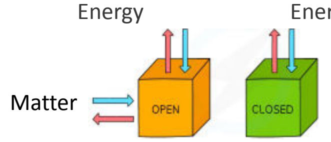
Energy

Keyword	Definition
Efficiency	Proportion of supplied energy which is transferred usefully (carries out intended task)
Energy transfer	Energy can be transferred usefully, stored or dissipated but cannot be created or destroyed
Insulator	A material with a low thermal conductivity
Power	Rate at which energy is transferred in unit time
Renewable	A resource which can be replenished as it is being used
System	A group of objects which interact
Thermal conductivity	A measure of how fast heat can transfer through a material
Work done	A measure of energy when a force moves an object through a distance

Energy system

- Energy will often be described as part of an energy **system**
- In physics, a system is defined as:
  An object or group of objects
- When describing the changes within a system, only the objects or group of objects and the surroundings need to be considered
- A system, for example, can be **closed** or **open**
  - An **open system** allows the exchange of energy and matter to or from its surroundings
  - A **closed system** can exchange energy but not matter to or from its surroundings



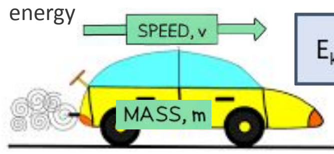
Energy Store	Description
Magnetic	Energy due to the force of attraction (or repulsion) between 2 magnets
Elastic	Energy stored in a stretched spring or stretched elastic band
Nuclear	Energy contained within the nucleus of an atom
Gravitational potential	Energy an object has due to its position from the ground
Electrostatic	Energy due to the force of attraction (or repulsion) between 2 charged objects
Thermal	Energy a substance has due to its temperature
Chemical	Energy found in fuels, foods or batteries.
Kinetic	Energy an object has because it is moving

Kinetic energy

The kinetic energy (E_k) of an object (also known as its kinetic store) is defined as:

The energy an object has due its mass and speed

This means that any object in **motion** has kinetic energy

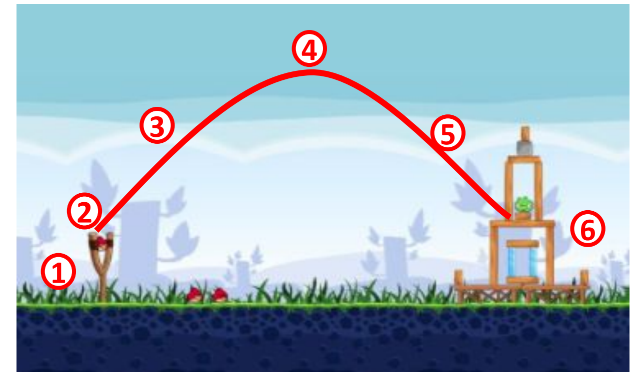


$E_k = \frac{1}{2}\ m\ x\ v^2$

Power

Power is the **rate at which energy is transferred.**
In other words, **power is the rate of doing work**.
The unit of power is the watt, **W**
A power rating of **one watt means one joule of energy is transferred per second**,
or **1 joule of work is done in 1 second**.
1 watt = 1 joule per second 1W = 1 J/s

Changes in stores example



In this case the system is the catapult, the angry bird projectile and the target blocks. The energy stored in the stretched catapult is the maximum amount of energy available.

1 = Elastic potential energy is stored in the stretched catapult
2 = The elastic store (Ee) decreases and is transferred to the kinetic store (Ek) in the bird
3 = As the height increases the gravitational potential energy store (Ep) increases and the kinetic store(Ek) is decreasing
4 = At the top of the trajectory the Ep is at a maximum and the Ek is at a minimum
5 = As the projectile falls the Ep store will decrease and the Ek will increase again
6 = The bird is back to the original height, so the Ep has reduced to zero and the Ek is back at a maximum
For calculations we assume perfect energy transfers, however no energy transfer is perfect in reality and some energy will be transferred to the surroundings (dissipated) as thermal energy into the thermal energy store. When producing a physics model for a game such as angry birds only perfect energy transfers will be considered.

Thermal conductivity

The **thermal conductivity** of a material is a measure of its ability to conduct **heat.** The direction of heat transfer is **hot** to **cold**
The higher the thermal conductivity of a material, the higher the rate of energy transfer by conduction across the material
Materials with **high** thermal conductivity **heat up faster** than materials with **low** thermal conductivity.
If a house was built of materials with a high thermal conductivity, they would be very cold to live in as thermal energy would be able to leave the house easily.

Equations to learn

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

Kinetic Energy (J) = ½ x mass (kg) x speed² (m/s)

$$E_p = mgh$$

Gravitational Energy (J) = mass (kg) x gravitational field strength (N/kg) x height change (m)

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

Power (W) = Energy transfer (J) / time **(s)** or Power (W) = Work done(J) / time(s)

$$efficiency = \frac{useful\ power\ output\ (W)}{total\ power\ input\ (W)}$$

$$efficiency = \frac{useful\ output\ energy\ transfer\ (J)}{total\ input\ energy\ transfer\ (J)}$$

Equations given

$$E_e = \frac{1}{2}ke^2$$

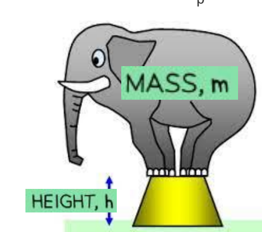
Elastic Energy (J) = ½ x spring constant (N/m) x extension² (m)

Gravitational potential energy

The gravitational potential energy (E_p) of an object (also known as its gravitational store) is defined as:

The energy an object has due to its height in a gravitational field

This means:
If an object is lifted up it will **gain** E_p
If it falls, it will **lose** E_p



Ep =m x g x h

Energy dissipation

Dissipation is a term that is often used to describe ways in which energy is wasted. Any energy that is not transferred to useful energy stores is said to be wasted because it is lost to the surroundings
A mechanical brake applies a friction force to convert the kinetic energy of the vehicle into thermal energy which then dissipates into the atmosphere.

Energy Resources	Renewable	Transport	Electricity generation	Heating	Reliable	Produces CO_2	Environmental impact
Fossil fuels		✔	✔	✔	✔	✔	Greenhouse effect, pollutant gases
Nuclear fuel			✔		✔		Waste storage, accidents have long lasting effect
Biofuel	✔	✔	✔	✔	✔	✔	Farmland could be used for food
Wind	✔	✔	✔				Noisy. Some think wind farms are ugly
Hydro-electricity	✔		✔		✔		Dams flood farmland, loss of habitat
Geothermal	✔		✔	✔	✔		Large ugly buildings, loss of habitat
Tidal	✔		✔				Can affect life in estuaries, change/affect habitat
Solar	✔		✔	✔			Mining of rare metals for solar cells
Wave	✔		✔				Can affect sea life

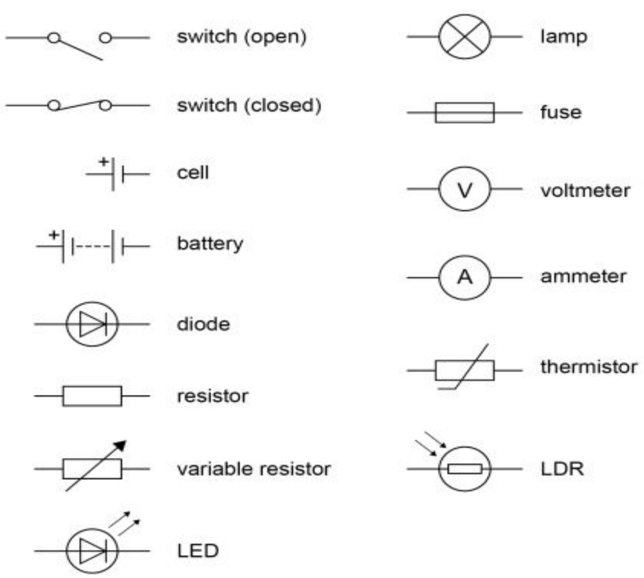
Useful YouTube links:

Energy resources Energy stores Power

Physics - Electricity

Keyword	Definition
Alternating	When a potential difference (or current) changes polarity from + to – (or reverses direction)
Current	The rate of flow of charge measured in amperes. Measured using an ammeter in series. Conventional current flows from + to – .
Directly proportional	Results which when graphed give a **straight line through the origin (0.0)**
Electric field	Area around a charged object that can have an effect on other charged objects.
Mains electricity	In the U.K. domestic mains electricity is an ac supply. It has a frequency of 50 Hz and is 230V
Potential difference	The 'push' in a circuit which causes current to flow, measured in volts using a voltmeter in parallel in a circuit.
Power	Energy transferred per second. Measured in watts W.
Resistance	Restriction of the flow of current measured in ohms. Can be measured in a circuit using an ohm meter or by dividing the voltage by the current.

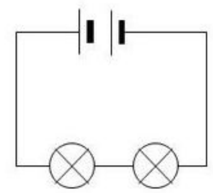
Circuit Symbols



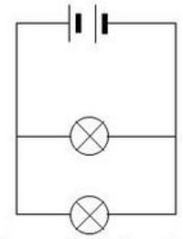
Resistors are used to control or change the current.
Fixed resistors are used to lower the current.
Variable resistors, thermistors and LDRs (light dependent resistors) can change their resistance and change the current.
Variable resistors can be changed by moving a slider or turning a dial.

Types of circuit

Series



Parallel

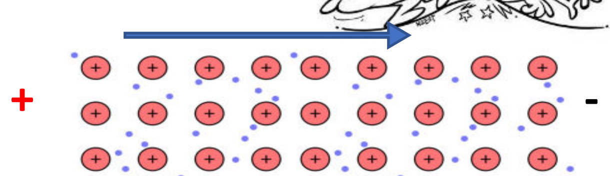


In a series circuit	**In a parallel circuit**
Components make one continuous path	Components are placed in more than one path
Current is the same in all parts of the circuit.	**The current is split between the branches of the circuit.**
The potential difference is shared by the components in proportion to their resistance	The potential difference is the same in each path
The total resistance is the sum of all the individual resistances	The total resistance is less than that of the path with the smallest resistance

	Series	Parallel
Current	Constant in all parts $I_1 = I_2 = I_3$	Split between the branches based on the resistance $I_{total} = I_1 + I_2 + I_3$
Voltage	Shared by the components $V_{total} = V_1 + V_2 + V_3$	All components get the full voltage $V_{total} = V_1 = V_2 = V_3$
Resistance	Sum of the individual resistances $R_{total} = R_1 + R_2 + R_3$	Less than the smallest resistance in the circuit

Resistance

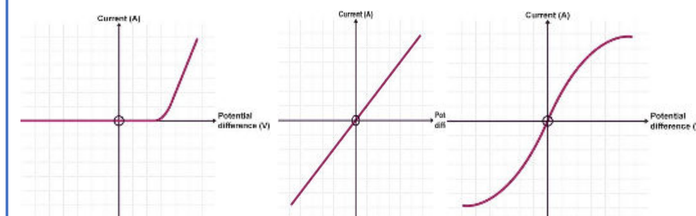
Resistance makes it harder for current to flow. A greater potential difference will cause more current to flow.



Electrons in a wire must move past the metal ions. They collide with the ions and transfer energy to them, heating the wire up. The hotter a wire is the more the metal ions vibrate. This makes it harder for the electrons to move past them.

The hotter a wire is, the greater its resistance.

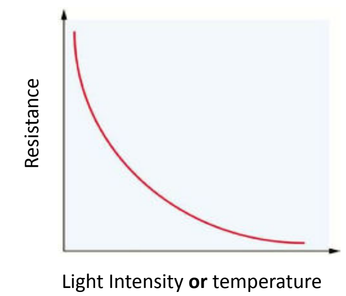
Current - Voltage graphs



Diodes have high resistance in one direction and low resistance in the other	Resistors at a constant temperature have a constant resistance so constant gradient	As the bulb temperature increases so does the resistance, giving a changing gradient

LDRs and Thermistors

Both behave in similar ways.
As light intensity or temperature increases, the resistance of the component decreases.
These components can be used for sensing – e.g., thermistors in thermostats, LDRs to turn lights on when it gets dark.



Equations to know

Power (W) = Current (A) x Potential Difference (V)
P = I x V

Power (W) = Current (A)^2 x Resistance (Ω)
$P = I^2 x R$

Potential Difference (V) = Current (A) x Resistance (Ω)
V = I x R

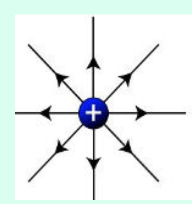
Energy (J) = Potential Difference (V) x Charge (C)
E = V x Q

Charge (C) = Current (A) x Time (s)
Q = I x t

Energy (J) = Power (W) x Time (s)
E = P x t

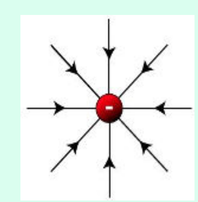
Static Electricity – Physics only

A static charge is produced when two different insulators rub together.
The friction causes **electrons** to transfer from one material to another.
The material that gains the electrons becomes negative; the material that loses electrons becomes positive.
The size of the charges is equal.



Fields

When an object becomes charged it is surrounded by an electric field.
The field radiates out from the positively charged object and in to the negatively charged object.
The field is strongest close to the object.

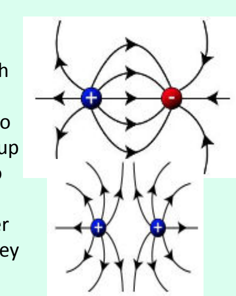


Sparking

When an object gains a static charge, it gains a potential difference.
If the charged object is brought close to an object at a lower potential difference, or one which is Earthed a spark can jump between them. A spark is the electrons moving from a high potential difference to a low potential difference

Attract and repel

When two charged objects are brought near to each other they attract or repel.
Objects with opposite charges attract – this is due to the electric field lines from the two objects joining up
Objects with the same charges repel – this is due to the field lines not joining up between the object.
The larger the charge on the objects and the smaller the distance between them, the bigger the force they will experience.



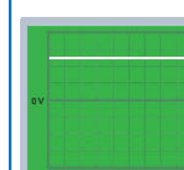
Direct and Alternating Current

AC

Alternating current is produced by a potential difference which changes polarity from + to -
This means the current changes direction of flow.
The national grid uses AC

Higher Tier – Frequency is 1/time period
The peak potential difference is measured from the central 0V position

DC



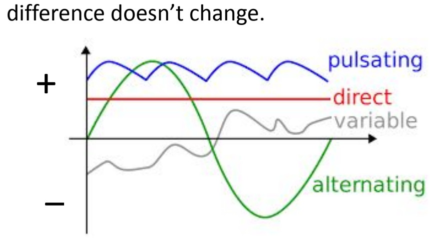
Direct current does not change as the potential difference producing it is constant.
The current flows one way.
Battery operated devices use DC

Alternating potential difference

This is where the polarity of the potential difference changes from positive to negative.

Direct potential difference

This is where the polarity of the potential difference doesn't change.



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Energy transfers in electrical devices

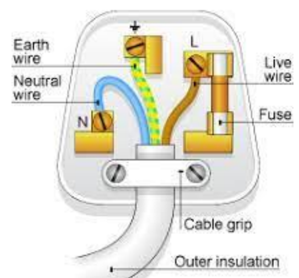
The purpose of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful. The other way of saying this is that work is done when charge flows in a circuit.

Most appliances we use, transfer energy from the AC mains. For example:
To the kinetic energy store of a motor, which are used commonly in refrigerators to compress the refrigerant chemical into a liquid to reduce the temperature.
Or to the thermal energy store of heating devices, such as kettles to heat water.
A washing machine transfers electrical potential energy from the AC mains supply to kinetic energy in the electric motor (to spin the drum), along with thermal energy (heat). Eventually, all the energy of the input is dissipated to the surroundings.

The amount of energy transferred by an appliance depends on the power of the appliance and the time it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for. **E = Pt**
Also, since potential difference. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the potential difference. **E=QV**

Three core cable

Most electrical appliances are connected to the mains using three core cable, the insulation around these helps us identify which wire is which.



live wire – brown
neutral wire – blue
earth wire – green and yellow stripes.

Wire	Function
Live	Carries the alternating potential difference from the power supply.
Neutral	Takes the electric current back to the source to complete the circuit.
Earth	This is the safety wire. There could be an electrical fault in the circuit, which could happen when the live wire loosens and touches the casing. To prevent this, the Earth wire gives the current an alternative path to flow, which also prevents the appliance from operating.

- The potential difference between the live wire and earth at 0 V is about 230 V.
- The neutral wire is at, or close to, earth potential (0 V).
- The earth wire is at 0 V, it only carries a current if there is a fault.

Earth, fuse and safety
If the case of an appliance becomes live due to a fault, the earth wire provides a **low resistance path** to the Earth. This causes a **surge** of current in the **earth wire** and hence also in the live wire. The high current through the thin metal wire in the **fuse** causes it to melt and break. This cuts off the supply of electricity to the appliance, making it **safe** to touch.
Safety notes:
Even if a circuit is switched off (i.e., the switch is open), the live wire can still be dangerous. If you touch it, you may complete a circuit between the live wire and the earth (because you'll be standing on the floor), so you get a shock.
The live wire is the most dangerous one, since it is at 230 V. it should never touch the earth wire (unless the insulation is between them, of course!), because this would make a complete circuit from your mains supply to the ground (earth). A shock or fire would be highly likely.

Power

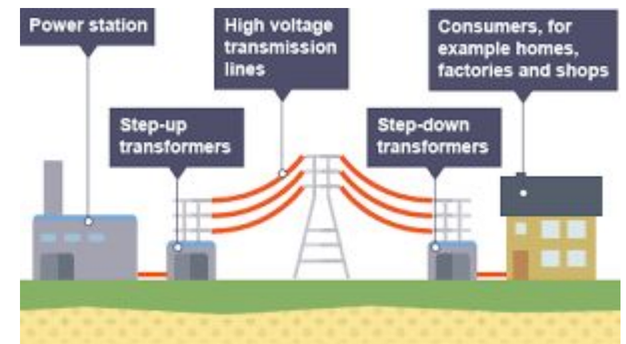
The power of a circuit represents the energy transferred per second. It is measured in Watts where 1W = 1 Joule per second.

These equations can be used to calculate power:

Power(W) = Voltage(V) × Current(A)
Power(W) = Current(A)^2 × Resistance(Ω)
Energy(J) = Power(W) × Time(s)

National Grid

The National Grid is a network of cables and transformers which connects every power station to every home, shop, school, hospital etc. Demand for power changes due to the seasons, weather and time of day. For example, at the end of a popular sports TV programme there is a sudden demand for electricity as people put their kettles on at the same time. To meet this demand, the National Grid switches on extra hydroelectric power stations or buys extra electricity from abroad.



There are two types of transformers; together they improve the efficiency of the energy transfer from power station to homes and schools etc.:

- Step-up transformers increase the potential difference from the power station to the transmission cables.
- This reduces the current
- So, less energy is lost as thermal energy.
- This increases the efficiency of transfer.
- Step-down transformers decrease the potential difference from the cables to a much lower value (230V, generally) for domestic use. This increases the current again which is suitable for the appliances we use.

Equations to know

Power (W) = Current (A) x Potential Difference (V)
$P = I \times V$

Power (W) = Current (A)^2 x Resistance (Ω)
$P = I^2 \times R$

Potential Difference (V) = Current (A) x Resistance (Ω)
$V = I \times R$

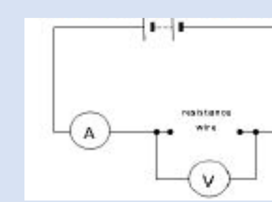
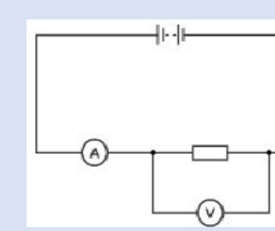
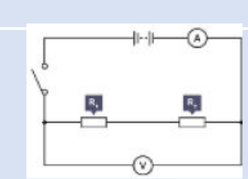
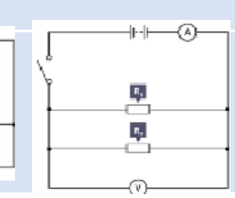
Energy (J) = Potential Difference (V) x Charge (C)
$E = V \times Q$

Charge (C) = Current (A) x Time (s)
$Q = I \times t$

Energy (J) = Power (W) x Time (s)
$E = P \times t$

Useful YouTube links:

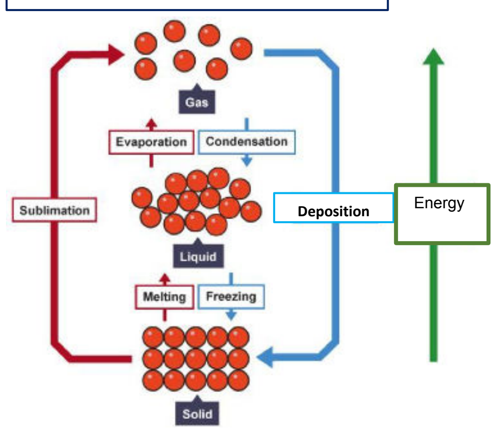
Required Practical's

How does the length of a wire affect its resistance?	Independent: length of wire Dependent: resistance (determined by measuring I and V and then R=V/I) Control: temperature, wire thickness	
Investigate current – voltage graphs for , a resistor, a bulb and a diode,	This set-up is used to collect data to plot an I-V graph for a resistor. (just remove the resistor and add the bulb or diode for the other practical's). Ammeters are always connected in series and voltmeters in parallel. The variable resistor alters the pd. Take a minimum of 6 values of V and I. To obtain negative values, just reverse the connections to the power supply.	
What happens to resistance in series and parallel circuits?	Use R=V/I to determine total R.	 

Physics Particles – Year 9

Keyword	Definition
Condensing	Change of state from a gas to a liquid
Compression	Squeezing or pressing together.
Density	Mass per unit volume of a substance, e.g. kg/m^3.
Deposition	Change of state from a gas to a solid
Displacement	Distance in a given direction.
Evaporation	Change of state from a liquid to a gas
Freezing	Change of state from a liquid to a solid
Mass	The quantity of matter in an object (measured in kilograms, **kg**).
Melting	Change of state from a solid to a liquid
States of Matter	Solids, liquids or gases
Sublimation	Change of state from a solid to a gas
Temperature	A way of indicating the average kinetic energy of the particles in a substance.
Vibrate	To oscillate (move to and fro) around a certain position.

Changes in State



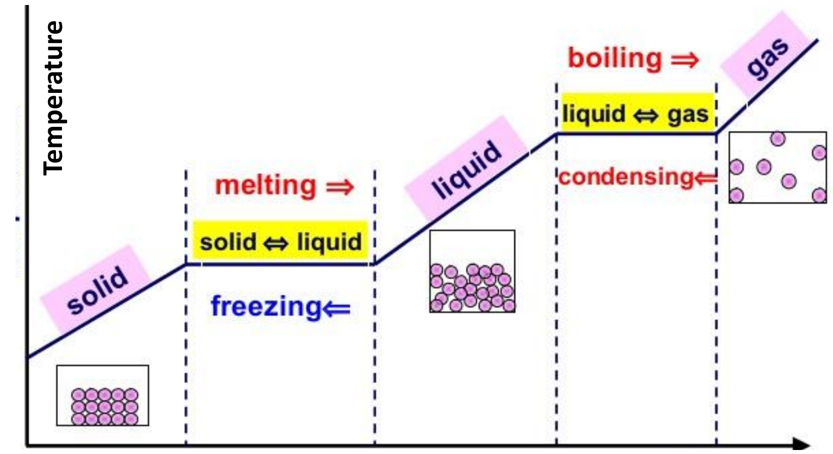
- Changes of state are physical changes.
- Heating will cause an increase in energy, causing a change in the motion or the arrangement of the particles.

The States of Matter

State	Solid	Liquid	Gas
Closeness of particles	Very close	Close	Far apart
Arrangement of particles	Regular pattern	Randomly arranged	Randomly arranged
Movement of particles	Vibrate around a fixed position	Move around each other	Move quickly in all directions
Energy of particles	Low energy	Greater energy	Highest energy
2D diagram			

The three **states of matter** are solid, liquid and gas. The **particle model** represents **particles** by small, solid spheres. It describes the arrangement, movement and **energy** of particles in a substance. The model can be used to explain the **physical properties** of solids, liquids and gases

Changes in State



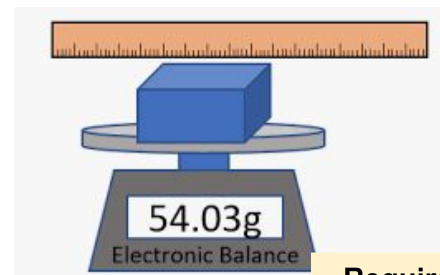
- When a substance gains thermal energy the temperature line increases in value
- When a substance is changing state, the line remains constant.

Mathematical Skills:

- *Be prepared to interpret graphs showing the temperature of a substance against the energy it has been provided; being able to describe the state of matter / changes of state at various points.*

Density of a Regular Object

- Use a ruler to measure the length (*l*), width (*w*) and height (*h*) of the object.
- Place the object on the balance and measure its mass.
- Calculate the volume of the cube using (l × w × h).
- .Using the equation density = mass ÷ volume, divide the mass value by the volume value to calculate the density



Required Practical

Limitations of the Particle Model

The particle model assumes that particles are the same in all substances. However, particles in real life may be different from element to element in the following ways:

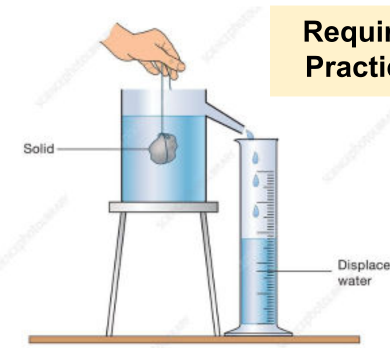
- mass or size
- the force of attraction to other particles
- energy
- diagrams only show 2 dimensions
- Particles are drawn in diagrams as solid spheres

Density of an Irregular Object

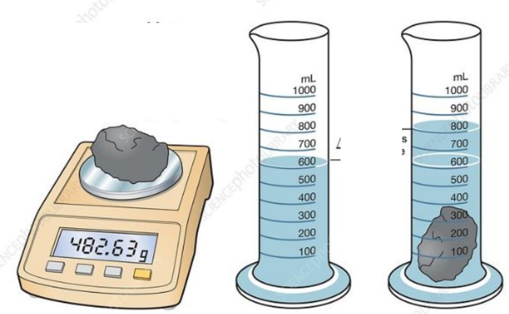
Required Practical

Step 1
- Take the mass of the object using a balance

Step 2 (method using Eureka (displacement) can)
- Tie string around the object
- Fill the Eureka can with water up to the spout
- Fully submerge.the object under the water
- Catch the displaced water in a measuring cylinder
- Volume of water displaced = volume of the object

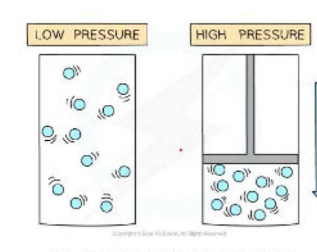


Step 2 (method using measuring cylinder)
- Fill the measuring cylinder with enough water to submerge the object
- Take a reading of the initial volume
- Place the object in the water and measure the final volume.
- Calculate the volume of the object by final volume – initial volume = object volume



Step 3
- Using the equation density = mass ÷ volume, divide the mass value by the volume value

Gas Pressure & Temperature



- If there are more particles in a container, there are more collisions with the walls of the container – so pressure is higher.
  If the particles are heated, they gain more kinetic energy, so the collisions with the wall are more frequent – so pressure increases

Equation to learn

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

Relevant Modules:

- Energy Changes in systems
- Atomic Structure

Useful YouTube links:

Density

Physics – Particles – Part 2

Keyword	Definition
Internal energy	The energy of the particles within a substance due to their individual motion and positions.
Latent heat	The energy transferred to or from a substance when it changes its state.
Mass	The quantity of matter in an object (measured in kilograms, **kg**).
Specific heat capacity	The energy needed to raise the temperature of 1 kg of a substance by 1°C.
Specific latent heat of fusion	The energy needed to change the state of 1 kg of a substance between solid and liquid states, with no change of temperature.
Specific latent heat of vaporisation	The energy needed to change the state of 1 kg of a substance between liquid and gaseous states, with no change of the temperature.
Temperature	A way of indicating the average kinetic energy of the particles in a substance.
Vibrate	To oscillate (move to and fro) around a certain position.

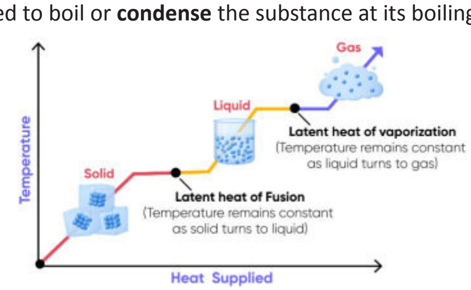
Specific Latent Heat

The energy required for a particular change in state is given by the **specific latent heat.**

Specific latent heat is the amount of energy required to change the state of 1 kilogram (kg) of a material without changing its temperature.

As there are two boundaries, solid/liquid and liquid/gas, each material has two specific latent heats:

- The latent heat of fusion - the amount of energy needed to **melt** or **freeze** the substance at its melting point
- The latent heat of vaporisation - the amount of energy needed to boil or **condense** the substance at its boiling point.



Internal Energy

Internal energy is defined as:

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

The molecules within a substance have energy in their:

- **Kinetic store** (due to their random motion / vibration)
- **Potential store** (due to their position relative to each other)

Together, these stores form the total energy that makes up the internal energy of the system.

Internal energy and change of state.

When a substance reaches the temperature it changes state, energy will stop being transferred to the kinetic store of the molecules and energy will be transferred to their potential store instead

This energy is now used to overcome the intermolecular forces of attraction between the molecules, causing them to move further apart from each another and leading to a **change of state.**

For example, solid to a liquid

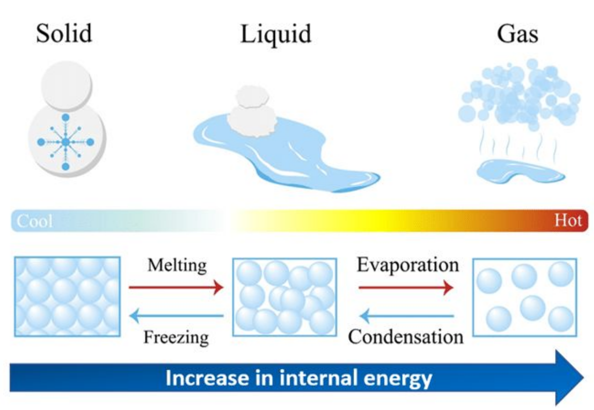
When a substance changes its state:

- The **potential energy** of the molecules **increases**, allowing them to overcome the **intermolecular forces of attraction**
- The **kinetic energy** remains the **same**, meaning that the **temperature** will remain the same, even though the substance is still being heated.

Internal energy and heating.

Heating a system changes a substance's internal energy by **increasing the kinetic energy** of its particles

- The **temperature** of the substance is related to the average kinetic energy of the molecules
- The higher the temperature, the higher the kinetic energy of the molecules and vice versa
- This means they move around **faster**



Calculating thermal energy changes

The amount of **thermal energy** stored or released as the temperature of a system changes can be calculated using the equation:

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

$E = m \times L$

Where:

- E = change in thermal energy, measured in joules (J)
- m = mass, measured in kilograms (kg)
- L = specific latent heat, (measured in joules per kilogram (J/kg)

This equation is given to you in the exam

Specific Heat Capacity

Heating materials

When materials are heated, the **molecules** gain **kinetic energy** and start moving faster. The result is that the material gets hotter.

Temperature is a measure of the average kinetic energy of the molecules.

Different materials require different amounts of energy to change temperature. The amount of energy needed depends on:

- The mass of the material
- The substance of the material (**specific heat capacity**)
- The desired temperature change

It takes less energy to raise the temperature of a block of aluminium by 1°C than it does to raise the same amount of water by 1°C. The amount of energy required to change the temperature of a material depends on the specific heat capacity of the material.

Calculating thermal energy changes

The specific heat capacity of a material is the energy required to raise one kilogram (kg) of the material by one degree Celsius (°C).

The amount of **thermal energy** stored or released as the temperature of a system changes can be calculated using the equation:

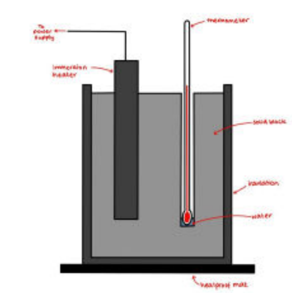
change in thermal energy = mass × specific heat capacity × temperature change

$\Delta E = m\ c\ \Delta\theta$

Where:

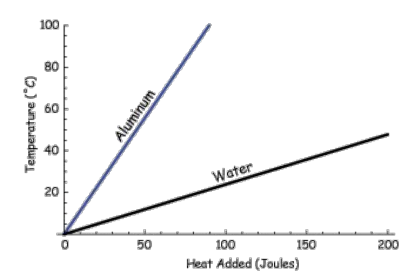
- **ΔE = C**hange in thermal energy, measured in joules (J)
- m = mass, measured in kilograms (kg)
- c= specific heat capacity, measured in joules per kilogram per degree Celsius (J/kg°C)
- **$\Delta\theta$ =** temperature change, measured in degrees Celsius (°C)

Specific Heat Capacity required practical



Method

1. Measure and record the mass of the metal block in kg.
2. Place a heater in the larger hole in the block.
3. Use the pipette to put a small amount of oil or water in the hole to increase thermal contact.
4. Put the thermometer in this hole.
5. Switch the power pack to **12V**. Turn it on.
6. Measure the temperature and start the stop clock.
7. Record the temperature every minute for 10 minutes.
8. Calculate the power of the heater in Watts (if it is unknown). To do this, multiply the ammeter reading by the voltmeter reading. P= I x V.
9. Calculate the work done by the heater in Joules. To do this, multiply the time in seconds by the power of the heater. W = P x t.
10. Plot a graph of work done on the x axis and temperature on the y axis.



Specific heat capacity can be calculated by finding the gradient of the line. This can be done by the finding the change in y and dividing it by the change in x.

Frequently asked questions

Why do you need to insulate the block (to stop heat loss to the atmosphere)

Why is your answer not the true value (because not all the heat was transferred into the block and through to the thermometer)

Why is the temperature increase slower at first? (because it takes some time for the block to heat up and for the heat to reach the thermometer.) It may not be a block of metal. You could use a kettle to heat an amount of water or any other way of heating something.

Physics – Atomic Structure

Keyword	Definition
Activity	Activity is the rate at which a source of unstable nuclei decays.. Activity is measured in becquerel (Bq)
Alpha particle (α)	Two neutrons and two protons. it is the same as a helium nucleus.
Atomic mass	The number of protons and neutrons in an atom's nucleus.
Atomic number	The number of protons in an atom.(also the number of electrons in an atom).
Beta particle (β)	A high energy electron emitted from the nucleus.
Count rate	Count-rate is the number of decays recorded each second by a detector (e.g., Geiger-Muller tube)
Gamma ray (γ)	Electromagnetic radiation emitted from the nucleus.
Helium nuclei	Two protons and two neutrons. The nucleus has a positive 2 charge (2^+)
Half life	The time taken for the number of radioactive nuclei or the count rate in a sample to halve.
Radioisotope	The unstable form of an element that emit radiation to transform into a more stable form

Irradiation and Contamination

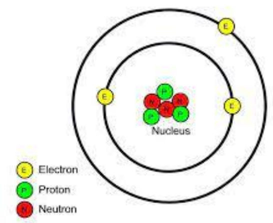
Irradiation is where a material is exposed to alpha, beta or gamma radiation
Contamination is where small amounts of the radioactive isotope leak onto the material. The only way a material can become radioactive is if that material becomes contaminated
Although irradiation can cause harm, contamination has the potential to cause far more harm, particularly if a radioactive source gets into a human body due to the continuous exposure to radiation that it will produce

The Atom

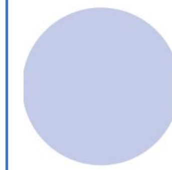
Atoms have a tiny, dense, **positively charged nucleus** at their centre with **negatively charged electrons** orbiting around the nucleus
Atomic radius = 1×10^{-10} metres,
Nucleus radius = 1×10^{-14} metres.
The radius of the nucleus is over 10,000 times smaller than the whole atom, but it contains almost **all of the mass** of the atom

In an atom the number of negative electrons is equal to the number of positive protons in the nucleus. Therefore, atoms have no overall electrical charge. All atoms of a particular element have the same number of protons.
The number of protons in an atom of an element is called its atomic number. The total number of protons and neutrons in an atom is called its mass number.

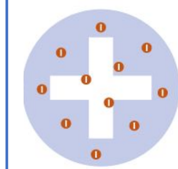
Atoms can be represented as
(Mass Number) 7 Li
(Atomic number) 3



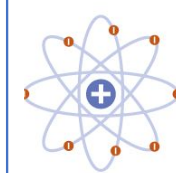
History of the atom



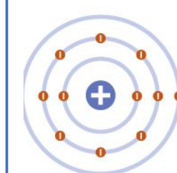
1803 Dalton
Solid Sphere Model
Tiny spheres that could not be divided.



1904 J.J. Thomson
Plum Pudding Model
Discovery of the electron led to the plum pudding model of the atom. This suggested that the atom is a ball of positive charge with negative electrons embedded in it.



1911 Rutherford
Nuclear Model
The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged.



1913 Niels Bohr
Niels Bohr adapted the nuclear model by suggesting that electrons orbit the nucleus at specific distances. The theoretical calculations of Bohr agreed with experimental observations.

Later experiments led to the idea that the positive charge of any nucleus could be subdivided into a whole number of smaller particles, each particle having the same amount of positive charge. The name proton was given to these particles.

The experimental work of James Chadwick provided the evidence to show the existence of neutrons within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea.

Nuclear equations

A nucleus changes into a new element by emitting **alpha** or **beta particles**. These changes are described using nuclear equations.

Alpha decay

Alpha decay (two **protons** and two **neutrons**) changes the **mass number** of the element by -4 and the **atomic number** by -2. An alpha particle is the same as a helium-4 **nucleus**.

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

$$\text{e.g. } {}^{212}_{84}Po \rightarrow {}^{208}_{82}Y + {}^{4}_{2}\alpha$$

Beta minus decay

A beta, β^-, particle is a high energy electron emitted from the nucleus.
β^- decay is when a **neutron turns into a proton emitting an electron from the nucleus.** The mass number of the element stays the same, but the atomic number increases by +1 because there is now an extra proton.

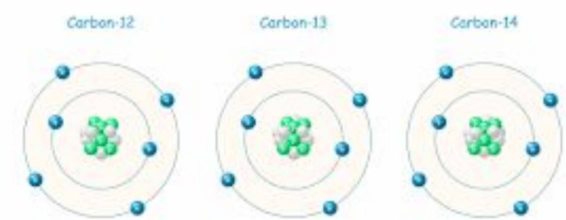
$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta$$

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$$

A Gamma ray is pure energy and will not change the structure of the nucleus in any way

Isotopes

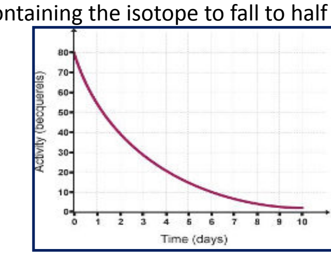
Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.
For example, isotopes of Carbon



Carbon – 12	Carbon – 13	Carbon – 14
Protons = 6	Protons = 6	Protons = 6
Electrons= 6	Electrons= 6	Electrons= 6
Neutrons = 6	Neutrons = 7	Neutrons = 8

Half life

Radioactive decay is random.
The half-life of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve, or the time it takes for the count rate (or activity) from a sample containing the isotope to fall to half its initial level.



Different radioactive isotopes have different half-lives. for example, the half-life of carbon - 14 is 5715 years but the half-life of francium, - 223 is just 20 minutes.
It is possible to find the half-life of a radioactive substance from a graph of the count rate against time
This graph shows the decay curve for the radioactive substance.

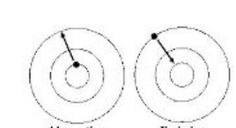
Properties of alpha, beta and gamma

Type of Radiation	Penetration in Air	Stopped by	Ionisation Power
Alpha	< 5cm	Paper/skin	High
Beta	< 1m	Aluminium	Low
Gamma	< 1km	Lead	Very low

Absorption & Emission of EM Radiation

Electrons in an atom are arranged in energy levels. Lower energy levels are closer to the nucleus, whilst higher energy levels are **further away** from the nucleus. These electrons can **absorb** energy. This happens when waves of electromagnetic radiation hit them.

When electrons absorb electromagnetic radiation, they move to a **higher energy level.** When an electron has moved up an energy level, it be **unstable**.



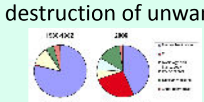
Eventually, it will move back down to its **original** energy level. As it moves back down, It **emits** a wave of electromagnetic radiation.

Separate Physics only

Background radiation is around us all of the time.
It comes from: natural sources such as rocks and cosmic rays from space or man-made sources such as the fallout from nuclear weapons testing and nuclear accidents.
The level of background radiation and radiation dose may be affected by occupation and/or location.
Radiation dose is measured in sieverts (Sv)

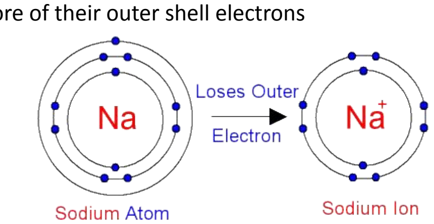
Nuclear fission is the splitting of a large and unstable nucleus (e.g., uranium or plutonium). Usually, for fission to occur the unstable nucleus must first absorb a neutron. The nucleus undergoing fission splits into two smaller nuclei, roughly equal in size, and emits two or three neutrons plus gamma rays. Energy is released by the fission reaction. All the fission products have kinetic energy. The neutrons may go on to start a chain reaction. In a nuclear reactor the chain reaction is controlled, whereas the explosion caused by a nuclear weapon is an uncontrolled chain reaction.

Nuclear radiations are used in medicine for the: exploration of internal organs also the control or destruction of unwanted tissue.



Ions

Atoms can turn into a positive ion if they lose one or more of their outer shell electrons

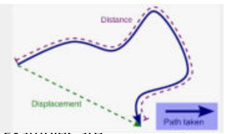


Forces – Part 1

Keyword	Definition
Balanced (forces)	When forces are equal and opposite each other also called **equilibrium**
Centre of mass	A point in the middle of an object where all its mass acts
Force	Something that makes a change happen
Force arrows	Show direction and size of a force
Magnitude	The value of a force in newtons
Newton (N)	**Unit that force is measured in**
Newtonmeter	A spring calibrated so it has a scale to measure force
Resultant (force)	The overall force once all the forces are considered
Scalar	Things that have magnitude but not direction
Unbalanced (forces)	When opposing forces are not equal
Vector	Things that have a magnitude and a direction. Forces are always vectors

Scalar and vector quantities

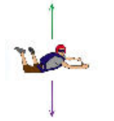
A scalar quantity is described by magnitude, it is a single number only.
A vector quantity has both magnitude and direction. They are important in the study of motion. It may be represented by an arrow. The length of the arrow is magnitude, the direction of the arrow is direction.

Scalar	Vector
 Examples are: Speed, volume, mass and time.	 Examples are: Force, velocity, acceleration, weight and momentum

Distance is how far an object moves, a number, so is scalar. Displacement includes the distance an object moves and its direction. It is measured using a straight line from where the object started to where it ended, regardless of the path taken

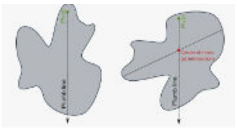
Terminal velocity

An object falling through a fluid initially accelerates due to the force of gravity. Eventually the resultant force will be zero and the object will move at its terminal velocity.

		
Weight > drag	Drag is increasing	Weight = drag force

Weight

Weight is the force acting on an object due to gravity.
The weight of an object is considered to act at a single point called the centre of mass.
Weight can be measured using a calibrated spring-balance (a newtonmeter)

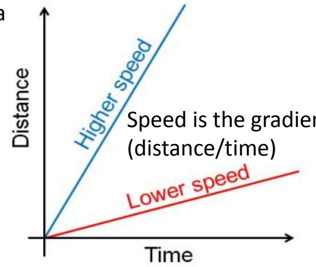


Weight can be calculated using the equation (must learn):
Weight = mass x gravitational field strength
$W = mg$
Units: w = newtons (N), m = mass (kg), g = gravitational field strength (N/kg)

Speed and velocity

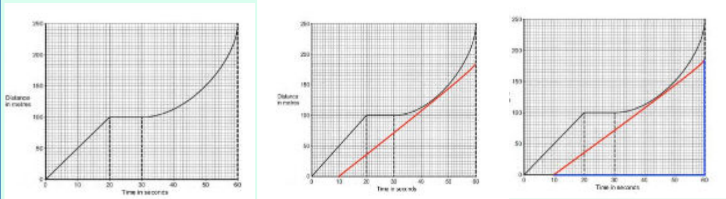
Speed does not involve direction. Speed is a scalar quantity. Speed of an object is rarely constant
and can be dependent on age, terrain, fitness and distance tra
Speed can be calculated using the equation (must learn):
Distance travelled = speed x time
$s = vt$
Units: s = distance travelled (m), v = speed (m/s), t = time (s)

Typical speeds			
Walking	1.5 m/s	Cycling	6 m/s
Running	3 m/s	Sound	330 m/s



Speed and velocity (Higher tier only)

If an object is accelerating, the speed can be calculated by drawing a tangent and measuring the gradient at that time



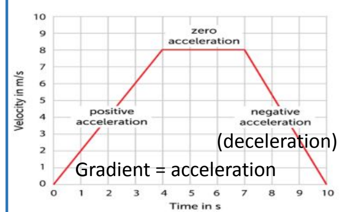
distance = 185m
time = 60 – 10 = 50s

$\frac{\text{distance}}{\text{time}}$ = speed

185/50 = 3.7 m/s

Acceleration

Average acceleration can be calculated using the equation (must learn):
acceleration = change in velocity / time taken for the change
$a = \Delta v / t$ Units: a = acceleration (m/s^2), Δv = change in velocity (m/s), t = time (s)



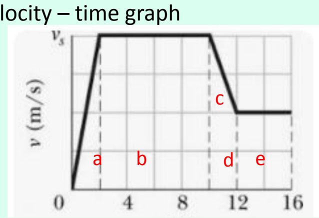
Average acceleration can be calculated using the equation (must learn)
(final velocity)^2 - (initial velocity)^2 = 2 x acceleration x distance $v^2 - u^2 = 2as$
Units: v = final velocity (m/s), u = initial velocity (m/s), a = acceleration (m/s^2), s = distance (m)

Acceleration (Higher tier only)

Distance travelled can be calculated from the area under a velocity – time graph

I can either count squares (if appropriate) or calculate area

A = (2 x 4) /2 = 4m B = 8 x 4 = 32m C = (2 x 2) /2 = 2m
D = 2 x 2 = 4m E = 4 x 2 = 8m Total distance = 50m

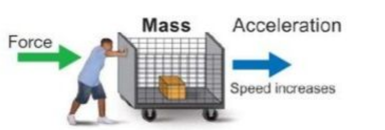
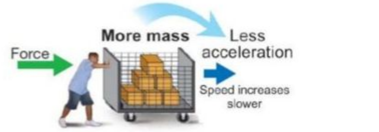


Newtons first law

If the resultant force on an object is zero and the object is stationary, it remains stationary.
If the resultant force is zero and the object is moving, it continues to move at the same speed in the same direction

An object at rest will remain at rest 	Unless acted on by an unbalanced force 	An object in motion will continue with constant speed and direction 	Unless acted on by an unbalanced force 

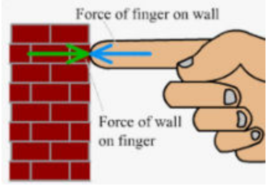
Newtons second law

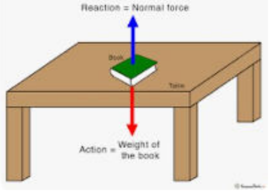
The acceleration of an object is proportional to the resultant force acting on it	**The acceleration is inversely proportional to the mass of the object**
	

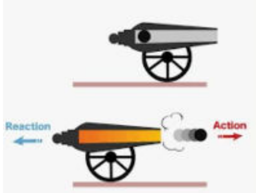
This can be calculated using the equation (must learn):
Resultant force = mass x acceleration $f = ma$
Units: f = resultant force (N), m = mass (kg), a = acceleration (m/s^2)

Newtons third law

Whenever two objects interact, the forces they exert on each other are equal and opposite

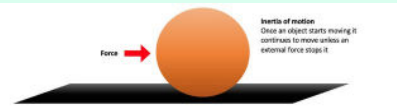






Inertia (Higher tier only)

A body at rest or moving at a constant speed in a straight line, will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by an external unbalanced force.



Both obje... ertia

Inertial mass (Higher tier only)

The same applied force, the acceleration is inversely proportional to the objects inertial mass

Contact and non-contact forces

Contact = touching e.g., friction, air resistance, tension and normal contact force.
Non-contact = physically separated e.g., gravitational , electrostatic and magnetic forces.

Forces – Part 2

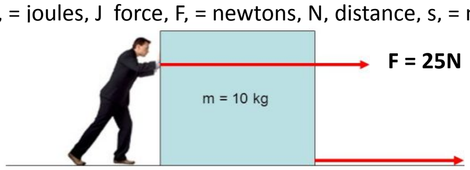
Keyword	Definition
Balanced (forces)	When forces are equal and opposite each other also called **equilibrium**
Deformation	A change in shape or size
Force	Something that makes a change happen
Force arrows	Show direction and size of a force
Magnitude	The value of a force in newtons
newton (N)	**Unit that force is measured in**
Newtonmeter	A spring calibrated so it has a scale to measure force
Pivot	The central point, pin, or shaft on which a mechanism turns
Resultant (force)	The overall force once all the forces are considered
Unbalanced (forces)	When opposing forces are not equal to each other
Vector	Things that have a magnitude and a direction. Forces are always vectors

Work done

When a force causes an object to move through a distance work is done on the object.

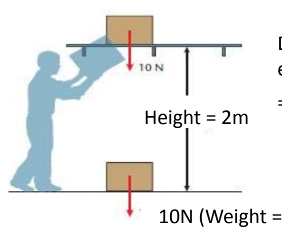
work done = force × distance (along line of action of force)

W, = joules, J force, F, = newtons, N, distance, s, = metres



Work done = Force x distance = 25 x 2 = 50Nm (Joules)

One joule of work is done when a force of one newton causes a displacement of one metre. 1 joule = 1 newton-metre



Doing work = increasing energy in gravitational store

= 10N x 2m = 20Nm (Joules)

Moments (Physics only)

A force or a system of forces may cause an object to rotate. The turning effect of force is called the moment of the force. The size of the moment is defined by the equation:

moment of a force = force × distance

moment of a force, M, in newton-metres, Nm,

force, F, in newtons, N,

distance, d, is the perpendicular distance from the pivot to the line of action of the force, in metres, m.

Resultant forces

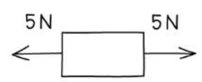
Several forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force.

This single resultant force determines:

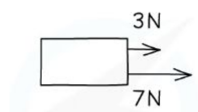
- The **direction** in which the object will move as a result of all the forces
- The **magnitude** of the final force experienced by the object.

Resultant forces can be calculated by adding or subtracting all of the forces acting on the object

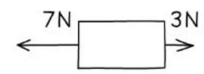
- Forces working in opposite directions are **subtracted** from each other
- Forces working in the same direction are **added** together



Resultant force = 0N
Forces balanced



Resultant force = 3N + 7N = 10N Right



Resultant force = 7N – 3N = 4N Left

Free body diagrams – HT only

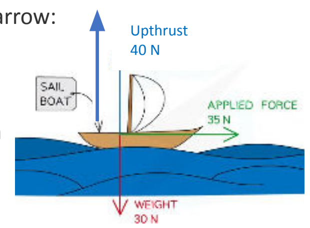
Each force is represented as a **vector** arrow, where each arrow:

- Is scaled to the **magnitude** of the force it represents
- Points in the **direction** that the force acts
- Is **labelled** with the name of the force it represents

Decide whether the resultant force is approx. up or down

Decide whether the resultant force is approx. left or right

The resultant force is directed **up** and to the **right**



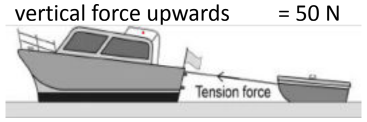
Resolving forces – HT only

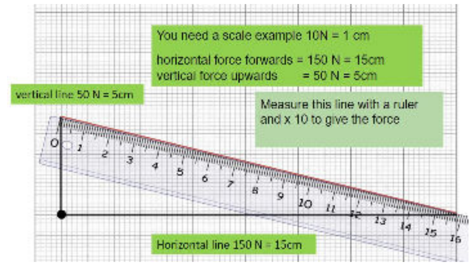
A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.

Example: The tension force in the tow rope causes a horizontal force forwards and a vertical force upwards on the dinghy.

horizontal force forwards = 150 N

vertical force upwards = 50 N





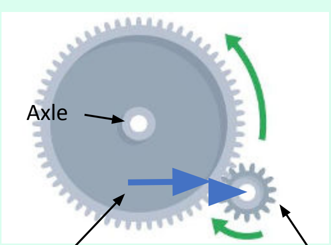
Gears (Physics only)

Gears

They consist of wheels with toothed edges that rotate on an axle or shaft, which acts as the **pivot**

The teeth of one gear fit into the teeth of another gear. This lets one gear turn the other, meaning one axle or shaft can be used to turn another shaft

As one gear turns, the other must also turn.



Larger distance
Larger moment

smaller distance
smaller moment

Where the gears meet, the teeth will then move in the **same** direction. One of the gears will then move clockwise, and the other anticlockwise (in opposite directions)

Although the force will be the same on both gears, the **moment** will not be. This depends on the size of the gear, which changes the distance of the teeth to the pivot.

- If a larger gear is driven by a smaller gear, the large gear will rotate slower than the smaller gear but will have a greater moment. E.g., a low gear on a bike or car
- If a smaller gear is driven by a larger gear, the smaller gear will rotate quicker than the larger gear but will have a smaller moment. E.g., a high gear on a bike.

This is because the turning force on the larger gear wheel acts further from its pivot than the turning force of the smaller gear wheel acting on its own pivot

Forces and elasticity

Forces can cause stretching, bending or compression of an object.

Stretching, bending and compression require **multiple forces** to be acting on an object.

e.g., if you pushed a spring, it would move one direction. But if you pushed both ends of the spring, the spring would compress.

Deformation is a change in shape. An object is said to be deformed when it has changed shape and length, this is due to the effect of the forces. There are two types of deformation: elastic and inelastic.

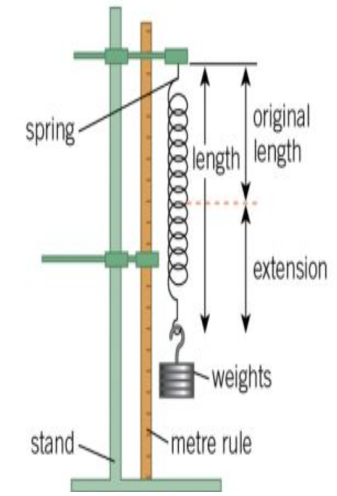
Elastic deformation is reversible. If an object completely returns to 'normal' once all forces are removed, it is said to be elastically deformed. (normal = the object has completely returned to its original shape, size and length).

Inelastic deformation is irreversible. if an object doesn't completely return to 'normal' once all forces are removed, it is said to be inelastically deformed.

The relationship between force and extension (Required Practical)

Hooke's Law

Hooke's law is used to describe the relationship between **force applied** to an elastic object and the **extension (or compression)** of the elastic object. It is a linear relationship, where force is directly proportional to the extension. If an object doesn't obey Hooke's law, there is a non-linear relationship between force and extension.



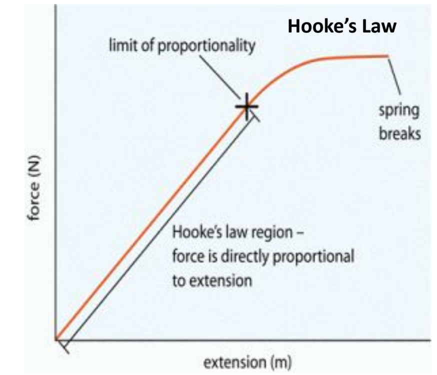
force = spring constant × extension

F = k x e

(*F*) = newtons (N)

(*k*) = newtons per metre (N/m)

(*e*), or increase in length, = metres (m)



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

The work done in stretching (or compressing) a spring (up to the limit of proportionality) can be calculated using :

$E_e = ½ k e^2$

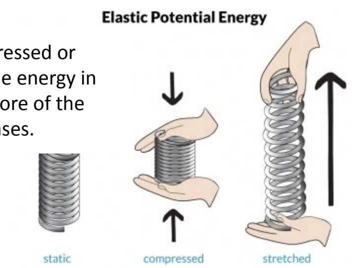
E_e = elastic potential energy (J)

K = spring constant (N/m)

e = extension (m)

You should be able to apply this equation which is given on the Physics equation sheet.

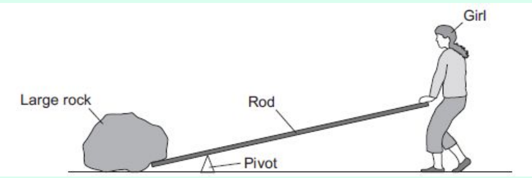
When compressed or stretched, the energy in the elastic store of the spring increases.



Levers (Physics only)

Levers

Levers **increase** the size of a **force** acting on an object to make the object turn more easily.



To make a lever work better:

Increase the **size** of the force applied

Increase the **distance** of the force from the pivot.

Forces – Part 2

Keyword	Definition
Conservation of momentum	In an isolated system the total momentum of two or more bodies acting upon each other remains constant unless an external force is applied. Therefore, momentum can neither be created nor destroyed.
Momentum (HT)	Vector quantity that is a property of moving objects [momentum = mass x velocity] (kg m/s) also written as p = mv
speed	Speed is a measure of the distance travelled by an object in a given length of time
velocity	The velocity. of an object is its speed in a particular direction. Velocity is a vector.

Momentum – Physics only

Force and momentum

When a force acts on an object that is moving, or able to move, there is a change in **momentum**:

- in equations, change in momentum is shown as $m\Delta v$
- Δv is the change in velocity (Δ is the Greek letter delta, representing 'change in')

Calculating rate of change of momentum

You can combine two equations to show how to calculate the force involved when a change in momentum happens:

force = mass × acceleration

F = m x a

a = change in velocity/time taken = $\Delta v/\Delta t$

So;

F = (m x Δv)/Δt

Force = change in momentum/time taken

force (*F*) in newtons (N)

change in momentum (*m*Δ*v*) in kilogram metres per second (kg m/s)

time taken (Δ*t*) is measured in seconds (s)

The equation shows that the force involved is equal to the **rate of change** of momentum.

Example calculation

A 1,500 kg car accelerates from rest to a velocity of 30 m/s. This takes 20 seconds. Calculate the force acting on the car.

F = (m x Δv)/Δt

Δv = 30 - 0 = 30m/s

F = (1,500 x 30)/20

F = 2,250N

Car safety features

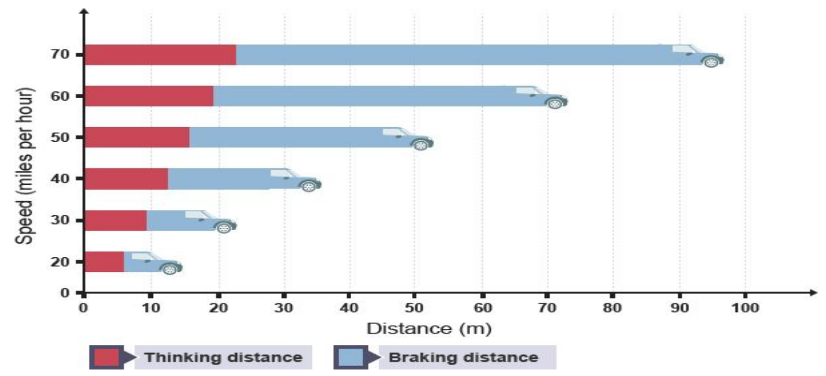
During a collision there is a change in momentum. The force of the collision is equal to the rate of change of momentum. Car safety features such as seatbelts, airbags and crumple zones all work to change the shape of the car, which increases the time taken for the collision.. These different safety features decrease the rate of change of momentum, which decreases the force of the collision on any people within the car.

Stopping distances

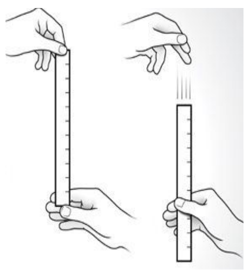
In an emergency, a driver must bring their vehicle to a stop in the shortest distance possible:

stopping distance = thinking distance + braking distance

The diagram shows some typical stopping distances for an average car in normal conditions.



Reaction times



Reaction time varies from person to person but is between typically 0.2 s and 0.9 s. Longer reaction times increase the **thinking distance** when stopping from a given speed.

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,

This is a required practical studied in the Homeostasis unit in Biology.

Braking distance

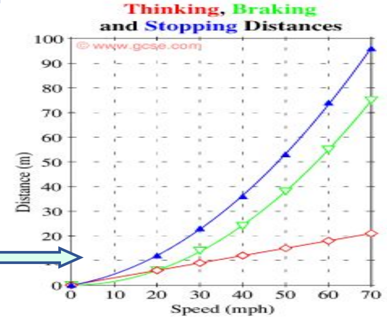
Forces and braking	
Stopping distance	thinking distance + braking distance
Thinking distance	The distance travelled in the time it takes to react (typically 0.2s)
Factors affecting thinking distance	1. Tiredness 2. Drugs 3. Alcohol 4. Distractions (phones)
Braking distance	The distance travelled under a braking force
Factors affecting braking distance	1. Road conditions (ice, water) 2. Tyre condition 3. Brake condition

Typical stopping distances

It is important to be able to:

- estimate how the stopping distance for a vehicle varies with different speeds
- interpret graphs relating speed to stopping distance

Physics only



Momentum – Higher tier only

Momentum is the product of **mass** and **velocity**. Momentum is also a **vector** quantity - this means it has both a **magnitude** and an associated direction.

For example, an elephant has no momentum when it is standing still. When it begins to walk, it will have momentum in the same direction as it is travelling. The faster the elephant walks, the larger its momentum will be.

Calculating momentum

Momentum can be calculated using the equation:

momentum = mass × velocity

- momentum (*p*) in kilogram metres per second (kg m/s)
- mass (*m*) in kilograms (kg)
- velocity (*v*) in metres per second (m/s)

Example

A lorry has a mass of 7,500 kg. It travels south at a speed of 25 m/s. Calculate the momentum of the lorry.

p = m x v

p = 7,500 x 25

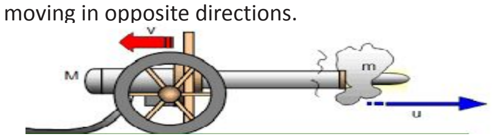
p = 187,500kgm/s (south)

Conservation of momentum in a closed system:

total momentum before an event = total momentum after the event

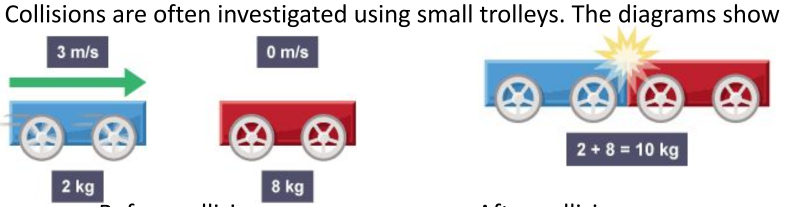
A 'closed system' is something that is not affected by external forces. This is called the principle of **conservation of momentum**. Momentum is conserved in **collisions** and **explosions.**

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.



Calculations involving collisions

Collisions are often investigated using small trolleys. The diagrams show an example.



Before collision After collision

You can use the principle of conservation of momentum to calculate the velocity of the combined trolleys after the collision.

First calculate the momentum of both trolleys before the collision:

2 kg trolley = 2 × 3 = 6 kg m/s

4 kg trolley = 8 × 0 = 0 kg m/s

Total momentum before collision = 6 + 0 = 6 kg m/s

Total momentum (*p*) after collision = 6 kg m/s (because momentum is conserved)

Mass (*m*) after collision = 10 kg

Next, change the subject of p = m v to find v:

v = p/m

v = 6 /10

v = 0.6m/s

Useful YouTube links:

Momentum | Change in momentum | Hooke's law RP | Moments

Waves

Keyword	Definition
Absorb	Energy taken in from a wave by a material, heating it
Emit	Energy being released by an object as a wave
Frequency	Number of oscillations per second or waves passing a point per second measured in Hertz
Oscillation	A regular periodic motion or change
Period	The time taken for one complete oscillation
Reflect	Wave bounces off a material
Refract	Wave changing direction due to changing speed
Transmit	Energy passing through a material as a wave
Wavelength	Length of one complete wave to same point on adjacent wave in metres

Equations

$$v = f\lambda$$

wave speed = frequency x wavelength
(m/s) (Hz) (m)

$$f = \frac{1}{T}$$

frequency = 1 ÷ time period
(Hz) (s)

Properties of electromagnetic waves

Atoms can interact with electromagnetic (EM) waves in one of two ways, they can be:

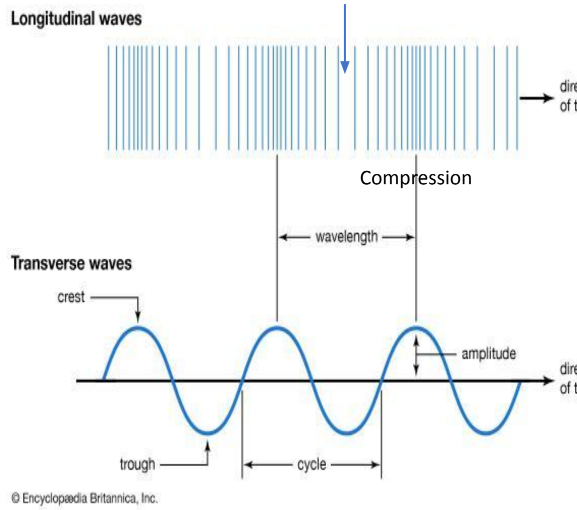
- Absorbed
- Emitted

When an EM wave hits an atom, it can be **absorbed** by one of the electrons giving it energy. This causes the electron to move **up** to a higher energy level.
Then, when, an electron moves back down to a lower energy level it will **emit** an EM wave in the process.

Gamma rays can originate from changes in the nucleus of an atom (see atomic structure unit)
Ultraviolet waves, X rays and gamma rays can have hazardous effects on the human body tissue. The effects depend on the type of radiation and the size of the dose.
Radiation dose (in sieverts) is a measure of the risk of harm resulting from an exposure of the body to radiation.
1000 millisieverts (mSv) = 1 sievert (Sv).
Ultraviolet waves can cause skin to age prematurely and increase the risk of skin cancer. X- rays and gamma rays are ionising radiation that can cause mutation of genes and cancer.

Transverse & Longitudinal Waves

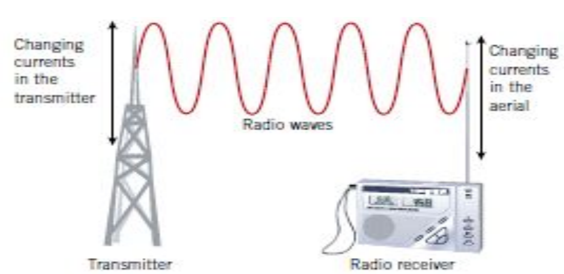
Transverse wave motion is **perpendicular** to the direction of travel and energy transfer.
Longitudinal wave motion is **parallel** to the direction of travel and energy transfer



Transverse wave examples – Light, water surface, plucked string, slinky, seismic S-waves
Longitudinal wave examples – Sound, slinky, seismic P-waves

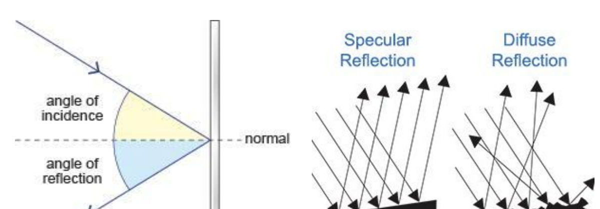
Properties of EM waves– Higher tier only

Radio waves can be produced by oscillations in a circuit. Radio waves absorbed by an antenna can create an alternating current with the same frequency as the wave.



Reflection - Higher tier only

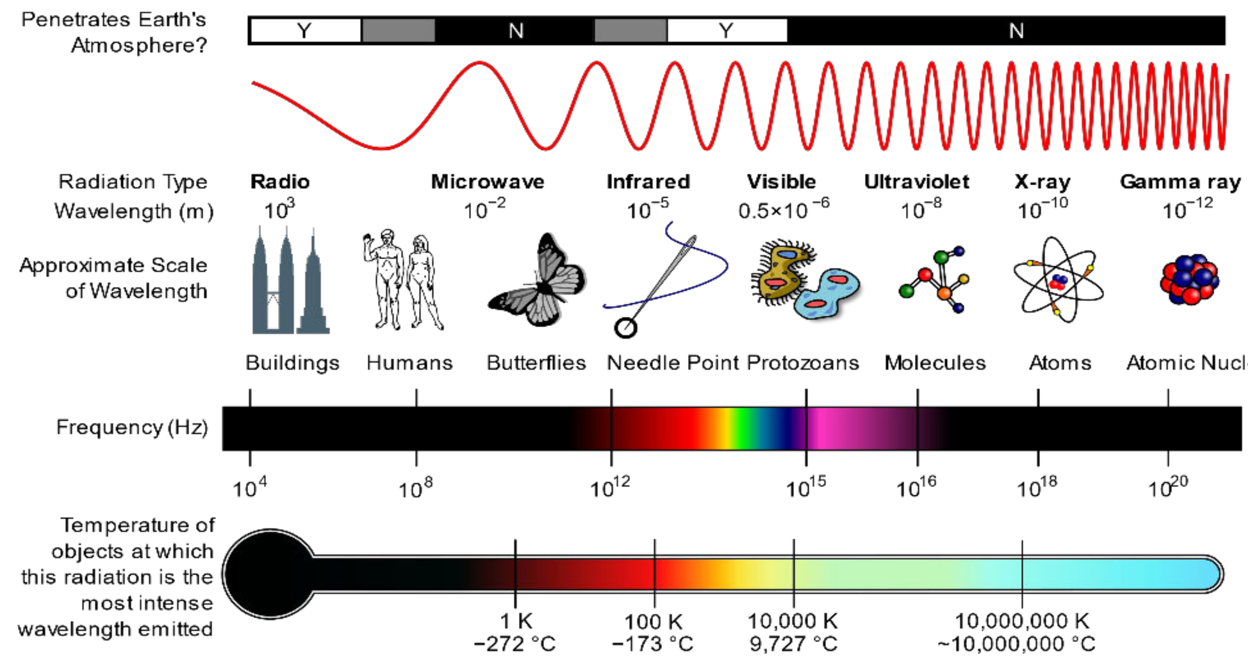
All waves can reflect. In reflection the incident angle is equal to the reflected angle when measured from the normal. Flat surfaces give specular reflections which can form images and diffuse reflections which don't.



Physics only

Electromagnetic Spectrum

EM waves are all transverse and travel in straight lines at the speed of light ($3x10^8$ m/s)



Uses of electromagnetic waves

Radio	Used for television, radio and Bluetooth. A signal carried by radio waves can get from a transmitting mast to a receiver by being reflected off a charged layer in the atmosphere.
Microwaves	Microwaves: obviously, cooking food, but also communication with satellites and mobile phones; Wi-Fi internet. Unlike radio waves, microwaves can pass through the atmosphere. In microwave ovens, the microwaves cause the water particles in the food to vibrate, heating it up.
Infrared	Electrical heaters, cooking food, infrared cameras. All objects emit infrared, but hotter objects emit more. An infrared camera detects infrared instead of visible light, so it can see hotter objects in the dark – night vision.
Visible	Fibre optic communication (like the best broadband). Optical fibres reflect pulses of light all the way along their length. The pulses of light transmit the information.
Ultraviolet	Energy efficient lamps, sun tanning, security markings
X-rays	Both medical imaging for diagnosis (like broken bones) and medical treatments. X-rays can pass through soft tissue (like muscle), but not bone. That's why an X-ray image works to show up bones, and any breaks.
Gamma	Used in medical treatments such as radiotherapy, also for imaging (see atomic structure unit), It is also used to sterilise equipment

Refraction – Higher tier only

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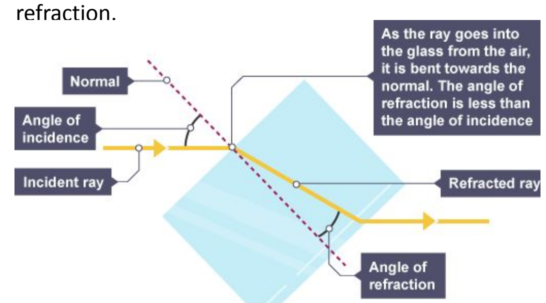
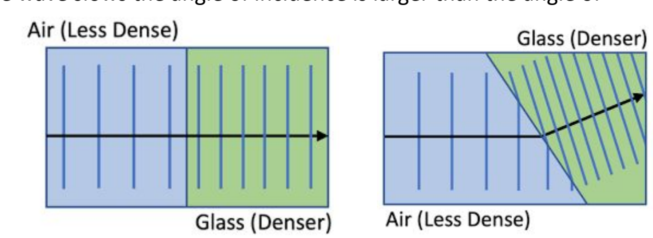
All waves can refract. In refraction the wave changes direction as it changes velocity between materials, which affects the wavelength too as the frequency remains constant. If the wave slows the angle of incidence is larger than the angle of refraction.





As the wave front travels from a less dense medium, to a denser medium, the wave will slow down, This can be seen as the waves are closer together

Magnetism and electromagnetism

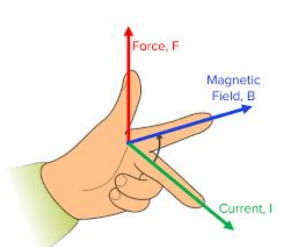
Key term	Definition
Domain	A magnetic domain is **a microscopic region within a magnetic material** where the atomic or molecular magnetic moments are aligned in the same direction.
Flux density	Strength of a magnetic field in a volume of space
Induced magnetism	Magnetism produced in magnetic material by a permanent magnet or electromagnet
Induction	A potential difference produced when the flux passing through a conductor changes (direction or strength)
Magnetic Field	Area around a magnet where it will produce a force on another magnet or magnetic metal. Points from North to South pole
Motor effect	Force produced on a conductor carrying a current placed at right angles to a magnetic field
Solenoid	A coil of wire carrying a current. Produces a magnetic field with the same shape as a bar magnet
Tesla	The unit used to measure magnetic flux density

Magnetic metals.

Examples: Nickel, Iron, Cobalt and Steel. (N.I.C.S.)
These metals will show induced magnetism.
They can be made into permanent magnets if the domains can be permanently aligned.

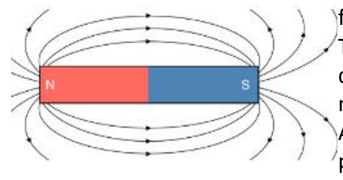
Motor effect & Left Hand Rule Higher tier only.

When a wire carrying a current is perpendicular to a permanent magnetic field it will experience a force.
Reversing either the direction of the current or the direction of the field will reverse the direction of the force.
Increasing the strength of the field or the size of the current will increase the size of the force. This can be shown using Fleming's Left Hand Rule .

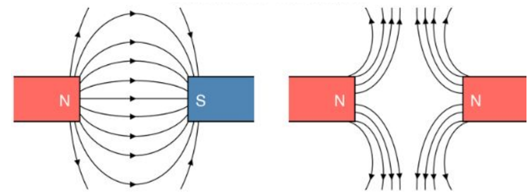


Hold your thumb, forefinger and second finger at right angles to each other: the forefinger is pointed in the direction of the magnetic field lines - from north to south; the second finger is pointed in the direction the current flows; the thumb shows the direction of the force on the conductor carrying the current

Magnetic fields



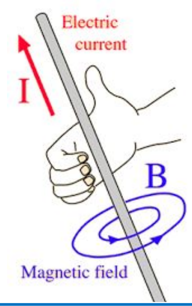
Magnetic field lines never cross each other.
Closer the lines, stronger the magnetic field.
The arrow heads on the lines, show the direction of the force exerted by magnetic north pole.
Arrowheads point from north pole to south pole of the magnet.



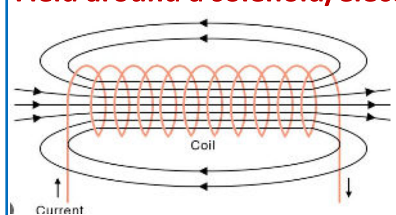
The field is strongest at the poles.
In attraction the field lines between magnets join up, in repulsion they do not.

Field around a wire

A wire carrying a current has a circular magnetic field around it.
This can be shown using a plotting compass or iron filings.
The field direction is found using the right-hand grip rule, where the thumb points in the direction of the current and the fingers point in the direction of the field lines.



Field around a solenoid/electromagnet



If a current carrying wire is formed into a coil the field lines form the same shape as a bar magnet.
The field can be made stronger with more coils, a higher current, or adding a soft iron core.

Adding an iron core to a solenoid makes it an electromagnet. As the iron becomes magnetised an electromagnet is stronger than a solenoid.

Force on a conductor. Higher tier only

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

F = BIL

Where:
F is force in Newtons
B is flux density in Tesla
I is current in Amperes
L is length in metres

Transformers – Potential difference & Power Physics HT

This equation can be used to calculate the output from a particular transformer, or to work out how to design a transformer to make a particular voltage change:

$$\frac{\text{Primary voltage}}{\text{Secondary voltage}} = \frac{\text{no. of turns on primary coil}}{\text{no. of turns on secondary coil}}$$

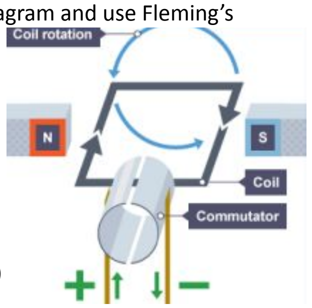
Assuming that a transformer is 100% efficient, this equation can be used to calculate power output from the transformer.

potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil

Motors Higher tier only

Electric motors make use of the motor effect.
A coil of wire carrying a current is placed in a magnetic field; as you know, the magnetic fields interact to cause a force each other.
If the coil is set up so it can spin, it most certainly will. In fact, it will spin round and round (rotate). This is thanks to the force acting **up** on one side of the coil, and **down** on the other – see the diagram and use Fleming's left-hand rule to see why this happens.

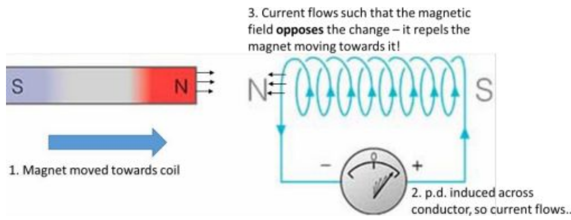
The direction of each quantity fits with the left-hand rule
The magnetic field goes from N to S of course, and the arrows on the coil show the direction of the current.
So, the left side of the coil has a force downwards exerted on it (use the left-hand rule). The right side of the coil has a force upwards exerted on it, so, it rotates as shown.
(The commutator just allows the coil to spin without the wires getting tangled up)



Induced potential and the generator effect – Physics Higher tier only

The motor effect can be switched around – instead of using interacting magnetic fields to produce movement, you can use movement to produce a current in a wire.
1. Place a conductor (e.g. coil of wire/solenoid) in a magnetic field and move it around (e.g. rotate the coil)
2. OR keep the coil still but change the magnetic field (e.g. flip N and S back and forth)
3. Either of these induces a potential difference across the ends of the conductor
4. Assuming your conductor is part of a complete circuit, a current starts to flow in the conductor thanks to this potential difference.

This is called the GENERATOR EFFECT, because the method is used to generate electricity. It is also known as electromagnetic induction. Now, importantly, the current in the conductor produces a magnetic field, as always. But the direction of the magnetic field acts to oppose the change, the 'change' being the original 1 or 2 from the steps above.
This is shown in the diagram right.



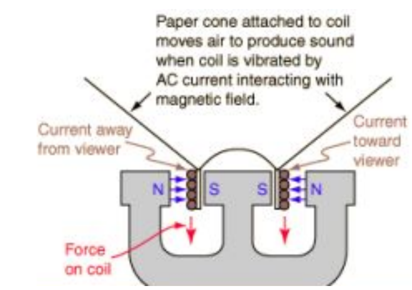
Factors affecting induced potentials - Physics Higher tier only

The size of the induced potential in the generator effect depends on:
- The size/strength of the magnetic field (larger magnetic field = larger induced potential)
- The number of turns on the solenoid (more turns = larger induced potential)
- The speed of movements/changes to magnetic fields (faster = larger induced potential)

Loudspeakers and microphones – Physics Higher tier only

The motor effect is also used in loudspeakers and headphones. They have a 'moving coil' which moves in a magnetic field according to the current running through the coil. This moving coil is connected to a cone that moves with it. The cone causes vibrations in the air around it – in other words, it causes sound waves.
Microphones do the exact opposite: sound waves (pressure variations) cause the cone the move, which causes a changing current in the coil.

Just like in a motor, a force is produced on the coil of wire by placing it in a magnetic field (that's a permanent magnet at the bottom) and turning on the current.
As the current alternates in direction (i.e. AC is used), and the size of the current is varied, the coil moves back and forth.
As you can see, the coil is joined to a cone, which moves with it.
The cone vibrates the air according to the current, then. The current transfers the information about the sound being played



Transformers - Physics Higher tier only

These only work on alternating current. The a.c. in the primary coil produces an alternating magnetic field in the iron core. The changing magnetic field induces an alternating potential difference in the secondary coil. The more coils on the secondary, the higher the potential difference. A step-up transformer has more coils on the secondary than the primary. As the power either side is the same - if the p.d. increases the current decreases.