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Physics Topic 4.1.1
Conservation and dissipation of energy

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Section 1: Key terms

Dissipation	Energy becoming **spread out** to the stores of surrounding objects (usually wasted thermal energy.)
Lubrication	A method of reducing unwanted energy transfers by application of a **lubricant** (e.g. **oil**) to **reduce friction**. Occurs in machines.
Insulation	A method of reducing energy transfers by the use of **insulators**. Occurs in buildings e.g. Loft insulation.
Conservation of energy	The law that states that **energy cannot be created or destroyed**.
Closed system	An isolated system in which **no energy transfers** take place **out of or into** the **energy stores** of the system.
Work	Work is done on an object when a force makes the object move.
System	Object or group of objects.
Friction	A **contact force** resisting the relative motion between two surfaces. Friction in machines always **causes energy** to be **wasted**.
Input energy	**Energy supplied** to a device.
Useful energy	Energy transferred to where it is wanted in the way it is needed.
Wasted energy	Energy that is **not usefully** transferred.
Efficiency of a device	The proportion of the total input energy that is transferred in useful ways.

Section 3: Methods of energy transfer (also known as energy carriers)

Mechanical	Energy transferred by forces acting on objects.
Electrical	Energy transferred when an electric current flows through a device.
Radiation	Energy transferred by electromagnetic radiation (light, microwaves, sound etc.)
Heating	Energy transferred by conduction, convection or radiation.

Section 2: Different kinds of energy stores

There are a limited number of **energy stores**.

Chemical energy	(e.g. fuel + oxygen) – Can be changed by bonds being made/broken
Kinetic energy	All **moving** objects have it.
Gravitational Potential energy	Energy stored in objects raised up against the force from **gravity** (possessed by anything that can **fall**.)
Elastic Potential energy	Energy stored in an object that has been **stretched** (stretched springs, rubber bands, elastic band etc.)
Thermal (Heat) energy	Flows from **hot** objects to colder objects.
Nuclear store	Energy stored in the **nuclei** of atoms. Can be released by the fusing or splitting of nuclei.
Magnetic	Two separated magnets that are attracting, or repelling.
Vibrational	Energy from vibrations or moving to and fro (e.g. a pendulum.

Light, electrical (as in a current) or sound are **not energy stores**. These are active processes and cannot be stored in a stable state. Electricity is a **flow of charge** that **transfers energy** from **one energy store to another**.

Section 4: Energy transfers

A Coal fire	Energy is shifted from a store when a fuel like coal burns. The chemical store (fuel) is depleted and the thermal store is filled.
Bow & arrow	Elastic potential energy → kinetic and thermal energy
Placing a book on a shelf	When the book is lifted onto the shelf, energy is shifted from the chemical store of your arm to the gravitational store of the book.
Apple falling from a tree	When an apple falls and gains speed, its store of gravitational potential energy decreases and its kinetic energy store increases. When it hits the ground its kinetic energy is then transferred into thermal and sound energy.

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Physics Topic 4.1.2
Conservation and dissipation of energy

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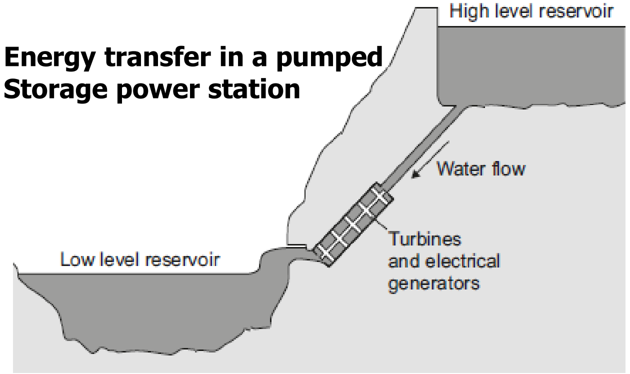
Energy transfer in a pumped Storage power station



When electricity is needed, water from the high level reservoir is allowed to flow into the low level reservoir. The flowing water generates electricity. The water in the high level reservoir stores **gravitational potential energy**. The flowing water has **kinetic energy**. The water turns the turbine which is connected to the generator. The generator produces some **sound**, this is **wasted energy**.

Section 5: Equations to learn

Equation	Units
Kinetic energy = 0.5 x mass x velocity^2 $E_k = 0.5\ m\ v^2$	Energy – Joules (J) Mass – kilograms (kg) Velocity – metres per second (m/s)
Gravitational potential energy = mass x gravitational field strength x height $E_p = m\ g\ h$	Energy – Joules (J) Mass – kilograms (kg) Gravitational field strength – Newtons per kilogram (N/kg) Height – metres (m)
Power =energy transferred ÷ time $P = \frac{E}{t}$	Power – Watts (W) Energy transferred – Joules (J) Time – seconds (s)
Power = work done ÷ time $P = \frac{W}{t}$	Power – Watts (W) Work done – Joules (J) Time – seconds (s)
Work done = force x distance moved	Work done – Joules (J) Force – Newtons (N) Distance – Metres (m)
Efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$	Energy – Joules (J)
Efficiency = $\frac{\text{useful power output}}{\text{total power input}}$	Power – Watts (W)

Section 6: Improving efficiency (HT)

Why devices waste energy	How to reduce the problem
Friction between moving parts **causes heating**	**Lubrication** of moving parts **reduces friction**
The resistance of a wire causes wire to get **hot** when **current passes** through.	Use **wires** with **as little resistance** as possible
Air resistance causes force on a vehicle that **opposes** it's motion.	**Streamline** the **shape** of the vehicle to reduce air resistance.
Working machinery **creates sound**	**Tighten loose parts** to reduce vibration which will reduce the noise.

Section 7: Energy dissipation & Electrical appliances

An electrical appliance is designed for a particular purpose and should dissipate (waste) as little energy as possible.

Appliance	Useful energy	Wasted energy
Light bulb	**Light** emitted from glowing element	Filament heats surroundings
Electric heater	**Heating** the surroundings	Light emitted from the glowing element
Toaster	**Heating** bread	Toaster case heats up and heats air around it.
kettle	**Heating** water	Kettle itself also heats up and the air around it.
TV	Light and sound	Heating of the TV's casing and heat transferred to surroundings.

KNOWLEDGE | Physics Topic 4.3.2 Energy transfer by heating | ORGANISER

Section 1: Key terms

Thermal conductivity	A measure of how good something is at **conducting**.
(Thermal) Insulator	Thermal insulators **reduce energy transfers** (prevent heat loss to surroundings and hence have a **low thermal conductivity**)
Thermal Conductor	Good at **transferring heat** energy.
Specific heat capacity	The specific heat capacity of a substance is the **amount of energy** needed to change the **temperature of 1 kg** of the substance by **1°C**. Its units are J/kg/°C
Joulemeter	Energy meter (measures energy supplied)

Section 2: Energy transfer by conduction

The higher the Thermal conductivity of a material the **higher the rate of energy transfer** by **conduction** across the material.

Metals	**Metals** are the **best conductors** of energy, Copper is a better conductor than steel.
Non-metals	**Non-metal** material (like wool and fibreglass) are the **best insulators**.

Factors affecting insulation

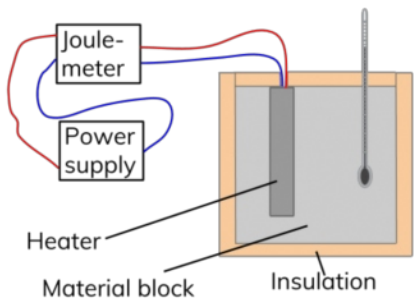
Thickness of material	The **thicker** the material the **better the insulation.**
Thermal conductivity	The **lower** the **thermal conductivity** the **better the insulator.**

Section 3: Specific heat capacity

Putting the same amount of heat into some materials gives a bigger temperature rise than in other materials. The specific heat capacity of a substance is the **energy needed** to **raise** the **temperature** of **1 kg** of a material by **1°C**.
Investigations show that when a substance is heated, its temperature rise depends upon three factors:

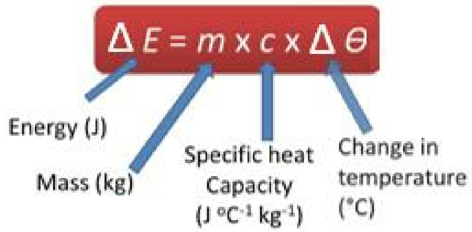
Amount of energy supplied to it	Specific heat capacity **increases** with **temperature**.
Mass of the substance	The **greater the mass** the more **slowly** its **temperature increases** when its **heated**.
What the substance is	**Metals** tend to have **lower specific heat capacities**. **Water** has a **high specific heat capacity**. Hence it takes less energy to raise the temperature of a block of aluminium metal by 1°C than it does to raise the same amount of water by 1°C.

Measuring specific heat capacity



A metal block of **known mass** is heated. A **joulemeter** is used to **measure the energy** supplied ΔE and a **thermometer** to **measure the temperature rise Δθ**.

The measurements are then inserted into the equation and used to calculate the specific heat capacity:



Storage Heaters

Storage heaters **use electricity at night** (off peak hours) to **heat special bricks** (which have a high specific heat capacity). The bricks **store** lots of **energy** and **take time** to heat up and cool down. Hence during the day (on peak) they **release heat slowly** when **the heater element is on** and cool down slowly when it is off.

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Physics Topics 4.3.2 / 4.1.1
Energy transfer by heating

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Section 4: Heating and insulating buildings

Homes are heated by electric or gas heaters, oil or gas central heating systems or solid fuels in stoves or fireplaces. A **poorly insulated house loses** more **energy** and so **costs more** to heat. It also means that **more pollution**, particularly carbon dioxide is released into the environment. The rate of energy transfer can be reduced by:

How to prevent heat loss from a house

Loft insulation	Contains **fibreglass** which **traps air**, **reducing convection** which is a good insulator.	
Cavity wall insulation	**Traps air pockets** in gaps which is a good insulator	
Double glazed windows	**Traps air** in **gaps between glass** which is a good insulator.	
Aluminium foil behind radiators	**Reflects radiation**.	
External walls with thicker bricks	**Thicker** bricks have a **lower thermal conductivity**.	

Section 5: Infrared radiation Key terms (Triple only)

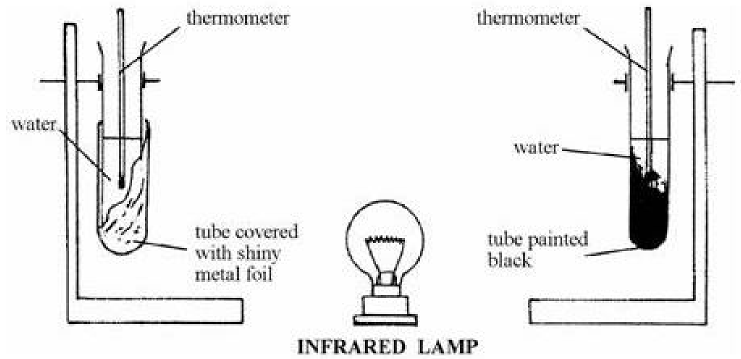
Electromagnetic radiation	**Transverse waves** that travel at **300,000,000 m/s**. Includes radio, microwave, infrared, visible, Ultraviolet, X-ray and gamma waves.
Infrared radiation	An **electromagnetic wave**. **Emitted** by **warm objects**. Also known as heat or thermal radiation.
Black body	A body that **absorbs all the radiation** that hits it.
Black body radiation	The **radiation emitted** by a **perfect black body**
Greenhouse gases	gases that contribute to the **greenhouse effect** by **absorbing infrared radiation**

Section 6: Infrared radiation (Triple only)

The Sun emits all types of electromagnetic radiation. Infrared radiation consists purely of electromagnetic waves of a certain range of frequencies. The **hotter** an object is, the **more infrared radiation** it **emits in a given time**.

What happens to infrared waves when they strike different surfaces.

Dark matt surfaces **absorb infrared radiation** much **better** than light glossy surfaces, **silvered surfaces reflect** nearly all heat radiation falling on them. **Dark matt surfaces** also **emit more infrared radiation**.



In the experiment above, the infrared lamp **radiates energy** to the test tubes. The **black painted tube absorbs** most of the energy (and **its temperature increases faster**) whereas the **shiny foil reflected** most of **the energy** that reached it.

Absorption and emission of infrared radiation

The **temperature** of an object **will increase** if it **absorbs more radiation than it emits.**

The **Earth's temperature depends** on a lot of factors like the **absorption of infrared radiation**. **Greenhouse gases** in the atmosphere (CO_2, CH_4 & H_2O) **absorb infrared radiation preventing it escaping** into space. This **process** is known as the **Greenhouse effect** and **makes the Earth warmer** than it would be if these gases were not present in the atmosphere.

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Physics Topic 4.1.3
Energy resources

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Section 1: Key terms	
Renewable resources	Resources that will **replenish themselves** (made quicker than they are used). They will **not run out**.
Non-renewable resources	Resources in **limited supply** that are used quicker than they are made, so they **will run out**.

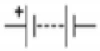
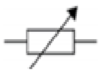
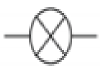
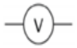
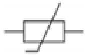
Section 2: Energy Resources

Our **energy demands** are met mostly by burning fossil fuels (oil, coal and gas). Fossil fuels are non-renewable and causes major environmental problems, hence there is an increasing demand for renewable resources which are less damaging to the environment.

Resource	Renewable?	Uses	Advantages	Disadvantages
Fossil Fuels	Non-Renewable	Electricity, transport, heating	**Reliable** – electricity can be generated all of the time. Relatively **cheap** way of generating electricity.	Produces **carbon dioxide**, a greenhouse gas that causes **global warming.** Can produce **sulphur dioxide**, a gas that causes **acid rain**.
Nuclear Fuel	Non-Renewable	Electricity	Produces **no carbon dioxide** when generating electricity. **Reliable** – electricity can be generated all of the time.	Produces **nuclear waste** that remains **radioactive** for thousands of years. **Expensive** to build and **decommission** power stations.
Bio Fuel	Renewable	Heating, electricity	**Carbon neutral**. **Reliable** – electricity can be generated all of the time.	Production of fuel may damage ecosystems and create a **monoculture**.
Wind	Renewable	Electricity	**No CO_2** produced while generating electricity. Cheap to use.	**Unreliable** – may not produce electricity during **low wind**. **Expensive** to construct.
Hydroelectricity	Renewable	Electricity	**No CO_2** produced while generating electricity. Cheap to use.	Blocks rivers stopping **fish migration**. **Unreliable** – may not produce electricity during **droughts**.
Geothermal	Renewable	Electricity, heating	Does not damage **ecosystems**. **Reliable** source of electricity generation. Cheap to use.	Fluids drawn from ground may contain **greenhouse gases** such as **CO_2** and **methane**. These contribute to **global warming**.
Tidal	Renewable	Electricity	**No CO_2** produced while generating electricity. Cheap to use.	**Unreliable** – **tides vary**. May damage **tidal ecosystem** e.g. mudflats.
Waves	Renewable	Electricity	**No CO_2** produced while generating electricity. Cheap to use.	**Unreliable** – may not produce electricity during **calm** seas.
Solar	Renewable	Electricity, heating	**No CO_2** produced while generating electricity. Cheap to use.	**Unreliable** – does not produce electricity at **night**. Limited production on **cloudy** days. **Expensive** to construct.

KNOWLEDGE — Physics Topic 4.2.1 Particles at Work – Electric circuits — ORGANISER

Section 1: Circuit Symbols

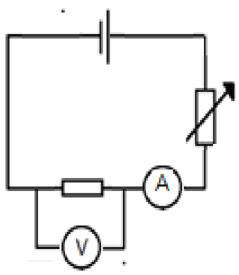
Symbol	Name	Function
	**Switch (open)**	Enables current to be switched on or off.
	**Cell**	Pushes electrons around a complete circuit.
	**Battery**	Supplies electrical energy, consists of two or more cells.
	**Diode**	Allows current in one direction only.
	**LED**	Light emitting diode emits light when a current passes through it in the correct direction.
	**Resistor**	Limits the current in a circuit.
	**Variable resistor**	Allows current to be varied.
	**Bulb**	Emits light as a signal when a current passes through it.
	**Fuse**	Breaks the circuit if current exceeds a certain amount.
	**Voltmeter**	Measures potential difference (voltage).
	**Ammeter**	Measures electric current.
	**Thermistor**	Temperature dependent resistor. Has high resistance when temperature is low.
	**LDR**	A light dependent resistor. Has high resistance when levels of light are low.

Section 2: Key Terms

Electric current	**Flow** of electric **charge**. Units amperes, A
Potential difference	The potential difference (**voltage**) between two points in an electric circuit is the energy transferred (or the work done) when a coulomb of charge passes between the points. Units volt, V
Resistance	Resistance is caused by anything that **opposes the flow of electric charge**. Units ohm, Ω
Charge	Anything **charged** that is **able to move within a circuit**. Electrons or ions. Units are coulombs, C
Series	A circuit with only **one route for charge to take**. The different components are connected in a line, end to end.
Parallel	A circuit with **more than one route for charge to take**. Each component **separately connected** to the +ve and –ve terminals.

Section 3: The standard test circuit

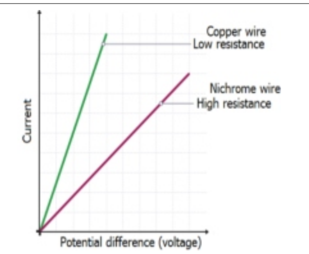
The standard test circuit is used to test components and determine the resistance of a component. By measuring the current through and potential difference across the component, the resistance can then be calculated and IV graphs obtained.

Standard test circuit		The **Ammeter** must be in **series** and placed **anywhere** in the **circuit**. The **voltmeter** must be placed in **parallel around** the **component** (so that it can compare the energy the charge has before and after passing through the component).

Section 4: Current-potential difference graphs

Increasing or decreasing the **potential difference** of the circuit will affect the current. Plotting current-potential difference results for different wires tells us about the resistance of these wires.

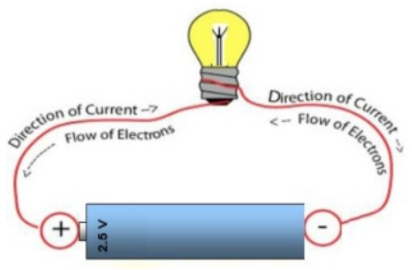
The **steeper the line**, **the lower the resistance** of the wire.



Section 5: Factors affecting resistance of a wire

Length of wire	The resistance of a wire is affected by length. Resistance of a **long wire is greater** than the resistance of a **short wire** because electrons collide with more metallic nuclei as they pass through.
Thickness of wire	The resistance of a **thin wire is greater** than the resistance of **a thick wire** because a thin wire has fewer electrons to carry the current.
Temperature	As **temperature increases** the metal nuclei begin to vibrate more. The electrons will have more chance of colliding and so **resistance increases**.

Electrical **current** is **NOT** the flow of electrons, it's the **flow of electric charge**, and as charge can be positive or negative then naturally **current** is in the **direction** of positive charge flow, and in the **opposite direction** to negative charge flow.



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Physics Topic 4.2.1
Particles at Work – Electric circuits

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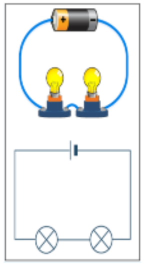
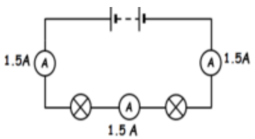
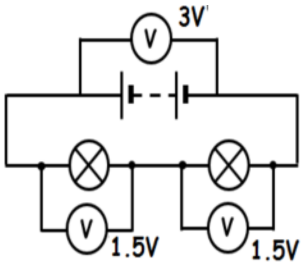
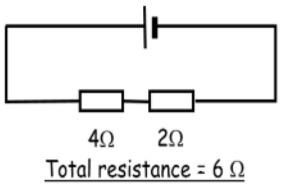
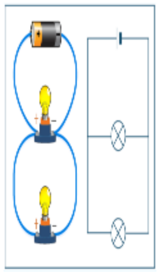
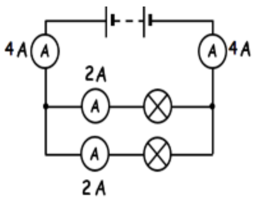
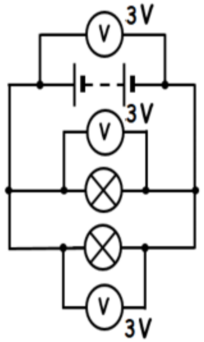
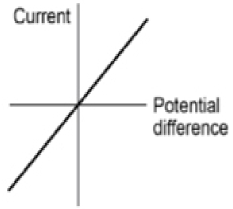
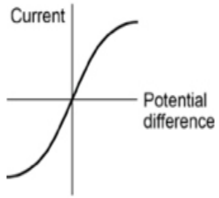
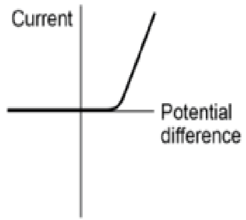
Section 6: V, I and R in Series and Parallel

Components connected in…	Current	Potential Difference	Resistance
Series 	The **current** is the **same everywhere** in the circuit and in every component. 	The total **potential difference** of the power supply is **shared** between the components. 	The **total resistance** is the **sum** of the **individual resistances**. $R_{total} = R_1 + R_2$ Adding **more resistors increases resistance.** 
Parallel 	The **total current** through the whole circuit is the **sum** of the **currents** through **the separate components**. 	The **potential difference** across each component is the **same**. 	The **total resistance** of **two resistors** is **less** than the **resistance** of the **smallest** individual **resistor**.  The **total resistance** for this circuit is **less than 2Ω** (the resistance of the smallest resistor). Resistance **decreases** as **more resistors** are added.

Section 7: IV Graphs

Graph	Example	Explanation
	**Ohmic conductor** (Fixed resistor or wire)	**Fixed Resistor or wires are Ohmic Conductors**. Current and potential difference are **directly proportional**. **Resistance is constant**.
	Filament Lamp (bulb) **non** Ohmic conductors	Resistance of a filament lamp is **not constant**. As temperature increases, resistance increases. **Ions** within the lamp **vibrate more,** increasing **collisions** with **electrons**.
	**Diode** or LED	**Diode/LED** The **current** through a diode/LED flows in **one direction only**. The diode has a **very high resistance in the reverse direction**.

Section 8: Equations to learn

Charge = current x time $Q = I \times t$	Charge flow - coulomb (C) Current – amperes (A) Time – seconds (s)
Potential difference = current x resistance $V = I \times R$	Potential difference – volts (V) Current – amperes (A) Resistance – ohms (Ω)
Energy transferred = charge x potential difference $E = Q \times V$	Energy = joules (J) Charge flow - coulomb (C) Potential difference – volts (V)

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Physics Topic 4.2.5
Particles at Work – Static Electricity (triple)

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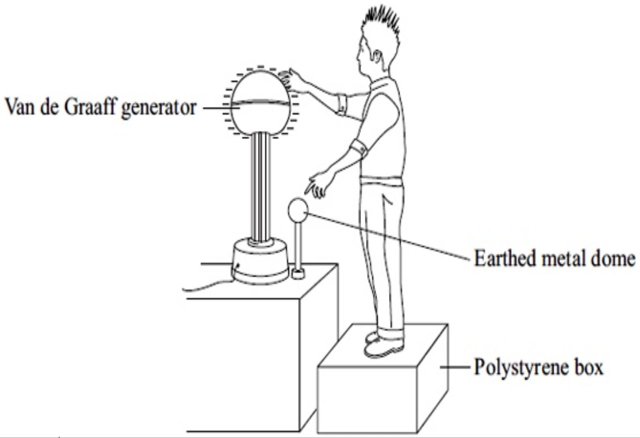
Section 9: Static electricity	
Static electricity is all about charges which are **not free to move**. This causes them to build up in one place which leads to **sparks** or **shocks** when they finally do move.	
Build up of **static** is caused by **friction**	When **two insulating materials** are **rubbed together**, **electrons are scraped off** one and dumped on the other. This leaves a **positive static charge** on one, and a **negative** static charge on the other.
Only electrons move	When electrons (negatively charged particles) move, ions form. **Both positive and negative electrostatic charges form** as a result.
Positive charges don't move	A positive charge is always caused by **electrons being removed** (so the positive charges don't move!)
Like charges repel	Two things with the **same charge** will **repel** each other.

Van de Graff Generator



When the Van de Graaff generator is switched on, **each hair gains** the **same negative charge**. Similar **charges repel** so the students **hair stands on end**.

Examples of **static electricity**	• **Attracting dust**: many objects around a house are insulating materials and get easily charged. Dust particles are attracted to anything that's charged (TV screen, glass, plastic etc.) • **Clinging clothes and crackles**: When synthetic clothes are dragged over each other (in tumble drier or over your head) electrons get scraped off leaving static electricity. • **Bad hair days**: Static builds up on hair, each strand having the same charge, so they repel each other.

Section 10: Key Terms	
Static electricity	It's the movement of electrons from one insulator to another. The insulator that loses electrons becomes positively charged and the insulator that gains the electrons becomes negatively charged
Insulator	An electrical insulator does not easily allow electricity to pass through it.
Earthing	Connecting a charged object to the ground using a conductor (e.g. copper wire) prevents build up of charge.

Section 11: Dangers	
Lightning	Lightning is a sudden electrostatic discharge that usually occurs during a thunderstorm. This occurs between electrically charged regions of a cloud, between two clouds, or between a cloud and the ground.
Synthetic clothes	Static charge can build up on synthetic materials if they are rubbed against each other. The charge can eventually build up large enough to cause a spark, dangerous if close to flammable gases or fuel fumes.
Grain chutes, paper rollers, fuel pipes	Static can build up when grain shoots out of pipes/paper drags over rollers/fuel flows out of filler pipes. Can lead to a spark which might cause an explosion in dusty or fumey places (like petrol station)
The solution to the problem	Earthing of objects prevents build up of static charge. Earthing cables can be attached to prevent sparks. Conducting soles in shoes prevent static electricity from building up hence preventing you getting a shock.

Section 12: Uses	
Electrostatic paint sprayers	Used to paint bikes and cars providing a fine even coat.
Defibrillator	A shock from a defibrillator can restore normal heart rhythm. Consists of two paddles connected to a power supply which are placed on the patients chest. The charge passes through the paddles to the patient which makes the heart contract.

KNOWLEDGE

Physics Topic 4.2.3 / 4.2.4
Particles at Work – Electricity in the home

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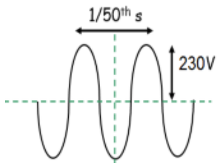
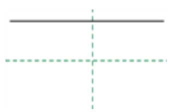
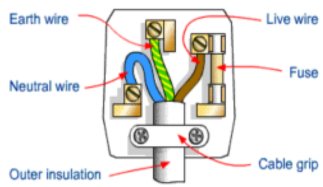
Section 1: Key Terms

Electric current	**Flow** of electric **charge**. Units amperes, A
Alternating Current **AC**	The **current alternates** (changes direction) **e.g. mains electricity**
Direct Current **DC**	The **current** flows in **one direction only e.g. cells or batteries.**
Mains Electricity	Electricity provided by the National Grid (is an **alternating current** of **230 V** and a frequency of **50 Hz.**)
National Grid	A series of **cables** and **transformers** linking power stations to consumers.
Step-up Transformer	**Increases the potential difference** for **transmission** across power cables. This makes the National Grid **efficient**.
Step-down Transformer	**Reduces the potential difference** from the cables to 230 V for use by consumers.

Section 2: Alternating current

Alternating Current **AC**	 The **current alternates** (changes direction.)
Direct current **DC**	 Direct current flows **in one direction**

Section 3: plugs, sockets & cables

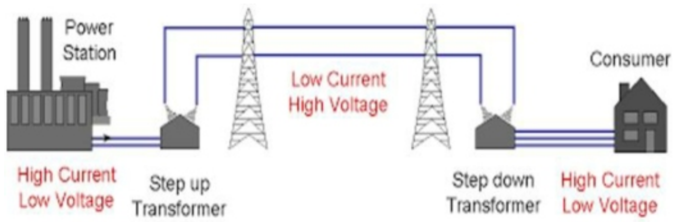
Three pin electrical plug	
Live wire	Carries the current (**brown** wire). Connects to fuse. About 230V.
Neutral wire	Completes the circuit (**blue** wire). Around 0V
Earth	Prevents electric shock (**green & yellow** wire). Is connected to the longest pin in a plug and carries current safely to earth if there is a fault.
Fuse	Contains a thin wire that melts and cuts off the current if too much current passes through it.
Sockets and plug cases	made of **plastic** because it's a good electrical **insulator**.
Mains cable	made up of two or three insulated copper wires surrounded by an outer layer of plastic.

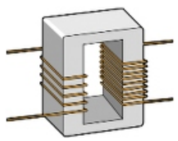
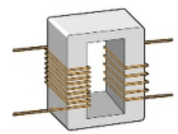
Section 5: Equations to learn

Equation	Units
Charge flow = current x time Q = I x t	Charge flow - coulomb (C) Current – amperes (A) Time – seconds (s)
Power = potential difference x current P = V x I	Power – watt (W) Potential difference – volts (V) Current – amperes (A)
Power = current^2 x resistance P = I^2 x R	Power – watt (W) Current – amperes (A) Resistance – ohms (Ω)
Energy transferred = power x time E = P x t	Energy = joules (J) Power – watt (W) Time – seconds (s)

Section 4: The National Grid

The National Grid supplies electricity from power stations via a series of cables and transformers to customers at **high voltages** to **reduce energy loss**.



Step-up transformer	Step-down transformer
	
More turns on secondary coil than on primary, therefore **increases voltage**. Increasing voltage **decreases the current** in the wires which means **less resistance**. Less resistance means **less energy lost as heat**, therefore it is **more efficient** to transmit electricity at high voltage.	Fewer turns on secondary coil than on primary, therefore **decreases voltage**. Reducing the voltage makes it **safer** to use in the **home**.

Section 6: Choosing appliances

Clockwork radio	Battery radio
Store **elastic potential energy** in a **spring** when someone winds them up. They are **free** to use. **Better for the environment**.	Stores **chemical energy** and turns it into **electrical energy**. **Expensive to buy** and have to be replaced when used up. A **lot of energy and harmful chemicals** go into making batteries.

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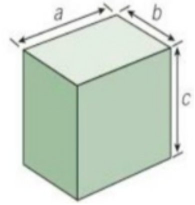
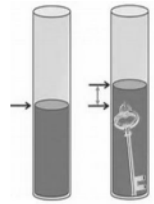
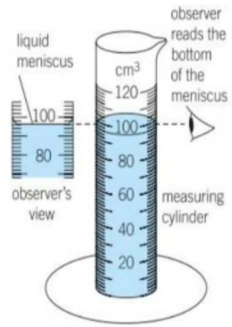
Physics Topics 4.3.1/2/3
Particles at Work – Molecules and matter

Section 1: Key Terms

Density	How much **mass** a substance contains **compared to its volume**. Solids are usually dense because the particles are closely packed.
State of matter	The way in which the **particles are arranged** – solid, liquid or gas.
Change of state	When a substance **changes from one state of matter** to another (e.g. melting is the change from a solid to a liquid). Energy changes the state, not the temperature.
Physical change	A change that can be **reversed** to recover the original material. **E.g. a change of state.**
Chemical change	A change that **creates new products**. It **should not be reversed**. E.g. a chemical reaction.
Internal energy	The **energy stored** inside a system **by the particles** (atoms and molecules) that make up the system. Internal energy is the **total kinetic energy and potential energy of all the particles.**
Kinetic energy	**Energy stored** within **moving objects** (e.g. particles).
Potential energy	**Energy stored** in **particles** because of their **position.** The **further apart** particles are, **the greater the potential energy.**
Specific heat capacity	The specific heat capacity of a substance is the **amount of energy** required to **raise the temperature of one kilogram** of the substance **by one degree Celsius**.
Temperature	The **average kinetic energy** of the **particles**.
Specific latent heat	The **amount of energy** required to **change the state of one kilogram** of the substance with **no change in temperature**.
Latent heat of fusion	**Energy required** to change state from **solid to liquid**.
Latent heat of vaporisation	**Energy required** to change state from **liquid to vapour**.
Gas Pressure	The **force** exerted by gases on surface as the **particles collide** with it. **As temperature increases, gas pressure increases** if the volume stays constant.

Section 2: Density

The **density of water** is **1000 kg/m^3** . Objects that have a lower density than water will float in water. **Density** can be **calculated** by measuring its **mass** and **volume**.

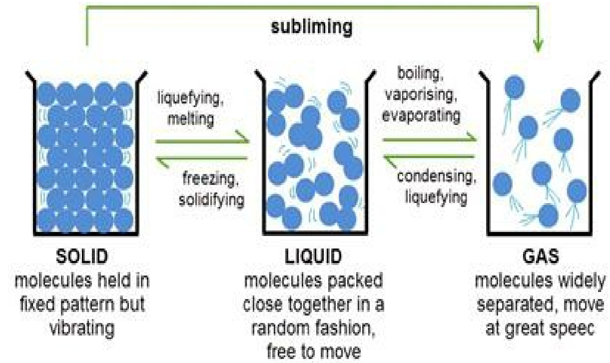
Measure **volume** of a **cuboid** = a x b x c	
Volume of an **irregular object** can be found by **dropping in a liquid** and **measuring Displacement**.	
When reading a meniscus the observer must read the **bottom** of the **meniscus**.	

Calculation	Equation	Symbol equation	Units
Density	Density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{v}$	Density = kg/m^3 Mass = kg Volume = m^3

Section 3: States of matter

Everything around you is made up of matter and exists in one of **three states**. **Solids**, **liquids** and **gases** are made of particles, the physical arrangement of particles determines the state of a particular substance.

Kinetic theory of matter



Changes of state

Condensation	Process in which a gas turns into a liquid
Evaporation	Process in which a liquid turns into a gas
Freezing	Process in which a liquid turns into a solid
Melting	Process in which a solid turns into a liquid
Sublimation	Process in which a solid turns into a gas

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Physics Topics 4.3.1/3
Particles at Work – Molecules and matter

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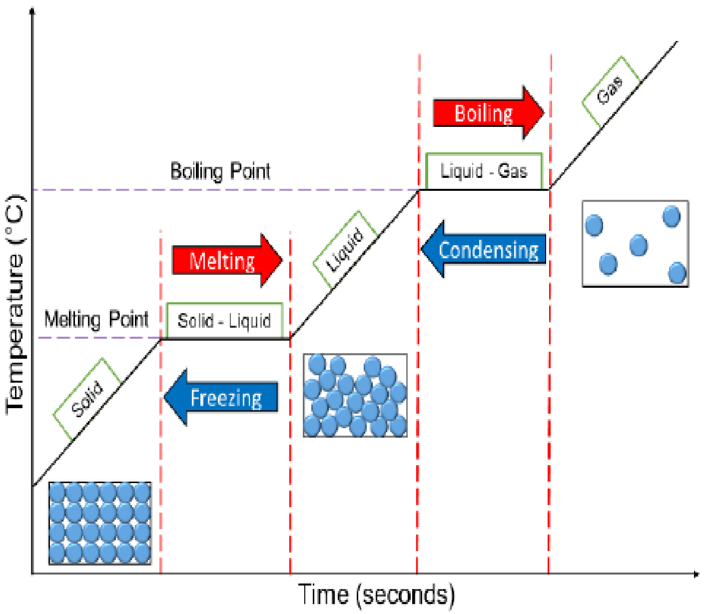
Section 4: The Heating Curve



Solid	Particles are closely packed, fixed and arranged in regular layers. As more energy is absorbed the kinetic energy and therefore the internal energy of the material increases.
Melting	Temperature doesn't change. Energy is used to weaken the forces between particles. As more energy is absorbed the potential energy and therefore the internal energy of the material increases.
Liquid	Particles are touching but no longer arranged regularly. They are able to move. As more energy is absorbed the kinetic energy and therefore the internal energy of the material increases.
Evaporation	Temperature doesn't change. Energy is used to weaken the forces between particles. As more energy is absorbed the potential energy and therefore the internal energy of the material increases.
Boiling point	The temperature at which a liquid boils and turns into a gas
Melting point	The temperature at which a solid melts and turns into a liquid.
Gas	Particles move randomly. As more energy is absorbed the particles move more quickly and the temperature increases.

State	Particle arrangement	Distance between molecules	Strength of forces	Movement of particles	Internal energy
Solid	Fixed	Close together	Strong	vibrates	Lowest internal energy
Liquid	Not fixed	Touching but not arranged regularly	Weak	Move about	Higher than solids but lower than gases
Gas	Not fixed	Far apart	Very weak (insignificant)	Move about freely	Highest internal energy.

Section 5: Internal energy

The energy stored by the **particles** of a substance is called its **internal** energy. This is caused by their individual motions and positions. The internal energy is the sum of a particles

- **kinetic energy** (due their individual motions relative to each other.)
- **potential energy** (due to their individual positions relative to each other.)

Increasing the temperature increases the **internal energy** of a substance because:

- Increasing temperature increases kinetic energy
- If it melts or boils, the potential energy increases.

Section 6: Specific latent heat

The **latent heat** is the **energy needed** for a substance to **change its state without changing** its **temperature**.

Specific latent heat of fusion $L_f = \frac{\text{energy, } E}{\text{mass, } m}$

Specific latent heat of vaporisation $L_v = \frac{\text{energy, } E}{\text{mass, } m}$

Section 7: Gas Pressure

Gas Pressure	Caused by the force exerted when particles collide with their container
Increasing temperature increases the gas pressure	Gas molecules move faster and hit the surfaces with more force. The number of impacts between the gas molecules and the surface of the container increases, so the total force of impact increases
Motion of gases	The unpredictable motion of smoke particles is evidence of the random motion of gas molecules – this is called Brownian motion
Gas pressure and Volume **(Triple only)**	A fixed mass of gas at a constant temperature, the pressure is increased if the volume is decreased as the number of molecular impacts per second increases
Boyle's Law **(Triple only)**	Pressure (p) x Volume (V) = constant (Pa) (m^3)

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Physics Topics 4.4.1/2/3
Particles at work – Atomic structure

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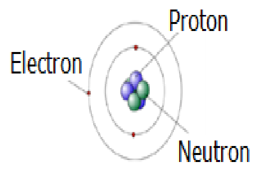
Section 1: Key Terms

Atom	The **smallest part of an element** that can exist. All substances are made of atoms. **No** overall **electrical charge**. **Very small**, radius of 0.1 nm.
Element	An element **contains only one type of atom**. Found on the Periodic Table. There are about 100 elements.
Isotope	An atom of the **same element** with **different numbers of neutrons**.
Radioactive decay	When an **unstable nucleus changes** to **become more stable** and **gives out radiation**. **Random**.
Activity	The **rate at which decay occurs**. Measured in **becquerels (Bq).**
Count rate	**Number of decays** recorded **each second** by a Geiger-Muller tube.
Half life	The **time it takes** for the **number of nuclei of the isotope in a sample to halve** Or, The **time it takes for the count rate** (or activity) from a sample containing the isotope **to fall to half its initial level**.
Contamination	Is when **radioactive particles get into objects** e.g. within liquids, with the body or on the skin.
Irradiation	When an object is **exposed to radiation**. The object does not become radioactive itself.
Ionisation	Radiation can ionise by **removing electrons from atoms to form ions**. If this happens in **DNA** it could lead to a **mutation that causes cancer**.
Peer review	The **checking of scientific results** by other **scientific experts**.

Section 2: Development of Atomic Model

Plum Pudding 	Thompson's plum pudding model shows that the atom is a **ball of positive charge** with **negative electrons embedded** in it. Was **incorrect**.
Nuclear Model 	**Rutherford's** alpha particle scattering experiment found a **central area of positive charge.** The nuclear model has a **positive nucleus** and **electrons in shells.** Later, neutrons were discovered and included in the nucleus.

Energy levels:
Absorption of radiation may lead to electrons moving further from the nucleus (higher energy level).
Emission of radiation may lead to electrons moving closer to the nucleus (lower energy level).

Section 3: Atomic mass number and atomic number

Atomic mass number → $^{14}_{6}C$ ← Atomic number	**Atomic number** – the **number of protons** (the number of electrons is the same in an atom)
	Mass number – the total number of **protons** and **neutrons**

Section 4: Properties of Sub-Atomic Particles

Sub-atomic particle	Mass	Charge	Position in Atom
Proton	1	+1	Nucleus
Neutron	1	0	Nucleus
Electron	$\frac{1}{2000}$	-1	Orbiting in shells

Section 5: Nuclear Radiation

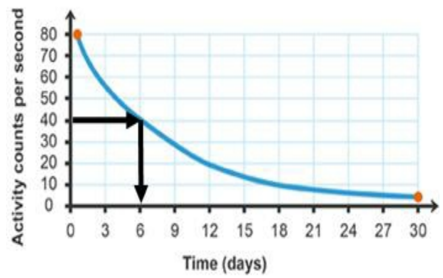
Radiation	Range in air	Absorbed by	Ionizing Power	Product emitted when nuclei decays
Alpha	Short – **up to 5 cm**	**Paper** and **skin**	**Very High**	**2 protons** and **2 neutrons**
Beta	Medium – **about 1 m**	About 5 mm of **aluminium.**	**Medium**	**Electron**
Gamma	**Unlimited** – spreads out	**Several centimetres** of **lead.**	**Low**	**Electromagnetic wave**

Section 6: Nuclear Decay Equations

Alpha decay	$^{219}_{86}Rn \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$ In alpha decay a **helium nucleus** (2 protons and 2 neutrons) is **emitted**. The new element formed has a **mass number** that has **decreased by 4** and **atomic number** that has **decreased** by **2**.
Beta decay	$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ In beta decay a **neutron turns into a proton**. An **electron** is **emitted**. The new element formed has a **mass number** that **stays** the **same** and an **atomic number** which **increased by 1**.
Gamma ray	There are **no changes to** the **nucleus** when gamma rays are emitted.

Section 7: Activity & half-life

Halve the initial activity (80 ÷ 2 = 40)
Draw a line across on the graph until you reach the curve
Draw a line down (half-life = 6 days)
Half life **never** drops to zero.



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Physics Topics 4.4.3/4
Particles at work – Atomic structure (triple)

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Section 8: Key Terms

Background radiation	Background radiation **is around us all of the time**. It comes from: • **natural sources** such as **rocks** and **cosmic rays** from space • **man-made sources** such as the **fallout f**rom **nuclear weapons testing** and **nuclear accidents**.
Radiation dose	A measure of the **amount of exposure** to **radiation**, measured in **sieverts (Sv)**.
Radioactive isotopes	Isotopes **used in medicine** for **medical imaging**, **treatment of cancer** and as **tracers** to monitor organs.
Radioactive tracers	**Trace** the **flow of a substance** through an organ.
Nuclear Fission	**Splitting of** an atom's **nucleus** into **two smaller nuclei** and the release of two or three neutrons and energy.
Nuclear Fusion	is the **joining** of **two light nuclei** to form a **heavier nucleus**. In this process some of the **mass** may be **converted** into the **energy of radiation**.

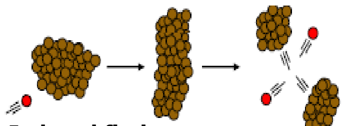
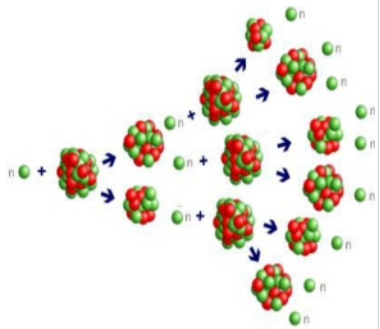
Section 9: Radioactive isotopes and medicine

Used in medicine **for medical imaging**, **treatment of cancer** and **tracers** to monitor/explore internal organs. How useful the radioactive isotope is depends on it's half life and the type of radiation given out.

Radioactive tracers	Radioactive Tracers (like radioactive Iodine) contain a **radioactive isotope** that **emits gamma** radiation. **Radioactive Iodine** is used because: • Half life of 8 days (lasts lone enough for test but decays completely after a few weeks). • Emits gamma so can be detected outside the body. • Decays into a stable product.
Gamma Cameras	Take **images** of **internal body organs**. Before image is taken, patient is injected with solution containing a gamma-emitting radioactive isotope. The solution is absorbed by the organ and the camera detects the gamma radiation. The half life of the radioactive isotope **should not be** too **long** (to avoid unnecessary risks) **or too short** (so a useful image produced).
Gamma beams	**Gamma** beams (or radioactive implants) can **destroy cancer cells** in a tumour.

Section 10: Nuclear Fission

Nuclear fission is the **splitting of a large and unstable atom's nucleus** (e.g. uranium or plutonium) into two smaller nuclei and the release of neutrons and energy.

Induced fission	Energy is released in a nuclear reactor because of nuclear fission. In induced fission, the nucleus of an atom is struck by a neutron, causing the nucleus to split into two smaller fragment nuclei. Energy is also released.	 **Induced fission**
Nuclear fission in **Power Stations**	• Unstable nuclei are **bombarded with neutrons**. • The nuclei undergo fission and split. • **Two smaller nuclei are formed** plus neutrons. • **Energy is released**. • Released neutrons cause more nuclei to split which produces a **chain reaction**. • The reaction is **controlled** using **control rods** which **absorb the neutrons** (slowing down the chain reaction). • A coolant removes the heat energy, usually to produce steam.	 **Chain reaction** (extremely dangerous if not controlled). The explosion caused by a nuclear weapon is caused by an **uncontrolled** chain reaction.

Section 11: Nuclear fusion

Process of forcing the nuclei of two atoms close together forming a single larger nucleus. The two nuclei collide at high speed. Energy is released when the nuclei fuse together. The **suns core releases energy** due to the **nuclear fusion** reaction of **hydrogen nuclei into helium nuclei**.

Nuclear fission	Nuclear fusion
Been used for over 50 years.	A **developing technology**. Needs to be at a **high temperature** and **pressure** for reaction take place and generate energy.
Uses uranium (only found in some parts of world)	Hydrogen fuel easily available as present in sea water
Produces radioactive waste which has to be stored safely and securely.	Reaction product helium is stable.

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Physics Topic 4.5.1 Forces in balance

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Section 1: Key terms

Scalar	A quantity with **magnitude (size) only,** e.g. speed, distance, time, area, volume.
Vector	A quantity that has both **magnitude (size)** and **direction,** e.g. all forces, displacement, velocity, weight, momentum.
Distance	How much ground an object has covered during its motion (scalar).
Displacement	Displacement is **distance** in a given **direction** (vector).
Magnitude	The value of a force in newtons.
Friction	The force **opposing** the **relative motion** of **two solid surfaces** in **contact**.
Contact force	Force between objects that are **touching** e.g. friction, air resistance.
Non-contact force	Force that acts on things **not touching** e.g. gravitational force, magnetic force.
Balanced forces	When forces are equal and opposite each other, also known as **equilibrium**.
Newton	Unit force is measured in.
Weight	The **force of gravity** acting **on an object's mass.** Measured using a **newtonmeter**.
Centre of mass	A **point** in the **middle** of an object where **all its mass acts**.
Resultant force	The **overall force** once all the forces have been considered.
Work done	Work is done when an **object is moved through a distance**. When work is done **against friction** there is a **temperature rise**.
Newton's first law	If the forces on an object are balanced the object will either: 1. Remain still 2. Keep moving with the same velocity
Newton's third law	When **two objects interact** they exert an **equal and opposite** force on each other.
Moment (HT)	**Turning effect** of a force
Load (HT)	Weight of an object

Section 2: Types of forces

Force	**Between**	**Contact or non-contact**	**Example**
Friction	Two moving surfaces	Contact	Brakes
Upthrust	An object & water	Contact	Boat
Reaction	Two stationary objects	Contact	Book on shelf
Air resistance	A moving object & air	Contact	Plane
Weight	Two masses	Non-contact	You and the earth
Tension	Two ends of an elastic material	Contact	Spring
Magnetic	Magnetic & magnetic materials	Non-contact	Magnet picking up a nail

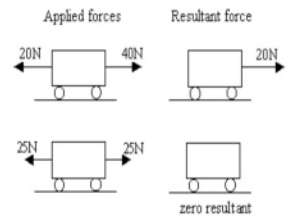
Section 3: Resultant forces

If the resultant force on an object **is zero**, then the object **stays at rest** or at the **same speed and direction**.

If the resultant force is **greater than zero**, the **speed or direction** of the object **will change**.

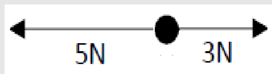
If two forces act on an object along the **same line**:

- the resultant force is **their sum** if the **forces act** in the **same direction**.
- the resultant force is their **difference** if the forces **act in opposite directions**.



A **free-body** force diagram of an object shows **the forces acting on it**.

Each force is shown on the diagram by a **vector** (an arrow pointing in direction of the force.)

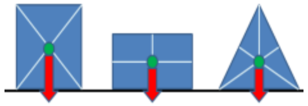


Free body force diagram (HT) showing forces in opposite directions.

Section 4: Centre of mass

Point at which mass of an object appears to be concentrated is known as its **centre of mass**. When an object is freely suspended, it comes to rest with its centre of mass **directly below the point of suspension**.

The centre of mass of a **regular shape** is at the **centre** (where the axes of symmetry meet.)

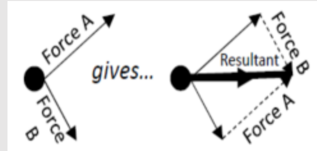


Section 5: The parallelogram of forces (HT)

The parallelogram of forces is a scale diagram of two force vectors which is used to find the **resultant of two forces** that are **not parallel** (don't act along the same line).

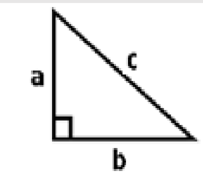
Force A and Force B are two forces that are **not parallel**.

The resultant is the **diagonal** of the parallelogram that **starts** at the **origin** of the two forces.



Resulting displacement (HT)

The resulting displacement (c) is **measured** using a **ruler** on a scale diagram or calculated using **Pythagoras**.



$$c = \sqrt{a^2 + b^2}$$

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Physics Topic 4.5.1 & 4.5.4
Forces in balance (Triple)

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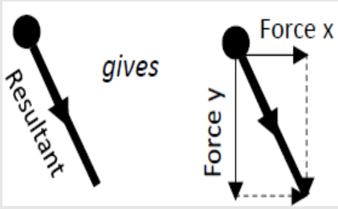
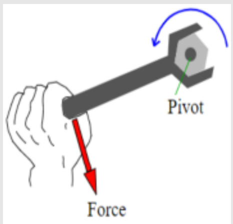
Section 6: Resolution of forces (HT)

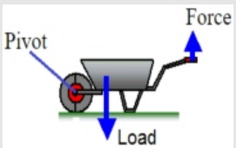
Resolving a force means finding perpendicular components that have a resultant force that is equal to the force.	
Drawing two forces at **right angles** to represent a **single resultant force**.	
Equilibrium	For an object in **equilibrium**, the resultant force is zero. For e.g. an object at rest has a resultant force of zero so is in equilibrium.

Section 7: Moments at work (Triple)

The **moment** of a force is **a measure** of the **turning effect** of the force on an object.

Moment of a force (turning effect) can be **increased** by: • Increasing the **size** of the force. • Using a spanner with a **longer** handle (**distance** the force is applied is further from the pivot.)	
To calculate a moment you need to know:	• How much **force** is being applied (Newtons, N) • The **distance** from the pivot that the force is being applied (Meters, m) **Moment = force x distance**
Unit for moment	(newton metre Nm)

A **small force** over a **large distance** can generate the **same moment** as a **large force** over a **small distance**.

Examples of levers include **scissors** and **wheelbarrows**.	

Section 8: Levers and gears (Triple)

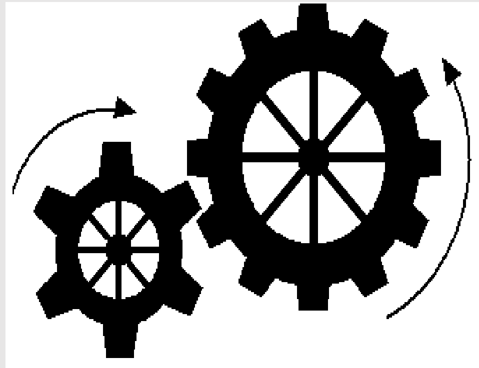
Levers use the idea of **balanced moments** to make it **easier** for us to do **work**. Levers **increase the distance** from the **pivot** at which the **force is applied**. Levers act as **force multipliers** as less force is required to get the same moment by increasing the distance.

Gears are like levers because they can **multiply the effect** of a **turning force**.

Gears are wheels with toothed edges that rotate on an axle or shaft. When one gear turns, it causes the other gear to rotate in the opposite direction.

If you want to **increase the moment of a turning force**, you need a **small gear** wheel to **drive** a **large gear** wheel. We see this in cars.

When a car is in **low gear**, a **small gear wheel** turns (effort) a **large gear wheel** (load.) The load force is larger than the effort force hence it is acting as a **force multiplier**.



Changing gears (Triple)

Low gear to high gear	A low gear ratio gives low speed and a high turning effect. A high gear ratio gives high speed and a low turning effect.

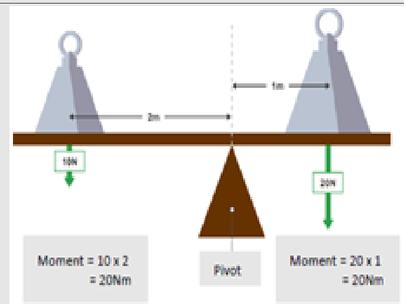
Section 9: Moments and equilibrium (Triple)

If an object at rest doesn't turn, the sum of the anticlockwise moments about any point = the sum of the clockwise moments about any point. This is the **principle of moments**.

Applying the principle of moments gives the equation

$$W_1d_1 = W_2d_2$$

W = Weight in newtons, N
d = distance in metres, m



KNOWLEDGE

Physics Topic 4.5.6
Forces in action - Motion

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Section 1: Key terms

Displacement	The **distance** an object moves in a given **direction**. A **vector** quantity.
Velocity	The **speed** of an object in a **given direction**. A **vector**.
Acceleration	The **change** of an object's **velocity per second**.
Deceleration	A negative acceleration, the object is slowing down.
Gradient	Change in quantity on the y-axis divided by change in quantity on the x-axis.

Section 2: Distance-time graphs

A distance-time graph **shows** the **distance** of an object from a starting point (plotted on y-axis) **against** the **time** taken (plotted on the x-axis.)

Constant speed - **straight line** that slopes **upwards**.

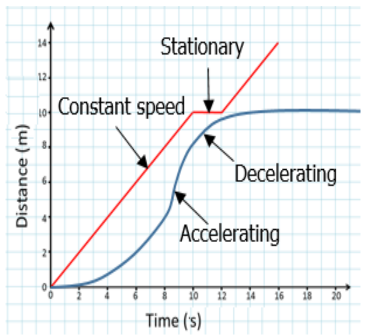
Accelerating - **curved** line getting **steeper**.

Decelerating - curved line getting **less steep**.

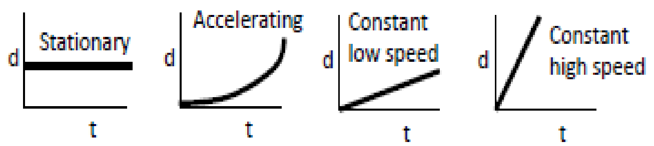
Stationary - **horizontal** line, the **gradient** is **zero**.

The **gradient** represents the object's **speed**.

The **steeper** the gradient, the **greater** the speed.



Slopes of distance-time graphs



Section 3: Velocity-time graph

A velocity-time graph **shows** the **velocity** of an object (plotted on y-axis) **against** the **time** taken (plotted on the x-axis.) A **motion sensor** linked to a computer can be used to **measure velocity changes**.

Constant velocity (zero acceleration)- **horizontal line**

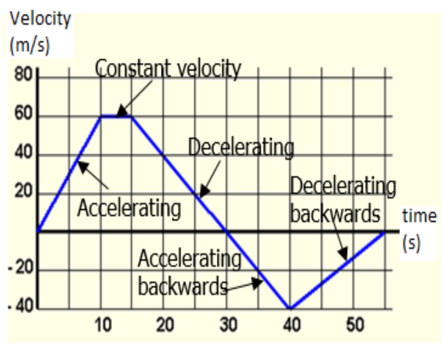
Constant acceleration - **straight line** with velocity **increasing**

Constant deceleration - **straight line** with velocity **decreasing**

Stationary - **horizontal line on x-axis** (velocity = 0)

Moving **backwards** - **below x-axis**

The **steeper** the **gradient** the **greater** the **acceleration**.

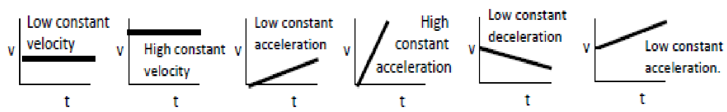


Velocity-time graph

A **positive gradient** represents **acceleration**, a negative gradient represents deceleration.

Area under the graph represents **distance** travelled (HT).

Slopes of velocity-time graphs

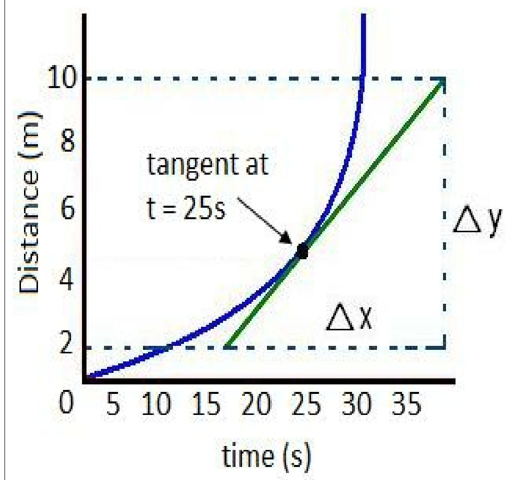


Section 4: Equations to learn

Distance = speed x time s = v x t	Distance – metres (m) Speed – meters per second (m/s) Time – seconds (s)
Acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$ a = ΔV/t	Acceleration – metres per second (m/s^2) Change in velocity – meters per second (m/s) Time taken – seconds (s)

Section 5: Calculating the gradient (HT)

The distance-time graph for an object moving at **changing speed** is a **curve**. **To find the speed** at a particular instant in time, draw a **tangent** to the line **at that instant** and determine the **gradient** of the tangent.



Calculating the gradient:

$$\text{slope} = \frac{\Delta y}{\Delta x}$$

or

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

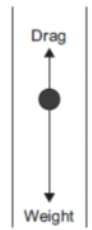
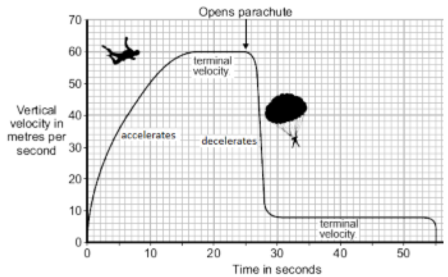
KNOWLEDGE

Physics Topic 4.5.6.3
Forces in action – Forces and motion

ORGANISER

Section 1: Key terms	
Displacement	The **distance** an object moves in a given **direction**. A **vector** quantity.
Velocity	The **speed** of an object in a **given direction**. A **vector**.
Acceleration	The **change** of an object's **velocity per second**.
Resultant force	The **overall force** once all the forces have been considered.
Terminal velocity	The **velocity** an object **eventually reaches** when it is falling. The **weight of the object** is then **equal** to the **frictional force** on the object.
Stopping distance	The **shortest distance** a vehicle can **safely stop** in. It depends on **thinking distance** and **braking distance**.
Momentum	A **moving object** with **mass** has momentum. Momentum is "**mass in motion**" It is a vector quantity.
Conservation of momentum (HT)	In a closed system, **total momentum before** an event **is the same** as the **total momentum after** the event.
Closed system (HT & Triple)	A **system** with **no external forces** acting on it.

Section 2: Forces and acceleration		
Newton's second law of motion	The acceleration of an object is: • Directly proportional to the force • Indirectly proportional to mass	We can **investigate** the **relationship** between force and acceleration by using a trolley with constant mass, newton-meter, motion sensor and a computer.
Effect of force	The **greater the resultant force** on an object, the **greater** the objects **acceleration**. If an object is not accelerating then the resultant force on the object must be zero.	
Effect of mass	The **greater the mass** of an object, the **smaller** its **acceleration** for a given force.	
Calculation of resultant force	Resultant force = mass x acceleration f = m x a	Force – newtons (N) Mass – kilograms (kg) Acceleration = metres per second squared (m/s^2)
Inertia (HT)	the inertia of an object is its tendency to stay at rest or in uniform motion (moving at constant speed in a straight line.)	

Section 3: Weight and terminal velocity	
Weight	The weight of an object is the force acting on the object **due to gravity**. Measured in newtons, N.
Mass	The **quantity** of matter in it. Measured in Kg.
Gravitational field strength.	The gravitational force on a 1 kg object is called the gravitational field strength. An object acted on only by gravity accelerates at about 10 m/s^2 on the Earth.
Calculating weight	weight = mass x gravitational field strength. w = m x g Weight – newtons (N) Mass – kilograms (kg) GFS – newtons per kilogram (N/kg)
Terminal velocity Ball bearing falling though a fluid.  The ball bearing reaches its terminal velocity when the **drag is equal to the weight**.	When a parachutist jumps out of a plane, the only force acting is weight (gravity.) As the parachutist falls air resistance acts upwards. The resultant force is downwards as weight is greater than air resistance, hence the parachutist accelerates. As velocity increases, so does air resistance. **Terminal velocity** is reached **when** the **forces are balanced** (when air resistance = weight.)  When the parachute opens, the surface area increases hence there's much more air resistance. The weight (downwards force) is still the same, hence the **terminal velocity decreases** allowing the parachutist to hit the ground at a safe speed.

KNOWLEDGE

Physics Topic 4.5.6.3 & 4.5.3
Forces in action – Forces and motion

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Section 4: Forces and braking

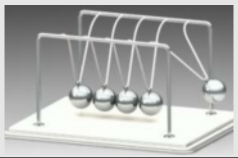
Thinking distance	The **distance** a **car travels** while the **driver reacts**.
Factors affecting thinking distance	1. Tiredness 2. Drugs 3. Alcohol 4. Distractions (e.g. mobile phones)
Braking distance	The **distance a car travels** while the car is **stopped** by the **brakes**.
Factors affecting braking distance	1. How fast you are going 2. Road conditions (weather e.g. Water or ice) 3. Conditions of tyres and brakes. 4. Type of road surface 5. Mass of vehicle
Stopping distance	The **sum** of the **thinking distance** and **braking distance**.

Section 5: Momentum (HT)

All moving objects have momentum. The greater the mass **and** velocity of an object, the greater its momentum. Momentum has size **and** direction so is a vector quantity.

Calculating Momentum	Momentum = mass x velocity p = m x v	Momentum – Kg m/s Mass - Kg Velocity – m/s

In a **closed** system, **total momentum before** an event **is the same** as the **total momentum after** the event. Momentum is conserved in a collision or an explosion as no external forces act on the objects. After a collision, the colliding objects may move off together or may move apart.



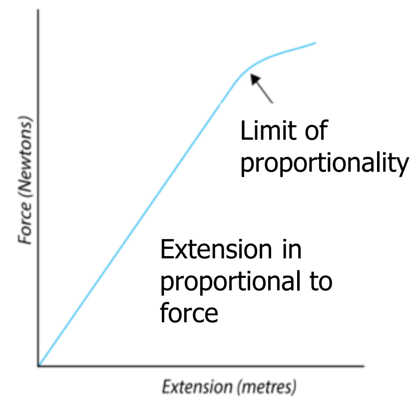
Section 6: Forces and elasticity

Elastic deformation	Occurs when a **spring is stretched** and **can** then **return** to its **original length**.
Inelastic deformation	Occurs when a **spring is stretched** and its **length** is **permanently altered**.
Limit of proportionality	The **length** a spring can be **stretched before it no longer is able to return to its original length**. Beyond the limit of proportionality, a force-extension graph is curved.
Extension	Difference between the length of an object and its original length.

Force extension graph

If you hang small weights from a spring it will stretch. If you plot a graph of the spring's extension against force applied, you get a straight line that passes through the origin. The **extension** is **directly proportional** to the **force applied.**

However if you **apply too much force**, the line begins to **curve** because you have exceeded the **line of proportionality**.



Objects and materials that behave like this are said to obey **Hooke's law**. Hooke's law states that extension is directly proportional to the force applied, provided the limit of proportionality is not exceeded.

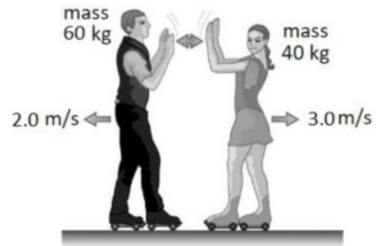
Hooke's law	Force applied = spring constant x extension F = k x e	Force – newtons, N Spring constant N/m Extension – metres m

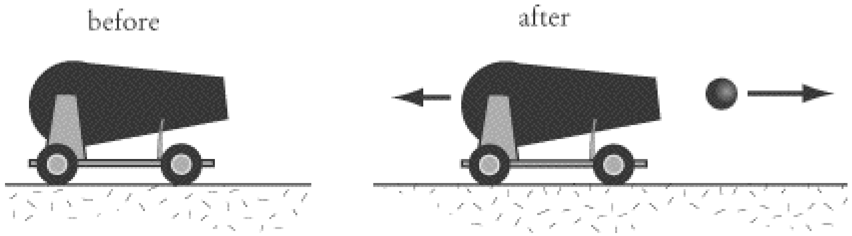
KNOWLEDGE — Physics Topic 4.5.7 Forces in action – Forces & motion (triple) — ORGANISER

Section 7: Using conservation of momentum (triple only)

When two objects push each other apart, they move with **different speeds** if they have **unequal masses** and with equal and opposite momentum, so their **total momentum is zero**. This means that the **momentum lost** by one of the objects will be **gained** by the other object. Hence whenever two objects collide or interact, **momentum is conserved**.

Calculating Momentum	Momentum = mass x velocity p = m x v	Momentum – kg m/s Mass - kg Velocity – m/s

Two roller skaters, a girl and a boy stand facing each other on flat level ground. When one of the roller skaters pushes the other one away, they **move away** in **opposite directions** at **different velocities** because they have **different masses.**	 Momentum of boy = 60 x 2 = 120 kg m/s Momentum of girl = **-**40 x 3 = **-**120 kg m/s **Total momentum** = 120 – 120 **= 0 kg m/s** The **minus sign** tells you that the momentum of the girl is in **the opposite direction** to the momentum of the boy.
Explosions	Total momentum after an explosion is the same as before the explosion. The total momentum **after** the explosion is **zero.** **Momentum before = Momentum after**



Section 8: Impact forces (HT triple only)

Collisions	When two vehicles collide, the **force of the impact depends** on the **mass, change of velocity** and **length** of the impact time. • They exert **equal and opposite forces** on each other • Their **total momentum** is **unchanged.**
Length of impact time	**Longer** the **impact time**, the **more the impact force** is **reduced.**

Impact force

Impact force = change in momentum / time taken

$$F = \frac{m\Delta v}{\Delta t}$$

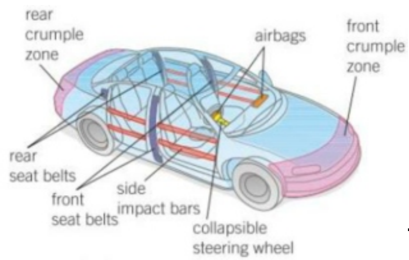
Force	F	Newtons, N
$m\Delta v$	Change in momentum	kg m/s
Δt	Time taken	s

Section 9: Safety first (HT triple only)

When you are driving in a car or riding a bike you want to feel safe if you crash. Different safety features have been designed to **increase the impact time** and hence **decrease the rate of change in momentum.**

Cycle helmets & cushioned surfaces in playgrounds/gyms	Reduce impact forces by increasing impact time.
Seat belts & air bags	Spread force across chest and increase impact time. Hence reduces impact force on head.
Crumple zones & collapsible steering wheels.	Give way in an impact and hence increase the impact time.

Car safety features



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Physics Topic 4.5.5
Forces in action – Forces & pressure (triple)

Section 1: Key terms

Pressure	The **force per unit area**, measured in **Pa** (which is equal to 1 N/m^2).
Density	**Mass per unit volume** of a substance.
Fluid	A **liquid or** a **gas**.
Earth's atmosphere	Relatively **thin layer of gases** that **surround** planet **Earth**.
Atmospheric pressure	The **pressure exerted** by the **weight** of the **atmosphere**.
altitude	The **height** of an object in **relation to sea level**.
Upthrust (HT)	The **upward force** that **acts** on a **body** partly or completely **submerged** in a **fluid**.
Flotation (HT)	The action of **floating** in a **liquid or** a **gas**.

Section 2: Pressure and surfaces

Pressure is caused when **objects exert forces** on each other, or when a **fluid exerts a force** on an object in contact with the fluid.

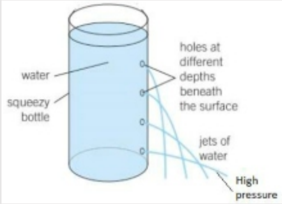
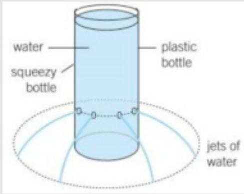
Pressure depends on	• **Area of contact** on which the force acts • **Size** of the **force**	
Calculating pressure	Pressure = $\frac{\text{force}}{\text{area}}$ $p = F/A$	Pressure – pascals, Pa Force – newtons, N Area – metres squared m^2
Effect of area on pressure	Caterpillar tracks fitted to vehicles **increases the contact area** that the tracks have to the ground. This **reduces the pressure** of the vehicle on the ground because its **weight** is **spread over** a **larger contact area**. Useful for **driving** on **sandy, muddy or snow covered ground.**	

Section 3: Pressure in a liquid at rest (HT)

The pressure at the bottom of a column of liquid depends upon:
- Height of the column (higher the column, the greater the pressure.)
- Density of the liquid (greater the density, the greater the pressure.)

Calculating pressure due to column height of a liquid of given density.	Pressure = height x density x gravitational field strength $P = h \times \rho \times g$	Pressure – Pa Height – m Density – m^3 Gravity – N/kg

Section 3: Pressure in a liquid at rest continued (HT)

Pressure increases with depth	The **further the hole** is **below** the level of water in the bottle, the **greater the force** which the **jet leaves** the bottle	
Same pressure at same depth	The **pressure along** the **horizontal line** is **constant** (the jets from these holes are at the same pressure.	

Section 4: Atmospheric pressure

Air molecules colliding with a surface create atmospheric pressure.

Atmospheric pressure	At sea level 100 kPa Mount Everest 30 kPa
Altitude	Atmospheric pressure **decreases with higher altitude** as the number of air molecules (& hence the weight of air) above a surface decreases as the height above ground level increases.
Density of atmosphere	The atmosphere gets less dense with increasing altitude.

Section 5: Upthrust and flotation. (HT)

When an object floats, it experiences a greater pressure on its base, compared to the top surface. This creates a resultant force upwards called **upthrust**.

The upthrust on an object in a fluid:
- Is an upward force on the object due to the fluid
- Is caused by the pressure of the fluid

The pressure at a point in a fluid depends on the density of the fluid and the depth of the fluid at that point.

An object sinks if its weight is greater than the upthrust on it when it is fully immersed. A ship floats because it displaces more water than the weight of the ship hence its weight is equal to the upthrust.

KNOWLEDGE

Physics Topic 4.6.1 Waves , electromagnetism & space – Wave properties

ORGANISER

Section 1: Key terms

Amplitude	The **maximum displacement** of a point on a wave away from its **undisturbed** (rest) **position**.
Wavelength	The **distance** from a point on one wave to the **equivalent point** on the **next wave**. E.g. crest to crest. Measured in **metres**.
Frequency	The **number of waves** passing a certain **point each second**. Measured in **hertz (Hz)**
Longitudinal	**Oscillations** are along **the same direction as the direction of travel** e.g. **sound** waves.
Transverse	**Oscillations are at right angles** to the **direction of travel** e.g. **water** waves, all **electromagnetic** waves.
Period	The **time needed** for **one wave** to **pass a given point**.
Compression	Stretched out region of a **longitudinal** wave where the **particles are closest together**.
Rarefaction	Region in a **longitudinal** wave where the particles are **furthest apart**. (The stretched out section.)
Oscillate	**Swing back** and **forth** in a regular rhythm.
Absorb	When the **energy** of an **EM wave** is **taken up by an object**.
Transmit	When a wave is able to **pass through** a material.
Reflect (HT)	The wave **bounces off a surface**; the **angle of incidence** is **equal** to the **angle of reflection**.
Refract (HT)	The wave **changes direction** when it enters a **medium of different density** where it has a **different speed**.
Medium	The **substance** that **carries a wave** (or disturbance) from one location to another.
Vacuum	A **space** entirely **devoid of matter**.

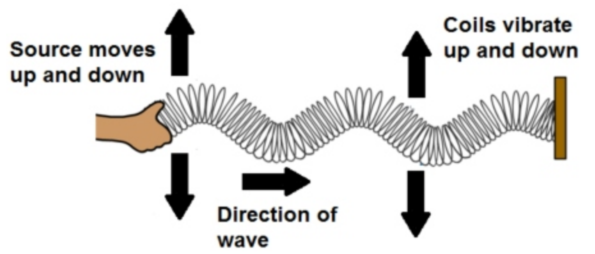
Section 2: The nature of waves

Waves **transfer energy** not matter. Waves can be used to transfer energy and information. **Mechanical waves** travel through a medium, for example light waves and radio waves, they can be **transverse** or **longitudinal**. **Electromagnetic waves** can travel through a vacuum and are **transverse**.

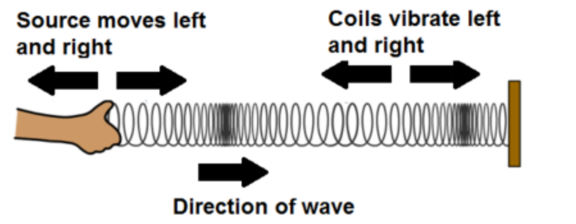
Transverse waves	Longitudinal waves
All electromagnetic waves (visible light, IR, Ultraviolet etc.) S waves. Ripples on the surface of water.	Sound waves. P waves.

Section 2: The nature of waves (continued)

Transverse waves have **oscillations** that are **perpendicular** to the direction in which the waves transfer energy.

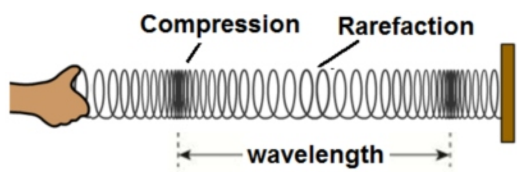


Longitudinal waves have **oscillations** that are **parallel** to the direction in which the waves transfer energy.

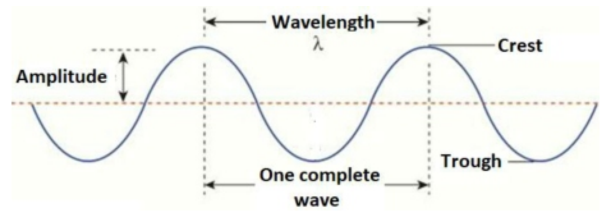


Section 3: The properties of waves

Longitudinal waves are made up of **compressions** and **rarefactions**. The **wavelength** is the **distance** from the **middle** of **one compression** to the **middle** of the **next compression**.



Distance from one crest to the next crest is the **wavelength**. The **amplitude** is the height of the wave crest.



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Section 3: The properties of waves (continued)

Period of a wave	period of a wave = $\frac{1}{\text{frequency}}$	
Calculating wave **speed**	Wave speed = frequency x wavelength $V = f\lambda$	Wave speed - m/s Frequency – hertz, Hz Wavelength – metres, m

Section 4: Investigating waves

Measuring the Speed of Sound

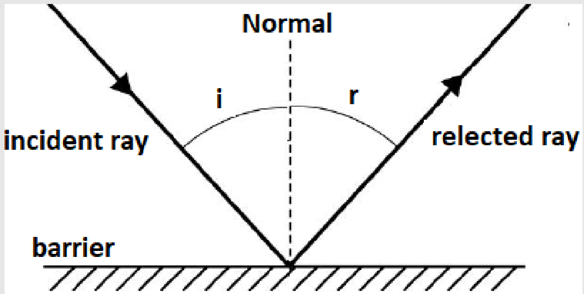
- **Measure** the **distance** to a **building.**
- **Fire a starting pistol** and **start a timer.**
- **Stop the timer** when the **echo** is heard.
- **Half** your value for **time.**
- Work out the **speed** using **distance divided by time.**

Measuring the Speed of ripples in a water tank

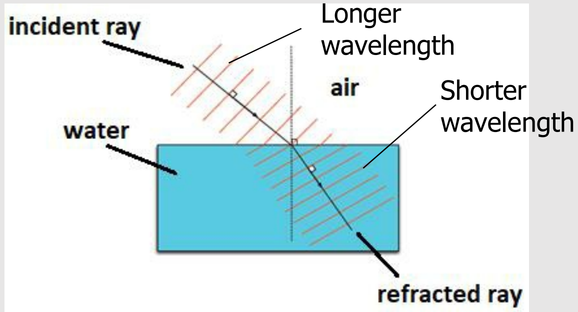
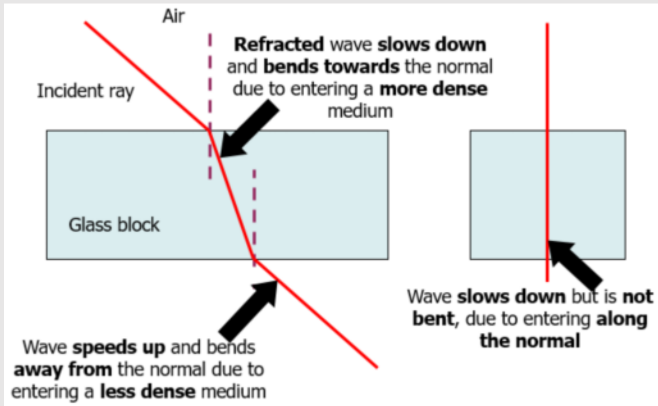
- Use a **ruler** to create **plane waves.**
- **Measure time** taken for a **wave** to travel from one end of tank to the other.
- **Measure distance** travelled.
- Work out the **speed** using **distance divided by time.**

Section 5: Reflection and refraction (HT)

The behaviour of waves can be investigated with water waves in a ripple tank. Waves travelling towards a barrier of a boundary are called **incident** waves.

Reflection	Takes place at the barrier in a tank. The **Reflected wavefront** moves away from barrier at **same angle** to the barrier as the **incident wavefront** because there is **no change** in **speed** or **wavelength.**  **Angle of incidence (i) = angle of reflection (r)**

Section 5: Reflection and refraction continued (HT)

Refraction	Waves **change speed** and **wavelength** when they **cross** a **boundary** between **different substances.** This can be seen in a ripple tank at the boundary between deep and shallow water. Unless the waves meet the boundary at right angles, the **change in speed causes** a **change in direction.** This effect is called **refraction.**  
Waves and substances (HT)	When waves meet a boundary with a different substance they may be: • Totally or partially **reflected** • **Transmitted** through the substance • **Absorbed** by the substance.

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Section 6: Key terms (Triple)	
Ultrasound	Frequencies of sound above 20 kHz (20000 Hz.)
Sonar	A system for the detection of objects under water by emitting sound pulses and detecting or measuring their return after being reflected.
Seismic waves	Produced by earthquakes. P waves are longitudinal and S waves are transverse (cannot travel through a liquid.)
Epicentre	The point where an earthquake occurs is called its focus. The nearest point on the Earth's surface to the focus is the epicentre.

Section 6: Sound waves (Triple)

Sound waves are caused by vibrating objects. Sound can travel through media like solids, liquids or gases but it can't travel through a vacuum (there are no particles.)

Investigating sound waves	To investigate sound waves use a **signal generator** and a **loudspeaker**. The loudspeaker produces sound waves as it pushes the surrounding air backwards and forwards. Sound waves **cannot pass** through a **vacuum**, this can be investigated using a electric bell in a bell jar. As the **air is pumped out** of the bell jar, the **ringing sound fades** away.
Amplitude	The **loudness** of a note **increases if** the **amplitude** of the sound waves **increases**.
Frequency	The **pitch** of a note **increases** if the **frequency** of the sound wave **increases.**
The ear	When sound reaches your ear, air particles in your **ear canal** vibrate against your **ear drum**, which vibrates against **three tiny bones**. These set **inner-ear fluid** moving which moves thousands of **delicate cells** which send **signals** to the **brain** causing the sensation of sound. The **conversion of sound waves to vibrations** of solids works over a **limited frequency range**, restricting the range of human hearing from 20 Hz to about 20 kHz.
Echo sounding (Sonar)	Uses pulses of high-frequency sound waves to: • detect objects in deep water and • to measure water depth below a ship

Section 7: The uses of ultrasound (Triple HT)

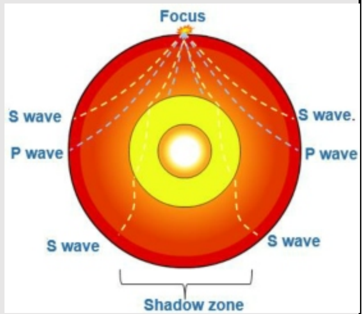
Ultrasound waves have a **frequency higher** than the **upper limit of hearing** for **humans**.
Ultrasound waves are **partially reflected** when they **meet a boundary** between two different media (e.g. two different types of body tissue.) The **time taken** for the **reflections to reach** a **detector** can be used to **determine how far** away such a boundary is.

Ultrasound scanners	Used for prenatal scans of a baby in the womb. Also used to obtain images of organs in the body (e.g. kidney). It is non-ionising so is harmless.
Industrial imaging	Detecting flaws in metal casting (e.g. internal cracking) as they are partially reflected by cracks.

Section 8: Seismic waves (Triple HT)

Seismic waves are waves produced in an earthquake (sudden release of energy caused by the movement of tectonic plates) and travel through the Earth. They spread out from an **epicentre.**

P-waves	• **P**rimary waves. • Travel through both solids and liquids • Longitudinal waves that push and pull on material as they move through the Earth.
S-Waves	• **S**econdary waves • Slower; they arrive a few minutes after P-waves. • Cannot travel through liquids. • Transverse waves shake the material they pass through from side to side.



The paths of these seismic waves are curved because the density is gradually changing.

The study of seismic waves have provided new evidence that led to discoveries about parts of the Earth which are not directly observable (e.g. the structure and size of the Earth's core.)

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Physics Topic 4.6.2 Waves , electromagnetism & space – Light properties

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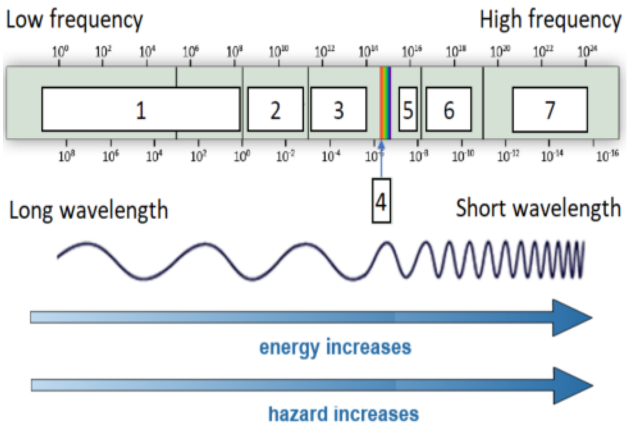
Section 1: Key terms

Electromagnetic Spectrum	The collective name for **all types of EM radiation**. They are all **transverse waves** that travel at **300,000,000 m/s** (speed of light).
Wavelength	The distance from one wave crest to the next.
Frequency	The **number of wave crests** passing a fixed point every second.
Carrier wave (HT)	Waves used to carry information. They do this by varying their amplitude.
Ionising radiation	**High energy radiation** which can **remove electrons** leaving **ions**. If this happens **in DNA** it can cause a **mutation** that could lead to **cancer**.
Radiation dose	A **measure of** the **risk of harm** resulting **from exposure** of the body **to ionising radiation**. Measured in **Sieverts**.

Section 2: The electromagnetic spectrum

The waves in the electromagnetic spectrum are grouped together according to their wavelength and frequency. They are **transverse** waves **that transfer energy** (not matter) from a source to an absorber. The **human eye** can only **detect visible light**.



1.	Radio	5.	Ultraviolet
2.	Microwaves	6.	X-rays
3.	Infrared	7.	Gamma
4.	Visible		

Section 3: Uses and Risks of EM Radiation

EM Wave	Use	Why it's suitable (HT)	Risks
Radio	**Television** and **radio**	**Reflected** by **ionosphere** so can broadcast over **long distances**. Is a **carrier** wave.	
Microwaves	**Satellite communications, cooking food**	Able to **pass through the atmosphere** to **satellites**. Has a **heating** effect. Is a **carrier** wave.	Internal heating of the body (cooked from the inside.)
Infrared	**Electrical heaters, cooking food, infrared cameras**	Has a **heating** effect. **Emitted by objects** so can be **detected**.	Skin burns
Visible Light	**Fibre optic communications**	Able to **pass along a cable** by **total internal reflection**.	Blindness from bright light.
Ultraviolet	**Energy efficient lamps, sun tanning, checking bank notes.**	**Increases** amount of **melanin** (brown pigment) in **skin**.	**Premature skin ageing**, increase **risk of skin cancer**
X-Rays	**Medical imaging and treatments**	**Absorbed by bone** but **transmitted through soft tissue.**	**Ionising** – can cause **mutation of genes** and **cancer**
Gamma	**Medical imaging and treatments**	Able to **pass out of body** and be **detected by gamma cameras**. Can **kill cancerous cells**.	**Ionising** – can cause **mutation of genes** and **cancer**

Section 4: Production of electromagnetic waves

Radio (HT)	**Radio waves** are produced by **oscillations** in **electrical circuits.** When radio waves are absorbed they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves make electrons vibrate in an electrical circuit.
Gamma	**Gamma rays** are produced from the **decay** of an **unstable nucleus**.

Section 5: Equations to learn

Calculation	Equation	Symbol equation	Units
Wave speed	Wave speed = frequency x wavelength	$v = f\,\lambda$	Wave speed - metres per second (m/s) Frequency - hertz (Hz) Wavelength - metres (m)

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Physics Topic 4.6.1 Waves , electromagnetism & space – Light properties

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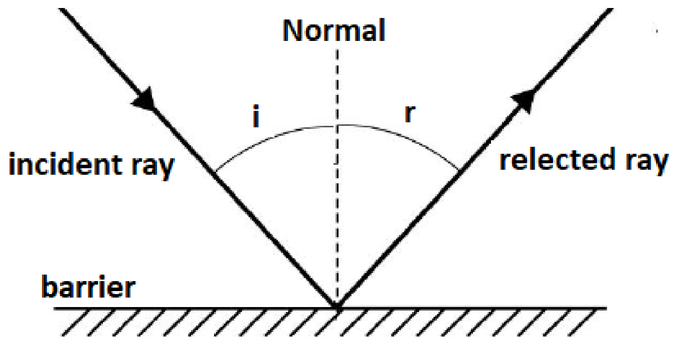
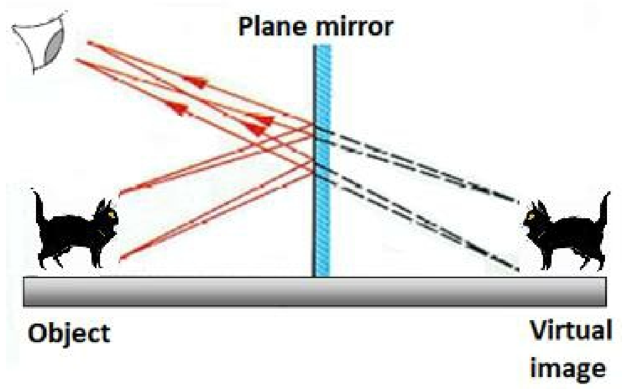
Section 1: Key terms (triple)

Reflect	The wave **bounces off a surface**; the **angle of incidence** is **equal** to the **angle of reflection**.
Refract	The wave **changes direction** when it enters a **medium of different density** where it has a **different speed**.
Normal	The normal at a point on a mirror is a **line drawn perpendicular** to the mirror at the **point of incidence.**
Law of reflection	The law of reflection states that the **angle of incidence** = **the angle of reflection.**
Plane mirror	A mirror with a **flat** (planar) **reflective surface.**
Real image	An image that can **seen on a screen** because it is formed by focussing light rays onto the screen.
Virtual image	An image formed at a place where the **light rays appear to come from** after they've been reflected (or refracted.)
Specular reflection	**Reflection** from a **smooth surface**, **parallel rays** are **reflected** in a **single direction.**
Diffuse reflection	**Reflection** from a **rough surface**, **parallel rays** are **scattered** in **different directions.**
Transparent	A transparent object **lets all light** that enters it **pass through** (and doesn't scatter or refract the light.)
Translucent	A translucent object **lets light pass** though but it **scatters** (or refracts) **the light** inside it.
Convex lens	**Focuses parallel rays** to a **point** called the **principal focus.**
Principal focus	The point where **parallel rays** are **focussed** to.
Concave lens	A concave lens (or diverging lens) makes **parallel rays spread out** as if they had come from a point called the principal focus.
Magnification	The image height ÷ the object height.
Focal length	**Distance** from the **centre of a lens to** the **point where light rays parallel** to the principal axis **are focussed.**
Magnifying lens	A convex lens used to form a **virtual image of an object.**

Section 2: Reflection of light (triple)

Law of reflection	 The angle of incidence (i), is the angle between the incident ray and the normal. The angle of reflection (r), is the angle between the reflected ray and the normal. The **Law of reflection** states that: **the angle of incidence = the angle of reflection.**
Image formed by a plane mirror	 The image formed by a plane mirror is **virtual, upright** and **laterally inverted** (back to front but not upside down.)

KNOWLEDGE

Physics Topic 4.6.2 Waves, electromagnetism & space – Light (triple)

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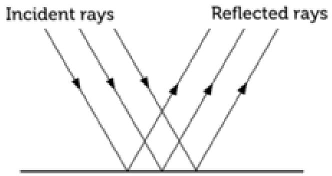
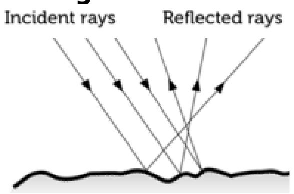
Section 2: Reflection of light (continued)

<table>
<tr><td>Specular reflection</td><td>Reflection from a smooth surface is called Specular reflection because reflection occurs in a single direction without scattering.



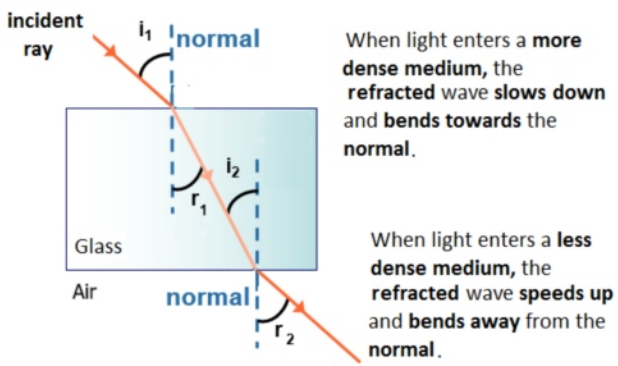
</td></tr>
<tr><td>Diffuse reflection</td><td>Reflection from a rough surface is called diffuse reflection because the light is scattered.



</td></tr>
</table>

Section 2: Refraction of light (triple)

<table>
<tr><td>Refraction</td><td>Refraction is a change in direction of waves when they travel across a boundary from one medium to another.

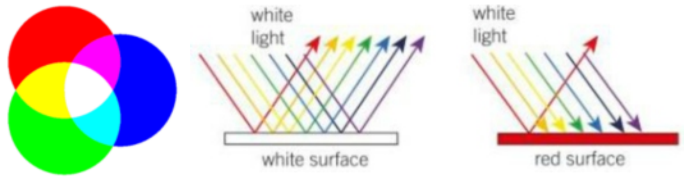


When a light enters a more dense medium (air into glass) the angle of refraction r_1 is less than the angle of incidence i_1. When light enters a less dense medium (from glass into air,) the angle of refraction r_2 is more than the angle of incidence i_2.</td></tr>
</table>

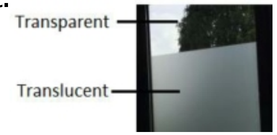
Section 3: Light and colour (triple)

<table>
<tr><td>Wavelength</td><td>The wavelength of light decreases from red to violet across the visible spectrum.

</td></tr>
<tr><td>Colour of a surface</td><td>Depends on the pigments of the surface materials and the wavelengths of light the pigments absorb & transmit.



A white surface has no pigments so it reflects light of any wavelength either partially or totally.
The colour of an opaque object is determined by which wavelengths of light are more strongly reflected, wavelengths that are not reflected are absorbed.
A book that has a red colour has pigments that absorb all the colours of light except for red. If all wavelengths are absorbed the object appears black.</td></tr>
<tr><td>Translucent</td><td>Objects that transmit light are either translucent or transparent. A translucent object lets light pass through it but scatters or refracts the light. This is because the material of the object has lots of internal boundaries that change the direction of light rays repeatedly. You can see light that passes through but you can't see images through it. E.g. bathroom windows are translucent.</td></tr>
<tr><td>Transparent</td><td>A transparent object transmit all the incident light (lets all the light that enters it pass through it) and does not scatter or refract the light inside the object. This is why you can clearly see through a transparent object.



</td></tr>
</table>

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Physics Topic 4.6.2 Waves, electromagnetism & space – Light (triple)

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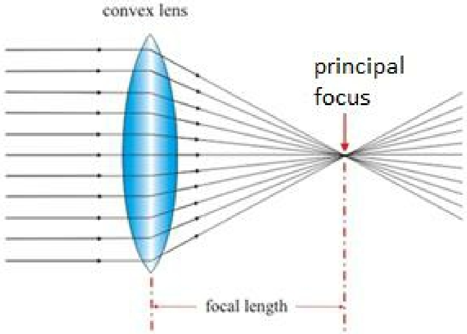
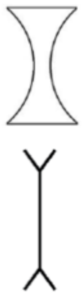
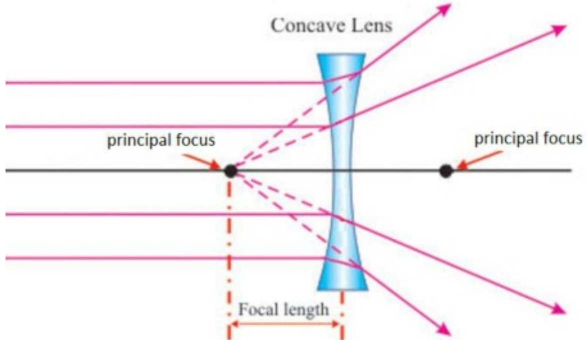
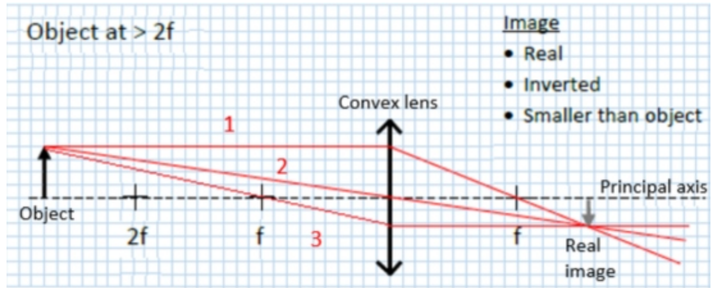
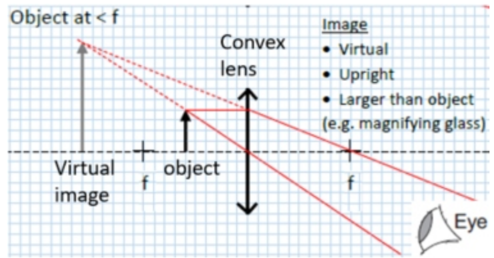
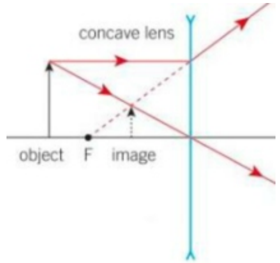
<table>
<tr><th colspan="2">Section 4: Lenses (triple)</th></tr>
<tr><td>Convex (converging lens)
</td><td>A convex lens focuses parallel rays to a point called the principal focus (or focal point).


The distance from the centre of the lens to the principal focus is called the focal length. The image can be either real or virtual. Used as a magnifying glass and in a camera to form a clear image of a distant object.</td></tr>
<tr><td>Concave (diverging lens)
</td><td>A concave lens makes parallel rays spread out as if they had come from a point called the principal focus (or focal point). The image produced is always virtual.


A concave lens is used to correct short sight.</td></tr>
<tr><td>Magnification</td><td>$$\text{Magnification} = \frac{\text{image height}}{\text{object height}}$$
As magnification is a ratio, there are no units.</td></tr>
</table>

<table>
<tr><td>Real image (convex lens)</td><td colspan="2">A real image is formed by a convex lens if the object is further away than the principal focus f of the lens.


To locate the image and determine its nature:
• Ray 1 is parallel to axis and is refracted through f.
• Ray 2 passes straight through the centre of the lens.
• Ray 3 passes through f and is refracted parallel to the axis.</td></tr>
<tr><td>Virtual image (convex lens)</td><td colspan="2">When an object is placed between a convex lens and its principal focus f, the image formed is virtual, upright, magnified and on the same side of the lens as the object.

</td></tr>
<tr><td>Virtual image (concave lens)</td><td>The image formed by a concave lens is always virtual, upright and smaller than the object.</td><td>
</td></tr>
</table>

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Physics Topic 4.7.1 Magnetism

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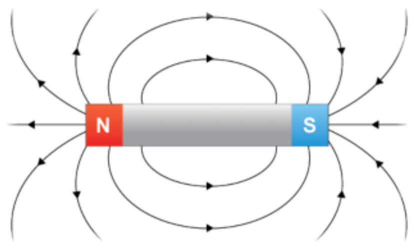
Section 1: Electromagnetism Key Terms

Pole	The **places** on a magnet where the **magnetic forces** are **strongest**.
Magnetic Field	The **area** around a magnet where a **force acts** on another magnet or magnetic material.
Repel	Occurs when two **like poles** are brought close together. The magnets **push apart**.
Attract	Occurs when two **opposite poles** are brought close together. The magnets **move together**.
Permanent magnet	A magnet that produces its **own magnetic field**.
Induced magnet	A magnetic material that **becomes a magnet** when it is placed in a **magnetic field**. When **removed** from the **field** it **quickly loses its magnetism**.
Magnetic material	There are four magnetic materials: **iron**, **steel**, **cobalt** and **nickel**.
Compass	Compasses contain small bar magnets which **points** to the **north pole** of the **Earth's magnetic field**.
Solenoid	A solenoid is a long **coil of wire** that produces a controlled magnetic field.
Electromagnet	A **solenoid containing an iron core** which increases its strength.
Motor effect (HT)	The **force produced** between a **conductor** carrying a current **within a magnetic field** and **the magnet producing the field**.
Magnetic flux density (HT)	A measure of the strength of a magnetic field.

Section 2: Magnetic fields

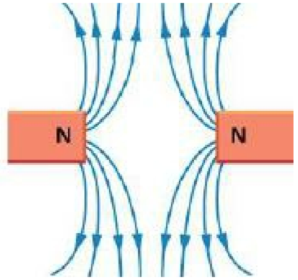
The **magnetic field lines** of a bar magnet curve around from the **north** pole of the bar magnet to the **south pole**.
The **field lines** always go from **north** to **south** and **never touch**.



Section 2: Magnetic fields (continued)

Like poles repel.

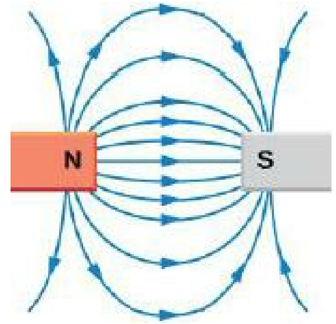
When **two north poles** (or two south poles) are placed together, they will **repel** each other.



Unlike poles attract.

When a **north pole** and a **south pole** are placed together, they will **attract**.

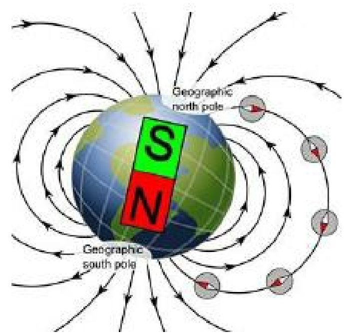
Attraction and repulsion between
two magnetic poles are examples of **non-contact forces.**



Induced magnetism is **magnetism** created in an **unmagnetised magnetic material** when the material is **placed in a magnetic field.**

Steel is used **instead** of **iron** to make **permanent magnets** because steel **does not lose** its **magnetism easily** but **iron does.**

The **Earth** behaves as if there is a **bar magnet** inside it. The geographic north pole is a **magnetic south pole**. A **compass** will point towards **geographical north** and is the **north-seeking pole**.
We know it is the **core** of the Earth that is magnetic(not the whole thing) because a compass at the **north pole** points below your feet.



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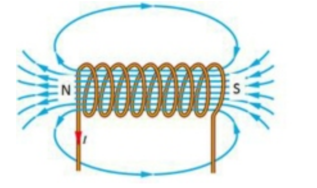
Section 3: Magnetic fields of electric currents

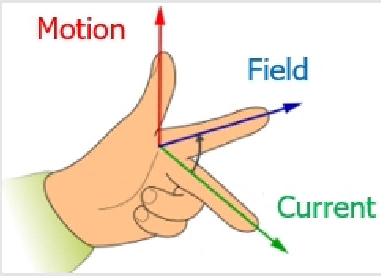
We can increase the strength of the magnetic field by putting a **magnetic** (e.g. iron) **core** in the **solenoid** (long coil of wire.) The magnetic field in a **solenoid** is concentrated **inside the coil in a uniform direction**, otherwise it acts in the same way as a bar magnet.



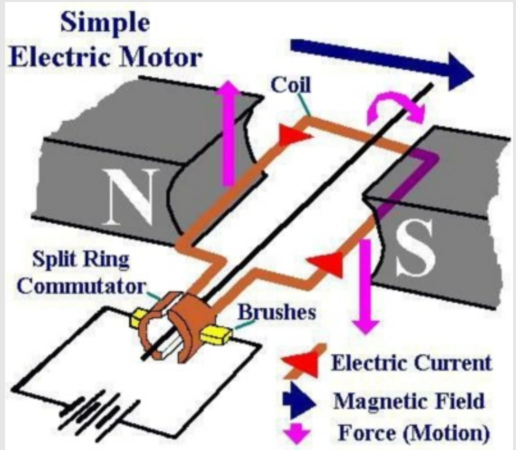
Increasing current	**Increasing current** makes the **magnetic field stronger**. **Reversing** the **direction** of the current **reverses the magnetic field lines**.
Electromagnet	An electromagnet is a **solenoid** that has an **iron core**. It consists of an **insulated wire** wrapped around an iron bar.
Increasing the force of a solenoid	• Add an **iron core** • Increase the **number of coils** of wire • Increase the **current** • Move the magnetic material **closer** to the solenoid.

Section 4: The motor effect (HT)

When a **conductor carrying a current is placed in a magnetic field, the magnet producing the field and the conductor exert a force on each othe**r. This can be used to create a motor.

Fleming's left hand rule	• Fleming's left hand rule shows the various **directions of actions** in an **electric motor**. • Thumb – direction of the **magnetic force** • First finger – direction of the **magnetic field** • Second finger – direction of the **current** in the wire.	
Flux density	**Magnetic flux density** is a **measure** of the **strength** of a **magnetic field**. It is the number of lines of magnetic flux in a given area. F=B x I x L Force = magnetic flux density x current x length	Force - newtons, N Magnetic flux density – tesla,T Current – amps, A Length – metres, m

Section 5: An electric motor (HT)

Electric motor	An electric motor is a device that makes use of the **motor effect**. The following statements explain how the electric motor creates a **turning force**: • The power supply applies a **potential difference** across the coil • A **current flows** through the coil • A **magnetic field** is created around the coil • The magnetic field **interacts** with the **magnetic field** of the **permanent magnets** • This creates a force that makes the **coil spin**. 
Increasing size of the turning force by:	• Increasing the **current** • Increasing **strength** of **magnetic field** • Increase the **number of turns** on the **coil** of wire • Adding an **iron core** inside the **coil**.
Reverse direction of force by:	• Reverse **poles** of **magnet** • Reverse **current**

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Physics Topic 4.7.2/3 Electromagnetism & the Generator Effect

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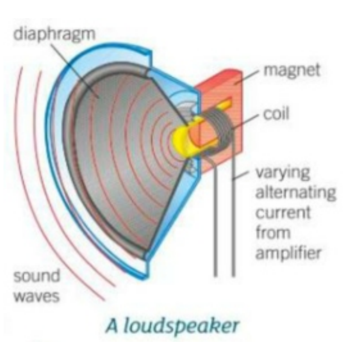
Section 6: Loudspeakers and headphones (triple HT)

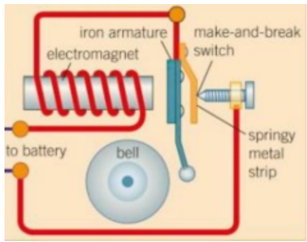
Loudspeakers and headphones **use the motor effect** to convert variations in current in electrical circuits to **pressure variations** in **sound waves**. They are known as **moving coil sound devices**.

- A coil that experiences a current in a magnetic field experiences a force (**the motor effect**)
- The **current** from the **amplifier varies**, so the **current** in the **coil varies**, and so **the force exerted** on the **coil varies**
- The **force moves the coil**
- The coil moves the **diaphragm** making it vibrate.
- The **vibrating** diaphragm sets up **compressions** and **rarefactions** in the **surrounding air** which **produces sound** waves.



A loudspeaker

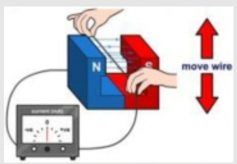
Section 7: Electromagnets in devices (triple)

Electromagnets used in many devices	• Scrapyard crane • Circuit breaker • Electric bell (see diagram) • Relays	

An electromagnet works in a circuit breaker, electric bell or relay by attracting an **iron armature** which **opens a switch**.

Section 8: The generator effect (triple HT)

The **generator effect** is the effect of **inducing** a **potential difference** using a **magnetic field**. When a **conductor** crosses **through** the **lines of a magnetic field**, a **potential difference** is **induced** across the **ends of** the **conductor**. If the conductor is part of a complete circuit, **the induced potential difference** makes an **electric current** pass around the circuit.



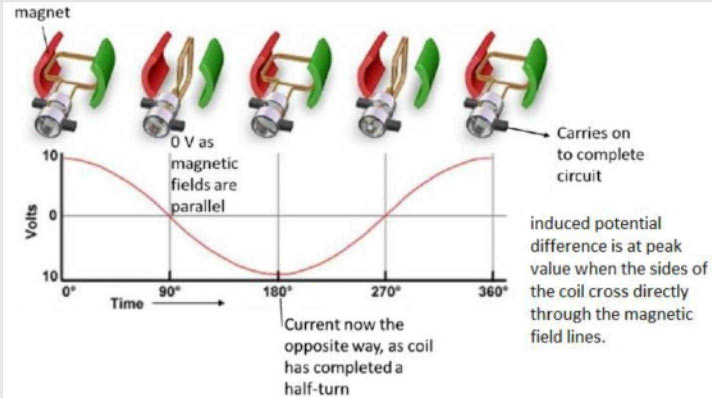
Section 8: The generator effect (triple HT) continued

The wire and magnetic field must **move perpendicular** to each other to **induce a current**. If they move parallel to each other, **no current** is induced.

Factors **affecting size** of induced potential difference/induced current	• **Speed of movement**: Faster the conductor passes through the lines of magnetic field, the bigger the induced potential difference/current. • Use a **stronger magnet** (Stronger magnet larger induced potential.)
Factors **affecting direction** of induced potential difference/induced current	• **Reverse magnet** • **Reverse movement**

Section 9: The alternating-current generator (triple HT)

Depending on the set up, the **generator effect** can be used in an **alternator** to **generate ac** and in a **dynamo** to generate **dc**.

Alternator	**ac** is generated in an **alternator**. It is made up of a **coil** that **spins** in a **uniform magnetic field**.  Each end of the coil of wire spin inside, and make contact with, a complete loop of conductor that's connected to the rest of the circuit. Since every **180° turn** of the coil the **current flips direction**, you get **ac**.

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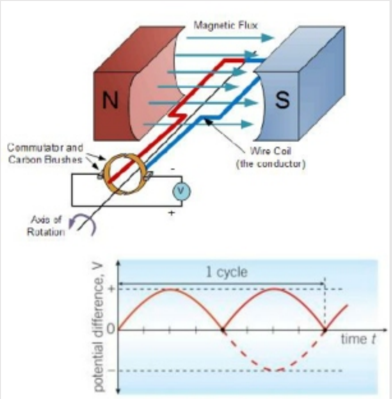
Section 9: The alternating-current generator (triple HT) cont.'

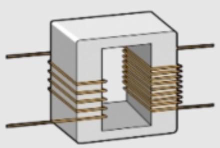
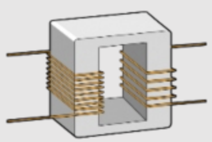
Dynamo

dc is generated in an **dynamo**. To prevent the current flipping direction every half-turn, a clever **split ring commutator** is used. This ensures that the **current** is **restricted** to **one direction only in the coil** – direct potential difference.



Section 10: Transformers (triple HT)

Transformers are **used to increase or decrease** the **size** of an **alternating potential difference**. It **only works** with **ac** as a **changing magnetic field** is **necessary to induce ac** in the secondary coil. Transformers have a primary coil, a secondary coil and an iron core (iron used as **easily magnetised**.)

Step-up transformer	Step-down transformer
	
More turns on secondary coil than on primary, therefore **increases voltage**. Increasing voltage **decreases the current** in the wires which means **less resistance**. Less resistance means **less energy lost as heat**, therefore it is **more efficient** to transmit electricity at high voltage.	Fewer turns on secondary coil than on primary, therefore **decreases voltage**. Reducing the voltage makes it **safer** to use in the **home**.

Section 11: Transformers in action (triple HT)

In transformers, the ratio of the potential difference across the coils is equal to the ratio of the number of turns on each coil. This is the **transformer equation**.

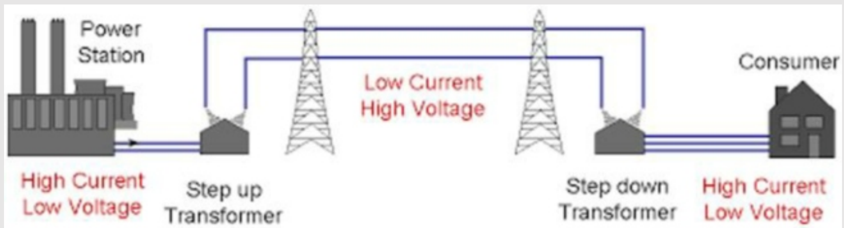
Transformer equation	$\frac{V_p}{V_s} = \frac{N_p}{N_s}$	V_p = potential difference across primary coil (V) V_s = potential difference across secondary coil (V) N_p = number of turns on primary coil N_s = number of turns on secondary coil

In a step-up transformer, $V_s > V_p$
In a step-down transformer $V_s < V_p$
In a step-up transformer $Ns>Np$
In a step-down transformer $Ns<Np$

Assuming Transformers are 100% efficient, the electrical power input is equal to the electrical power output. This results in a **transformer efficiency** equation.

Transformer efficiency	$V_p \times I_p = V_s \times I_s$	V_p = primary potential difference (V) I_p = primary current (A) V_s = secondary potential difference (V) I_s = secondary current (A)

The National Grid supplies electricity from power stations via a series of cables and transformers to customers at **high voltages** to **reduce energy loss**. A **high grid potential difference** reduces the **current** that is needed, so it reduces the **heating effect** and hence **reduces power loss** and makes the system more **efficient**.



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Physics Topic 4.8.1
Space Physics terms & our Solar System

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Section 1: Space Key Terms (triple)

Star	A **self luminous gaseous** spheroidal celestial body of great mass which **produces energy** by means of **nuclear fusion** reactions
Sun	The star around which **Earth orbits**
Planet	An astronomical object that orbits a **star**, has enough mass to be round and **does not emit its own light**. It removes debris from around its orbit. It can be terrestrial (dense and rocky) or Jovian (gas giant)
Dwarf planet	An object which **doesn't quite meet the criteria for a planet**, it hasn't cleared debris from its orbit path
Universe	**All of space** and everything in it (including stars, planets and galaxies)
Asteroid	**Irregularly shaped rock** that **orbits** the sun
Orbit	A curved path of a **planet**, **satellite** or spacecraft around an object such as the sun (due to attraction of gravity)
Comet	A celestial object consisting of a **nucleus of ice and dust**. When near the sun, a "tail" of gas and dust particles point away from the sun
Natural satellite	Any celestial body in space that **orbits** about **a larger body**. Moons are called natural satellites as they orbit planets
Artificial satellite	An object that **people have made** and **launched into orbit** using rockets
Galaxy	A s**ystem** of millions or billions **of stars** that **extends** over many **billions** of **light-years**. Held together by **gravity**
Big Bang	The leading explanation about **how** the **universe began**
CMBR	**C**osmic **m**icrowave **b**ackground **r**adiation, a remnant from the very early stage of the universe which is only explained by the big bang theory
Nuclear fusion	A **nuclear reaction** in which atomic nuclei of low atomic number **fuse** to form a **heavier nucleus with** the **release** of **energy**
Protostar	A star-to-be. A concentration of gas and dust that becomes hot enough to cause nuclear fusion
Solar system	Our solar system is made up of **the sun** and **all** the **objects that orbit** around it
Light year	The **distance light travels** in a **year**
Dark matter	Matter in a galaxy that cannot be seen
Nebula	Interstellar cloud of dust, hydrogen, helium and other ionised gases

Section 1: Space Key terms (triple) Continued

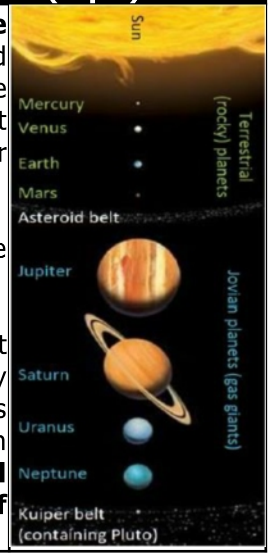
Supernova	The explosion of a red supergiant after it collapses
White dwarf	A star that has collapsed from the red giant stage to become much more hotter and denser
Black dwarf	A star that has faded out and gone cold
Neutron star	The highly compressed core of a massive star that remains after a supernova explosion
Black hole	An object in space that has so much mass that nothing, not even light can escape its gravitational field
Red giant	A star that has expanded and cooled, resulting in it becoming red and much larger and cooler than it was before it expanded.
Centripetal force	The resultant force towards the centre of a circle acting on an object moving in a circular path
Red shift	Increase in the wavelength of electromagnetic waves emitted by a star or galaxy due its motion away from us

Section 2: Formation of the Solar System (triple)

Within our **solar system** there is **one star**, the **Sun**, plus the **eight planets** and **the dwarf planets** that orbit around the Sun. **Natural satellites**, the **moons** that orbit planets, are also part of the solar system.

Our solar system is a small part of the **Milky Way galaxy**.

The Sun, was formed form a cloud of dust and gas (**nebula**) pulled together by **gravitational attraction**. This causes **fusion reactions** which lead to an **equilibrium** between the **gravitational collapse** of a star and the **expansion of a star** due to **fusion energy**.



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Physics Topic 4.8.1
Life Cycle of a Star & Orbits

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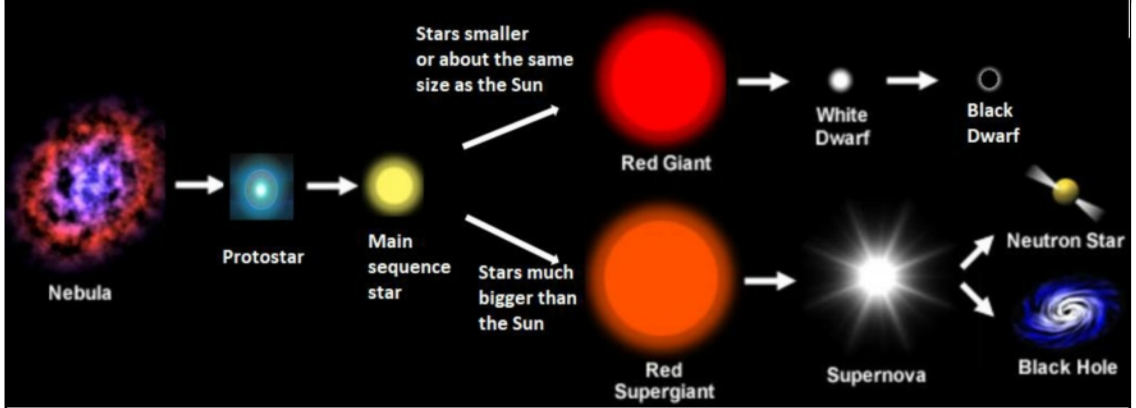
Section 3: The life history of a star (triple)



1. All stars (including the Sun) form out of clouds of dust and gas called **nebula**
2. The **force of gravity** makes the dust and gas spiral in together to form a **protostar**
3. **Gravitational energy** is converted into **thermal** energy so temperature rises. When temperature gets hot enough, **hydrogen nuclei** undergo **nuclear fusion** to form **helium nuclei** and **give out** massive amounts of **heat and light**. A **star** is born.
4. Eventually the **hydrogen begins to run out**. **Heavier elements** are made by **nuclear fusion of helium**. The star goes from main sequence to **red giant** (if it's a small star) or a **red super giant** (if it's a big star). The **surface temperature decreases** and **relative luminosity decreases**.

Small stars

5. When there is **no more light elements** in the core to use, **fusion stops** and because of its **own gravity**, the **star collapses and shrinks** becoming a **white dwarf**. The surface temperature increases and the relative luminosity decreases.
6. The star then **cools, fades** and **stops emitting energy & radiation** and becomes a **black dwarf**.

Big stars

5. Big stars undergo **more fusion** and form heavier elements like iron. They swell out to become **red super giants.**
6. Eventually they explode in a cataclysmic explosion called a **supernova**.
7. The exploding supernova throws its outer layers of dust and gas into space leaving a very **dense core** called a **neutron star**.
8. If the star is **big enough** this will become a **black hole**.

Fusion processes in stars produce all the naturally occurring elements. **Elements heavier** than **Iron** are **produced** in a **supernova**. **Supernova explosions distribute** all the **elements throughout** the known **universe**.

Section 4: Planets, satellites and orbits (triple)

A **planet** is an astronomical object that **orbits a star** e.g. The Earth. A natural satellite is any **celestial body** in space that **orbits** about **a larger body** e.g. the **Moon**. An **artificial satellite** is a **man-made** object that has been **launched into orbit using rockets** e.g. communication satellites.

The **force of gravity** between:

- A **planet** and the **Sun** keeps the **planet moving** along its **orbit**.
- A **satellite (e.g. the Moon)** and the **Earth** keeps the **satellite moving** along its **orbit.**

Circular orbits (HT)

The planets orbit the Sun in a **circular motion**. Each planet orbits at a different speeds and this is **related** to the **distance** from the Sun.

The **further a satellite** is from the **Earth** (or a **planet** is **from the Sun**):

- the **less the speed** needed for it to stay in orbit and
- the **longer** the time taken for **one orbit**.

The **direction of motion** of any planet in a circular orbit is **continually changing** and is **always at right angles** to the **direction of the force of gravity** on it. This is an example of a **centripetal force**.

The **magnitude of velocity** (**speed**) of a satellite in circular orbit **doesn't change** but **its direction** of its velocity **continually changes**. As velocity is a vector and includes direction, the **satellite must** be constantly **accelerating** in order to change direction.

For a stable orbit, the **radius must change** if the **speed changes**.

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Physics Topic 4.8.2
Red Shift & the future of the Universe

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Section 5: The expanding universe – red shift (triple)

People can find out lots of things about stars and galaxies by **studying** the **light** from them. In 1929, the astronomer Edwin Hubble observed that the light from galaxies moving away from the Earth had longer wavelengths than expected.
The **wavelength** of **light** increases across the **spectrum** from **blue to red**.
You can tell if a star or galaxy is moving towards/away from Earth by observing whether the light is **blue shifted** or **red shifted**.
The **red-shift** of a galaxy is the shift to **longer wavelengths** (and lower frequencies) of the **light from** a **galaxy** because it is **moving away** from you.

Speed	The **faster** a distant galaxy is moving away from you, the **greater** its **red-shift** is.
Distance	The **further** away a distant galaxy is, the **greater** its **red-shift** is. Hence the **further away** from the Earth, the **faster** a galaxy is moving.

All the distant galaxies are **moving away** from you because the **universe** is **expanding**. This supports the **big bang theory**.

Section 6: The beginning and future of the Universe (triple)

The **Big Bang theory** was put forward as a model to **explain** the **expansion** of the **universe**. This says that:

- The universe is expanding after **exploding suddenly** (the Big Bang) from a **very small point** and a **extremely hot and dense region**.
- **Space, time and matter** were **created** in the Big Bang.
- The universe has **been expanding ever since** the Big Bang.

The **red shifts** of the **distant galaxies** provide **evidence** that the **universe** is **expanding**.

CMBR	In 1965, Scientists detected **C**osmic **m**icrowave **b**ackground **r**adiation (CMBR) coming from **every direction** in **space**. The existence of CMBR can **only be explained** by the **Big Bang theory**. CMBR was created as **high energy gamma** radiation **just after** the **big bang**. It has been travelling through space since then. As the universe has expanded, the CMBR has stretched out from Gamma into longer wavelengths and is now **microwave** radiation.

Section 6: The beginning and future of the Universe (triple) cont.'

The future of the universe	Will the universe expand forever? Or will the force of gravity between distant galaxies stop them moving away from each other? **The answer depends on** the **density of the universe** which takes into account: • Total **mass** of galaxies • How much **matter** is between them • How much **space** they take up Astronomers know that the galaxies would spin much faster if their stars were the only matter in galaxies. The missing matter is called **dark matter**. Depending on how much dark matter there is, the universe may have different possible futures. • If **density** of the universe **is less** than a particular amount, it **will expand forever** and the **stars will** eventually **die** out (as will everything else) – **the big yawn**. • If **density** of the universe is **greater** than a particular amount, it will **stop expanding** and go **into reverse** – **the big crunch.** Observations that the **distant galaxies are accelerating away** has led astronomers to **conclude** that the **universe is heading** for **the big yawn**. They think that an **unknown** source of **energy** must be **causing this accelerating** motion – **dark energy**. There is still a lot about the universe, for e.g. dark mass and dark energy, that astronomers don't understand. New telescopes and technologies will help improve understanding and will allow astronomers to observe the universe in a different way and make new discoveries.