Physics

Velocity is defined as the rate of change of displacement
Fluids are substances that can flow and take the shape of their container.

Mass, Weight & Density

Mass is the quantity of matter in an object at rest relative to the observer.

Weight is the effect of the gravitational field on an object with mass

A gravitational field is the force per unit mass acting on an object in a gravitational field

A balance is used to measure mass or to compare the weights of objects

Density is mass per unit volume of a material.

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

Volume is the amount of space occupied by an object in a three-dimensional space

Upthrust is the upward force exerted on an object by a fluid that opposes the downward force of weight and is caused by the pressure difference between the top and bottom of the object

- The idea of an object floating or sinking depends on two factors:
    1.) The density of the object
    2.) The upthrust it experiences

Effects of forces

A **force** is the effect of a push or pull on an object due to the interaction with another object

- ❖ It can cause changes in shape, size, or direction.

A **resultant force** is a single force that represents the combined effect of all forces acting on an object. It determines both the direction and the magnitude of the overall force experienced by the object

The two possible outcomes when forces combine are: balanced and unbalanced forces

A **balanced force** occurs when the forces acting on an object have equal magnitude but work in opposite directions, resulting in no net force

Unbalanced force occurs when forces acting on an object have different magnitude and do not act in opposite directions, resulting in a net force that causes the object to accelerate in the direction of the net force

Newton's first law of motion:

Object's will continue to move at the same velocity or remain at rest unless acted on by a resultant force

- The effect of zero-resultant force on an object will be:
  - ❖ Object at rest will remain at rest
  - ❖ Object in motion will continue to move with constant velocity
- Constant velocity refers to motion at a steady speed in a straight line

Newton's second law of motion:

An object's acceleration is directly proportional to the forces acted on it and is inversely proportional to the object's mass

Force (f) = mass (m) x acceleration (a)

Hooke's law states that the extension of a spring is directly proportional to the force (load) acting on it

$$\textbf{Spring constant (k)} = \frac{force\ (f)}{extension\ (x)}$$

- ❖ The **spring constant** is the force per unit extension and measure how stiff the spring is

The **elastic limit or the limit of proportionality** is the point beyond which the spring will no longer return to its original length when stretched, violating Hooke's law.

Circular motion is the motion of an object in a circular path where the velocity of the object keeps changing due to the constant change in direction of motion.

- The factors needed to maintain circular motion are:

1. The mass of the object
2. The speed of the object
3. The radius of the object

Friction is the contact force that opposes motion and produces heating

Drag is the frictional force acting on objects moving through fluids, caused by the collisions between particles.

Moment

A **moment** is the turning effect of a force about a pivot

- Moments do not cause motion. The resultant force causes motion, and moments describe the turning effect due to forces about a pivot.

Moment = force x perpendicular distance to the pivot

The **principle of moments** specifically applies to balanced systems

The principle of moments describes a system in equilibrium conditions

Equilibrium is the state in which an object remains unchanged in its motion or rotation, with balanced forces and moments acting upon it.

- Objects in equilibrium can either be stationary or moving with constant velocity

The **resultant moment** is the net turning effect produced by the combination of all forces acting on an object, determining its rotational motion

The **center of gravity** is the point at which the weight of the object can be considered to act

Stability is the ability of an object to maintain its equilibrium position, where its center of gravity lies above its base

- The two factors that affect the stability of an object are:
    1. Width of the base
    2. centre of gravity

An object suspended from a point will vertically align its centre of gravity with the pivoting point.

An irregular shape can be suspended from different points, and a plum line can be used to draw vertical lines that intersect at the centre of gravity

Momentum

Momentum is the product of an object's velocity and mass.

- It is a vector quantity (so it can be positive or negative)

Momentum = mass (m) x velocity (v)

- Momentum keeps an object moving in the same direction, making it resistant to changes in the direction, especially for objects with large mass
- The three conditions under which the momentum of an object will change are:
    1.) Magnitude of speed changes (accelerates or decelerates)
    2.) Direction changes
    3.) Mass changes

The principle of conservation of momentum states that, in a closed system:

The total momentum before an event = the total momentum after an event

- **A closed system** refers to a system where total momentum remains constant and no external forces are acting on the system

Impulse is the product of force and the time duration for which it acts

Impulse = Force x change in time

Force is the rate of change of momentum

Energy, Work & Power

A **system** is an object or a group of objects

Energy stores refer to the different ways in which energy is stored in objects.

Energy transfer pathways are how energy is transferred from one store to another.

- The four energy transfer pathways are:

1. **Mechanical:** a form of energy transfer pathway when an object moves due to a force acting on it.
2. **Electrical:** a type of energy transfer pathway when a charge moves through a potential difference (voltage)
3. radiation
4. heating

Kinetic energy is the energy stored possessed by objects in motion, determined by their mass and speed.

$$K = \frac{1}{2}mv^2$$

Gravitational potential energy is the energy possessed by an object due to its height in a gravitational field.

$$E_p = m\,g\,h$$

Energy flow diagrams show energy stores and transfer pathways

Total energy in = useful energy out + wasted energy

A Sankey diagram is a graphical representation of energy transfers, characterized by splitting arrows that show the proportions of energy transfers taking place

Work done is the product of the force applied on an object and the distance over which the force is applied.

Work done (w) = force (f) x distance (d)

Energy transferred = work done

1 joule = 1 newton metre

Power is the rate at which energy is transferred or work is done, measured in Watts (W)

Power = Work done (W) / time (t)

Power = energy transferred / time

- The rate of doing work refers to the amount of work done or energy transferred per unit of time.

Efficiency is a measure of the amount of useful power or energy output in comparison to the total power or energy output.

Efficiency = Useful energy output / total energy input x 100

Energy sources

Solar energy

The sun is the primary source of energy on Earth

Solar energy is transferred to the earth by radiation, in the form of visible light and infrared radiation.

- **Solar cells**, also known as photovoltaic cells are devices made of semiconducting material that produce electricity from sunlight in a process called the photoelectric effect.
- **Solar panels** are devices that transfer energy from sunlight to the thermal storage of the panels, which is then used to heat water.
- **The solar furnace** consists of large curved mirrors that focus sunlight onto a small area, which heats water to produce steam, which then turns turbines to generate electricity.

Advantages:	**Disadvantages:**
1.) Renewable 2.) Reliable in hot climates 3.) Does not contribute to global warming 4.) Can be used in remote locations	1.) Solar farms need to be large-scale to produce a significant amount of electricity.

Fossil fuels

Fossil fuels are natural resources formed over millions of years from the remains of plants and animals

Three main fossil fuels are: natural gas (methane), oil, and gas

Burning of fossil fuels produces:

- Carbon dioxide which is a greenhouse gas that contributes to global warming
- Sulphur dioxide which causes acid rain

Main uses of fossil fuels:

1.) Transportation
2.) Electricity generation
3.) Produces heat in homes and industries

Disadvantages:

1.) Non-renewable
2.) Produces carbon dioxide which is a greenhouse gas that contributes to global warming
3.) Produces sulphur dioxide which causes acid rain

Biofuels

Biofuels are produced from plant matter, which undergo processes like fermentation or distillation to extract ethanol or methane for use as an alternative fuel to fossil fuels.

Advantages:

1.) Renewable
2.) Carbon neutral (having a balance between emitting carbon and absorbing carbon from the atmosphere)

Nuclear fuels

Nuclear fuels refer to materials such as uranium used in nuclear reactors to release energy during nuclear fission reactions.

Process of generating electricity in nuclear power stations:

Nuclear power stations use energy released in nuclear fission to heat water which converts into steam. This steam then turns turbines connected to generators to generate electricity.

Advantages:	**Disadvantages:**

Nuclear power stations **release no pollution** into the atmosphere during normal operation.	**Non-renewable** because there is a finite supply of uranium ore found in the ground.

Wave & tidal power

Power is generated by the turning of turbines caused by the rise and fall of waves or tides.

Advantages:

1.) Renewable
2.) Produce no pollution

Process of generating electricity in wave and tidal power stations:

- Wave and tidal power stations generate electricity by utilising the motion of waves to turn turbines, which then generate electricity through electromagnetic induction
- The main purpose of underwater turbines is to transfer energy from the kinetic store of the moving water to the kinetic store of the turbines, which turns generators that generate electricity

Process of generating electricity in tidal barrages:

- Tidal barrages are small systems that produce small amounts of electricity

Process of generating electricity in hydroelectric dams:

- Hydroelectric dams are structures built across a river to store water at a height in reservoirs. The water can be released, flowing over a turbine that turns a generator that generates electricity
- Hydroelectric dams can release significant amounts of greenhouse gases due to the fossil fuels used to pump the water back up to the reservoir

Advantages of hydroelectric dams:	**Disadvantages of hydroelectric dams:**

1.) They can produce large amounts of energy 2.) They are very responsive because they can be easily turned on and off to meet changing demand	1.) Pumping systems use fossil fuels to pump the water back up to the reservoir. The usage of fossil fuels releases greenhouse gases into the atmosphere, contributing to global warming 2.) Building dams can cause flooding of the banks of the river, leading to loss of habitat for many organisms 3.) Dams are expensive to build

Geothermal energy

Geothermal energy is the energy stored in the thermal storage of rocks beneath the Earth's surface from tectonic heating. The hot rocks are used to heat water that can be used as a hot water supply and to produce steam to turn turbines for electricity generation.

Process of generating electricity in geothermal power stations:

Geothermal energy generates electricity by heating water and generating steam using the hot rocks beneath the Earth's surface, which drives turbines to produce electricity.

Advantages:	**Disadvantages:**
1.) Renewable resource 2.) Reliable because the rocks remain hot for years so they can consistently produce electricity	1.) Methane (natural gas) is found between the spaces in the rocks so when water is injected into these spaces, it causes methane to be forced out (fracking). Since methane is a greenhouse gas (even without combustion), it contributes to global warming. 2.) Geothermal activity depends on tectonic activity so there are only a few locations suitable on earth

	3.) Not very efficient (about 12%) 4.) Expensive to produce electricity

Nuclear fusion

Nuclear fusion is the process by which small nuclei combine to form a larger nucleus, releasing a massive amount of energy.

- Fusion reactions require nearly as much energy as they release.
- The sun's energy is an example of nuclear fusion, where the hydrogen nuclei combine to form a helium nucleus, releasing massive amounts of energy

Advantages:	**Disadvantage:**
1.) Provides virtually limitless energy with minimal environmental impact 2.) No greenhouse gas is generated 3.) Produces minimal radioactive waste	1.) It requires extremely high temperatures and pressure to sustain and initiate a fusion reaction.

Scientists are searching for methods to practically sustain fusion reactions at lower temperatures and pressures on Earth.

Difference between nuclear fusion and nuclear fission:

Nuclear fusion	Nuclear fission
involves the combining of smaller nuclei to build a larger nucleus, releasing energy in the process.	involves the splitting of larger nuclei to smaller nuclei, in order to release a massive amount of energy.

Pressure

Pressure is force per unit area or the concentration of force

Pressure (P) = Force (F) / Area (A)

Pressure is measured in **Pascal**

- The area used in calculating the pressure should always be the cross-sectional area (perpendicular to the applied force)

The force exerted on an object suspended in a liquid acts in all directions, evenly.

Pressure (P) = density (*p)* x gravitational field (g) x change in depth (h)

Kinetic particle model of matter

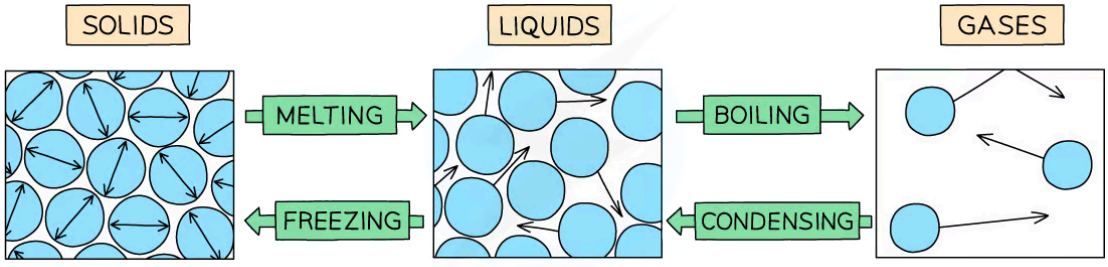
The **kinetic theory of matter** simply states that all matter is made up of tiny particles which are in constant motion.

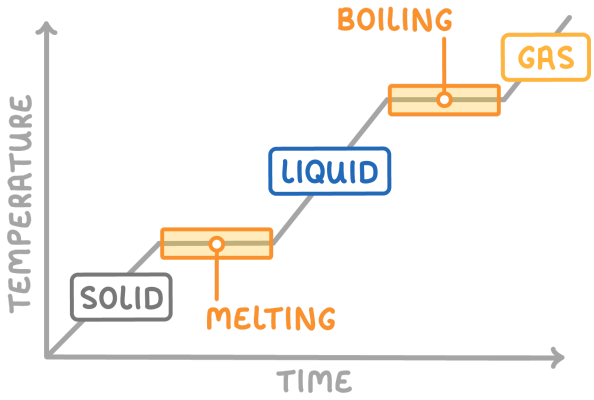
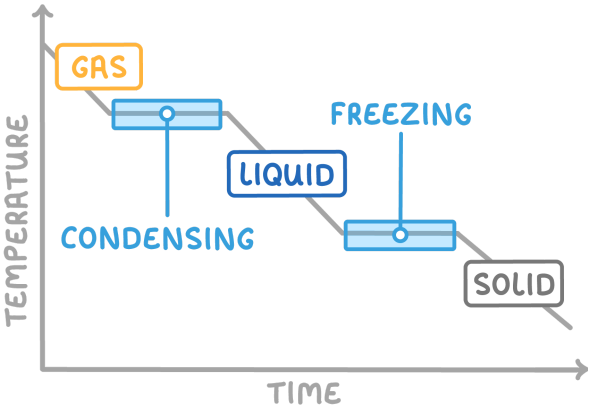
Three states of matter:

Solids	Liquids	Gases
Have fixed shaped	Flow to take the shape of the container	Flow to take the shape of the container
Have fixed volume	Have fixed volume	No fixed volume
Not compressible	Moderately compressible	Highly compressible
Very high density	Medium density	Low density
Particles are arranged in a regular pattern and vibrate about a fixed point	Molecules are randomly arranged and move around each other	Molecules are randomly arranged and move quickly in all directions
Particles have low energy	Particles have greater energy	Particles have highest energy

Changes of state are **reversible**

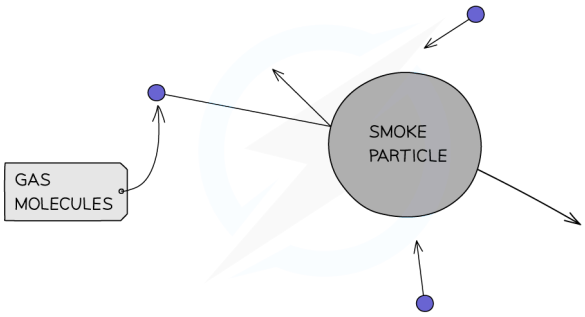
When a substance changes state, the only thing that changes is its energy.

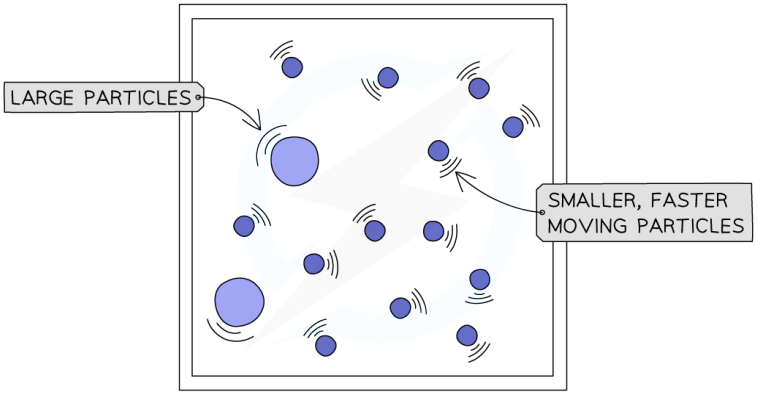


HEATING CURVE	COOLING CURVE
	

BROWNIAN MOTION

Brownian motion is the random movement of particles suspended in a liquid or a gas produced by large number of collisions with smaller particles which are often too small to see





ABSOLUTE ZERO

- Particles gain kinetic energy as their temperature increases. So there must be a temperature in which all the particles are stationary. This is the lowest possible temperature as particles cannot travel any slower than 0 m/s.

The temperature at which all the particles are stationary is called **absolute zero** and has a value of **- 273° C.**

Temperature measured in kelvin is called **absolute temperature.**

➔ It starts with **absolute zero.**

➔ 0 K (kelvin) = - 273° C (celsius)

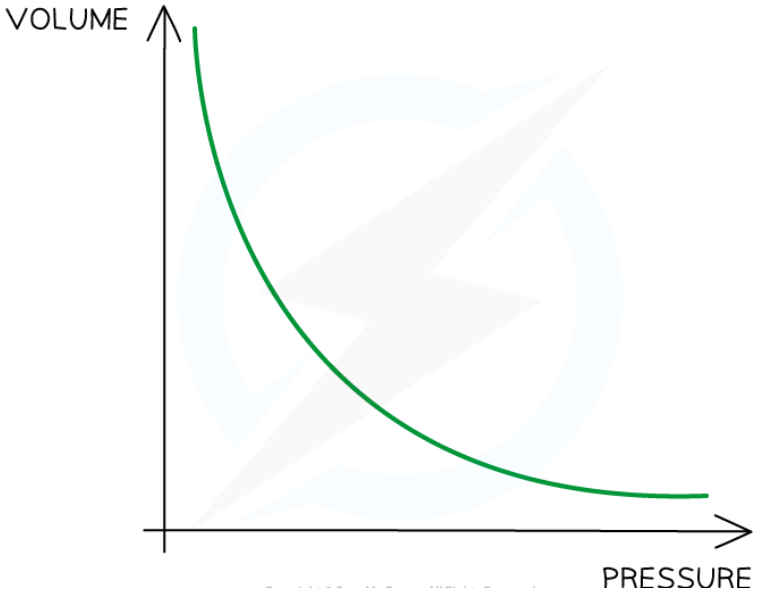
Conversion between Kelvin temperature and degrees celsius: T (K) = θ (C) + 273

BOYLE'S LAW

Boyle's law states that the volume of a fixed mass of gas is inversely proportional to its pressure, provided its temperature remains constant

If the temperature T of an ideal gas is constant, then **boyle's law** is given by:

$P \propto \frac{1}{V}$	**pV = constant** Constant because if pressure is increased volume decreases (vice-versa)	**$p_1V_1 = p_2V_2$** P_1 = initial pressure V_1 = initial volume P_2 = final pressure V_2 = final volume



NOTE: the curve 'tend towards zero' meaning the curve gets closer and closer but never touches the axis, or zero.

Thermal properties of matter

THERMAL EXPANSION

It happens because:

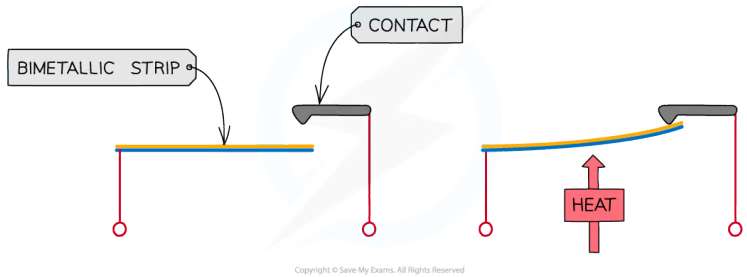
- ➔ The molecules start to move around (or vibrate) faster as they gain kinetic energy
- ➔ This causes them to collide with each other more often and push each other apart

Remember: it is the material that expands, not the molecules

State	Magnitude of expansion	Explanation
Solid	Expands slightly	They have the lowest energy particles amongst the three states so they cannot overcome the intermolecular forces of attraction holding them together
Liquid	Expands more than solids	The molecules have enough energy to partially overcome the intermolecular forces of attraction holding them together **Exception:** liquid paraffin expands very rapidly on heating
Gas	Expands the most	The molecules have enough energy to completely overcome the intermolecular forces of attraction holding them together

Applications of thermal expansion

Liquid-in-glass thermometer	Relies on the thermal expansion of liquids to measure temperature It consists of: ● A thin glass capillary tube containing a liquid that expands with temperature. ● A scale along the side of the tube that allows the temperature to be measured based on the length of the liquid within the tube
Temperature - activated switches used in thermostats or fire alarms	They utilise a bimetallic strip (made from two types of metal) The metal that expands more is on the outside of the curve

SPECIFIC HEAT CAPACITY

Internal energy is the total energy stored inside a system by the particles that make up the system due to their motion and positions.

Temperature is a measure of the average kinetic energy of the individual particles
The amount by which the temperature increases depends on:

1. Mass of substance
2. Type of material
3. Amount of thermal energy transferred into the system

Specific heat capacity (c) is the amount of energy required to raise the temperature of 1kg of substance by 1°C

➔ Measured in **joules per kilogram per degree celsius** (J / kg°C)

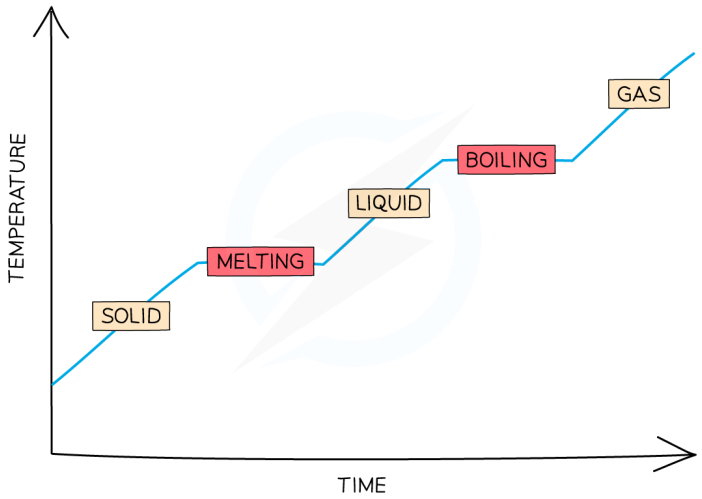
$c = \frac{\Delta E}{m\Delta\theta}$	ΔE = change in thermal energy (Joules) m = mass (kilograms) $\Delta\theta$ = change in temperature

Different substances have different specific heat capacities:

- Low specific heat capacity means the substance heats up and cools down more quickly
- High specific heat capacity means the substance heats up and cools down slowly

Fixed points

The melting (0° C) and boiling points (100° C) of pure water are known as **fixed points**



EVAPORATION

Factors affecting the rate of evaporation:

Temperature of the liquid Increased temperature means increased kinetic energy. This means molecules with more energy are more likely to overcome the intermolecular forces holding them and escape the surface ● Therefore higher temperature leads to higher rate of evaporation
Surface area of the liquid Molecules only escape the intermolecular forces of attraction at the surface. ● Therefore a larger surface area leads to a higher rate of evaporation
Air movement Air movement carries away the water vapour which has just evaporated. This replaces the air above the liquid with drier air, which accepts water vapour more easily ● Therefore increasing air movement increases rate of evaporation

Evaporation & cooling

As evaporation occurs the liquid cools. This is called the **cooling effect**

➔ This occurs because the most energetic particles leave, reducing the average kinetic energy

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- Placing an object next to this liquids cools the object

- This is because the cool liquid absorbs thermal energy from the surrounding

This process is used in some **refrigerators** and **air condition units**

Evaporation	Boiling
Occurs at a range of temperatures between the melting and the boiling point	Only happens at the boiling point
Happens only at the surface	Happens throughout the liquid
Bubbling effect is not necessary	A boiling liquid bubbles

Thermal energy transfers

CONDUCTION

Conduction is the transfer of heat from one region to another through particle vibrations and the movement of free electrons

➔ Main method of thermal energy transfer in **solids.**

➔ Does not happens as easily in fluids:

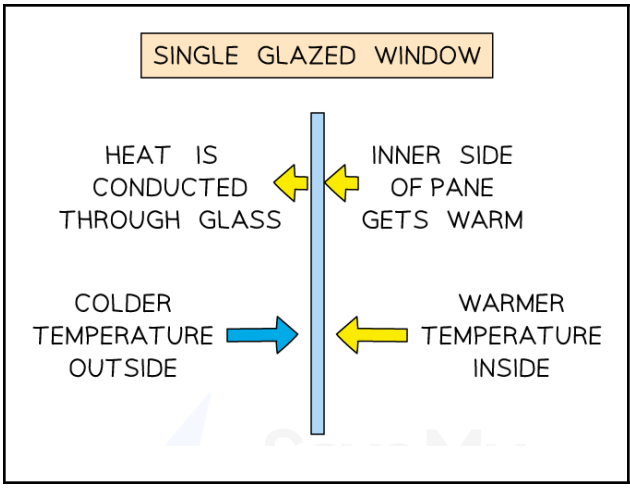
- In liquids particles are close, but slide past each other
- In gases particles are spread apart so vibrations to be passed between particles is extremely difficult

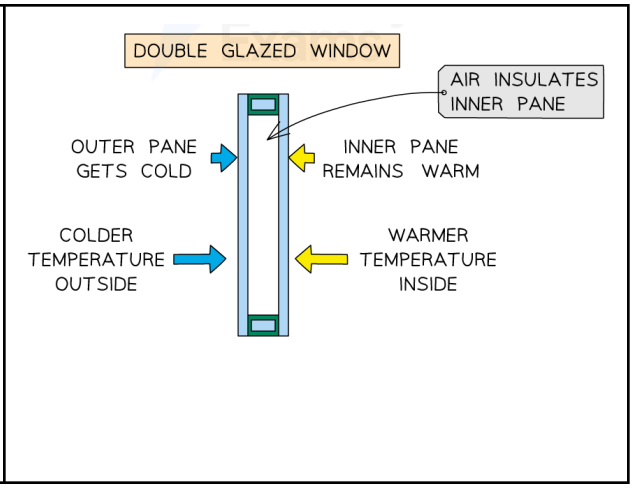
Conduction can occur through two methods:

1. **Atomic vibrations**
2. **Free electron collisions**

Conductors	Insulators
Materials that conduct thermal energy or electricity. **Example:** most metals ➔ This is because they have a high number of free electrons (unlike non-metals).	Materials that insulate thermal energy or electricity **Example:** air, glass, rubber

Example: double glazed windows





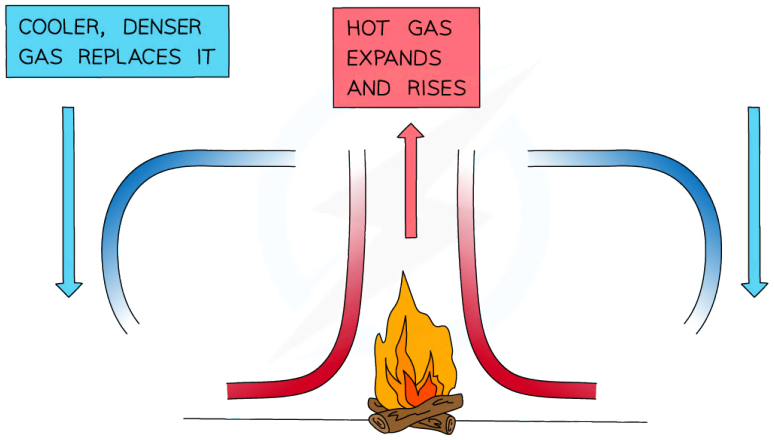
CONVECTION

Convection is the transfer of thermal energy through a material by the movement of the material itself.

➔ Convection can only occur in fluids (gases and liquids) cannot happen in solids

When a fluid is heated:	**When the fluid cools down:**
• Heated molecules **gain energy** and push each other apart making the fluid to **expand** • This means that the expanded fluid is **less dense** • The **hot fluid rises** and the cooler liquid moves in to take its place	• The molecules **lose energy** and collide less making the fluid to **contract** • This means that the contracted fluid is **more dense** • The **cool fluid falls down**

The resulting motion is called a **convection current.**



RADIATION

Thermal energy radiation or **infrared radiation** is the only form of thermal energy transer that does not involve the movement of particles

- ➔ This means it does not require a medium (unlike convection and conduction) and can **travel through vacuum**
- ➔ All objects give off thermal radiation. The hotter the object the more thermal radiation it emits

The amount of thermal radiation emitted by an object depends on:

1. **Surface color of the object**
2. **Texture of the surface**

Colour / texture	Absorber	Emitter
Black	Good absorber	Good emitter
White	Poor absorber	Poor emitter
Shiny	Very poor absorber (it reflects)	Very poor emitter

Thermal equilibrium

As an object absorbs thermal radiation it will become hotter. As it gets hotter it will also enit more thermal radiation.

Eventually the object will reach a point where it is absorbing and emitting radiation at the same rate. This point is called **thermal equilibrium**

- At thermal equilibrium, an object has **constant temperature.**

Remember: the process will always move towards thermal equilibrium

- ➔ If temperature increases, rate of emitting radiation would be more than rate of absorbing
- ➔ If temperature decreases, rate of absorbing radiation would be more than rate of emitting

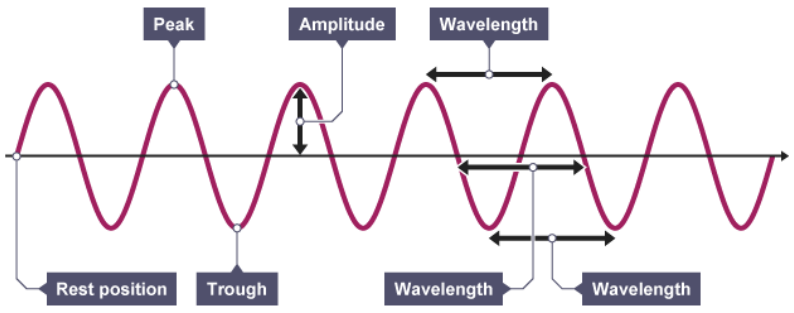
Greenhouse effect
The earth contains several different gases that act like a blanket, keeping the earth warm. They are called **greenhouse gases.** ***Examples***: carbon dioxide, methane, chlorofluorocarbon (CFCs). ● Carbon dioxide allows short wavelength (visible light) radiation to pass through. ● The ground becomes warm by **absorbing** the radiation and **re-emits** longer wavelengths, infrared radiation. ● Carbon dioxide does not let all of this infrared radiation pass through. Much of it is **reflected** back into the atmosphere, making the atmosphere warm ● This gradual warming of the atmosphere over many years is referred to as global warming

General properties of waves

Waves transfer energy without transferring matter

Waves are oscillations or vibrations around a fixed point

Features of waves:

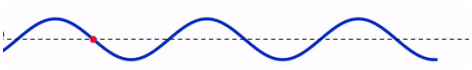


Wavelength	The distance from one point on the wave to the same point on the next wave

	➔ Measured in meters (m)
Frequency	The number of waves passing a point in a second ➔ Measured in Hertz (Hz)
Amplitude	The distance from the undisturbed position to the peak or trough of a wave ➔ Measured in meters (m)
Wave speed	The distance traveled by a wave each second **Wave Speed** (v) **= wavelength** (f) **x frequency** (λ) ➔ Measured in meters per second (m/s)

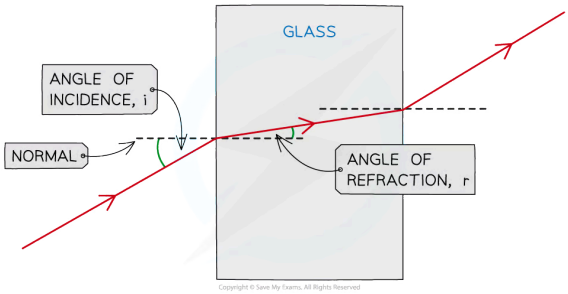
Waves are of 2 types:

Transverse waves	Longitudinal waves
Waves where the direction of vibration is perpendicular to the direction of propagation ➔ The energy transfer is perpendicular to the wave motion	Waves where the direction of vibration is parallel to the direction of propagation ➔ The energy transfer is parallel to the wave motion
They can move in solids and, the surface of liquids but not in liquids or gases	They can move in solids, liquids, and gases
They can move in the vacuum	They can NOT move in a vacuum (require a medium)
Pressure and density are constant	Pressure and density changes
The structure consists of: ● **Crests** - The highest point on a wave above the equilibrium (rest position) ● **Troughs** - the lowest point on a wave below the equilibrium (rest position)	The structure consists of: ● **Compressions** - a region of high density ● **Rarefactions** - a region of low-density
Examples: ➢ electromagnetic waves (spectrum) ➢ ripples on the surface of the water	Examples: ➢ Sound waves ➢ Seismic P waves (fast-moving

➢ seismic S-waves (slow-moving earthquake waves)	earthquake waves)
	

WAVE BEHAVIOUR

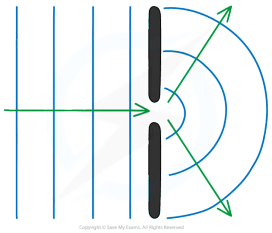
Reflection
A wave hits a boundary between two media at a plane surface and does not pass through, but instead stays in the original medium

Refraction
A wave passes a boundary between two different transparent media and changes speed A consequence of refraction: 1. Change in wavelength (not frequency) 2. Change in direction --- If the wave **slows down** (less dense to more dense), it bends **towards** the normal. If the wave **speeds up** (more dense to less dense), it turns **away** from the norma.l 

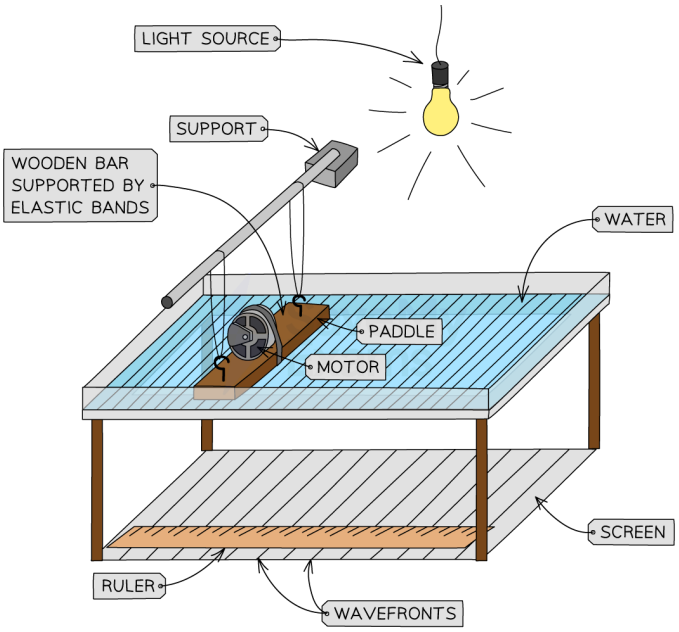
Diffraction
When Waves pass through a narrow gap, the waves spread out ➔ The extent of diffraction depends on the width of the gap compared to the wavelength

Diffraction is highest when the **width of the gap = wavelength**

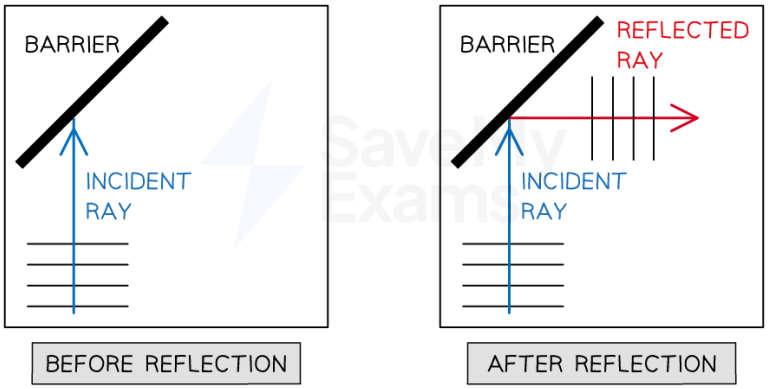
Note: As the gap gets bigger the effect gradually decreases

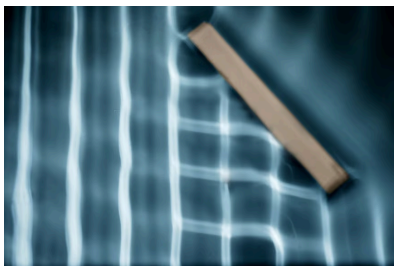
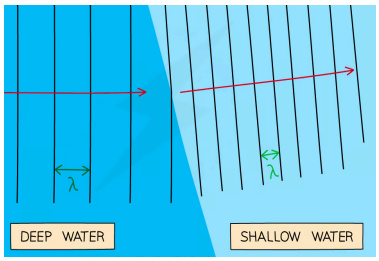
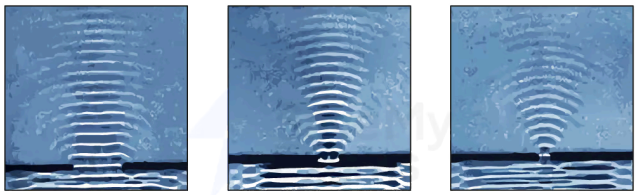


RIPPLE TANKS



Wavefronts are **reflected** off a metal bar (plane surface) placed in the water of the ripple tank.



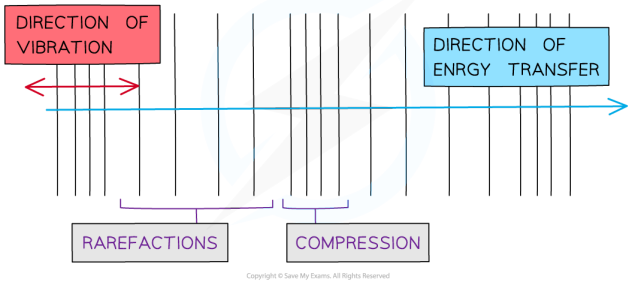
Refraction can be shown by placing a glass block below the surface of the water.	 
Diffraction can be shown by placing small barriers with a gap or edge in the tank.	

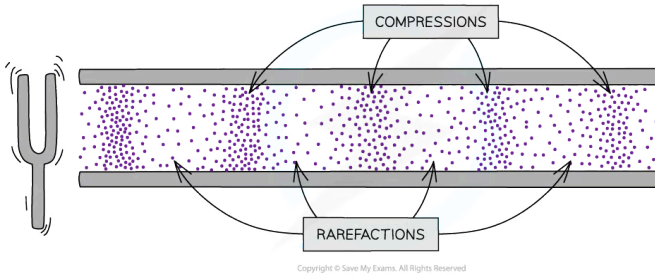
Sound

Sound waves are vibrations caused by particles moving back and forth.

In a vacuum, there are no particles, so sound can't travel in a vacuum

Sound waves are **longitudinal** having compressions and rarefaction:





Speed of sound:

The higher the temperature, the greater the speed of sound

In solids (fastest)	5000 m/s
In liquids (relatively slow)	1500m/s
In air	330 - 350 m/s

Measuring sound:

Method 1:

1. Use a trundle wheel to measure the distance of 100m between 2 people
2. One person should have 2 wooden blocks to bang together (above their head)
3. The second person should have a stopwatch which they start they starts when they see the first person banging the blocks and stops when they hear the sound
4. Repeat several times and calculate an average time
5. Repeat for various distances
6. Use speed = distance/time to calculate speed

Method 2:

1. Connect two microphones to an oscilloscope.
2. Measure the distance between microphones (e.g., 2 m, 2.5 m, 3 m, etc.).
3. Set an oscilloscope to trigger detecting sound at the first microphone.
4. Make a loud clap using wooden blocks near the first microphone.
5. Record the time difference of sound reaching the two microphones using the oscilloscope.
6. Repeat for several distances and calculate the average time.
7. Take repeated readings to minimize timing errors.
8. Increase the distance between microphones to reduce percentage error in timing.

➔ Experiment 2 (oscilloscope): Most accurate as timing is automated.

➔ Manual methods (e.g., stopwatch): Less accurate due to reaction time (variation up to 0.2 s).

Effects of sound waves

Sound waves reflect off hard surfaces. The reflection of a sound wave is called an **echo.**

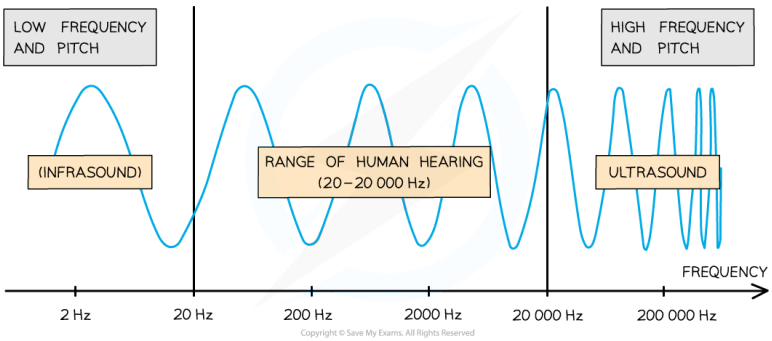
- The frequency is related tothe pitch
- The amplitude is related to the loudness

ULTRASOUND

The range of frequencies audible to normal humans is **20 - 20,000 Hz**

➢ It decreases with age

Ultrasound is a sound with a frequency higher than 20,000Hz



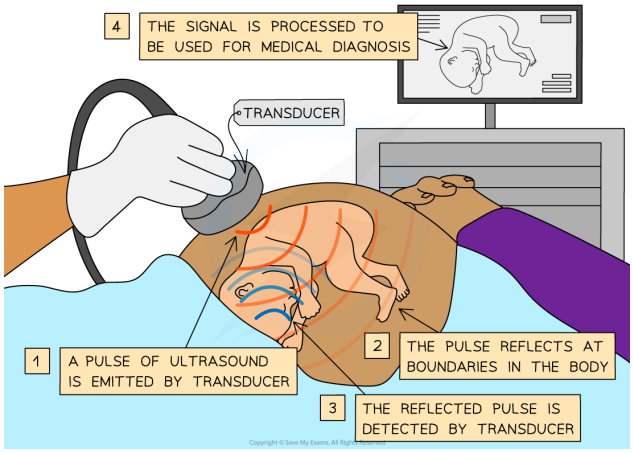
Uses of Ultrasound

1. **Non-destructive material testing:**
    - Detects cracks in metals and assess structural integrity.
2. **Medical imaging:**

In medicine ultrasound is **harmless** and **non-invasive and** can be used to:

- ➔ To construct images of a fetus
- ➔ To construct 2D images of internal organs or structures unless surrounded by a bone
- ➔ Medical treatment for removing kidney stones

The ultrasound waves are reflected to the **transducer** by boundaries between tissues in the path of the beam



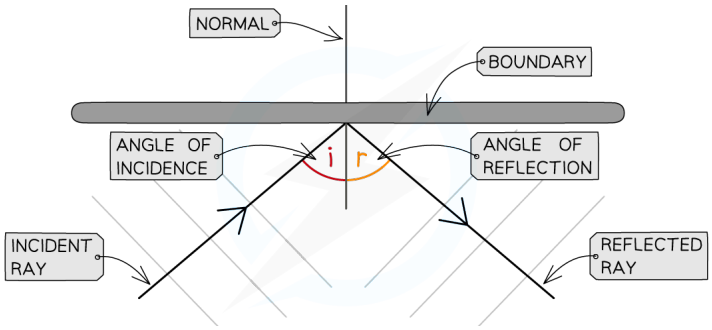
3. **Sonar:**
    - Measuring underwater depth and detecting objects.
    - The distance the wave travels is twice the depth of the ocean

Depth = 0.5 x speed x time

Light

Normal	The line perpendicular to the boundary between the two media
Angle of incident	The angle between the ray approaching the boundary and the normal

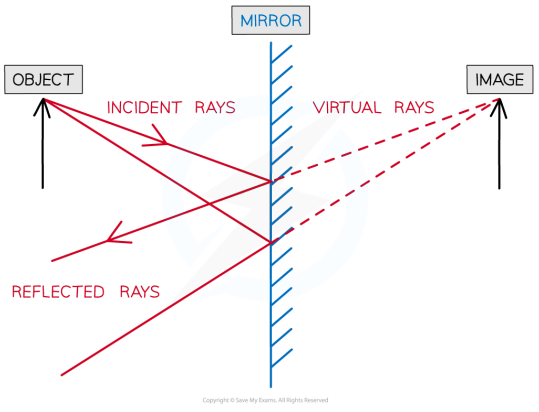
Angle of reflection	The angle between the ray leaving the boundary and the normal



REFLECTION

The law of reflection: **angle of incidence (i) = angle of reflection (r)**

➔ Used in devices such as **mirrors, cameras, optical fibers and periscopes**

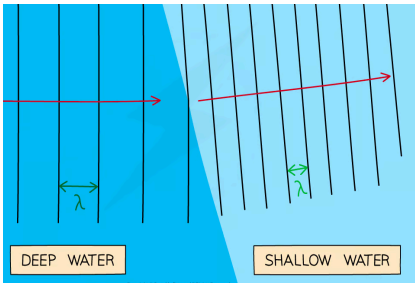
The image in a plane mirror will be:
• Same size as the object • The same distance from the mirror as the object • Virtual • Upright

Mnemonics: **SSUV**

REFRACTION

Refraction is the change in wave speed that an incident ray experiences while passing a boundary between two transparent media.

- ➔ When ray moves from **less dense to more dense** (slows down) the refracted ray bends **toward** the normal
- ➔ When ray moves from **more dense to less dense** (speeds up) the refracted ray bends **away** from the normal

Remember: Shallow water has less wavelength than deep water (more denser)



NOTE: only wave speed and wavelength change frequency stays the same

REFRACTIVE INDEX (n)

A measure of how much the ray in bent when a change of speed occurs when passing from one medium to another

- ➔ Since this value is a ratio, it has **no units**

NOTE: the refractive index of a material is always bigger than 1

It can be measured in 2 ways:

1. **Using ratio of speed**

   The ratio of the speeds when travelling in two different mediums (here 1 is vacuum)

$$\text{Refractive index (n)} = \frac{\text{Speed of light in a vacuum}}{\text{Speed of light in a medium}}$$

Note: the refractive index of a material is always lesser than the speed of light in a vacuum

2. **Using ratio of angles → SNELL'S LAW**

   The ratio of the sine of the angle of incidence and the sine of angle of reflection of a wave in two different regions

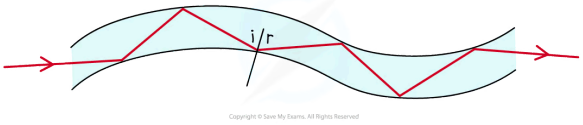
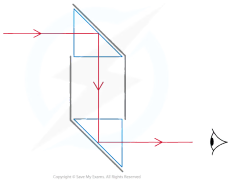
$$\text{Refractive index (n)} = \frac{\sin\ (\text{angle of incidence})}{\sin\ (\text{angle of refraction})}$$

TOTAL INTERNAL REFLECTION

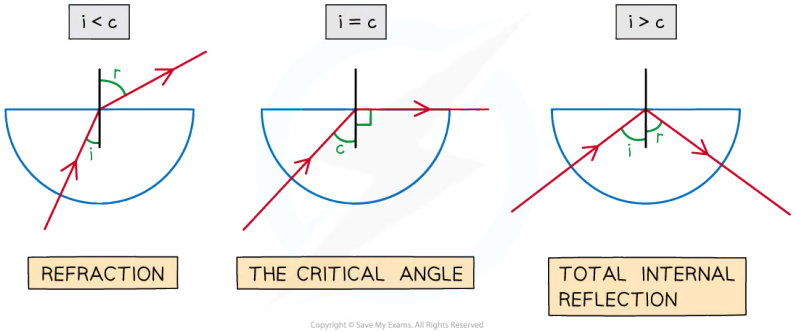
Total incident ray occurs when light travels from a denser material to less dense material and all of it is reflected back into the 1 medium

- ➔ In TIR the light ray is **brighter** than normal reflection
- ➔ For TIR to occur the: **Incident ray > critical angle**

TIR is used in:

optical fibres	periscopes (uses 2 right-angled prisms)
	

Critical angle is the angle of incidence when the refracted ray appears parallel to the surface of the block and the angle of reflection is 90°



The critical angle (c) is inversely proportional to the refractive index (n)

$$\textbf{Sin c} = \frac{1}{n}$$

Electromagnetic spectrum

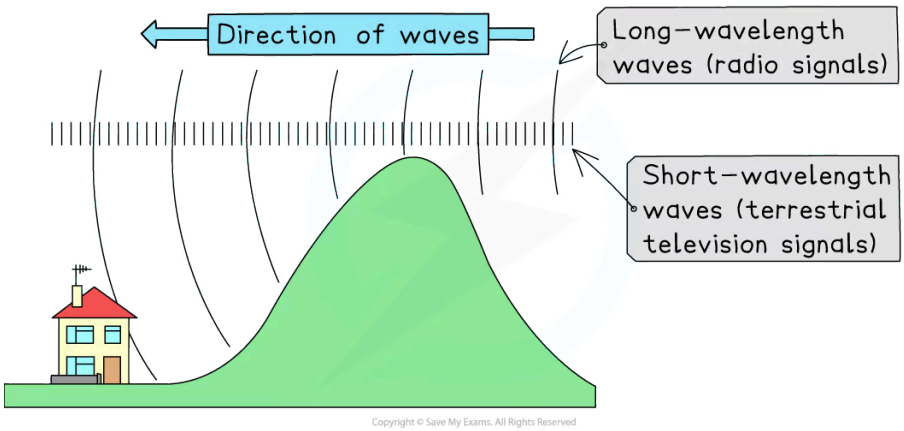
Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber

The speed of all electromagnetic waves in a vacuum (and air approximately) is: **3 x 10^8 m/s**

Waves arranged from greatest wavelength to smallest wavelength →

Radio waves	**Microwaves**	**Infrared radiation**	**Visible light**	**Ultraviolet**	**X-rays**	**Gamma rays**
Rich	Men	In	Vegas	Use	Expensive	Gadgets

USES

Radio waves	Can be used to transmit signals over **short distances** ● They **diffract** around a hill this is because their wavelength is similar to the size of the hill  **1. Bluetooth:** signal is weakened across a wall 2. Short-distance **radio and television transmission** **3. Radio frequency identification is** used to identify objects, people, or animals by scanning an RFID tag
Microwaves	Can be used to transmit signals over **long distances** ● As they are NOT reflected, refracted, or absorbed by the atmosphere or ionosphere ● This means they can penetrate most walls and can be easily

	transmitted and recepted --- 1. **Heating food** 2. **Mobile phones** and **wireless internet** using microwave transmitter masts to the nearest phone 3. **Communication** using **artificial satellites** --- **Low-orbit satellites (or polar satellites):** ➔ Orbit around the Earth's pole at a height of 200 km above sea level ➔ Used for **monitoring weather, military applications,** and **taking images of the earth's surface** **Advantages:** ● Shorter time delay for signal in comparison to geostationary satellites ● Signals are much clearer **Diadvantages** ● Limited use as more than one satellite is required for continuous operation --- **Geostationary satellites:** ➔ Orbit around the Earth's equator at a height of about 36,000 km ➔ Used for **radio** and **telecommunication broadcasting around the world**
Infrared radiation	Warm objects emit infrared radiation 1. **Thermal imaging cameras** are used in security cameras and also in medicine as they detect hot spots (which the body emits) and allow pictures to be taken in the dark 2. **Remote controls** use a small infrared transmitter to send signals to devices such as television 3. **Optical fiber** is used in communication because these waves can undergo total internal reflection

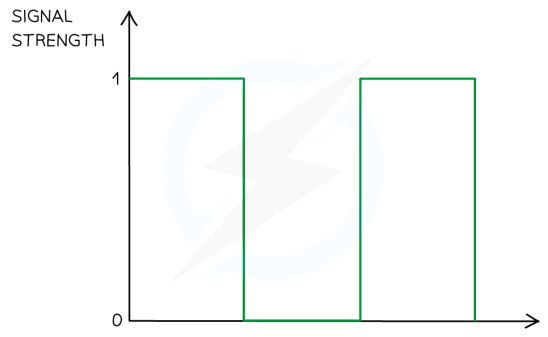
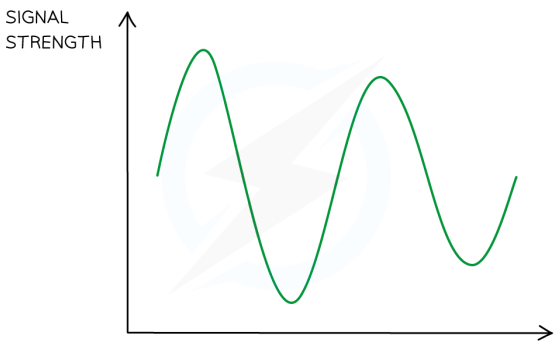
Visible light	Red light has the longest wavelength (lowest frequency) Visible light is the only part of the electromagnetic spectrum that the human eye can see 1. **Photography** 2. **Videography** 3. **Illumination**
Ultraviolet	When certain substances are exposed to ultraviolet, they absorb and re-emit it as visible light, making them glow. This is known as **fluorescence.** 1. **Forensic** scientists use this to find evidence 2. **Security marking** of valuable equipment (like money) 3. **Fluorescent bulbs** (energy-efficient lamps) 4. Getting a **suntan**
X-rays	X-rays penetrate through tissue but are absorbed by denser parts such as bones 1. In **medicine** to see bones inside a body 2. In **airports** for security
Gamma rays	1. **Sterilizing** food and surgical instruments 2. In **cancer detection and treatment** as it kills cancerous cells 3. Engineering applications as it **detects flaws in metals**

DANGERS:

Radio waves	No known danger
Microwaves	Certain frequencies of microwaves are absorbed by water molecules ● Since humans contain a lot of water, there is a **risk of internal heating from microwaves** ➔ Microwaves used for communication emit very small amounts of energy so they are not known to cause harm ➔ Microwaves used for heating food emit very large amounts of energy, however, that energy is prevented

	from escaping by the metal grid in the glass door
Infrared radiation	High frequency can cause **skin burns**
Visible light	No known danger
Ultraviolet	If absorbed in high amounts it can lead to **skin cancer, premature aging,** and **eye damage**
X-rays & Gamma rays	Highly ionising so can **cause mutation or damage to body cells** which can **lead to cancer**

TYPES OF SIGNALS

Digital signal	Analogue signal
Can only **take one of two discrete states**. They are usually referred to as: ● 1s and 0s ● Highs and lows ● On and off	Signals **vary continuously** - they can take any value
	

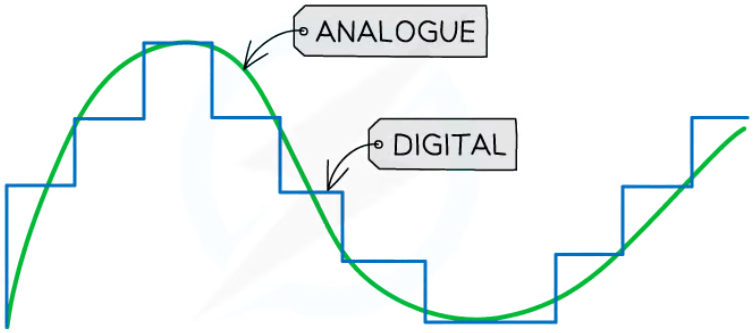
Transmission of sound

Sound waves can be transmitted as a **digital** or **analogue signal**

➔ Signals for speech or music are made of varying frequencies. For information to travel clearly, the signal needs to be transmitted with as little interference as possible

➔ To ensure this the signal undergoes **digital sampling.** In this, the signal is converted **both before transmission and after being received**

- Before transmission: **analogue to digital**
- After transmission: **digital to analogue**

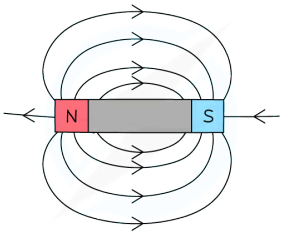


Benefits of digital signaling

1. **Increased rate of data transmission** (data can be transmitted at a faster rate)
2. **Increased range** (can travel over longer distances) **due to accurate signal regeneration (**because the value can be either 1 or 0)

Magnetism

A **magnetic field** is a region in which a magnetic pole experiences a force.

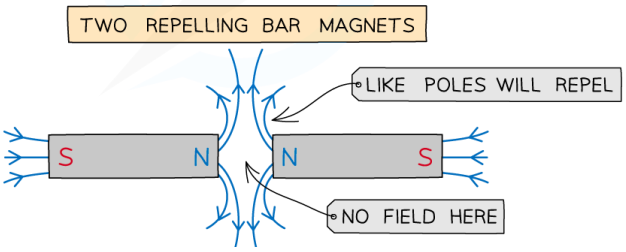


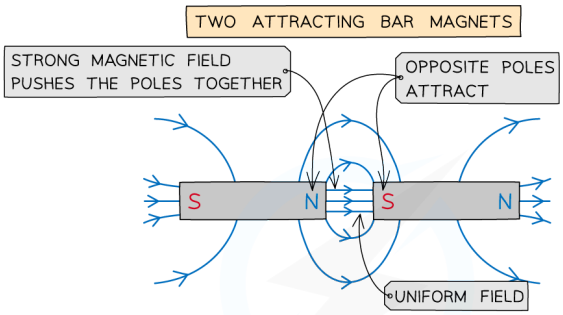
- The density of the field lines indicates field strength: closer lines represent stronger magnetic fields
- The field lines always go from north pole to south pole

The magnetic metals are: **iron, cobalt, nickel and steel** (alloy of iron)

Law of magnetic poles: Like poles repel and unlike poles attract

➔ The attraction or repulsion between the two poles of a magnet is an example of **non-contact force**





There are 2 types of magnets:

1. **Permanent:** material that produces its own magnetic field and doesn't lose magnetism
2. **Induced** (or temporary): a material with a soft iron core that becomes a magnet temporarily when it is placed in a magnetic field

Soft materials	Hard materials
Magnetizes & demagnetizes easily	Harder to magnetise but retains magnetism
Example: iron	Example: steel
Uses: electromagnets, transformers e.t.c	Uses: permanent magnets - compass, speakers

There are 2 ways of plotting magnetic fields:

1. Using iron filings
    - Place a piece of paper on top of the magnet
    - Gently sprinkle iron filings on top of the paper
    - Carefully tap the paper to allow the iron filings to settle on the field lines
2. Using plotting compasses

- Place a magnet on a piece of paper and mark a dot near one end of the magnet (corner).
- Use a plotting compass next to the dot; draw a new dot where the compass needle points away from the first dot.
- Move the compass to the new dot and repeat the process to create a chain of dots across the magnet.
- Connect the dots with a smooth curve to form a magnetic field line, noting that field lines run from the magnet's north pole to its south pole.
- Repeat the steps to draw additional magnetic field lines around the magnet for a complete visualisation of the magnetic field.

Electrical quantities

CHARGE

Electrostatic charge is the property of an object, causing it to attract or repel with other objects

- ❖ Electric charge is measured in **coulombs (C).**

Conductors	Insulators
A **Conductor** is a material that allows charge (usually electrons) to flow through it easily	An **insulator** is a material that has no free charges and, hence doesn't allow the flow of charge through it easily
Examples: metals and carbon	**Examples:** plastics (polythene, acetate) perspex, nylon

When certain insulating materials are rubbed against each other, they can become electrically charged. This is called **charging by friction.**

The electric charge held by a charged insulator is called **static electricity**

- One gains a net positive charge and the other gains a net negative charge
  - ➔ If an object gains electrons, it becomes negatively charged
  - ➔ If an object loses electrons, it becomes positively charged

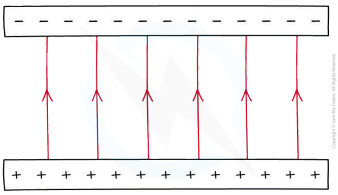
ELECTRIC FIELD

Electric field is a region of space in which an electric charge experiences a force.

The **direction of an electric field** is the direction of the force on a positive charge at that point

- ➔ If the charge is positive, the field lines are radially outwards
- ➔ If the charge is negative, the field lines are radially inwards





Electric field between two parallel plates is a **uniform electric field**

CURRENT

The charge passing a point in a circuit per unit time is called **electric current**

- ❖ Measured in **Amperes (A) or amps**

$$\textbf{\textit{Current (I)}} = \frac{charge\ (Q)}{time\ (t)}$$

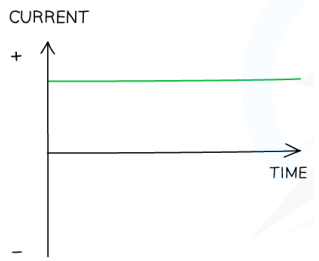
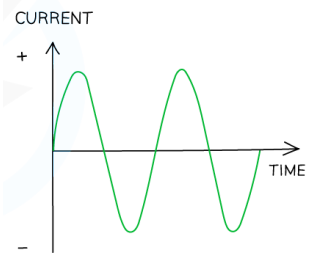
Current can be measured using a device called **ammeters**

- ➔ Connected in **series** with circuit components
- ➔ Ammeters are of 2 types: **digital** and **analogue**

Conventional current & electron flow (flow in opposite directions)

- Current is the flow of positive charge i.e., from the positive terminal to the negative terminal. This is known as **conventional current**
- Electrons are negatively charged, so they are attracted to the positive terminal. Hence, electrons flow from the negative terminal to the positive terminal.

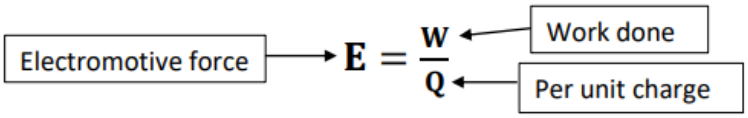
Direct current (d.c)	Alternating current (a.c)
A **direct current** is the current that constantly flows in the same direction in the current, from positive to negative	An **Alternating current** is the current that continuously changes direction, going back and forth around a circuit
Produced by Electric cells or batteries	Produced by Electrical generators i.e. mains electricity
Involves a positive and negative terminal	Involves two identical terminals (therefore the

	current changes direction as the polarity of the terminals change)
	

ELECTROMOTIVE FORCE (e.m.f)

The electrical work done by a source in moving a unit charge around a complete circuit is known as **electromotive force**

- Measured in **volts (V)**



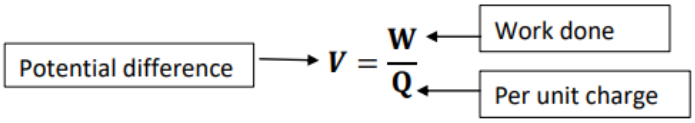
POTENTIAL DIFFERENCE (also called **voltage**)

The work done by a unit charge passing through a component is called a **potential difference**

- Measured in **volts (V)**

Potential difference can be measured using a device called a **voltmeter**

- ➔ Connected in **parallel** with circuit components
- ➔ voltmeters are of 2 types: **digital** and **analogue**



RESISTANCE

Resistance is the opposition to current

What causes electric resistance?

In a conductor, free electrons are in random motion. When connected to a cell, an electric field causes the electrons to move in a specific direction. While moving, they collide with lattice ions.

Ohm's law: Voltage (V) = Current (I) x Resistance (R)

Factors affecting resistance of a conductor (or conducting wire):

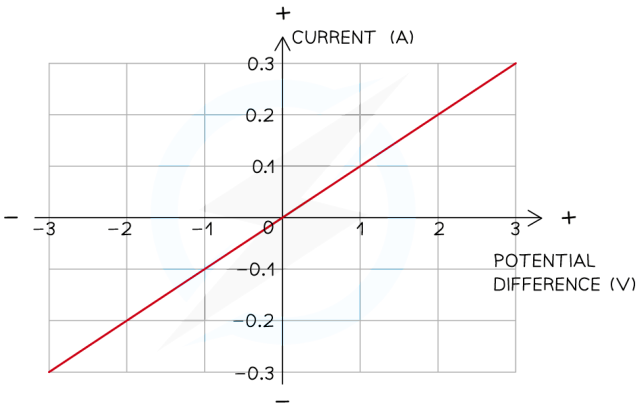
1. **Length** increases, resistance increases (directly proportional)
2. **Area of cross-section** increases, resistance decreases (inversely proportional)
3. **Temperature** increases, resistance increases (directly proportional)

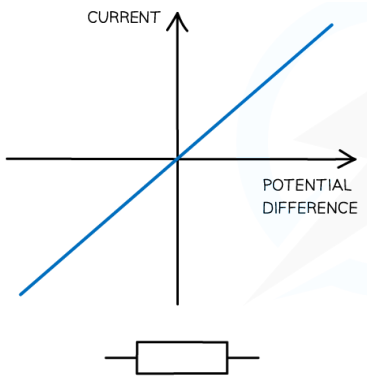
Current-voltage graphs

The resistance of some resistors is a constant value, they are called **carbon resistors**
The resistance of some resistors can be varied, they are called **variable resistors or rheostat**

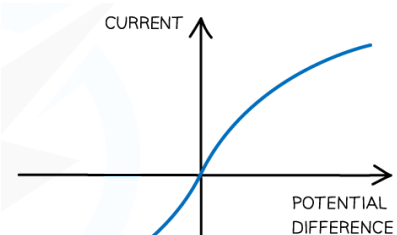
Ohmic resistors	Non-ohmic resistors
Obey ohm's law	Violates ohm's law
The I-V graph is linear (straight line that passes through the origin)	The I-V graph is non-linear (it is not a straight line)
At a given temperature, the resistance is constant	At a given temperature, the resistance is not constant
Examples: fixed resistors	Examples: filament lamps, diodes, LDRs, thermistors

I - V graph for a wire of fixed resistor





I - V graph for a filament lamp

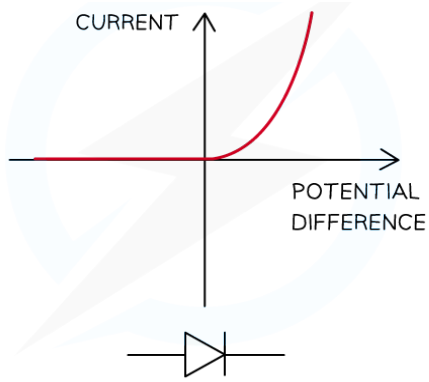


- As current increases, resistance increases (non-ohmic resistor; violates ohm's law)
- The high current, causes the temperature of the filament to increase
- High temperature means that the particles have higher kinetic energy so they vibrate more, causing an increase in resistance.
- Since resistance opposes current, current increases at a slow rate.

I - V graph for diode

A diode allows current to flow in one direction only (**forward bias**)

In the reverse direction the diode offers very high resistance (opposition to current). This is called **reverse bias**



- During forward bias (graph on right side), the I -V graph shows a sharp increase in current as voltage increases.
  → showing very low resistance
- During reverse boas (graph on left side), the I - V graph shows a zero reading of current.
  → showing high resistance

ELECTRICAL ENERGY

The amount of energy transferred by an electrical appliance depends on:

- How long the appliance runs for
- The power rating of the appliance (P = VI)

Energy (E) = voltage (V) x Current (I) x Time (t)

ELECTRICAL POWER

The rate at which energy is transferred by an appliance is called its **power**

In terms of energy: **power = energy / time**

In terms of work: **power = work / time**

In terms of current & voltage: **power = voltage (V) x Current (I)**

Conversion between kWh and J

Remember: energy = power x time

= kW (1000 W) x h (3600s)

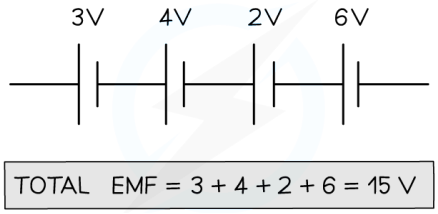
1kWh = 3.6 x 10^6 J

Electric circuits

Component	Symbol	Function
Cell		Supplies electrical energy to the circuit
Battery		A combination of cells that provides electrical energy to the circuit
Resistor		Limits or controls the current flow in a circuit
Variable resistor		Adjusts, the resistance, thereby controlling the current
Thermistor		A temperature-dependent resistor. ➔ Resistance decreases as temperature increases
Light - dependent resistors (LDR)		A sensory resistor sensitive to light intensity ➔ Resistance decreases as light intensity increases.
Diode		Allows current to flow in only one direction
Light - emitting diode (LED)		Emits light when current flows through it in the allowed direction
Ammeter		Connected in series and measures the current in a circuit
Voltmeter		Connected in parallel and measures the voltage in a circuit
Lamp		Emits light when current flows through it
Switch		Opens or closes a circuit to control whether current flows
Motor		Converts electrical energy into kinetic energy, causing rotational motion

Heater		Converts electrical energy into thermal energy
Bell		Produces sound when current passes through it
Relay		Uses a small current to switch on a larger current in another circuit
Transformer		Steps up or steps down the voltage and current in a circuit
Fuse		Protects the circuit from overcurrent by breaking the circuit during surges

Electromotive force (e.m.f) : the combined e.m.f is equal to the sum of their individual e.m.f(s)

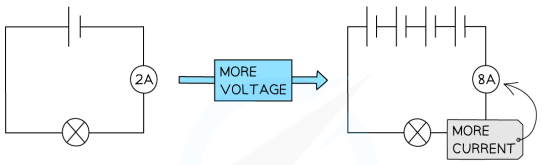
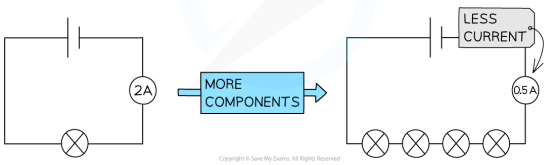


SERIES CIRCUIT

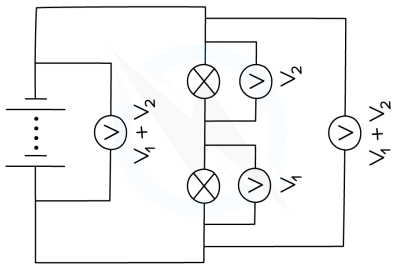
A series circuit contains a single complete loop

In a series circuit:

Current has same value at any point

Current will increase if voltage (think: e.m.f) increases ➔ More current from the source	
Current will decrease if voltage (think: potential difference) decreases ➔ More the number of components, more the potential difference	

Potential difference: the e.m.f of the power source is split across the potential difference of the components



Resistance: combined resistance is equal to the sum of individual resistance

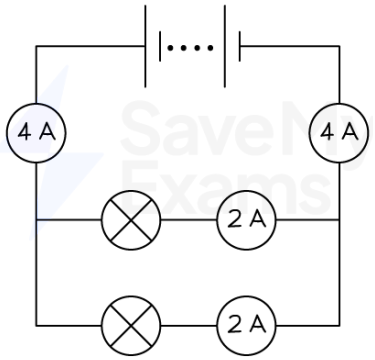
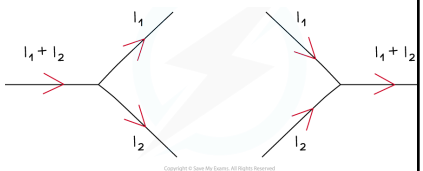
TOTAL VOLTAGE = $V_1 + V_2 + V_3$

COMBINED RESISTANCE = $R_1 + R_2 + R_3$

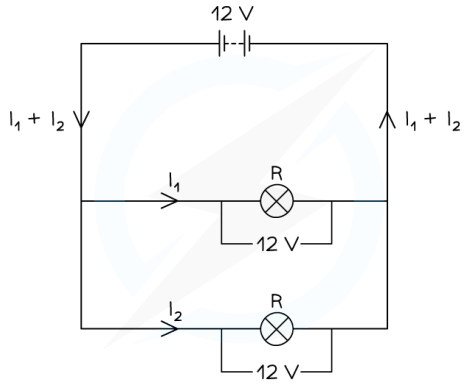
PARALLEL CIRCUIT

A parallel circuit consists of multiple loops containing circuit components

In a parallel circuit:

Current splits in each branch at a junction ➔ This means current from the source is larger than current in each branch ➔ Current before a junction is equal to the sum of currents along each branch after the junction **Note:** Current does not always split equally. There can be cases where one branch has more current than the others	
At a junction in a parallel circuit the current is conserved - This is because current is a flow of electrons - Electrons can be neither created nor destroyed - they are physical matter - At a junction, some of the electrons will go one way and the rest will go the other	

Potential difference: across each component is same as e.m.f of the power source



Resistance: combined resistance is less than the resistance of each resistor

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

Advantages of parallel circuit:

1. Each branch has the same potential difference
   → If bulbs are attached each will glow with the same intensity
2. In one branch falters, the rest continue to function as current passes through each branch independently
   → If one bulb breaks, the rest still continue to function
3. Each component in each branch can be switched on/off individually
   → each bulb has its own switch in the same circuit

	Series circuit	**Parallel circuit**
Current	Same at all points	Splits in each branch
Potential difference	E.m.f of power source is split across all components	Same as the e.m.f of power source across all components
Resistance	Combined resistance is the sum of individual resistances	Combined resistance is less than individual resistance (s)

The nuclear model of the atom