The Ultimate IGCSE Guide to Physics

By CGPwned

Unit 1: Solids, Liquids and Gases

Density

SO what's density? Well, all solids, liquids and gases have different properties and characteristics. One such characteristic is density. Solids are often very dense, liquids are less dense than solids, and gases have very low densities. Density is how much mass something has for a certain volume – in other words, how 'squashed up' something is.
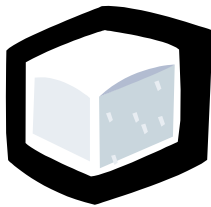
To calculate density, use this equation:

Density = Mass/Volume
$$P = m/v$$

Example: A piece of iron has a mass of 390kg and a volume of $0.05m^3$. What is its density?

$P = m/v$
$P = 390kg/0.05m^3$
$= 7800kg/m^3$ ←Remember the unit! Density can be kg/m^3, g/cm^3…etc

Calculating Volumes for the Density

For a cuboid like this, simply multiply its length, width and height. I'm assuming you know this, but if not, work up your maths man…

As for irregular solids, measure out a certain amount of water with a measuring cylinder. This is the control (something to compare results to). Do the same with another measuring cylinder, and drop the solid in. Note the rise in the level of water. The difference between the two measurements is the volume of the solid, in this case, 10ml.
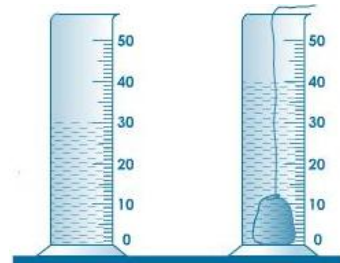
Pressure

Pressure in Solids

Lets start like this: You can easily push a pin into a piece of wood quite easily, but it is pretty much impossible to make a hole in the wood with your finger. You can try with little success (and end up with splinters all over your fingers). Why is that? The small point of the drawing pin concentrates all your pushing force into a tiny area, so the pin goes into the wood easily.

To get to the point, pressure is defined as the force per unit area. Force is measured in newtons (N) and area is measured in square metres (m^2). The unit for pressure is N/m^2 or Pa (for Pascals).

Unfortunately, there is an equation that comes with pressure and this is ONLY FOR SOLIDS:

Pressure (in Pascals) = Force (in newtons)/Area (in square metres)
$$p = f/a$$

Example: A woman weighs 600N and the total area of her shoes in contact with the ground is $0.0015m^2$. Find the pressure she is exerting to the ground.

$p = f/a$
$p = 600N/0.0015m^2$
$= 400000Pa$ (or 400kPa)

Pressure in Liquids and Gases

Pressure in liquids act equally in all directions as long as the liquid is not moving. This is the same for gases. The pressure in air is a staggering 100000Pa, but since the pressure inside our bodies are similar, we don't feel the pressure. The pressure in air is also referred to as 1.0 atmosphere.

To calculate pressure in liquids use the following equation:

Pressure (in Pa) = Height/Depth (in m) x Density (in kg/m^3) x Gravitational Field Strength (in N/kg)
Or p = hdg ← Note that g is usually 10N/kgv

Example: Justin Bieber's (oh my god!) swimming pool has a depth of 3m. What is the total pressure of the swimming pool? Take the gravitational field strength to be 10N/kg and the density of water to be 1kg/m^3 (ignore the swimming pool being chlorinated 'cause JB's swimming pool is always clean anyways).

p = hdg (the actual equation is p=hpg, but I'm not bothered finding that special p for density)
p = 3m x 1kg/m^3 x 10N/kg
p = 30Pa

The Brownian Motion

Brownian Motion: The continual random movement of microscopic particles. When particles collide into one another, this causes a change in speed and direction of the particles, making them randomly move about.

Boyle's Law

This is all summarized into the following equation:

Pressure$_1$ x Volume$_1$ = Pressure$_2$ x Volume$_2$
Or $p_1V_1 = p_2V_2$

Example: Atmospheric pressure is 100kPa. Some air in a sealed container has a volume of 2m^3 at atmospheric pressure. What would be the pressure of the air if you reduced its volume to 0.2m^3?

100kPa = 100000Pa
$P_1V_1 = p_2V_2$
100000Pa x 2m^3 = p_2 x 0.2m^3
200000 = 0.2p_2
P_2 = 1000000Pa
 = 1000kPa

And in words…

Boyle's Law: At a constant temperature and with a fixed mass of gas, pressure is inversely proportional to volume.

Question: How does a gas exert a pressure on the walls of its container?

Billions of tiny air particles move about in continual random motion. Particle collisions with the walls of the container exerts a force, which gets distributed over the area of the wall of the container, hence, exerting a pressure.

Pressure Law

Temperature also has an effect on the pressure of a gas. This is shown in an experiment set up on the right. When water is heated gradually, the air is also heated, changing the reading on the pressure gauge. Plot down the results and you'd get a graph that looks something like this.
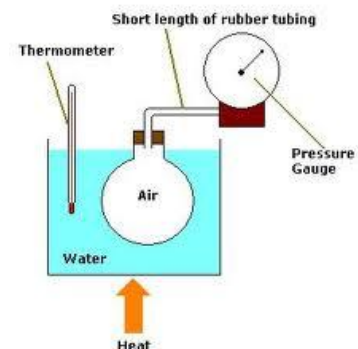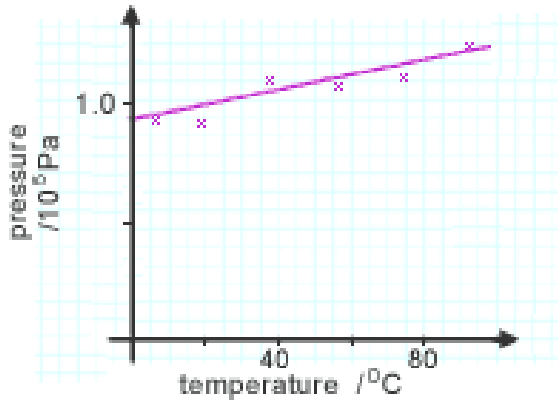
Wait a minute…shouldn't the pressure be at zero pascals? No. This is because pressure is NOT proportional to temperate in Celsius. But what happens if you continue cooling the gas? You'd find that when pressure is zero, the temperate would be at -273^{0}C. This temperate is known as absolute zero. When converted to kelvins (another type of measurement for temperature), absolute zero is zero kelvins. But back to the point, what would happen if you converted the temperatures into kelvins?

Converting between Kelvins and Celsius

Kelvins = Celsius + 273
Celsius = Kelvins – 273

If you convert the temperatures into kelvins, this is what happens:

There is a positive correlation! This shows that pressure of gas is proportional to temperature in Kelvin. This leads into the Pressure Law equation: (Note that temperatures must be in Kelvin)

$$Pressure_1/Temperature_1 = Pressure_1/Temperature_1$$
$$Or\ p_1/T_1 = p_2/T_2$$

Example: You take an empty tin and put the lid on tightly. You heat it using a Bunsen burner until the temperature of the air inside is 50^{0}C. What is the pressure of the air inside the tin? The temperature of the room is 20^{0}C and atmospheric pressure is 100kPa.
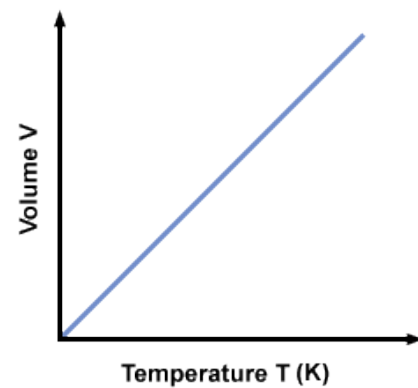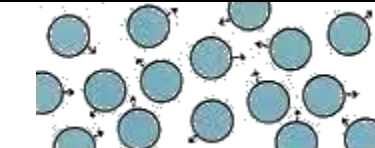

We must first convert the temperature in Kelvin, so:

T_1 = 20 + 273 = 293K (This is the temperature OUTSIDE the tin)
T_2 = 50 + 273 = 323K (This is the temperature INSIDE the tin)
$p_1/T_1 = p_2/T_2$
100kPa/293K = p_2/323K
p_2 = 110kPa

Now to summarise the Pressure Law:

Pressure Law: With a fixed mass of gas at a constant volume, pressure is proportional to temperature (in Kelvins).

States of Matter

Solids	Liquids	Gases
⟳ Particles are closely packed. ⟳ Regular structure. ⟳ Vibrate about fixed positions.	⟳ Particles are closely packed. ⟳ Irregular structure. ⟳ Random motion within structure.	⟳ No fixed positions. ⟳ Move at rapid random motion. ⟳ Are very spread out.

Change in States of Matter
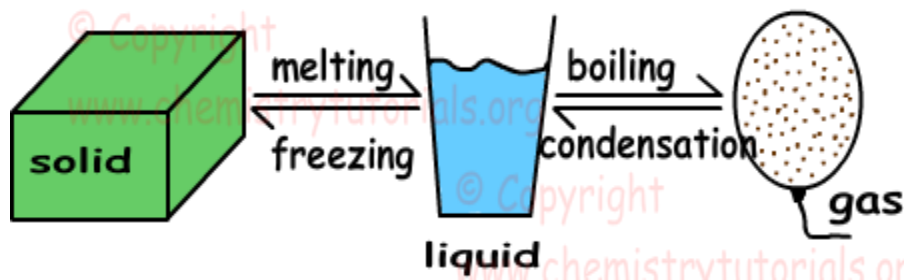
Unit 2: Energy

What the hell is energy? Well, energy is used everywhere! We need to use energy to walk, to life objects, to push, to pull, and in most cases, to think. Machines also need to use energy to power up. That's why your iPod can't last forever without electricity! We get our energy from food and it is then transferred into other forms of energy such as kinetic energy and heat energy. What the hell are you talking about? Well you will find out later.

<u>Define Energy</u>: Energy is the <u>ability</u> to <u>do work</u>.

<u>Types of Energy and Energy Conversions</u>

This table summarises some of the different types of energy that you will need to learn about in GCSE.

Energy	Description
Chemical	Energy that is stored in food or batteries. We burn it into other forms of energy.
Thermal	Also known as heat energy. Most energy is wasted by turning into this. We use thermal energy to keep ourselves warm.
Sound	Also a possible form of waste energy. But I'm sure you know what sound is. It is a series of longitudinal waves – but we'll get to that later.
Light	This energy emits a light. We need light to see things. Things like light bulbs have energy that is converted to this.
Electrical	Most of the energy we need is converted from electrical energy. Electrical energy can be made from other forms of energy.
Gravitational Potential	Stored energy that varies depending on where you are. The higher, the more.
Kinetic	Also known as movement energy. Electrical energy is converted to kinetic energy to make motors work. We get this from chemical energy.
Geothermal	Energy from the heat underground – stored in the Earth's core. This is found in volcanoes and thermal springs.
Elastic Potential	Energy that is stored in springs. This type of energy is found in catapults and bows.
Nuclear Energy	The energy released when unstable uranium atoms in the nuclear reactor break down and form a chain reaction.

Energy is <u>converted</u> in different ways. Here are some examples:

- When we <u>run</u>, <u>chemical energy</u> from our <u>food</u> is <u>converted</u> to <u>kinetic energy</u>. Some of it is <u>wasted</u> by being converted <u>into thermal energy</u>, making us hot.
- When a <u>vibrator</u> is used, <u>chemical energy</u> from the <u>battery</u> is <u>converted</u> into <u>electrical energy</u>, which is <u>then converted</u> into <u>kinetic energy</u>. Some is <u>wasted</u> through <u>sound energy</u>.

<u>Efficiency</u>

Energy will <u>never disappear</u>. It can only be <u>wasted</u> – or <u>converted into other forms</u> of energy. Physicists believe that <u>the amount of energy in the Universe is constant</u> – which means we cannot use energy up.

This leads us to the Law of Conservation of Energy.

<u>The Law of Conservation of Energy states that:</u>

Energy is not created or destroyed in any process. It is just converted from one type to another.

<u>Drawing Sankey Diagrams</u>

When we are considering energy transfers, we must remember that <u>a proportion of the energy input is wasted</u>. Real systems can <u>never have 100% efficiency</u>. The useful output energy will always be less than the input. Efficiency is given in percentage – usually anyway, but read the question for the specific unit.

This is a <u>Sankey diagram</u>.

How does it work? Well the Sankey diagram always <u>points right</u>. The <u>input energy</u> is written at the <u>beginning</u> of the arrow, with the amount of <u>energy specified in joules</u>. Then the arrow <u>splits</u> into more arrows. The arrow that goes <u>straight right is the useful</u> energy (which needs to be stated too). The arrow <u>pointing down is wasted energy</u>.
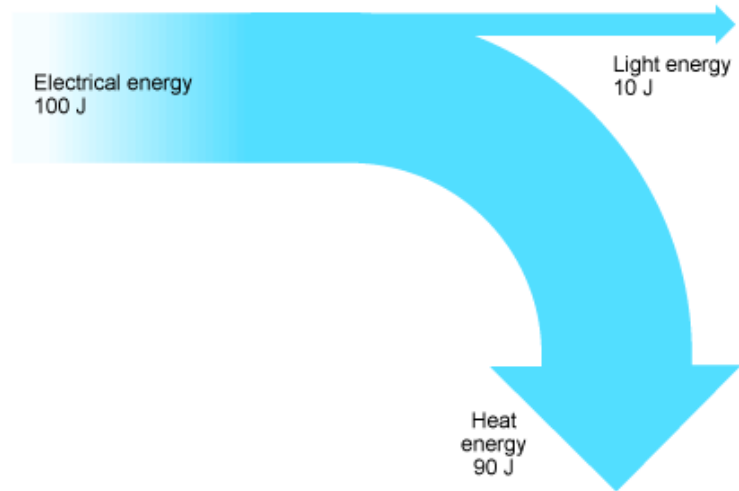
When drawing the Sankey, you need to remember several things:

- ✓ All forms of energy must be stated – both the input and the output(s).
- ✓ The total output energy must equal to the input energy.
- ✓ The wasted energy slopes down.
- ✓ The size of the output arrows depend on their energy. As you can see, heat energy is 90 J, therefore the arrow is a lot bigger than the light energy arrow.
- ✓ The size also needs to be proportional – depending on the question.

To calculate efficiency:

Efficiency = Useful energy output / Total energy input

So in the case of the above diagram:

Efficiency = 10J / 100J
Efficiency = 0.1 or 10%

<u>Some Everyday Examples of Heat Loss (4.5)</u>

- ↝ A filament lamp might have a 5% efficiency. The other 95% is lost through heat.
- ↝ Nuclear power has an efficiency of 35%. The rest is lost through heat and other forms of energy.
- ↝ When one is running, some of his/her energy is lost through heat and friction.
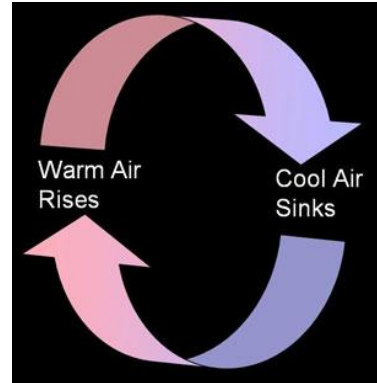
<u>Energy Transfer</u>

Energy transfer may take place by:

<u>Conduction</u>

Transfer of thermal energy through a substance without the substance itself moving. Metals are good thermal conductors. Something like plastic is not, and therefore, it is a good insulator. Conduction is carried out when particles transfer their energy to other particles. These gain energy and then pass it on to other particles, and so on. In thermal conductors, there are free electrons that can move easily through the structure of the conductor to speed the energy transfer.

Convection

Convection is the transfer of heat through fluids (liquids and gases) by the upward movement of warmer, less dense regions of fluid. Hot air tends to rise and cool air tends to fall. ACs and heaters are therefore, positioned differently. The AC is positioned near the ceiling, so cool air that comes out of it will fall, whereas, heaters are placed on the floor so hot air can rise from it. In cooking ovens, a heating element is placed at the bottom of the oven. It heats the nearby air, which makes it rise. Woolen clothing trap air, which forms an insulating layer to prevent heat loss. Convection can be seen by placing potassium manganate (VII) into a beaker of water on a Bunsen burner. The hotter water expands and floats up to the beaker. Colder water sinks to take its place and gets heated too. Meanwhile the hot air starts to cool and sink. This makes a circulating current, called convection current.
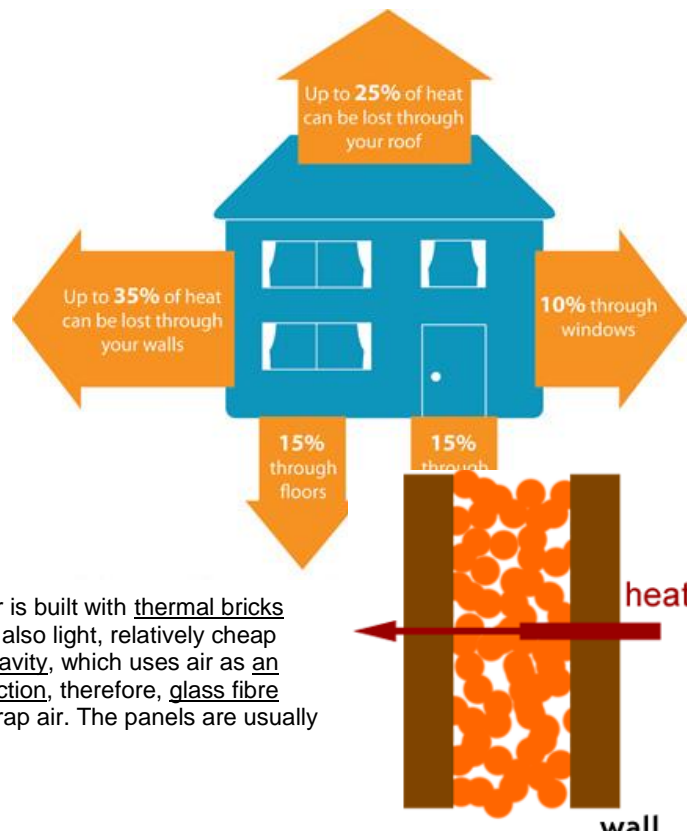

Warm Air Rises   Cool Air Sinks

Radiation

Thermal radiation is the transfer of energy by infra-red (IR) waves. IR waves travel in a straight line, and are used in special cameras and other devices. It can travel through a vacuum. We receive heat from the Sun through radiation.

IR waves can be reflected and absorbed by different materials. Shiny surfaces are good reflectors. Dark surfaces are poor reflectors, but good absorbers of heat radiation.

House Insulation

Heat can be lost through walls by conduction. Conduction is the main way heat is lost in a house. Heat however, can be lost through convection in the roof.

Below are ways to reduce energy transfers.

Up to **25%** of heat can be lost through your roof

Up to **35%** of heat can be lost through your walls

10% through windows

15% through floors

15% through

Ways to Reduce Heat Transfer in a House

Walls

The picture on the right shows cavity wall insulation. The outer layer is made with bricks – which have good insulating properties, are strong and have good weathering properties. The inner layer is built with thermal bricks which have very good insulation properties. They are also light, relatively cheap and quick to work with. In the middle, there is an air cavity, which uses air as an insulator. However, air can still be lost through convection, therefore, glass fibre matting or foam can be injected into the air cavity to trap air. The panels are usually surfaced with aluminium foil to reflect IR waves.

heat

wall

Double Glazing

This is a typical double glazed window. Glass is a poor conductor. Two layers of glass are used to trap a layer of air for insulation. Some double glazing uses a special glass to increase the greenhouse effect (heat radiation from the Sun can
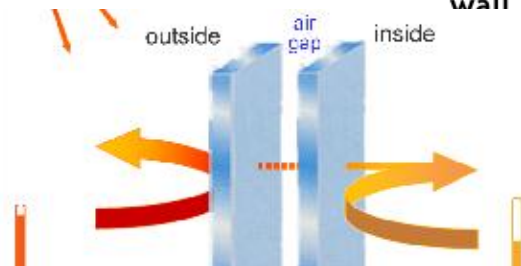
outside   air gap   inside

get in but radiation from inside the house is mainly reflected back again).

Loft Insulation

Roof insulation in modern houses uses similar panels to those used in the wall cavities, trapping a thick layer of air. This takes advantage of the poor conducting property of air, whilst also preventing convection currents circulating. Again, reflective foil is used to reduce radiation heat loss.
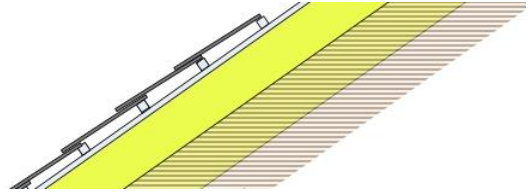
Other Ways to Reduce Energy Transfer

- Reduction or elimination of draughts from poorly fitting doors and windows.
- Curtains to reflect/absorb heat.
- Carpets to prevent loss of heat through the floor.

In Humans and Animals

- Fire fighters use protective clothing to reduce the amount of heat getting to their bodies.
- Clothes trap air around the body to provide insulation.
- Hats are the human equivalent of loft insulation.
- Marathon runners or people suffering from hypothermia are wrapped in thin, highly reflective blankets.
- Birds fluff up their feathers to trap air.
- Some huddle together for warmth.
- Other animals curl into small balls – this minimizes the exposed surface area.

Work

Work done is equal to energy transferred (because energy is the ability to do work). To calculate work:

Work Done (joules) = Force (newtons) x Distance (metres)
$$W = F \times D$$

Example: A weightlifter raises an object that weights 500N through a distance of 2m. Calculate the work done:

$$W = F \times D$$
$$= 500N \times 2m$$
$$= 1000J$$

Gravitational Potential Energy

Gravitational potential energy is the energy possessed because of its position. It increases with height, if the mass and gravitational field is constant. If an object is raised above the ground, it gains GPE. Once it is dropped, the GPE turns into kinetic energy. When the object reaches the ground, all the KE is turned into heat, sound and other forms of energy. To calculate GPE:

Change in GPE (joules) = Mass (kg) x Gravitational Field Strength (N/kg) x Height (m)
$$GPE = m\,g\,h$$

Kinetic Energy

Kinetic energy is movement energy. To calculate kinetic energy:

KE (joules) = ½ x mass (kg) x velocity^2 (m/s)
$$KE = \tfrac{1}{2}\,mv^2$$

*Note: work done = gain in GPE = gain in KE

Power

Power is the rate of transfer or energy or work. To calculate power:

$$\text{Power (watts) = Work Done (joules) / Time Taken (seconds)}$$
$$P = W/t$$

Energy Resources and Electricity Generation

Wind	Wind is caused by huge convection currents in the Earth's atmosphere, driven by heat energy from the Sun. The moving air has huge amounts of kinetic energy, and this can be transferred into electrical energy using wind turbines.	KE → Electrical Energy Ads: Renewable DisAds: Noisy, ugly, wind level varies
Waves	Wave machines use the up and down movement of waves to turn electricity generators.	KE → Electrical Energy Ads: Renewable DisAds: Difficult to build
Tides	Tidal barrages are built across the mouths of rivers. As water moves in or out of the river mouth when the tide turns, the kinetic energy in the water is used to turn electricity generators.	KE → Electrical Energy Ads: Renewable DisAds: Expensive, harm wildlife
Water	Hydroelectric power (HEP) schemes store water high up in dams. The water has gravitational potential energy. As the water rushes down through pipes, this GPE is transferred to kinetic energy, which turns electricity generators.	GPE → KE → Electrical Energy Ads: Renewable DisAds: Ugly, disrupt wildlife, expensive
Geother-mal	In some places the rocks underground are hot. Deep wells can be drilled and cold water pumped down to be heated by the rocks. It returns to the surface as hot water and steam, where its energy can be used to drive turbines and electricity generators	Thermal Energy → KE → Electrical Energy Ads: Renewable DisAds: Deep drilling is difficult
Solar Heating	Solar panels do not generate electricity. Instead they heat up water directly. A pump pushes cold water from a storage tank through pipes in the solar panel. The water is heated by heat energy from the Sun and returns to the tank.	Thermal Energy → Electrical Energy Ads: Renewable, quick DisAds: Sun's heat energy varies
Solar Cells	Solar cells are devices that convert light energy directly into electrical energy. You may have seen small solar cells on calculators. Larger arrays of solar cells are used to power road signs, and even larger arrays are used to power satellites in orbit around Earth.	Light Energy → Electrical Energy Ads: Renewable DisAds: Sunshine varies, expensive, not very efficient
Fossil Fuels	Coal, oil and natural gas are called fossil fuels. Chemical energy from dead remains is stored within these. The energy is transferred to thermal energy and light energy when the fuels burn.	Chemical Energy → Heat Energy → Electrical Energy Ads: Efficient DisAds: Scarce, causes pollution
Nuclear	The heat from the chain reaction caused by the radioactive	Thermal Energy → KE → Electrical Energy

Power	decay of unstable uranium-236 nuclei is used to boil water, which produces steam that turns turbines.	Ads: Efficient DisAds: Highly dangerous, U-236 is scarce
Biomass	Biomass fuels come from living things such as wood. Chemical energy stored in these are burned to release heat energy which heats up water into steam. The steam is then used to turn turbines which generate electricity.	Chemical Energy → Heat Energy → Electrical Energy Ads: Renewable DisAds: Huge areas of land are needed

Speed, Velocity and Acceleration

Speed

To calculate speed:

> Speed (m/s) = Total Distance Moved / Time Taken
> V = d/t

Understanding Distance-Time Graphs

The gradient of the line tells us the speed of the car. The steeper, the faster. The picture on the right shows acceleration on a distance-time graph. A straight line means a steady speed. A horizontal line means stationary.
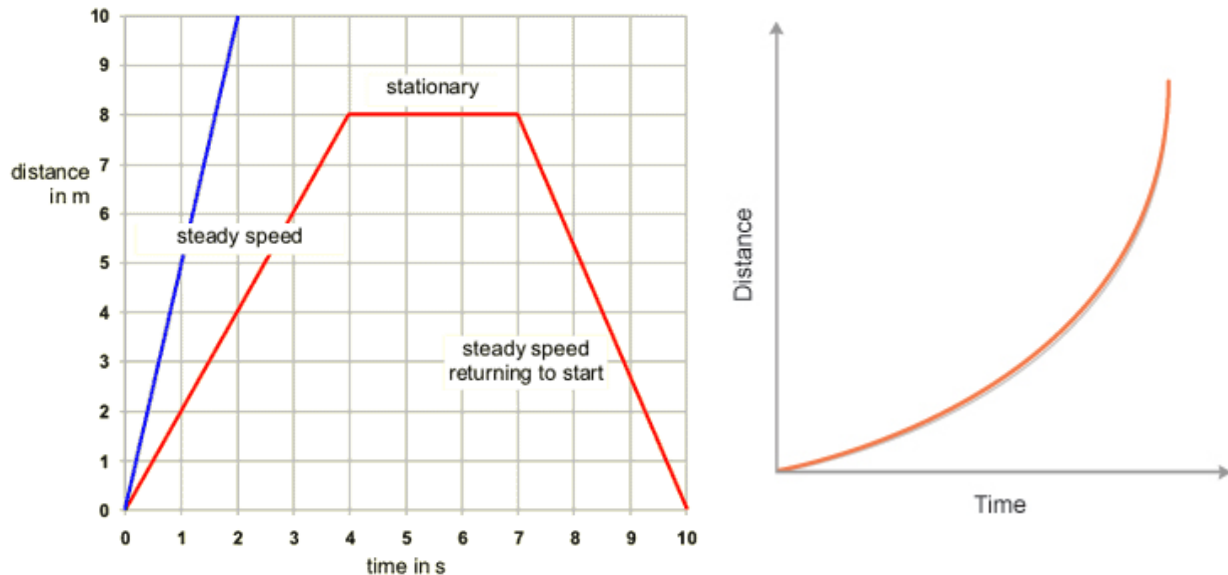
What's the difference between speed and velocity? Velocity is speed at a particular direction.
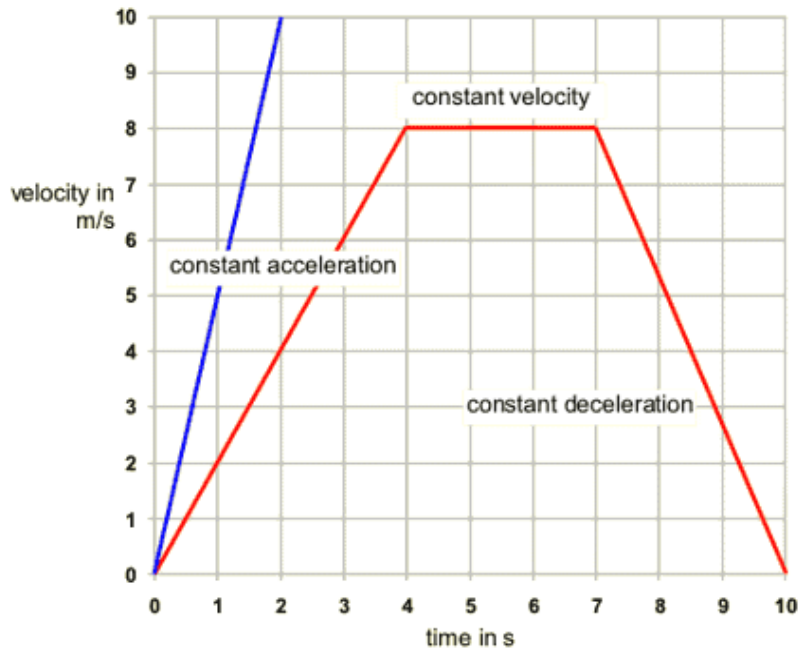
Acceleration

Acceleration is the rate at which objects change their velocity. To calculate acceleration:

> Acceleration (m/s^2) = (Final velocity – Initial Velocity) / Time Taken
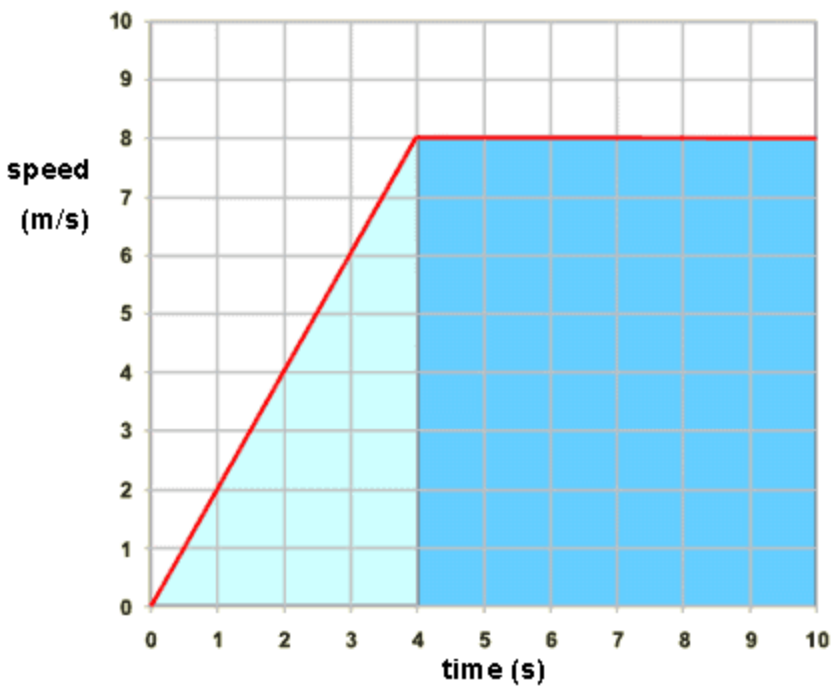> A = (V-U)/t

CGPwned
Science

Velocity-Time Graphs

The <u>steeper</u> the gradient, the <u>greater</u> the acceleration.

The <u>area</u> under the line on a speed-time graph represents the <u>distance travelled</u>.

For the first four seconds: ½ x 4 x 8 = 16m

For the next six seconds: 6 x 8 = 48m

Total Distance Travelled = 16 + 48 = 64m

Unit 3: Electricity

Unit	What It Measures
Ampere (A)	Current (I)
Coulomb (C)	Charge (Q)
Joule (J)	Energy (E)

Ohm (Ω)	Resistance (R)
Second (s)	Time (t)
Voltage (V)	Volts (V)
Watt (W)	Power (P)

earth wire provides a low resistance in case of a fault.
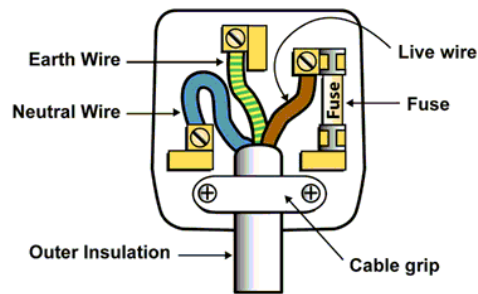
The live wire provides a path which electricity from the power station travels along. The neutral wire completes the circuit. The path for the current to flow

Hazards of Electricity

Hazard	What Makes It Dangerous
Frayed Cables	▪ Can expose metal wires. Touching these would give an electric shock. ▪ Heat may cause fire.
Long Cables	▪ Might trip someone. ▪ If put in a bunch, the high current will cause it to heat up and potentially cause a fire. ▪ It could lead to the earth wire being easily pulled out.
Damaged Plugs	▪ May expose parts of the plug that are carrying electricity.
Water Around Sockets	▪ Water conducts electricity at high voltages, Touching the water can cause an electric shock.
Pushing Metal Objects into Sockets	▪ Metals conduct electricity. Push a metal object into a socket and you get an electric shock and die.

Safety Features

Safety Feature	How It Helps
Insulation/Double Insulation	Most modern appliances are made from an insulator like plastic. Electrical parts are covered with plastic so if a fault develops, the dangerous parts won't be touched by the user. Double insulation doesn't require an earth wire.
Earthing	Appliances with metal casing should be connected to the earth wire so if the live wire becomes frayed or breaks, and comes into contact with the casing, the earth wire provides a low resistance path for the current for the electricity to pass back down to the earth without giving the user an electric shock.
Fuses	A fuse is found in a plug and contains a think piece of wire made from a metal with a low melting point. If too large a current flow through the circuit, the fuse wire melts, shutting the circuit off, preventing you from getting a shock and the ignition of an electrical fire. The blown fuse must be replaced. When choosing the right fuse, you choose the next biggest choice from the current rating of your device.
Circuit Breakers	A modernized form of a fuse. If a large current flows in a circuit, the switch opens, breaking the circuit. Once the fault has been corrected, the reset button can be pressed so it can be used again.

Electrical Heating and How It Is Used

Wiring in a house is designed to let current pass through it easily – it has a low resistance.

However, things such as kettles or toasters have wires with high resistance. As the current passes through the element, energy is transferred and the element heats up. This heating effect is also used in dishwashers, cookers, washing machines etc.

It is also used in lights. Normal light bulbs have a very thin filament which gets so hot when current passes through it that it glows white. This effect is what causes electric fires too, but can be used in fan heaters, hair dryers…etc.

Resistors and Resistance

Resistors are used in circuits to control the sizes of currents and voltages. Without one, the voltage across a bulb may cause too large a current to flow through and cause the bulb to blow. An extra amount of energy is needed to push charges through the

resistance, and this can cause a rise in temperature as the energy may be converted to heat.

There are two types:

- Fixed resistors – They have a <u>fixed amount</u> of resistance.
- Variable resistors – Resistance can be <u>varied</u> to increase/decrease the current. It is used in the remote control to alter the volume of the TV, and also used to control the speed of a motor.

<u>Ohm's Law</u>

To calculate resistance:

$$\text{Voltage (V)} = \text{Current (A)} \times \text{Resistance } (\Omega)$$
$$V = IR$$

Ohm's Law: The current that flows through a conductor is directly proportional to the potential difference (voltage) across its ends, provided its temperature remains the same.
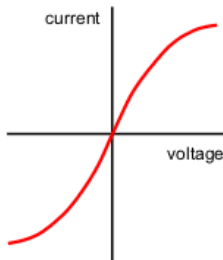
Basically, current flowing through a wire/resistor is <u>directly proportional</u> to the voltage. It also means that <u>resistance stays constant</u>.

However, this is not the case for a <u>metal filament bulb</u>. Resistance of the bulb increases because temperature increases. When <u>temperature increases</u>, the positive atoms <u>vibrate more vigorously, impeding</u> the flow of electrons. You get a <u>curve</u> (left picture).
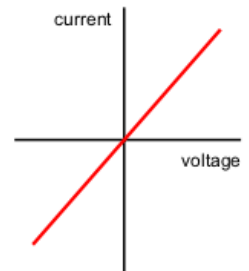
<u>Thermistors</u>

Thermistors are used as <u>temperature sensors</u>, for example, in fire alarms. It is made from <u>semiconducting material</u> such as silicon or germanium.


- At <u>low</u> temperatures, the resistance of a thermistor is <u>high</u>, and <u>little current</u> can flow through them.
- At <u>high</u> temperatures, the resistance of a thermistor is <u>low</u>, and <u>more current</u> can flow through them.

<u>Light-Dependent Resistors (LDR)</u>

LDRs (light-dependent resistors) are used to detect light levels, for example, in automatic security lights, photographic equipment, automatic lighting controls and burglar alarms.

- In the dark and at low light levels, the resistance of an LDR is high, and little current can flow through it.
- In bright light, the resistance of an LDR is low, and more current can flow through it.
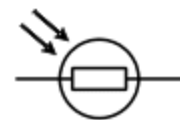
<u>Diodes</u>

Diodes are resistors that direct the flow of current to one <u>direction only</u>. Current can only flow through one direction due to a part of the diode with low resistance and cannot flow the opposite way due to the high resistance at the other end of the diode. Diodes are used in <u>rectifier circuits</u> that convert alternating current to direct current. It can also make <u>logic gates</u>

(something in the Cambridge syllabus and thank GOD it is not Edexcel).

All these resistors can be investigated by sticking them into a circuit and adjusting the voltage, then comparing it with the current and then plotting a graph.
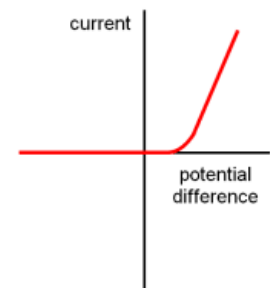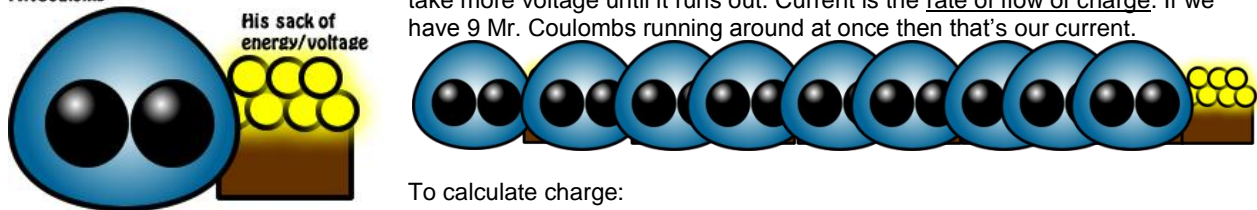
Current and Circuits

Explaining Charge, Current and Voltage

Meet Mr.Coulomb:
Mr. Coulomb is a single charge. He carries voltage, emptying it for his fellow light bulbs, arriving at the batteries to take more voltage until it runs out. Current is the <u>rate of flow of charge</u>. If we have 9 Mr. Coulombs running around at once then that's our current.

Mr.Coulomb

His sack of
energy/voltage

To calculate charge:

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

Indicating the Presence of a Current

Lamps and LEDs (light emitting diodes) will glow when there is a current flowing in the circuit.

Different Types of Circuits

Series Circuits

In a series circuit, current is the <u>same throughout</u> the circuit. The size of the current <u>depends on the voltage supplied and the number and nature of the other components in the circuit</u>. If more bulbs are added, there will be a greater resistance throughout the circuit.

In a series circuit, the total resistance is the resistance of all the other resistors added up.

2Ω 1Ω 3Ω

is the same as: 6Ω
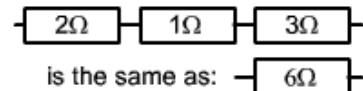
- ✓ One switch can turn on all the components together.
- ✓ If there is a fault in the circuit, the whole thing stops working.
- ✓ Voltage is shared between all the components – the more bulbs added the dimmer they become. The larger the resistance of the component, the bigger its share of voltage.
- ✓ Decorative lights (the ones you put on Christmas trees) are wired in series.

Parallel Circuits

Parallel circuits have <u>branches</u> so there are more paths for the current to flow. This means that it is possible to turn different parts of the circuit on or off by using switches. The voltages across components in a parallel circuit are <u>all equal</u>. Current however, <u>halves at every junction</u>.

- ✓ Switches can be placed to switch individual bulbs or switch them all on together.
- ✓ If one bulb breaks, only the other components from the same branch would break.
- ✓ If more bulbs are added, since voltage is the same, all bulbs will be equally bright – however, voltage runs out quicker.
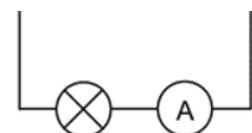- ✓ Lights in your home are wired in parallel.

Measuring Voltage and Current

Voltage

- ✓ Use a voltmeter.
- ✓ The voltmeter must be connected in <u>parallel</u>.
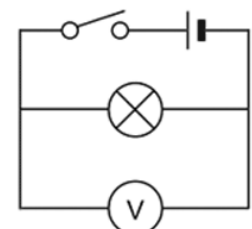
Current

✓ Use an ammeter.
✓ The voltmeter must be connected in <u>series</u>.

And another relationship…to calculate power:

$$\text{Power (W) = Current (A) x Voltage (V)}$$
$$P = I \times V$$

Short Circuits

Current will always choose the path with <u>least resistance</u>. This circuit will not light because there is a path available with less resistance (i.e. without a bulb) for Mr. Coulomb. This obviously means that the current would choose to take that path instead, which means the bulb won't light.
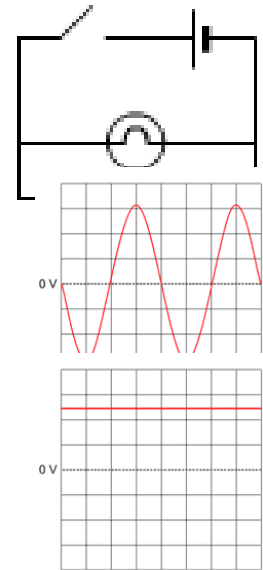
A.C and D.C

Alternating Current

✓ The flow of electricity is constantly changing direction.
✓ Mains electricity supply provides alternating current.

Direct Current

✓ The flow of electricity is in one direction.
✓ Cells and batteries provide this.

Conductors and Insulators

✓ Conductors allow current to flow easily through the circuit. These are usually metals, where charge is carried by the free electrons that are able to move throughout the whole of the metal.
✓ Insulators are poor conductors. These are things like plastic and fabric.

More Relationships

Energy Transfer

To calculate energy transfer:

$$\text{Energy Transferred (J) = Current (A) x Voltage (V) x Time (s)}$$
$$E = I \times V \times t$$

Explaining Charge, Current and Voltage (cont.)
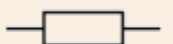
Current:

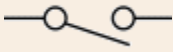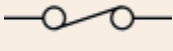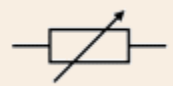✓ The rate of flow of charge/electrons
✓ Is equivalent to one coulomb per second

Voltage:

✓ Energy transferred per unit charge passed
✓ Joule per coulomb
✓ Is the force that pushes the current around the circuit

Circuit Symbols

	Open Switch
	Closed Switch
	Lamp
	Cell
	Battery
	Voltmeter
	Resistor
	Fuse
	Ammeter
	Variable resistor
	Thermistor
	Light dependent resistor (LDR)

Electric Charge

Insulating materials can be given an electric charge by rubbing them –or charging by friction. This does not create charge, but separates them.

When two uncharged insulators (a plastic rod and a cloth) are rubbed together, electrons from the rod would be rubbed onto the cloth, making the cloth negatively charged and the rod positively charged. Remember, it's the electrons that move, not protons.

Also remember:

- ✓ Like forces attract
- ✓ Unlike forces repel

Electrostatic Phenomena: When electrons are rubbed onto insulating materials, charging them up, and therefore, making them repel or attract other objects.

Dangers of Static Electricity

- ✓ Airplanes can get charged when flying to the air. As it increases, so does the voltage between it and the earth. When airplanes are being refueled, the high charges could escape to the earth as a spark (much like getting an electric shock, but bigger) during refueling and cause in explosion. Solution's to earth the plane with a conductor as it lands.
- ✓ Fuel tankers may build up charge as it travels (because of the road or the air). If charges escape as a spark, you may get an explosion. Solution again is the earth the fuel tanker before fuel is transferred.
- ✓ Our clothing may get charged with electricity – which charges us negatively. Since our body is a conductor, charges can escape from us too. If we touch someone when charged, the charges may escape to the earth or the next person, which creates an electric shock. Ouch.

Uses of Static Electricity

Photocopiers

I.   Drum is charged negatively where places are to be copied (the dark spots).
II. Toner of the opposite charge of the drum would stick to the charged areas.
III. Negatively charged paper is pressed against drum, where the toner charges are attracted to the paper, forming the image.
IV. Paper is then heated to form a permanent image.

Inkjet Printers

I.   A drop of ink is given a charge.
II. One of the charged deflectors is negative and the other is positive, so when the charged ink drops between the deflectors, (if say the ink drop was negatively charged), it would be repelled away by the negative deflector and attracted to the positive deflector until it falls onto the right place on the paper.

Electrostatic Paint Sprayers
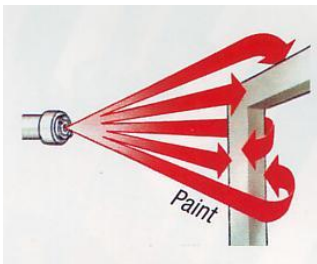
These spray positively charged paint. It is very efficient because when each drop of paint is of the same charge, the repel each other, increasing spread of paint. Also, the charged paint would attract to the negatively charged
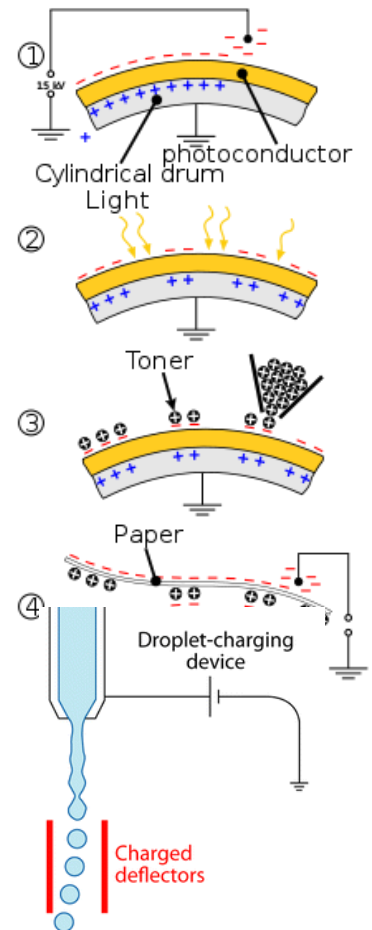
object, which means less paint is wasted, tight corners can easily be coated with paint.

Electrostatic Precipitators

When fossil fuels are burnt, they release waste gases with smoke particles of carbon and other disgusting stuff. To clean the smoke, electrostatic precipitators are used and this diagram shows how:

Unit   4: Forces and Motion
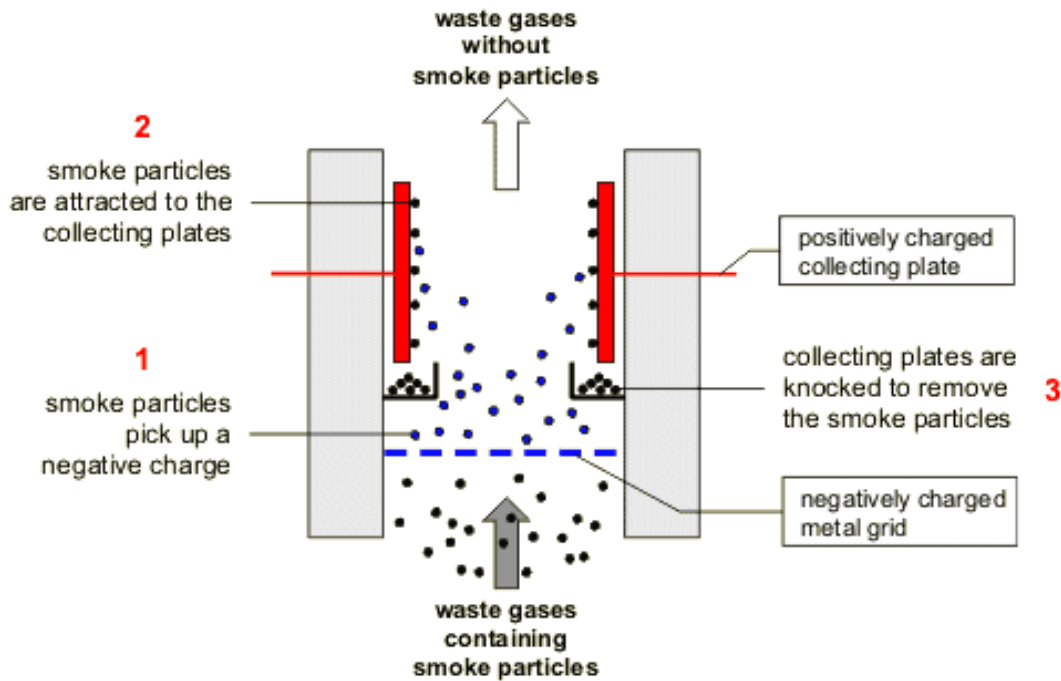
Type of Force	What is it?
Push	A force
Friction	A force that opposes motion
Normal Reaction Force	The force that acts in an upward direction to the skater and prevents him from sinking into the ground.
Gravitational Force/Weight	The pull of the Earth
Air Resistance/Drag	A force that opposes the movement of objects in the air.
Upthrust	An upward push
Magnetic Force	Used to make electric motors rotate.

Electrostatic Force	To do with the attractions and repulsions between charges.

A force is a push or pull of one body on another.
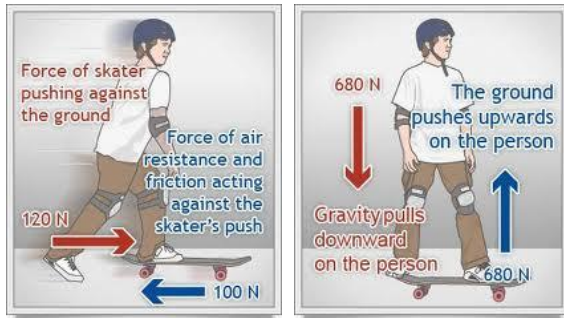
Force is a vector quantity. It changes in size and direction. Other examples of vector quantities include velocity, acceleration and momentum. Scalar quantities only change in size, for example, temperature. Forces are measured in newtons (N). 1kg is equivalent to about 10N.

Looking back at the right picture, if the forces are all equal and then cancel each other out, the forces and balanced and therefore, the unbalanced force is zero. If you look at the left picture, you can see that the forces are not equal. The skater is moving right at 120N, cancelling out the 100N. Here, there is an unbalanced force or resultant force of 120-100 = 20N.

Newton's Laws of Motion

Newton's 1st Law: If the forces on an object is balanced – there is no resultant force – the object will either remain at rest or carry on moving at constant speed in a straight line. If the forces on an object is unbalanced, the object will accelerate.

Newton's 2nd Law: Resultant force (N) = mass (kg) x acceleration (m/s^2) or $F = ma$

Newton's 3rd Law: For every action there is an equal and opposite reaction.

Terminal Velocity

An object moving through the air experiences air resistance or drag. The size of this depends on the object's shape and speed. Objects falling through the air experiences two significant forces: weight and drag.

When an object has just been released, there is a starting velocity of 0m/s. This means there is no drag. The resulting downward acting force is just the weight force of the Earth.

When it starts moving, it has a drag force acting against it, m. As the object is accelerating, it is getting faster. The faster the object moves, the bigger the drag force is.

The object then reaches a point where the drag force exactly balances the weight force. Acceleration is now at zero and the falling object is moving a constant speed. The object has reached terminal velocity.
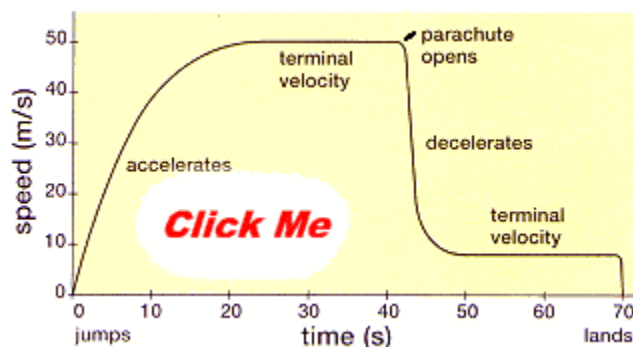
When a skydiver jumps off the plane, she will accelerate until she reaches terminal velocity. When her parachute opens, it will cause a sudden increase in drag force. This means that there will be an unbalanced force acting upwards, causing her to decelerate. As she slows down, the drag force decreases and a new terminal velocity is reached.

Or she simply forgets her parachute and dies.

Thinking Distance and Braking Distance

Thinking distance is the time taken for the driver to respond or react. This can be increased if the driver is tired, under the influence of alcohol/drugs or there is poor visibility.

Braking distance is the distance taken for the vehicle to decelerate to rest after the driver has hit the brakes. This can be increased if the road is slippery or the tyres are screwed up.

Vehicles with a larger mass will have smaller rates of deceleration as you can see in F = ma.

Rearranging the equation gives a = F/m. If the braking force of two cars, one that weighs 1000kg and one that weighs 1500kg for example, then the car with the bigger mass will come to rest at a longer time than the other car.

Similarly if a car is breaking from higher velocity, it takes longer to stop.

Momentum

Momentum is <u>quantity possessed by masses in motion</u>. In other words, it is a measure of how difficult it is to stop something that is moving. We can calculate it using the formula:

$$Momentum (kg\ m/s) = mass (kg) \times velocity (m/s)$$
$$p = m \times v$$

Remember momentum is a <u>vector quantity</u>.

Also, the rate of increase of momentum is proportional to the force applied. This leads us to:

$$Force = change\ in\ momentum/time\ taken$$
$$F = (mv - mu)/t$$

Momentum is also conserved, therefore:

$$Momentum\ before\ the\ collision = Momentum\ after\ the\ collision$$

Collisions with no kinetic energy lost are called elastic collisions. These are usually collisions between gas molecules (they continue moving in a container and does not end up in a pile at the bottom).

When a ball bounces off the ground, the collision is partially elastic – the ball rebounds, regaining its original shape, but loses some of its kinetic energy.

When two objects collide and stick together, the collision is inelastic.

Example:

A railway truck with a mass of 5000kg rolling at 3m/s collides with a stationary truck of 10000kg (note that a stationary truck is 0m/s). At what speed do they move after the collision?

We have to take both momentums into consideration. If we picturise this somehow, when the trucks collide, both trucks will move in the same direction as the moving truck, however, they'd move at a slower speed because the crash has caused a lost in momentum of the moving truck. This momentum is conserved however, when both trucks move the same direction – they just do it a different speed. Confusing I know.

Yeah I know, I used Microsoft Word shapes.
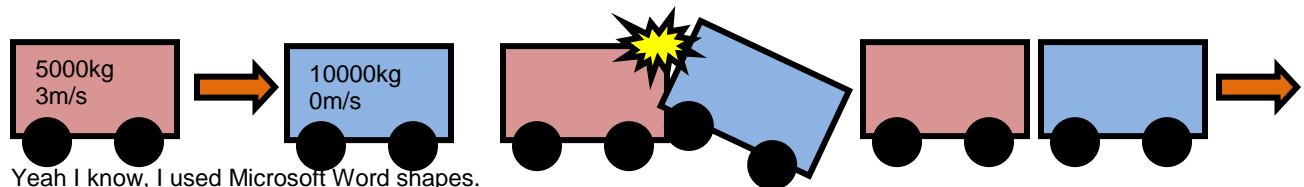
Anyways we have to consider both momentums (the blue truck has a momentum of 10000 x 0 = 0 kg m/s. It has no momentum. It doesn't need to be stopped because it is already stopped).

To get the point:

Momentum of Red Truck + Momentum of Blue Truck = Momentum of Both Trucks Moving Together After Colliding
*Note: Conservation of momentum remember?

Therefore,

5000kg x 3m/s + 10000kg x 0m/s = (5000kg + 10000kg) x v

So v = 15000 kg m/s divided by 15000 kg = 1 m/s

So both trucks will move 1 m/s right

Remember you have to <u>consider both speeds</u>.

<u>Car Safety</u>

Cars are designed to have crumple zones, which collapse during a collision and increase the time during which the car is decelerating, decreasing the force.

Example:

A car travelling at 20 m/s collides with a stationary lorry and is brought to rest in just 0.02s. A woman in the car has a mass of 50 kg. What force does the woman experience?

Remember a stationary lorry has a momentum of 0 kg m/s.

$$\text{Force = change in momentum/time taken}$$
$$= (50 \text{ kg x } 20 \text{ m/s} - 50 \text{ kg x } 0)/0.02$$
$$= 50000N$$

Using the same example, if the car was to have a crumple zone and the deceleration time (time taken) is increased from 0.02s to 1s, the impact causes a much smaller force of just 1000N to act on the passage, greatly increasing the chances of survival.

The Turning Effect of Forces

Forces have a turning effect. They tend to make objects turn around a fixed point called a pivot or a fulcrum. The turning effect of a force about a pivot is called its <u>moment</u>.

Moment (Nm) = force (N) x perpendicular distance from pivot (m)
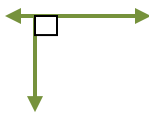
The perpendicular distance is basically the distance from the pivot to the line of force. It has to be 90^0 for the correct value.

An object will be in balance if:

Sum of anticlockwise moments = sum of clockwise movements

<u>Centre of Gravity</u>

The centre of gravity is the <u>point where the whole of the weight of the object appears of act</u>. It can be found by drawing lines of symmetry (if the object is rectangular or symmetrical) and finding the point which all the lines intersect, or, for an irregular shape, by suspending it freely by a point on its edge and using a plumb line to indicate the space directly vertical to the point. The centre of gravity is always <u>vertically below the pivot</u> so you can work out the centre of gravity by drawing a point somewhere in the middle of the plumb line, or suspending the object at different points on its edge and finding out where all the lines intersect.

Objects with a low centre of gravity and a wide base are stable as it is difficult to knock over.

center of disc
callipers
center of mass discovered
extra mass
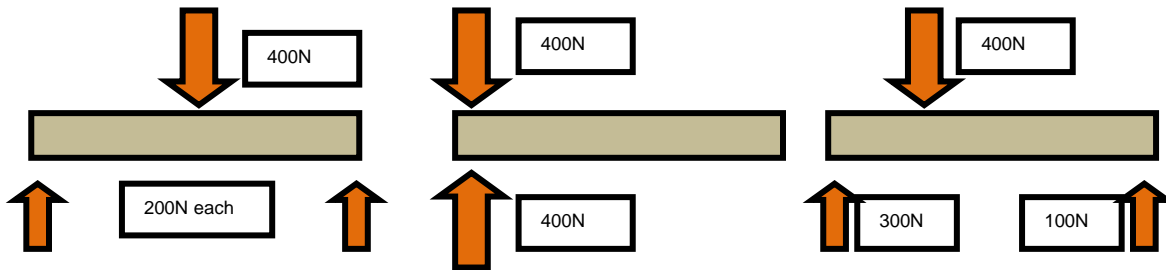wooden disc
plumb line
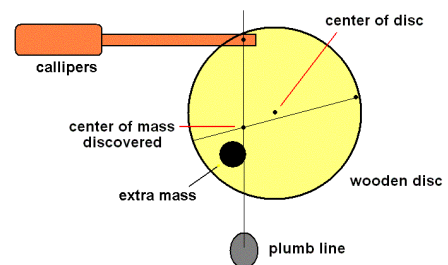
Parallel Forces Acting on a Plane

That's basically using the principle of moments (clockwise moment = anticlockwise moment) to find out whatever the question asks.
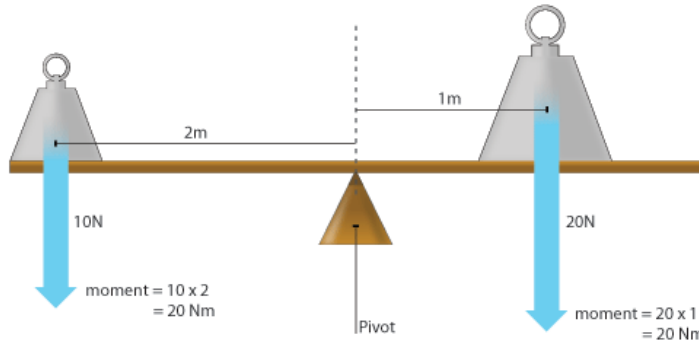
Forces Acting on a Beam

The upward forces on a light beam, supported at its ends, vary with the position of a heavy object placed on the beam.

For example(s):

Hooke's Law

Elastic behavior is the ability of a material to recover its original shape after the forces causing deformation have been removed. Hooke's Law states that: load force is directly proportional to extension provided that it is within its elastic limit
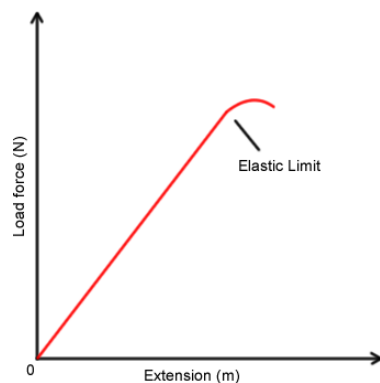
Once the spring or whatever has been stretched beyond the elastic limit, it will change shape permanently and will not return to its original shape.
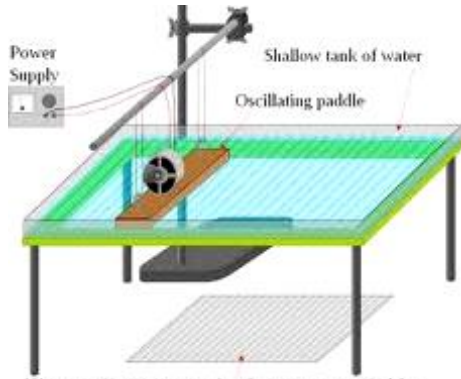
Helical springs and metal wires give you a graph like the left one (except in metal wires, the graph is steeper). However, elastic bands do not obey Hooke's Law and you get a graph like this (right).
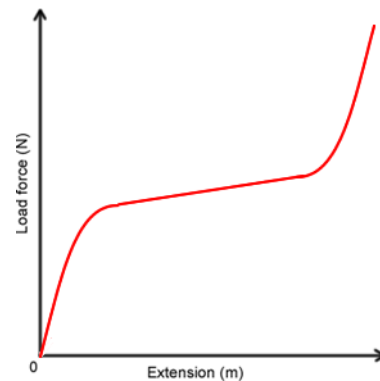
Unit 5: Waves

Waves transfer energy and information without transferring matter.

Waves can be shown by waggling one end of a rope or slinky. It can also be shown in water using a ripple tank.

Power Supply — Shallow tank of water — Oscillating paddle

Wave patterns on a viewing screen or table

The motor/oscillating paddle can be adjusted to produce vibrations that cause ripples in the water. Because of the light, these ripples can be seen under the tank.

✓ Transverse waves move at right angles to the direction of the motion of the wave. Examples include light waves and water waves.

✓ Longitudinal waves move along the direction of the motion of the wave. Examples include sound waves.
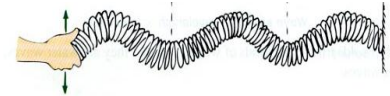
Amplitude (A)	Maximum movement of particles from their resting position
Wavelength (m)	Distance between a point on a wave and the same point on the next wave
Period (s)	The time it takes to produce one wave
Frequency (Hz)	The number of waves produced each second

Wavelength (m), Amplitude, Peak, Time (s), Trough
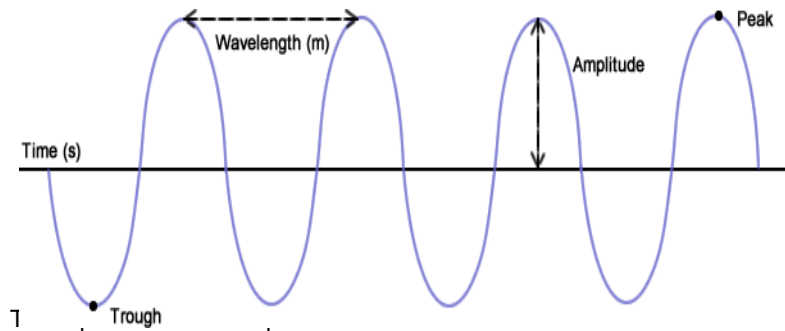
Wave speed (m/s) = frequency (Hz) x wavelength (m)
$$V = f \times \lambda$$

The equation for frequency:

Frequency (Hz) = 1/time period (s)
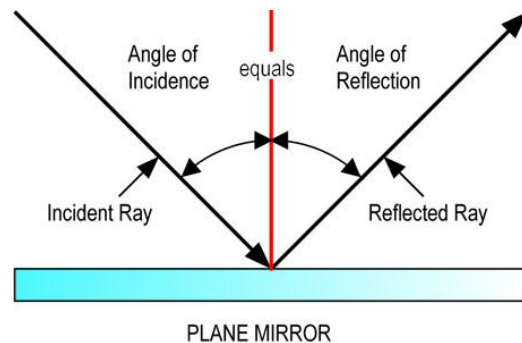$$f = 1/T$$

Reflection
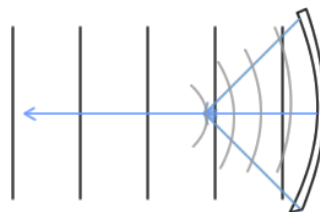
When waves strike a straight or flat barrier:

Angle of incidence = Angle of reflection

Note that the red line is called the normal line.

Angle of Incidence equals Angle of Reflection
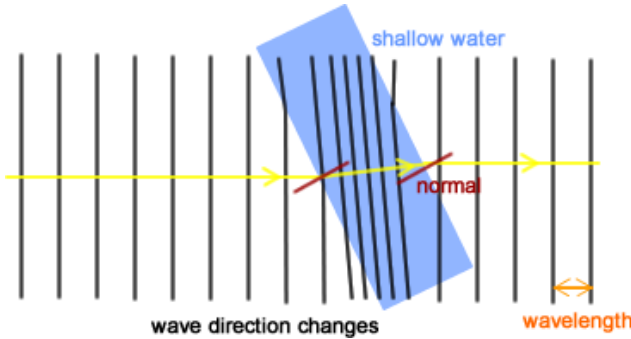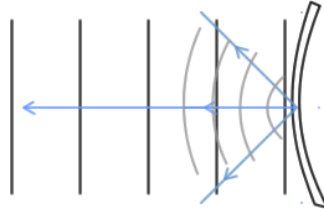
Incident Ray — Reflected Ray

PLANE MIRROR

When waves strike a concave barrier, they converge.

When waves strike a convex barrier, they <u>diverge</u>.

Refraction

Refraction is the change in direction when waves enter a medium. The <u>length of the waves is altered</u> but the <u>frequency isn't</u>. When waves hit shallow water, they'll slow down and bend towards the normal. When the waves leave the shallow water, it will bend away from the normal.

shallow water

normal

wave direction changes

wavelength

Diffraction

If a barrier with <u>a large gap</u> is placed in the path of waves, the majority of the waves passing through the gap continue in a <u>straight line</u>. There are regions to the left and right of the gap where there are no waves. If the size of the gap is adjusted so that it is <u>equal to the wavelength of the water waves</u>, they will <u>diffract</u>. Diffraction can also happen when waves pass a <u>single edge</u>. Examples of this include radio waves that are diffracted as they pass over hills.
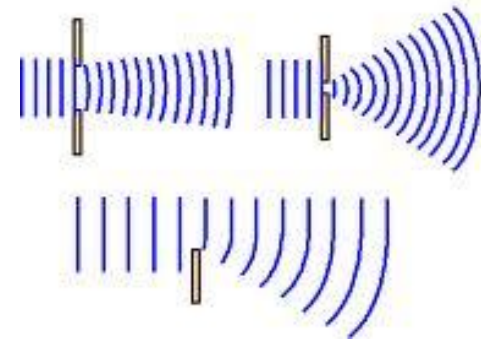
The Electromagnetic Spectrum

The electromagnetic spectrum is a <u>continuous spectrum of waves</u>. At one end of the spectrum, the waves have very long wavelengths. At the other end, the waves have very short wavelengths. All the waves have similar properties:
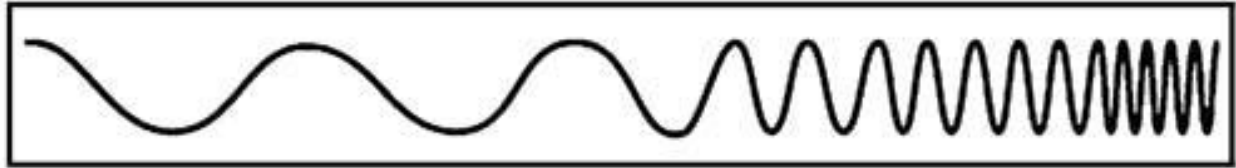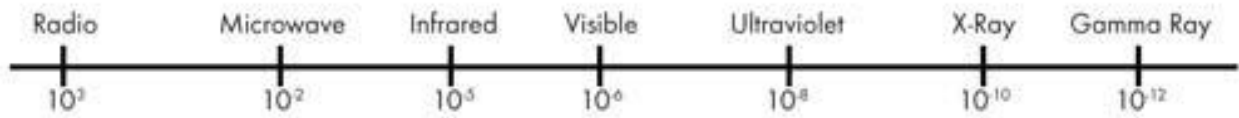
- ✓ They all transfer energy
- ✓ They are all transverse waves
- ✓ They all travel at the speed of light in vacuum (300 000 000m/s)
- ✓ They can all be reflected, refracted and diffracted

Below is a picture that shows the order of the EM spectrum in decreasing wavelength and increasing frequency. Learn them all (except for the actual wavelengths and frequencies).

The Electromagnetic Spectrum

Wavelength (meters)

Radio	Microwave	Infrared	Visible	Ultraviolet	X-Ray	Gamma Ray
10^3	10^{-2}	10^{-5}	10^{-6}	10^{-8}	10^{-10}	10^{-12}

Frequency (Hz)

Decreasing wavelength ⟶
Increasing frequency ⟶

10^4	10^8	10^{12}	10^{15}	10^{16}	10^{18}	10^{20}

Wave	Uses	Dangers of Excessive Exposure
Radio Waves	Broadcasting and Communication – This includes television, telephone conversations, radio broadcasts…	None
Microwaves	Heating food and satellite communication	Can directly heat internal body tissue – serious damage can occur before pain is felt
Infrared	Heating devices and night vision cameras	Readily absorbed by skin and can cause skin burns
Visible Light	Used by us to see things, in photography and optical fibres	None
Ultraviolet	Used in fluorescent lamps and sterilizing water	Causes skin to tan. Overexposure will lead to sunburn, blistering, skin cancer and blindness
X-rays	Observing internal structure of objects and materials and medical applications	Cell mutation and cancer
Gamma Rays	Sterilising food and equipment as well as treat certain types of cancer	Cell mutation and cancer

Light

Light is a transverse wave that can be reflected, refracted and diffracted. When it strikes a flat mirror/surface, the angle of incidence = angle of reflection.

The image seen in a mirror is called a virtual image. There are no rays of light actually coming from the place where the image seems to be (inside the mirror). It cannot be reproduced on screen. It's simply a misinterpretation of the brain. The opposite of this is a real image. The image produced in a mirror is the same distance behind the mirror as the object is in front of it. It is also laterally inverted. This means when you raise your left hand, your mirror image raises his right hand.

To summarise:

10cm   10cm
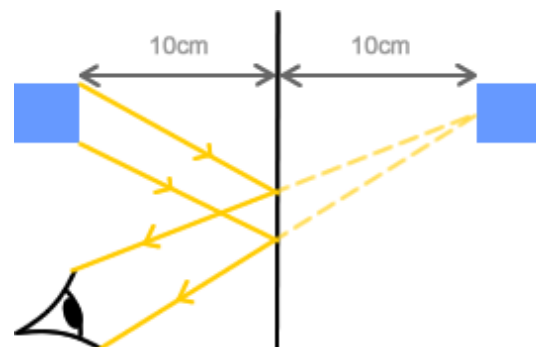
✓ The image is as far behind the mirror as the object is in front
✓ The image is the same size as the object
✓ The image is virtual
✓ The image is laterally inverted

Refraction of Light

In vacuum, light travels at around 300 000 000m/s. However, when it enters a new medium such as water, it travels more slowly and may cause a change in direction. This change in direction is called refraction.
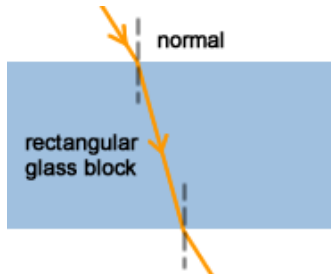
When white light passes through a prism, it emerges as a band of colours called a spectrum. It's formed because white light is a mixture of colours and each colour travels through the prism at a slightly different speed, so each colour is refracted by a different angle. The prism has a refractive index for each colour and as a result, each colour emerges from the prism travelling at a slightly different direction. This is called dispersion.
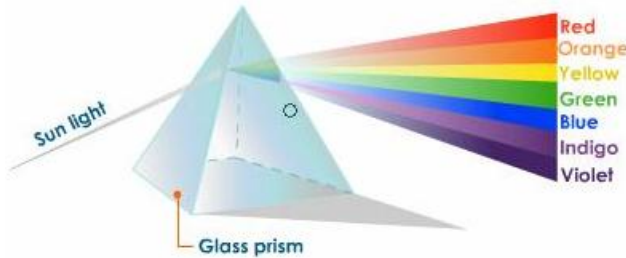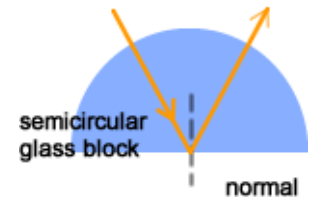
Refractive Index

The refractive index (n) is a constant that determines the amount of refraction in a material. Its formula is:

$$n = \sin i / \sin r$$

The RF is simply a ratio between the sine of i and the sine of r, so there is no unit.

Finding the RF of a Glass Block

1. Set up a ray box and shine light into rectangular glass block.
2. Measure the angle of incidence and angle of refraction.
3. Repeat step 2 a few times.
4. Use the formula to work out the refractive index (use deg, not radians).
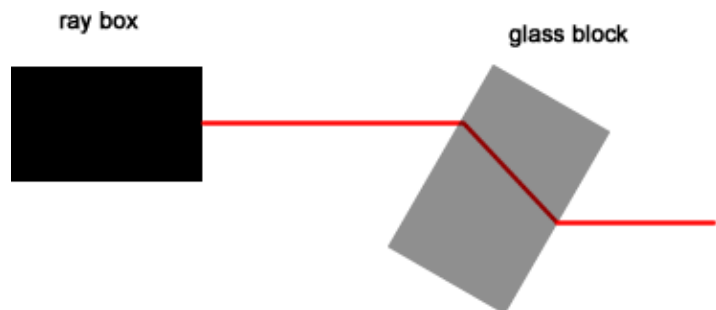
Total Internal Reflection

When a ray of light passes from an optically more dense medium into an optically less dense medium such as from glass to air, the majority of the light is refracted away from the normal. However, there is a small amount that is reflected from the boundary. Total internal reflection occurs when all light is reflected from the boundary.
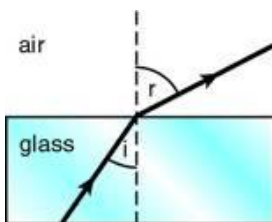
if the angle of incidence is less than the critical angle, the light refracts away from the normal
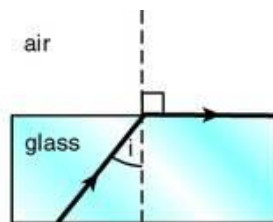
if the angle of incidence is equal to the critical angle, the light refracts at 90° to the normal
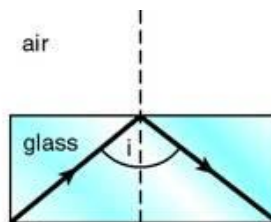
if the angle of incidence is greater than the critical angle, total internal reflection occurs

When the incidence ray is at an angle where the refracted ray is 90° to the normal, it is called the critical angle. It is the angle at which anything bigger, and total internal reflection will occur. Its formula:

$$n = 1 / \sin c$$

Optical Fibres

 The fibres are very narrow, so light entering the inner core always strikes the boundary of the two glasses at an angle greater than the critical angle. Bundles of fibres carry sufficient light for images 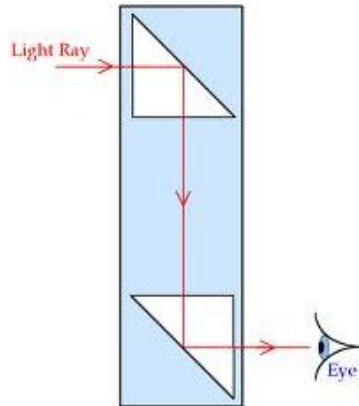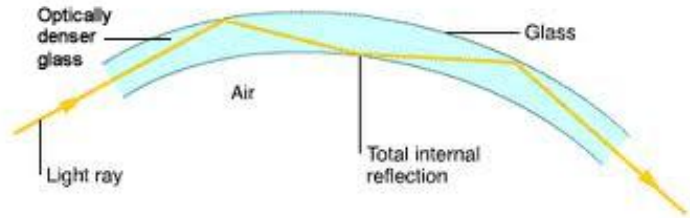of objects to be seen through them. Optical fibres are used in <u>endoscopes</u> to see inside the body. It <u>illuminates</u> the object to be viewed.

The Prismatic Periscope

Unlike normal periscopes (which use plane mirrors to reflect light), prismatic periscopes use <u>glass prisms</u>. Light strikes the prism at an angle greater than the critical angle for glass. The light then gets totally internally reflected twice before emerging parallel to the direction in which it was originally travelling.

The final image created is <u>sharper</u> and <u>brighter</u> than those produced by a plane mirror periscope. As well as that, <u>no multiple images </u>will be created.

Sound Waves

Sound waves are <u>longitudinal waves </u>that travel through gases, liquids and solids. They travel slower in air, at around 340m/s and faster in solids. Sound waves <u>cannot travel in vacuum</u>. Sound waves can be <u>reflected</u>, <u>refracted</u> and <u>diffracted</u>.

Frequency Range for Humans: 20Hz – 20 000Hz (hertz)

Measuring the Speed of Sound

1. Stand 50m away from a large, blank wall and clap wood blocks. Listen for an echo. Set up a rhythm of claps so that the echo comes exactly between two claps. Ask a friend to time 20 claps. During this time, sound has travelled 2000m (to the wall and back 20 times). Divide this distance by the time to work out the speed of sound.

2. Turn on the single generator so it produces a known frequency (such as 1 kHz). Move the microphones so that the two waves that form on the oscilloscope are exactly on top of each other. This would show that the microphones are at 1 wavelength away from each other. Measure the distance between the microphones. The speed of sound can be worked out using the formula $v = f \times \lambda$
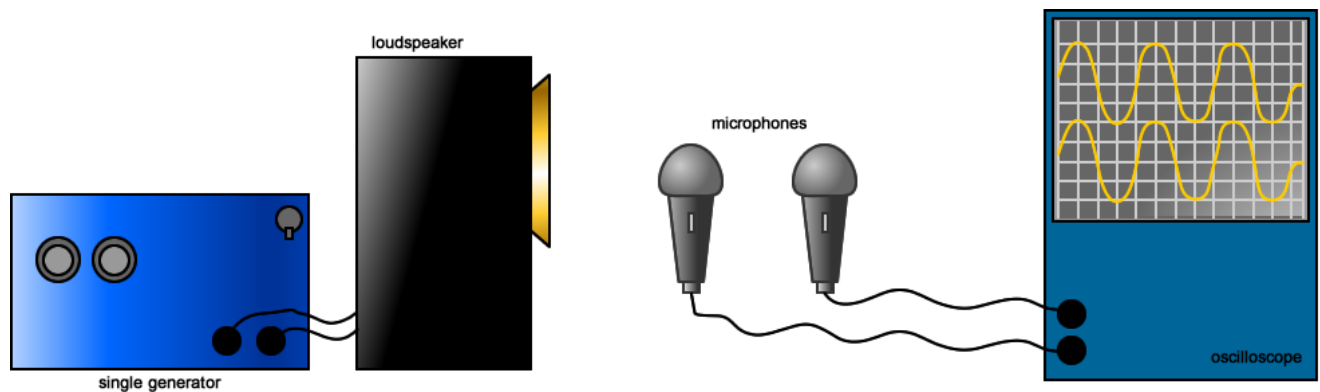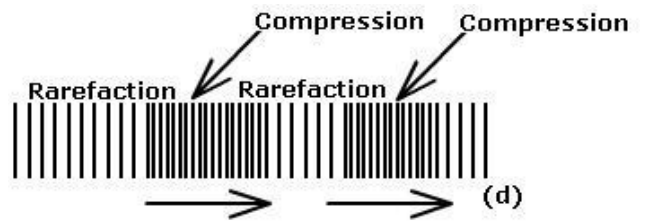
An image of a sound wave produced in a oscilloscope will look like this:

To determine the frequency of a sound wave, find the time period for one complete wave and use the relationship f = 1/T to find calculate the frequency.

- ✓ The loudness of a sound depends on the amplitude of the vibration (of the waves).
- ✓ The pitch of the sound depends on the frequency of the vibration.
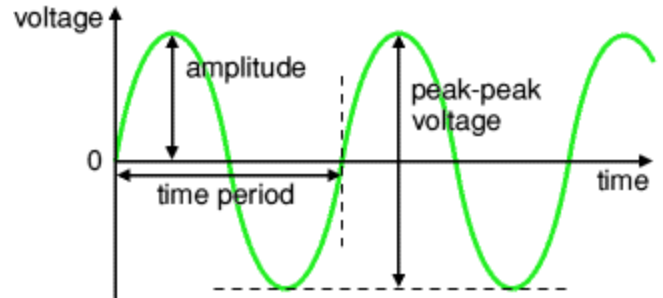
Letter	Description
P	High pitched, loud
Q	Low pitched, soft
R	High pitched, soft
S	Low pitched, soft
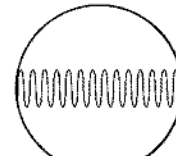
- ✓ The higher the frequency, the higher the pitch.
- ✓ The higher the amplitude, the louder the sound.

Digital and Analogue Signals

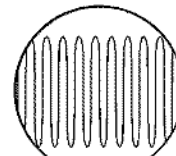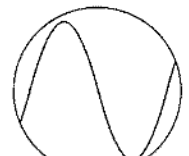When telephones, fax-machines and internet-linked computers transmit information, they must convert the information into a stream of electrical/light pulses. These pulses carry information as analogue or digital signals.

Digital Signal	Information is converted into a sequence of 0s and 1s called a binary code. These numbers are then converted into a series of electrical pulses.
Analogue Signal	Information is converted into electrical voltages or currents that vary continuously.

Advantages of Using Digital Signals

All signals become weaker during transmission as they lose energy or they pick up unwanted signals such as interference or noise. As a result, signals need to be amplified.

Regeneration of digital signals creates a clean, accurate copy of the original signal as it simply restores their distinct '0' and '1' shape.

On the other hand, when analogue signals are amplified, any accompanying noise is also amplified. These unwanted noises may drown out the original signal or introduce errors in the information being carried.
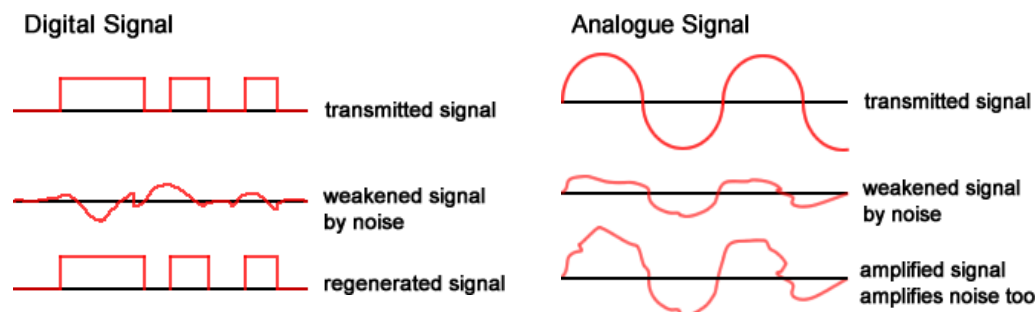
Digital signals can be made very short so more pulses can be carried around per second, meaning more information is passed on.

Unit 6: Radioactivity

The Atom

Atoms are made up of electrons protons and neutrons.
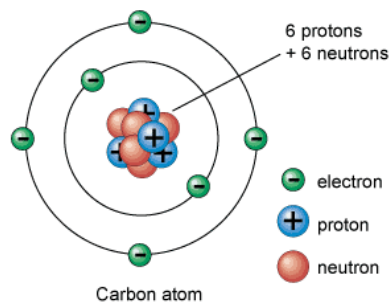
Atomic Particle	Relative Mass of Particle	Relative Charge
Neutron	1	0
Proton	1	+1
Electron	1/1836	-1

- The mass number shows the sum of the number of protons + neutrons
- The atomic number shows the number of protons (not necessarily electrons!)
- Number of neutrons = mass number – atomic number
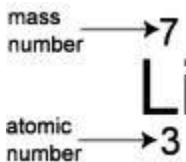
The number of protons in an atom identifies the element. The chemical behaviour of the element depends on the number of electrons it has.

Atoms of an element with the same number of protons but a different number of neutrons are called isotopes.

Understanding the Stability of Atoms

The protons are held in the nucleus by the nuclear force of neutrons. It is strong enough to hold the protons together as they would try to repel each other due to like positive charges. Too many or too few neutrons will make the nucleus unstable. The unstable nucleus will eventually decay, giving out energy and altering its balance of neutrons and protons. It may also give out ionising radiations in a random process. Since the process is random, it is not possible to predict which unstable nucleus in a piece of radioactive material will decay, or when the decay will happen.

Ionising Radiation α β γ

There are three types of   ionising radiation: alpha, beta and gamma radiation. Ionising radiation causes uncharged atoms to lose electrons, turning it into an ion. The penetration power of the radiation depends on the interaction between the radiation particles and other particles. If they have a small range, it means they interact frequently with atoms along their
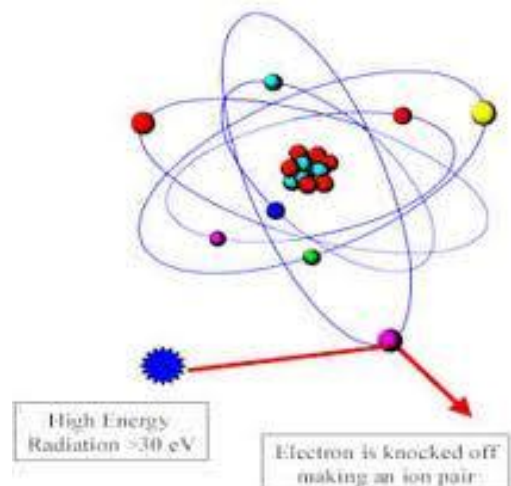
paths (such as atoms in the air) and therefore, lose their energy quicker.

| Radiation	About	Ionising Power	Penetrating Power	Range in Air	Radiation Stopped By
Alpha	Fast – moving helium ($^4_2$He) nuclei that are thrown out of unstable nuclei. They have a relatively large mass and a relative charge of +2.	High	Weak	5 – 8cm	A few mm of Paper
Beta	Very fast – moving electrons that are ejected by a decaying nucleus. However, the electrons don't come from the shell. It involves a neutron splitting up into a proton and an electron. The electron is ejected at high speed as a beta particle and the proton remains in the nucleus. Beta particles are very light and have a relative charge of -1. Since they are smaller and carry less charge, they interact with matter in their paths less frequently and therefore, have a greater range.	Medium	Medium	500 – 1000cm	A few mm of Alnuminium
Gamma	Electromagnetic waves that are weakly ionising and move very fast, making them extremely penetrating. Since they are waves, they have no mass or charge. Gamma radiation is emitted in 'packets' of energy called photons.	Weak	Strong	Infinite	A few cm of Lead

Describing the Effects on the Atomic and Mass Numbers of a Nucleus of the Emission of Each of the Three Types of Radiation

If the decay process involves the nucleus ejecting either an alpha or a beta particle, the atomic number will change. This basically means that alpha or beta causes the original element to transform into a different element. Gamma radiation – since they are waves, will not change either the atomic or mass number of the element.

α
β
γ

Paper   Aluminium   Lead
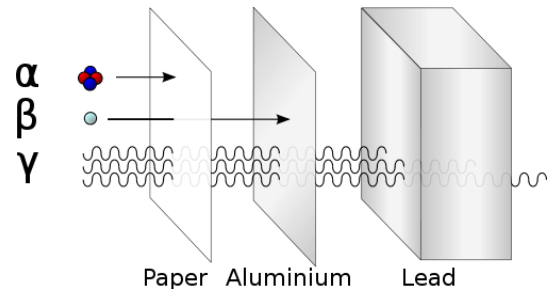
Alpha

The general form of an alpha decay equation is:

$$^A_Z Y \rightarrow ^{A-4}_{Z-2} W + ^4_2 He + Energy$$

The helium nucleus is the alpha particle. This is called a <u>nuclear equation</u>. Everything needs to be balanced out. Here is an example of alpha decay involving a radium atom splitting into a radon atom and an alpha particle:

$$^{222}_{88} Ra \rightarrow ^{218}_{86} Rn + ^4_2 He + Energy$$
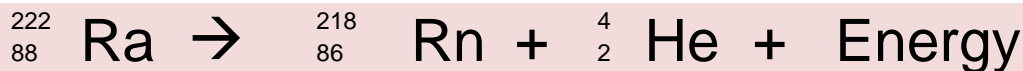
Beta

The general form of the beta decay equation is:

$$^A_Z Y \rightarrow ^A_{Z+1} W + ^0_{-1} e + Energy$$

An example involving the radioactive isotope of carbon, carbon-14, decaying to form the stable isotope of the gas nitrogen:

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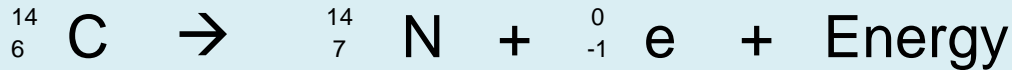
Gamma

As mentioned earlier, gamma rays don't alter the mass or atomic number of the nucleus. It is emitted when an unstable nucleus have surplus energy, even after emitting an alpha or beta particle.

Detecting Ionising Radiation

Photographic film is used by scientists to detect radioactivity. If the film becomes fogged, it shows that the scientist has been exposed to a certain amount of radiation. These films are checked regularly to ensure that the safety limit for exposure to ionising radiation is not exceeded.

The Geiger – Müller Tube

When ionising radiation enters the tube, it causes the low pressure gas inside to form ions. The ions allow a pulse of current to flow from the electrode to the conducting layer. This then gets recorde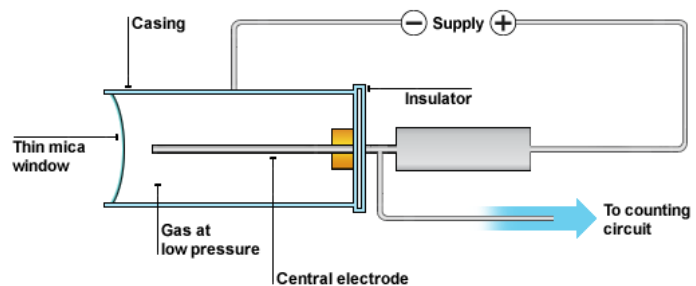d in the counting circuit as a 'click' sound. Sometimes, GM tubes are connected to rate meters, which measure the number of ionising events per second and therefore, give out a measure of radioactivity in Becquerels.

Radioactivity is measured in Becquerels (Bq). It is a measure of how many unstable nuclei are disintegrating per second. More practical units are kBq (an average of 1000 disintegrations per second) and MBq (an average of 1000000 disintegrations per second), as 1 Bq is an extremely small unit.

Background Radiation

Background radiation is low-level ionising radiation that is produced all the time. Sources include:

- Radon gas
- Ground, buildings and medical facilities
- Nuclear power
- Cosmic Rays from nuclear reactions in stars

Half – Life

The half – life of a radioactive sample is the average time taken for half the original mass of the sample to decay. It is different for different radioactive isotopes.

Plotting the count rate in Bq or the mass, will get you a graph that looks something like the one on the right. Notice however, the line will never reach the x – axis, because 0 isn't the half of any other number but 0.

In this example, the half life can be deduced by dividing the initial mass/count rate by 2. In this case, it's 100/2 = 50. The time it takes for 50kg of tritium to decay is about 13 years.

This means that in 13 years time (i.e. it's second half life), half the remaining mass will be gone. In this case, that's 50/2 = 25kg gone.
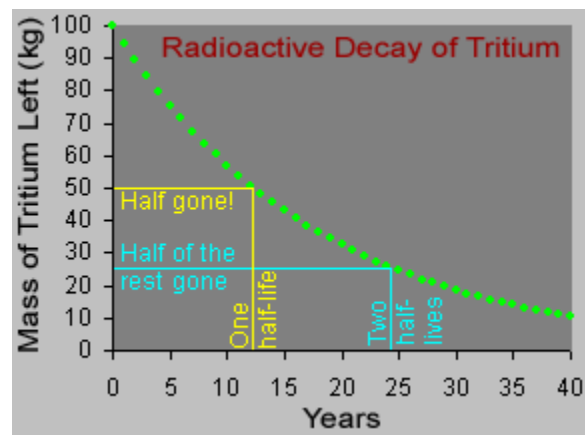
Example:

The activity of a sample of a certain isotope is found to be 200 Bq. If the isotope has a half-life of 20 minutes, what will the activity of the sample be after one hour?

After 20 minutes, the activity will be 200/2 = 100
After 40 minutes, the activity will be 100/2 = 50
After 60 minutes… 50/2 = 25 Bq

Uses of Radioactivity

Medical Tracers

Radioactive isotopes are used as tracers to help doctors identify diseased organs. It is a chemical compound that emits gamma radiation. The tracer is either swallowed or injected. Its passage around the body can be traced using a gamma ray camera.

Different compounds are chosen for different diagnostic tasks. For example, the isotope iodine -123 is absorbed by the thyroid gland in the same way as the stable form of iodine. The isotope decays and emits gamma radiation. The gamma ray camera can then be used to form a clear image of the thyroid gland. The half-life of iodine-123 is about 13 hours. A short half-life is important as this means the activity of the tracer decreases to a very low level in a few days.

Radiotherapy

Cancer can be treated by chemicals containing radioactive isotopes. Unfortunately, the radiation kills healthy cells as well as diseased ones. To minimize damage, chemicals are used to target the location of the cancer in the body. They may emit alpha or beta radiation. Both types have a short range in the body, and so they will only affect a small volume of tissue close to the target.

Sterilisation Using Radiation – Called Irradiation

Ionising radiation is used to kill micro-organisms on surgical instruments and other medical equipment. Some food products are treated in a similar way to make sure they are free from any bacteria that will cause food poisoning. However, it will not destroy any poisons that bacteria may have already produced. Irradiation however, does not destroy vitamins in the food.

Non-medical Tracers

Gamma rays can be used to track the flow of liquids in industrial processes. Complex piping systems, like heat exchangers in power stations, can be monitored for leaks. Radioactive tracers are even used to measure the rate of dispersal of sewage.
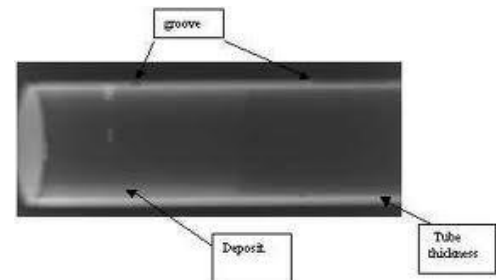
Radioactive Dating

Radioactive dating measures the levels of the isotope carbon-14, to predict the age of living organisms. Since the chemical behaviour of the isotopes is the same, this means that carbon-14 reacts with oxygen to form carbon dioxide, and this is also absorbed by plants for photosynthesis. Incorporated in plant material, the isotope enters the food chain. This means that in living organisms, the carbon-14 atoms are continuously replaced by new ones.

When an organism dies, the replacement process stops, and the carbon-14 decays in the remains of the organism. By measuring the amount of carbon-14 still present in the dead organism, it is possible to estimate when the organism died. The half-life for carbon-14 is about 5600 years.

Dangers of Ionising Radiation

- Radiation can cause cell mutations in living organisms, leading to cancer. This is because the radiation may cause the cell to start behaving in an unexpected way. The cell may either die, or start dividing uncontrollably.
- Radiation can damage cells and tissue – but cells usually suffer this all the time and can repair itself, unless of course, it starts to mutate. Alpha particles have little penetrating power and present little risk when outside the body. However, if the alpha source is breathed in or taken in through eating food, the problem of alpha radiation is a lot greater as its ionising power is strong. Beta and gamma radiation can penetrate skin and flesh from outside the body, causing cell damage. The damage depends on how much of the energy of the radioactive particle is absorbed by ionising atoms along their path. When absorbed by the body, beta and gamma emitters present less risk than alpha emitters, because of their low ionising power.
- Disposal of Radioactive waste – nuclear waste must be stored in sealed containers that can contain the radioactivity for enormously long periods of time, as the radioactive isotopes used have an extremely long half-life (we're talking millions of years).

Safety precautions for handling radioactive materials in the lab include:

- ✓ Storing samples in lead containers
- ✓ Clearly labeling the containers as a radiation hazard
- ✓ Handling samples using tongs and kept as far from the body as possible
- ✓ In the nuclear industry, they are handled by operators who are shielded by lead and thick glass viewing panels.

Geiger and Marsden's Experiments – Rutherford's Nuclear Model

Rutherford was a scientist who wanted to know what the atom was really made out of and how it looked. He worked with Geiger and Marsden to carry out a series of experiments that involves firing alpha particles at very thin gold foil.

The zinc sulphide screen gives out tiny sparks of light, called scintillations, when hit by an alpha particle. Most of the
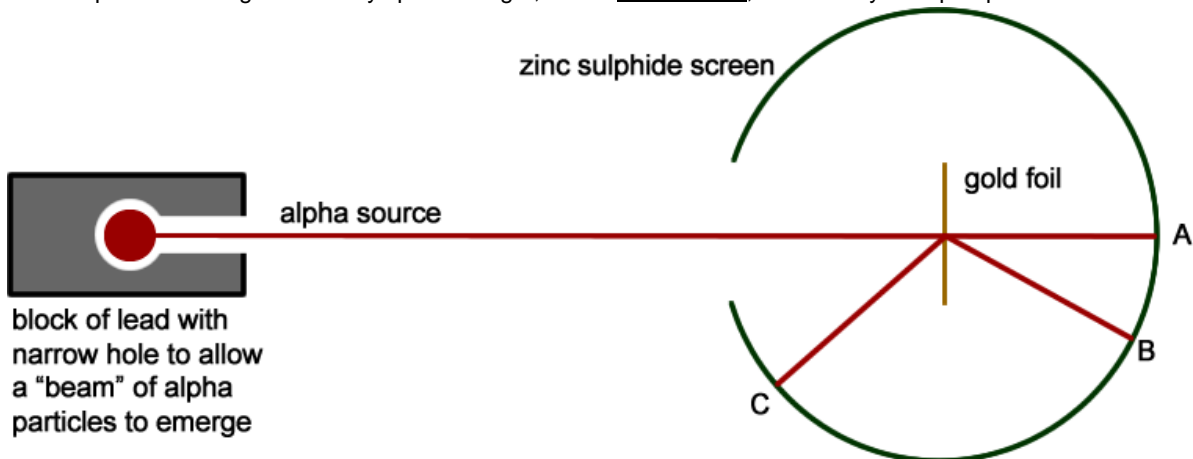
alpha particles passed straight through the gold foil (A). Once in a while, an alpha particle was knocked off course (B). A very small proportion (about 1 in 8000) actually seemed to bounce off the gold foil (C).

Rutherford deduced these things:

- Since most of the alpha particles passed straight through the gold foil, most of each gold atom must be empty space.
- However, he knew that atoms did have mass so they could not just be empty space. The rare event of a rebound meant that an alpha particle had run into something massive. He realised that the mast must be concentrated in a very tiny volume at the centre of the atom, called the nucleus.
- The deflections and rebounds were because the positive charges on the alpha particles we repelled by positive charges in the nuclei.

The amount of deflection depended on:

- The speed of the alpha particle – the particle is deflected less if it is travelling faster
- The nuclear charge – if the nucleus is strongly positive, then the alpha particle will be more strongly repelled

▪ How close the alpha particle gets to the positively charged nucleus
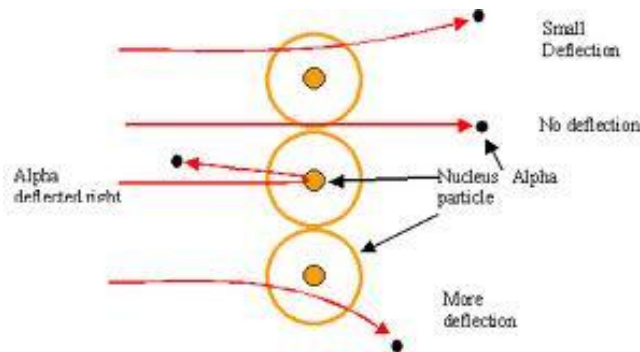
From this, the experiment gave evidence for the existence of the nucleus as well as an estimation of the size of the nucleus (its diameter is about 10000 times smaller than the diameter of its atom).

Nuclear Fission

Uranium-235 is used as fuel in a nuclear reactor, because its nuclei can be split by a neutron. The process of splitting an atom is called fission. U-235 is called a fissile material because it goes through the splitting process easily.

The process is shown below:
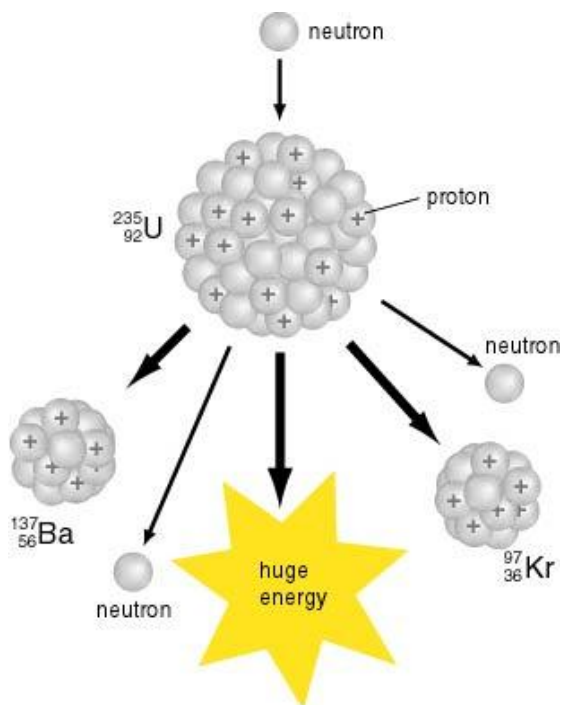
In the fission reaction, a slow-moving neutron is absorbed by a nucleus of uranium – 235 (as faster, more energetic neutrons do not cause fission; also it has a neutral charge and so, is not repelled by the positive charges of the nuclei)

The resulting uranium-236 is unstable and splits apart.

This forms two daughter nuclei: barium-144 and krypton-89 as well as gamma radiation and three more neutrons.

The process produces a huge amount of energy, most of which is carried away as kinetic energy of the two lighter nuclei.

The three neutrons produced may hit other uranium-235 nuclei, causing the process to repeat continuously. This results in a chain reaction.

The reaction is controlled to avoid a nuclear explosion. The heat produced is used to heat water into steam, which will then drive turbines to turn generators.

The equation for this decay is:

$$^{236}_{92}U \rightarrow \ ^{144}_{56}Ba \ + \ ^{89}_{36}Kr \ + \ 3 \ ^{1}_{0}n \ + \ \text{Gamma radiation}$$
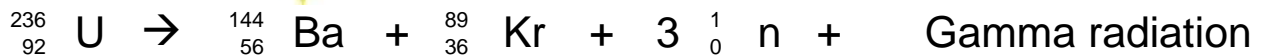
The Nuclear Reactor

▪ The graphite moderator absorbs some of the kinetic energy of the neutrons to slow them down and increase the probability of them being absorbed.

▪ The control rods, made of boron or cadmium, absorb the neutrons to take them out of the fission process completely or to control the reaction.
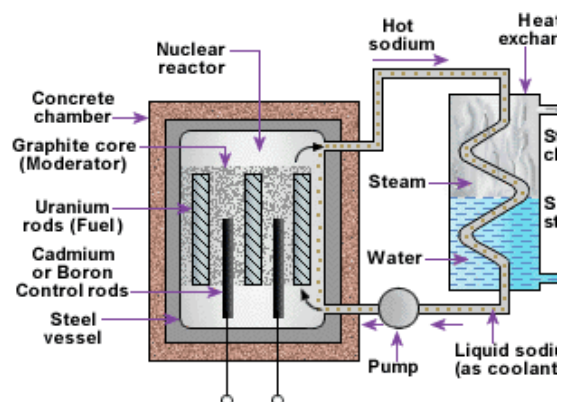
Unit 7: Magnets and Electromagnetism

Magnets repel and attract other magnets, as well as magnetic substances. Like poles repel and unlike poles attract.

Hard magnetic materials are 'hard' to demagnetise – and are used for making magnets and other things that we want to stay magnetised. Such materials include steel.

Soft magnetic materials demagnetise easily and are used in things like relays and electric motors. Such materials include iron.

Magnetism can be induced into certain alloys, compounds and metals. The permanent magnet induces a magnetic effect in the unmagnetised material with an unlike pole nearest the pole of the magnet (e.g. sticking the North pole of a magnet near a paperclip will cause the side of the paperclip facing the magnet to have a South pole). This is why unmagnetised materials like iron are always attracted to magnets.

Magnetic field lines show the direction, strength and shape of the magnetic field. It always goes from the North to the South.

Electromagnets

When a current flows in a wire, a magnetic field is produced. It can be made by coiling a wire (a solenoid) around a soft iron core and connecting the wires to a cell. The magnet can be made stronger by increasing the current or number of coils.
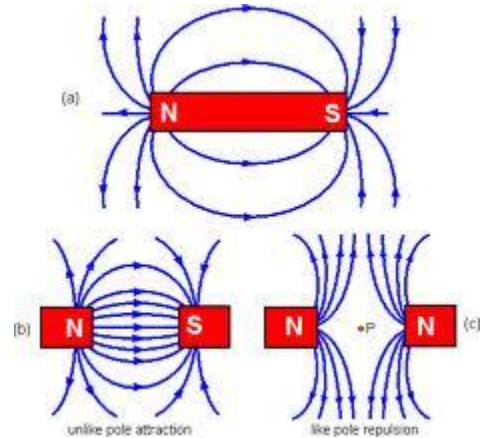
a) Shows the field lines of a permanent bar magnet; b) shows a uniform magnetic field pattern; c) shows the field lines between two magnets

Straight wire	
Flat circular coil	
Solenoid	

The Right-Hand Grip Rule

The right hand grip rule is a good way to remember the direction of the field lines. Using the thumb of your right hand, point towards the direction of the current and wrap your hands normally around the wire. The thumb shows the current and the fingers show the field.
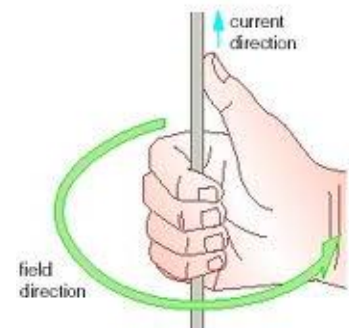
Note: In magnetism, when pointing towards the direction of the current, you do it, the 'convectional current' way – as in current flows from positive to negative (I don't know why but yeah).

The Motor Effect

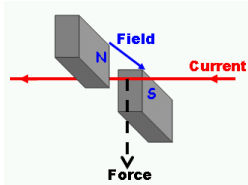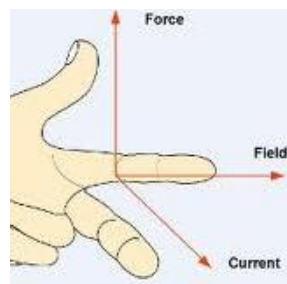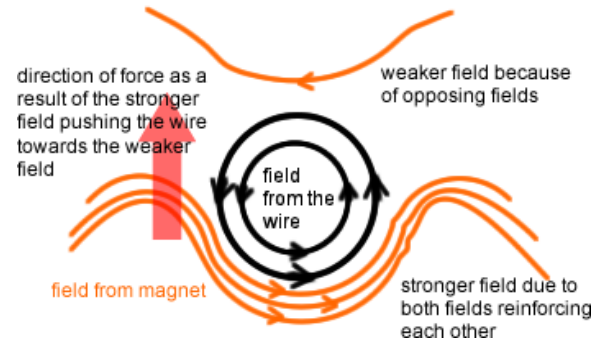There is a force on a charged particle when it moves in a magnetic field as long as it is not parallel to the field. Since an electric current is a flow of electrons – which are charged particles, we can see this effect. If we pass a current through a wire held at 90^0 to the field of the magnet, the wire will move. This motion is the result of a force created by overlapping fields called the motor effect.

This is because (referring to the above diagram) there are two magnetic fields, one from the current flowing through the wire; and one from the magnets. At some points, the field lines of both fields are in the same direction, so they reinforce each other and produce a stronger field. At other points however, the go against – or in opposite directions to each other, producing a weaker field (like forces in a way, when there are two opposing forces, the stronger force cancels out the weaker force but the overall decreased). Anyways unbalanced force is force that pushes it the wire experiences a the weaker field. This from the stronger field to by increasing the force can be increased stronger magnet. current or using a

direction of force as a result of the stronger field pushing the wire towards the weaker field

weaker field because of opposing fields

field from the wire

field from magnet

stronger field due to both fields reinforcing each other

Fleming's Left

Hand Rule

If shown a diagram and asked to predict the direction of the movement of the wire, you can use Fleming's Left Hand Rule (note: remember the name – it will be asked).
REMEMBER: THE CURRENT WE'RE TALKING ABOUT IS THE CONVECTIONAL CURRENT.

The Moving-Coil Loudspeaker

The moving-coil loudspeaker uses the motor effect to change electrical energy to sound energy. Signals from the source such as an amplifier are fed into the coil of the speaker as currents that are continually changing in size and direction. This means each time the current changes, the direction of the wire's field changes and overlaps with the magnet's field differently. This results in a varying – vibrating force that causes the cone to vibrate, creating sound waves that we hear.
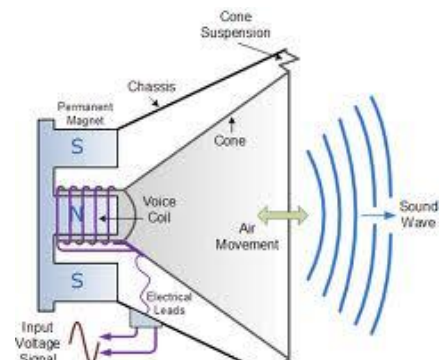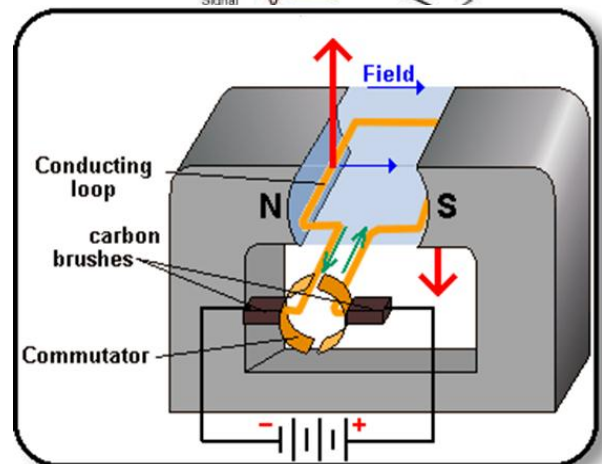
The Electric Motor

Get ready to not get anything!

When a current passes through the conducting loop of wire, one side of the loop experiences a downward force and the other side experiences an upward force – this is because when the current comes back to the carbon brushes, its direction relative to the field has changed. And so loop turns clockwise. After turning 180^0 (a half turn), the split rings (the yellow thing stuck to the brushes) swap over (they turn with the loop) so their connections to the supply through the brushes change direction. This also means that the current flowing through each direction changes direction. This ensures that the rotation is continuous.

Increasing the rate at which the motor turns can be done by:

✓ Increasing the number of loops
✓ Increasing the strength of the magnetic field

✓ Increasing the current

This side of the loop gets pushed up

N

Current goes from positive to negative

This side of the loop gets pushed down

S

carbon brush

carbon brush

split ring commutator

battery cells

As a result of the change in the direction of the current, this side gets pushed up

N

Current goes from positive to negative

As a result of the change in the direction of the current, this side gets pushed down

S

carbon brush

carbon brush

the sides of the split ring swap over and the direction of the current switches. if there was no split ring, the arrows of the current will be reversed and the loop won't rotate

battery cells

Electromagnetic Induction

Motors use electricity to produce movement. Generators do the opposite. When we move a wire across a magnetic field at right angles, a voltage is underlined induced. If the wire is part of a complete circuit, a current flows. This is called electromagnetic induction.

It can be increased by:
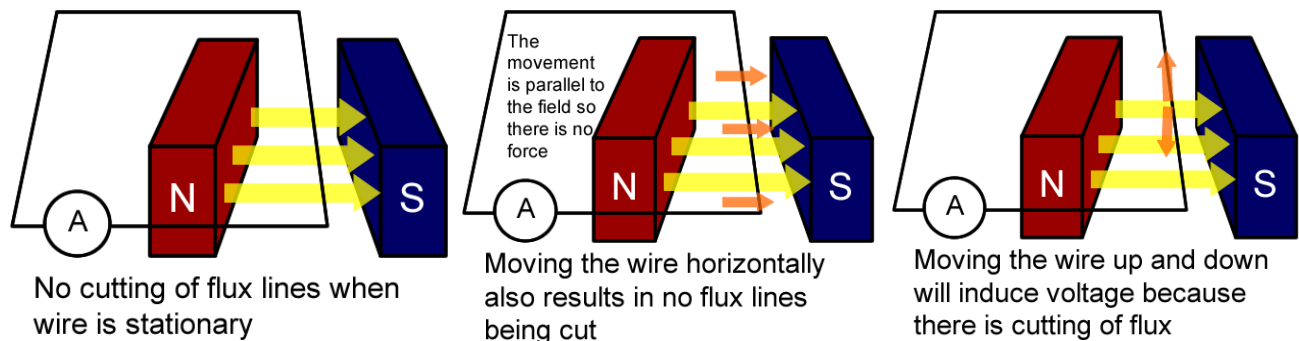
✓ Moving the wire more quickly
✓ Using a stronger magnetic
✓ Coiling the wire

You can also induce voltage by pushing a magnet into a coil. To increase the voltage:

✓ Move the magnet more quickly
✓ Using a stronger magnet
✓ Using a coil with more turns
✓ Using a coil with a larger cross-sectional area

Coil or Loop

Direction of Movement
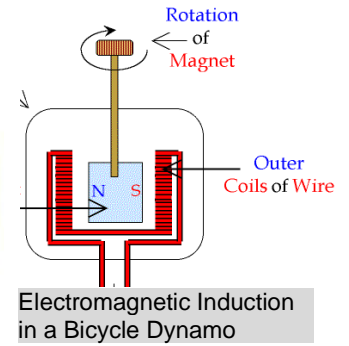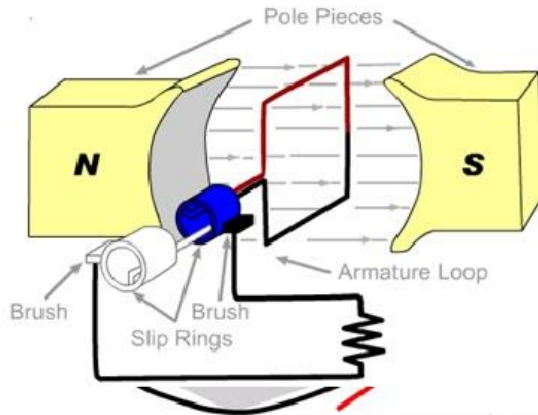
N   S

Magnet

0
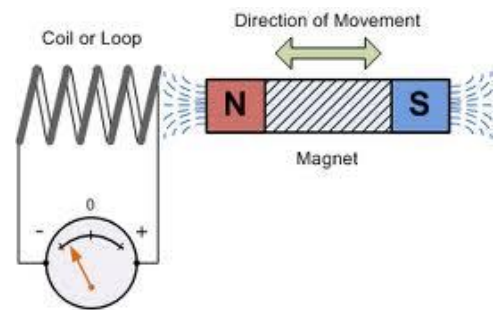
Since there is a force acting on a charged particle in a magnetic field as long as it is not parallel to the field. Why is that? Because voltage is generated when the magnetic lines of flux (field lines) are being cut. The size of the induced voltage across the ends of a wire (coil) is directly proportional to the rate at which the magnetic lines of flux are being cut.

A

N   S

No cutting of flux lines when wire is stationary

The movement is parallel to the field so there is no force

A

N   S

Moving the wire horizontally also results in no flux lines being cut

A

N   S

Moving the wire up and down will induce voltage because there is cutting of flux

Generating Electricity

As the coil (armature loop) rotates (due to movement such as the spinning of turbines), its wires cut through the magnetic field lines, resulting current to be induced. Since movement is controlled, the coil will only spin one way. This means that the current will change direction every half turn (left hand rule). This means the induced current is alternating.
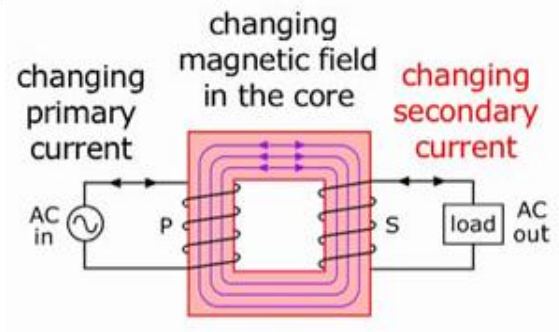
The Transformer

Transformers are used to increase or decrease voltages using the concept of electromagnetic induction. Step-up transformers increase them and step-down transformers decrease them.

How does it work? When an alternating current is passed through the coil, its field is continuously changing (because the direction of the current changes). If a second coil is placed near the first, this changing or fluctuating magnetic field will pass through it and cut through the wires of the second coil, inducing voltage across it. It's abit like moving a magnet in and out of a solenoid. The first coil is called the primary coil and the second coil is called the secondary coil. Note: transformers don't work unless the input voltage/current is alternating.

Electromagnetic Induction in a Bicycle Dynamo

As the cyclist pedals, the magnet rotates. Its field cuts through the coils, inducing a current

The relationship between the voltage and the number of turns on the primary and secondary coils:

Input voltage/Output voltage = number of turns on the primary coil/number of turns on the secondary coil
$V_p/V_s = n_p/n_s$

If the efficiency of the transformer is 100% then:

Input power = Output power
$P_{in} = P_{Out}$
Power = Voltage x Current so
$V_p \times I_p = V_s \times I_s$

The National Grid

The UK National Gird is a network of wires and cables that carries electrical energy from power stations to consumers such as factories and homes. High currents will result in lots of energy lost in the form of heat, therefore, current is kept at a minimum, and this is done by producing high voltages.

$P = VI$
$V = IR$ --- so substituting V results in $P = (IR)I$, or $P = I^2R$ ←the formula for power loss in transmission lines

Input power = Output power, so power is constant. Increasing the current will result in energy lost so that's not good. Therefore, to reduce current you must increase voltage. This is done by passing the generated electricity through step-up transformers. The voltage is increased here to about 400kV. This then passes through the cables to some step-down transformers, which decreases the voltage to 230V, increasing the current at the same time. The electricity then goes to our houses.

Unit 8: Astronomy
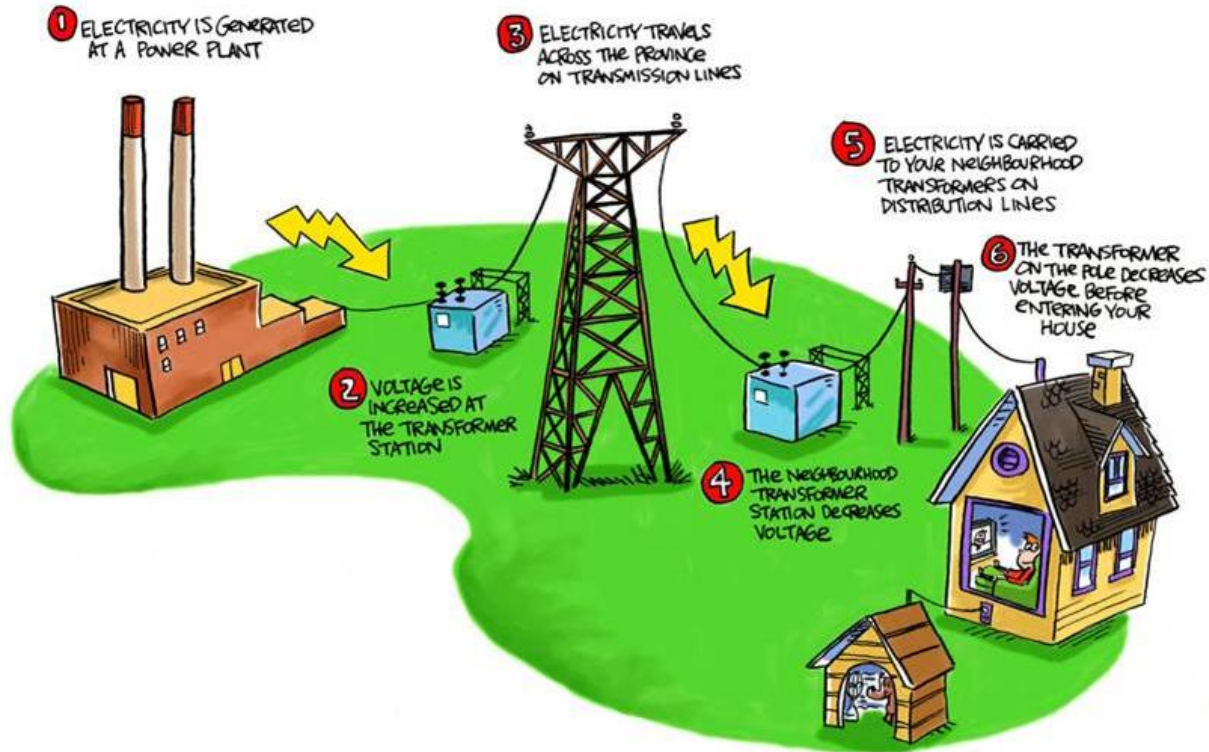
Planets are non-luminous objects. They are held in orbit by the gravitational pull of the sun. Their orbits are elliptical (like circles).

Moons are examples of natural satellites. They are natural objects that orbit a planet. They are non-luminous objects and their motions are determined by gravitational forces of the planet they orbit around.

Comets are made up of dust and ice. They also orbit the sun. Their orbits are:

- Elliptical
- Close to the sun at one focus
- At the far end of the solar system at another focus
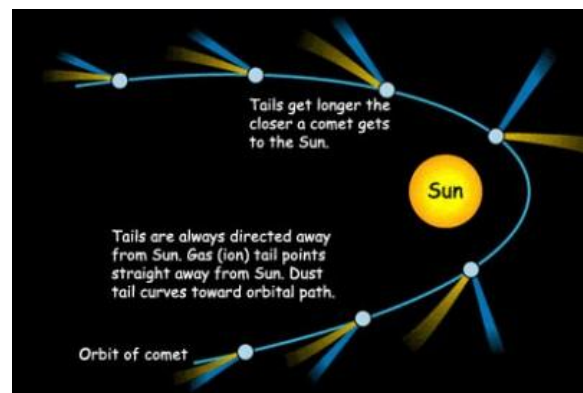- Has a period of more than 1 Earth year

All these belong to the solar system, which is part of the Milky Way galaxy.

A galaxy is a large collection of billions of stars. The universe is a large collection of billions of galaxies.

The orbital speed is calculated by:

Orbital speed = (2 x π x orbital radius) / time period
Or orbital speed = 2πr/T

Gravitational Force

CGPwned
Science

Gravitational force:

- Causes the planets to orbit the sun
- Causes the moon and artificial satellites (as in man-made) to orbit the Earth
- Causes comets to orbit the sun

The force of gravity acts between all objects.

If mass increases, the force of gravity increases.

If distance increases, the force of gravity decreases.

It is a force of attraction between two objects due to its masses. If the masses of the objects are small, the gravitational attraction is too small to be noticeable. However, when the masses are as big as planets, the force is more obvious (it causes planets to orbit the sun).

And that's all for physics!