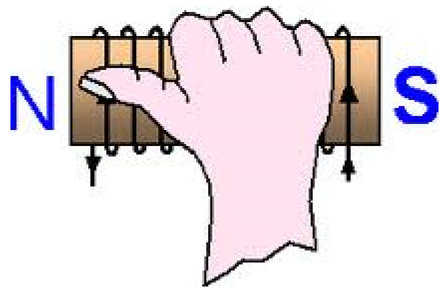
- The induced EMF can be increased by:
  - moving the wire faster
  - using a stronger magnet
  - Increasing length of wire in magnetic field, e.g. looping the wire through the field several times.
- The current and EMF direction can be reversed by:
  - moving the wire in the opposite direction
  - turning the magnet round so that the field direction is reversed
- **Fleming's right-hand rule** gives the current direction:



Bar magnet pushed into coil



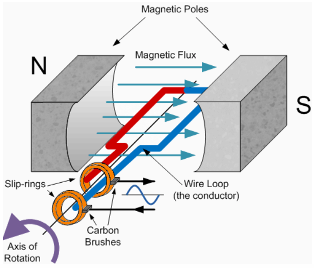
- The induced EMF (and current) can be increased by:
  - moving the magnet faster
  - using a stronger magnet
  - increasing the number of turns in the coil
- If the magnet is pulled away, the direction of the induced EMF (and current) is reversed
- Using South pole instead of North pole reverses direction of induced EMF (and current)
- If the magnet is held still, there is no EMF
- An induced current always flows in a direction such that it opposes the change which produced it.
- When a magnet is moved towards a coil the pole of the coil and magnet next to each other are the same.
- When the magnet is moved away the poles are opposite (opposite poles attract).
- The pole-type (north or south) is controlled by the direction in which the current is induced.
- The direction of the current is given by the **right-hand grip rule:**

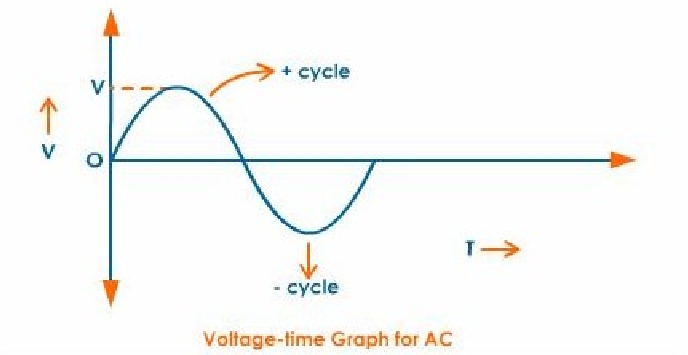


- The fingers point in the conventional current direction and the thumb gives the North Pole.

4.14. Applications

- In a direct current (d.c) the electrons flow in a singular direction.
- In an alternating current (a.c) the direction of flow is reversed in regular time periods.
- A.C Generator:
  - The coil is made of insulated copper wire and is rotated by turning the shaft; the slip rings are fixed to the coil and rotate with it.
  - The brushes are 2 contacts which rub against the slip rings and keep the coil connected to the outside part of the circuit, usually made of carbon.
  - When the coil is rotated, it cuts magnetic field lines, so an EMF is generated, which makes a current flow.
  - Each side of the coil travels upwards then downwards then upwards etc. so the current flows backwards then forwards then backwards etc. so it is an alternating current.





- The current is maximum when the coil is horizontal since field lines are being cut at the fastest rate and 0 when the coil is vertical, since it is cutting NO field lines.
- The EMF can be increased by:
  - increasing the number of turns on the coil
  - increasing the area of the coil
  - using a stronger magnet
  - rotating the coil faster

4.15. Transformers

- AC currents can be increased or decreased by using a transformer.
- Consists of a primary coil, a secondary coil and an iron core.
- The iron core gets magnetized by the incoming current and this magnetism then creates a current in the leaving wire.
- The power is the same on both sides (assume= 100% efficiency).
- You can figure out number of coils and the voltage with:

$$\frac{Output\ voltage}{Input\ voltage} = \frac{Turns\ on\ output\ coil}{Turns\ on\ input\ coil}$$

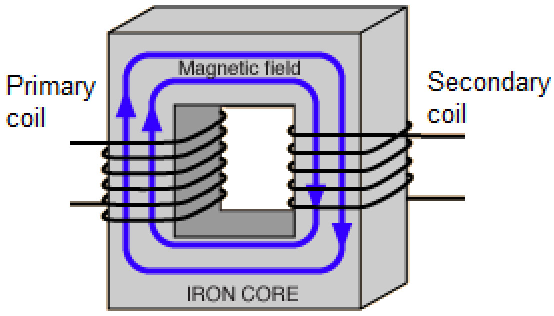
$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$V_{In} \times I_{In} = V_{Out} \times I_{Out}$$

$$V_P \times I_P = V_S \times I_S$$

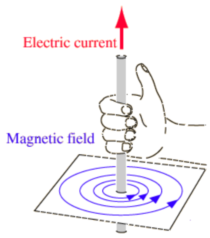
(Under 100% efficiency)

- When magnetic field is changed across the primary coil by connecting it with A.C. an e.m.f. induces across the secondary coil.
- The iron core channels the alternating field through the secondary coil, inducing an alternating e.m.f. across it.
- A **step-up** transformer increases the voltage and a **step-down** transformer decreases it.
- Transformers used to make high voltage AC currents.
- Since power lost in a resistor $\mathbf{P} = \mathbf{I}^2 \times \mathbf{R}$, having a lower current will decrease the power loss.
- Since transmission cables are many kilometres long they have a lot of resistance, so a transformer is used to increase the voltage and decrease the current to decease power lost.
- The advantages of high-voltage transmission:
  - Less power lost
  - Thinner, light, and cheaper cables can be used since current is reduced

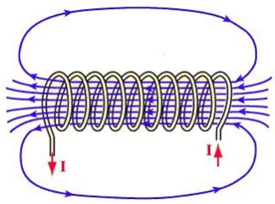


4.16. Electromagnetic Effect of a Current

- Magnetic field around a current carrying wire



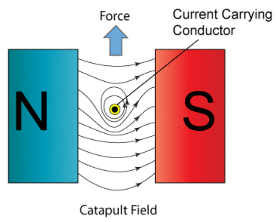
- Magnetic field around a current carrying solenoid



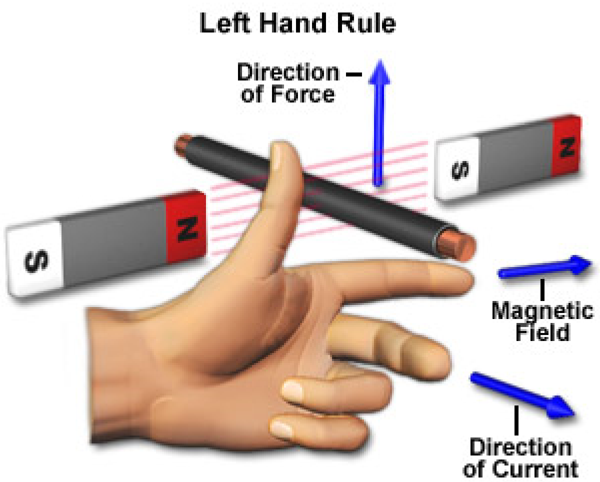
- Increasing the strength of the field
- Increasing the current increases the strength of the field
- Increasing the number of turns of a coil increases the strength increases the strength of the field.
- Reversing the current direction reverses the magnetic field direction (right-hand rule).
- The direction of a magnetic field line at a point is the direction of the force on the N pole of a magnet at that point
- Magnetic effect of current is used in a relay and a circuit breaker.

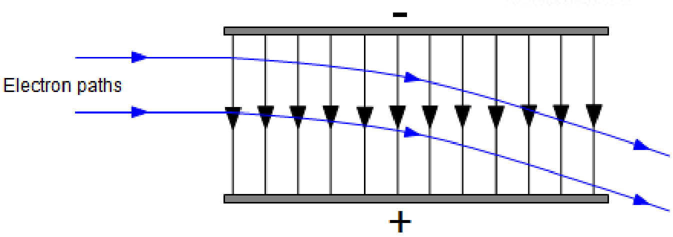
4.17. Force on a Current-Carrying Conductor

- If a current carrying conductor is in a magnetic field, it warps the field lines.
- The field lines from the magnet want to straighten out naturally.
- This causes a catapult like action on the wire creating a force

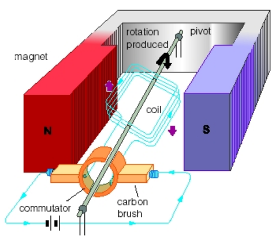


- If you reverse current, you will reverse direction of force
- If you reverse direction of field, you will reverse direction of force.
- The direction of the force, current or magnetic field is given by **Fleming's left-hand rule:**





4.18. D.C. Motor



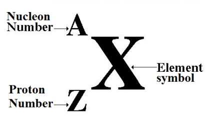
- When a current-carrying coil is in a magnetic field, it experiences a turning effect.
- A DC motor runs on a direct current.
- The coil is made of insulated copper wire and is free to rotate between the poles of the magnet.
- The commutator (split-ring) is fixed to the coil and rotates with it.
- When the coil overshoots the vertical, the commutator changes direction of the current through it, so the forces change direction and keep the coil turning.
- The brushes are two contacts which rub against the commutator and keep the coil connected to battery, usually made of carbon
- The max. turning effect is when the coil is horizontal.
- There is no force when the coil is vertical, but it always overshoots this position

Turning effect increased by:	Reversing rotation can be done by:
Increasing the current	Reversing the battery
Using a stronger magnet - increasing the strength of the magnetic field	Reversing the poles
Increasing the number of turns on the coil.	

5. Atomic Physics

5.1. The Atom

- **Atoms consist of:**
  - **Nucleus:** central part of atom made of protons (positively charged) and neutrons. These two types of particles are called nucleons. They are bound together by the strong nuclear force.
  - **Electrons:** almost mass-less particles which orbit nucleus in shells
- This is proved by Rutherford's Gold Foil Experiment[2]
- **Proton number:** number of protons in an atom
- **Nucleon number:** the number of nucleons (protons + neutrons) in an atom
- The following is the nuclide notation for atoms



- **Isotope:**
  - Atoms of the same element that have different numbers of neutrons e.g. Carbon 12 and Carbon 14.
  - There are non-radioactive isotopes and radio-isotopes.
  - Radio isotopes are unstable atoms, which break down giving radiation
- Uses:
  - **Medical use:** cancer treatment (radiotherapy) – rays kill cancer cells using cobalt-60

- **Industrial use:** to check for leaks – radioisotopes (tracers) added to oil/gas. At leaks radiation is detected using a Geiger counter.
- **Archaeological use:** carbon 14 – used for carbon dating

5.2. Detection of Radioactivity

- **Background radiation:** small amount of radiation around us all time because of radioactive materials in the environment. It mainly comes from natural sources such as soil, rocks, air, building materials, food and drink – and even space.
- A Geiger-Müller (GM) tube can be used to detects α, β and γ radiation

5.3. Type of Radioactive Emissions

- Radioactive emissions occur randomly over space & time

	Alpha (α)	Beta (β)	Gamma (γ)
Nature	Helium nucleus (2 protons and neutrons)	One high speed electron	Electro-magnetic radiation
Charge	+2	-1	none
Penetration	Stopped by paper	Stopped by aluminum	Only reduced by lead
Effect from fields	Deflected	Very deflected	Not deflected
Ionizing effect	Very strong	Weak	Very weak
Speed	$\frac{1}{10}\text{v of light}$	$\frac{9}{10}\text{v of light}$	v of light

- Depending on their charge, they will be affected by electric and magnetic fields.

5.4. Radioactive Decay

- **Radioactive decay:** A radioisotope (unstable arrangement of neutrons and protons) is altered to make a more stable arrangement.
- The parent nucleus becomes a daughter nucleus and a particle (decay products).
- The nucleus changes when undergoing alpha or beta decay

Alpha decay:

- An element with a proton number 2 lower and nucleon number 4 lower, and an alpha particle is made (2p + 2n)

e.g. Radium-226 nucleus → Radon-222 + helium-4 nucleus

$$^{226}_{88}\text{Ra} \rightarrow \, ^{222}_{86}\text{Rn} + \, ^{4}_{2}\text{He}$$

Beta decay:

- A neutron changes into a proton, an electron and an antineutrino so an element with the same nucleon number but with a proton number 1 higher e.g.

e.g. iodine-131 → xenon-131 + antineutrino + beta particle

$$^{131}_{53}I \rightarrow \, ^{131}_{54}\text{Xe} + \, ^{0}_{-1}\beta + \, ^{0}_{0}v$$

Gamma emission:

- Gamma emission by itself causes no change in mass number or atomic number; they just emit energy
- Some isotopes do not change in mass or atomic number however they emit energy as their particles rearrange themselves to become more stable

5.5. Half Life

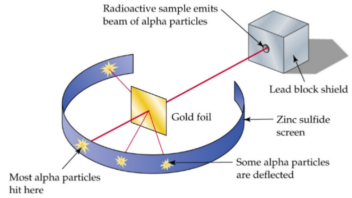
- **Half-life of a radioisotope:** is the time taken for half the nuclei present in any given sample to decay.
- Some nuclei are more stable than others.
- Remember to factor background radiation in half-life calculations involving tables and decay curves

5.6. Safety Precautions

- Radioactive material is stored in a lead container
- Picked up with tongs, not bare hands
- Kept away from the body and not pointed at people
- Left out of its container for as short a time as possible

5.7. Rutherford's Experiment

- Thin gold foil is bombarded with alpha particles, which are positively charged.
- Most passed straight through, but few were repelled so strongly that they were bounced back or deflected at large angles.
  Rutherford concluded that the atom must be largely empty space, with its positive charge and most of its mass concentrated in a tiny nucleus.



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