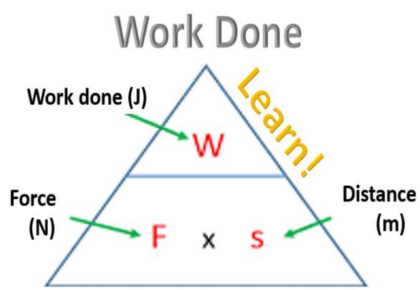
Knowledge Organiser – 6.1 Energy

joule (J) = unit of energy

6.1.1.1 Energy stores and systems

Energy store	Description	Examples
Magnetic	The energy stored when **repelling poles have been pushed closer** together or when **attracting poles have been pulled further apart.**	Fridge magnets, compasses, maglev trains which use magnetic levitation.
Internal (thermal)	Total kinetic and potential energy of the particles in an object, eg **the vibrations - also known as the kinetic energy - of particles**. In **hotter objects, the particles have more internal energy** & vibrate faster.	Human bodies, hot coffees, stoves or hobs. Ice particles vibrate slower, but still have energy.
Chemical	The energy **stored in chemical bonds**, such as those between molecules.	Foods, muscles, electrical cells.
Kinetic	Energy of a **moving object**.	Runners, buses, comets.
Electrostatic	The energy stored when **repelling charges have been moved closer together** or when attracting charges have been pulled further apart.	Thunderclouds, Van De Graaff generators.
Elastic potential	The energy stored when an **object is stretched or squashed**.	Drawn catapults, compressed springs, inflated balloons.
Gravitational potential	The energy of an **object at height**.	Aeroplanes, kites, mugs on a table.
Nuclear	The energy stored in the **nucleus of an atom.**	Uranium nuclear power, nuclear reactors.

- When a **force** causes a body to move, work is being done on the object by the force.
- Work is the measure of energy transfer when a force (*F*) moves an object through a distance (*d*).
- When work is done, **energy** has been transferred from one energy store to another.
- Therefore Energy transferred = work done



Distance must be in the line of action of the force

Quantity	Unit
Current	A
Energy	J
Mass	kg
Power	W
Time	s
Temp	°c
Height	m
Velocity	m/s
Extension	m
Spring constant	N/m
Force	N
Gravitational field strength	N/kg
Specific heat capacity	J/kg°C

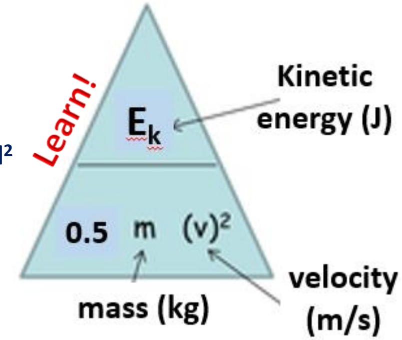
6.1.1.2 Changes in energy

Kinetic energy of a moving object can be calculated using the equation:

kinetic energy = 0.5 × mass × speed²

$E_k = \frac{1}{2} m v^2$

- kinetic energy, *Ek*, in joules, J
- mass, *m*, in kilograms, kg
- speed, *v*, in metres per second, m/s

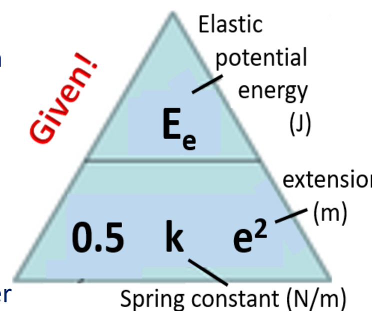


Elastic potential energy stored in a stretched spring can be calculated using the equation (assuming the limit of proportionality has not been exceeded:

elastic potential energy = 0.5 × spring constant × extension²

$E_e = \frac{1}{2} k e^2$

- elastic potential energy, *Ee*, in joules, J
- spring constant, *k*, in newtons per metre, N/m
- extension, *e*, in metres, m

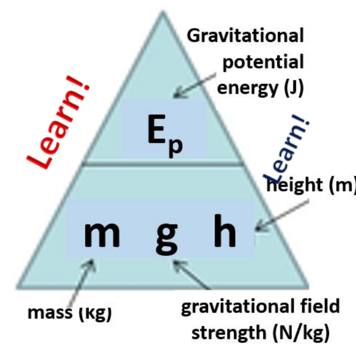


Gravitational potential energy gained by an object raised above ground level can be calculated using the equation:

g.p.e. = mass × gravitational field strength × height

$E_p = mgh$

- gravitational potential energy, *Ep*, in joules, J
- mass, *m*, in kilograms, kg
- gravitational field strength, *g*, in newtons per kilogram, N/kg
- height, *h*, in metres, m



Gravitational field strength is 9.8N/kg on Earth.
(g will be given in the exam).

Knowledge Organiser – 6.1 Energy

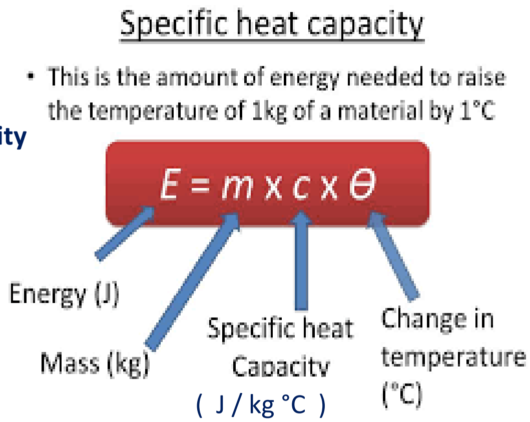
6.1.1.3 Energy changes in systems

The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:

change in thermal energy = mass × specific heat capacity × temperature change

$$\Delta E = m\,c\,\Delta\theta$$ **Given!**

- change in thermal energy, Δ*E*, in joules, J
- mass, *m*, in kilograms, kg
- specific heat capacity, *c*, in joules per kilogram per degree Celsius, J/kg °C
- temperature change, Δ*ϑ*, in degrees Celsius, °C



6.1.1.4 Power

Power is defined as the rate at which energy is transferred or the rate at which work is done.

- power, *P*, in watts, W
- energy transferred, *E*, in joules, J
- time, *t*, in seconds, s
- work done, *W*, in joules, J

An energy transfer of 1 joule per second is equal to a power of 1 watt

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time taken (s)}}$$

$$\text{power (W)} = \frac{\text{energy transferred (J)}}{\text{time taken (s)}}$$

Learn!

Example

Two electric motors are used to lift a 5 N weight through a vertical height of 6 m.
Motor A does this in 5 seconds.
Motor B does this in 10 seconds.

For both motors the work done is:
W = F x d = 5N x 6m = 30J

For motor A:
$P = \frac{W}{t} = \frac{30J}{5s} = \underline{6W}$

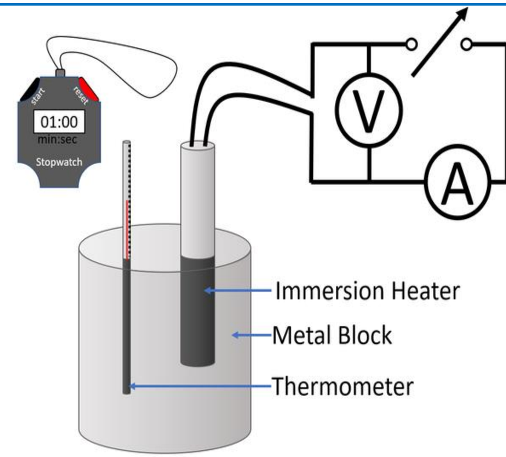
For motor B:
$P = \frac{W}{t} = \frac{30J}{10s} = \underline{3W}$

Motor B is twice as powerful as motor A.

RPA: an investigation to determine the specific heat capacity of one or more materials. The investigation involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored

Method:

1. Place the immersion heater into central hole at top of block.
2. Place the thermometer into smaller hole and add drops of oil into the hole to ensure thermometer is surrounded by hot material.
3. Fully insulate the block by wrapping it loosely with cotton wool.
4. Record the temperature of the block.
5. Connect the heater to the power supply and turn it off after ten minutes. After ten minutes the temperature will still rise even though the heater has been turned off and then it will begin to cool.
6. Record the highest temperature that it reaches and calculate the temperature rise during the experiment.



Improving accuracy:

- Place the metal block on a heatproof mat to reduce the thermal energy lost to the table surface by conduction.
- Wrap the metal block in a thermal insulator to reduce the thermal energy lost to the air.
- Place the electronic balance on a flat, level surface to get an accurate reading of the mass.

Improving precision:

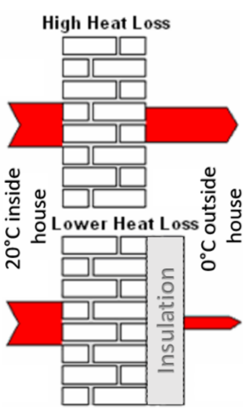
- Use a data logger rather than a thermometer to reduce the random error & add more decimal places.
- Ensure the immersion heater and block begin at room temperature to reduce the error in repeat readings.
- Ensure the same thickness and type of insulator is used for every repeat measurement reduce anomalies.

Knowledge Organiser – 6.1 Energy

6.1.2.1 Energy transfers in a system

Energy cannot be created or destroyed, only transformed from one form to another (**Law of conservation of energy**).
"**Work done**" is another way of describing energy transfer.

- where there are energy transfers in a **closed system**, there is **no net change to the total energy.**
- In all system changes energy is dissipated, so that it is stored in less useful ways. This energy is often described as being 'wasted'.
- Unwanted energy transfers can be reduced, eg. through lubrication and the use of thermal insulation.
- The higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material.



The rate of cooling of a building is affected by the **thickness** and **thermal conductivity of its walls.**
Higher thermal conductivity = higher rate of energy transfer = house cools down quicker.

6.1.2.2 Efficiency

$$\frac{\text{Useful energy output}}{\text{total energy input}} \times 100\%$$

Learn!

OR

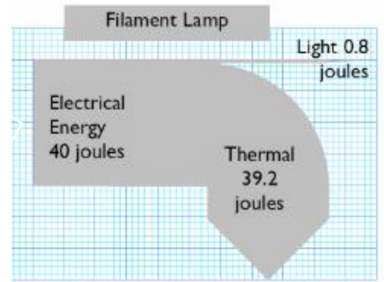
$$\frac{\text{Useful power output}}{\text{total power input}} \times 100\%$$

Efficiency can be represented as a decimal or percentage. It has to be <100% (or <1.0) as all energy transfers involve wasted energy.

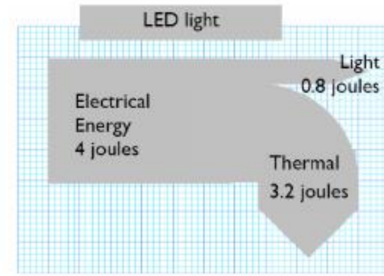
In a <u>closed system</u> there is <u>no net change</u> to the total energy

Total IN = total OUT

<u>Increase</u> <u>efficiency</u> by insulating or streamlining/ lubricating to reduce friction.



$\frac{0.8}{40} \times 100 =$ 2%

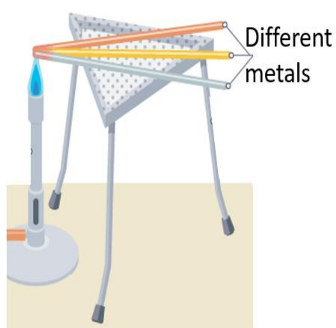


$\frac{0.8}{4} \times 100 =$ 20%

The LED is 10 x more efficient than the filament lamp

Investigate thermal conductivity using rods of different materials (NOT RPA)

Whichever rod gets hottest first at the other end is the best conductor. The material that **heats the quickest** is said to have a <u>higher thermal conductivity</u>



6.1.3 National and Global energy resources

- Main energy resources available for use on Earth include: fossil fuels (coal, oil and gas), nuclear fuel, biofuel, wind, hydro-electricity, geothermal, the tides, the Sun and water waves.
- A **renewable energy** resource is one that is **being** (or can be) **replenished** as it is used.
- A **Non-renewable energy** source **cannot be replaced** after it has been used. It is **finite**
- The uses of energy resources include: transport, electricity generation and heating.

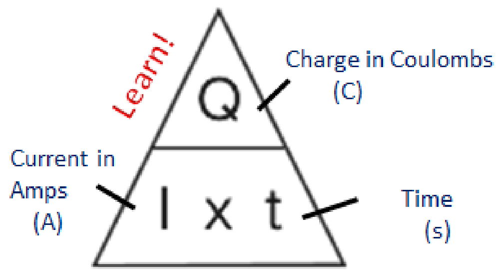
	Positives	Negatives
Fossil fuel (coal/oil/gas)	Reliable, cheap to run and mine	Finite, atmospheric pollution (CO_2, SO_2, NO_x)
Nuclear	Reliable, No CO_2, lots energy released	Long-lasting toxic waste, finite
Wind	Infinite, free, no atmospheric pollution	Unreliable (not always windy), visual pollution, costly to build, sometime noisy
Sun	Infinite, free, put on buildings/ in fields	Costly to set up, pollution from batteries
Geothermal	Infinite, free, no atmospheric pollution	Products from ground may contain toxic elements
Tidal	Barrages reduce flooding eg Thames, free, no pollution, reliable(2 tides/day)	Disturb ecology and shipping lanes, costly to build
Biofuel	Can be regrown, cheap, carbon neutral	Use up land that could grow food/ livestock
Hydroelectricity	No atmospheric pollution, free	High rainfall needed, floods valleys therefore habitats/ villages destroyed
Water Waves	No atmospheric pollution, free	Disturb ecology and shipping lanes, costly to build, unreliable (sea does not always have waves)

Knowledge Organiser – 6.2 Electricity

6.2.1.2 Electrical charge and current

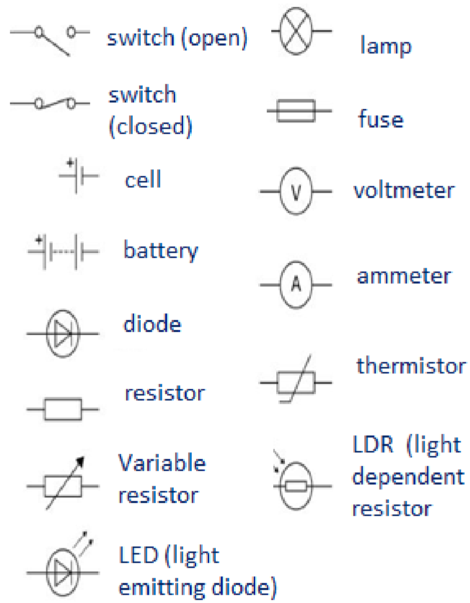
Electric current is a flow of electrical charge.
Size of current is **rate of flow of electrical charge.**

Charge flow, current and time are linked by the equation:
charge flow = current × time



- Current has **same value at any point in a single closed loop.**
- Measured with **Ammeter**

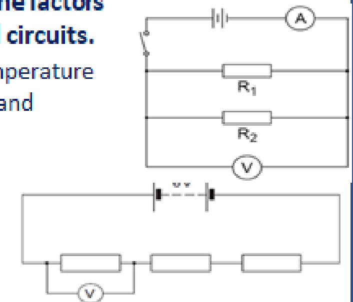
6.2.1.1 Standard circuit diagram symbols



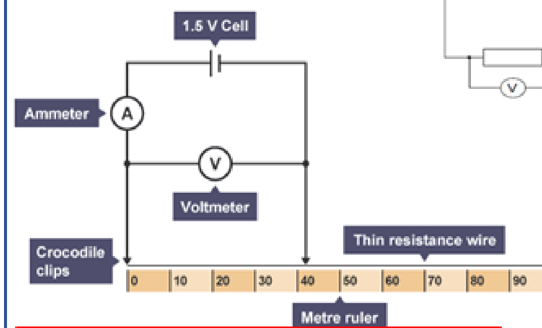
RPA: use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits.

- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

IV: resistors in series or parallel



IV: Length of a wire



Hazard	Consequences	Control measures
Heating of wires	Minor burns	Set up circuit before closing the switch

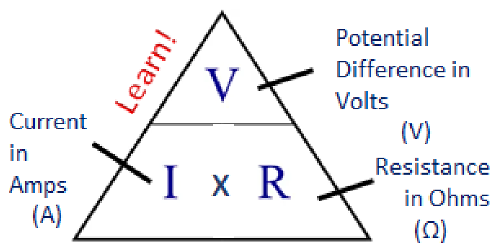
- In series, the resistance of the network is equal to the sum of the other resistances.
- In parallel, the resistance of the network is less than either of the other resistances.

6.2.1.3 Current, resistance and potential difference

- **Potential difference** is the amount of work energy required to move an electric charge (Coulomb) from one point to another
- Current (*I*) through a component depends on the **resistance** (*R*) of the component and the **potential difference** (*V*) **across the component.**
- The **greater the resistance** of the component the **smaller the current for a given potential difference (pd) across the component.**
- Measured with **Voltmeter**
- **Voltmeter must be connected in parallel**

Current, **potential difference** and **resistance** can be calculated using the equation:

potential difference = current × resistance



Resistance

- **Metal atoms (ions)** in a **wire have delocalised electrons** which are free to move and **carry the charge.**
- **Electrons moving** around the circuit **collide with the ions.**
- This is called **resistance.**

Units of resistance = ohms, Ω

Components with high resistance often **get hot** (e.g. filament lamp).

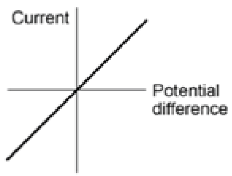
- **Electrons colliding** with the ions **transfer energy** as **heat** and **light.**
- **Causes the ions to vibrate more, increasing** the **resistance** even more.
- This makes it harder for the electrons to pass through without collisions.

E.g. What is the resistance of a component if 12 V causes a current of 2 A through it?
R = V / I = 12V / 2A = 6Ω

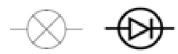
Knowledge Organiser – 6.2 Electricity

6.2.1.4 Resistors

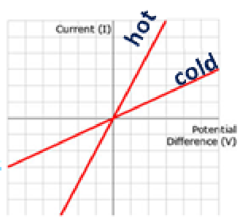
- **Current through an ohmic conductor** (at a constant temperature) is **directly proportional to the potential difference** across the resistor.
- **Resistance remains constant as the current changes.**



- **Resistance of components such as lamps, diodes, thermistors** and **LDRs** is **not** constant; it **changes with the current through the component.**
- SEE RPA

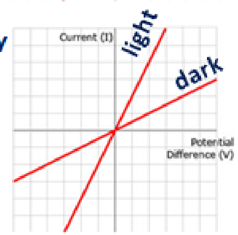


- **Resistance of a thermistor decreases as the temperature** increases.
- Low temperature = High resistance
- Used in heat activate fire alarms and thermostats



- **Resistance of an LDR decreases** as **light intensity increases**

  Low light levels = high resistance.
- An **LDR** can be used in lights that come on when it's dark.



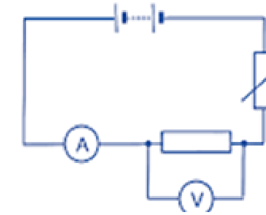
Unit	symbol
Potential difference	V
Current	A
Energy	J
Work done	J
Charge	C
Time	s
Power	W
Resistance	Ω

Charge is a property of a body which experiences a force in an electric field. **Charge** is measured in **coulombs** (C).

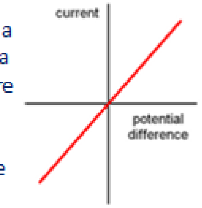
Since electrons are so small and one electron will not have much of an effect anywhere, it is more useful to refer to packages of electrons. One coulomb of charge is a package equivalent to 6,250,000,000,000,000,000 electrons.

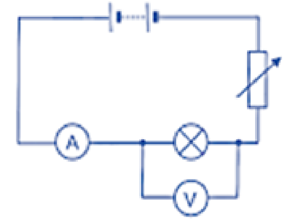
One volt is the **potential difference when one coulomb** of **charge** transfers one **joule** of energy.

RPA: use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature

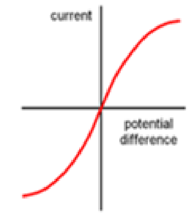


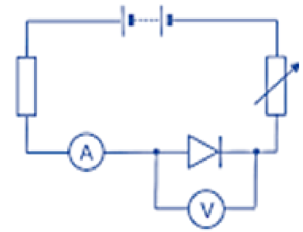
The current through a **resistor** at constant a constant temperature is directly proportional to the potential difference across the resistor.



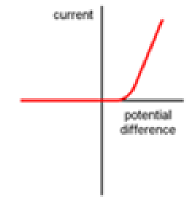


The resistance of a **bulb** increases as the temperature of the filament increases.





The current through a **diode** flows in one direction. It has very high resistance in the opposite direction.



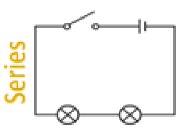
6.2.2 Series and Parallel circuits

For components connected in series:

- same **current (A)** through each component
- total **potential difference (V)** of the power supply is **shared between components**
- total resistance of two components is the sum of the resistance of each component.

  $R_{total} = R_1 + R_2$ resistance, R, in ohms, Ω

Series

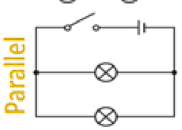


A	V
Same	Shared

For components connected in parallel:

- **potential difference** across each component is the **same**
- **total current** through the whole circuit is **sum of the currents** through the separate components
- **total resistance** of **two resistors is less** than the **resistance** of the **smallest individual resistor.**

Parallel

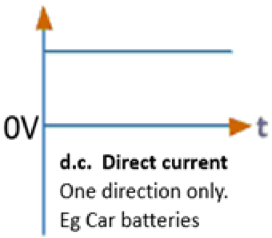


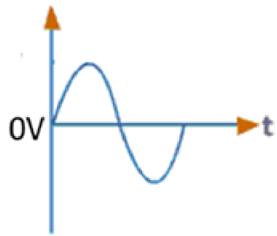
A	V
Shared	Same

Knowledge Organiser – 6.2 Electricity

6.2.3 Domestic uses and safety

6.2.3.1 Direct and alternating potential difference



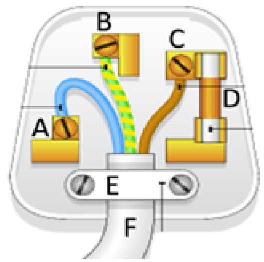


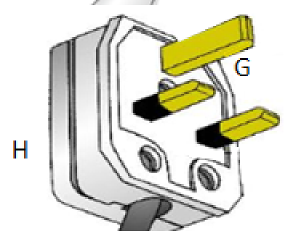
a.c. Alternating current
In the UK, electricity has a p.d. of 230V & a frequency of 50Hz (it changes direction 50 times a second).

6.2.3.2 Mains electricity

A= neutral wire, close to 0V.
B= earth wire, 0V, only carries current if there's a fault, stops appliance becoming live.
C= live wire, 230V between earth and live.
D= Fuse, internal wire melts when current is too big so breaks the circuit.

E= cable grip
F= three-core cable, copper wire = flexible and good conductor, plastic coating.
G= brass pins, hard wearing, good conductor
H= plastic casing is an insulator

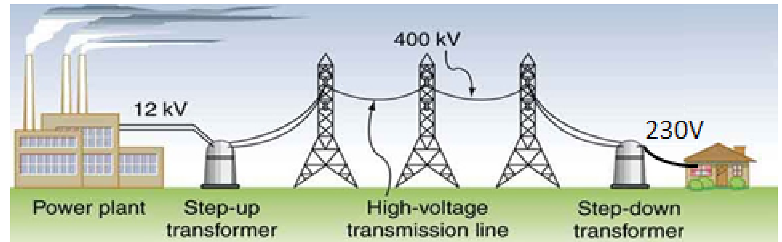




- a live wire may be dangerous even when a switch in the mains circuit is open
- It is dangerous to provide any connection between the live wire and earth.

6.2.4 Energy Transfers

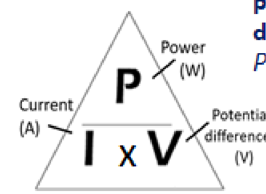
6.2.4.3 The National Grid



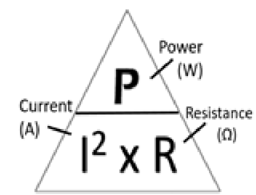
- Network of cables and transformers linking power stations to consumers
- Step-up transformers = higher potential difference
- Reduced energy loss because resistance is lower in cables (high volts = fewer amps for same power)
- Step-down transformers = decrease potential difference to safe level for domestic use (about 230V in UK)
- Underground cables protected from bad weather but get damaged by diggers in building projects

E.g. What is the potential difference between two points if 5 C of charge shifts 10 J?
V= E/Q
= 10J / 5C
= **2 volts**

6.2.4.1 Power



power = potential difference × current
P = V I

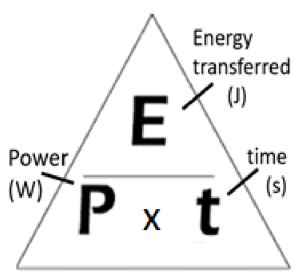


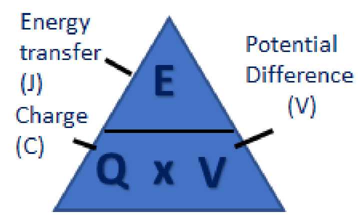
power = current^2 × resistance
$P = I^2 R$

- power, *P*, in watts, W
- potential difference, *V*, in volts, V
- current, *I*, in amps, A
- resistance, *R*, in ohms, Ω

6.2.4.2 Energy transfers in everyday appliances

- The rate at which energy is transferred by an appliance is called the **power**.
- Also known as "**work done**" by the components in the circuit when charge flows.
- The energy transferred by an appliance depends on how long it is switched on for and the power of the appliance.





- energy transferred, *E*, in joules, J
- power, *P*, in watts, W
- time, *t*, in seconds, s
- charge flow, *Q*, in coulombs, C
- potential difference, *V*, in volts, V

Knowledge Organiser – 6.2 Electricity (Separate Physics)

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

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

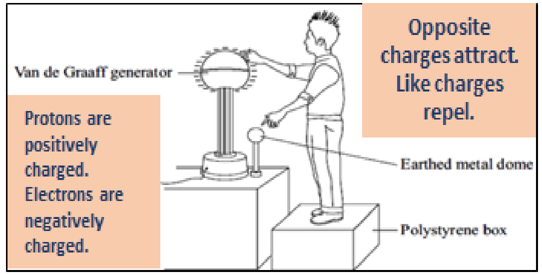
Insulator → An electrical insulator does not easily allow electricity to pass through it.

Earthing → Connecting a charged object to the ground using a conductor (e.g. copper wire) prevents build up of charge.

Van de Graff Generator:

When the Van de Graff generator is switched on, each hair gains the same negative charge. Similar charges repel so the student's hair stands on end.

Static Uses: Paint Sprayer: Electrostatic paint sprayers Used to paint bikes and cars providing a fine even coat.



Protons are positively charged. Electrons are negatively charged.

Opposite charges attract. Like charges repel.

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.

All charged objects have an **electric field** around them, which shows how they will interact with other charged particles.

A radial field around a positive charge

A **Van de Graff generator** removes electrons to produce a positive charge. A person does not have to touch the Van de Graff generator to start feeling the effects, as static electricity is a **non-contact force**. This force will act on any charged particle in the electric field around the generator.

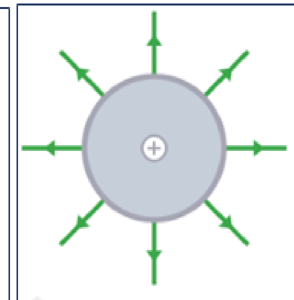
Examples of static electricity :

- **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.

Static Uses: Defibrillator

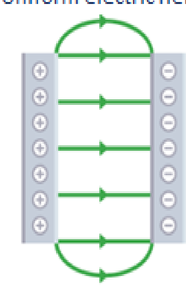
A shock from a defibrillator can restore normal heart rhythm. Consists of two paddles connected to a power supply which are placed on the patients chest. The charge passes through the paddles to the patient which makes the heart contract

When a polythene rod is rubbed with a duster, the **friction** causes electrons to gain energy. Electrons gain enough energy to leave the atom and 'rub off' onto the polythene rod.
the polythene rod has gained electrons, giving it a negative charge the duster has lost electrons, giving it a positive charge



A radial field around a positive charge

Uniform electric field



Field lines point away from + and towards -

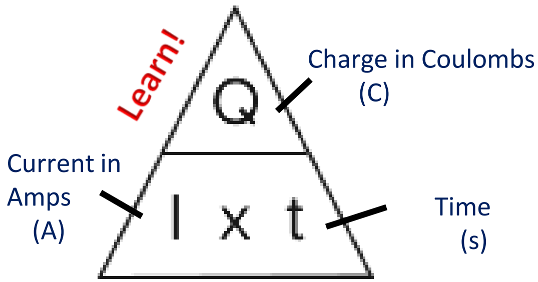
If the field is strong enough, charges can be forced though insulators such as air and a spark will occur → lightning strike. It may also happen if a charged person touches a conductor.
e.g. A person dragging their feet across the carpet may become charged, so if they reach out to touch a door handle there is a spark and they feel a small shock.

Knowledge Organiser – 6.2 Electricity

6.2.1.2 Electrical charge and current

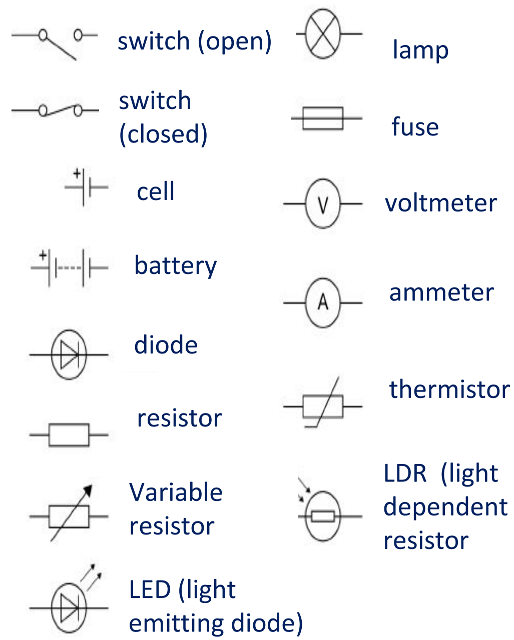
Electric current is a flow of electrical charge.
Size of current is **rate of flow of electrical charge**.

Charge flow, current and time are linked by the equation:
charge flow = current × time



- Current has **same value at any point in a single closed loop**.
- Measured with **Ammeter**

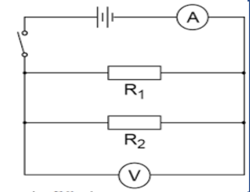
6.2.1.1 Standard circuit diagram symbols



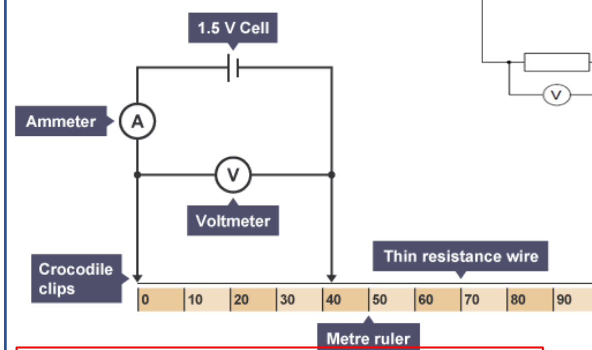
RPA: use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits.

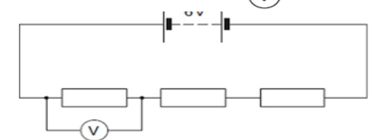
- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

IV: resistors in series or parallel



IV: Length of a wire





- In series, the resistance of the network is equal to the <u>sum of the other</u> resistances.
- In parallel, the resistance of the network is <u>less than either</u> of the other resistances.

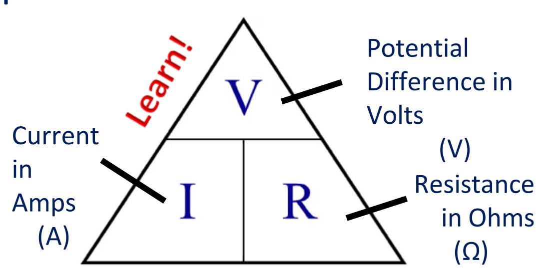
Hazard	Consequences	Control measures
Heating of wires	Minor burns	Set up circuit <u>before</u> closing the switch

6.2.1.3 Current, resistance and potential difference

- **Potential difference** is the amount of work energy required to move an electric charge (Coulomb) from one point to another
- Current (*I*) through a component depends on the **resistance** (*R*) of the component and the **potential difference** (*V*) **across the component**.
- The **greater the resistance** of the component the **smaller the current for a given potential difference (pd) across the component**.
- Measured with **Voltmeter**
- **Voltmeter must be connected in parallel**

Current, **potential difference** and **resistance** can be calculated using the equation:

potential difference = current × resistance



Resistance

- **Metal atoms (ions)** in a **wire have delocalised electrons** which are free to move and **carry the charge**.
- **Electrons moving** around the circuit **collide with the ions**.
- This is called **resistance**.

Units of resistance = ohms, Ω

Components with high resistance often **get hot** (e.g. filament lamp).

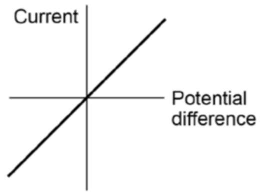
- **Electrons colliding** with the ions **transfer energy** as **heat** and **light**.
- **Causes the ions to vibrate more**, **increasing** the **resistance** even more.
- This makes it harder for the electrons to pass through without collisions.

<u>E.g.</u> What is the resistance of a component if 12 V causes a current of 2 A through it?
R = V / I = 12V / 2A = <u>6Ω</u>

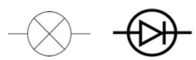
Knowledge Organiser – 6.2 Electricity

6.2.1.4 Resistors

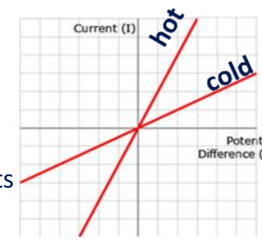
- **Current through an ohmic conductor** (at a constant temperature) is **directly proportional to the potential difference** across the resistor.
- **Resistance remains constant as the current changes**.



- **Resistance of components such as lamps, diodes, thermistors** and **LDRs** is **not** constant; it **changes with the current through the component**.
- SEE RPA

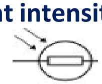


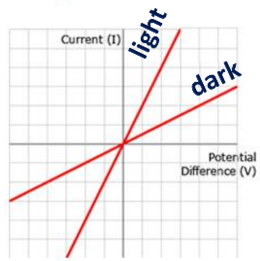
- **Resistance of a thermistor decreases as the temperature** increases.
- Low temperature = High resistance
- Used in heat activate fire alarms and thermostats



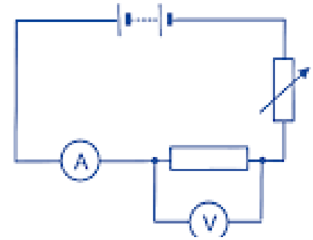
- **Resistance of an LDR decreases** as **light intensity increases**

  Low light levels = high resistance.
- An **LDR** can be used in lights that come on when it's dark.

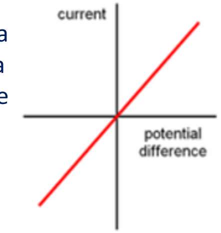


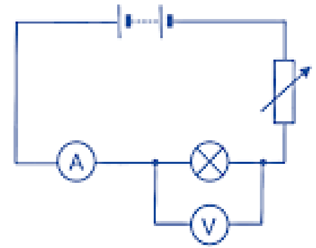


RPA: use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature

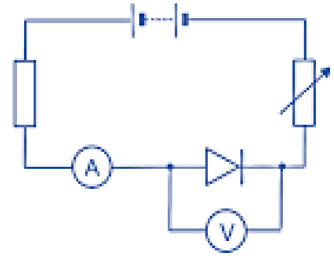


The current through a **resistor** at constant a constant temperature is directly proportional to the potential difference across the resistor.

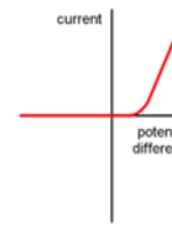




The resistance of a **bulb** increases as the temperature of the filament increases.



The current through a **diode** flows in one direction. It has very high resistance in the opposite direction.



Unit	symbol
Potential difference	V
Current	A
Energy	J
Work done	J
Charge	C
Time	s
Power	W
Resistance	Ω

Charge is a property of a body which experiences a force in an electric field. **Charge** is measured in **coulombs** (C).

Since electrons are so small and one electron will not have much of an effect anywhere, it is more useful to refer to packages of electrons. One coulomb of charge is a package equivalent to 6,250,000,000,000,000,000 electrons.

One volt is the **potential difference when one coulomb** of **charge** transfers one **joule** of energy.

6.2.2 Series and Parallel circuits

For components connected in series:

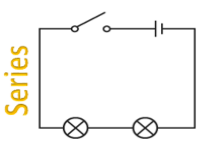
- same **current (A)** through each component
- total **potential difference (V)** of the power supply is **shared between components**
- total resistance of two components is the sum of the resistance of each component.

  *R*total = *R*1 + *R*2 resistance, *R*, in ohms, Ω

For components connected in parallel:

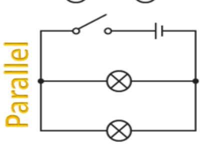
- **potential difference** across each component is the **same**
- **total current** through the whole circuit is **sum of the currents** through the separate components
- **total resistance** of **two resistors is less** than the **resistance** of the **smallest individual resistor.**

Series



A Same | V Shared

Parallel

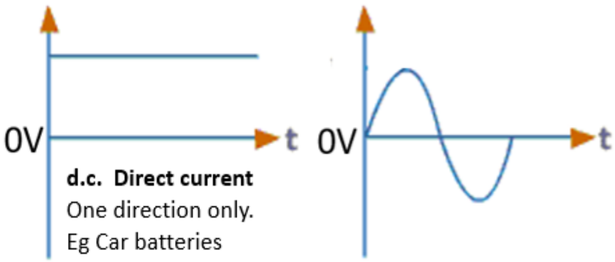


A Shared | V Same

Knowledge Organiser – 6.2 Electricity

6.2.3 Domestic uses and safety

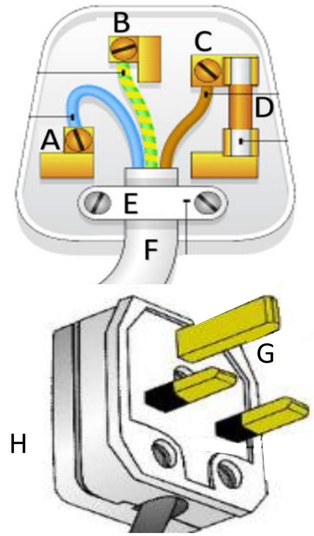
6.2.3.1 Direct and alternating potential difference



d.c. Direct current
One direction only.
Eg Car batteries

a.c. Alternating current
In the UK, electricity has a p.d. of 230V & a frequency of 50Hz (it changes direction 50 times a second).

6.2.3.2 Mains electricity



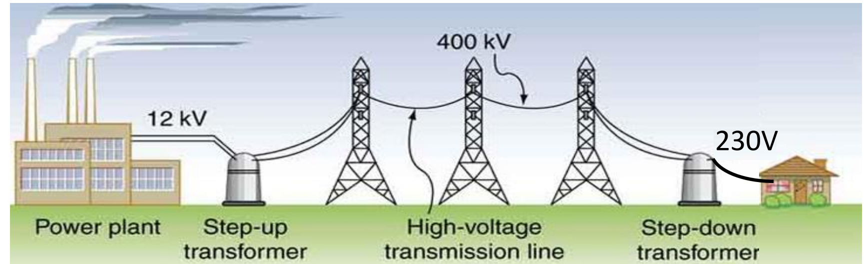
A= neutral wire, close to 0V.
B= earth wire, 0V, only carries current if there's a fault, stops appliance becoming live.
C= live wire, 230V between earth and live.
D= Fuse, internal wire melts when current is too big so breaks the circuit.

E= cable grip
F= three-core cable, copper wire = flexible and good conductor, plastic coating.
G= brass pins, hard wearing, good conductor
H= plastic casing is an insulator

- a live wire may be dangerous even when a switch in the mains circuit is open
- It is dangerous to provide any connection between the live wire and earth.

6.2.4 Energy Transfers

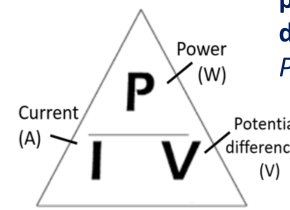
6.2.4.3 The National Grid



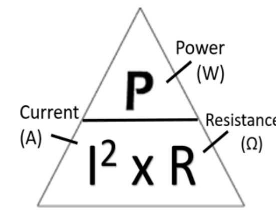
- Network of cables and transformers linking power stations to consumers
- Step-up transformers = higher potential difference
- Reduced energy loss because resistance is lower in cables (high volts = fewer amps for same power)
- Step-down transformers = decrease potential difference to safe level for domestic use (about 230V in UK)
- Underground cables protected from bad weather but get damaged by diggers in building projects

E.g. What is the potential difference between two points if 5 C of charge shifts 10 J?
V= E/Q
= 10J / 5C
= **2 volts**

6.2.4.1 Power



power = potential difference × current
P = *V I*

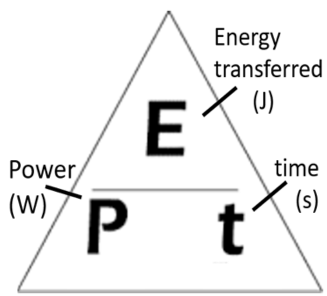


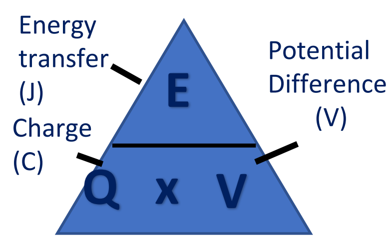
power = current² × resistance
$P = I^2 R$

- power, *P*, in watts, W
- potential difference, *V*, in volts, V
- current, *I*, in amps, A
- resistance, *R*, in ohms, Ω

6.2.4.2 Energy transfers in everyday appliances

- The rate at which energy is transferred by an appliance is called the **power**.
- Also known as "**work done**" by the components in the circuit when charge flows.
- The energy transferred by an appliance depends on how long it is switched on for and the power of the appliance.





- energy transferred, *E*, in joules, J
- power, *P*, in watts, W
- time, *t*, in seconds, s
- charge flow, *Q*, in coulombs, C
- potential difference, *V*, in volts, V

Knowledge Organiser – 6.3 Particle model of matter

6.3.1.1 Density of materials

The particle model can be used to explain the different states of matter differences in density.

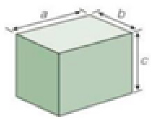
Calculation	Equation	Symbol equation	Units
Density	Density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{v}$	Density = kg/m³ Mass = kg Volume = m³

RPA: Measuring volume of irregular objects and calculating density

Method 1: Regular solid volume

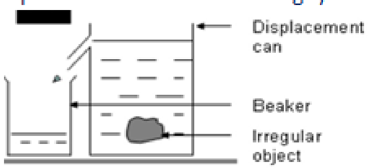
Length x width x height

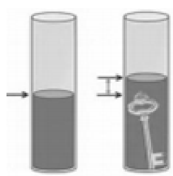
Sphere: $\frac{4}{3}\pi(\frac{d}{2})^3$

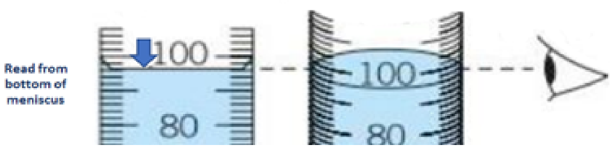


Method 2: Stone or other irregular shaped object volume

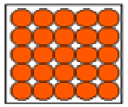
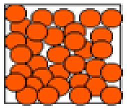
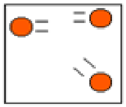
Displacement can or measuring cylinder







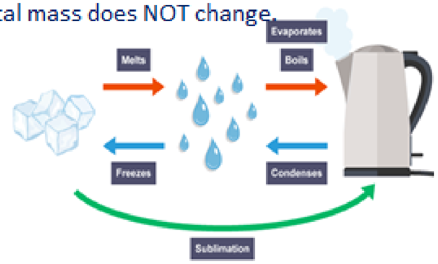
Measure mass of object and then use density equation.

Solid	Liquid	Gas
Particles closely packed - vibrate - Little energy - Very strong forces of attraction	Particles touching, - Move past each other - Some energy - Relatively strong forces of attraction	Particles very far apart - Move very fast - Lots of energy - Weak forces of attraction
		

6.3.1.2 Changes of State

Conservation of mass

- The number of particles does not change during a change of state, only their spacing and arrangement.
- Total mass does NOT change.



- Change of state is **physical.**
- The material **recovers its original properties** if the change is reversed.

Key Terms	Particle Model of Matter Definitions
condensation	A change of state in which gas becomes liquid by cooling.
energy	The capacity for doing work
evaporation	The process in which a liquid changes state and turns into a gas.
freeze	A change of state in which liquid becomes solid by cooling.
Internal energy	The total kinetic energy and potential energy of the particles in an object. Heating changes the energy stored within the object by increasing the energy of the particles that make up the system.
Kinetic energy	Energy which an object possesses by being in motion
Melting	The process that occurs when a solid turns into a liquid when it is heated
Specific heat capacity	The amount of energy needed to raise the temperature of 1 kg of substance by 1°C
Specific latent heat	The amount of energy needed to melt or vaporise 1 kg at its melting or boiling point
Sublimation	When a solid turns straight into a gas on heating, without becoming a liquid first, or when a gas turns straight into a solid, without becoming a liquid.
Temperature	How warm or cold something is
Thermal energy	Scientific term for heat energy

6.3.1.3 Internal Energy

- **Internal Energy:** Energy is stored inside a system by the particles that make up the system. Internal energy is the **total kinetic energy** and **potential energy** of **all the particles** that make up a system.
- Heating **increases** the energy of the particles
- Either **raises the temperature** of the system **or produces a change of state.**

6.3.2.2 Temperature changes in a system and specific heat capacity

The change in temperature of a system depends on:

- the amount of **thermal energy** transferred to the system
- the mass of the substance
- the nature of the substance itself

change in thermal energy = mass × specific heat capacity x temperature change

$$\Delta E = mc\Delta\theta$$

Units Used:-

- change in thermal energy, ΔE, in joules, J
- mass, m, in kilograms, kg
- specific heat capacity, c,
- in joules per kilogram per degree Celsius, J/kg °C
- temperature change, $\Delta\theta$, in degrees Celsius, °C.

Knowledge Organiser – 6.3 Particle model of matter (Sep Physics 4.3)

6.3.2.3 Changes of heat and specific latent heat

If a <u>change of state</u> happens:

- The energy needed for a substance to change state is called **latent heat.**
- When a change of state occurs, the energy supplied **changes the energy stored** (internal energy) but **does not change the temperature.**
- **specific latent heat** of a substance is the amount of energy required to **change the state of one kilogram of the substance** with no change in temperature.

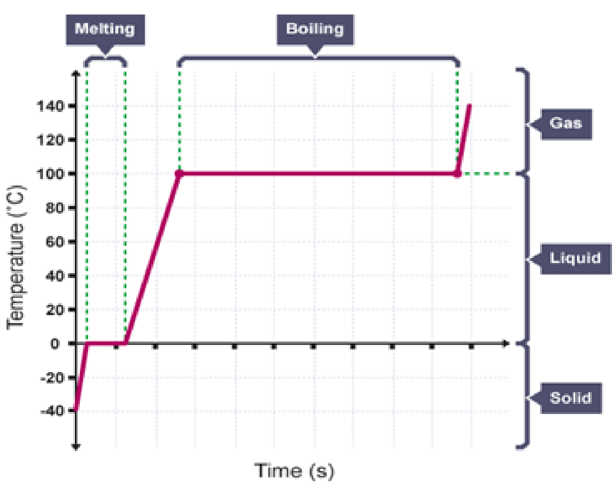
energy for a change of state = mass × specific latent heat

$$E = mL$$

- energy, E, in joules, J
- mass, m, in kilograms, kg
- specific latent heat, L, in joules per kilogram, J/kg
- **specific latent heat**, L, in joules per kilogram, J/kg

Specific latent heat of fusion – change of state from solid to liquid

Specific latent heat of vaporisation – change of state from liquid to vapour



6.3.3.1 Particle motion in gases

- Molecules of gas in **constant random motion**
- **Temperature** of gas related to average **kinetic energy** of the molecules
- Changing the **temperature** of a gas, held at constant volume, changes the **pressure** exerted by the gas

The pressure in the atmosphere (atmospheric pressure) at sea level is about **100,000 N/m²**.

The **pressure** caused by a gas can be calculated using the equation:

Pressure	=	**force**	x	**area**
N/m²		**N**		**m²**

(HT) Mechanical work transfers energy from the person or machine's store of chemical energy to the internal energy store of the gas.

When a person presses a piston down on a column of gas, they apply a force that moves the piston a certain distance. They have done work on the gas by compressing it.

work done = force × distance

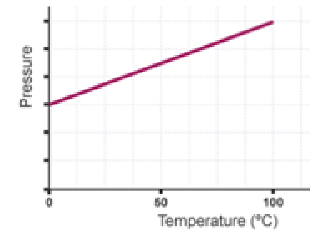
Real-life context → a bicycle pump gets warm when it is used to inflate a tyre as thermal energy is transferred (work is done) when the air is compressed.

4.3.3.3 Pressure in gases

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

As the **temperature increases,** the **pressure increases** showing that pressure is **proportional** to temperature.



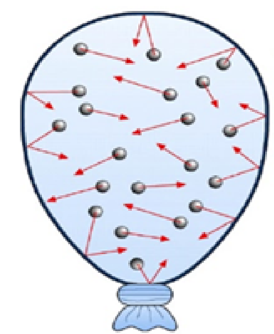
Motion of gases →
The unpredictable motion of smoke particles is evidence of the random motion of gas molecules – called Brownian motion

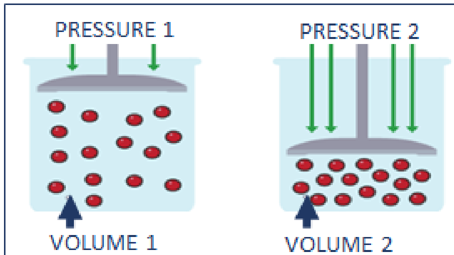
4.3.3.3 Pressure in gases

The force acting on the container due to these collisions is at **right angles to the container.**

For example, the collisions caused by a gas trapped inside a balloon cause forces to act outwards **in all directions,** giving the balloon its **shape.**

A person standing in a room full of air is constantly being hit by the particles of the gases that make up the air .





Gas pressure and Volume → If a balloon is squeezed it will get smaller. If the pressure is increased, the volume will decrease.

Boyle's Law → Pressure (p) x Volume (V) = constant
Pa (Pascal) m³

This is also shown as:-

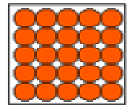
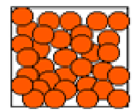
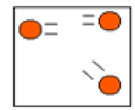
$$p_1V_1 = p_2V_2$$

Knowledge Organiser – 6.3 Particle model of matter

6.3.1.1 Density of materials

The particle model can be used to explain the different states of matter differences in density.

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

Solid	Liquid	Gas
Particles closely packed - vibrate - Little energy - Very strong forces of attraction	Particles touching, - Move past each other - Some energy - Relatively strong forces of attraction	Particles very far apart - Move very fast - Lots of energy - Weak forces of attraction
		

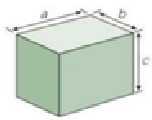
Key Terms	Particle Model of Matter Definitions
condensation	A change of state in which gas becomes liquid by cooling.
energy	The capacity for doing work
evaporation	The process in which a liquid changes state and turns into a gas.
freeze	A change of state in which liquid becomes solid by cooling.
Internal energy	The total kinetic energy and potential energy of the particles in an object. Heating changes the energy stored within the object by increasing the energy of the particles that make up the system.
Kinetic energy	Energy which an object possesses by being in motion
Melting	The process that occurs when a solid turns into a liquid when it is heated
Specific heat capacity	The amount of energy needed to raise the temperature of 1 kg of substance by 1°C
Specific latent heat	The amount of energy needed to melt or vaporise 1 kg at its melting or boiling point
Sublimation	When a solid turns straight into a gas on heating, without becoming a liquid first, or when a gas turns straight into a solid, without becoming a liquid.
Temperature	How warm or cold something is
Thermal energy	Scientific term for heat energy

RPA: Measuring volume of irregular objects and calculating density

Method 1: Regular solid volume

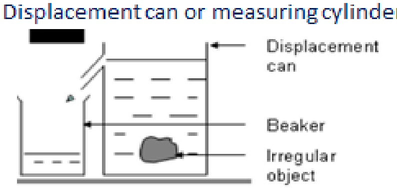
Length x width x height

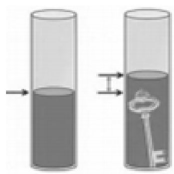
Sphere: $\frac{4}{3}\pi(\frac{d}{2})^3$

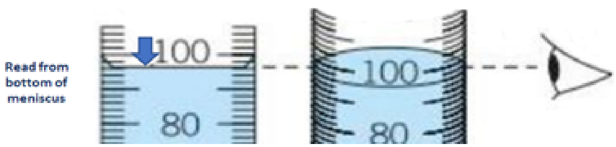


Method 2: Stone or other irregular shaped object volume

Displacement can or measuring cylinder





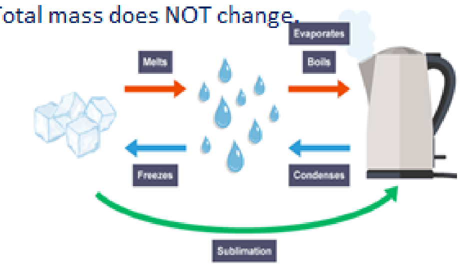


Measure mass of object and then use density equation.

6.3.1.2 Changes of State

Conservation of mass

- The number of particles does not change during a change of state, only their spacing and arrangement.
- Total mass does NOT change.



- Change of state is **physical**.
- The material **recovers its original properties** if the change is reversed.

6.3.1.3 Internal Energy

- **Internal Energy**: Energy is stored inside a system by the particles that make up the system. Internal energy is the **total kinetic energy** and **potential energy** of **all the particles** that make up a system.
- Heating **increases** the energy of the particles
- Either **raises the temperature** of the system **or produces a change of state.**

6.3.2.2 Temperature changes in a system and specific heat capacity

The change in temperature of a system depends on:

- the amount of **thermal energy** transferred to the system
- the mass of the substance
- the nature of the substance itself

change in thermal energy = mass × specific heat capacity x temperature change

$$\Delta E = mc\Delta\theta$$

Units Used:-

- change in thermal energy, ΔE, in joules, J
- mass, m, in kilograms, kg
- specific heat capacity, c,
- in joules per kilogram per degree Celsius, J/kg °C
- temperature change, $\Delta\theta$, in degrees Celsius, °C.

Knowledge Organiser – 6.3 Particle model of matter

6.3.2.3 Changes of heat and specific latent heat

If a change of state happens:

- The energy needed for a substance to change state is called **latent heat.**
- When a change of state occurs, the energy supplied **changes the energy stored** (internal energy) but **does not change the temperature.**
- **specific latent heat** of a substance is the amount of energy required to **change the state of one kilogram of the substance** with no change in temperature.

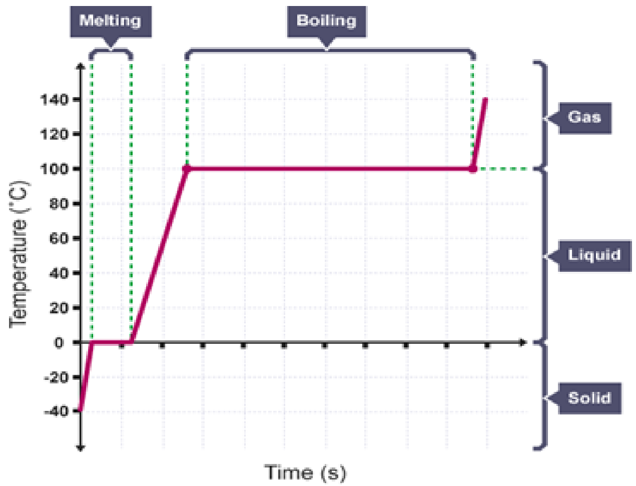
energy for a change of state = mass × specific latent heat

$$E = mL$$

- energy, *E*, in joules, J
- mass, *m*, in kilograms, kg
- specific latent heat, *L*, in joules per kilogram, J/kg
- **specific latent heat**, *L*, in joules per kilogram, J/kg

Specific latent heat of fusion – change of state from solid to liquid

Specific latent heat of vaporisation – change of state from liquid to vapour



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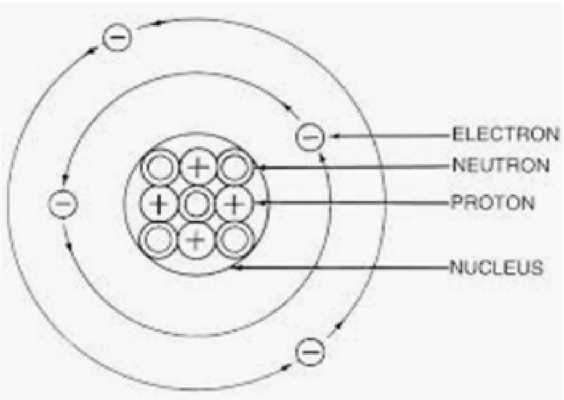
Knowledge Organiser – 6.4 Atomic Structure

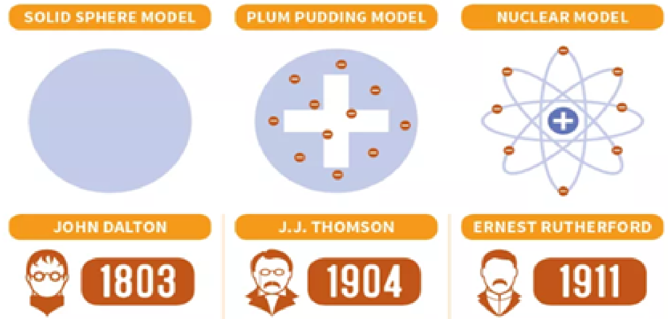
6.4.1.1 The structure of an atom

Atoms are very small, having a radius of about **1 x 10^{-10} metres.** They make up all of the matter around us. The basic structure of an atom consists of a **positively charged nucleus** composed of **protons** and **neutrons** surrounded by **negatively charged electrons.**



The electrons are arranged at different distances from the nucleus known both as **shells** and **energy levels.** They are the represented by the circles around the nucleus on the diagram.

Electron arrangements can change with **absorption** of electromagnetic radiation or **emission** of electromagnetic radiation.

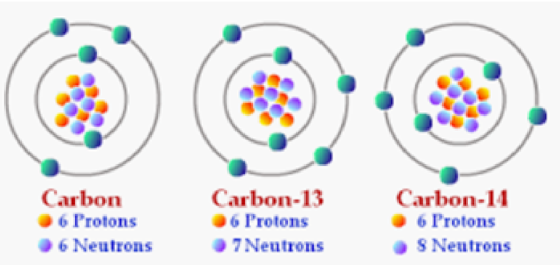


6.4.1.2 Mass number, atomic number and isotopes

The numbers on the periodic table are called the **mass number** and the **atomic number.**
<u>The atomic number (proton number):</u> Smaller number, tells you the number of protons are in an atom of that element. There will be the same number of electrons as protons.
<u>Mass number:</u> larger number, tells you how many neutrons and protons combined are in that atom. Calculate neutrons by taking away the atomic number from the mass number.

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

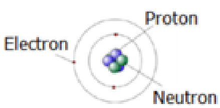


<u>Isotopes:</u> Versions of same element (same number of protons) with **different numbers** of **neutrons** in their nuclei.
Atoms turn into **positive ions**, if they lose one or more outer electron(s)

6.4.1.3 The development of the model of the atom

- **Experimental evidence** may lead to a scientific model changing over time. Atoms were originally thought to have been **solid spheres of matter**.
- The **discovery** of the **electron** led to the **plum pudding model** which suggested a **positive ball of charge** containing negative particles.

- Rutherford's **<u>alpha particle scattering</u>** experiment (using gold leaf) led to the conclusion that the **mass of an atom** was **concentrated** with **a positively** charged **nucleus.**
- This **nuclear model replaced**
- the previous one.



- Niels Bohr adapted the nuclear model by suggesting that **electrons orbit the nucleus at specific distances.**
- Later experiments identified positive particles which were called **protons.**
- The experimental work of James **Chadwick** provided the evidence to show the existence of **neutrons within the nucleus.**

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

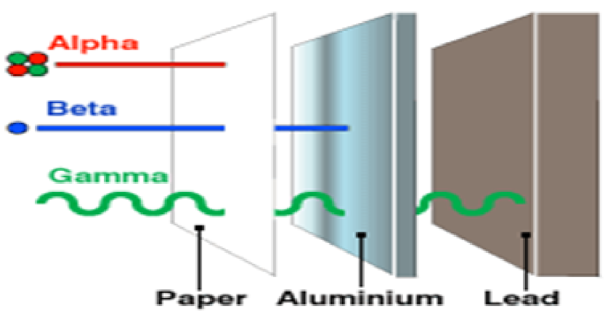
Knowledge Organiser – 6.4 Atomic Structure

6.4.2.1 Radioactive decay and nuclear radiation

Some atomic **nuclei** are **unstable**, radiation is given out and the nucleus becomes more stable. This is a **random process** called **radioactive decay**.

- **Alpha particles** consist of two neutrons and two protons (same as a helium nucleus)
- **Beta particles** consist of a high speed electron ejected from the nucleus as a neutron turned into a proton.
- **Gamma rays** are electromagnetic radiation form the nucleus.
- **Neutron** emission is a decay process where one or more neutrons are ejected from a nucleus. It can occur in nuclei that are neutron rich/proton poor. As only one or more neutrons are lost, the atom becomes a different isotope of the original element.

Each type of radiation has **a different range** and **penetration power;** Alpha has the **highest ionising power** although having the shortest range and is least penetrating.



- **Activity** is the rate at which a source of unstable nuclei decays.
- Activity is measured in **becquerel** (Bq)
- **Count-rate** is the number of decays recorded each second by a detector (e.g. Geiger-Muller tube).

6.4.2.2 Nuclear equations

Are used to represent radioactive decay.

Alpha decay causes both the mass and charge of a nucleus to decrease. $^{4}_{2}He$

Beta decay causes the charge to increase But does not change the mass of the nucleus $^{0}_{-1}e$

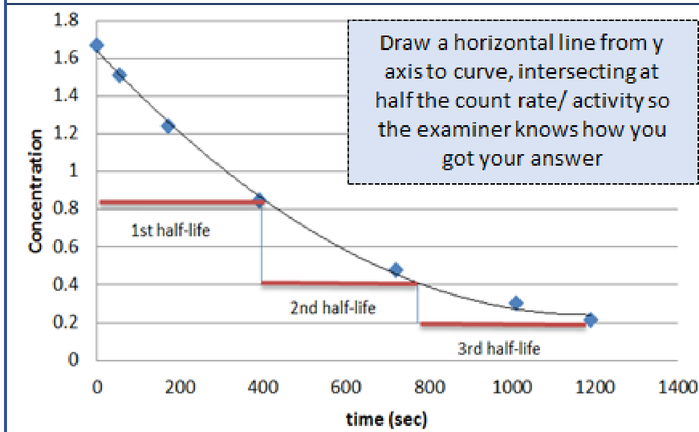
Gamma ray emission does not cause a change in the mass or charge of a nucleus.

$$^{235}_{92}U \xrightarrow[\text{an alpha particle}]{\text{decay by releasing}} {}^{4}_{2}\alpha + {}^{231}_{90}Th$$

$$^{14}_{6}C \xrightarrow[\text{an beta particle}]{\text{decay by releasing}} {}^{0}_{-1}\beta + {}^{14}_{7}N$$

$$^{235}_{92}U \xrightarrow[\text{a gamma wave}]{\text{decay by releasing}} {}^{0}_{0}\gamma + {}^{235}_{92}U$$

6.4.2.3 Half-lives and the random nature of radioactive decay



(HT Only) Calculating half life.

Question:

The half-life of cobalt-60 is 5 years. If there are 100 g of cobalt-60 in a sample, how much will be left after 15 years?

15 years is three half-lives so the fraction remaining will be $(\frac{1}{2})^3 = \frac{1}{8} = 12.5g$

As a ratio of what was present originally compared to what was left, this would be 100:12.5 or 1:0.125

A **half-life** is either:-

- the time it takes for the number of nuclei of a radioactive isotope in a sample to halve

or

- the time is takes for the count rate from that sample to fall to half of its initial level.

6.4.2.4 Radioactive contamination

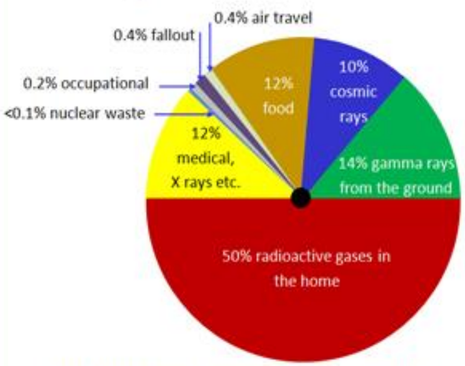
Irradiation: Exposing an object to **nuclear radiation**, the object **does not** become **radioactive** but it can still **damage cells.**

Irradiation	Contamination
Occurs when an object is exposed to a source of radiation outside the object	Occurs if the radioactive source is on or in the object
Doesn't cause the object to become radioactive	A contaminated object will be radioactive for as long as the source is on or in it
Can be blocked from the object with suitable shielding	Once an object is contaminated, the radiation cannot be blocked from the object
Stops as soon as the source is removed	It can be very difficult to remove all of the contamination

Radioactive Contamination: **Unwanted** presence of **materials** containing **radioactive atoms** on other materials.

Knowledge Organiser – 6.4 Atomic Structure (Sep Physics 4.4)

4.4.3.1 Background Radiation



Radiation dose is measured in Sv (sieverts)

You will be provided with this unit in your exam.

You must know .... 1 Sv = 1000 mSv

Note → 1 Sv = 1 J/kg (absorbed dose per kg as opposed to exposed dose per kg)

1 Sv will cause illness if absorbed all at once, and 8 Sv will result in death, even with treatment.

Background radiation falls into 2 categories:
- **Natural** e.g. rocks, cosmic rays from space.
- **Man-made** e.g. fallout from nuclear weapons testing and nuclear accidents

Some people may be exposed to more radiation because of their **occupation** e.g. radiographer or their **location** e.g. Dartmoor

Did you know? A **banana** produces approximately 98.2 nanosieverts!

4.4.3.2 Radioactive isotopes

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

4.4.3.3 Uses of Radiation

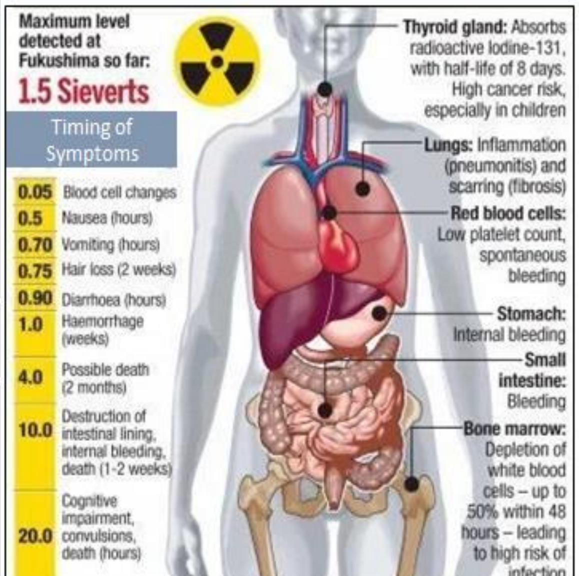
Radioactive Tracers:

e.g. 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:

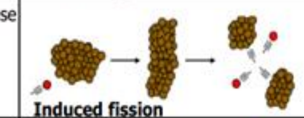
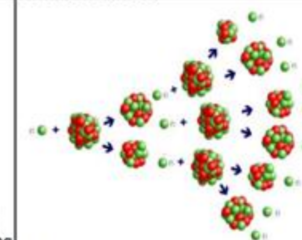
Take images of internal body organs.
- ✓ Before image is taken, patient is injected with solution containing a gamma-emitting radioactive isotope.
- ✓ The solution is absorbed by the organ and the camera detects the gamma radiation.
- ✓ The half life of the radioactive isotope should not be too long (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**.



4.4.4.1 Nuclear Fission

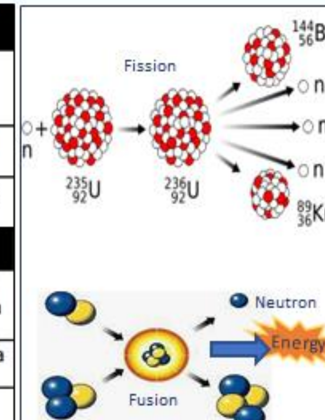
Nuclear fission is the **splitting of a large and unstable atom's nucleus** (e.g. uranium or plutonium) into two smaller nuclei and the release of neutrons and energy.

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.	
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.

4.4.4.2 Nuclear fusion

- 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 from nuclear fusion of H nuclei into He nuclei.

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



Knowledge Organiser – 6.4 Atomic Structure

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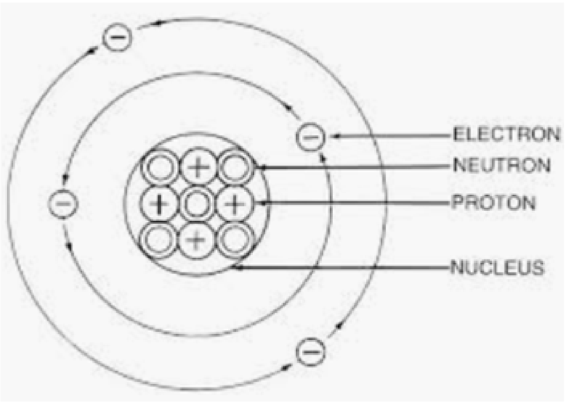

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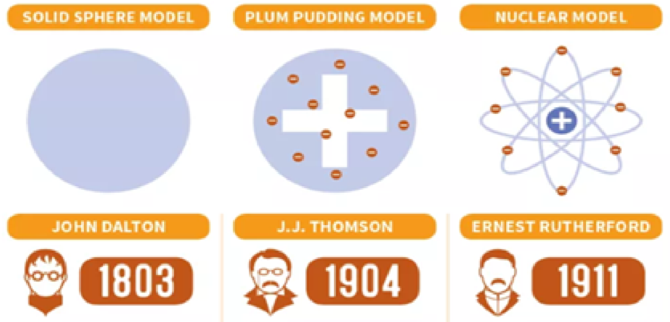

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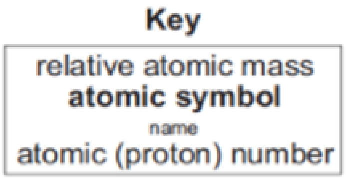

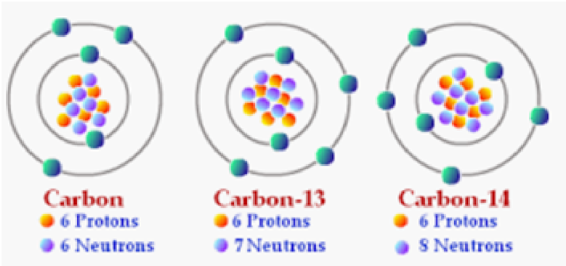

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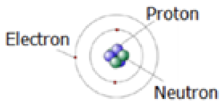

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Knowledge Organiser – 6.4 Atomic Structure

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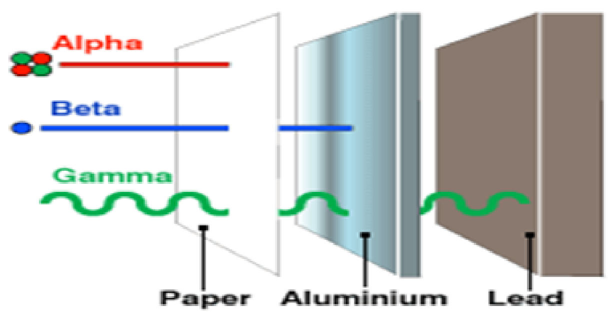


- **Activity** is the rate at which a source of unstable nuclei decays.
- Activity is measured in **becquerel** (Bq)
- **Count-rate** is the number of decays recorded each second by a detector (e.g. Geiger-Muller tube).

6.4.2.2 Nuclear equations

Are used to represent radioactive decay.

Alpha decay causes both the mass and charge of a nucleus to decrease. $^{4}_{2}He$

Beta decay causes the charge to increase But does not change the mass of the nucleus $^{0}_{-1}e$

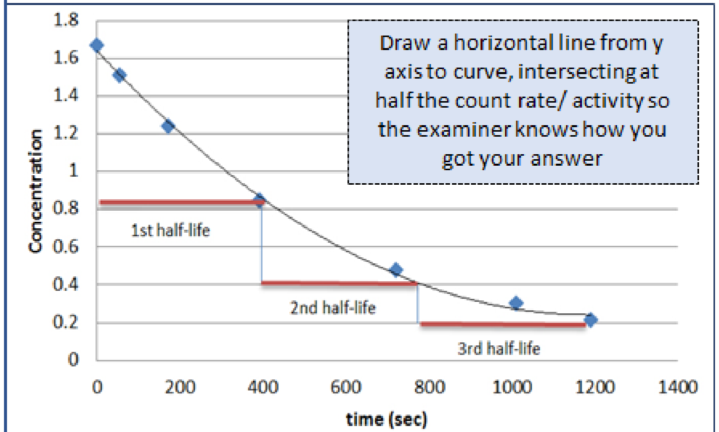
Gamma ray emission does not cause a change in the mass or charge of a nucleus.

$$^{235}_{92}U \xrightarrow[\text{an alpha particle}]{\text{decay by releasing}} {}^{4}_{2}\alpha + {}^{231}_{90}Th$$

$$^{14}_{6}C \xrightarrow[\text{an beta particle}]{\text{decay by releasing}} {}^{0}_{-1}\beta + {}^{14}_{7}N$$

$$^{235}_{92}U \xrightarrow[\text{a gamma wave}]{\text{decay by releasing}} {}^{0}_{0}\gamma + {}^{235}_{92}U$$

6.4.2.3 Half-lives and the random nature of radioactive decay



(HT Only) Calculating half life.

Question:

The half-life of cobalt-60 is 5 years. If there are 100 g of cobalt-60 in a sample, how much will be left after 15 years?

15 years is three half-lives so the fraction remaining will be $(\frac{1}{2})^3 = \frac{1}{8} = 12.5g$

As a ratio of what was present originally compared to what was left, this would be 100:12.5 or 1:0.125

A **half-life** is either:-

- the time it takes for the number of nuclei of a radioactive isotope in a sample to halve

or

- the time is takes for the count rate from that sample to fall to half of its initial level.

6.4.2.4 Radioactive contamination

Irradiation: Exposing an object to **nuclear radiation**, the object **does not** become **radioactive** but it can still **damage cells.**

Irradiation	Contamination
Occurs when an object is exposed to a source of radiation outside the object	Occurs if the radioactive source is on or in the object
Doesn't cause the object to become radioactive	A contaminated object will be radioactive for as long as the source is on or in it
Can be blocked from the object with suitable shielding	Once an object is contaminated, the radiation cannot be blocked from the object
Stops as soon as the source is removed	It can be very difficult to remove all of the contamination

Radioactive Contamination: **Unwanted** presence of **materials** containing **radioactive atoms** on other materials.

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.1.1 Scalar and vector quantities

Scalar quantities have **magnitude (size)** only.

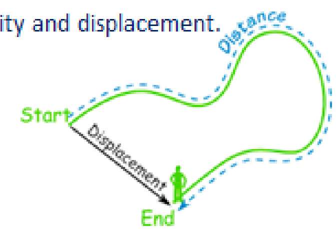
- Represented by a **number**.

Example: speed and distance.

Vector quantities have **magnitude** and **direction**.

- Represented by a **number** and an **arrow**.

Example: velocity and displacement.



6.5.1.2 Contact and non-contact forces

A **force** is a **push** or **pull** that acts on an object when it interacts with another object.

A force is a vector quantity.

- **Contact** forces – the objects are **touching** each other.
  Example: friction, air resistance, and tension.
- **Non-contact** forces – the objects are **separated.**
  Example: magnetic and gravitational force.

6.5.1.3 Gravity

Weight is the force acting on an object due to gravity. This can be calculated by:

Weight (N) = mass (kg) x gravitational field strength (N/kg)

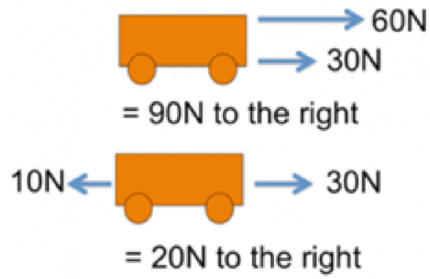
W = m x g

The weight of an object acts at an object's '**centre of mass'**.

The weight and mass of an object are **directly proportional.**

Weight is measured using a **newtonmeter.**

6.5.1.4 Resultant forces



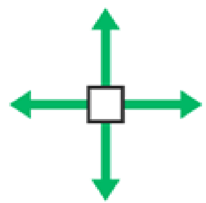
Forces acting in **opposite** directions will leave behind an overall force called a **resultant** force.

(HT) You will need to know:

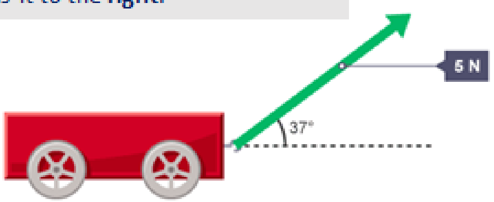
- (HT) A single force can be resolved into two components acting at right angles to each other. The two component forces together have the **same effect as the single force**.
- (HT) Students should be able to use **vector diagrams** to illustrate **resolution** of forces, **equilibrium** situations and determine the **resultant of two forces**, to include **both** magnitude and direction (scale drawings only)

6.5.1.4 HT only

Free body diagram: models the forces acting on an object. The object or 'body' is usually shown as a box or a dot. The forces are shown as thin arrows pointing away from the centre of the box or dot.



Resolving forces: Two forces can be added together to find a **resultant force**. A single force can be **resolved** (broken down) into **two** component forces at **right angles** to each other.
In the diagram of a toy trailer below, when a child pulls on the handle, some of the **5 newton** (N) force pulls the trailer **upwards** away from the ground and **some of the force** pulls it to the **right**.



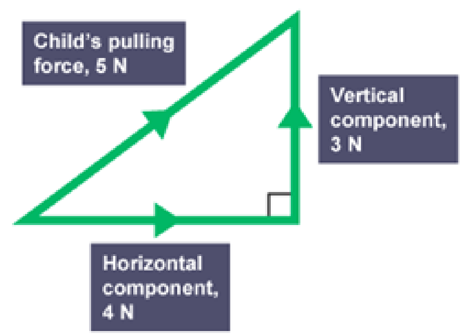
Vector diagrams: can be used to resolve the pulling force into a **horizontal component** acting to the **right** and a **vertical component** acting **upwards.**

Draw a right-angled triangle to scale, in which each side represents a force.

For the toy trailer example above, draw:

- a line representing the 5 N force at 37°
- a horizontal line ending directly below the end the first line
- a vertical line between ends of the two lines
- arrow heads to show the direction in which each force acts

Measure the lengths of the horizontal and vertical lines. Use the scale for the first line to convert these lengths to the corresponding forces.



Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.2 Work Done and Energy Transfer

When a **force** causes an object to move a **distance, work** is done on that object.

Work done (J) = Force (N) x distance (m)
W = F x s

- work done, *W*, in joules, J
- force, *F*, in newtons, N
- distance, *s*, in metres, m
- One joule of work is done when a force of one newton causes a displacement of one metre.
- 1 joule = 1 newton-metre

6.5.3 Forces and elasticity

- To change the shape of a stationary object (by stretching, bending or compressing), **more than one force has to be applied**
- The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

Force (N) = spring constant (N/m) x extension (m)
F = k x e

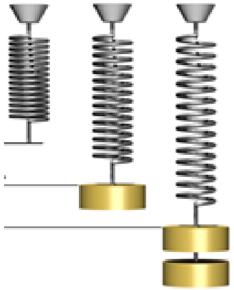
- Force, F, in newtons, N
- spring constant, k, in newtons per metre, N/m
- extension, e, in metres, m
- Also applies to the **compression** of an elastic object, where 'e' would be the compression of the object.

- A force that stretches (or compresses) a spring does work and **elastic potential energy is stored in the spring.** Provided the spring is not inelastically deformed, the **work done on the spring and the elastic potential energy stored are equal.**

elastic potential energy = 0.5 × spring constant × extension²

$$E_e = \frac{1}{2} k e^2$$

RPA: Investigate the relationship between force and extension for a spring

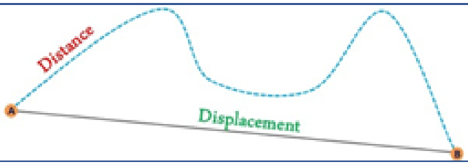


When a force acts on an **elastic** object, the object will extend a proportional amount until it is **permanently deformed** (won't return to original shape).

By **adding** more **weight** to a spring and measuring its **extension**; the extension of a spring can be found.
You may also have to use the equation in the equation sheet to find the elastic potential energy.

6.5.4.1.1 Distance and displacement

Displacement is how far an object moves in a straight line from start to finish. It is **vector.**
Distance is how far an object moves. It is **scalar.**



6.5.4.1.2 Speed

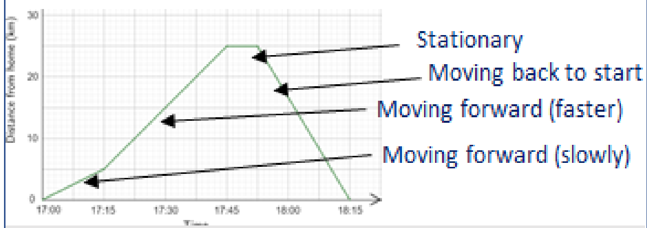
Speed is a **scalar** quantity. The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled. The speed of a moving object is rarely constant and always fluctuating.

Activity	Typical Value
walking	**1.5m/s**
running	**3m/s**
cycling	**6m/s**
driving a car	25mph (40km/h)
train travel	60mph (95km/h)
aeroplane travel	550mph (885km/h)
speed of sound	*330m/s*

For an object travelling at a constant speed:
Speed (m/s) = distance (m) ÷ time (s)
v = s ÷ t

6.5.4.1.4 Distance-time relationship

- If an object moves along a straight line, the distance travelled can be represented by a distance–time graph.
- The speed of an object can be calculated from the gradient of its distance–time graph



(HT) If an object is accelerating, its **speed at any particular time** can be determined by **drawing a tangent** and **measuring the gradient** of the distance–time graph at that time

6.5.4.1.3 Velocity

Velocity is the **speed** in a **direction.**
It is a **vector.**

(HT only) Motion in a **circle** involves **constant speed** but **changing velocity.**

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.4.1.5 Acceleration

Average acceleration can also be calculated using:

Acceleration (m/s²) = change in velocity (m/s) ÷ time (s)

$a = \Delta v \div t$

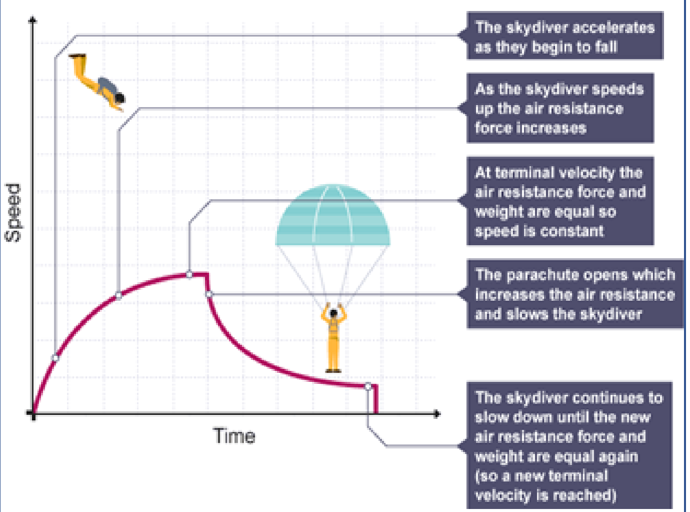
- acceleration, a, in **metres per second squared**, m/s2
- change in velocity, Δv, in **metres per second**, m/s
- time, t, in **seconds**, s

- An object that **slows down** is **decelerating.**
- The **acceleration** of an object can be calculated from the **gradient of a velocity–time** graph.

Uniform acceleration can also be calculated using:

$$(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$$

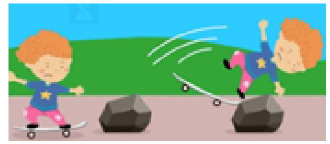
- final velocity, v, in metres per second, m/s
- initial velocity, u, in metres per second, m/s
- acceleration, a, in metres per second squared, m/s2
- distance, s, in metres, m



6.5.4.2.1 Newton's first law

An object will not move or change speed unless a force acts on it.

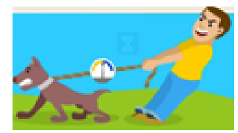
- A stationary object will stay **stationary.**
- A moving object will continue at a **constant speed.**



(HT) The **tendency of an object to stay still** or stay at a constant speed is inertia.

6.5.4.2.3 Newton's third law

When two objects interact, the forces they exert on each other are **equal and opposite.**



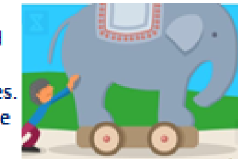
6.5.4.2.2 Newton's second law

Force (N) = mass (kg) x acceleration

F = m x a

The **acceleration** of an object depends on mass and force.

- If the mass **increases** and the force **stays the same**; the acceleration **decreases.**
- If the mass **stays the same** and the force **increases**; the acceleration **increases.**

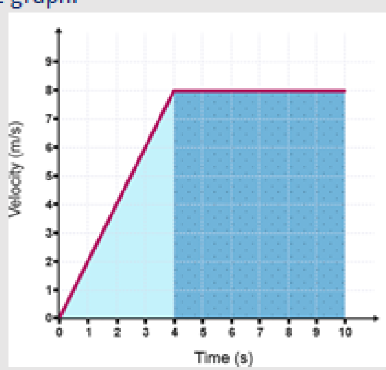


(HT) **inertial mass:**

- measure of **how difficult it is to change the velocity** of an object
- the **ratio of force over acceleration.**

6.5.4.1.5 Acceleration (HT)

The distance travelled by an object (or displacement of an object) can be calculated from the <u>area</u> under a velocity-time graph.



e.g. for graph above…

Area of triangle = 4 x 8 = 32m

Area of rectangle = 6 x 8 = 48m

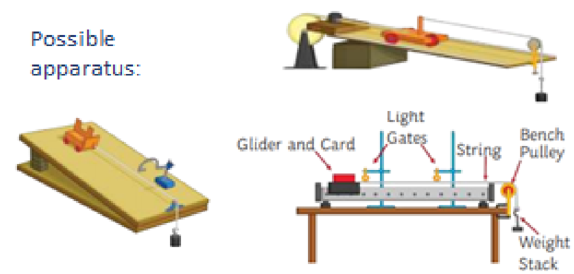
Total distance travelled = 32 + 48 = <u>80m</u>

RPA

<u>Version 1-</u> Investigate the <u>**effect of varying the force**</u> on the acceleration of an object of constant mass, AND

<u>Version 2-</u> the effect of <u>**varying the mass**</u> of an object on the acceleration produced by a constant force.

Possible apparatus:



Something is a <u>**fair test**</u> when only the independent variable has been allowed to affect the dependent variable.

e.g. for version 1- The IV was force. The DV was acceleration.

The CV were:

- same **total mass**
- same surface/glider/string/pulley (**friction**)
- same **gradient** if you used a ramp

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.4.3.1 Stopping distance

The stopping distance of a vehicle is the sum of the drivers **reaction time** (**thinking distance**) and the **braking distance.**
Greater speed = greater stopping distance

6.5.4.3.2 Reaction time

Reaction times vary from person to person but are usually in the range of **0.2 s to 0.9 s**.
A drivers reaction time is affected by **tiredness, distractions, drugs** and **alcohol**.

There are different ways to measure reaction times.

- One simple method involves **dropping a ruler** between someone's open thumb and forefinger.
- The **higher the reaction time** needed to grasp the falling ruler, the **further the ruler falls** before being stopped.

6.5.4.3.3 Factors affecting braking distance 1

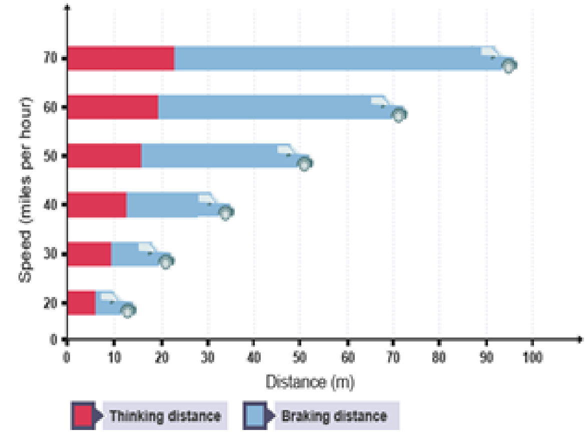
The braking distance of a car can be affected by:

- **wet** or **icy road conditions**
- **faulty tires** or **brakes.**

6.5.4.3.4 Factors affecting braking distance 2

When a force is applied to the brakes of a vehicle, work done between the **brakes** and the **wheel** reduces the **kinetic energy** of the vehicle.

- This would increase the **temperature** of the brakes.
- **Large decelerations** may lead to brakes **overheating** and maybe the **loss control.**



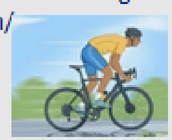
4.5.7.1. Momentum (HT)

Momentum is a property of moving objects. Momentum can be calculated by the equation:

Momentum = mass x velocity
(kg m/s) (kg) (m/s)
p = m x v

- momentum, *p*, in kilograms metre per second,
- kg m/s mass, *m*, in kilograms, kg
- velocity, *v*, in metres per second, m/s

Calculate the momentum of a 85kg cyclist travelling at 7m/



p = m × v
p = 85kg × 7m/s
p = 595kg m/s

4.5.7.2 Conservation of Momentum

In a closed system, the total momentum before an event is equal to the total momentum after the event; this is called **conservation of momentum**.

- Conservation of momentum explains why a gun or cannon **recoils backwards** when it is fired.
- When a cannon is fired, the cannon ball gains **forward momentum** and the cannon gains **backward momentum.**
- Before the cannon is fired (the 'event'), the total momentum is **zero**. This is because **neither object is moving.**
- The **total momentum** of the cannon and the cannon ball after being fired is also **zero**, with the cannon and ball moving in **opposite directions.**

4.5.7.3 Changes in Momentum

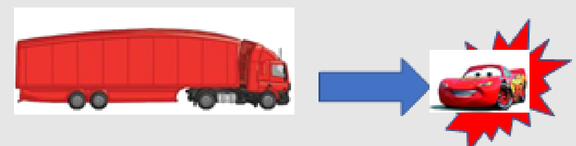
When a force acts on a moving or moveable object there is a change of momentum.
The equations for calculating force and acceleration can be combined:

F = m × a and a = (v – u) ÷ t

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

This equation tells you that the **force is equal to the rate of change of momentum in the object.**

A lorry with a mass of 12 000kg, travelling at 20m/s, collides with a <u>**stationary**</u> car with a mass of 1500kg. After the collision, the vehicles move off together.



Calculate their <u>**velocity**</u>.

Step 1: find the momentum of each vehicle before the collision.
Calculate the **momentum** of the lorry: **p = m × v**
Lorry → p = 12 000 × 20 = **240 000 kg m/s**
Calculate the momentum of the car: **p = m × v**
Car → p = 1500 × 0 = **0 kg m/s**

Units of momentum are
kg m/s

Step 2: find the total momentum (lorry + car) **before** the collision.
total momentum before = **240 000 + 0 = 240 000 kg m/s**

Step 3: use the law of conservation of momentum and rearrange the equation.

$$\frac{p}{m} = v$$

total momentum before collision = total momentum after collision

V = p/m = 240 000 kg m/s ÷ (12 000 + 1500) = **17.78 m/s.**

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

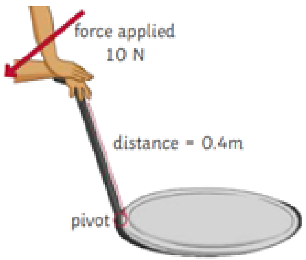
4.5.4 Moments

A moment is the turning effect produced by a force.
To find the size of a moment, use the equation:

moment (Nm) = force (N) × distance (m)

Remember that the distance is the perpendicular distance from the pivot to the line of action of the force.

4.5.4 Worked example



A crowbar is being used to lift a manhole cover. Calculate the moment produced.

M = F × d
M = 10N × 0.4m
M= <u>40Nm</u>

To increase the turning affect achieved without increasing the amount of force applied, you would need to increase the distance between the force and the pivot.

For example, if the crowbar in the example above was 0.5m, then the moment would be:
M = F × d
M = 10N × 0.5m
M = <u>50Nm</u>

4.5.4 Levers

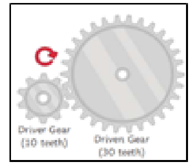
Levers can be used to increase the effect of a force applied, acting as a force multiplier. Some everyday examples include:

spanner

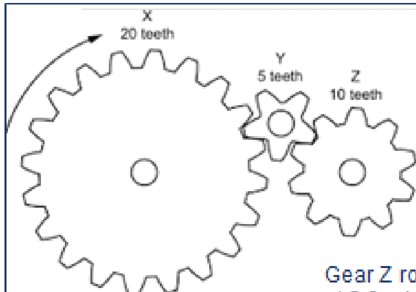
wheelbarrow

pair of scissors

4.5.4 Gears



- A **force multiplier** makes it **easier** to do work because the **same force** applied at a **greater distance** from the pivot increases the **moment produced.**
- A gear is a wheel which has '**teeth**' around the **circumference**.
- The teeth of different gears **lock together** and the gear can turn on an **axle**, turning the other gears it is connected to. Where the teeth meet, they must move in the **same direction.**
- This means that the gears **rotate in opposite directions.** If one gear is turning **clockwise**, it will turn the connected gear **anticlockwise.**
- When gears are connected, the **same force is applied to each**; however, if they are **different sizes**, they will produce **different moments**.
- This is because the moment is calculated using the **distance from the pivot** (the radius of the gear) and if the gear is **smaller**, it will move a **shorter distance.**
- If the gear is **larger**, it will move a **greater distance**.



Gear X rotates **clockwise** at **1.0** rotations per second

Gear Y rotates **anticlockwise** at **4.0** rotations per second

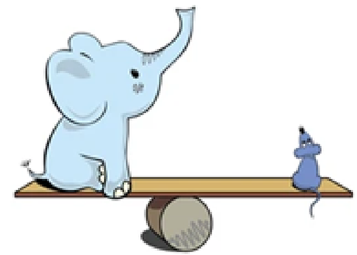
Gear Z rotates **clockwise** at **2.0** rotations per second

4.5.4 Balancing Moments

When the anticlockwise moment on an object is equal to the clockwise moment, the resultant moment is zero and the object does not move or turn.
To balance moments:
total anticlockwise moments = total clockwise moments

Worked example:
An elephant sits on a seesaw. It has a weight of 750N and is sat 2.5m from the pivot. A mouse with a weight of 60N is sitting on the other side of the seesaw. The seesaw is balanced.

What distance is the mouse from the pivot?



Step 1:	Step 2:	Step 3:
Calculate the anticlockwise moment. M = F × d = 750N × 2.5m = 1875Nm	total anticlockwise moments = total clockwise moments 1875Nm = 1875Nm	Use the value calculated for the moment to find the distance on the clockwise side. rearrange: d = M ÷ F d = 1875 ÷ 60 d = 31.25m

4.5.4 Worked example

A gear has a radius of 0.25m. It turns a second gear with a radius of 1.5m. The moment of the smallest gear is 30Nm. Calculate the moment of the largest gear.

Step 1: calculate the force using
M = F × d
Rearrange to F = M ÷ d
F = 30 ÷ 0.25
F = 120N

Step 2: use the force to calculate the moment of the larger gear.
M = F × d
M = 120 × 1.5
M = <u>180Nm</u>

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

4.5.5 Pressure and Pressure Difference in Fluids

4.5.5.1 Pressure in a fluid

A fluid is any material that **flows - liquid or gas.**
The pressure in a fluid causes a force at a right angle (normal) to the surface.
The pressure is calculated using the equation:

pressure (Pa) = force (N) surface area (m^2)

Worked example 1:
Find the pressure exerted by an elephant on a frozen pond. The force exerted by the elephant is 4500N and the area of the pond is 30m².
p = 4500 ÷ 30
p = **150Pa**

4.5.5.2 Atmospheric Pressure

- Surrounding the earth is a layer of air called the atmosphere.
- Compared to the size of the planet, this layer is relatively thin.
- The air becomes less dense the farther from the planet's surface you are (with increasing altitude).
- When the air molecules collide with the surface of the earth, pressure is exerted and this is called atmospheric pressure.
- The amount of air molecules above a surface decreases with altitude and so the pressure exerted also decreases with increasing height.

Worked example 2
The density of water is 1,000 kg/m^3. Calculate the **pressure** exerted by the water on the bottom of a 2.0 m deep swimming pool. (g = 9.8 N/kg).

$$p = h\,\rho\,g$$
$$p = 2.0 \times 1{,}000 \times 9.8$$
$$p = 19{,}600\ Pa$$

4.5.5.2 – Pressure in a fluid (HT)
You can find the pressure produced by a column of liquid using the equation:
pressure = height of column × density of liquid × gravitational field strength
(Pa) (m) (kg/m³) (N/kg)
The more water above an object, the greater the force applied and the greater the pressure exerted.

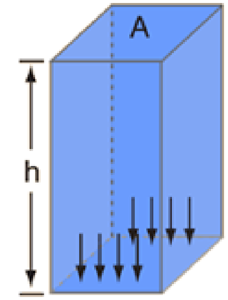
Demo 1
Water leaking from the hole higher up the bucket will be at a lower pressure than water leaking from the hole lower in the bucket.

Demo 2
When an object is submerged partially, it will have a greater pressure on the bottom surface than on the top surface (there is more water behind the force acting upwards). This creates an upwards resultant force called upthrust and this is what causes an object to float.

Worked example 3
A stone is dropped into a lake. Calculate the **increase in pressure** on the stone caused by the water when it sinks **from 1m deep to 6m deep.** (The density of water is 1,000 kg/m3 and gravitational field strength is 9.8 N/kg).

change in depth = 6 - 1 = 5 m

$$p = h\,\rho\,g$$
$$p = 5 \times 1{,}000 \times 9.8$$
$$p = 49{,}000\ Pa$$



Pressure at depth h:
p = ρgh

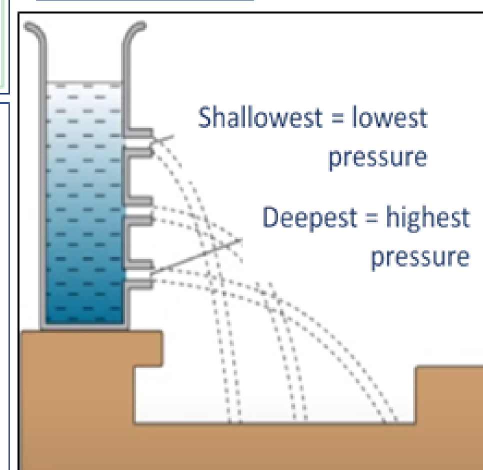
Lower case p is the symbol for **pressure**

Not to be confused with…

Symbol for **density** is the **lower case** Greek letter **rho.** Pronounced like "row". It looks like a fancy "p".

Not to be confused with…

Lower case p is **ALSO** the symbol for **momentum**



Knowledge Organiser – 6.5 Forces

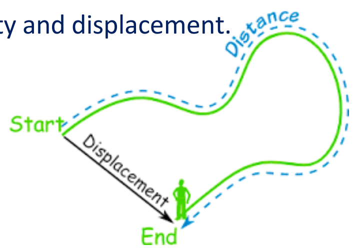
6.5.1.1 Scalar and vector quantities

Scalar quantities have **magnitude (size)** only.
- Represented by a **number**.

Example: speed and distance.

Vector quantities have **magnitude** and **direction**.
- Represented by a **number** and an **arrow**.

Example: velocity and displacement.



6.5.1.2 Contact and non-contact forces

A **force** is a **push** or **pull** that acts on an object when it interacts with another object.
A force is a vector quantity.

- **Contact** forces – the objects are **touching** each other.
  Example: friction, air resistance, and tension.
- **Non-contact** forces – the objects are **separated**.
  Example: magnetic and gravitational force.

6.5.1.3 Gravity

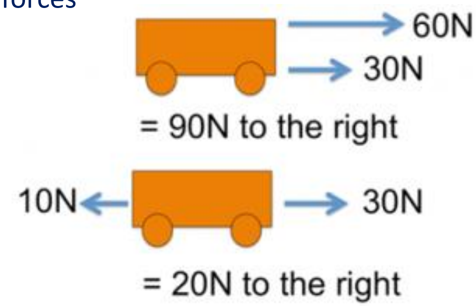
Weight is the force acting on an object due to gravity.
This can be calculated by:

Weight (N) = **mass (kg)** x **gravitational field strength (N/kg)**

W = **m** x **g**

The weight of an object acts at an object's '**centre of mass'**.
The weight and mass of an object are **directly proportional**.
Weight is measured using a **newtonmeter**.

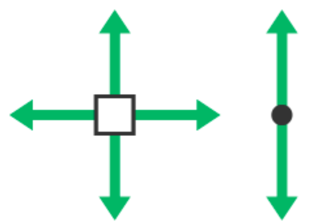
6.5.1.4 Resultant forces



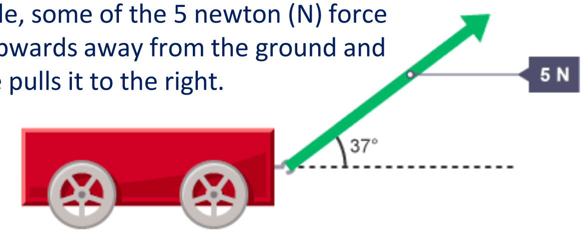
Forces acting in **opposite** directions will leave behind an overall force called a **resultant** force.

6.5.1.4 HT only

Free body diagram: models the forces acting on an object. The object or 'body' is usually shown as a box or a dot. The forces are shown as thin arrows pointing away from the centre of the box or dot.

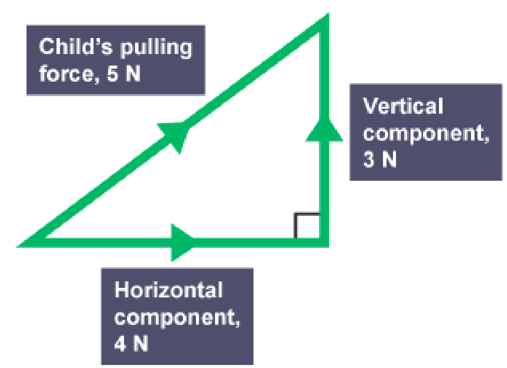


Resolving forces: Two forces can be added together to find a resultant force. A single force can be resolved (broken down) into two component forces at right angles to each other.
In the diagram of a toy trailer below, when a child pulls on the handle, some of the 5 newton (N) force pulls the trailer upwards away from the ground and some of the force pulls it to the right.



Vector diagrams: can be used to resolve the pulling force into a **horizontal component** acting to the **right** and a **vertical component** acting **upwards**.
Draw a right-angled triangle to scale, in which each side represents a force.
For the toy trailer example above, draw:
- a line representing the 5 N force at 37°
- a horizontal line ending directly below the end the first line
- a vertical line between ends of the two lines
- arrow heads to show the direction in which each force acts

Measure the lengths of the horizontal and vertical lines. Use the scale for the first line to convert these lengths to the corresponding forces.



Knowledge Organiser – 6.5 Forces

6.5.2 Work Done and Energy Transfer

When a **force** causes an object to move a **distance**, **work** is done on that object.

Work done (J) = **Force (N)** x **distance (m)**

W = **F** x **s**

- work done, *W*, in joules, J
- force, *F*, in newtons, N
- distance, *s*, in metres, m
- One joule of work is done when a force of one newton causes a displacement of one metre.
- 1 joule = 1 newton-metre

6.5.3 Forces and elasticity

- To change the shape of a stationary object (by stretching, bending or compressing), **more than one force has to be applied**
- The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

Force (N) = **spring constant (N/m)** x **extension (m)**

F = **k** x **e**

- Force, F, in newtons, N
- spring constant, k, in newtons per metre, N/m
- extension, e, in metres, m
- Also applies to the **compression** of an elastic object, where 'e' would be the compression of the object.

- A force that stretches (or compresses) a spring does work and **elastic potential energy is stored in the spring**. Provided the spring is not inelastically deformed, the **work done on the spring and the elastic potential energy stored are equal.**

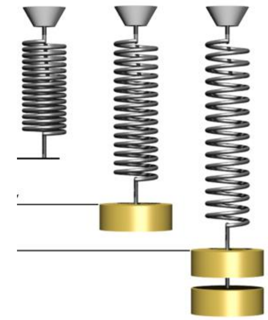
elastic potential energy = 0.5 × spring constant × extension^2

$$1.\ E_e = \frac{1}{2} k e^2$$

RPA: Investigate the relationship between force and extension for a spring

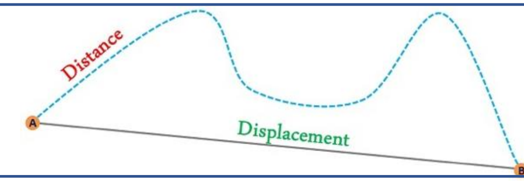
When a force acts on an **elastic** object, the object will extend a proportional amount until it is **permanently deformed** (won't return to original shape).

By **adding** more **weight** to a spring and measuring its **extension**; the extension of a spring can be found.
You may also have to use the equation in the equation sheet to find the elastic potential energy.



6.5.4.1.1 Distance and displacement

Displacement is how far an object moves in a straight line from start to finish. It is **vector**.
Distance is how far an object moves. It is **scalar**.



6.5.4.1.2 Speed

- Speed is a **scalar** quantity. The speed of moving objects often varies greatly.
- The typical speed of sound is 330 m/s.
- The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled.
- Typical values may be taken as:
  - walking- 1.5 m/s
  - running- 3 m/s
  - cycling- 6 m/s.

For an object travelling at a constant speed:

Speed (m/s) = **distance (m)** ÷ **time (s)**

v = **s** ÷ **t**

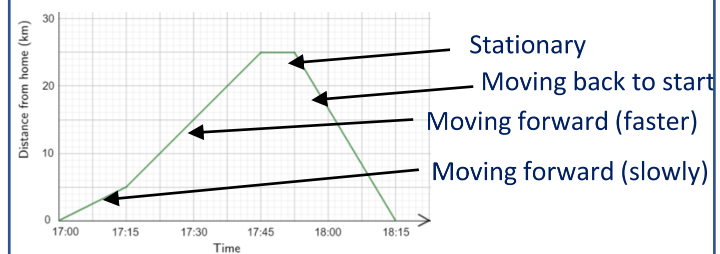
6.5.4.1.3 Velocity

Velocity is the **speed** in a **direction**.
It is a **vector**.

(HT only) Motion in a **circle** involves **constant speed** but **changing velocity**.

6.5.4.1.4 Distance-time relationship

- If an object moves along a straight line, the distance travelled can be represented by a distance–time graph.
- The speed of an object can be calculated from the gradient of its distance–time graph



(HT only) If an object is accelerating, its **speed at any particular time** can be determined by **drawing a tangent** and **measuring the gradient** of the distance–time graph at that time

Knowledge Organiser – 6.5 Forces

6.5.4.1.5 Acceleration

Average acceleration can also be calculated using:

Acceleration (m/s²) = change in velocity (m/s) ÷ time (s)

a = Δv ÷ t

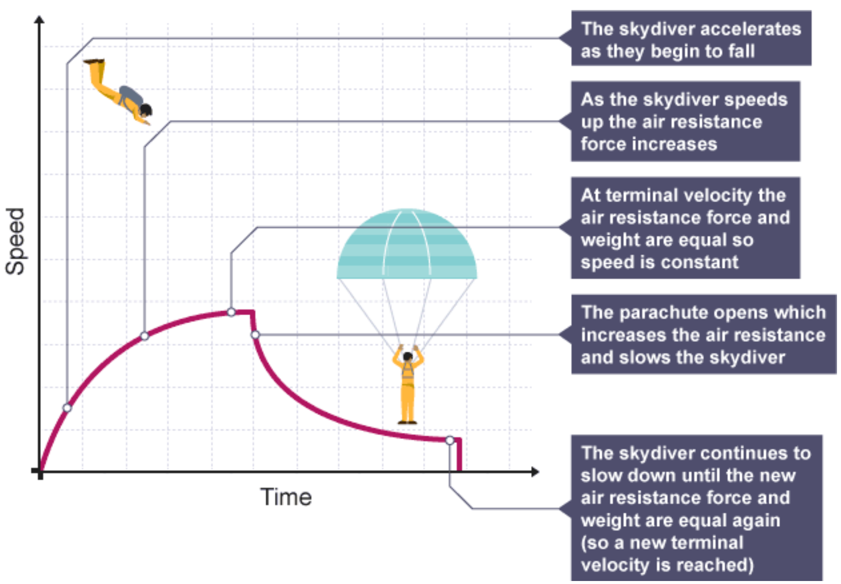
- acceleration, *a*, in **metres per second squared**, m/s2
- change in velocity, Δ*v*, in **metres per second**, m/s
- time, *t*, in **seconds**, s

- An object that **slows down** is **decelerating**.
- The **acceleration** of an object can be calculated from the **gradient of a velocity–time** graph.

Uniform acceleration can also be calculated using:

$$(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$$

- final velocity, *v*, in metres per second, m/s
- initial velocity, *u*, in metres per second, m/s
- acceleration, *a*, in metres per second squared, m/s2
- distance, *s*, in metres, m



6.5.4.2.1 Newton's first law

An object will not move or change speed unless a force acts on it.

- A stationary object will stay **stationary**.
- A moving object will continue at a **constant speed**.

(HT only) The **tendency of an object to stay still** or stay at a **constant speed** is **inertia**.

6.5.4.2.3 Newton's third law

When two objects interact, the forces they exert on each other are **equal and opposite**.

6.5.4.2.2 Newton's second law

The **acceleration** of an object depends on mass and force.

- If the mass **increases** and the force **stays the same**; the acceleration **decreases**.
- If the mass **stays the same** and the force **increases**; the acceleration **increases**.

Force (N) = mass (kg) x acceleration

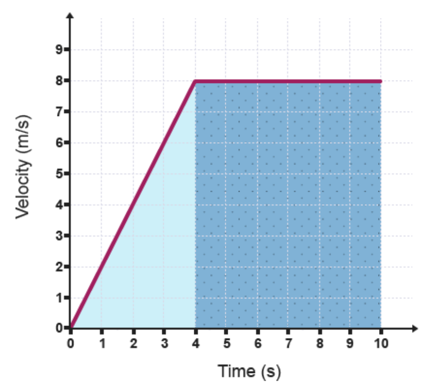
F = m x a

(HT only) **inertial mass:**

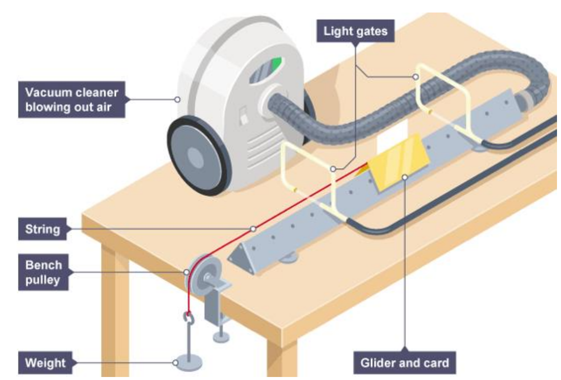
- measure of **how difficult it is to change the velocity** of an object
- the **ratio of force over acceleration**.

6.5.4.1.5 Acceleration (HT Only)

HT only: The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity-time graph.



RPA investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.



Knowledge Organiser – 6.5 Forces

6.5.4.3.1 Stopping distance

The stopping distance of a vehicle is the sum of the drivers **reaction time** (**thinking distance**) and the **braking distance**.
Greater speed = greater stopping distance

6.5.4.3.2 Reaction time

Reaction times vary from person to person but are usually in the range of **0.2 s to 0.9 s**.

A drivers reaction time is affected by **tiredness, distractions, drugs** and **alcohol**.

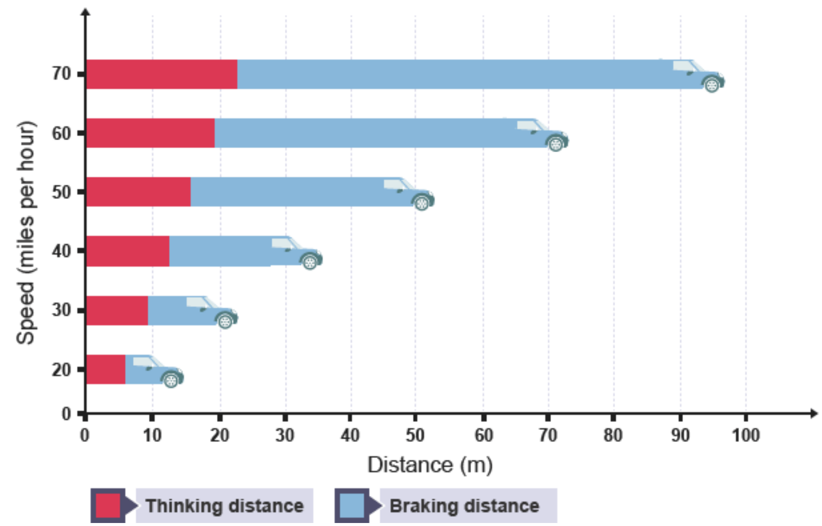
There are different ways to measure reaction times.

- One simple method involves dropping a ruler between someone's open thumb and forefinger.
- The higher the reaction time needed to grasp the falling ruler, the further the ruler falls before being stopped.

6.5.4.3.3 Factors affecting braking distance 1

The braking distance of a car can be affected by:

- **wet** or **icy road conditions**
- **faulty tires** or **brakes**.



6.5.4.3.4 Factors affecting braking distance 2

When a force is applied to the brakes of a vehicle, work done between the **brakes** and the **wheel** reduces the **kinetic energy** of the vehicle.

- This would increase the **temperature** of the brakes.
- **Large decelerations** may lead to brakes **overheating** and maybe the **loss control**.

6.5.5. Momentum (HT only)

Momentum is a property of moving objects.
Momentum can be calculated by the equation:

Momentum (kg m/s) = mass (kg) x velocity (m/s)

p = m x v

- momentum, *p*, in kilograms metre per second,
- kg m/s mass, *m*, in kilograms, kg
- velocity, *v*, in metres per second, m/s

In a closed system, the total momentum before an event is **equal** to the total momentum after the event; this is called **conservation of momentum**.

- Conservation of momentum explains why a gun or cannon recoils backwards when it is fired.
- When a cannon is fired, the cannon ball gains forward momentum and the cannon gains backward momentum.
- Before the cannon is fired (the 'event'), the total momentum is zero. This is because neither object is moving.
- The total momentum of the cannon and the cannon ball after being fired is also zero, with the cannon and cannon ball moving in opposite directions.

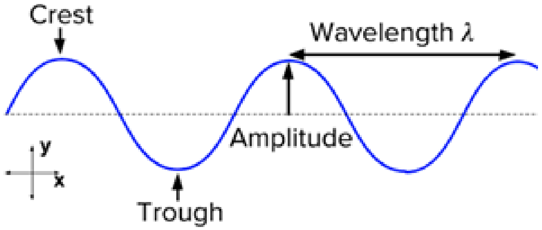
Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

6.6.1.1 Transverse and longitudinal waves

Waves can either be **transverse** or **longitudinal.**

1) Transverse waves

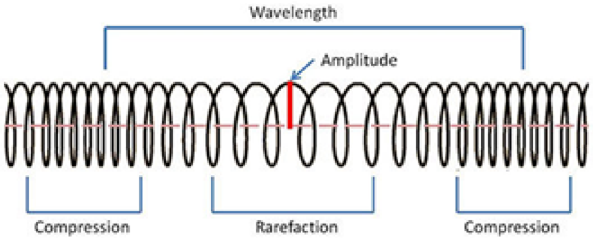
In **transverse** waves, the particles in the wave move **perpendicular** to the direction of the wave.
An example is a ripple on water or an electromagnetic wave.
It is the wave that travels NOT the water.



Remember: the waves move not the particles!

2) Longitudinal waves

In **longitudinal** waves, the particles in the wave move **parallel** to the direction of the wave. An example is a sound wave.



Remember: the waves move not the particles!

6.6.1.2 Properties of waves

Amplitude: the maximum displacement of a point on a wave from the undisturbed point.

Wavelength: the distance between a point on a wave and the same point on the next wave. Measured in metres (m).

Frequency: the number of waves passing a point each second. Measured in Hertz (Hz)

Period: time span of one wave in seconds

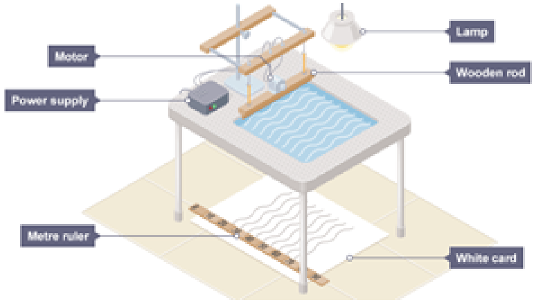
$$Period\ (T) = \frac{1}{Frequency\ (f)}$$

period, T, in seconds, s
frequency, f, in hertz, Hz

Wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. Measured in m/s

$$Wave\ speed\ (v) = frequency\ (f) \times wavelength(\lambda)$$

RPA: Measuring frequency, wavelength and speed of waves in solid and a liquid



Wavelength: Measure the length of a number of waves then divide by the number of waves to calculate the wavelength. It may be more practical to take a photograph of the card.

Frequency: Count the number of waves passing a point in ten seconds then divide by ten to record frequency.

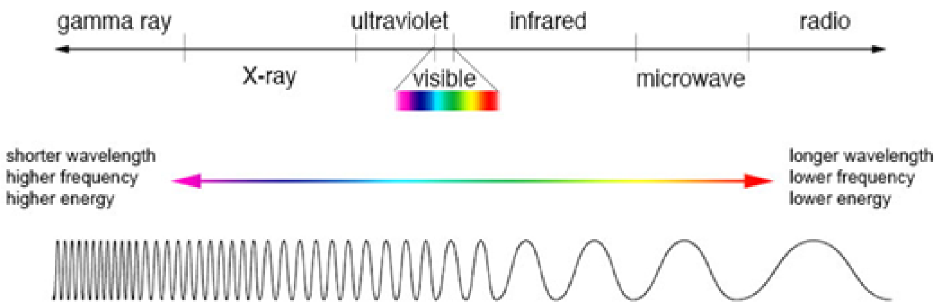
Wave speed: Calculate the speed of the waves using

$$Wave\ speed\ (v) = frequency\ (f) \times wavelength(\lambda)$$

Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

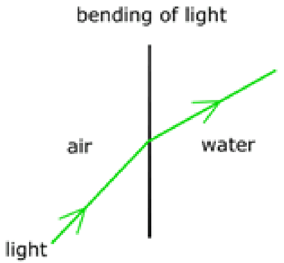
6.6.2.1 Types of electromagnetic waves

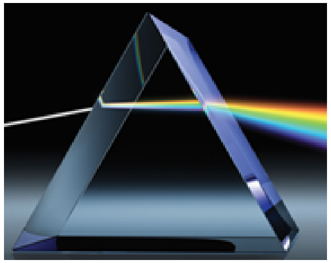
Electromagnetic waves are **transverse** waves that transfer energy from a source to an absorber. **All electromagnetic waves travel at the same speed as each other through a vacuum or air.**



6.6.2.2 Properties of electromagnetic waves 1

- (HT only) **Different substances** may **absorb**, **transmit**, **refract** or reflect electromagnetic waves in ways that **vary with wavelength.**
- (HT only) When electromagnetic waves meet a barrier of a **different density** they **change speed** and therefore direction. This is **refraction**..





6.6.2.3 Properties of electromagnetic radiation 2

Changes in **atoms and atomic nuclei** can generate or absorb electromagnetic radiation. Gamma rays, X-rays and ultraviolet waves are **ionising** and can have **hazardous effects** on human body tissues. The effect depends on the **dose and type** of radiation.

- UV rays can age skin prematurely and increase risk of skin cancer.
- Gamma rays and X-rays can mutate genes and cause cancer.

(HT only) **Radio waves** can be produced by **oscillations** in **electrical circuits.**
(HT only) 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 induce oscillations in an electrical circuit**.

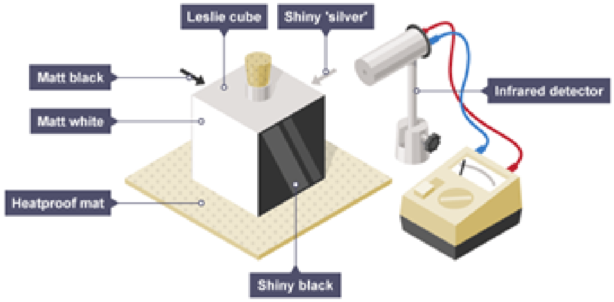
6.6.2.4 Uses and applications of electromagnetic waves

Different types of electromagnetic radiation have many uses:

- **Radio waves** – TV and radio
- **Microwaves** – Satellite communications and cooking food
- **Infrared** – Heating, cooking, and thermal cameras
- **Visible** – Fibre optic communication
- **Ultraviolet** – energy efficient lamps and sun tanning
- **X-ray and Gamma** – Medical imaging and treatment

(If higher tier you need to explain why each type of wave is suitable)

RPA: Investigating the absorption or emission of IR radiation by nature of surfaces



1. Fill the **Leslie cube** with boiling water and replace the lid.
2. Leave for one minute to allow the surfaces to heat up.
3. Use the **infrared detector** to measure the intensity of infrared radiation emitted from each surface….
   - **dark and matt**
   - **light and matt**
   - **dark and shiny**
   - **light and shiny**

The **matt black surfaces emit** the **most** IR radiation.
The **shiny silver emits the least.**

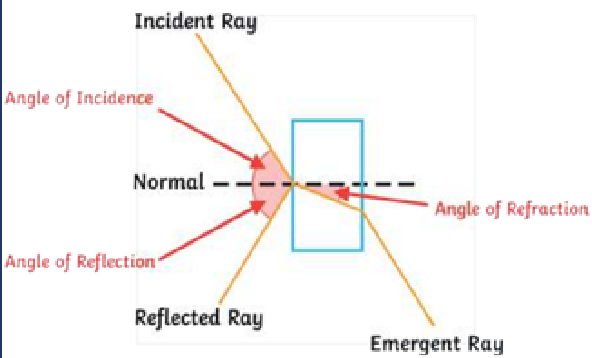
Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

RPA – Reflection of light

Aim: Investigate the reflection of light by different types of surface and the refraction of light by different substances. Method:

1. In a darkened room, set up the ray box on a flat surface and insert the filter to produce a single ray of light.
2. Place a glass block in the centre of a piece of plain A3 paper.
3. Draw a line around the glass block.
4. Draw a line at 90°C to the glass block and label the line normal, as shown in the diagram.
5. Position the ray box so the ray of light hits the glass at an angle.
6. Using a pencil, draw the incidence, reflected and emergent rays as shown in the diagram.
7. Remove the glass block and draw the refracted ray going through the block
8. Using a protractor, measure the angles of incidence, reflection and refraction. Record your results.
9. Repeat the experiment by placing a clear acrylic block on the A3 paper in the same position as the glass block.
10. The incident ray must follow the same line as before. Draw the reflected and refracted rays and measure using a protractor.
11. Collect four sets of results from other members of the class.

The law of reflection states:
angle of incidence = angle of reflection

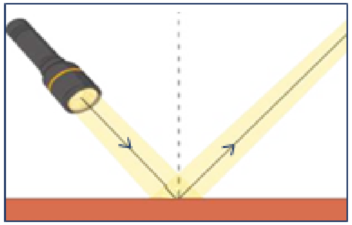


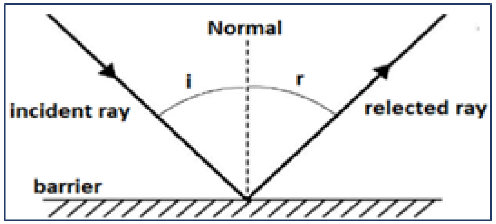
RPA Risk assessment:

- The ray box will **become hot** during use and may cause **minor burns**. To prevent this, you should **not touch the lamp** and ensure you allow time for the ray box to **cool** after use.
- You will be working in a **semi-dark** environment which means there is a higher risk of **trips or falls**. You should ensure your working space is **clear of bags and coats**, and that **stools** are tucked **under desks** before you start your investigation.

4.6.1.3 Reflection of Waves

- When a wave comes into contact with a surface or a boundary between two media (different materials), it can be reflected or it can be absorbed.
- What happens depends on the properties of the surface the wave hits.
- Specular reflection occurs when a wave is reflected in a single direction from a perfectly smooth surface.





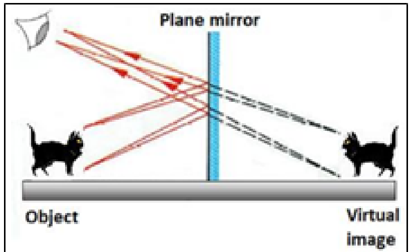
Key Terms 4.6.1.3

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 from a smooth surface, parallel rays are reflected in a single direction.
Diffuse	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

Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

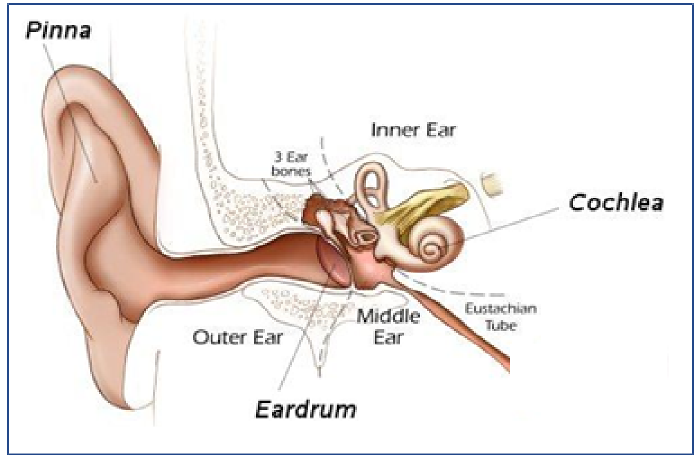
4.6.1.3 Image formed by a plane mirror

The image formed by a plane mirror is **virtual, upright and laterally inverted** (back to front but not upside down.)



4.6.1.4 Sound Waves (HT)

- A sound wave can travel through a **solid material**.
- This is because the **space between** the particles is so **small** (almost non-existent) and the vibrations are transmitted **more quickly** than in liquids or gases.
- The **speed of sound in air** is about **330m/s**. As the majority of space is **a vacuum** (no particles), sound waves do not travel in space.
- Sound waves within the range of **20Hz to 20kHz** can usually be detected by the **human** ear.
- **Vibrations** are passed along air particles down the **ear canal** and to the **ear drum**.
- The ear drum **vibrates** and **transmits** this to the **small ear bones** and then along the **cochlea**.
- The cochlea carries the vibrations to the **auditory nerve** which carries the sound wave as an **electrical impulse** to the **brain**.



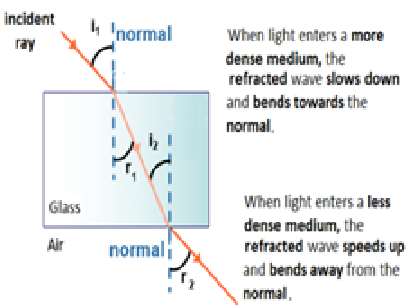
4.6.2.2 Refraction of light (HT)

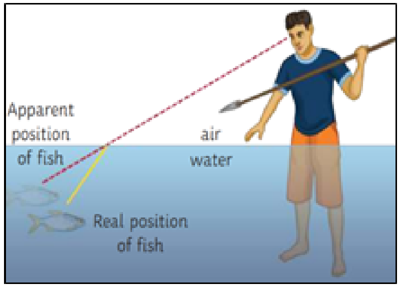
Refraction is a change in direction of waves when they travel across a boundary from one medium to another.

- When a light enters a more dense medium (air into glass) the angle of refraction r1 is less than the angle of incidence i1.
- When light enters a less dense medium (from glass into air,) the angle of refraction r2 is more than the angle of incidence i2.

Refraction occurs when a wave changes direction, usually at the boundary or two different materials. The density of the material affects the speed at which the wave can travel through it. When a wave passes from a more dense material to a less dense material, it speeds up and so will bend.

Imagine a car travelling across a muddy river at an angle. As it approaches the bank of the river, one of the wheels will be on the dry bank while the other is still in the mud. The wheel on the dry bank will move faster than the one still in the mud and it will change direction.





4.6.1.5 Waves for detection and exploration (HT)

- ❑ <u>Deep sea</u>: A high-frequency sound waves is sent out through the water & the time taken for the pulse to reflect back is measured.

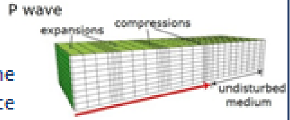
distance from object (m) = speed (of sound) (m/s) × time (s)

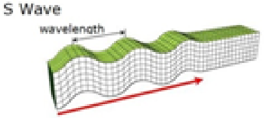
- ❑ <u>Earth structure</u>: Volcanoes, earthquakes and explosions cause seismic waves to travel through the earth.

- P-waves =**longitudinal** = travel **quickly** through **solids and liquids**.
- S-waves =**transverse** = travel **slower** and only in **solids**.

Seismic waves can **change direction** when they are reflected or refracted at the boundary of **different media** (solid, liquid or gas). The **epicentre** of an earthquake can be found by calculating the difference in **time taken** for S- and P-waves to reach a **certain point**. Since the waves can change direction, at **least three points** are used to triangulate the data and pinpoint the **source** (where they all **intercept**). The study of seismic waves has given scientists **new evidence** about the structure of the earth in parts which are **not visible** for **direct observations**.

- ❑ <u>Inside the Body</u>: Ultrasound = higher frequency than the range which is detectable by the human ear. When the waves reach a different media, they are **partially reflected** and a **detector** is used to measure the **time taken** and calculate the **distance**. Ultrasound is used for **medical** and **industrial imaging**.



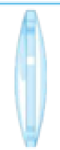


Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

4.6.2.5 Lenses

- Lenses use refraction in order to work.
- Projectors, microscopes and telescopes all use lenses to allow an object or image to be enlarged or viewed more easily.
- The human eye contains a lens which enables us to see objects at a range of distances.
- Depending on the type of lens, the light waves will be refracted differently to produce a different image.
- The two main lenses are convex lenses and concave lenses.

The table below compares them briefly.

convex lens	Lens	concave lens
⟷	Ray Diagram	>—<
	Illustration	
Causes parallel waves to **converge** at the principal focus.	Action	Causes parallel waves to **diverge** from the principal focus.
real or virtual	Type of Image	always virtual

- A **real image** is when light reflected from an object **converges** to form an image on a surface. For example, on the retina of the human eye.
- A **virtual image** occurs when the light waves are **diverging** and so appears to be coming from a different place. A virtual image **cannot** be projected onto a screen. For example, a **mirror** produces a **virtual image**.
- A **magnifying glass** uses a converging (convex) lens. It produces a **virtual image** which appears **larger** than the actual object.
- The **magnification** can be calculated using the equation:

$$\text{magnification} = \frac{\text{image height (mm)}}{\text{object height (mm)}}$$

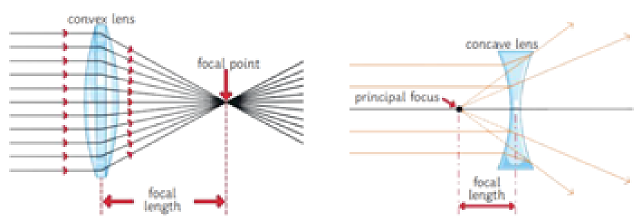
4.6.2.5 Lenses – Key Terms

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.

$$\frac{1}{\text{focal length}} = \frac{1}{\text{distance between lens and object}} + \frac{1}{\text{distance between lens and image}}$$

- **Focal length** depends on two factors: the **refractive index** of a material and **how curved** the surfaces of the lenses are.
- A **higher** refractive index makes the lens **flatter** in shape.
- To make a powerful lens **thinner**, a material with a higher refractive index can be used.
- Objects which are a distance **greater** than **one focal length** away from a converging lens will produce a **real image**.
- Objects which are **closer** than **one focal length** from the converging lens will produce a **virtual image**.
- The lens equation can be used to show the relationship between focal length, position of the object and position of the image: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

- An imaginary horizontal line through the middle of the lines is called the axis and this is where the principal focus forms.
- In a convex lens, the light rays enter the lens parallel to one another and then converge at the principal focus after the lens.
- In a concave lens, the light rays enter the lens parallel to one another and then diverge.
- The principal focus is the virtual source of the diverging rays before the lens



$$\text{power (D)} = \frac{1}{\text{focal length (m)}}$$

- D stands for dioptres which is the unit of measurement for lens power.
- In a converging lens the power is a positive value.
- In a diverging lens the power is a negative value.

4.6.2.6 Visible Light

The colours of the visible spectrum can be remembered with the rhyme:

Richard Of York Gave Battle In Vain

(red – orange – yellow – green – blue – indigo – violet)

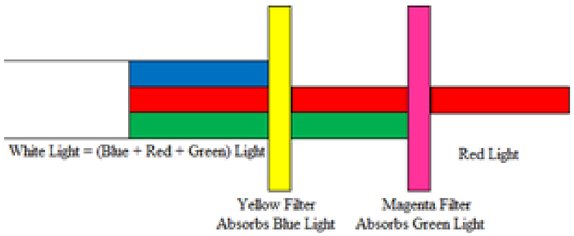
- ✓ These are all the wavelengths which are visible and detectable by the human eye.
- ✓ Each colour has a narrow range of wavelength and frequency within the spectrum.
- ✓ White light is the combination (full spectrum) of wavelengths in the visible light region of the electromagnetic spectrum.
- ✓ The Sun is a natural source for visible light waves and our eyes see the reflection of this sunlight off the objects around us.

Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

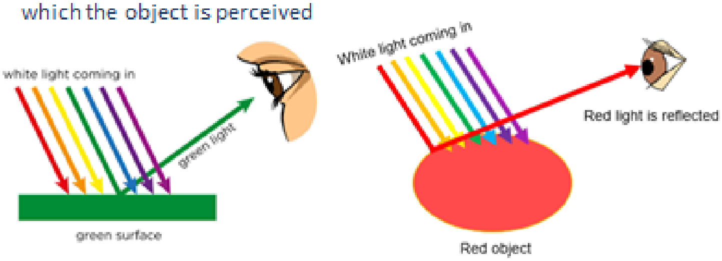
4.6.3 Black Body Radiation

4.6.3.1 Emission and absorption of infrared radiation

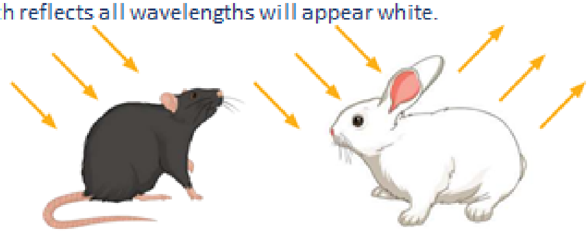
- A colour filter absorbs some wavelengths and only transmits certain wavelength(s).
- This means that a filter will absorb some colours and transmit others.
- E.g. red filter absorbs all other colours in the spectrum except red, which it transmits.
- Secondary colour filters allow only their primary colours through e.g.

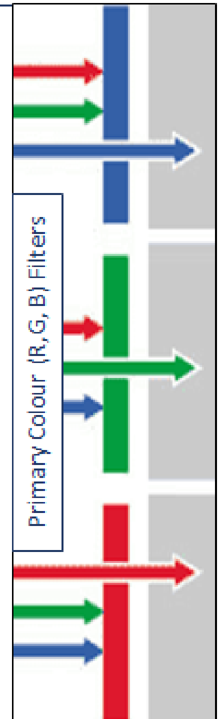


- An object which is transparent (see-through) or translucent (partially see-through) can transmit light.
- Opaque objects reflect and absorb light.
- The wavelengths which are reflected or absorbed determine the colour which the object is perceived



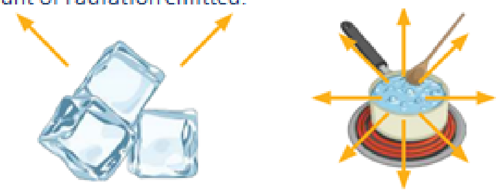
- An object which absorbs all wavelengths will appear black. An object which reflects all wavelengths will appear white.



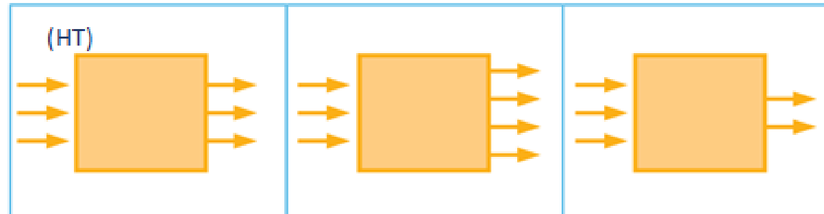


4.6.3.2 Perfect Black Bodies and Radiation

All objects emit and absorb infrared radiation. The hotter an object is, the greater the amount of radiation emitted.



- An object which **absorbs all** the radiation it is exposed to is called a **perfect black body**. **No** radiation is **reflected from** or **transmitted through** it.
- A perfect black body would be the **most effective** emitter
- An object which is a **good absorber** is *also* a **good emitter**.



An object **absorbing and emitting infrared radiation** at the **same rate** has a **constant temperature**.	An object **emitting more than it is absorbing** will **decrease** in **temperature**.	An object **absorbing more than it is emitting** will **increase** in **temperature**.

4.6.3.2 Temperature of the Earth (HT)

The temperature of the earth depends on:

- The rate at which light radiation and infrared radiation are absorbed by the earth's surface and atmosphere.
- The rate at which light radiation and infrared radiation are emitted by the earth's surface and atmosphere.

- Light and infrared radiation absorbed by the earth cause the **internal energy** of the planet to **increase** and in turn, the **surface** temperature of the earth **increases**.
- Energy from the surface of the earth can be transferred to the atmosphere by conduction and convection.
- The infrared radiation emitted from the earth's surface will either travel through the atmosphere and back into space or it will be absorbed (and reflected) by the greenhouse gases in the earth's atmosphere.

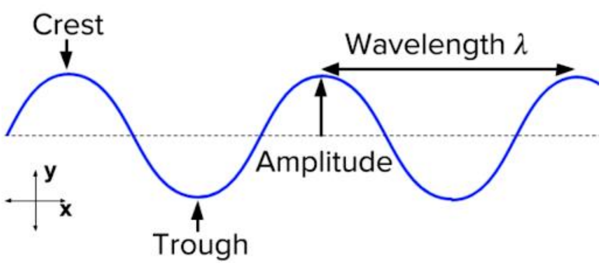
Knowledge Organiser – 6.6 Waves

6.6.1.1 Transverse and longitudinal waves

Waves can either be **transverse** or **longitudinal**.

1) Transverse waves

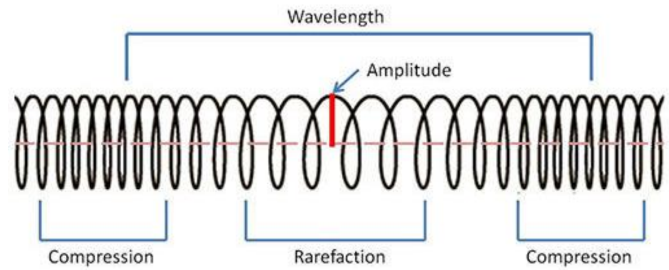
In **transverse** waves, the particles in the wave move **perpendicular** to the direction of the wave.
An example is a ripple on water or an electromagnetic wave.
It is the wave that travels NOT the water.



Remember: the waves move not the particles!

2) Longitudinal waves

In **longitudinal** waves, the particles in the wave move **parallel** to the direction of the wave. An example is a sound wave.



Remember: the waves move not the particles!

6.6.1.2 Properties of waves

Amplitude: the maximum displacement of a point on a wave from the undisturbed point.

Wavelength: the distance between a point on a wave and the same point on the next wave. Measured in metres (m).

Frequency: the number of waves passing a point each second. Measured in Hertz (Hz)

Period: time span of one wave in seconds

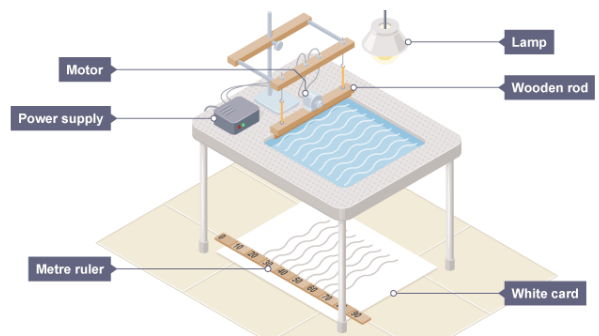
$$Period\ (T) = \frac{1}{Frequency\ (f)}$$

period, *T*, in seconds, s
frequency, *f*, in hertz, Hz

Wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. Measured in m/s

$$Wave\ speed\ (v) = frequency\ (f) \times wavelength(\lambda)$$

<u>RPA: Measuring frequency, wavelength and speed of waves in solid and a liquid</u>



Wavelength: Measure the length of a number of waves then divide by the number of waves to calculate the wavelength. It may be more practical to take a photograph of the card.

Frequency: Count the number of waves passing a point in ten seconds then divide by ten to record frequency.

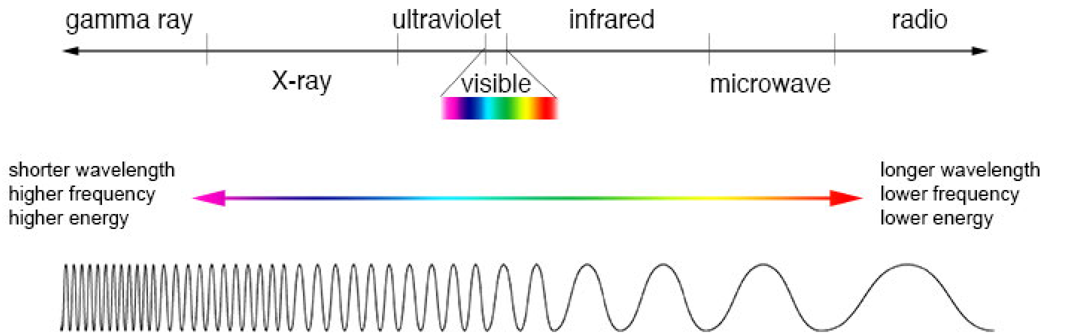
Wave speed: Calculate the speed of the waves using

$$Wave\ speed\ (v) = frequency\ (f) \times wavelength(\lambda)$$

Knowledge Organiser – 6.6 Waves

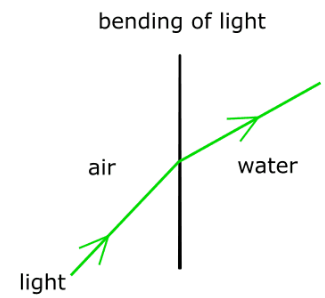
6.6.2.1 Types of electromagnetic waves

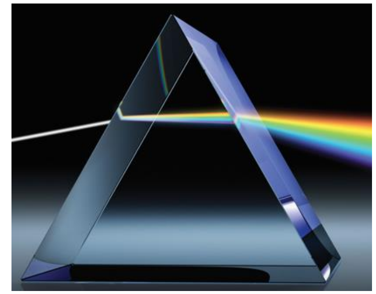
Electromagnetic waves are **transverse** waves that transfer energy from a source to an absorber. **All electromagnetic waves travel at the same speed as each other through a vacuum or air.**



6.6.2.2 Properties of electromagnetic waves 1

- (HT only) **Different substances** may **absorb**, **transmit**, **refract** or reflect electromagnetic waves in ways that **vary with wavelength.**
- (HT only) When electromagnetic waves meet a barrier of a **different density** they **change speed** and therefore direction. This is **refraction**..





6.6.2.3 Properties of electromagnetic radiation 2

Changes in **atoms and atomic nuclei** can generate or absorb electromagnetic radiation. Gamma rays, X-rays and ultraviolet waves are **ionising** and can have **hazardous effects** on human body tissues. The effect depends on the **dose and type** of radiation.

- UV rays can age skin prematurely and increase risk of skin cancer.
- Gamma rays and X-rays can mutate genes and cause cancer.

(HT only) **Radio waves** can be produced by **oscillations** in **electrical circuits**.
(HT only) 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 induce oscillations in an electrical circuit**.

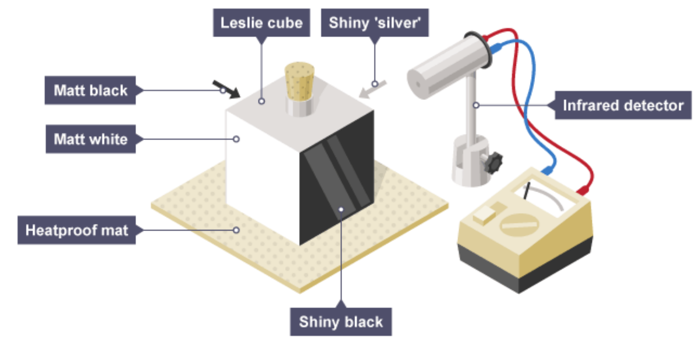
6.6.2.4 Uses and applications of electromagnetic waves

Different types of electromagnetic radiation have many uses:

- **Radio waves** – TV and radio
- **Microwaves** – Satellite communications and cooking food
- **Infrared** – Heating, cooking, and thermal cameras
- **Visible** – Fibre optic communication
- **Ultraviolet** – energy efficient lamps and sun tanning
- **X-ray and Gamma** – Medical imaging and treatment

(If higher tier you need to explain why each type of wave is suitable)

_RPA: Investigating the absorption or emission of IR radiation by nature of surfaces



1. Fill the **Leslie cube** with boiling water and replace the lid.
2.Leave for one minute to allow the surfaces to heat up.
3.Use the **infrared detector** to measure the intensity of infrared radiation emitted from each surface.

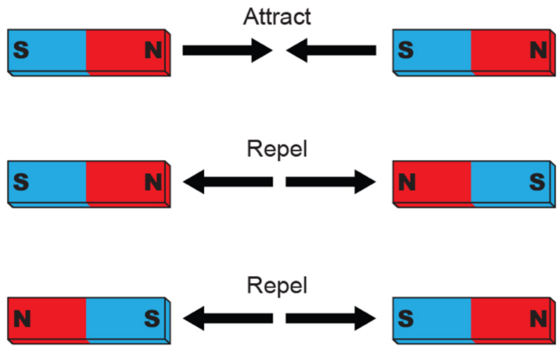
The **matte black surfaces emit** the **most** IR radiation.
The **shiny silver emits the least.**

Knowledge Organiser – 6.7 Magnetism and Electromagnetism

6.7.1.1 Poles of a magnet

The poles of magnet are where the magnetic forces are strongest. Two close together magnets will exert a non-contact force on each other.

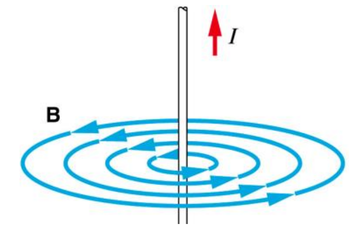
- Two opposite poles will attract (north and south).
- Two similar poles will repel (north and north or south and south).

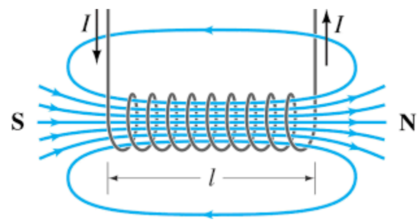


A **permanent** magnet **produces** its own magnetic field.
An **induced** magnet becomes a magnet when inside a magnetic field. Induced magnets lose their magnetism easily.

6.7.2.1 Electromagnetism

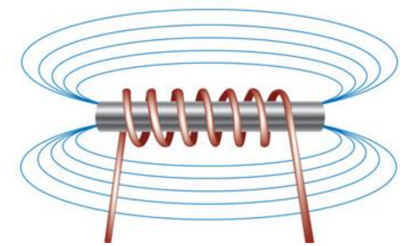
When a current flows through a wire a magnetic field is produced. The higher the current, the stronger the field.





If the wire is wrapped into a coil called a **solenoid** the magnetic field becomes **strong** and **uniform**. The magnetic field around a solenoid has a similar shape to that of a bar magnet.

Adding an iron core to a **solenoid** increases the strength of the magnetic field and turns it into an electromagnet.



How can we increase the strength of an electromagnet?

- **Increase the current**
- **Increase** the **size** and **number** of **coils**.

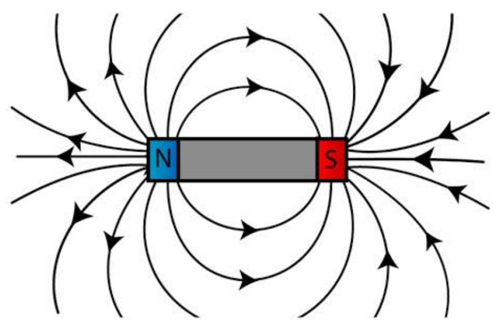
6.7.1.2 Magnetic field

magnetic field : the region around a magnet where a force acts on another magnet or on a magnetic material (iron, steel, cobalt and nickel)

The **field** of a **magnet** always **flows from the north pole to** the **south** pole.

The **strength** of the **field increases as the distance from the magnet decreases**.

Magnetic materials **always attract** a magnet and include **iron, cobalt, nickel, and steel**.



A **compass** is a small bar magnet that is attracted to the **Earth's magnetic field**. A compass can be used to draw a magnets field.

Knowledge Organiser – 6.7 Magnetism and Electromagnetism

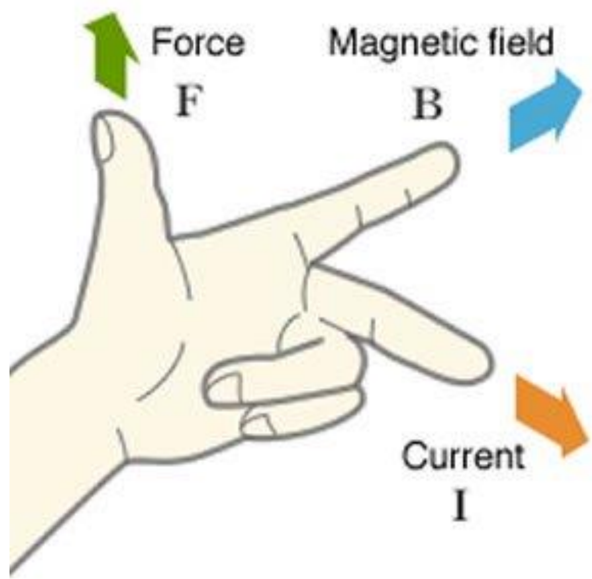
6.7.2.2. Fleming's left-hand rule (HT)

The **motor effect** 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 other.

The force on a given length of wire in a magnetic field increases when:

- The current in the wire increases.
- The strength of the magnetic field increases.

The force is greatest when the direction of the current is 90^{O} to the direction of the magnetic field.



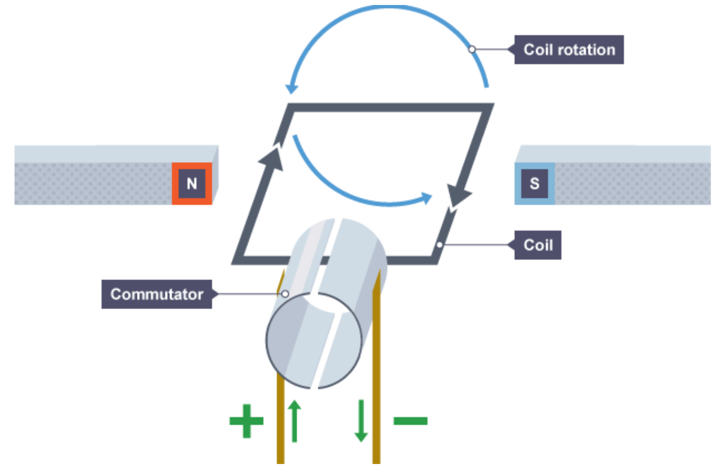
For a conductor at right angles to a magnetic field and carrying a current:

$$F = B \times I \times l$$

F = force measured in Newtons (N)
B = Magnetic flux density in tesla (T)
I = current in amperes (A)
l = Magnetic flux density in tesla (T)

6.7.2.3 Electric motors (HT)

A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor.



Starting from the position shown in the diagram of the **dc motor**:

1. current in the left hand part of the coil causes a downward force, and current in the right hand part of the coil causes an upward force
2. the coil rotates anti-clockwise because of these forces
3. When the coil is vertical, it moves parallel to the magnetic field, producing no force. This would tend to make the motor come to a stop, but two features allow the coil to continue rotating:
   - the momentum of the motor carries it on round a little
   - a **split ring commutator** changes the current direction every half turn
4. Once the conducting brushes reconnect with the commutator after a half turn:
5. current flows in the opposite direction through the wire in the coil
6. each side of the coil is now near the opposite magnetic pole
7. This means that the motor effect forces continue to cause anti-clockwise rotation of the coil.

Knowledge Organiser 4.8 Space Physics (Sep Physics)

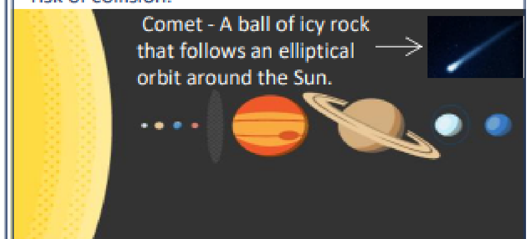
4.8.1.1 Our Solar System ;

- Our Sun is the only star in our solar system.
- There are 8 planets in our solar system.
- Moons are natural satellites.
- Our solar system is part of a galaxy called the Milky Way.
- The Sun formed from a cloud of gas called a nebula.
- The gas particles were attracted to each other by gravitational attraction.
- The start of our Sun was with gravity and fusion reactions which made an equilibrium between gravitational collapse and expansion due to fusion.

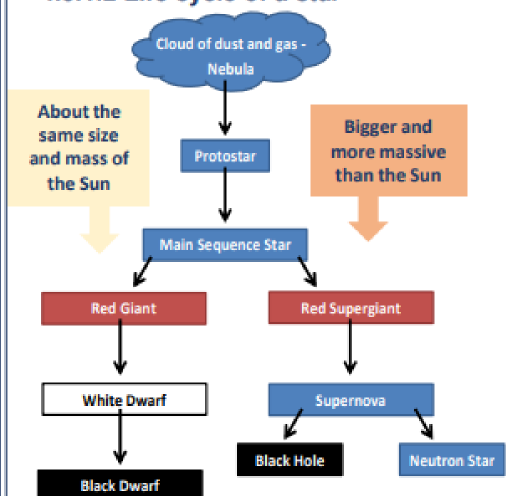
4.8.1.2 Life cycle of a star

- **Gravity** and **nuclear fusion** reactions drive the formation and development of stars.
- **Nebula**: A star forms from massive clouds of dust and gas in space, mostly composed of hydrogen.
- **Gravity** begins to pull the dust and gas together.
- **Protostar**: As the mass falls together it gets hot enough for the hydrogen nuclei to fuse together to make helium. Fusion process releases energy, keeping the core of the star hot.
- **Main sequence star**: Gravity holding the star together is balanced by higher pressure due to the high temperatures. The Sun is at this stable phase in its life.
- **Red giant star**: When all the hydrogen has been used up in the fusion process, larger nuclei begin to form and the star may expand to become a red giant.
- **White dwarf:** When all the nuclear reactions are over, a small star like the Sun may begin to contract under the pull of gravity. In this instance, the star becomes a white dwarf which fades and changes colour as it cools.
- **Supernova**: A larger star with more mass will go on making nuclear reactions, getting hotter and expanding until it explodes as a supernova.
- **Neutron star or black hole**: Depending on the mass at the start of its life, a supernova will leave behind either a neutron star or a black hole.

Universe - about 13.8 billion years ago all the matter in the Universe was concentrated into a single incredibly tiny point.
Galaxy - cluster of billions of stars
Star - large ball of burning gas
Planet - a celestial body moving in an elliptical orbit round a star.
Moon - natural satellite of a planet
Dwarf planet - a planetary-mass object that does not dominate its region of space (as a planet does) and is not a satellite.
Asteroid - A rock in space. Asteroids orbit the Sun but some may cross the Earth's orbit, producing a risk of collision.



4.8.1.2 Life cycle of a star



- **Stars about the same size as our Sun:**

follow the left hand path
main sequence star → red giant → white dwarf → black dwarf

- **Stars much bigger than our Sun:**

follow the right hand path
main sequence star → red super giant → supernova → neutron star or black hole

Main sequence stars

For most of its lifetime, a star is a **main sequence** star. It is stable, with balanced forces keeping it the same size all the time. During this period:

1. gravitational attraction tends to collapse the star
2. radiation pressure from the fusion reactions tends to expand the star
3. forces caused by gravitational attraction and fusion energy are balanced

The Sun is expected to be a main sequence star for billions of years.

Supernova (pl. supernovae)

All the naturally occurring **elements** in the Universe are produced by nuclear fusion reactions in stars. The heavy elements found on Earth, such as gold, came from material thrown out in previous supernova explosions.
For example, beryllium and carbon nuclei can be produced from helium nuclei:

$$^4_2\mathrm{He} + ^4_2\mathrm{He} \to ^8_4\mathrm{Be}$$

(two helium nuclei join to form a beryllium nucleus)

$$^4_2\mathrm{He} + ^8_4\mathrm{Be} \to ^{12}_6\mathrm{C}$$

(a helium nucleus and a beryllium nucleus join to form a carbon nucleus)

Fusion reactions

In a main sequence star, hydrogen nuclei fuse together to form helium nuclei. This happens in several steps, but one way to simplify the overall change is:

$$^2_1\mathrm{H} + ^3_1\mathrm{H} \to ^4_2\mathrm{He} + ^1_0\mathrm{n}$$

Two hydrogen nuclei fuse to produce a helium nucleus and a neutron.
The Big Bang produced **hydrogen** and **helium**. All the **other elements** have been produced by nuclear fusion reactions in stars and supernova explosions.

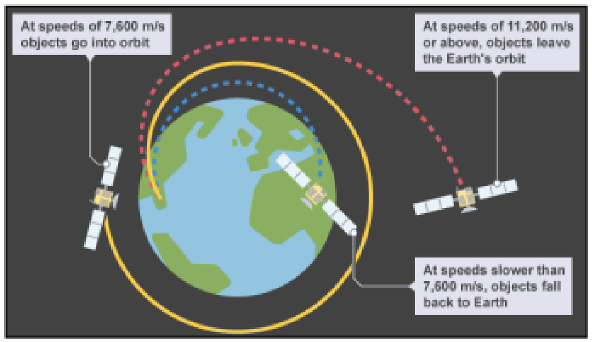
Knowledge Organiser 4.8 Space Physics (Sep Physics)

4.8.1.3 Orbital motion, natural and artificial satellites;

- Moons are natural satellites
- Elliptical orbits, are oval or egg-shaped and may take millions of years to complete.
- For an object to remain in a steady, circular orbit it must be travelling at the right speed.
- Artificial satellites are put into orbits around a planet by humans.
- **HT –** must be able to explain why satellites move with acceleration at a constant speed
  - ➢ it is the changing direction that makes it acceleration
- In circular orbits the force of gravity can lead to changing velocity but unchanged speed.
- **HT –** the relationship between radius of orbit and the speed at which the satellite orbits –
  - ➢ and it is … for a stable orbit of a satellite the…..

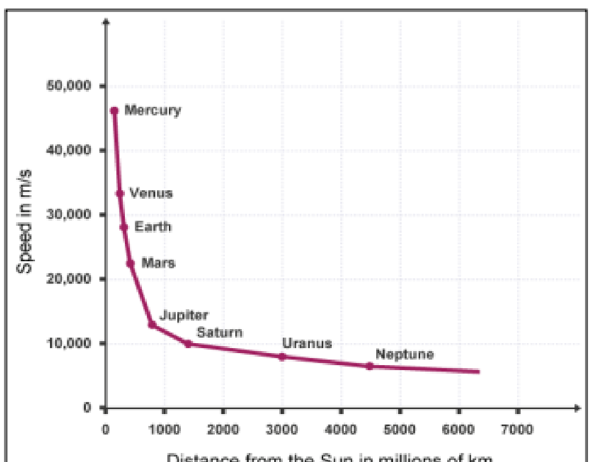
CLOSER TO THE PLANET A SATELLITE ORBITS, THE FASTER IT MUST MOVE.

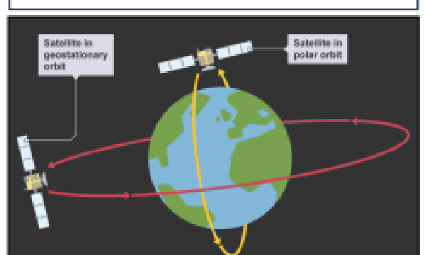
- Therefore, the further away from the planet the orbit is, the slower the satellite must move.



There are three possible outcomes:

1. If the satellite is moving too quickly then the gravitational attraction between the Earth and the satellite is too weak to keep it in orbit. If this is the case, the satellite will move off into space. This occurs at speeds around or above 11,200 metres per second (m/s).
2. If the satellite is moving too slowly then the gravitational attraction will be too strong, and the satellite will fall towards the Earth. This occurs at speeds below 7600 m/s.
3. A stable orbit is one in which the satellite's speed is just right - it will not move off into space or spiral into the Earth, but will travel around a fixed path.





4.8.2 Red-Shift

The Universe of full of galaxies which are **moving away from us.**

- There are huge distances between the distance between each one and between each galaxy & Earth.
- On Earth we can see the light from distant stars and galaxies.
- Light has different wavelengths and colour.
- The faster the galaxies are moving, the further away from us they are.
- This makes the light from the distant galaxies appear red – the longest wavelength of the electromagnetic spectrum.

These are what you need to explain:

- Red- shift means that distant galaxies are receding and moving faster away from us
- Since 1998, observations tell us that the furthest galaxies are receding ever faster
- This receding and fast movement tells us that the Universe is expanding
- The red-shift helps us give evidence for the Big Bang model.
- We observe the night sky and beyond and from centuries of observations using telescopes – scientists have put the model of the Big Bang to explain how it all started!
- We do not know much really – especially dark matter and dark energy.

The Big Bang is how astronomers explain the way the universe began. It is the idea that the universe began as just a single point, then expanded and stretched to grow as large as it is right now (and it could still be stretching).
This 'stretching' is what we see as the red-shift. This is very important …..
'the Universe began from a very small region that was extremely hot and dense' (exam words)
Astronomers have also discovered a cosmic microwave background radiation (CMBR). This comes from all directions in space and has a temperature of about -270 °C. The CMBR is the remains of the thermal energy from the Big Bang, spread thinly across the whole **Universe**.

Prediction from Big Bang theory	Evidence observed	Does evidence support the Big Bang theory?
More distant galaxies should move away faster	More distant galaxies have greater red-shift	Yes
Initial Big Bang heat should now be thinly spread across the whole Universe	CMBR is everywhere at a temperature of about -270°C	Yes