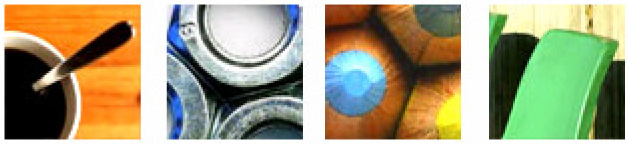



# PHYSICS
## GCSE

# Physics GCSE

Please choose a Topic



Glossary

These guides cover the main principles for most of the common specifications.

Please check your particular specification as there may be material which is not covered by these notes.

# Static Electricity

## Static charge

**Static means 'still' and is the word we use when we talk about charge that can't move.** A good example of this is when you rub a balloon on your hair and it sticks to the ceiling. You use **friction** to charge up the balloon.

**There are two kinds of charge:** positive (+) and negative (-).

All objects are made up of atoms, and all atoms contain **positive particles (protons)** and **negative particles (electrons).**

**And yet atoms don't have an overall charge. They are neutral**.

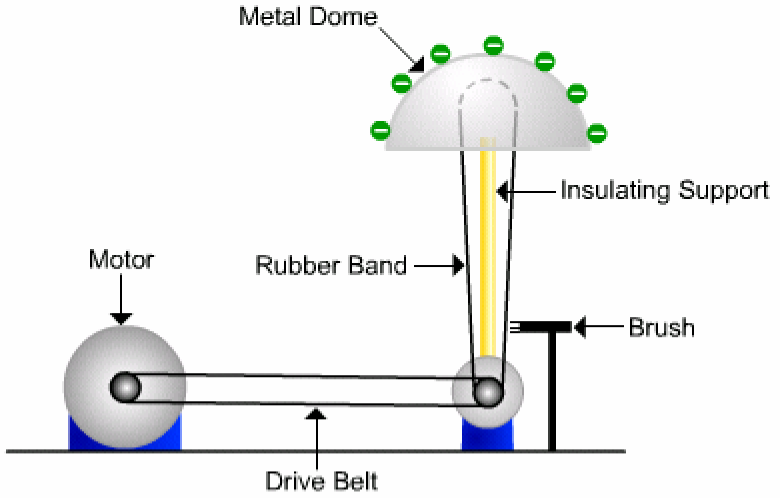
That's because atoms contain the same number of protons and electrons. So the positive and negative charges are cancelled out.

Static electricity is caused by an atom having too many or too few electrons (e-).

When insulating materials are rubbed together, electrons are knocked off one of them and onto the other.

This happens when a polythene strip is rubbed with a duster, the **electrons** move from the duster to the strip. The strip becomes **negative** (because it has more electrons than it needs to cancel out the **protons**) and the cloth becomes positive (because it has less electrons than it needs).

The way you may have seen static generated at school is with a **Van de Graaff Generator (see diagram).** The motor turns the rubber band and friction between the band and the rollers starts to build up huge amounts of charge.




This charge is then deposited on the metal dome, which is a **conductor**, but is insulated from everything else (like birds sitting on a power line), so it is able to store the charge.

The charge can build up in a big way, causing voltages as high as 50,000 Volts. A shock from this doesn't kill you, as the actual amount of charged particles stored on the dome is so small.

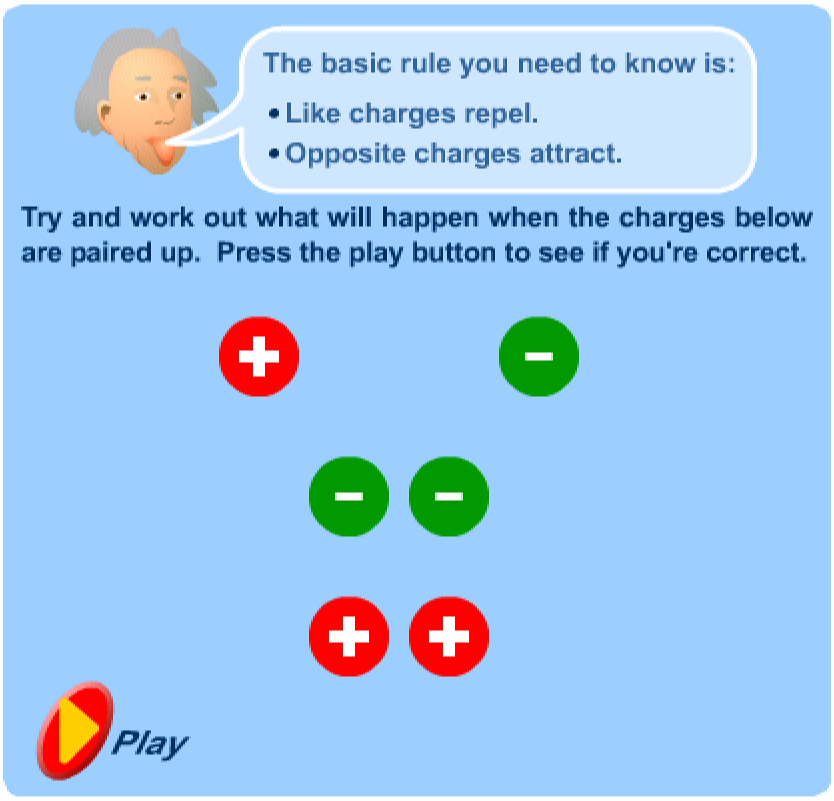
# Induction and earthing

**The basic rule you need to know is:**

**Like charges repel.**

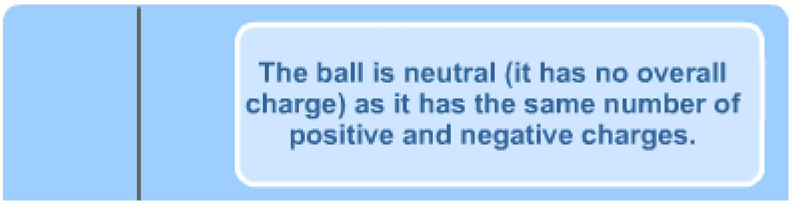
**Opposite charges attract.**

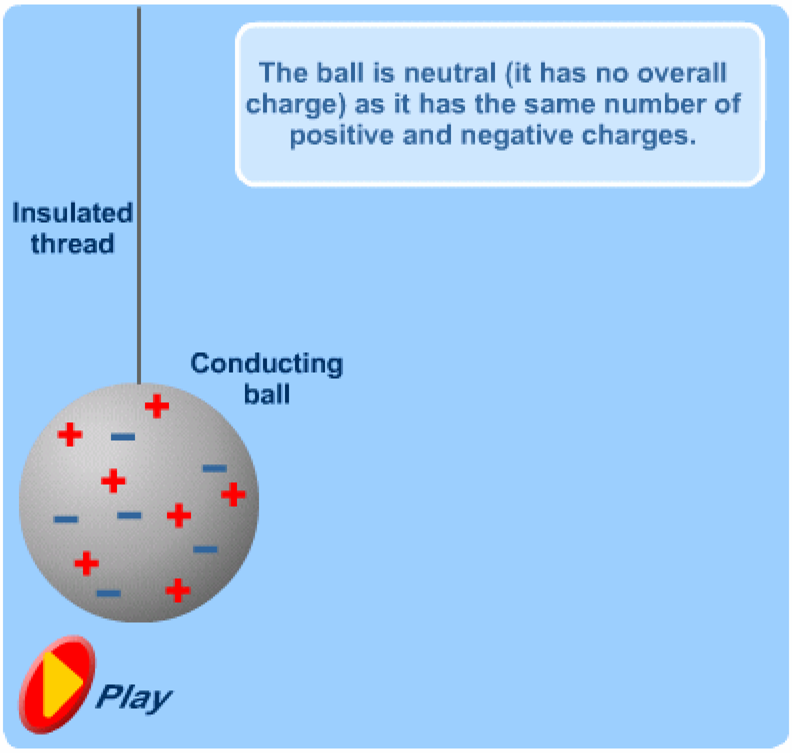
**Press the play button below to see how the charges move when placed together:**




**Induction**

This can lead to funny things happening when a charged object is brought near a neutral one. **Follow the steps of this example of induction:**






| | |
|---|---|
| **Step 1:** | Ball is neutral (no overall charge) as it has the same number of **positive** and **negative** charges. |
| **Step 2:** | A **negative** strip (excess **electrons**) is placed near the ball. |
| **Step 3:** | The **negative** charge of the strip causes the **electrons** to move to the opposite side of the ball, leaving the right hand side **positive.** |
| **Step 4:** | As opposite charges attract, there is an attractive force between them. If the strip is fixed, the ball will swing towards it. |

### Earthing

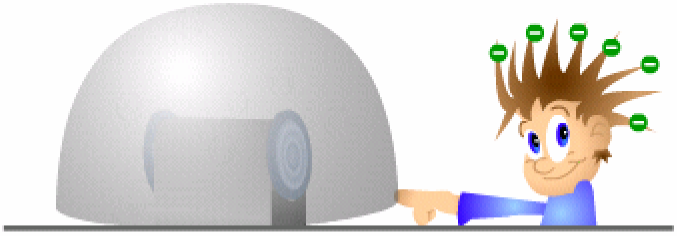
If enough charge builds up on an insulator, the charge can leap the gap, causing a spark. This can be prevented by **discharging** the object, gradually. This is called **earthing**. This is to do with Planet Earth - it's not just a silly name! The Earth can soak up any excess charge (see the section on Safety as well).

## Hair-raising examples

When static comes up in an exam, it is normally through an example. **Think about these:**

## Fun Static

When you rub your hair (e.g. balloon or jumper), or hold onto a Van de Graaff generator while you are insulated yourself, your hair stands on end (unless it's full of super strength gel!). Because each of the hairs has the same charge, they try to get as far away from each other as possible.

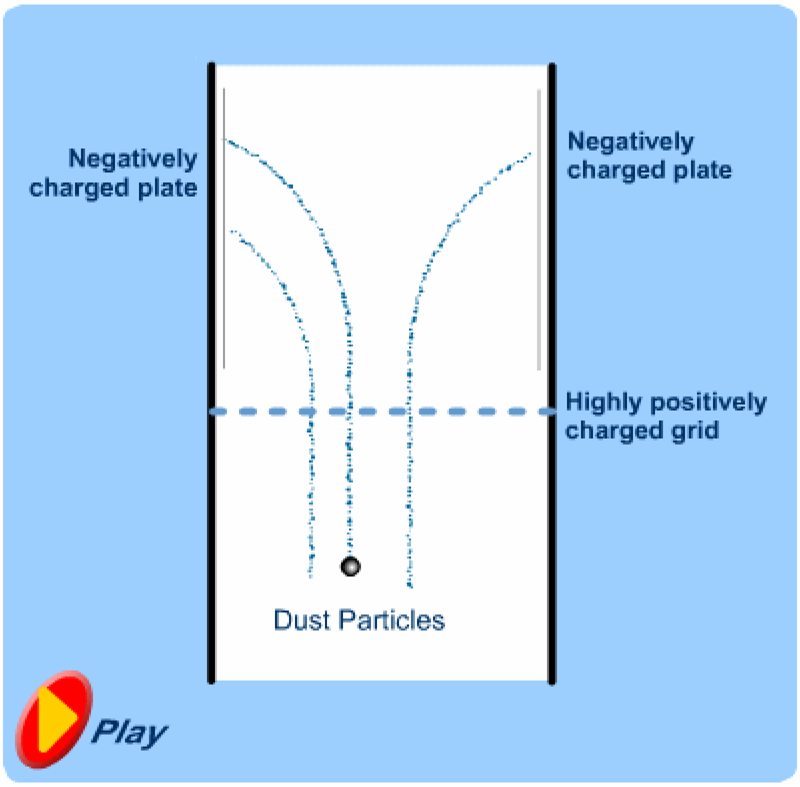


## Useful Static

Photocopiers and some computer printers want the toner to go in the right place. Give the toner charge and give the paper you want it to appear on the opposite charge. Bingo!

Special powder paints that have been charged, spread out to form a very even coating of paint on an earthed metal object - a car body or a bike frame, for example. It also means paint is not wasted as all the paint is attracted to the object. Less mess too!

Static is also used to remove pollution from smoke-stacks. Electrostatic plates are placed in the chimneys and they attract all the polluted dust.



## Nasty Static

If clouds get charged up enough, you get **lightning**, the biggest spark of all.

Static can also be dangerous when refuelling aircraft. The fuel rubs against the side of the hose and lots of charge builds up. If the plane isn't earthed, the spark can blow the plane up quicker than in Die Hard 2. A thin copper wire between the plane and earth is enough to carry the excess charge away.

# Basic Circuits

## Current, voltage and resistances

The main problem with electricity is that everyone uses it all the time, so they think they know how it works already. **It can be easy, particularly if you get the main terms right:**

**Current**- This is a measure of the **flow** of **electrons** around a circuit (measured in Amperes or Amps (A))

**Voltage**- This is a measure of how much **energy** the **electrons** are carrying around to the things in the circuit (measured in Volts (V))

**Resistance** - This is a measure of how hard it is for the **electrons** to travel through a part of the circuit (measured in Ohms (Ω))

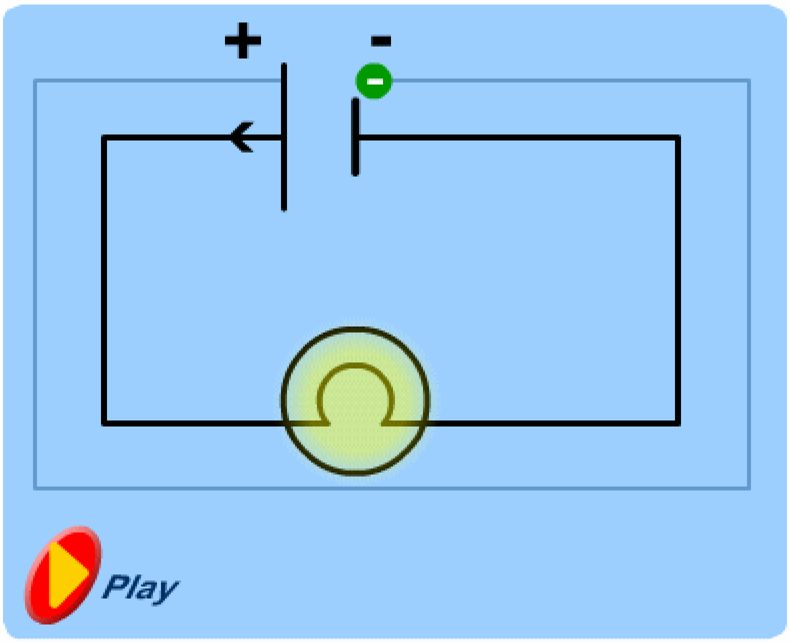
The main worries are the first two - people often get them mixed up. **Make sure you learn them!**

**That's all very well, but what is a circuit and what is an electron?** Well, a circuit is a collection of components wired to a battery or power supply, which pushes the small packets of charge, usually **electrons**, around it.

**Analogies** - ("it's a bit like...."). The problem with electricity is that you can't really see what's going on, so people come up with different ways of thinking about it. You might have heard people talk about water flowing (current?) due to pressure (voltage?) and meeting narrower pipes (resistance?). **Or**, there's the idea of cars, where resistors are muddy tracks instead of motorways, and you see how much petrol is used up to find the voltage. Pick whatever works for you, **but**, remember that they are only models and are not the whole story.

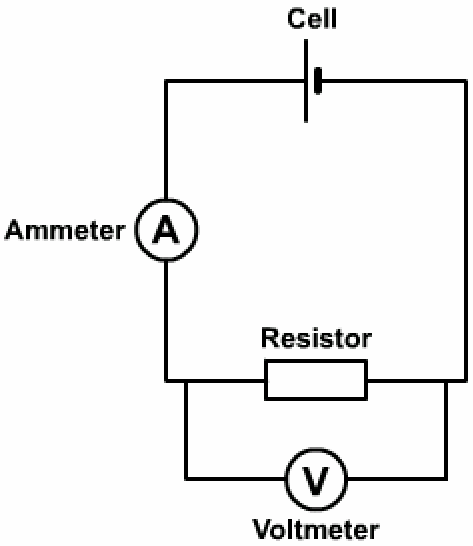
**Direction Problem!**

Current flows from the positive (+ve) terminal of the battery to the negative (-ve). This is called **conventional current flow.** The problem is, electrons are negatively charged, so they want to get away from the -**ve** and go to the +**ve**. So if electrons are going left to right, you say that the current is going right to left (how confusing is that!)




# Circuits

**Simple Measurement Circuit**



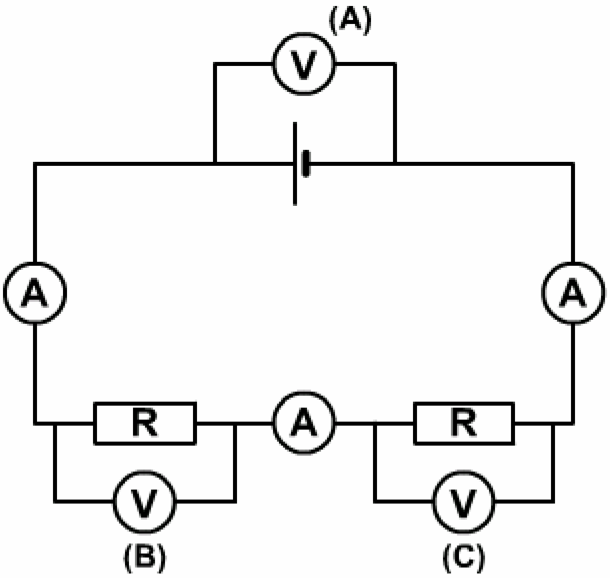

This shows how to connect a **Voltmeter** for measuring voltage and an **Ammeter** for measuring current. Thinking about how this works may help you understand voltage and current a little better.

An ammeter needs to measure the flow of charge, so it is in **series**. This means that all the charge has to flow through it and can be counted. It also means that an ammeter needs to have a very low resistance.

A voltmeter measures **voltage** across a component, which you may have heard as **potential difference**. Potential is to do with energy in physics, so what the voltmeter does is compare the energy difference between two points in a circuit, to see how much has been used up. This means it is in **parallel** and it also needs a high resistance (otherwise all the current would flow through the meter instead of the component).

Measuring voltage and current can be used to measure resistance (see formulae section).

## Series Circuits



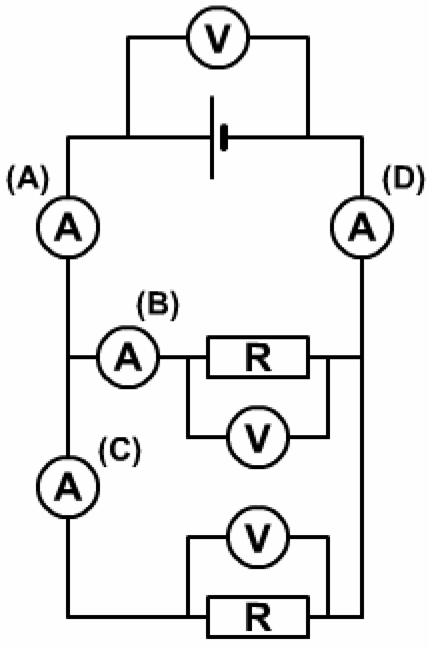

You should have come across the difference between **series** and **parallel** circuits many times, but that does not mean to say that you can't get confused! Series circuits are a bit pants, really. Any break in a circuit causes the whole thing to go down, so one faulty Christmas Tree light can cause the whole lot to go out (and then how do you figure out which one blew?).

**Current in series:** same all the way round (all the current has to flow through everything).

**Voltage in series:** voltages across each component add up to the total voltage supplied by the battery, as they have to share the voltage between them [(A) = (B) + (C) in the diagram]. Higher resistances will need more of the voltage.

Final point - **resistors in series:** To work out the total resistance of two resistors, just add them together. This is because the current has to go through both of them.

**Parallel Circuits**




More useful and more common, but a little harder to get your head round. The main deal is that each component is directly connected to the battery (follow the wires round the circuit to check), so they each get the full voltage.

**Voltage in parallel:** all voltages the same.

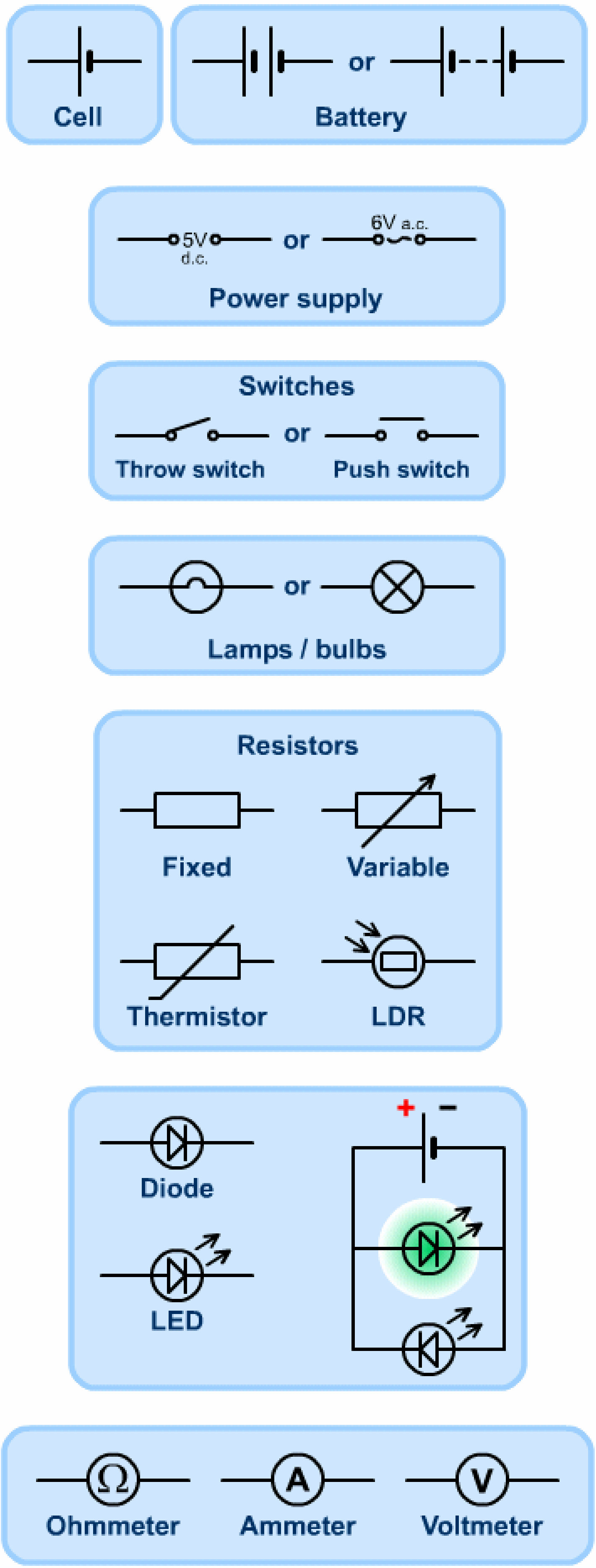
**Current in parallel:** the current is shared out between the branches, but recombines near the battery. In the diagram (A) = (B) + (C) = (D). How much current each branch gets depends on the individual resistors - **bigger resistance** = **lower current** (because it's harder for current to flow).

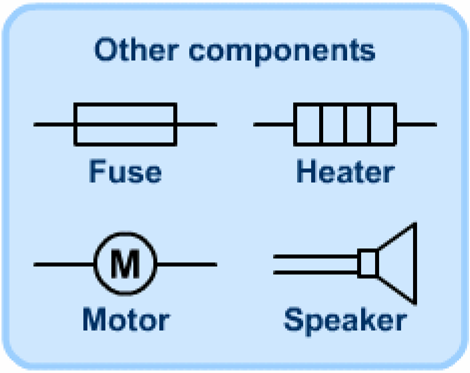
**Resistance in parallel:** you don't normally have to work out numbers, but the rule of thumb is that the total resistance of two resistors in parallel is **less** than the **lowest** individual resistor. This is because you are giving the current more ways to go.

**Nasty Circuits**

If you have a combination of **series** and **parallel** in one circuit take your time and analyse it bit by bit. Don't be ashamed to move your finger around the wires to see how it connects - I still do!!! Practise questions if you are not confident with this, but it is rare to get given anything really complicated at GCSE.

# Circuit symbols


Cell
or
Battery
5V
d.c.
or
6V a.c.
Power supply
Switches
or
Throw switch
Push switch
or
Lamps / bulbs
Resistors
Fixed
Variable
Thermistor
LDR
+
−
Diode
LED
Ω
Ohmmeter
A
Ammeter
V
Voltmeter




**Cells and Batteries:** strictly speaking, one cell represents 1.5V and you make a battery by adding more cells, so the left hand battery would be 3V (2 x 1.5). This is nit picking a bit though, often people just draw a cell and then write '6V' above it or something, which is usually fine.

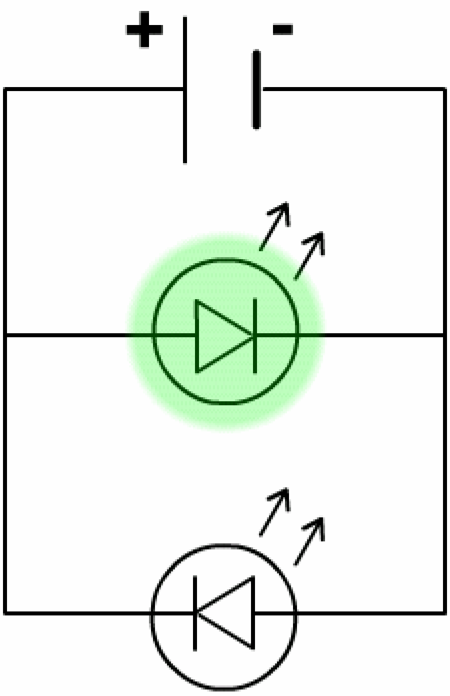
**Power Supplies:** come in all shapes and sizes, just label them as you want.

**Switches:** several types. I've shown the main two that you will come across

**Lamps/Bulbs:** either symbol could be used - it doesn't matter.

**Resistors:** a few types - **Fixed, Variable** (turn a knob or move a slider to change the resistance), **Thermistor** (as it gets hotter, its resistance decreases) and **Light Dependent Resistor or LDR** (the more light that shines on it, the lower its resistance gets).

**Diode:** A diode is like an electrical valve, it only lets current flow one way. If it is connected with the arrow pointing to the negative terminal, current can easily flow, if it is the other way round, it will block the current. In the diagram below, only LED (B) will light. An **LED or Light Emitting Diode** is just the same except it gives off light…



**Ohmmeter:** is connected directly to a resistor, of any kind, to find its resistance (no other circuit is used with it)

**Check in your syllabus to see if there are anymore you need to know!**

# Know your formulae

**General Note: All formulae are given in each possible arrangement, but it is easier to learn the first one and know how to rearrange them! Try the triangle method shown for Ohm's law on the other equations you learn.**

**Ohm's Law**

The law actually says that the resistance of a metal conductor is the same whatever the current - unless it's getting hotter. However most people think of these equations when the law gets mentioned:

$$V = IR$$

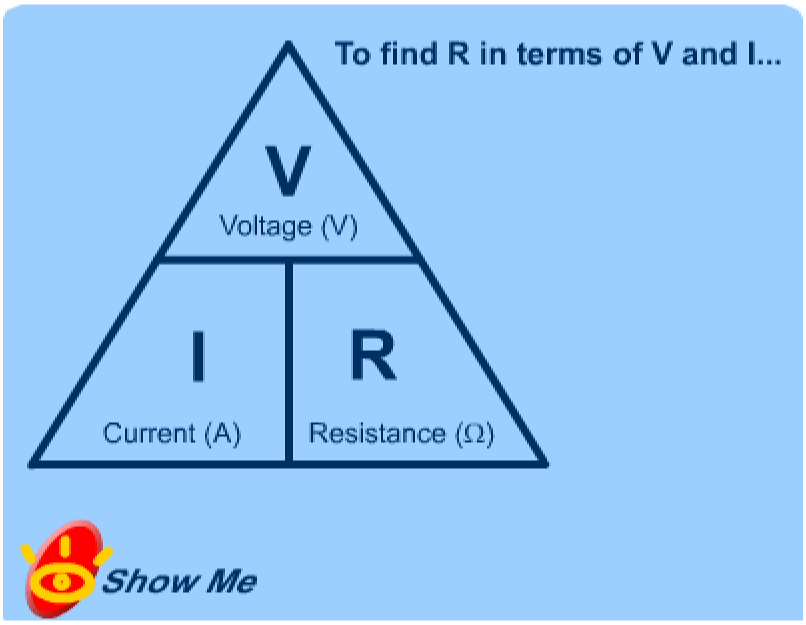
$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$

V is Voltage in Volts, I is Current in Amps and R is resistance in Ohms.

**Triangle method for rearranging a formula:**

Take the equation into a form where there is only multiplication and not division (V=IR in this case). The V goes on the top and the I and R slot in the bottom. Cover the one you want to know, and the other side of the equation will reveal itself.



## More Equations

Charge (Q) in Coulombs (C) and Time(t) in seconds(s):

$Q = It$

$I = \frac{Q}{t}$

$t = \frac{Q}{I}$

Energy (E) measured in Joules (J):

$E = Pt$

$E = QV$

$E = IVt$

Power (P) measured in Watts (W):

$P = VI$

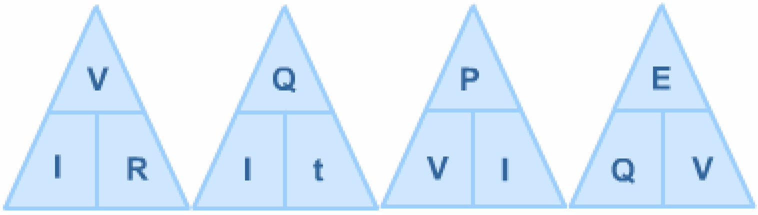
$V = \frac{P}{I}$

$I = \frac{P}{V}$

$P = I^2R$

$P = \frac{V^2}{R}$

**Here are the formulae you need in 'triangle' form:**




**Always remember to show all your working out, including writing the formula properly (not just the triangle!) and checking your units (e.g. check for mV or kW instead of V or W)**

**Prefixes:** These are little letters added to units to make them a different size. Always use the base unit if unsure. Check you know the information below. Base units are given in the topics, the ones to watch for are time (seconds) and mass (kilograms not grams).

| Prefixes: | Name: | Value: | Example: |
|---|---|---|---|
| M | Mega | x 1,000,000 | 1MW = 1,000,000W |
| k | kilo | x 1,000 | 1kg = 1,000g |
| c | centi | ÷ 100 | 1cm = 0.01m |
| m | milli | ÷ 1,000 | 1ms = 0.001s |

# Electricity at Home

## Mains supply (AC and DC)

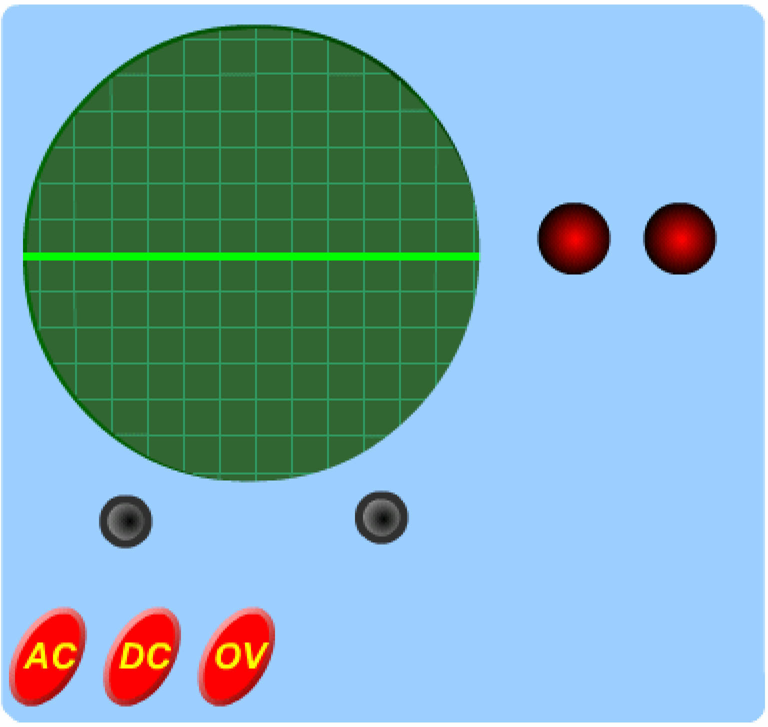
We use two main sorts of electrical supplies, **DC** and **AC**.

**DC**- This is **Direct Current.** The current flows in one direction only (conventional current flow) and has a consistent value. Provided by batteries or **DC** adaptors/transformers that plug into the mains supply.

**AC**- This is **Alternating Current.** The current flows first one way then the other (imagine the charge being first pushed then pulled around the circuit). In normal mains circuits this happens 50 times a second, so we say it has a frequency of 50Hz (see "Waves" section). **AC** is what comes out of the mains sockets, usually at around 240V.

Why have DC and AC? Many things won't work with an AC supply, **but**, it is very easy to change the voltage of **AC** using a **transformer** (these don't work with **DC**).

**You can compare the two types using an oscilloscope:**




### The Ring Main

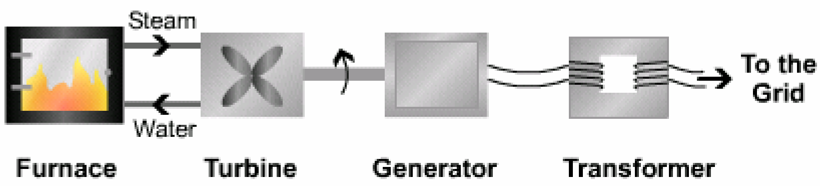
This is the name given to the circuit in your home. You don't need to know too much about it except that it is a kind of **parallel circuit** (so the toaster doesn't switch the kettle off!) and that the lighting circuit is separate from the circuit for sockets.

# The National Grid

This is the circuit that carries electricity all around the country, from the power stations to homes and businesses.

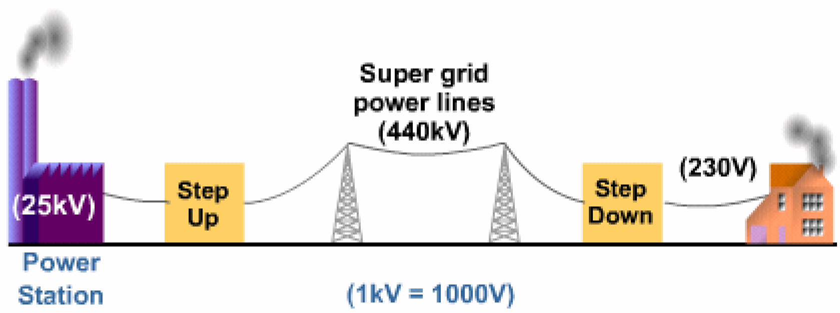
## Producing the Power

See the energy section for the different types of power source. Most power stations are similar, once they have generated steam. The steam turns a turbine which is connected to a generator. The generator converts energy into electricity and the transformer then changes the current and voltage of the electricity.




### Why The High Voltage?

This is to stop energy being wasted. You probably know that if you put too much current through a wire, it gets hot. Heat means wasted energy. If you think about the formula, **Power = Voltage x Current**, if you raise the voltage, you can transfer the same power with a lower current - less waste! This is why mains is AC, so that you can use transformers to change the voltage up and down. The 'Step up' and 'Step down' are the two types of transformer used. Step up transformers are located at power stations. Step down transformers are the ones you will see locally around your town or city.




**Note:** it is unlikely that your course requires you to know the voltages of the grid, but if so, check the values from your syllabus, in case they use different ones.

# Energy and the cost

Normally you wouldn't sit down and leaf through your electricity bill, but for GCSE, you need to know a bit about how this is done. The main thing to get right is the unit used.

**Kilowatt-hours (kWh)**

This is a unit of **energy** not power or time. It is the amount of energy if a 1kW appliance was left on for 1 hour. This means that:

$$\begin{aligned} \text{Energy} &= 1\text{kWh} \\ &= 1\text{kW} \times 1\text{h} \\ &= 1000\text{W} \times 3600\text{s} \\ &= 3600000\text{J} \, * \\ &= 3.6\text{MJ} \end{aligned}$$

$$*(\text{as} E = P \times t)$$

I know what I said about always using base units, but 1 joule is hardly anything, particularly when you have lots of appliances going.

### The Cost

So, 1 unit of electricity is 1kWh of electrical energy. This costs around 6p, though it may change depending on your supplier or if you have a deal for cheap electricity at night. **So a bill might break down like this:**

**Current Meter Reading:** 25361.2

**Previous Meter Reading:** 24321.5

**Units used:** 1039.7 [25361.2-24321.5]

**Cost per unit:** 6p

**Cost of electricity used:** £62.38 [1039.7 x 0.06]

You may also have standing charges and VAT as well, but these just add onto the final total.

# Safety last

Because we use electricity everyday, we often forget how dangerous it can be. Mains supply can kill, but a bit of common sense can go a long way

# Safety last

Because we use electricity everyday, we often forget how dangerous it can be. Mains supply can kill, but a bit of common sense can go a long way.

A common question is to give you a picture of domestic bliss and get you to identify the hazards, such as the person sticking their fingers in the toaster.

**Things to look for are:**

- bad wiring,

- water near appliances,

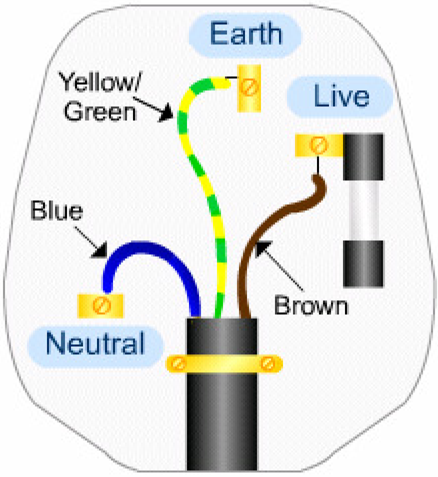
- too many double plugs/adaptors,

- frayed wires.

Just use your common sense and you should get some easy marks!

### Wiring a Plug

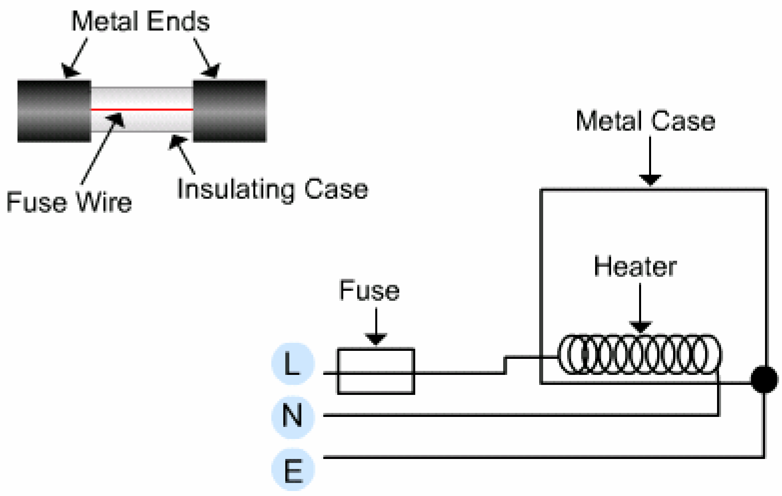
One big problem used to be wiring plugs. By law now, all new appliances are fitted with one already, which helps, but you do need to know what's going on inside there:




The important things to do are to get the wires correct and the right length. Don't show too much bare wire and use the cable grip as shown.

### Fuses

Fuses help protect the circuit against faults. The key thing is to get the wire just thick enough to carry the current you want, but thin enough to melt if there is a current surge.




In the diagram above, the electric fire has a metal case. If there was a fault and the live wire touched the case, there would be no visible sign of a problem, except that it wouldn't work. Anyone touching it would complete a circuit with earth causing a potentially fatal current to flow. If it is earthed, the earth wire allows this current to flow easily. A larger current than normal flows, causing the fuse to blow - disaster is avoided.

## Fuse Ratings

Common sizes are 3, 5 and 13Amp fuses, but there are many others. Always choose one slightly higher than the current rating of the appliance, so that it doesn't blow under normal conditions.

**For Example:** A mains (240V) kettle has a power rating of 3kW. What fuse should be used?

$$I = \frac{P}{V}$$

$$= \frac{3000}{240}$$

$$= 12.5A$$

Therefore, use a 13A fuse.

## Circuit Breakers

Fuses stop things getting too hot and catching fire but they don't always protect you! There might be a fault where there is not enough current to blow the fuse but more than enough to kill you.

The answer is a circuit breaker. Also called power breakers, MCB's and RCD's. They do exactly what the name suggests, they break the circuit if

The answer is a circuit breaker. Also called power breakers, MCB's and RCD's. They do exactly what the name suggests, they break the circuit if there is a problem. They automatically compare the current entering and leaving the circuit and even if there is the tiniest difference they 'trip' off.

## Earth

What's this earth business? Well, although you would probably class a lump of soil as an insulator, the Earth (yes, I do mean our planet) is very good at soaking up loose charge. The earth in your house could be connected to the plumbing (if your water comes in metal pipes)or to a large metal spike in the ground somewhere. Yes, it really does work!

## Double Insulation

If something is completely cased in an insulator, like plastic, it is said to be double insulated, and does not need earthing. You can't get a shock from the case!

# Describing waves

## What are waves?

Waves are moving energy. Light energy moving from the computer screen to your eye moves as light waves. Sound energy moving from a radio to your ear moves as sound waves.

Waves can move along ropes, strings or across the surface of water. Some waves can even travel through space. When waves move along, they make the surface or object move in regular patterns often called **wave disturbances**.

The important thing to notice is that no '**matter**' is moved with the wave. Water waves, which move the water particles up and down on the spot don't actually move any water along with the wave. Only the energy travels along.

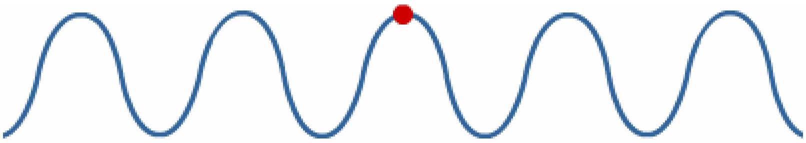
## Transverse and longitudinal waves

**All waves can be put into two groups:**

- **Transverse waves**

- **Longitudinal waves**

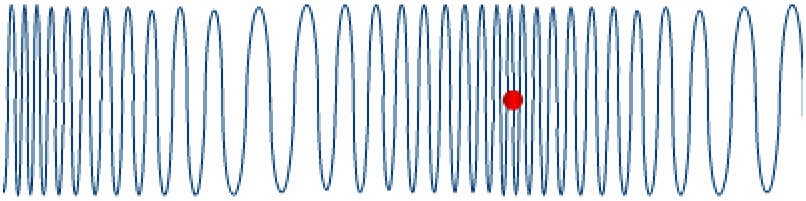
In transverse waves the particles vibrate at right angles to the movement of energy.



Show Answer

Examples are light waves, water waves and all electromagnetic waves.

In longitudinal waves the particles vibrate in the same direction as the movement of energy.



Examples are sound waves and seismic waves.

## Wave words

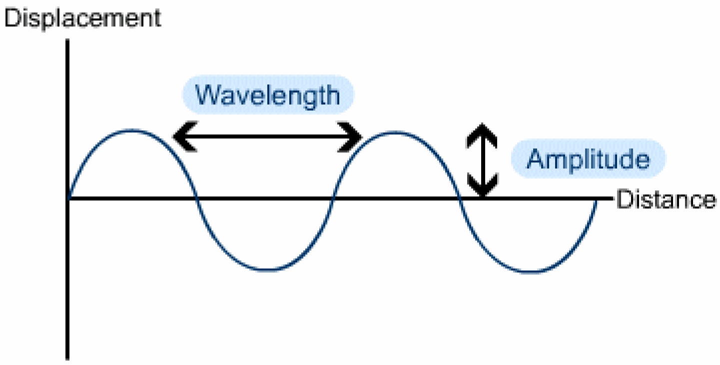
**To compare waves we need to be able describe their characteristics, these include:**

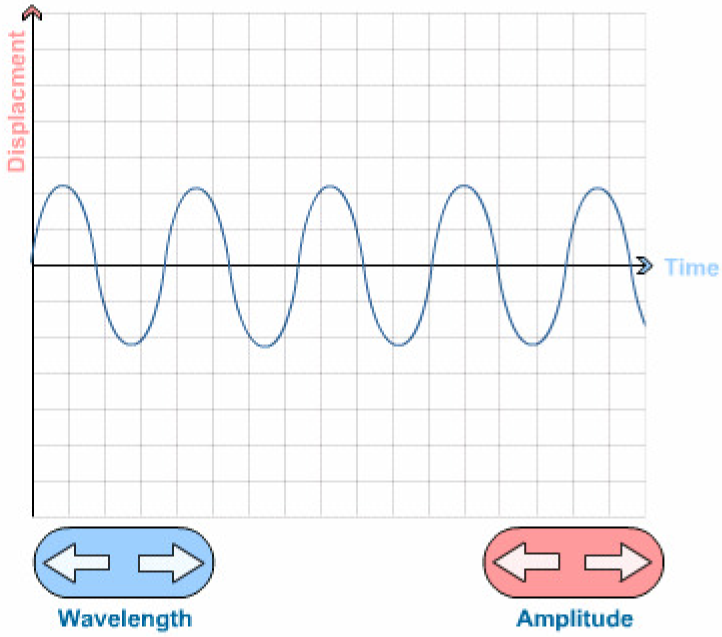
- **Amplitude**

- **Wavelength**

- **Time Period**

- **Frequency**

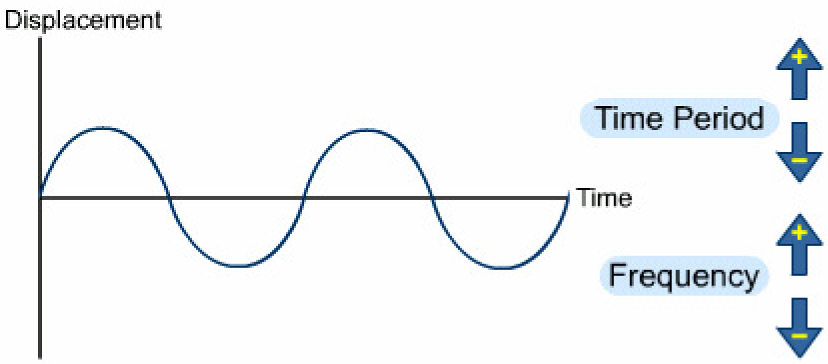





The amplitude of a wave is the height of the wave from the middle to a peak or trough. This is often called the **maximum displacement** of the wave. (The displacement of a particle is the distance a particle moves from the centre.)

Watch out. Many students make the mistake of measuring from a peak to a trough that gives double the correct answer.

The wavelength is the length of one complete wave. It can be measured, on a distance graph, from any point to the next similar point on the wave. **Remember one complete wave includes a peak and a trough.**




The **time period** of a wave is the **time it takes for one complete wave**.

The **frequency** of a wave is the **number of waves that travels past a point in one second**. Frequency is measured in Hertz (Hz). 1 Hz = 1 wave per second.

There is a simple relationship between frequency and time period. The lower the frequency is the longer the time period will be.

**Drag and drop the frequencies and time periods into the correct boxes:**

| | Frequency (Hz) | Time Period (s) |
|---|---|---|
| If 2 waves go past a point in a second | | |
| If 4 waves go past a point in a second | | |
| If 10 waves go past a point in a second | | |

| | | |
|---|---|---|
| 10 | ⅒ or 0.1 | 4 |
| ¼ or 0.25 | 2 | ½ or 0.5 |

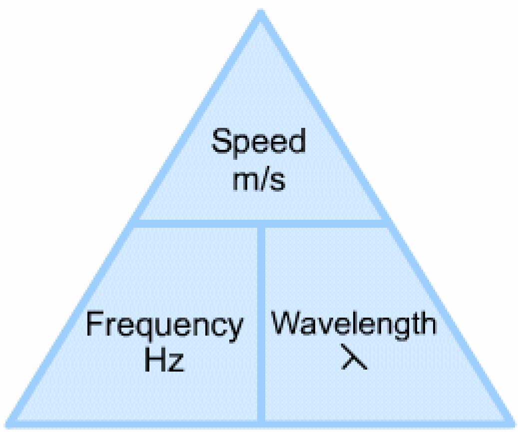
Mark Answer

# The wave equation

There is a simple relationship between speed, frequency and wavelength.

Speed = Frequency x Wavelength

**This can be put into an equation triangle:**




**You must use the correct units for each value:**

- Speed is in m/s (not km/s)

- Speed is in m/s (not km/s)
- Wavelength is in m (not km)
- Frequency is in Hz.

**Worked examples:**

| | |
|---|---|
| **1** | The speed of sound in air is 330 m/s. A note played on an instrument has a frequency of 110 Hz. What is the wavelength of the note?<br><br>Wavelength = Speed / frequency<br><br>= 330/110<br><br>= 3 m |
| **2** | The frequency of a water wave is 2 Hz and it has a wavelength of 0.02 m. What is the speed of the wave?<br><br>Speed = Frequency x wavelength<br><br>= 2 x 0.02<br><br>= 0.04 m/s |

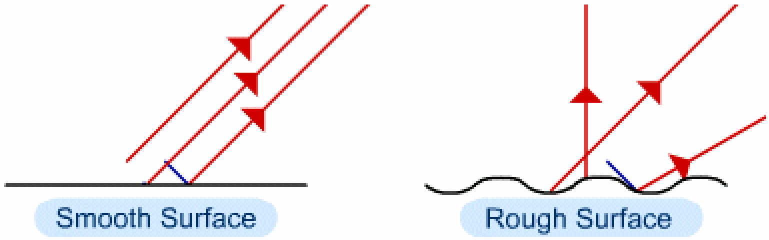
**Always remember to put units on your answers.**

Next QuickLearn

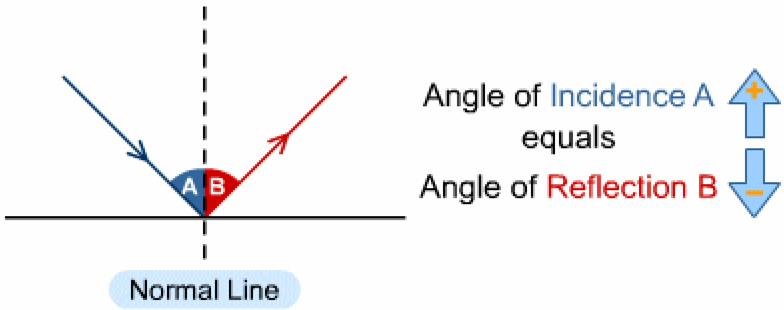
# Reflection of waves

## Light waves and the rules of reflection

When you see an object, light is bouncing off that object into your eye. Rough and smooth surfaces look different because of the way light bounces off them.




When light hits a mirror it bounces off the mirror. This is called reflection. The ray of light hitting the mirror is called the **incident ray**. The ray of light bouncing off is called the **reflected ray**. There are three rules of reflection:

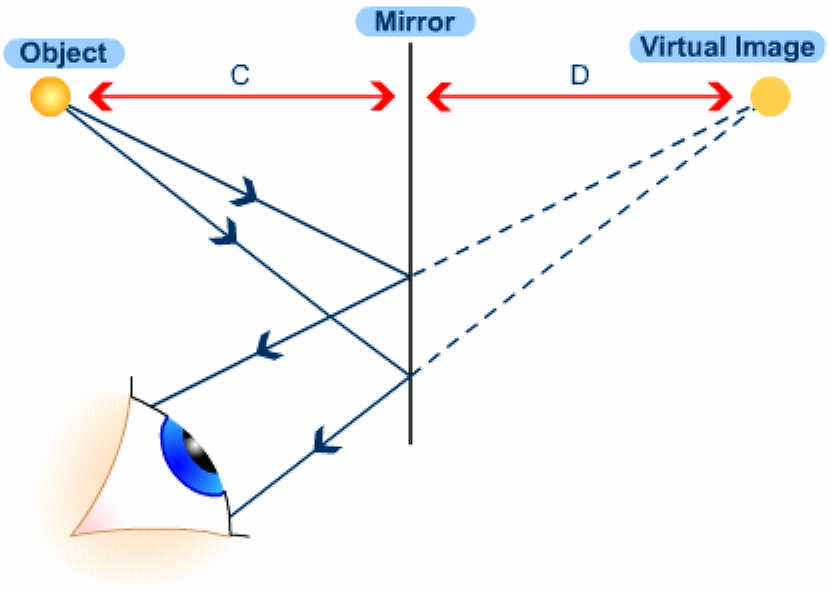



**Rule 1**: The angle of incidence is always the same size as the angle of reflection. (Angle A = Angle B)

The angles are always measured from the ray to the **normal line.** The normal line is a line at right angles to the mirror.

Watch out. Many students measure angles from the mirror to the ray. This will give the wrong answer.

Plane (flat) mirrors produce **virtual images**. This means that the images are not real, they don't exist. We can see these images because our brains think that they exist.




The rays of light reflect off the mirror (obeying rule 1), back into the eye. The brain thinks that light only travels in straight lines, so tracks the lines back to the point behind the mirror. This point is the virtual image. It doesn't really exist, but the brain thinks it does.

**Here are the other rules of reflection:**

**Rule 2**: The image is always the same distance behind the mirror as the object is in front (distance C = distance D).

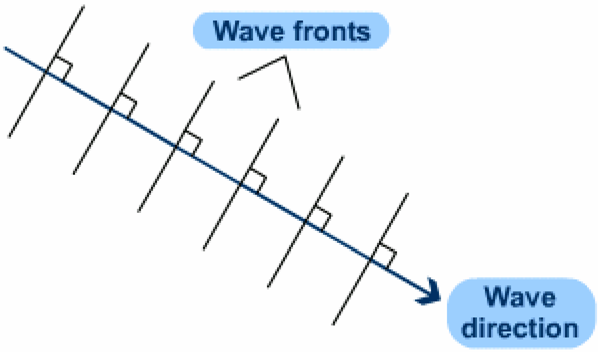
**Rule 3**: The image is always

- The same size as the object.

- Laterally inverted (left becomes right and right becomes left), which is why writing is back to front in a mirror.

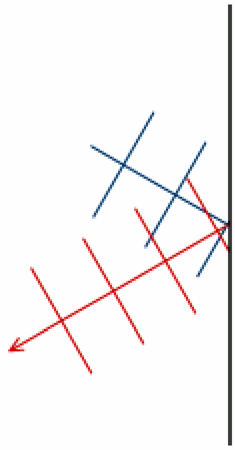
## Reflection of water waves

For water wave diagrams you need to draw in the wave direction and the **wave fronts**. The wave fronts are the peaks of the waves and will always be at right angles to the wave direction.

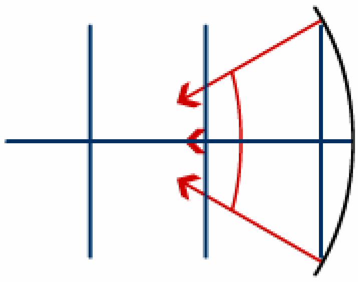



The distance between the wave fronts represents the wavelength. The closer the wave fronts are together the shorter the wavelength of the water wave.

If water waves hit a curved surface the wave fronts become curved. This can make the wave fronts go to a point. The more curved the surface is, the quicker the waves come to a point after hitting the surface.

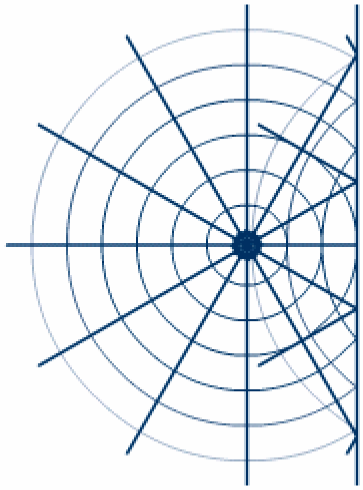


If water waves hit a curved surface the wave fronts become curved. This can make the wave fronts go to a point. The more curved the surface is, the quicker the waves come to a point after hitting the surface.



A raindrop hitting a puddle produces curved wave fronts. If these hit a plane (straight) surface the shape of the wave fronts curves the opposite way.

A raindrop hitting a puddle produces curved wave fronts. If these hit a plane (straight) surface the shape of the wave fronts curves the opposite way.

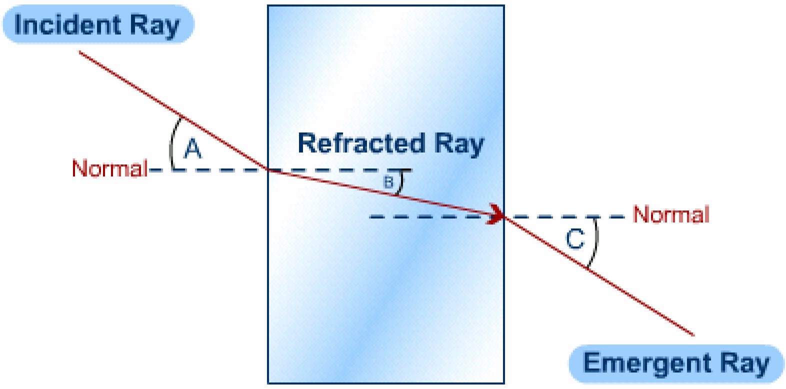


# Refraction of waves

## Refraction of light waves

**Why do swimming pools look shallower than they are? Why do straws look bent when they're in a drink? How can we bend light?** All these questions can be answered by looking at refraction.

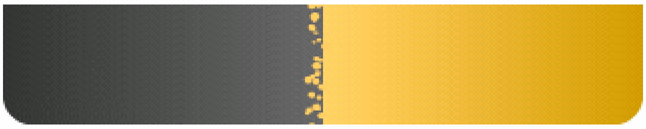
When light travels through air it travels at about 300 million m/s. When it travels through glass, water or any other transparent material it has to slow down. It's like running down the beach into the sea. When you hit the water you are slowed down. For light waves this can make them bend.



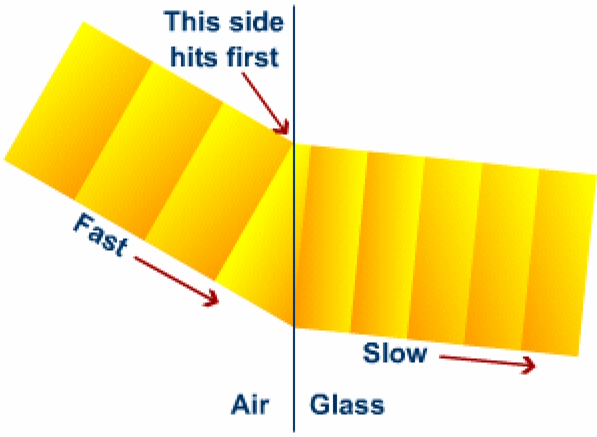

As the light wave goes into the block it **slows down** and **bends towards the normal line**, so angle A is always bigger than angle B. As the ray comes out of the block the light wave **speeds up** again and **bends away from the normal line**, so angle B is always smaller than angle C.

The only time light waves do not bend when changing speed, is if they are travelling along the normal line, at right angles to the boundary.

But why does the light wave bend when it changes speed? Imagine a car drives off a road onto a sandy beach. The first wheel to touch the sand (in this case the left) struggles for grip and slows that side of the car down. The right side of the car is still trying to travel at its normal speed. This makes the car swerve round to the right.

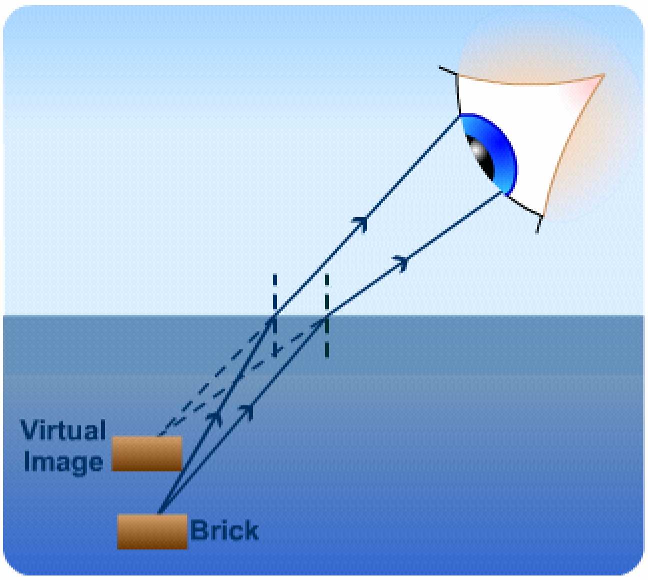


It is the same for light waves. If the ray doesn't hit the block at right angles one side will hit before the other. This slows one side of the ray down first, which makes the ray change direction.




**As the light wave has slowed down its wavelength gets smaller**. (The frequency does not change.) This fits with the relationship between speed, frequency and wavelength.

**Why does this make swimming pools look shallower than they really are?** Again it is the brain that sees a virtual image, that doesn't really exist.

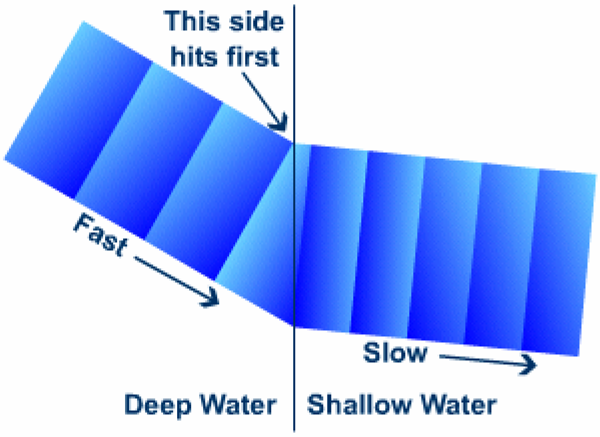



The light waves leaving the brick are refracted as they leave the water, bending away from the normal line. When these waves reach the eye the brain thinks they must have travelled in a straight line, so tracks them back to a point, the virtual image. So the brain sees the brick higher up than it actually is.

## Refraction of water waves

Water waves will refract when they slow down, in the same way as light waves. Water waves travel slower in shallower water. The deeper the water the faster the waves can travel, in fact in the ocean waves speeds can sometimes approach hundreds of miles per hour.

Refraction of water waves happens for the same reason as light waves. If one side of the wave hits a shallow region before the other side it makes the wave change direction.

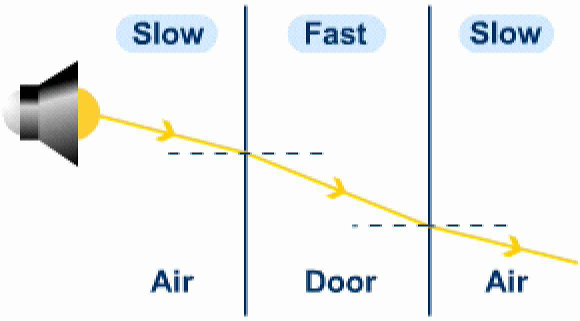



Again the wavelength of the wave changes as the speed changes. The slower the speed of the wave the shorter its wavelength will be. This keeps the frequency the same.

## Refraction of sound waves

Sound waves refract in the same way as light waves. When a sound wave is slowed down it bends towards the normal line and when it speeds up it bends away from the normal line.

**There is one big difference.** Light waves **slow down** when they enter liquids and solids. Sound waves **speed up** in liquids and solids.




Sound travels well in solids because the particles are close together so vibrations can be easily passed along.

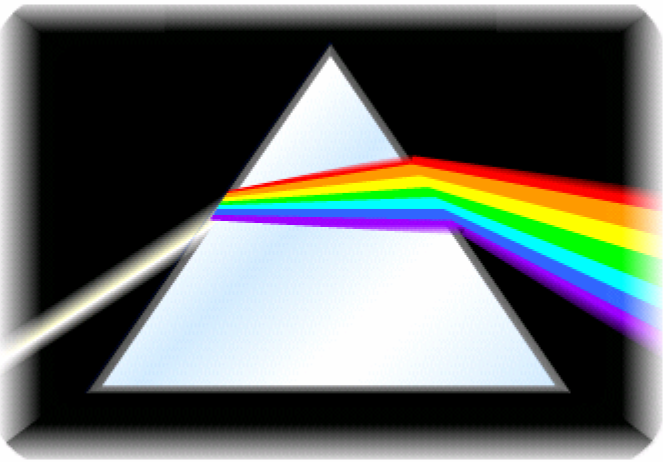
# Dispersion and total internal reflection

## Dispersion of light

**Why can you never find the pot of gold at the end of a rainbow?**

White light is made up of lots of different coloured light. Rainbows are made by raindrops splitting up the white light into the separate colours. This is caused by **refraction.**

You will know from the sections above that when light waves enter water they slow down and bend. Different coloured light has different frequencies. The **higher the frequency** of the light wave the **more it is slowed down** and the **more it is bent**.

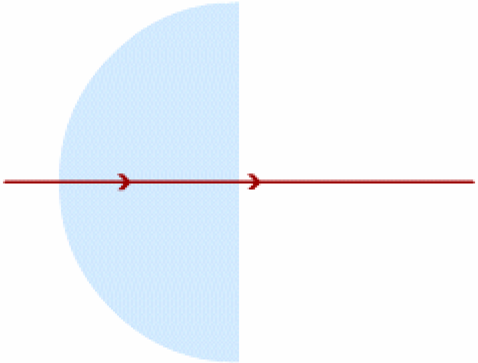


Red has a low frequency so is only bent a little. Violet has a much higher frequency so is bent more.

### Total internal reflection (TIR)

This is refraction taken to an extreme. **Press the button below to see the three possible situations:**

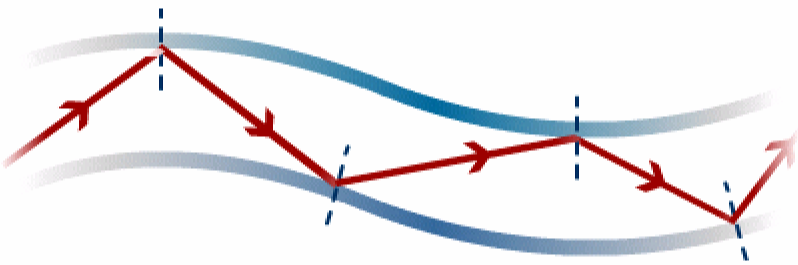
Angle of Incidence is less than critical angle



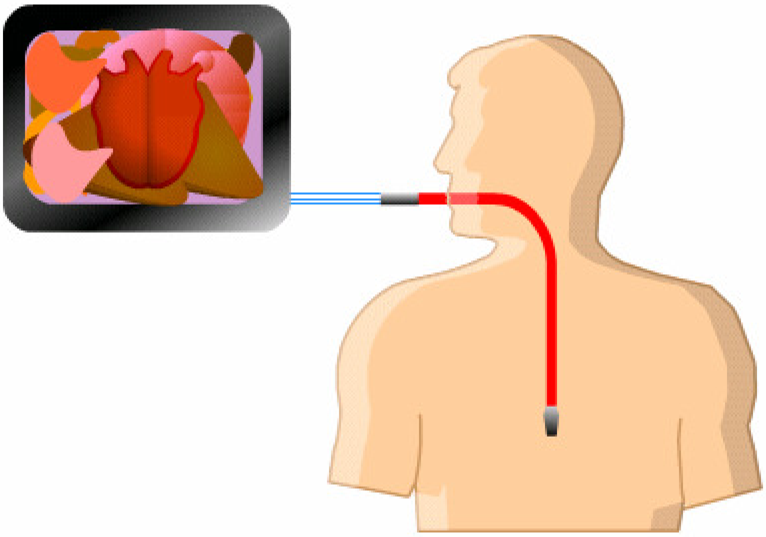
As the angle of incidence increases the angle of refraction increases until it gets to 90 degrees. At this point the angle of incidence is at the **critical angle**. If the angle of refraction gets any bigger the wave bounces off the surface of the block and reflects back into the block. This is called **total internal reflection**. When this total internal reflection happens the light wave obeys all the normal rules of reflection.

**In fact**, whenever light travels through glass, Perspex or water into air a small amount of light energy is reflected back into the block, by the boundary. It only becomes very noticeable when the angle of incidence is greater than the critical angle and TIR happens.

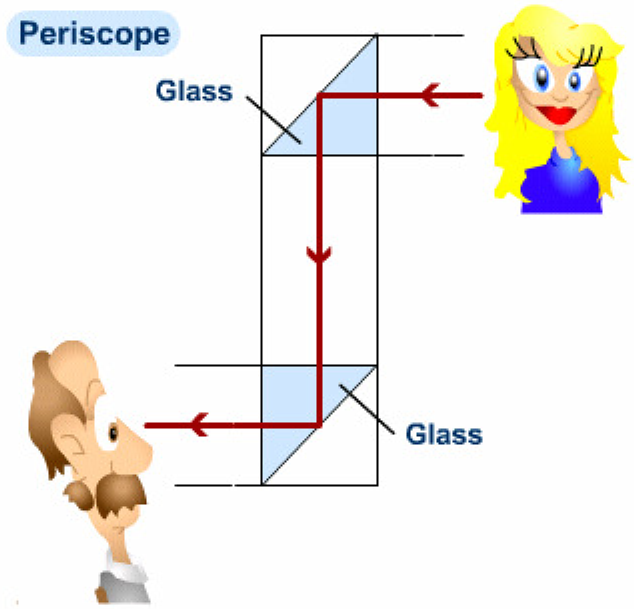
This strange occurrence has now become extremely useful. Light can be made to bounce along long glass fibres, reflecting off the inside walls as it travels along, until it emerges at the other end. This is repeated total internal reflection.

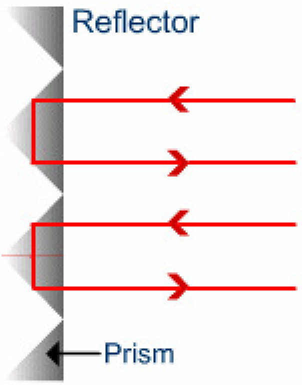


These fibres are called optical fibres. They are used in medicine, in endoscopes, to see inside patients. Optical fibres are also used for communications; information is carried as pulses of light along the cables.



Total internal reflection can also be used in periscopes and reflectors. Right-angled prisms can be used to make the light change direction:

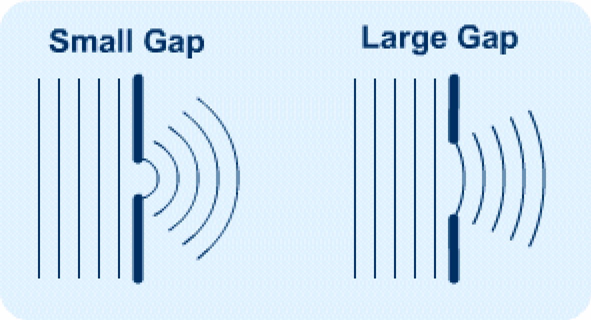


# Diffraction of waves

## Diffraction of water waves

Have you ever tried squashing plasticine through a small hole? Perhaps not, but if you have you may have noticed that it makes a bulge as it comes through the hole. The same thing happens to waves as they travel through small holes, or push past obstacles.




As the water waves go through the gap they spread out, this is called **diffraction**.

The longer the wavelength of the wave the larger the amount of diffraction.

The greatest diffraction happens when the gap size is about the same size as the wavelength.

## Diffraction of light and sound waves

Diffraction of sound and light happens in the same way as water waves. There are just a few extra points to remember:

**Diffraction of light**

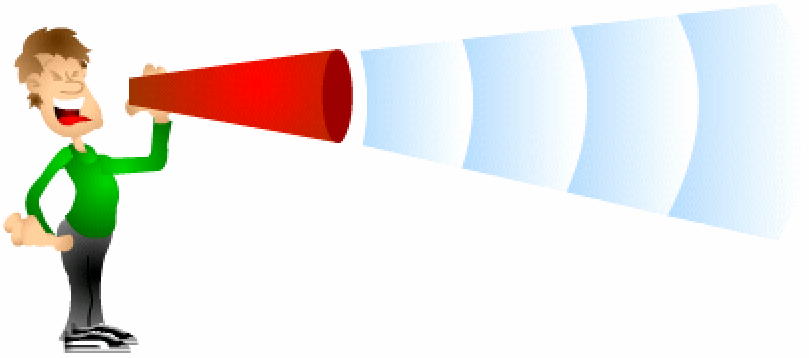
Light waves have a very short wavelength compared to water waves. Diffraction is most noticeable when the gap size is about the same as the wavelength of the wave. Therefore to diffract light the gap needs to be extremely small, in fact around one thousandth of a millimetre.

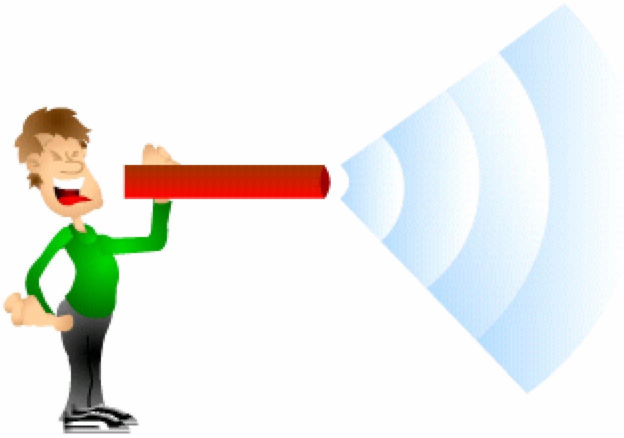
**Diffraction of sound**

Sound has a much longer wavelength than light. Sound waves can even diffract around buildings or through doorways. This is why you can often hear people when you can't see them.

As with all wave diffraction the amount of diffraction will depend on the wavelength of the sound wave and the size of the gap the wave is travelling through.

Sound waves are diffracted as they leave their source, for instance a loud speaker. The size of the source will affect how much diffraction occurs.





Previous QuickLearn

# Sound waves

**Sound waves are longitudinal waves, made by particles vibrating.** These vibrations are passed along to nearby particles, which then pass them on again. This is how sound waves travel along through solids, liquids and gases. When the particles vibrate near your eardrum, your eardrum vibrates. This movement gets turned into an electrical signal, which is then passed on to your brain.

Sound waves need particles to travel along, so they cannot travel in space, or any other vacuum. You can see the sun, but you can't hear the massive explosions that are taking place there, as light can travel in space but sound can't.

Sound can be reflected, refracted and diffracted which shows that it travels as a wave. Sound waves are longitudinal waves

The characteristics of sound waves decide the pitch and loudness of the sound.

## Pitch

The pitch of a note is how high the note is. A man's voice tends to have a lower pitch than a woman's voice. Bats makes such a high-pitched noise that humans find it hard to hear.

- The pitch of a note depends on the frequency of the wave.

- The higher the frequency of the wave the higher the note.

- The shorter the wavelength of the wave the higher the note.

**Click on the arrows to increase or decrease the pitch:**

Click to view the different frequencies of waves.

Show Me

# Loudness

How quiet a sound is depends on the amplitude of the sound wave.

- The greater the amplitude of the wave the louder the sound.

**Click on the arrows to increase or decrease the loudness:**

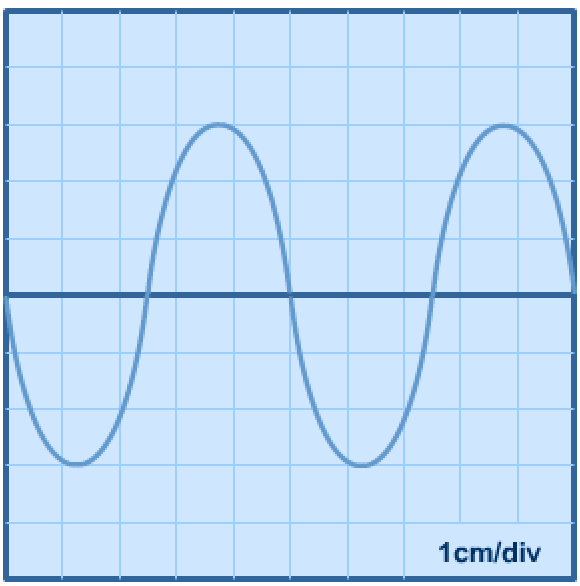
Click to view the different amplitudes of waves.

Show Me

# Oscilloscope traces

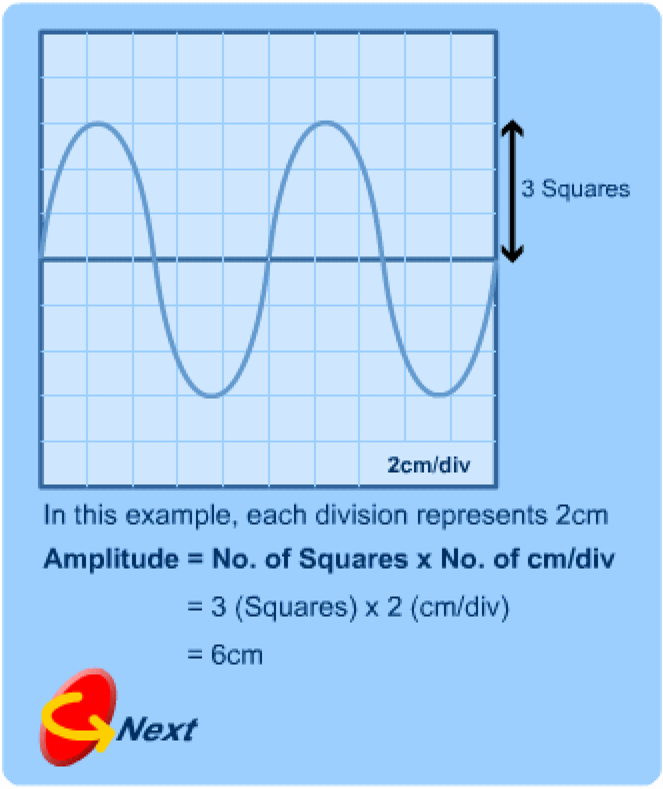
In describing waves the terms amplitude, time period and frequency were explained. Most waves can be made into electrical signals. We can use oscilloscopes to look at these electrical signals, which represent the waves, on a screen. We can then measure the characteristics of the wave on the screen.

**Measuring amplitude**

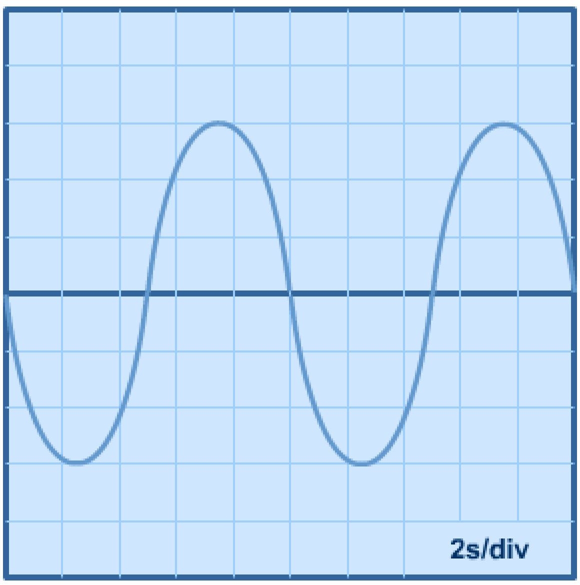


An **oscilloscope** has a scale on it that tells you what the height of each square is equivalent to. In the diagram above, the height of one square is equal to 1 cm. This is written as **1cm/division.** As the amplitude of the wave is 3 squares high the amplitude of the wave is 3 cm.

## Worked examples

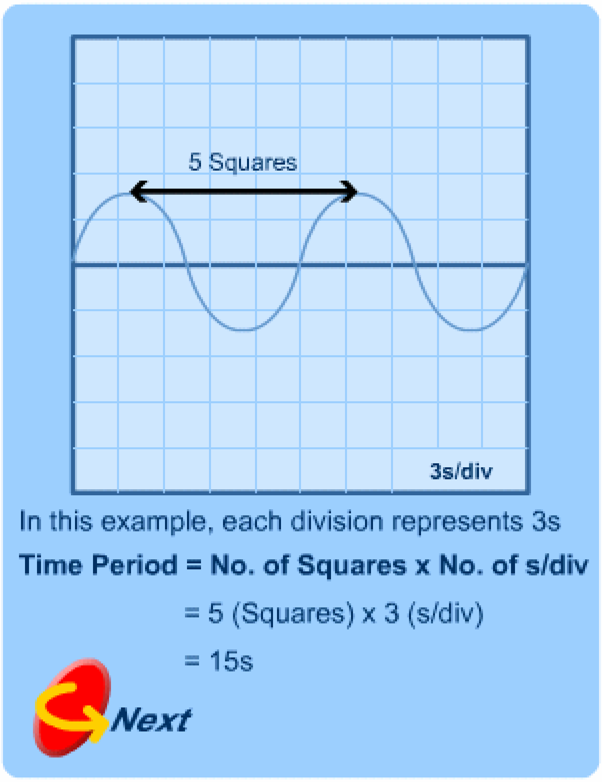



**Measuring time period (the time for one wave)**



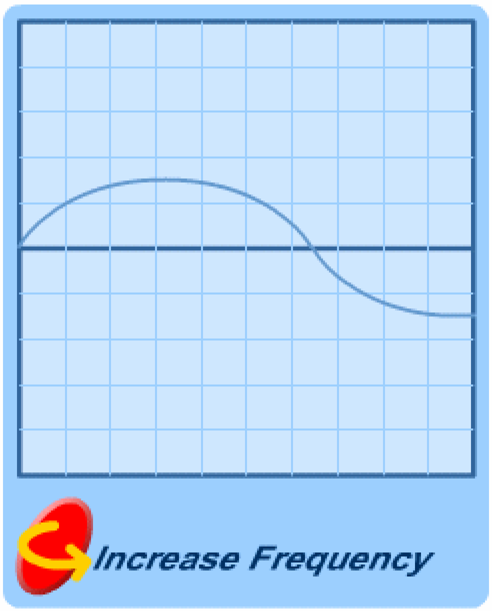
The oscilloscope also has a **'time-base scale'.** This tells you the scale across the screen. In the diagram above, each square across is equal to 2 seconds. As the wave is 4 squares long the time period of the wave is 2 x 4 = 8 seconds.

**Worked Examples**




**Don't forget, the longer the time period the lower the frequency.**

If the time-base scale stays the same it is easy to compare wave frequencies by looking at how many waves are on the screen, **for example:**




The more waves that fit on the screen the higher the frequency must be.

# Uses of sound waves

## Echoes

**Echoes are sound waves bouncing off surfaces.** Sound waves obey the same first rule of reflection. (**Remember:** the angle of incidence is the same as the angle of reflection.)

The echo is usually quieter than the original noise as energy is lost as the wave travels along.

You can work out how far away something is using echo-sounds.


If it takes 20 seconds for the echo to be detected it must have taken 20 seconds for the sound to travel to the object and back. **Using:**

**Distance = Speed x Time**

The distance can be calculated. The speed of sound is 330 m/s so the calculation becomes:

Distance = 330 m/s x 20 s = 6600 m

This is the distance **there and back**, so the object is half that distance away, 3300 m.

Watch out. Many students forget to halve the distance.

Shiny hard surfaces reflect sound better than soft, surfaces. Bathrooms are good rooms to sing in as the sound bounces well off tiled walls. If you sing in the living room most of the sound energy is lost, because the energy is absorbed by the carpet, furniture and curtains.

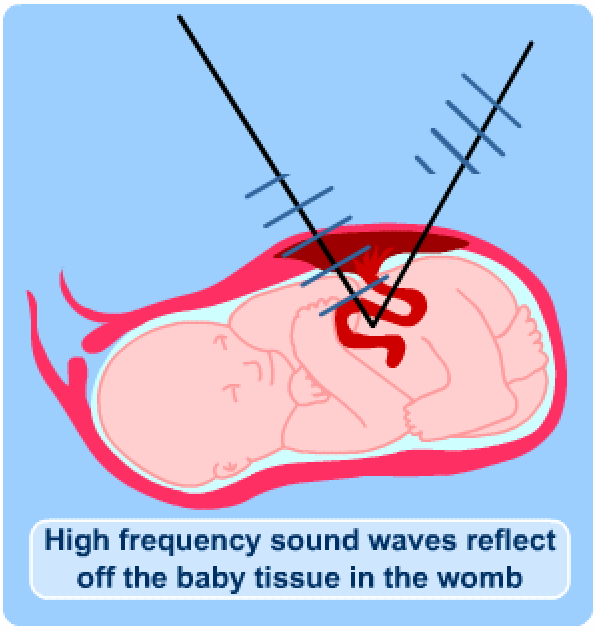
# Ultrasound

Sound waves that have a very high frequency are called **ultrasound** or **ultrasonic waves**. These sounds are so high that humans can't hear them. Dogs and bats have a higher hearing range than humans and can hear some ultrasonic waves.

Ultrasonic sound waves are made by electrical devices (like a loud speaker), which change electrical signals into sound waves.

There are many uses for ultrasound in medicine and industry. **Here are some of them:**

**Looking at babies in the womb (pre-natal scanning):**




- A receiver compares the length of time it takes for the ultrasound waves to be detected. The longer the time it takes for the wave to reach the receiver the deeper into the body the wave has gone. This information is then used to build up a picture of the baby in the womb, which is then shown on a visual display, like a computer screen.

- **Cleaning instruments:** Ultrasonic waves can be used to clean delicate instruments without having to take the equipment apart. The instrument is held in a liquid. The ultrasonic waves make the liquid particles vibrate at a high frequency, which cleans the surfaces of the equipment.

- **Detecting flaws and cracks in metal:** This works in the same way as scanning babies in the womb. The ultrasonic waves bounce off different surfaces in the metal. The time it takes for the waves to bounce back to the receiver allows us to work out the depth the wave has travelled into the metal.

# Electromagnetic spectrum

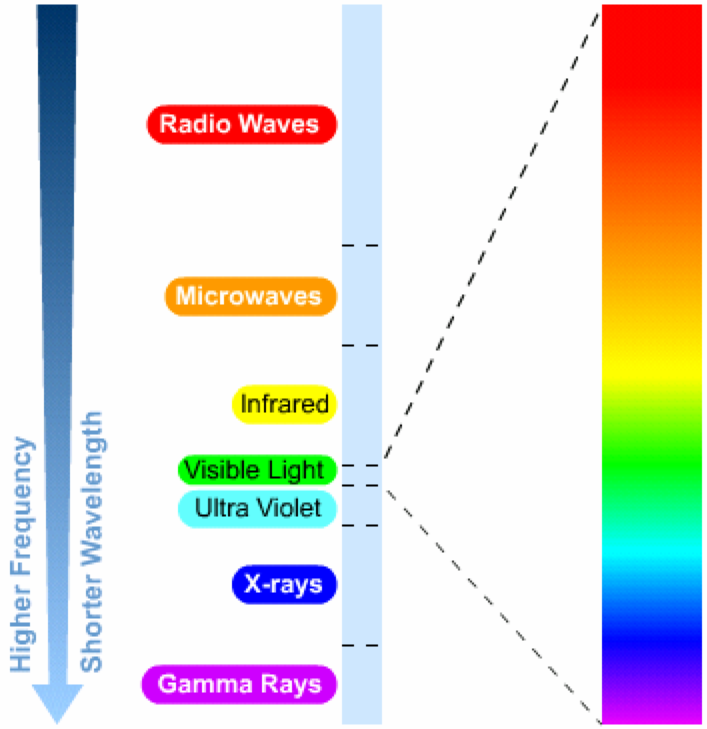
## Waves in the spectrum

White light can be split up into lots of different coloured light waves using a prism. We call this range of colours the **visible spectrum**, however, this is only a small part of a very much longer spectrum called the **electromagnetic spectrum**. Humans can only see the visible part of the spectrum; the rest of the electromagnetic spectrum is invisible to the human eye. Other animals are able to detect other parts of the spectrum that human's cannot see, for instance the infrared and ultraviolet waves.

All the parts of the electromagnetic spectrum can be **reflected**, **refracted** and **diffracted** which shows that each part is a type of wave. In fact, the electromagnetic spectrum is a whole continuous family of waves. They are all transverse waves. They all travel at the same speed through space. This speed is 300,000,000 m/s (the speed of light) this can also be written as 300 thousand km/s.

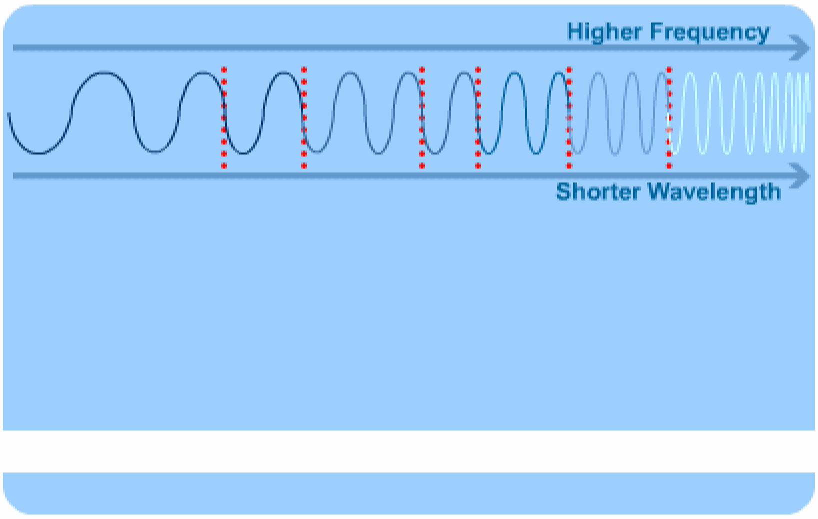
**Electromagnetic waves** do not need a medium (matter) to travel in. They can travel through space. This is fortunate as we get most of our energy from the sun as electromagnetic waves.

Although all the waves in the spectrum have the same speed, each type has its own range of frequencies and wavelengths. The difference in the frequencies gives each type of wave its own characteristics, for example, in the visible spectrum each different frequency has a different colour.



You will need to know the order of the spectrum. Remember gamma waves are at the high frequency end of the spectrum and radio waves are at the low frequency end.

Each type of wave in the spectrum has its own use. You will need to know the possible uses and dangers of each type of wave. **Move the mouse over the spectrum to see the information about each wave:**




The higher frequency radiations (U.V. X-rays and gamma waves) are the most dangerous. Low doses can cause normal cells to become cancerous. Higher doses will kill cells. This is because these types of radiation cause ionisation.

You should be able to describe ways of reducing the amount of radiation absorbed by people. **The main safety points are:**

- Point radiation sources away from people.

- Wear lead lined clothing (lead absorbs more radiation than most other materials).

- Wear gloves and use tongs when handling substances that emit radiation.

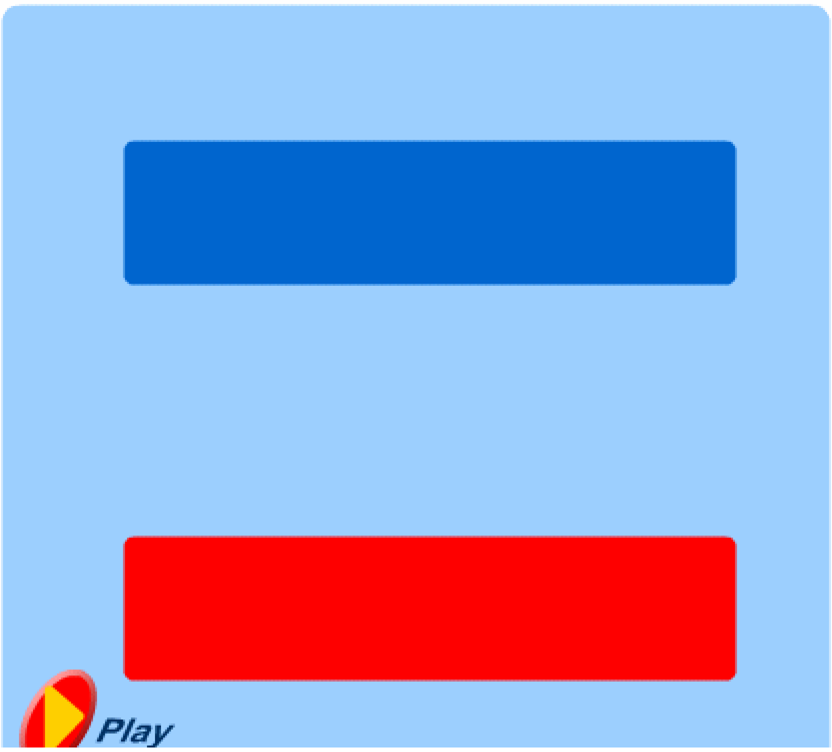
## Absorption and emission of waves – seeing colours

**Why do different objects look different colours?**

Each surface absorbs and reflects different frequencies of light. White surfaces reflect all colours. Black surfaces absorb all colours. Some people argue that black isn't really a colour at all; it's a lack of colour as all the light has been absorbed.

When any radiation is absorbed its energy is changed into heat energy. This means that black objects that absorb radiation easily heat up quickly, whereas white objects reflect the radiation so stay cooler.


A blue object reflects blue light and absorbs all the others. A red object reflects red light and absorbs the others and so on.

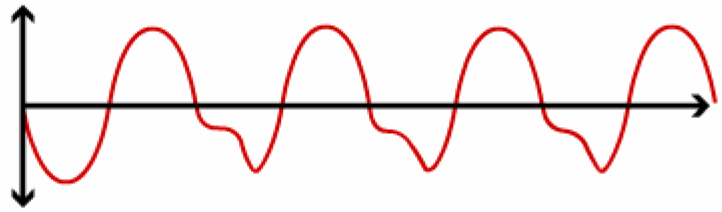


# Information carrying

## Types of signals

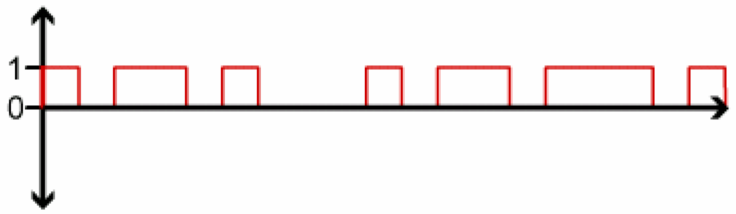
A rapidly increasing amount of people own mobile phones and there are very few houses in the U.K. that do not have some form of telecommunication. In the past all the systems were based on **analogue** signals but now the world is going **digital**.

**Analogue signals**



Analogue signals cover a whole continuous range of values.

**Digital signals**




Digital signals have only two values off (0) and on (1).

**Digital signals have two main advantages:**

- They are a higher quality than analogue signals. This is because they are not changed as much as analogue signals when they are **transmitted.** (Transmitted means moved or transferred from one point to another.)

- More information can be sent as a digital signal, in a certain length of time, compared with analogue signals.

When signals are transmitted they lose energy so signals are **amplified** to increase the energy again. Signals can also pick up extra, unwanted signals. This is called **noise**.

For analogue signals the different frequencies in the signal lose different amounts of energy. When the signal is amplified these differences and any noise are also amplified. This makes the signal deteriorate and become less and less like the original signal.

This problem is less noticeable with digital signals, as the on and off states are easy to see, even with some noise added. The quality of the signal is less affected by the transmission.

## Optical fibres versus copper cables

When telecommunications began signals were sent from house to house along copper cables, via switchboards. Now optical fibres have replaced many of these copper cables.

Electrical signals have to be used in copper cables, whereas electromagnetic waves can be used in optical fibres. By using digital signals, information can be sent along the optical fibres as pulses of light.

**There are three main advantages of using optical fibres rather than copper cables:**

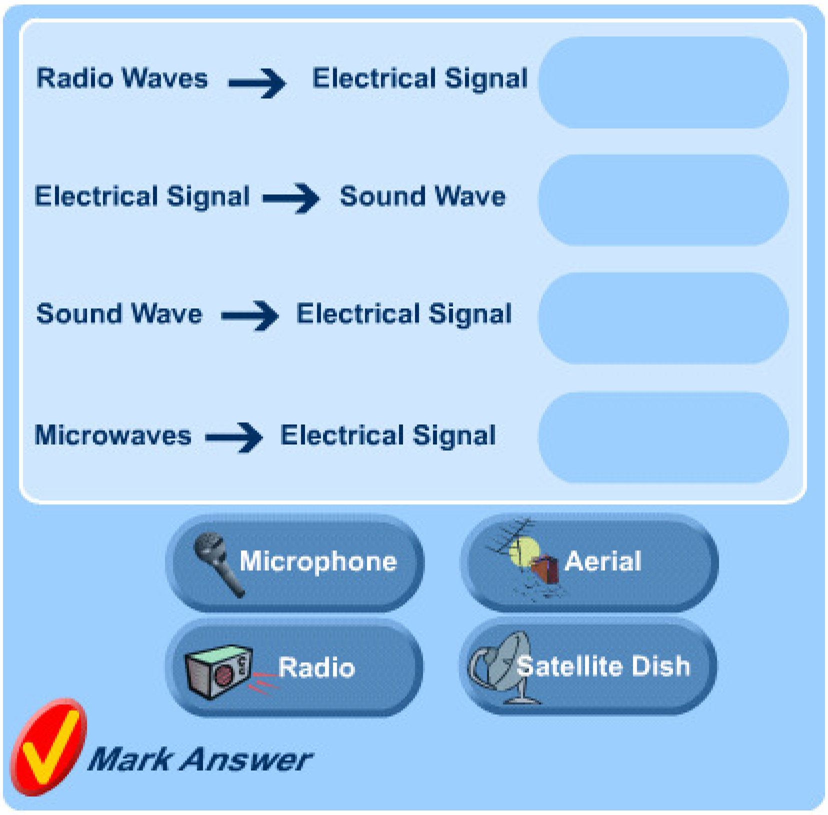
- Optical fibres allow much faster transmission (delivery) of the signals than copper cables.

- Optical fibres can also carry far more information than a copper cable that is the same diameter.

- Light pulses lose less energy as they travel along an optical fibre than an electrical signal in a copper cable.

## Changing waves into electrical signals

Waves have energy. This energy can be changed into other forms. For instance, when electromagnetic waves are absorbed by metal, the energy that is absorbed can be changed into an electrical signal as an alternating current. **Match the correct devices to the wave form changes below.**




Sound waves can also be converted to electrical signals, using a microphone. This is how speech and music can be transmitted long distances along cables. The electrical signals can then be converted to electromagnetic waves that can be sent along optical fibres or to satellites.

If waves are converted to electrical signals so that the frequency and amplitude of the electrical signal match the frequency and amplitude of the wave being converted, the electrical signal is an analogue signal. This signal can then be converted to a digital signal.

# What Can Forces Do?

## What can forces do?

**A force can do one of four things to an object:**

1. Make it **speed up** - accelerate.
2. Make it **slow down** - decelerate.
3. **Change its direction.**
4. **Change its shape.**

If something is doing one of these four things there must be a **net** force acting upon it.

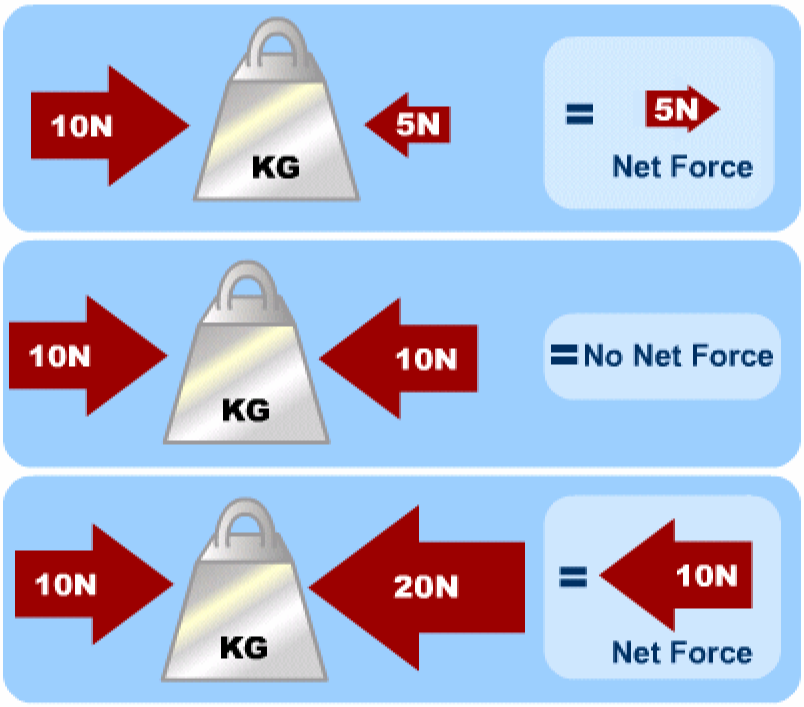
(**Note:** Other names for a **net force** are an **unbalanced force** or a **resultant force**.)

## Net forces

**What do we mean by a 'net' force?**

Well, forces do not add up like normal numbers - you must take their **direction** into account as well. For example, if you were teetering on the edge of a cliff and someone applied a force to you, you would probably like the force applied in a certain direction.

**It is easy to add up forces, just look at these three examples:**



# Newton's Laws

## Newton's First Law

**Newton's First Law states that:**

**'Every body continues in a state of rest or uniform motion unless acted upon by an external force.'**

This sounds really complicated… but isn't.

Imagine that you are playing table hockey. If you have not put your money in and you give the puck a hit, it doesn't travel very far. Friction stops it.

However, if you put your money in, air is pumped out of the holes in the table and so when you give the puck a flick, it will travel to the other end of the table. There is **much less friction** to slow the puck down. You need the end of the table to stop it. In both cases, a force starts and stops the puck, **but a force is not needed to keep it moving at a steady speed.**

So in other words, something without a **net** force acting on it will either **stay still** or **move at a constant speed** in a straight line until you apply a force to it.

**When you apply a force to it, it will either:**

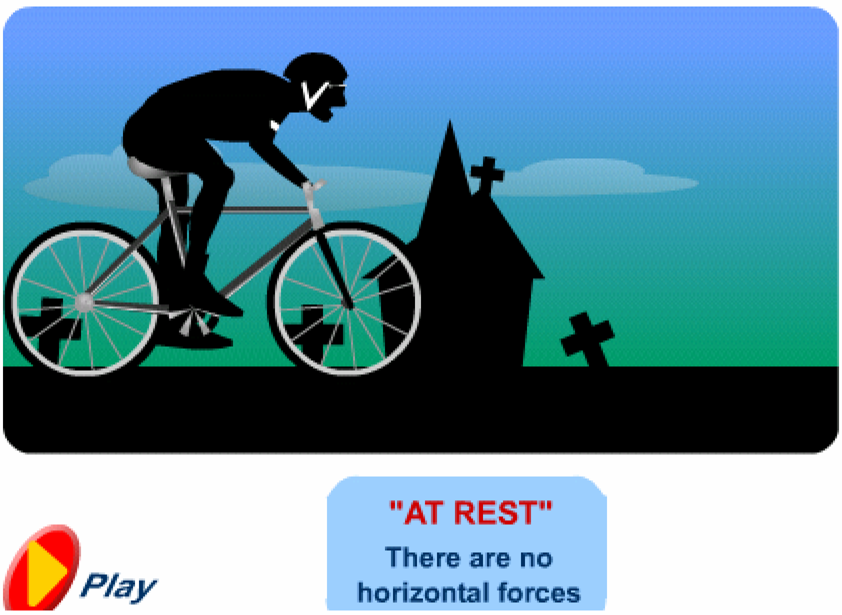
Speed up,

Slow down,

Change direction,

(Or change shape).

**The following example will help you understand this:**



# F = ma

Also known as **Newton's Second Law** - you will have seen this equation during your course.

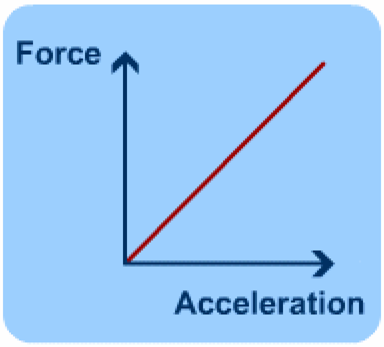
- F is the force in Newtons, N.

- m is the mass in kilograms, kg.

- a is the acceleration in $m/s^2$.

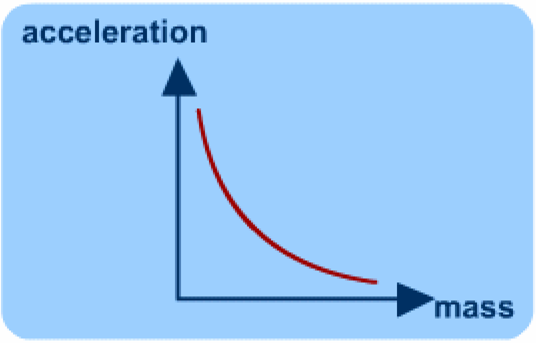
This shows that if you keep the mass constant and double the applied force the acceleration will double.

**If you plot a graph of force against acceleration it will look like this:**



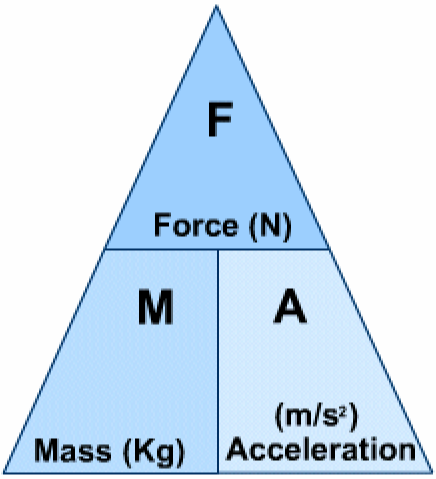

You can see here that force is proportional to acceleration. As you double the force the acceleration doubles, as you triple the force the acceleration triples.

**If you plot a graph of acceleration against mass it will look like this:**




You can see here that if you keep the force constant and increase the mass the acceleration will fall. Acceleration is inversely proportional to mass. If you double the mass the acceleration will halve.

It is helpful if you can rearrange this equation. **The triangle for this is as follows:**




**Some examples:**

**1. A 500kg car accelerates at 3 $m/s^2$.**

**How much force is exerted by the wheels to accelerate the car?**

**Answer:**

| | |
|---|---|
| **Write down the formula:** | $F = ma$ |
| **Plug in the numbers:** | $F = 500 \times 3$ |
| **Write down the answer:** | F=1500N |

**Note:** Don't forget the units!

**2. A 500kg car is accelerated by a force of 2000N.**

**What is its acceleration?**

**Answer:**

| | |
|---|---|
| **Write down the formula:** | $a = \frac{f}{m}$ |
| **Plug in the numbers:** | $a = \frac{2000}{500}$ |
| **Write down the answer:** | $a = 4\ m/s^2$ |

**Important point:** The equation works in exactly the same way for deceleration as it does for acceleration!

# Behaviour of Solids

## Hooke's Law, elastic and plastic behaviour

(**Note: Plastic** behaviour is sometimes called **inelastic** behaviour.)

In the 1600s, a scientist called Robert Hooke discovered a law for **elastic** materials.

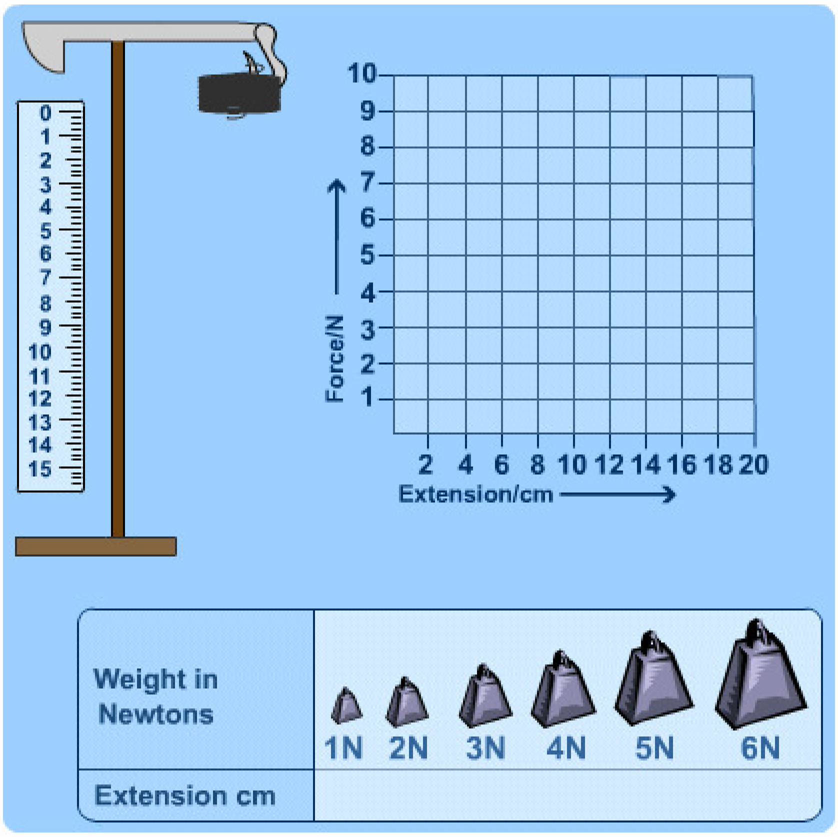
An **elastic** material is one that will return to its original shape when the force applied to it is taken away.

A **plastic** (or **inelastic**) material is one that stays deformed after you have taken the force away.

If you apply too big a force a material will lose its elasticity.

Hooke discovered that the amount a spring stretches is proportional to the amount of force applied to it. This means if you double the force its extension will double, if you triple the force the extension will triple and so on.

**Click on the weights below to see what happens:**



The **elastic limit** can be seen on the graph. This is where the graph stops being a straight line. If you stretch the spring beyond this point it will not return to its original shape.

**You can write Hooke's law as an equation:**

**F = kx**

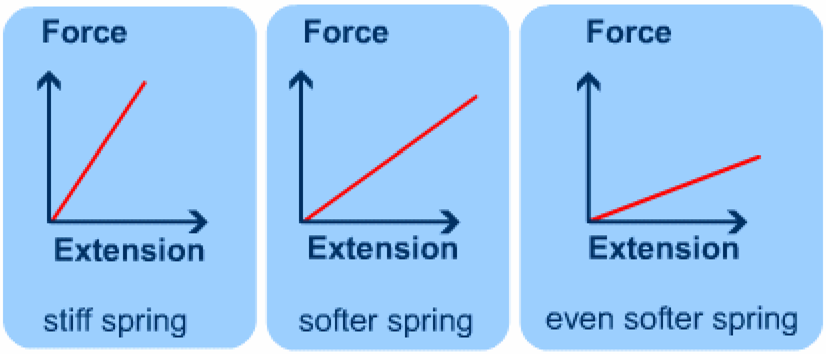
where:

F is the applied force (in newtons, N),

x is the extension (in metres, m) and

k is the spring constant (in N/m).

The spring constant measures how stiff the spring is. The larger the spring constant the stiffer the spring. You may be able to see this by looking at the graphs below:




**Elastic behaviour** is very important in car safety, as car seatbelts are made from elastic materials. However, after a crash they must be replaced as they will go past their elastic limit.

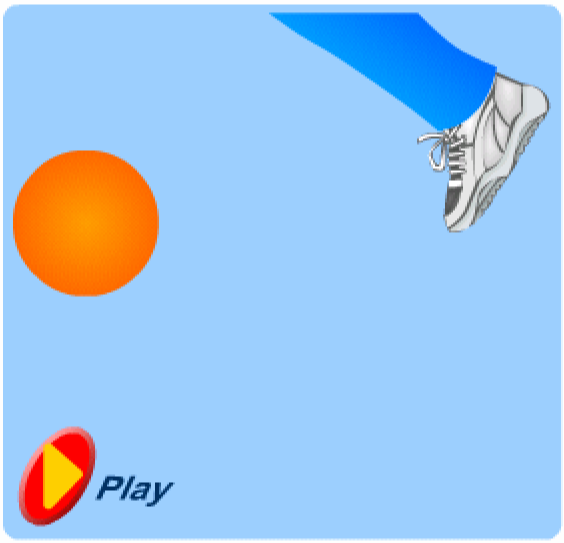
**Why have seat belts that are elastic?**

**Why not just have very rigid seatbelts that would keep you firmly in place?**

The reason for this, is that it would be very dangerous and cause large injuries. This is because it would slow your body down too quickly. The quicker a collision, the bigger the force that is produced.

This can be seen very plainly by comparing the effect of kicking a football, which squashes as you kick it giving a big collision time, followed by kicking a brick. The brick doesn't squash, giving a very quick collision time and a very painful foot.

**Press play to view this happening:**




This is why airbags and crumple zones can reduce injuries (these are both parts of a car designed to squash rather than be rigid).

So to reduce injuries in a collision, always slow down in as long a time as possible. This is why you bend your legs when landing after a jump and why parachutists roll when they hit the ground.

Previous QuickLearn

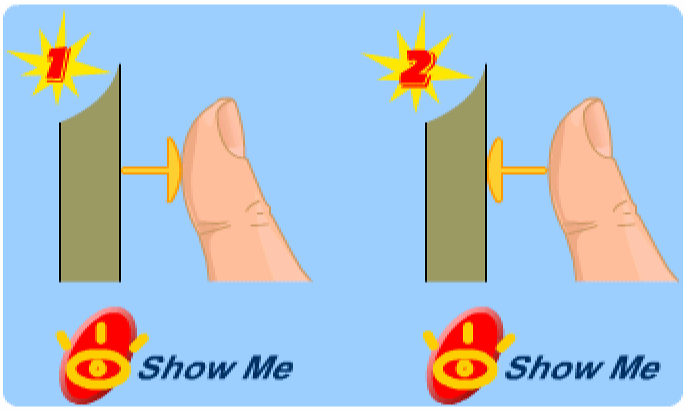
Next QuickLearn

# Forces and Pressure

## In solids

**Think about these two situations:**

1. Pushing a drawing pin into a wall pointy end towards the wall.
2. Pushing a drawing pin into a wall pointy end towards your thumb.




Two similar activities with two very different results.

The reason for this is the difference in pressure. Assuming the same force is applied, each case would have a different pressure acting on the thumb. In the first diagram the thumb pushes on a **large area** so the **force is spread out** and the **pressure is low**. In the second diagram the **force is concentrated** on a **small area** so the **pressure is much higher.**

**If a force is applied over a smaller surface area you get a larger pressure.**

**Pressure can be calculated using the following equation:**

Force will be in newtons, N.

Area will be in either $m^2$ or $cm^2$.

If the area is in $m^2$ then the pressure will be measured in Pascals or $N/m^2$.

If the area is in $cm^2$ then the pressure will be in $N/cm^2$.

**Example:**

**A lump of cheese of weight 20N stands on a table. It is a cubic lump**

**Example:**

**A lump of cheese of weight 20N stands on a table. It is a cubic lump with an area of $10cm^2$.**

**What pressure does it exert on the table?**

**Answer:**

**Write down the formula:** $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

**Plug in the numbers:** $P = \frac{20}{10}$

**Write down the answer:** $P = 2N/cm^2$

**Note:** Don't forget the units!

# In liquids

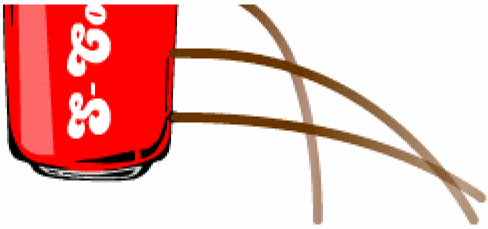
When it comes to pressure in liquids, there are 3 rules that you need to remember:

**1. Pressure increases with depth**

Have you ever noticed that when you dive down to the bottom of a swimming pool, your ears start to hurt? The further you dive down, the more it hurts.

This is because the pressure in a liquid increases as you go further below the surface of the liquid.

A common example in exams is this - a can full of water with holes down the sides. Notice how the further down the hole is, the faster the water comes out because the higher the pressure is in that part of the can.



**Here are some other common examples. Can you explain them?**

**Water comes out of a downstairs tap faster than an upstairs tap.**

**Dam walls have to be thicker at the bottom than at the top.**

You always get these ideas in any movie that has a submarine in it. You can guarantee that at some stage during the film, the sub will go too deep! Alarms will sound, people start to sweat, look nervous and the sub will creek and groan. Sometimes, the water will burst in and the sub will **'implode'** (that means explode inwards rather than outwards).

This is due to the fact that the pressure from the water outside the submarine increases as the sub goes deeper and deeper until the structure of the sub isn't strong enough to resist - and it is crushed.

**2. Pressure acts equally in all directions**

**To illustrate this:**

Grab a plastic bag.

Fill it with water.

Tie a knot in the top.

Squeeze it.

Water goes everywhere! And that's the point.

Water, from holes at the top of the bag, goes up.

Water, from holes at the side of the bag, goes sideways.

Water, from holes at the bottom of the bag, goes down.

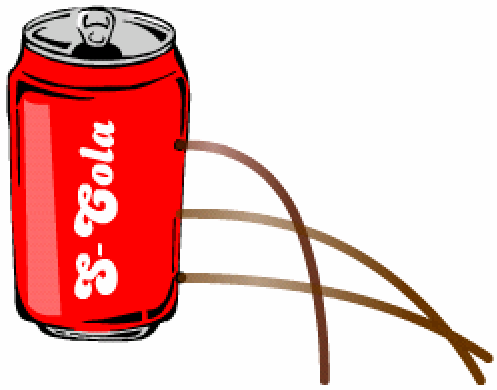
This shows that the pressure in the water (which makes the water squirt out of the bag) **is acting in all directions** - not just downwards!

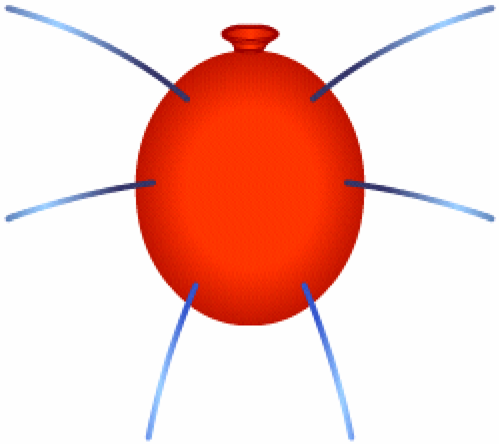
There's another example that helps to explain this. Remember when you are swimming at the bottom of the pool and your ears are hurting. It doesn't matter what you do with your head - turn left, right, twist it up or down - your ears hurt just as much. The water is pushing in on them from all sides equally - not just downwards.

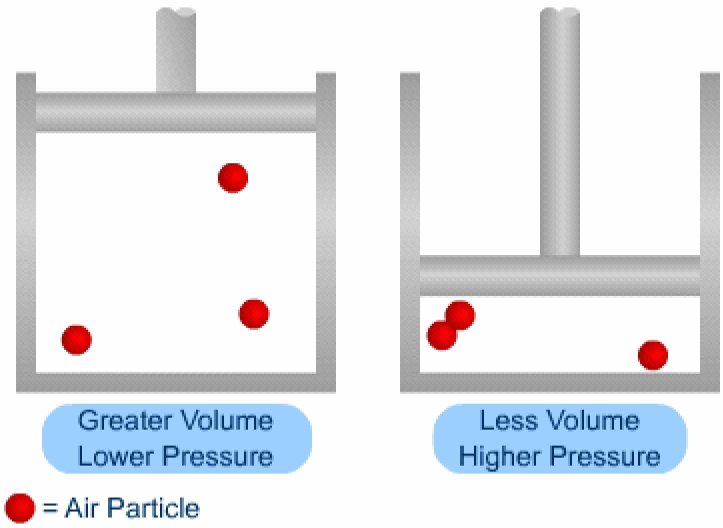
**3. Pressure is transmitted through liquids**

You can't squash liquids. We say that they are **'incompressible'.**

Fill a syringe with water. Put your thumb over the nozzle and press the plunger. It won't move. The water in the syringe can't be compressed.


S-Cola




Greater Volume
Lower Pressure
Less Volume
Higher Pressure
= Air Particle

Do the same thing with a syringe full of air and you can easily squash it. Air is compressible.

The fact that you can't compress liquids is extremely useful. It means that **pressure can be transmitted through liquids.**

An example - you connect two syringes together with a pipe and then fill them with water. Press one plunger in - and the other one comes out. That's because you have **transmitted pressure** from one plunger to the other.

This is used in **hydraulics.**

## Hydraulics

All hydraulics systems work because the pressure is the same throughout the system.

A really good example of this is a **car brake system.** You need to know all about this for your exams.

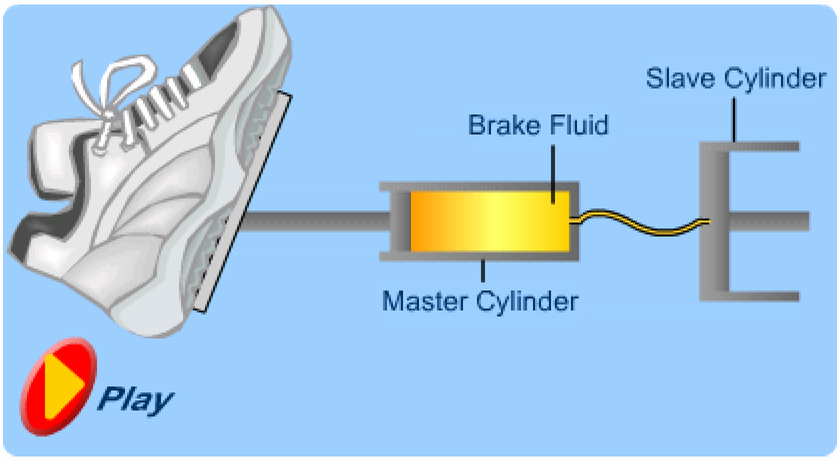
Think about it. If you are driving a car along a motorway, you can stop it quite quickly by pushing gently on the brake pedal.

Now here's an alternative. You are driving a car along a motorway and you decide to stop. So you open the door, and, using the same force as above, gently press down on the tarmac with your foot.

(P.S: In case you need to be told - don't try this!!!)

You won't be surprised to learn that the car doesn't stop nearly as quickly. And, you wreck your trainers!

**So how does the car turn the small force that you apply to the brake pedal into the huge force needed to stop a speeding car?**



If you look at the above diagram, you can see that the brake cylinder by the pedal (the master cylinder) that the driver presses is very narrow.

But the cylinders by the brakes (the slave cylinders) are very wide.

This means they apply a much larger force.

**Why?**

Because the pressure in the liquid is the same everywhere. So if the area is bigger in the slave cylinders the applied force must be bigger too.

This is easier to see with an example.

If you push the master cylinder with a force of 12N and it has an area of $3cm^2$.

**Using the equation:**

This means the pressure in the master cylinder must be:

Now, because pressure is the same throughout the system, that means that the pressure in the slave pistons must also be $4N/cm^2$.

If the slave cylinders have an area of $12cm^2$, using the equation:

Force = Pressure x area

Force = 4 x 12

Force = 48N

(**Note:** The pressure stayed the same.)

# In gases

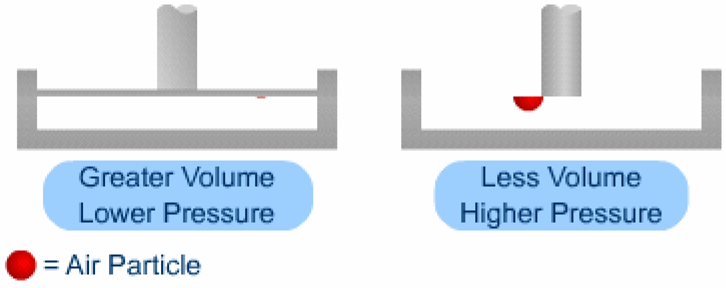
Although gases are compressible (squashy) they exert a pressure because of the **gas particles bouncing off things**. The pressure the air exerts at the surface of the Earth is about 100,000 Pa. Luckily, our bodies have evolved to cope with that pressure, or we would be squashed.

The diagram below illustrates how **gas particles exert more pressure when the gas is squashed**.

Both cylinders have the same number of particles in - and both sets of particles are going the same speed.

Notice that the particles in the small cylinder **hit the walls more frequently** - because there is less distance for the particles to cross from the top to the bottom of the cylinder.

Now remember that it is the **collisions that cause the pressure - more collisions means more pressure**. So the fact that there are more collisions in the small container means that the pressure is higher in the small container.




**Boyle's Law**

The diagram above explains why **changing the volume of a gas sample changes the pressure** of the gas. **Boyle's Law** is a way of calculating how much the pressure changes when the volume changes.

An eighteenth century scientist called Robert Boyle discovered that for a fixed mass of gas the pressure x the volume of the gas stays the same.

In other words, as you squeeze a gas its pressure will go up and its volume will get less.

**Important point:** The temperature and mass of gas must stay the same for this to be true!

**We can write this as:**

pressure x volume = constant

**or**

$P_1V_1 = P_2V_2$

**where:**

$P_1$ is the pressure of the gas at the start,

$V_1$ the volume of the gas at the start and

$P_2$ and $V_2$ the pressure and volume of the gas at the end.

**This tells us if we double the pressure of a gas its volume will halve. If we reduce the pressure by one half, the volume will double.**

**Example:**

**Imagine a balloon full of air. The air's pressure is $10N/cm^2$ and its volume is $300cm^3$.**

**You squash the balloon to 200cm$^3$ without any air escaping.**

**What is the pressure of the air inside the balloon?**

**Answer:**

**Write down the formula:**

$P_1V_1 = P_2V_2$

(**Remember:** $P_1$ is the pressure at the start, $V_1$ is the volume at the start, etc)

**Plug in the numbers:**

$10 \times 300 = P_2 \times 200$

**Rearrange the equation to give:**

**so**

$P_2 = 15$ N/cm$^2$.

**Remember:** The temperature and mass of gas must remain the same for this to work!

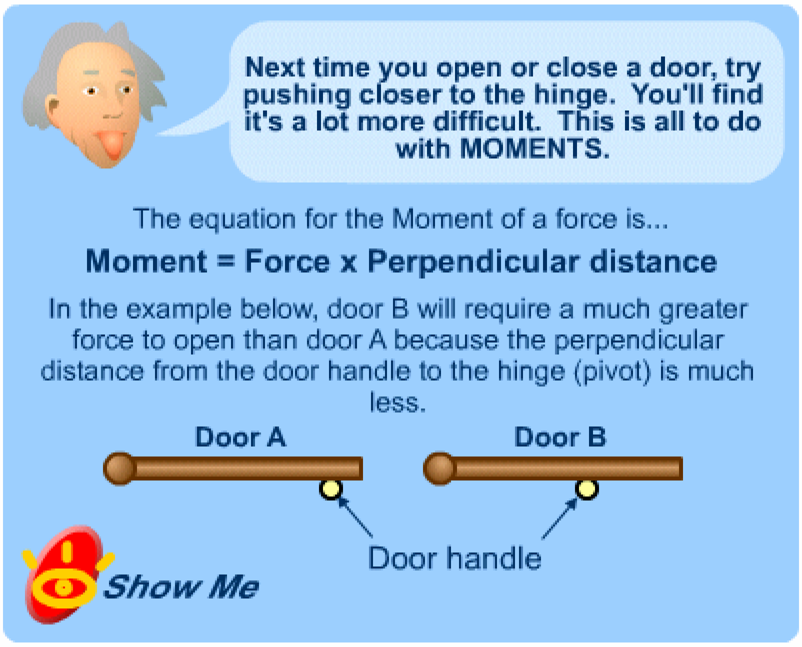
Previous QuickLearn

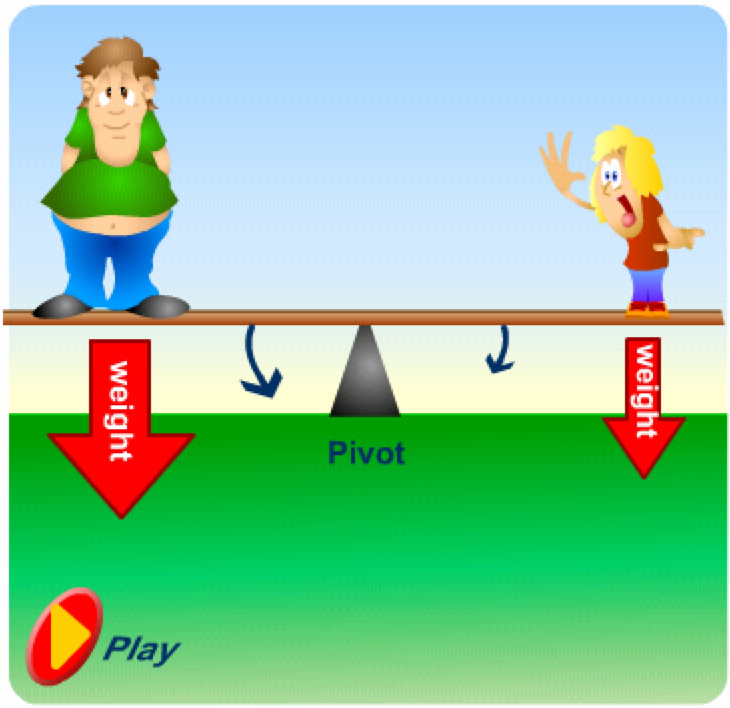
Next QuickLearn

# Moments

## Why door handles are near the edge of doors.

**Moments** make things turn or rotate. They are caused by forces but are not forces themselves. Like forces, moments have a direction. We say they are either clockwise or anti-clockwise, to show which way they will make something turn.



The bigger the force causing the turning effect the bigger the moment will be.

The further the force is from the pivot the bigger the moment will be.

**The size of a moment can be calculated using:**

**Moment = Force x Distance**

Force is measured in newtons, N.

Distance is measured in either m or cm.

If the distance is in m then the moment will be measured in **Nm**.

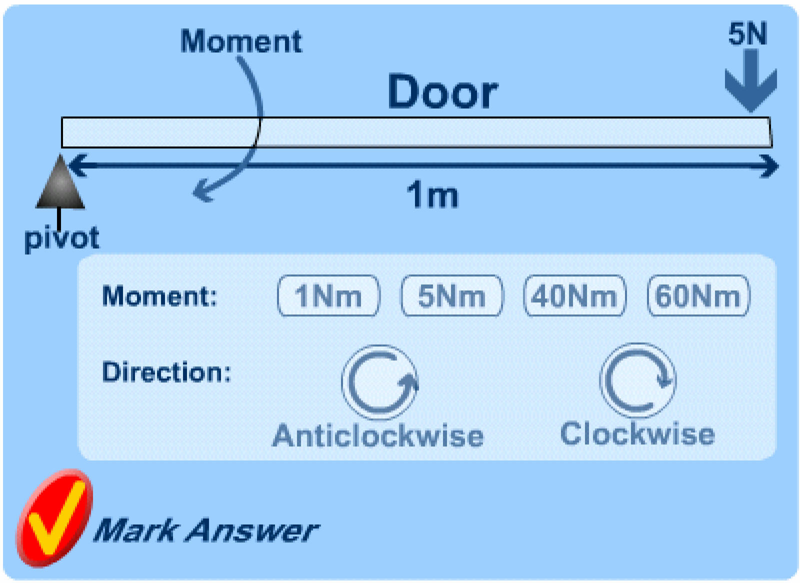
If the distance is in cm then the moment will be measured in **Ncm**.

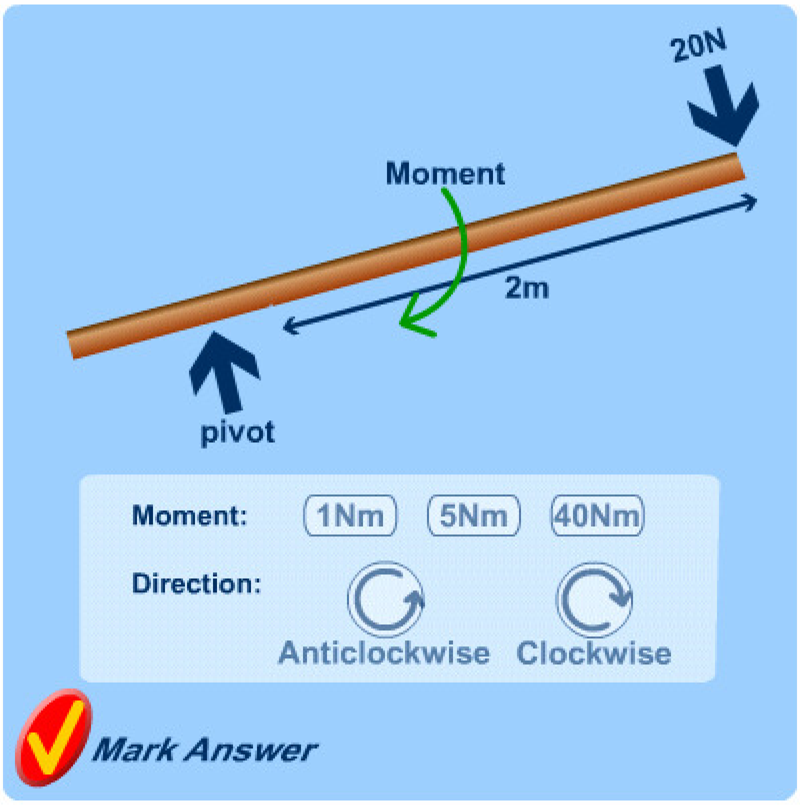
(**Note:** The force needs to be at right angles to the lever or rotating object.)

Here are some pictures involving moments.

**For each picture:**

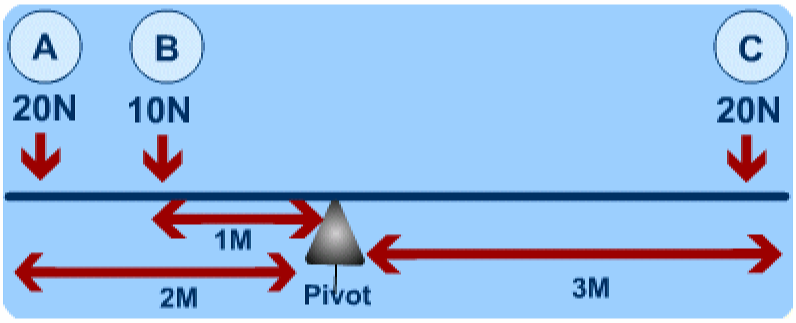
**Click on the moment and the direction that you think is correct then mark your answer.**




20N
Moment
2m
pivot
Moment:
1Nm
5Nm
40Nm
Direction:
Anticlockwise
Clockwise
Mark Answer


Pivot
10cm
10N
Don't forget: you need to convert cm into m
Moment:
1Nm
5Nm
40Nm
100Nm
Direction:
Anticlockwise
Clockwise
Mark Answer


In many situations there is more than one moment acting. To find the **net** or **resultant moment** the moments have to be added or subtracted, depending on their direction. **Here is a worked example:**




Moment due to **A** = 20 x 2 = 40 Nm anti-clockwise

Moment due to **B** = 10 x 1 = 10 Nm anti-clockwise

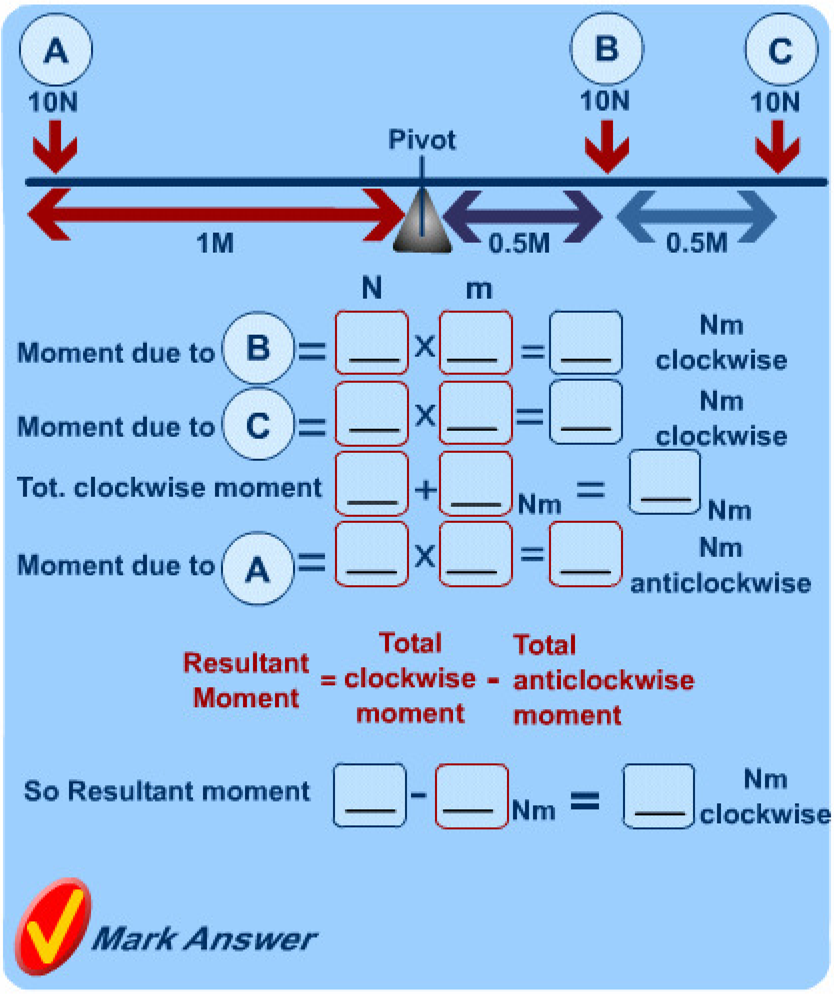
Moment due to **C** = 20 x 3 = 60 Nm clockwise

The total anticlockwise moment is 40 +10 = 50 Nm.

The total clockwise moment is 60 Nm.

So the resultant moment is 60 Nm – 50 Nm = 10 Nm clockwise.

**Now here is one for you to try. Fill the correct numbers into the boxes:**



# Types of Energy Transfers

## Energy

**Energy is needed for us to do work. Energy is measured in Joules, J or kilojoules, kJ.**

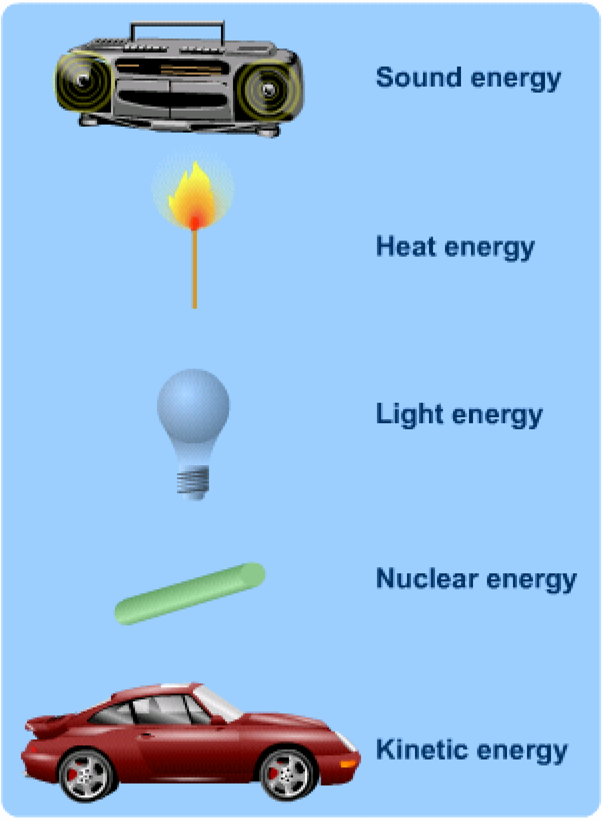
Many scientists believe that there is a certain amount of energy in the universe. As energy cannot be made this energy is just constantly moving around the universe being changed into different forms.

The Earth receives almost all its energy from the sun, but much of it leaves the Earth's atmosphere again and is lost in space.

## Types of energy

Although energy cannot be made or destroyed it can be changed into different forms.

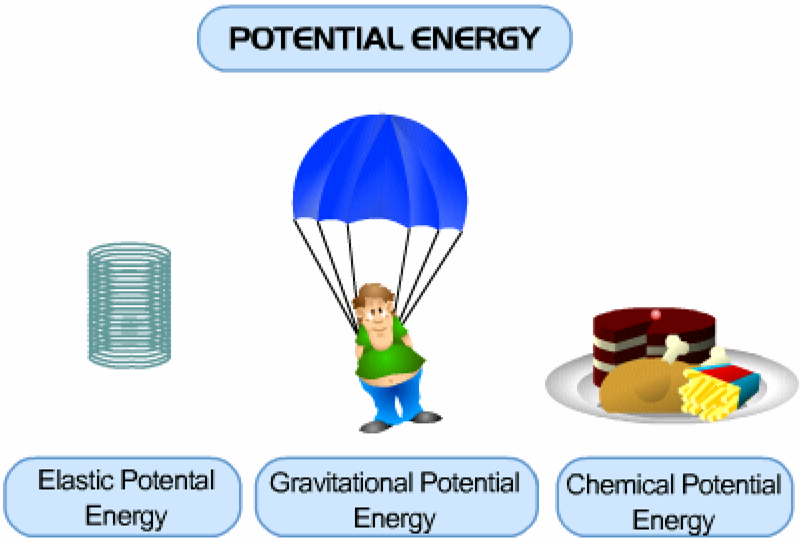
**There are many types of energy, but the ones listed below are the most common:**



**Kinetic energy** is a more scientific name for movement energy.

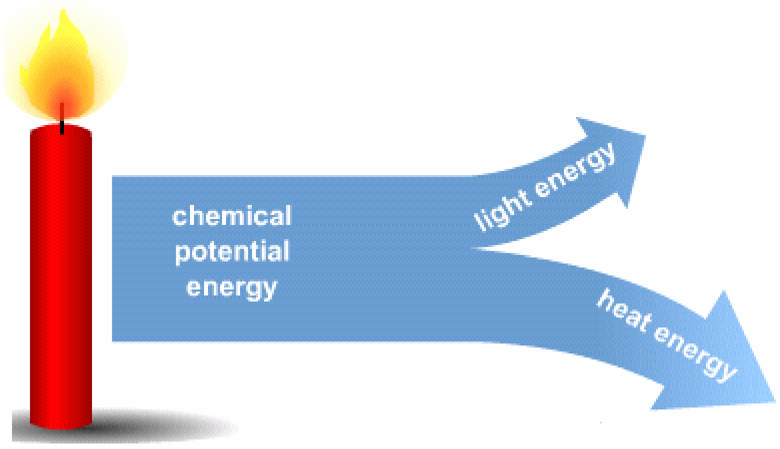
**Potential energy** is a more scientific name for stored energy.

**Potential energy can be divided into three types:**




# Changing energy

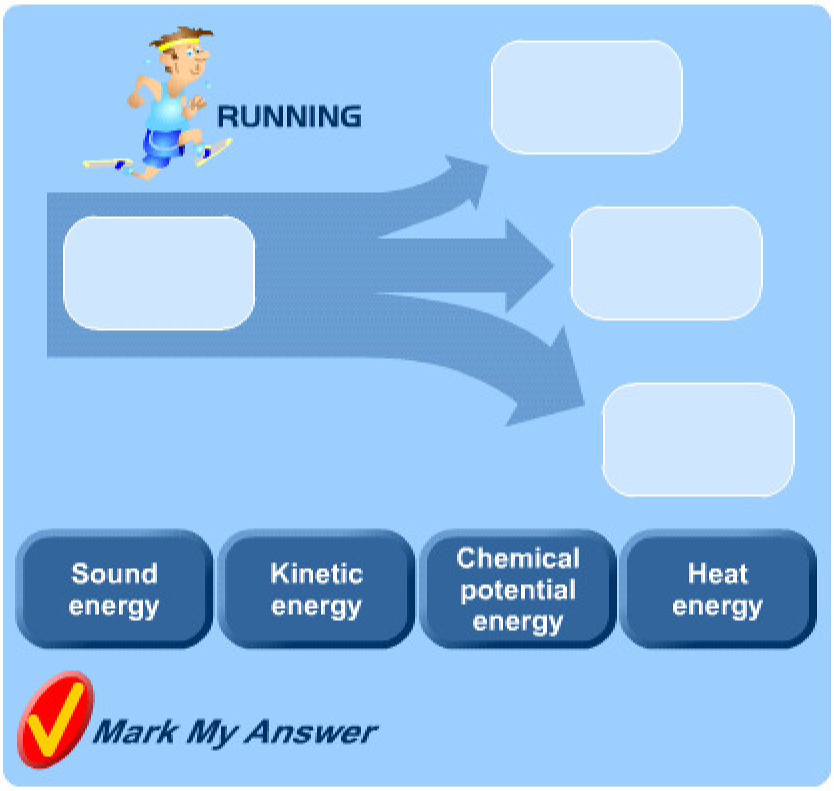
There are many different ways for energy to change its form. **We use Sankey Diagrams to show energy transfers:**




The bigger the arrow is the larger the amount of that type of energy.

**In the following diagram drag the correct energy labels to the appropriate arrows.**

**In the following diagram drag the correct energy labels to the appropriate arrows.**




Values for energy are often added to the diagrams.

**Always make sure that the total amount of energy coming out is equal to the energy put in!**

# How Does Heat Energy Move?

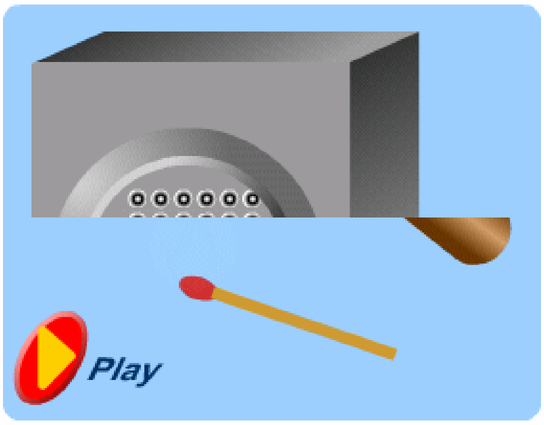
Hot objects have heat energy. **Heat energy always moves from something hot to something colder.** There is no such thing as cold energy, so an object can only get colder by heat energy moving away from it.

**There are three ways that heat energy can move:**

1. Conduction.
2. Convection.
3. Radiation.

## Conduction

When you first pour boiling water onto a Pot Noodle, the plastic container feels cool on the outside. Soon, the heat energy has worked its way through the plastic and the container starts to feel hot on the outside. Heat energy has travelled through the solid plastic container. **This process is called conduction.**




Atoms in a substance are always vibrating. If the substance gets hotter, the atoms vibrate more. The heat energy is given to the atoms, which makes them move about faster. **Note:** the atoms don't swap places, or move around they just vibrate more on the spot.

Have you ever danced next to someone really energetic? If so, you know that it makes you have to move about more – often just to get out of the way! It is like that for atoms passing heat energy on to each other.

Solids are better at conducting than liquids and gases because the atoms are closer together. If the atoms are too spaced out it makes it harder for the atoms to pass the energy along.

Metals are the best solids for conducting heat energy. In metals, there are free electrons that can move through the metal. These electrons are able to move from hot parts of the metal to colder parts, taking the heat energy with them. This is called **electron diffusion.**

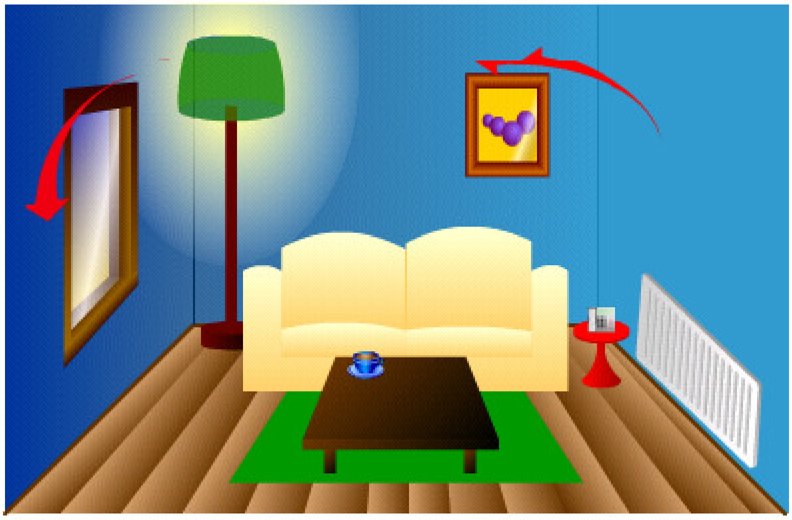
The poorest conductors are gases as their molecules are too far apart to affect each other much. This means that air is a terrible conductor of heat energy.

## Convection

Hot air rises in cold air. Hot water rises in cold water. This way of moving energy is called convection. When hot air rises, colder air has to move in to replace it. When hot water rises in a cup, colder water sinks to replace it.

This movement of a liquid or gas is called a **convection current**.

**Convection cannot happen in solids, as the atoms aren't able to move around.**

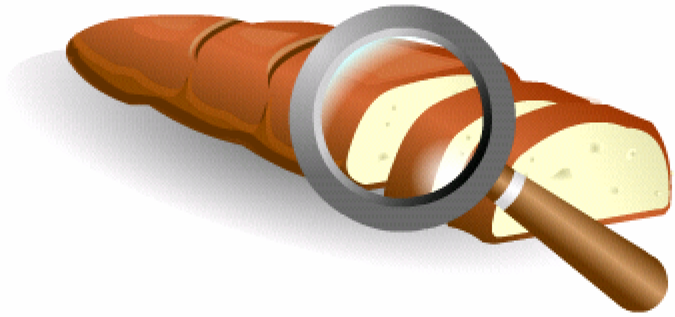


When a liquid or gas heats up, the particles move around more. This makes the particles spread out, so they have more room to move. This lowers the **density** of the substance. The hotter it gets, the lower the density goes. It is this lower density that makes the hotter substance rise. The cooler substance has a higher density, which makes it sink.

## Radiation

"How to toast bread!" When a piece of bread is put in a toaster the wires inside the toaster glow red hot on either side of the bread.

**How does the heat energy get to the bread?**



**Is it by conduction?**

No, the heat energy cannot conduct through the air to the bread because air is a very bad conductor.

**Is it by convection?**

No, hardly any of the heat energy could have travelled to the bread by convection, as the hot air particles would rise out of the toaster.

The heat energy must have reached the toast some other way. It travelled as radiated heat. This heat energy movement is sometimes called heat waves, but strictly speaking, it is **infrared radiation**.

Hot objects radiate heat to their colder surroundings. The weird thing is that the surface colour of an object makes a difference.

Black and dull surfaces emit (give out) and absorb radiation well.

White and shiny surfaces do not emit radiation well and reflect radiation instead of absorbing it.

**Which of these surfaces is best at emitting radiation?**

**Put them in order of best to worst:**

Marathon runners are wrapped in foil blankets at the end of the race. The shiny surface is a poor emitter of radiation and so prevents them losing too much precious body heat.

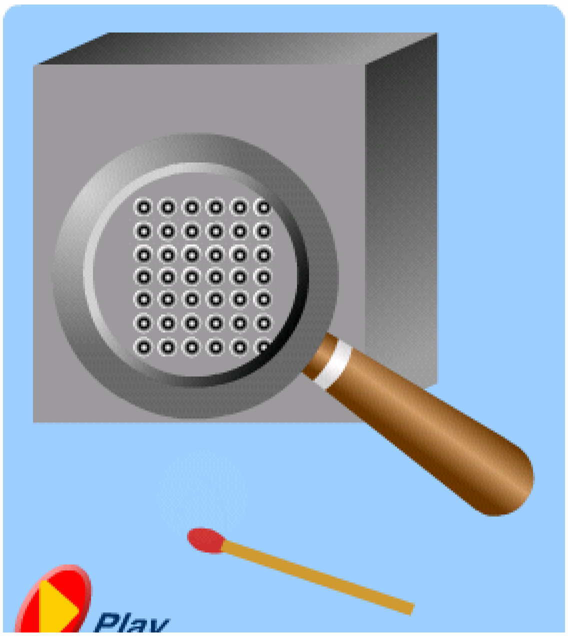
**So why do we paint radiators white so often?**

I guess people think it looks better.

**Which of these surfaces is best at absorbing radiation?**

**Put them in order of best to worst:**


Solar panels are always coloured black. They then absorb the maximum amount of the Sun's energy. This is very important considering the amount of sun we get in the UK. Wearing white in the summer should, in theory, be cooler than wearing black, as more of the incoming heat is reflected away.



# How Can We Stop Heat Moving?

## Insulation

If your house has a roof space, then it probably has insulation in it. That insulation is a thick layer of fibreglass. It's actually the air in between the fibreglass that makes it a good insulator.

**Air is a very bad conductor. Hardly any heat energy can conduct through the trapped air in the fibreglass.**

If air is so good why doesn't it work on its own?

Well, the air can **convect** the heat energy away from the house if it is able to move. If the air is trapped in small spaces between the fibres in the fibreglass it can't move so it doesn't convect the heat energy.

**Many insulators work because they contain trapped air.**

## Ways to save energy in the home

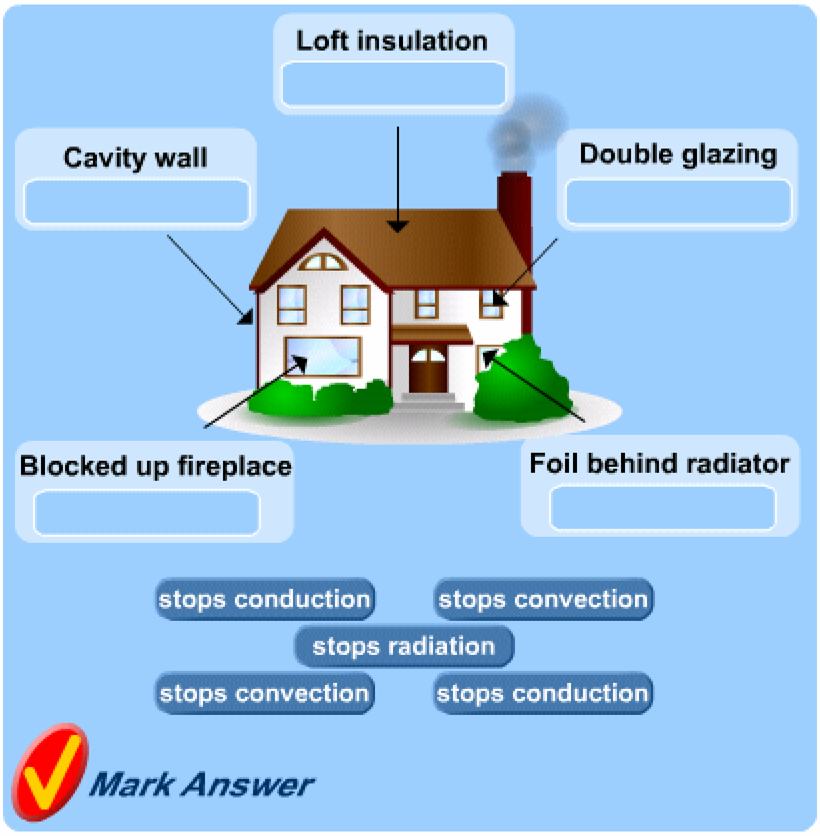
**There are two real reasons for reducing heat losses from a home:**

1. Saving energy means that less energy needs to be produced, so there will be less damage to the environment. (Think about the pollution from a coal-fired power station.)
2. Saving energy means using less energy so it costs less to heat the house. It can cost hundreds of pounds a year to heat a family house!

Obviously it also costs money to install (put in) insulators and other energy-saving devices. The **payback time** is how long it takes for the savings to cover the cost of installation.

Each method has to stop either conduction, convection, radiation, or any combination of them.

**See if you can identify how each method of insulation saves energy in the home, by dragging the coloured boxes into the correct place:**




**Of course you can do other things:** Use low energy light bulbs, turn down heating thermostats, and fit draught excluders, for example.

# Non-Renewable Energy Sources

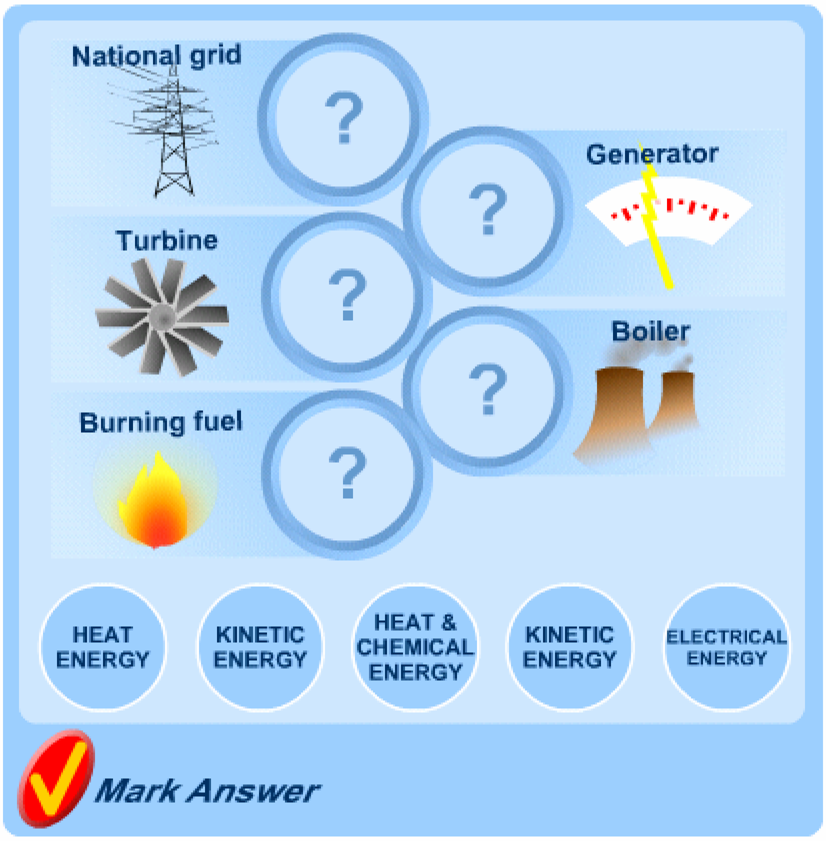
## Generating electricity in power stations

**All power stations use a similar process to produce electricity.**

1. Fuel is used to produce heat energy.
2. The heat energy heats water and turns it into steam.
3. The steam is pushed at high pressure along pipes to the turbines.
4. The steam makes the turbines spin, turning a generator which then produces electricity.

The electricity is then supplied to houses, factories and schools via the national grid.

**Drag the correct form of energy directly onto the actual source of the energy and mark you answer:**

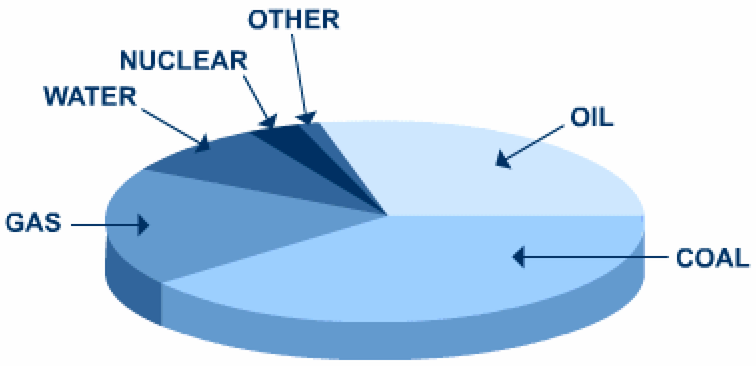



## Fossil fuels

# Fossil fuels

The fossil fuels are oil, gas and coal. They are **non-renewable** energy sources, which means when the existing supplies run out, they can't be replaced! We are very reliant on fossil fuels in the modern world.

**Do you remember all the aggro during the fuel crisis of September 2000 when there was a sudden shortage of petrol and diesel (both made from oil)?**




These fuels have many uses, but the main ones are for heating, transport and generating electricity. The USA uses more fuel per person than any other country and much of the developed world uses plenty. As developing countries become more industrial, they use more and more energy.

Fossil fuels are formed under the ground. Dead matter is squashed under extremely high pressure over millions of years. This is why we can't remake it when it runs out.

# Environmental impact of fossil fuels

When you burn any fossil fuel, gases escape into the air. The main two gases released are **carbon dioxide** and **sulphur dioxide.**

(**Note:** One reason why petrol tax is high in the UK is because the government was trying to discourage car use so that less pollution is released into the air.)

**Carbon dioxide** is the most common of several gases that contribute to the greenhouse effect. I think the effect is best experienced under a duvet! The heat that exists underneath can't easily get out, so you get hotter and hotter. For the Earth, the result is global warming. Sadly, it means more heat energy in the atmosphere, so the weather is more extreme (not just hotter). Worse still, is that the ice-caps melt raising the sea levels. Literally millions would be affected in countries like Bangladesh, even parts of England could go under the water.

**Sulphur dioxide** causes acid rain. The gas dissolves in rainwater to form an acid. The acid rain harms plants, animals and stonework. It is an international problem because acid rain clouds created in one country can be blown over to another country.

## Nuclear power

When your parents went to school, nuclear power stations were the great hope to solve all the world's energy problems. 1 kg of Uranium can produce the same amount of energy as 10,000 kg of coal. Since then, the negative side to nuclear power has changed many people's view. Accidents at power stations like Chernobyl showed us that although nuclear power has many advantages over the fossil fuels, it is also highly dangerous.

Uranium is the fuel used in many nuclear power stations. Uranium is not burnt like coal or gas. Instead nuclear fission takes place. Atoms of uranium are split up which releases large amounts of energy. Left uncontrolled this could cause an explosion as in nuclear weapons, but when controlled the energy can be used to heat water to produce steam, just like in other power stations.

Unfortunately, nuclear fission produces harmful radiation. Radioactive substances are produced that release alpha, beta and gamma radiation into the surroundings. This can be harmful to plant and animal life.

Accidents are rare, but can be serious. After the Chernobyl accident in the Ukraine, radioactive particles were carried in clouds across Europe contaminating land hundreds of miles away from the accident. 15 years later, there is still an area around the power station that people are not allowed into.

The waste from the reactors is also radioactive. It can be stored safely, but it stays radioactive for years. Unfortunately this waste has to be stored somewhere but nobody wants the nuclear waste buried near their town!

**So where are we going to keep putting it?**

# Alternative Energy Sources

Below is some general information about alternative energy sources, but there is a lot more on the web. Try the Centre for Alternative Technology or The Guardian Renewables page as a starting point if you are researching this area. For the exam, make sure that you know the advantages and disadvantages of each energy source.

Most of the alternative energy sources are renewable. This means there is either an endless supply of them so that they will not run out, or they can be easily replaced.

## The power of water

Nothing new here! Water wheels were used at the start of the industrial revolution. Now we can use water running down a hill or falling over a dam to turn a turbine. This is called **hydro-electric power (HEP).**

Some developing countries get all their energy from hydro-electricity schemes on large dams. The Aswan dam was the first and most famous, in Egypt on the Nile. The down side is that the large lakes made behind a dam can drastically change the countryside, sometimes covering small villages.

Big waves at sea also have a lot of energy - too much energy really, as no large-scale scheme has been designed to cope with it! Also, the tide has a lot of energy. If you block in the water at high tide and then let it out through a turbine as the tide falls, you can generate electricity. But as with the dams, this alters the natural water levels, so the local habitat is affected.

## Harnessing the weather

**Solar power** - The energy from the sun can be changed into electrical energy using solar panels. This is used in the UK even though it's not always sunny! Solar panels are often used alongside other energy sources, as it is not powerful enough to be used as the only source. Although the sun's energy is free the actual solar panels are very expensive to make which makes solar energy quite an expensive option.

This year, a company has started marketing roof tiles that are also solar cells, which can supplement your domestic electricity.

**Wind power** - Britain is a windy country! A lot of farmers make money by renting out land to build wind farms. This is a group of wind turbines that generate electricity from wind as slow as 5 miles per hour. It may only be a few years before over 10% of our electricity is wind generated. Look out too for the first wind turbines in back gardens. Unfortunately, some people don't like wind farms because they spoil the view or make a noise.

Wind power is a modern form of electricity production.

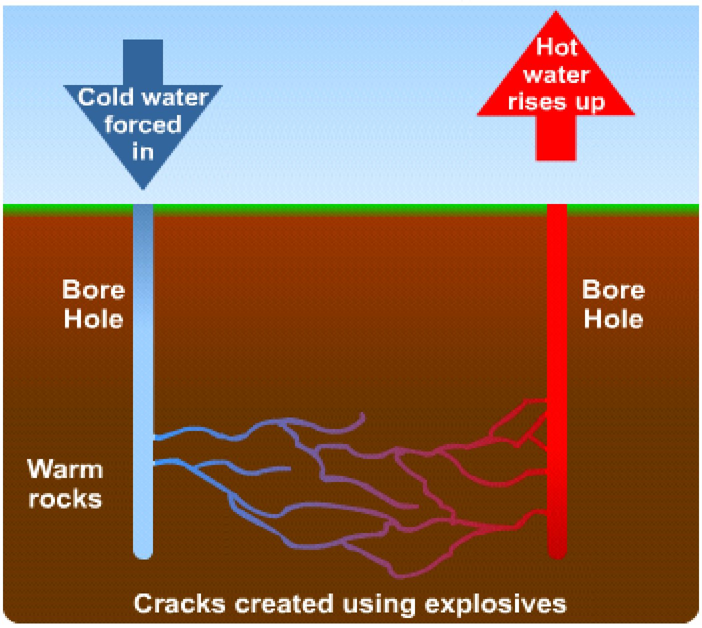
## Other alternatives

**Geothermal power** uses the natural heat in volcanic rock under the ground to generate electricity. This is popular in Iceland but not likely to happen in [illegible]

**Biomass** - when dead plants and animals rot the bacteria involved produce methane gas. This gas can be collected and burnt as a fuel. It is often called biogas. Although this makes good use of natural waste, unfortunately burning methane produces pollution like the fossil fuels.

**Burning waste** - Burning rubbish is not a way to avoid pollution, but it does preserve fossil fuels as well as avoid rubbish having to be put in landfill sites.

**Crops for fuel** - This is particularly popular in third world countries, as it is cheaper than buying fossil fuels. In Brazil, they grow a lot of Sugar Beet. It is processed into alcohol and used instead of petrol in cars.

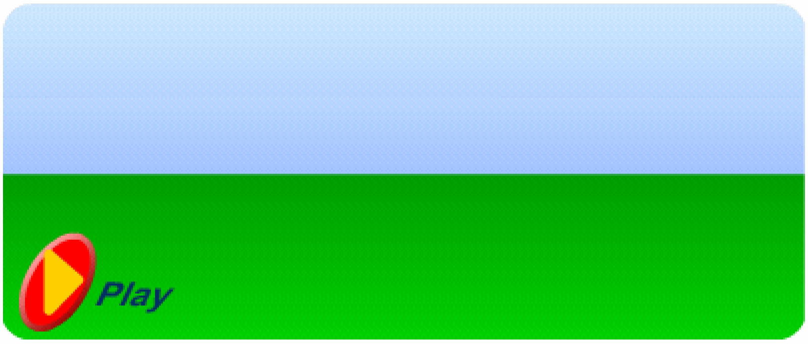


# Work And Energy

## Why do we have to do work?

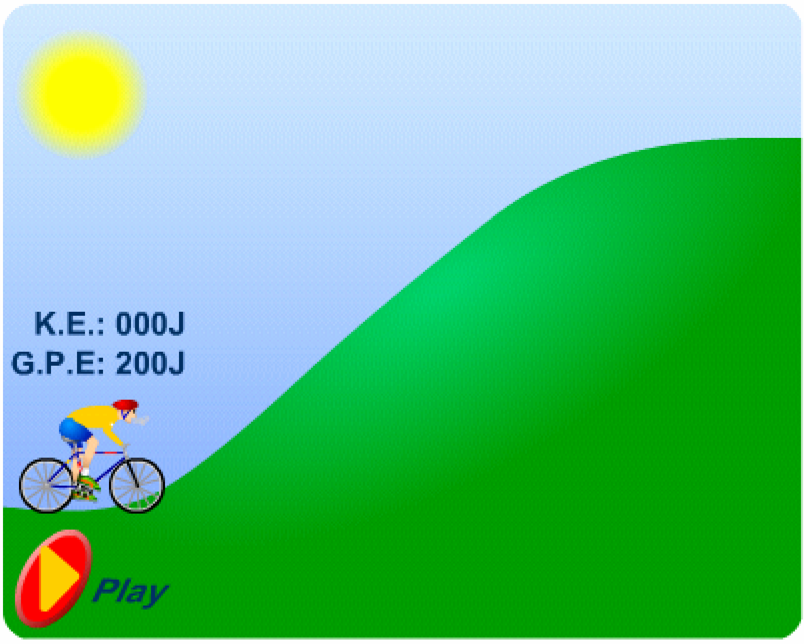
**Work is done whenever energy is changed from one form into another.**

If a football is kicked along the ground it has friction and air resistance trying to slow it down. The ball loses its kinetic energy as it slows down because it has to work against these forces. The kinetic energy is changed into heat energy.




If a cyclist travels up a hill, without pedalling, the kinetic energy the cyclist had at the bottom of the hill is changed into gravitational potential energy as he travels up the hill. The cyclist slows down as he loses kinetic energy.

The cyclist is doing work against the gravitational pull of the Earth trying to stop him going up hill.



# Calculating work done

**The amount of energy that has changed form is called the work done.**

A crane lifts up a car. The higher it lifts the car the more work it will do. The heavier the car is the more work the crane will do.

**So:**

The bigger the force the greater the work done.

The further the distance the greater the work done.

**The amount of energy or work done can be found using:**

**work done (or energy) = force x distance travelled**

Work done (or energy) is measured in joules, **J**.

Force is measured in newtons, **N**.

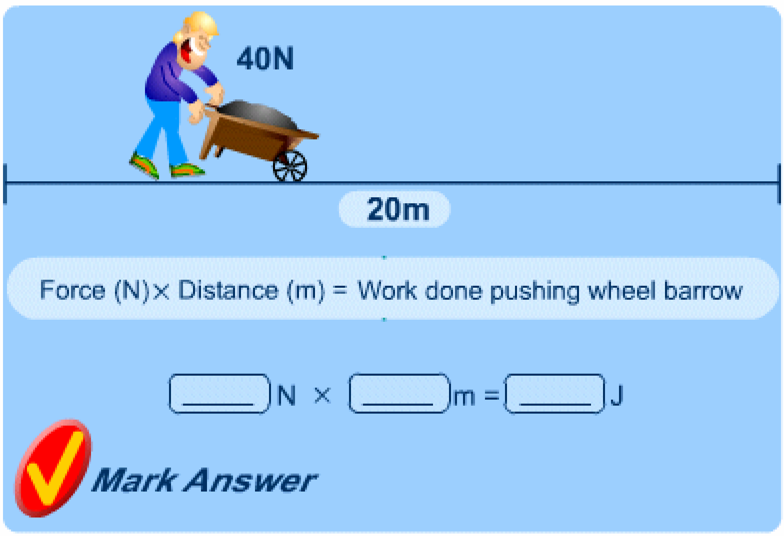
Distance is measured in metres, **m**. (Not cm!!)

**Note:** The force must be in the same direction as the distance travelled.

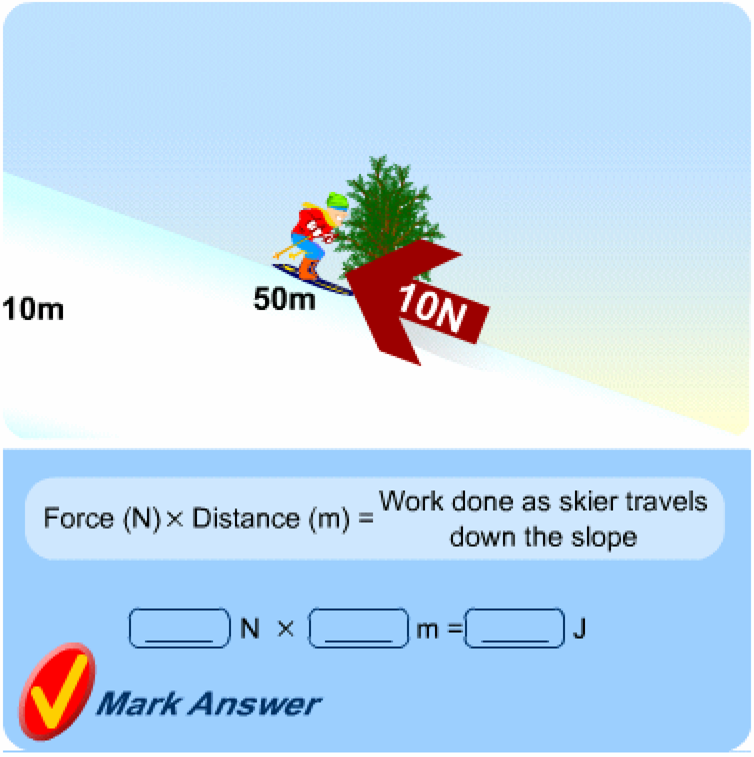
**Example 1:**

**Note:** The force must be in the same direction as the distance travelled.

**Example 1:**



**Example 2:**




**Note:** In example 2 many students would make the mistake of using the wrong distance. Remember the distance must be in the same direction as the force.

# Kinetic Energy

**Kinetic energy tells us how much movement energy something has.**

**Kinetic energy** doesn't just depend on how fast something is moving it also depends on mass.

If a car and a lorry are both travelling at the same speed the lorry will do much more damage if it hits something, than if the car does. The lorry has more kinetic energy even though they are both travelling at the same speed.

## Calculating kinetic energy – higher level only

**The amount of kinetic energy something has can be found using:**

**kinetic energy = ½ x mass x velocity$^2$**

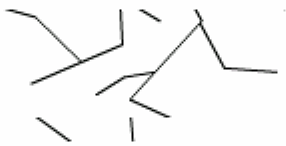
Kinetic energy is measured in joules, **J**.

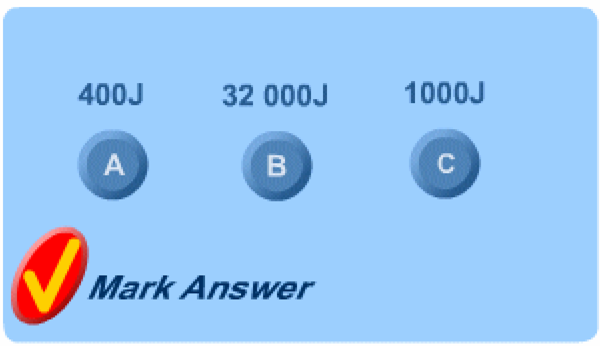
Mass is measured in kilograms, **kg**.

Velocity is measured in metres per second, **m/s**.

**Here's one to try!**

**A pig of mass 80 kg flies over the S-Cool offices at 5 m/s. Choose the correct value for its kinetic energy from the options below:**

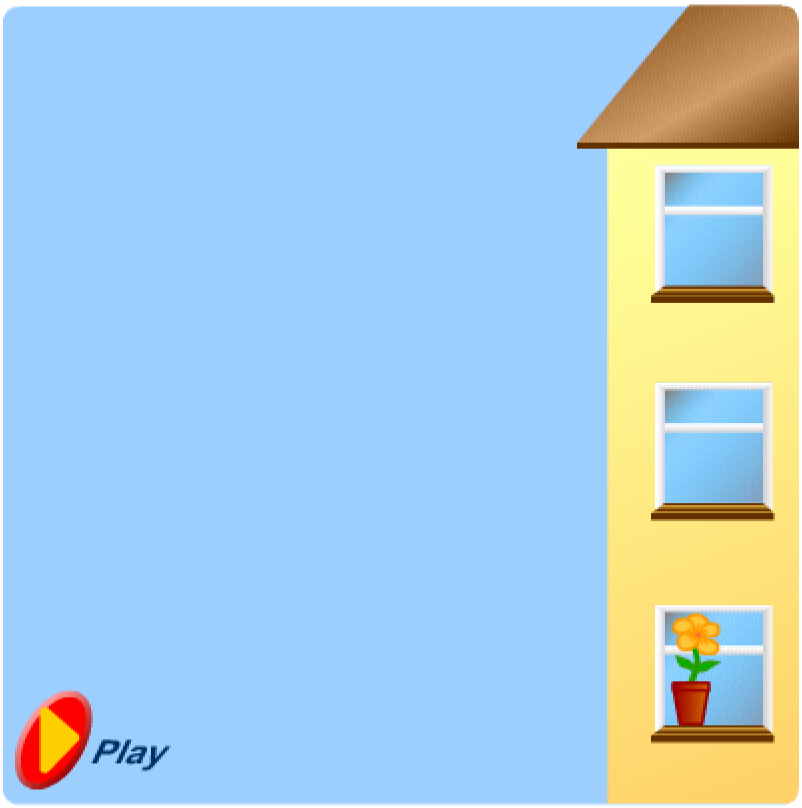




# Gravitational Potential Energy

**Gravitational potential energy (GPE) is a type of stored energy.**

If flower pots fall out of a tall building, one from the ground floor window and one from the fourth floor window. **Which plant would be more likely to survive after it has hit the ground?**



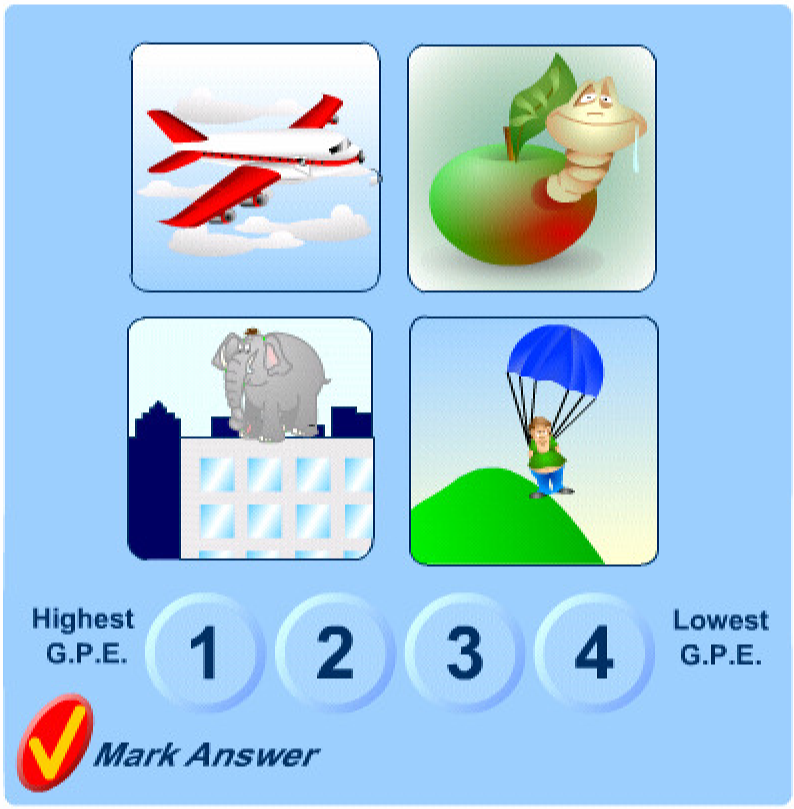

The higher up an object is the greater its gravitational potential energy. The larger the distance something falls through the greater the amount of GPE the object loses as it falls. As most of this GPE gets changed into kinetic energy, the higher up the object starts from the faster it will be falling when it hits the ground.

So a change in gravitational potential energy depends on the height an object moves through.

Lifting an apple up 1 metre is easier work than lifting an apple tree the same height. This is because a tree has more mass, so it needs to be given more gravitational **potential energy** to reach the same height.

So a change in gravitational potential energy also depends on the mass of the object that is changing height.

**Put the following pictures in order, starting with the object that you think will have the most GPE.**



# Calculating gravitational potential energy – higher level only

**The amount of gravitational potential energy can be found using:**

**Change in G.P.E.= mass x gravity x change in height**

Gravitational potential energy is measured in joules, **J**.

Gravity is measured in newtons per kilogram, **N/kg** (or metres per second squared $m/s^2$)

Height is measured in metres, **m**. (Not cm!!)

**Note:** The formula above is the same as:

**Work done (or energy) = Force x distance**

Where force is the weight of the object changing height. Weight is calculated using:

**weight = mass x gravity**

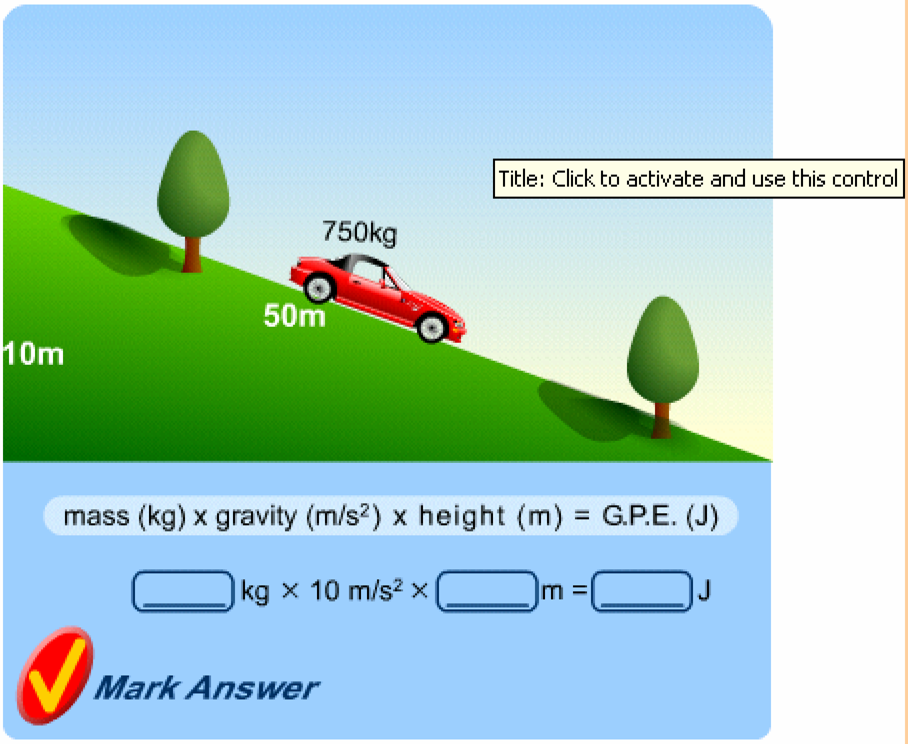
And the distance is the change in height.

**Here's one to try!**

In the example below, a car rolls down a frictionless slope.

How much gravitational potential energy does it lose by the time it reaches the bottom?

**Enter the correct values in the boxes below:**



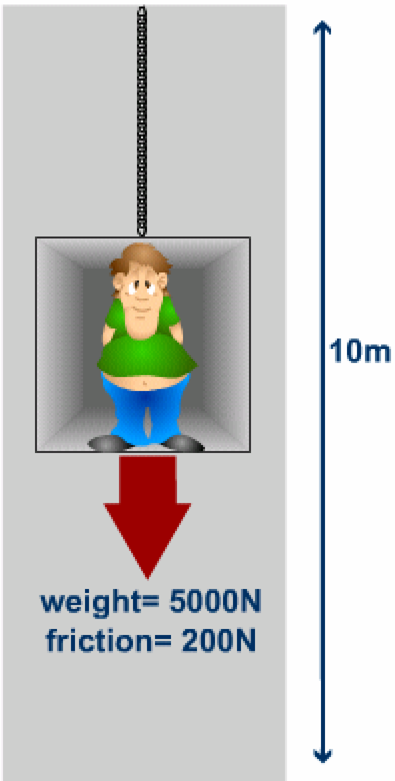

If your answer was incorrect, did you remember to use the right distance. Remember the force and distance must be in the same direction. Weight is downwards, so you must use the distance downwards, not the distance along the slope!

# Work Done By Unbalanced Forces

Unfortunately there are very few situations where there is only one force doing work. So before you can calculate the work done you need to find the resultant force that is acting.

Here is an example of the type of thing you may be asked:

**What amount of work must be done by the lift for it to reach the top?**




**Work done = force x distance**

**= 5200 N x 10 m**

**= 52 000 J or 52 kJ**

**Note:** Some of this energy is used to overcome friction, so the energy is lost as heat energy to the surroundings. The rest is stored in the lift as gravitational potential energy, as the lift is now higher up than it was before.

# Power And Efficiency

## How fast can you do work?

**Power tells us how fast work is done.**

In other words, it tells us how much energy is transferred per second.

## Calculating power

**Power can be calculated using:**

**power = energy transferred / time taken**

**or**

**power = work done / time taken**

Power is measured in watts, **W** or joules per second, **J/s**. **One watt is the same as one joule per second.**

Time is measured in seconds, **s**. (Not hours!!)

## Wasted energy

**So where does energy go?** When an object travels along, the friction or air resistance trying to slow it down changes the kinetic energy of the object into heat energy. This becomes wasted energy. It is lost to the surroundings and it is no longer useful to us. In fact most of the energy that is wasted is lost as heat energy to the surroundings.

As energy is often wasted when work is being done we need to know how efficient a process is. The more efficient a process is the less the amount of wasted energy. The efficiency of a machine is often given as a percentage. If a machine is 75 % efficient then 25 % of the energy put into it is wasted and only 75 % is changed into useful energy.

**For example,** a car that is 70 % efficient will turn 70 % of its energy into movement and 30 % into noise and heat.

## Calculating efficiency - Higher level

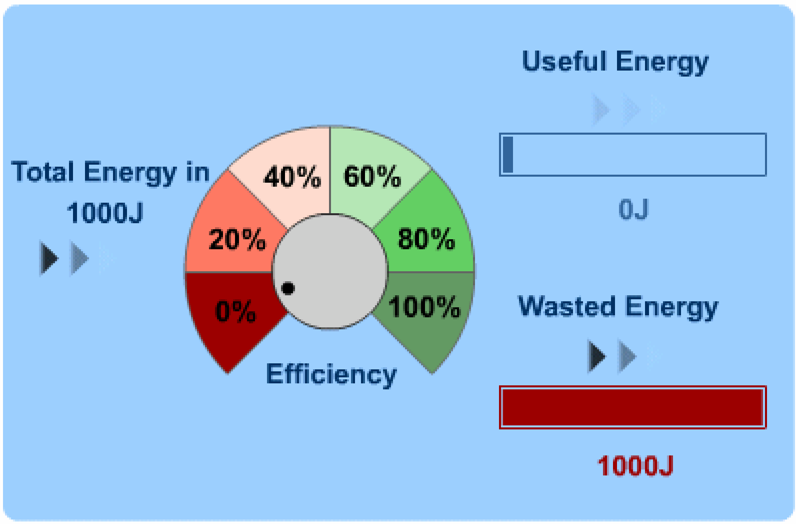
**There are two similar ways to calculate the efficiency of something:**

1. $\frac{\text{Power out}}{\text{Power in}} \times 100\% = \text{efficiency as a }\%$

2. $\frac{\text{Energy out}}{\text{Energy in}} \times 100\% = \text{efficiency as a }\%$

**In the diagram below, click the circle to change the efficiency of the motor:**

**In the diagram below, click the circle to change the efficiency of the motor:**



# Introduction

## Atomic structure

You need to know about the structure of an atom and the particles that make it up.

All atoms are made up of the same **3 basic particles:**

- **protons**
- **electrons**
- **neutrons**.

The only difference between one atom and the next is the number of these particles in the atom. That is enough to make things as different as gold and oxygen.

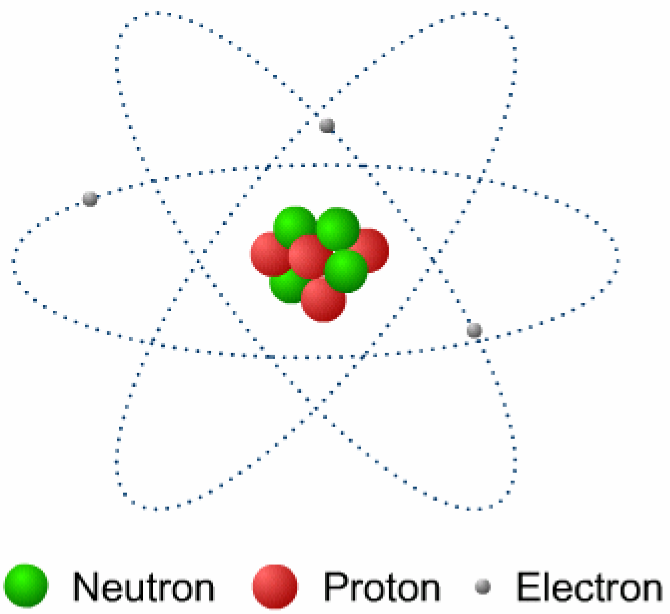
**Neutrons** and **protons** are heavy in comparison to electrons. In fact, a neutron or a proton weighs about 2000 times as much as an electron!

The other thing to remember is that **protons** have a positive charge, **electrons** have a negative charge and **neutrons** have no charge at all.

## How are these particles arranged?

An atom is not a solid thing. In fact, quite the opposite. Atoms are nearly completely empty.

Protons and neutrons are tightly clumped together in the middle, in the nucleus, while electrons spin around them. **This diagram gives you an idea of what they look like, but it is not to scale:**



To give you an idea of the proportions, imagine a full size football stadium. The nucleus would be equivalent to the size of an ant in the middle, with the electrons whizzing around the outskirts.

The central part of the atom is called the **nucleus**. That's where you find all the protons and **neutrons.**

As we said above, protons and neutrons are **heavy** compared to electrons, so you can see that all the mass is concentrated in the middle of the atom. Also, as all the protons are in the nucleus of the atom, the nucleus has a positive charge.

The **electrons** (negatively charged) orbit around the outside of the atom.

**So what have we learnt so far?**

An atom is made up of mostly empty space.

**P**rotons have a **p**ositive charge and a lot of mass.

**Neut**rons are **neut**ral but are as heavy as protons.

Electrons are negative and are only about $\frac{1}{2000}$ of the mass of the others.

To make sure you understand, here is a quick test. See if you can identify the correct sub-atomic particle in the table below. **Then mark your answer:**

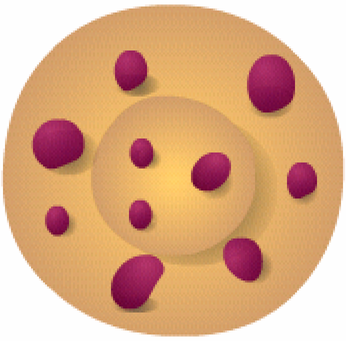
| Relative Mass | Charge | Location in atom | Answer |
|---|---|---|---|
| 1 | Positive | Within nucleus | |
| 1 | no charge | Within nucleus | |
| approx 1/2000 | Negative | Outside nucleus | |

Neutron Electron Proton

Mark Answer

# Plum pudding model

Scientists used to think that atoms were solid. They thought that they were a bit like plum puddings – a light sponge pudding with bits of plum mixed into it.



**This was a good model because:**

1. Atoms occupied the correct amount of space (it was the space filled by the sponge).
2. The mass of the atom was about right (because although the sponge filled the whole of the atom, it was very low density).
3. The charge on the positive sponge was balanced by the negative plums so that overall the atom was neutral.

# The alpha particle scattering experiment

Then a man called Ernest Rutherford performed a now famous experiment. He fired an alpha particle ($\alpha$-particle) at a thin sheet of gold foil.

$\alpha$-particles are fast moving, small, dense, positively charged particles, and all predictions said that they should smash through the soft spongy 'plum pudding' atoms almost unaffected.

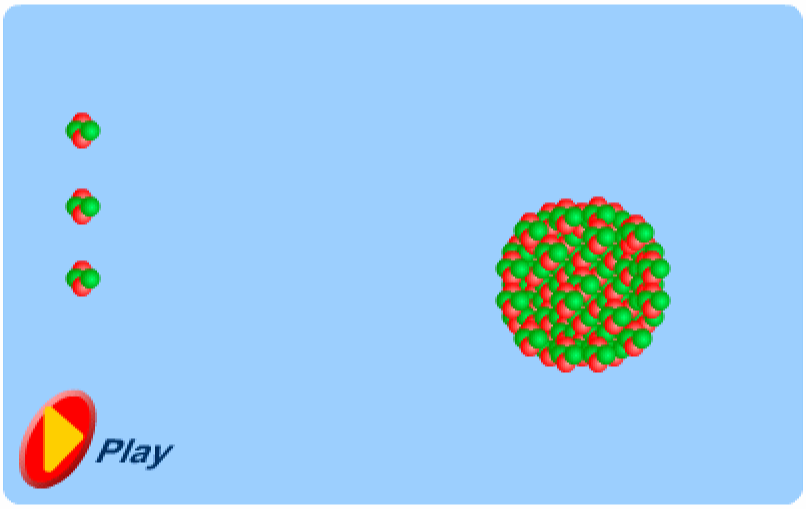
**And most of them did! So far so good.**

But Rutherford noticed that some $\alpha$-particles were deflected through big angles. Some even bounced straight back.

That seemed impossible – there shouldn't be anything dense enough in the 'plum pudding' atom to make the $\alpha$-particle bounce back.

**So this model was scientifically proven to be incorrect**

**The diagram below shows what happens to some of the $\alpha$-particles as they approach a nucleus.**




These observations allowed Rutherford to work out what was inside the atom.

**The Table below shows each of the observations Rutherford made to determine the structure of the atom:**

| Observation | Deduction |
|---|---|
| Alpha particle bounces back | Shows there must be small concentrated masses in the atom that were dense enough to make the alpha particles rebound. This is the evidence for the nucleus. |
| Alpha particle changing direction | The alpha particle is deflected by the gold nucleus as they both have a positive charge. This showed that the nucleus of an atom is positively charged. |
| Alpha partcles pass straight through | Many alpha particles passed straight through the gold showing that most of the atom is made up of space. |

The model of the atom that Rutherford came up with is called the **'nuclear model'**. It is the model of the atom that we still use today.

# Atomic equations and Isotopes

## Atomic notation and equations

To help us to describe atoms and nuclei, we use numbers and letters. **Here is an example:**

$$^{4}_{2}He$$

The atom in the diagram is described by the numbers and letters shown next to it. All atoms of a certain element will have the same number of protons in the nucleus.

The top number is called the **mass number** or the **nucleon number**. It tells you how many particles are in the nucleus, i.e. how many protons and neutrons.

The bottom number is called the **proton number** or the **atomic number**. It tells you how many protons there are in the nucleus.

The letters give you a clue as to the name of the atom. This is an atom of **'helium', He.**

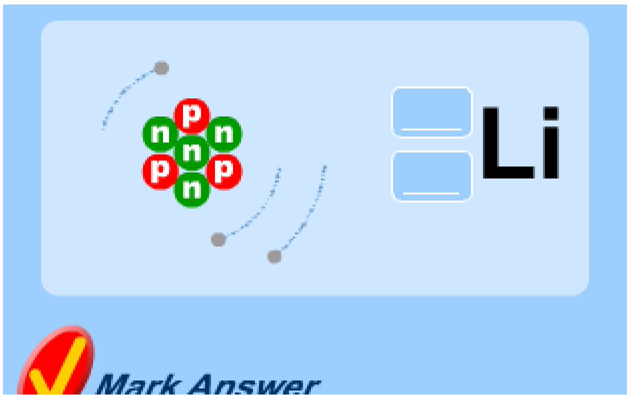
The number of **electrons** in an atom is the same as the number of **protons**. That makes the atom **neutral** overall (neither negative nor positive).

If the numbers are not equal, the atom becomes a charged particle. We call these charged particles ions.

Now it's your turn to have a go. Using the diagrams, you should be able to tell what the missing numbers are.

**Try typing them in the correct place and then check your answer.**

**Example 1: A Lithium Atom**



You can also write equations for nuclear reactions. In these equations you will need to make sure that:

1) The total number of protons is the same before and after the reaction.
2) The total number of nucleons is the same before and after the reaction.

In this reaction, carbon and helium is combined to form oxygen.

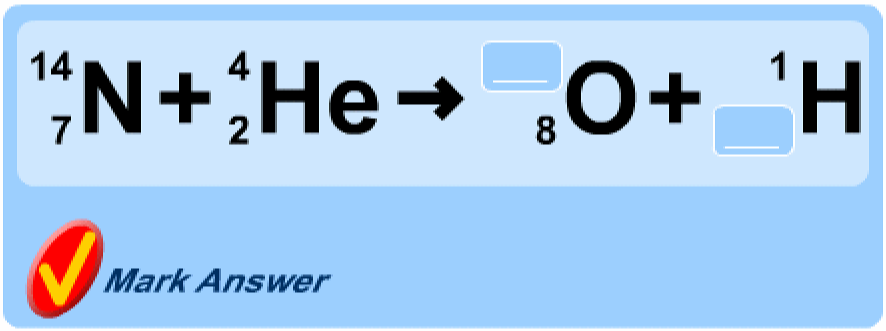
$$^{12}_{6}C + ^{4}_{2}He \rightarrow ^{16}_{8}O$$

Notice that if you add up the numbers at the top of each atom (the nucleon numbers) on the left hand side you get the same as the total for the numbers on the right hand side.

The same is true for the proton numbers.

Have a go at this one.

**Type the answer in the correct place and then mark your answer:**




These reactions will not happen in real life, but they should give you an idea of how the system works. We will come back to this idea again.

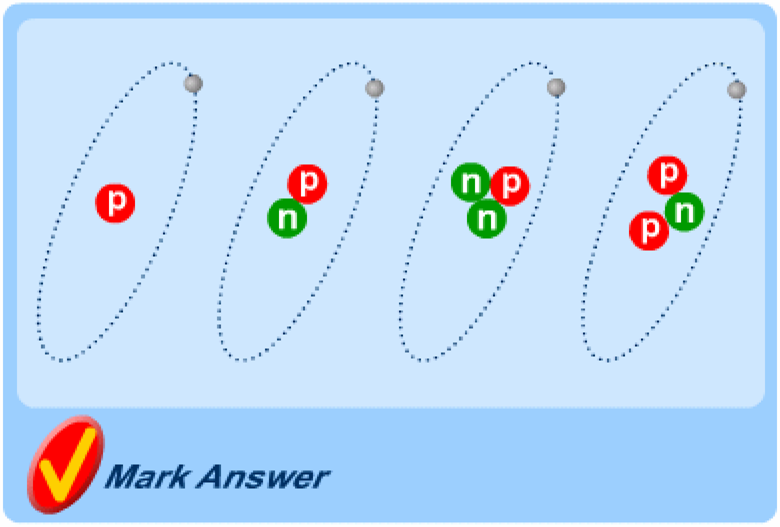
# Isotopes

The **number of protons** is the thing that decides how an atom is going to behave and therefore what element the atom belongs to. If you change the number of protons in an atom, you change the type of atom (it becomes an atom of another element.)

However, **you can change the number of neutrons** in an atom without changing the type of atom.

For example, hydrogen is an atom that contains only 1 proton. Atoms with more or less neutrons in them are called **isotopes**. The picture below shows three **isotopes of hydrogen**. So all the atoms below are hydrogen, except one. Which one?

**Click on the atom that is not an isotope of hydrogen and find out if you are correct:**




Some isotopes are radioactive. **Radioisotopes** are radioactive isotopes of an element.

Previous QuickLearn
Next QuickLearn

# Radiation

## What is radioactivity?

Some isotopes of atoms can be unstable.

**They may have:**

**a)** Too much energy

**or**

**b)** The wrong number of particles in the nucleus.

We call these **radioisotopes.**

To make themselves more stable, they throw out particles and/or energy from the nucleus. We call this process '**radioactive decay**'. The atom is also said to **disintegrate**.

The atom left behind (the daughter) is different from the original atom (the parent). It is an atom of a new element. For example uranium breaks down to radon which in turn breaks down into other elements.

The particles and energy given out are what we call **'radiation'** or **'radioactive emissions'**.

## Background radiation

There is a certain amount of radiation around us (and even inside us) all the time. There always has been – since the beginning of the Earth. It is called **Background radiation.**

Background radiation comes from a huge number of sources.

**The list below gives some of these sources:**

**See if you can number the sources listed here by the amount of background radiation they produce (1 = highest level of radiation):**

| Source of background radiation | Level of radiation |
|---|---|
| Nuclear waste | |
| Cosmic radiation | |
| Medical uses of radiation | |
| Rock & soil | |
| Radon gas | |
| Fall out from nuclear tests | |
| Inside the body | |

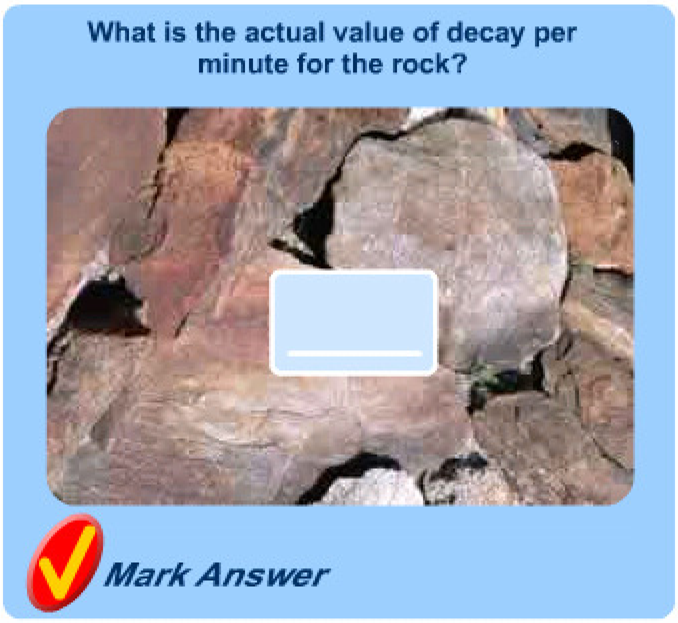
*Mark Answer*

In most areas, Background radiation is safe. It is at such a low level that it doesn't harm you. You need to be exposed to many times the normal background level before you notice any symptoms.

However, some areas of the country have a higher level of background radiation than others because the rocks near the surface contain more radioactive isotopes (for example, Cornwall).

**Look at this example:**

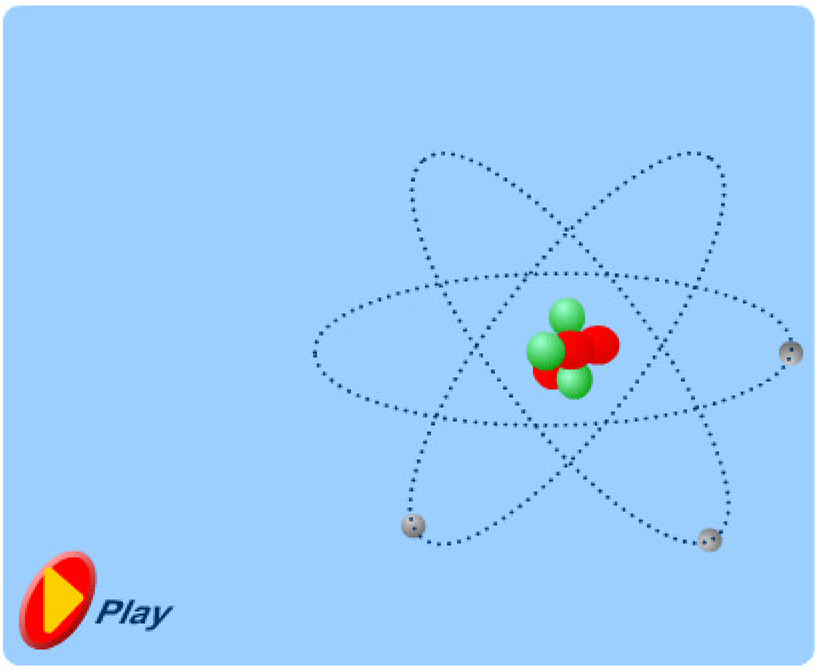
You use a radiation detector to record that a sample of rock produces **100 decays per minute.** You then remove the rock and record the background radiation in the room. It is **7 decays per minute.**




## Ionisation

The radiation emitted by radioactive substances has a huge amount of energy, which is why it is so dangerous. The energetic radiation causes **ionisation.**

When radiation hits a neutral atom, some of the energy from the radiation is passed to the atom. This energy can cause an electron from the atom to escape, leaving the atom with a positive charge. This positively charged atom is called an **ion**, so the process is called ionisation.



As the radiation travels along it ionises atoms that are close enough. The more atoms the radiation ionises the more energy the radiation gives away, until eventually there is no energy left. The radiation is then said to have been **absorbed**.

## Detecting radiation

You will see in the following quick learn that there is more than one type of radiation, but each sort causes ionisation. This is how we are able to detect radiation.

It is hard to detect the actual particles or waves emitted by radioactive substances, but it is easy to detect the positive and negative ions produced by the ionisation they cause. A device called a **Geiger-Muller** tube collects the charged ions and can measure the amount of ionisation that is taking place in a certain time. The greater the amount of ionisation the more radiation there must be.

**Click the 'show me' button to see the effect that different substances have on the Geiger Muller tube.**

***Show Me***

## Why is radiation harmful?

It is this process of ionisation that makes radioactive substances so dangerous. Living cells can be fatally damaged if molecules in the cell are ionised. This damage can kill cells or cause cancers to form. The greater the dose of radiation the more likely it is that cancer will occur.

# Types of Radiation

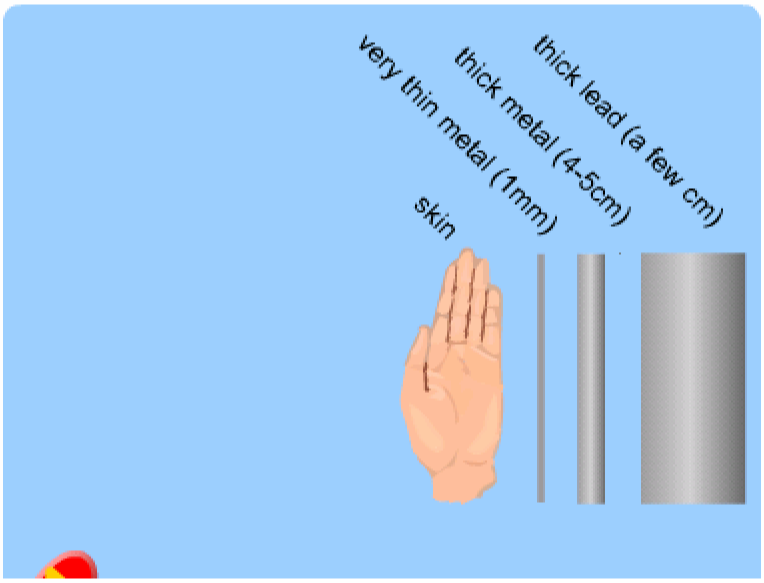
## Alpha, beta and gamma

There are three main types of radiation that can be emitted by radioactive particles. They are called **alpha**, , **beta**, , and **gamma**, . All three types of radiation come from the nucleus of the atom. All three types of radiation will cause ionisation, but they behave slightly differently, because of the way they are made up.

| Type of radiation | Greek symbol | What is it? | Charge |
|---|---|---|---|
| **Alpha** | α | **Particle** - A highly energetic **helium nucleus**, containing 2 protons and 2 neutrons. | Positive<br><br>2+ |
| **Beta** | β | **Particle** - A highly energetic electron, released from inside a nucleus. It has negligible mass. When a beta particle is produced a neutron in the nucleus divides into a proton and an electron. It is the electron that is rejected from the nucleus at high speed that is the beta particle. | Negative<br><br>1- |
| **Gamma** | γ | **Wave** - from the high frequency end of the electromagnetic spectrum. Waves have no mass. | No charge |

## Absorption of Alpha, Beta and Gamma

**The diagram below shows the penetration of alpha, beta and gamma rays.**



**The Table below explains why different types of radiation are absorbed by different things:**

| | |
|---|---|
| **Beta** | These are small particles with a negative charge. They can ionise fairly easily so can only travel through thin materials before they are absorbed. |
| **Gamma** | This is a wave that carries a huge amount of energy, but waves are not as good at ionising atoms as particles are. It is therefore really difficult to absorb them and they can even travel through thin lead and thick concrete. |
| **Alpha** | These are large particles with a positive charge. They can ionise atoms really easily so quickly lose their energy by ionising nearby atoms. This means they can be absorbed by just a few centimetres of air, a sheet of paper or by skin. |

## Dangers of handling radioactive substances

Each type of radiation that can be emitted can be absorbed by different materials and ionises different amounts. They are equally dangerous but for different reasons.

**Alpha particles:**

Although alpha particles cannot penetrate the skin, if it gets into the body it can ionise many atoms in a short distance. This makes it potentially extremely dangerous. A radioactive substance that emits just alpha particles can therefore be handled with rubber gloves, but it must not be inhaled, eaten, or allowed near open cuts or the eyes.

**Beta particles:**

Beta particles are much more penetrating and can travel easily through skin. Sources that emit beta particles must be held with long handled tongs and pointed away from the body. Inside of the body beta particles do not ionise as much as alpha particles but it is much harder to prevent them entering the body.

**Gamma waves:**

These waves are very penetrating and it is almost impossible to absorb them completely. Sources of gamma waves must also be held with long handled tongs and pointed away from the body. Lead lined clothing can reduce the amount of waves reaching the body. Gamma waves are the least ionising of the three types of radiation but it is extremely difficult to prevent them entering the body.

## Decay equations

When atoms disintegrate by radioactive decay, new daughter atoms are produced. We can work out which elements will be produced using decay equations. These are like the equations you may have used for chemical reactions. Each type of radiation has a chemical symbol that is used in the equation.

**Note:** the equations must always balance, so there are the same number of protons and neutrons on each side of the equation.

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

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

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

These equations are not likely to happen in real life, as usually a combination of alpha, beta and gamma are released rather than just one.

**Here's an example for you to try:**

A uranium atom decays releasing an alpha particle and a beta particle, what will the final daughter atom be?

**Lets do this in two steps:**

$$^{235}_{92}U \longrightarrow {}^{4}_{2}\alpha + {}^{\square}_{\square}?$$

Mark Answer

# Half-Life

## What is half-life?

**Radioactive substances** will give out radiation all the time, regardless of what happens to them physically or chemically. As they decay the atoms change to daughter atoms, until eventually there won't be any of the original atoms left.

Different substances decay at different rates and so will last for different lengths of time. We use the **half-life** of a substance to tell us which substances decay the quickest.

**Half-life – is the time it takes for half of the radioactive particles to decay.**

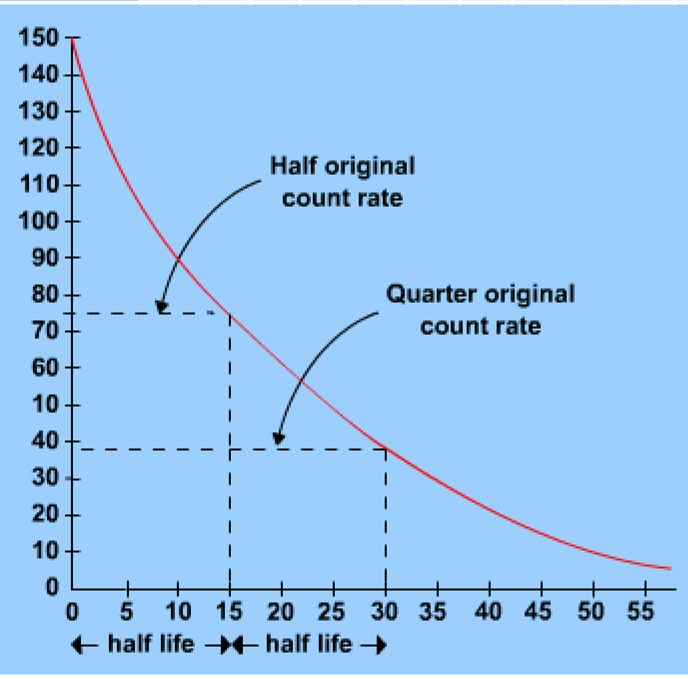
It is also the time it takes for the count-rate of a substance to reduce to half of the original value.

We cannot predict exactly which atom will decay at a certain time but we can estimate, using the half-life, how many will decay over a period of time.

The half-life of a substance can be found by measuring the count-rate of the substance with a Geiger-Muller tube over a period of time. By plotting a graph of count-rate against time the half-life can be seen on the graph.

**Here's an example:**

| Time/min. | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Count rate/min. | 150 | 118 | 92 | 75 | 63 | 52 | 38 | 35 | 26 | 19 | 17 |



This would also work if you plotted the number of parent atoms against time.

The longer the half-life of a substance the slower the substance will decay and the less radiation it will emit in a certain length of time.

The following radioactive substances contain 1000 unstable atoms. Below is a small test for you to try.

**Click on the up and down buttons get to the number of unstable atoms remaining after the length of time shown.**

| Half life | Length of time | No. of unstable atoms remaining (initial count 1000) |
|---|---|---|
| 20 years | 60 years | 1000 |
| 5 minutes | 5 minutes | 1000 |
| 6 months | 1 year | 1000 |
| 30 seconds | 1.5 minutes | 1000 |

Mark Answer

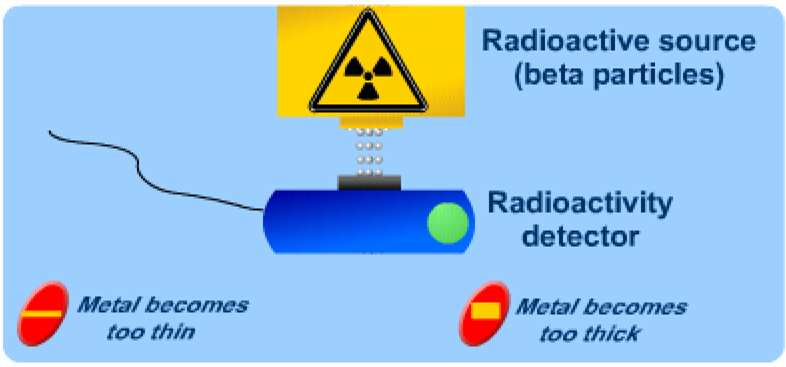
# Using radioactivity

Different radioactive substances can be used for different purposes. The type of radiation they emit and the half-life are the two things that help us decide what jobs a substance will be best for. Here are the main uses you will be expected to know about:

**1. Uses in medicine to kill cancer** – radiation damages or kills cells, which can cause cancer, but it can also be used to kill cancerous cells inside the body. Sources of radiation that are put in the body need to have a high count-rate and a short half life so that they are effective, but only stay in the body for a short period of time. If the radiation source is outside of the body it must be able to penetrate to the required depth in the body. (Alpha radiation can't travel through the skin remember!)

**2. Uses in industry** – one of the main uses for radioactivity in industry is to detect the thickness of materials. The thicker a material is the less the amount of radiation that will be able to penetrate it.

**Click on the buttons to change the thickness of the metal:**




**3.** Alpha particles would not be able to go through metal at all, gamma waves would go straight through regardless of the thickness. Beta particles should be used, as any change in thickness would change the amount of particles that could go through the metal.

**They can even use this idea to detect when toothpaste tubes are full of toothpaste!**

**4. Photographic radiation detectors** – these make use of the fact that radiation can change the colour of photographic film. The more radiation that is absorbed by the film the darker the colour it will go when it is developed. This is useful for people working with radiation, they wear radiation badges to show them how much radiation they are being exposed to.

**5. Dating materials** – The older a radioactive substance is the less radiation it will release. This can be used to find out how old things are. The half-life of the radioactive substance can be used to find the age of an object containing that substance.

**There are three main examples of this:**

**i) Carbon dating** – many natural substances contain two isotopes of Carbon. Carbon-12 is stable and doesn't disintegrate. Carbon-14 is radioactive. Over time Carbon-14 will slowly decay. As the half-life is very long for Carbon-14, objects that are thousands of years old can be compared to new substances and the change in the amount of Carbon-14 can date the object.

**ii)Uranium decays** by a series of disintegrations that eventually produces a stable isotope of lead. Types of rock (igneous) contain this type of uranium so can be dated, by comparing the amount of uranium and lead in the rock sample.

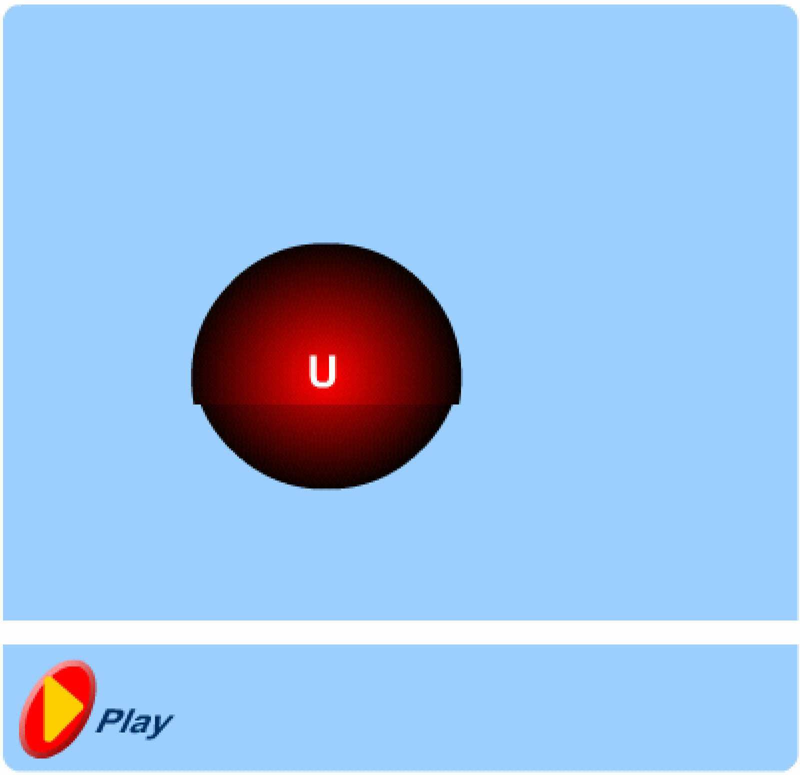
**iii) Igneous rocks** also contain potassium-40, which decays to a stable form of Argon. Argon is a gas but if it can't escape from the rock then the amount of trapped argon can be used to date the rock.

# Nuclear Power

## Nuclear fission

Nuclear power produces energy that is converted into electrical energy in nuclear power stations. **Nuclear fuel does not burn**. Instead a process called **nuclear fission** takes place.

During nuclear fission a neutron is fired at a Uranium atom. The neutron is absorbed, which makes the atom extremely unstable so it splits into two smaller atoms, releasing more neutrons and a huge amount of energy at the same time.




The neutrons that are released can go on to collide with other uranium atoms causing more fission and more neutrons to be released. This is called a **chain reaction**.

**The new atoms that are formed are radioactive.**

The amount of energy released during nuclear fission is much larger than the energy released when substances react chemically. For instance, 1 kg of uranium undergoing fission can release the same energy as 10 000kg of coal burning!

Uranium is not the only element that can be used in nuclear power. Plutonium is an alternative fuel.

**Note:** Don't confuse this with nuclear fusion, which is what happens in stars. Two hydrogen atoms are pushed together to fuse and make a helium atom. This also releases massive amounts of energy!

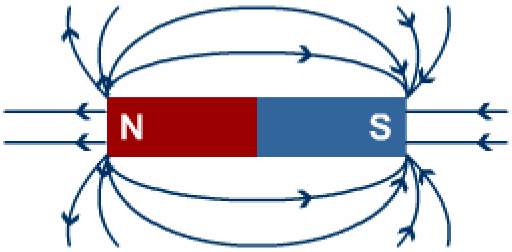
# Magnetism

**Magnetism** is an effect that we cannot see, hear or touch. Magnetic fields can be detected when they produce forces. For instance, if you put two magnets close together, they will either push apart or pull together.

**There are some simple facts about magnetism that you should know…**

## Magnetic fields

A magnet has a magnetic field around it. This field is strongest at its poles, which are at the ends of the magnet. A magnet has two poles, a North-seeking pole and a South-seeking pole. These names are often shortened to North pole and South pole.

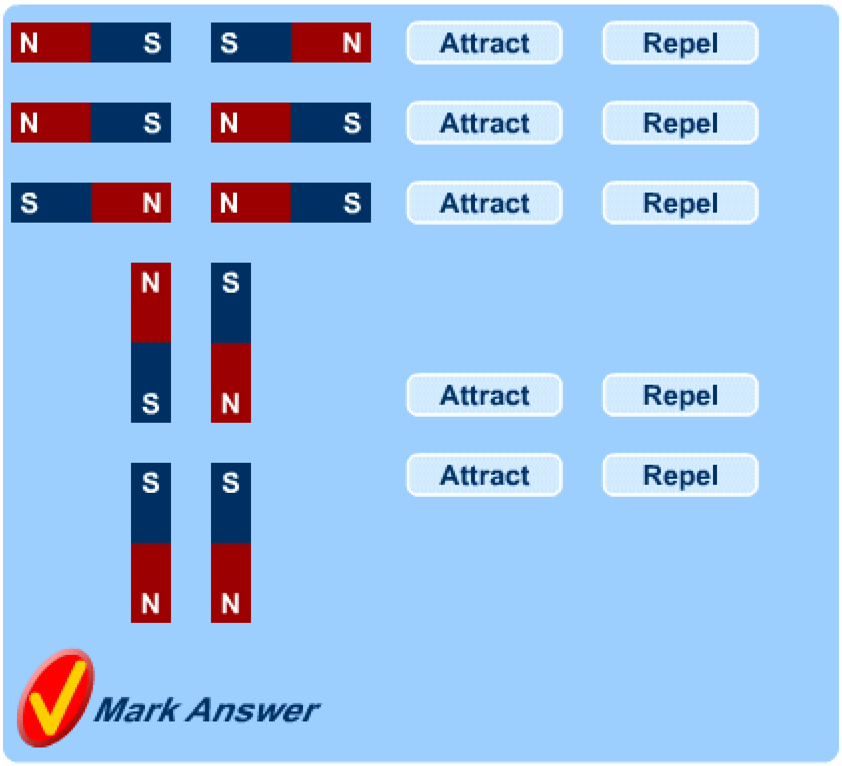



The field around a magnet can be represented on a diagram by lines with arrows on. These are called **field lines.** The closer together the lines are, the stronger the field. **The arrows always point from the North pole to the South pole.**

- Opposite poles will attract.

- Similar poles will repel.

**Use this information to predict whether the following magnets will attract or repel each other:**




# Magnetic materials and magnets

There are only a few natural elements that are magnetic. The main ones are iron, cobalt and nickel. Many other magnetic materials can be made, by mixing these elements with other substances. A good example is steel, which is a mixture of iron and carbon. Even some plastics are magnetic because they have magnetic substance mixed in them.

Only magnetic materials can be attracted to a magnet, or made into a magnet. Most magnets are made from iron and steel.

**Did you know that oxygen is actually magnetic when it is frozen?**

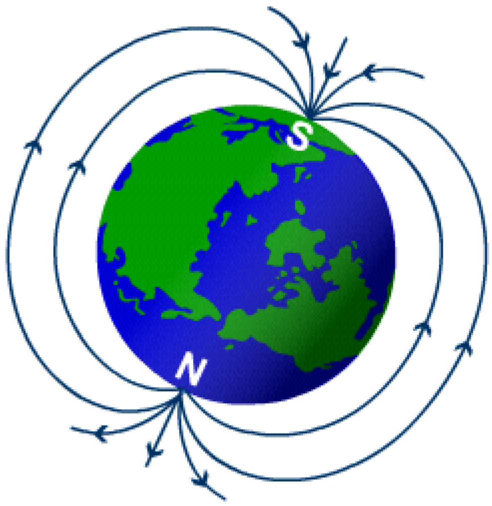
**So, what is the difference between a magnet and a piece of magnetic material?**

The easiest way to tell them apart is that a magnet can repel and attract another magnet. Whereas, a piece of magnetic material can only attract a magnet!

Magnetic materials do **not** have fields around them, but they are affected by near by magnetic fields.

## The Earth's magnetism

The earth has its own magnetic field around it. The iron core inside of the earth causes this field. Explorers have been using the Earth's magnetic field to find their way around for centuries. Magnets in compasses spin round until their North-seeking pole points to the North pole on the Earth.

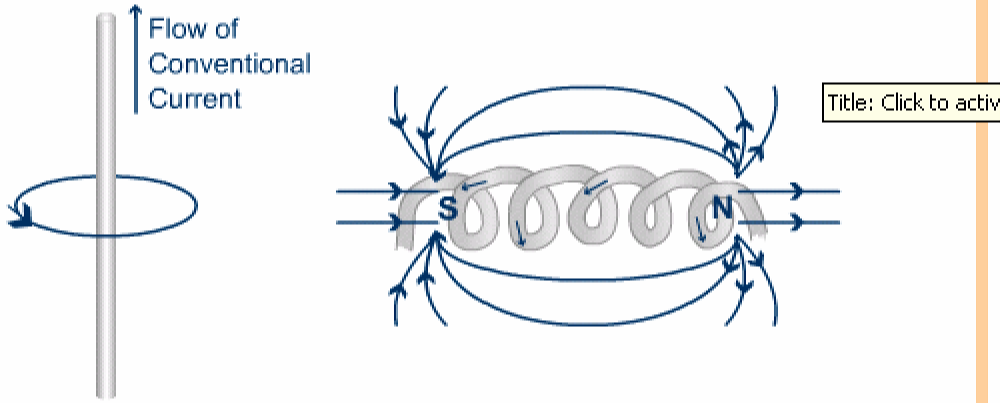


# Electromagnetism

## Currents and magnetic fields

All currents have a magnetic field around them. All the cables connecting electrical appliances to the mains in your home will have magnetic fields around them, and so do the large electricity power lines you can see on pylons outside.

A straight wire has a circular magnetic field around it. A coil of wire has a magnetic field around it, that is the same shape as a bar magnet.




If the conventional current flows the other way, the magnetic field will be in the opposite direction. As you move further away from the wire, the magnetic field gets weaker, which is why the lines are drawn further apart.

These types of magnets are called **electromagnets.** They are **temporary magnets** as they can be turned on and off with the current. Normal bar magnets are **permanent magnets** because it is very difficult for them to lose their magnetism.

**Electromagnets are far more useful than permanent magnets because:**

**1.** They can be switched on and off.

**2.** The strength of the magnetic field can be changed, by altering the current.

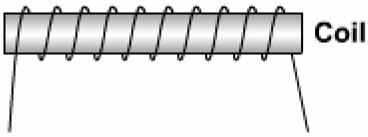
**3.** They can easily be made into a variety of shapes and are less expensive to make.

**The magnetic field around a coil electromagnet can be increased by:**

**1.** Increasing the current in the wire.

**2.** Putting more loops on the coil

**3.** Placing an iron or steel core inside of the coil.




Iron and steel behave slightly differently as cores, because iron is **magnetically soft** and steel is **magnetically hard.**

| Magnetically soft, for example, iron: | Magnetically hard, for example, steel: |
|---|---|
| - Easy to magnetise.<br><br>- Loses its magnetism quickly when the current is switched off. | - Harder to magnetise.<br><br>- Stays magnetic after the current is switched off. |

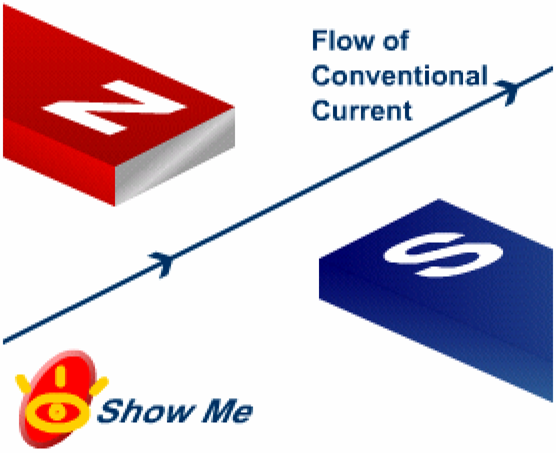
Most electromagnetic devices use iron as the core, because they want the magnetism to change quickly.

## The motor effect

When two magnets are close together, they affect each other and produce a force. The same happens when any two magnetic fields are close together.

If a wire carrying a current is placed in a magnetic field a force is produced. This is called the **motor effect.**

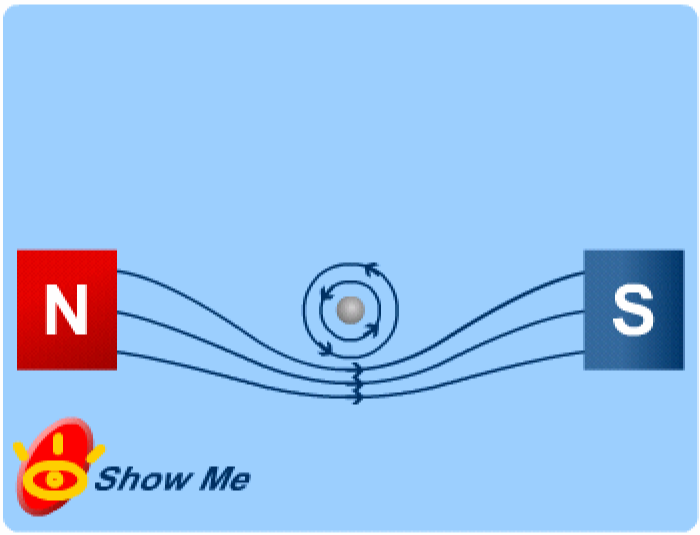
The direction of the force will depend on the direction of the magnetic field and the direction of the current in the field.



**Note:** The current, magnetic field and force will always be at right angles to each other, so the wire will not move towards the poles.

**So why does this happen?**

The magnetic field from the current is affected by the magnetic field from the magnet; this produces a force.




**To make the force bigger:**

- Increase the size of the current.

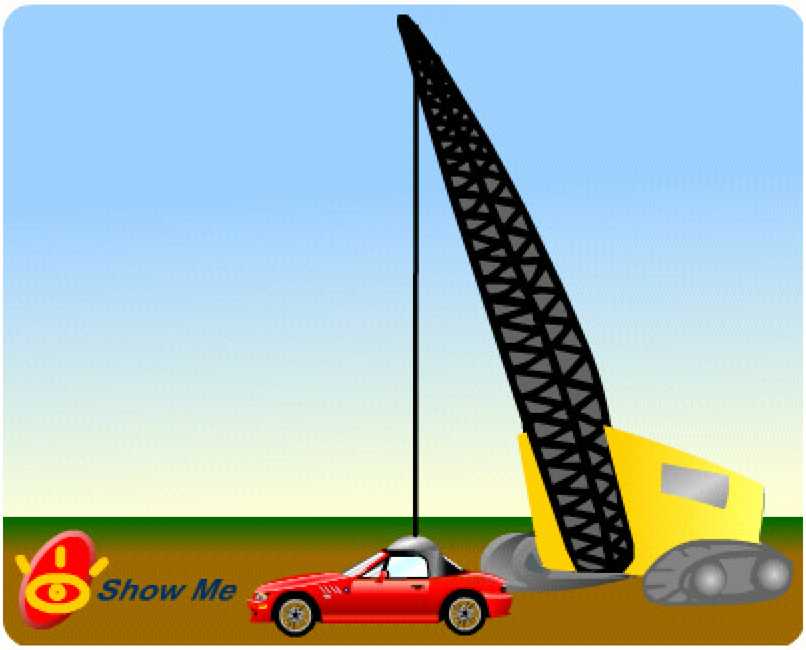
- Increase the strength of the permanent magnet.

Previous QuickLearn

Next QuickLearn

# Uses of Electromagnetism

## Dumping cars!




A huge electromagnet is often used to pick up cars. When the current is switched off, the magnet loses its magnetism and the car falls back down to the ground.

## Electric motors

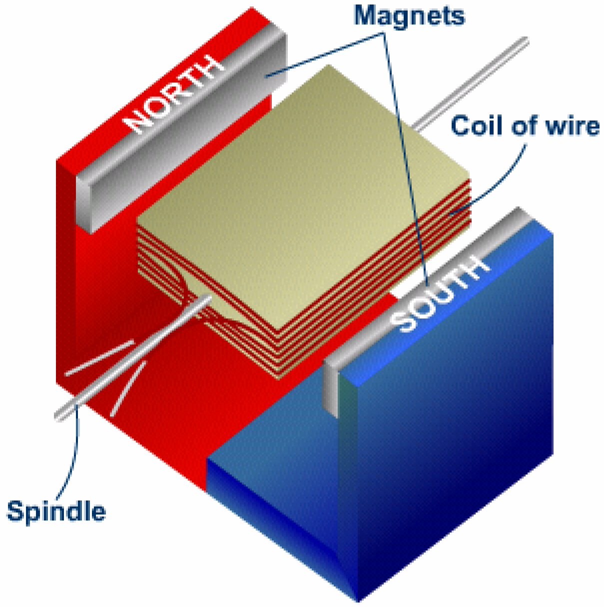
An electric motor uses the motor effect to spin a coil of wire inside a magnetic field.

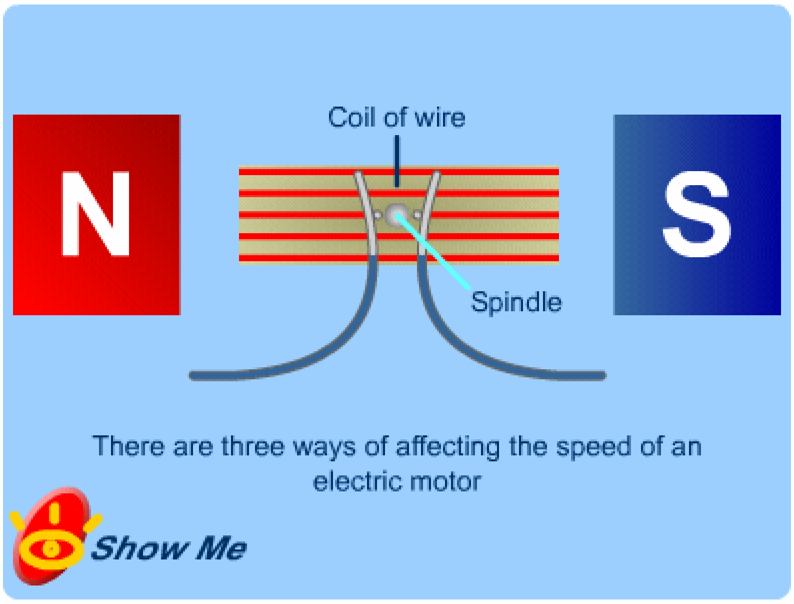
**To increase the speed of the motor:**

- Increase the current in the coil.

- Increase the number of loops on the spinning coil.

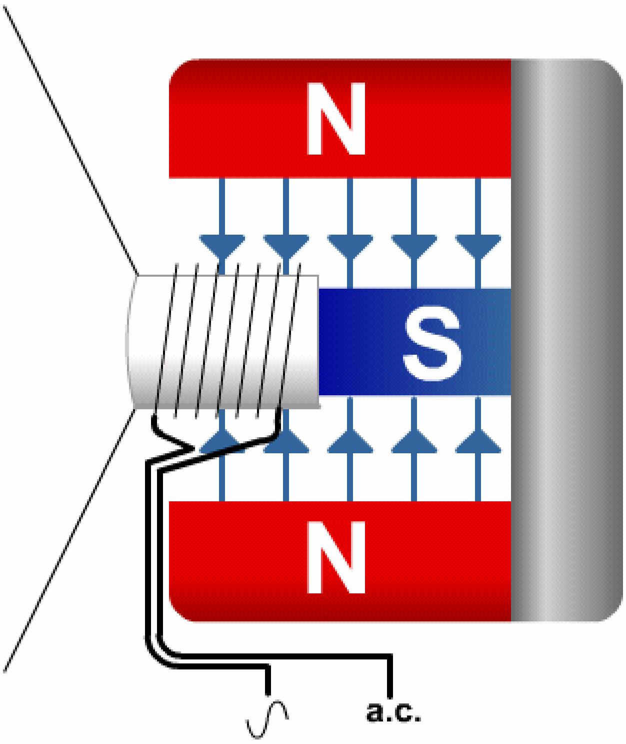
- Increase the strength of the magnet.




If either the magnetic poles are swapped around or the current flows in the opposite direction the motor will spin in the opposite direction.

## Loud speakers

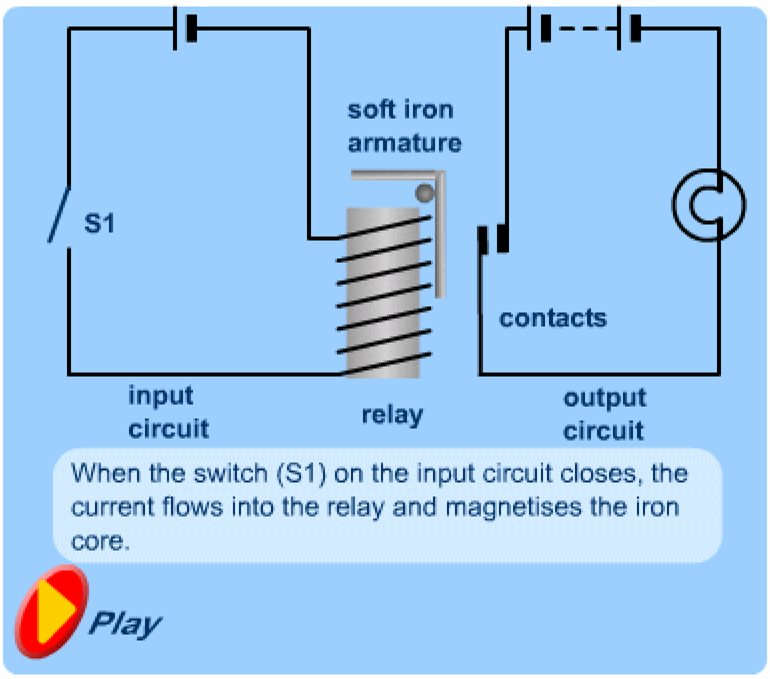



The alternating current that represents a sound wave flows through the coil. As the current carrying coil is inside a magnetic field a force is produced, which makes the coil move. This pulls the paper cone in the same direction. As the current changes direction, the force produced changes direction. This makes the paper cone move the opposite way. The backward and forward motion of the cone produces a sound wave in the air.

The higher the frequency of the electrical signal, the higher the frequency of the sound wave produced, so making a higher pitched noise. The greater the amplitude of the electrical signal, the greater the force produced, so the further the cone will move, making a louder noise.

## Relays

Relays are used as safety devices. **A large current circuit can be switched on by a small current circuit, as shown below:**




When the small current in the input circuit is switched on, the electromagnet becomes magnetic and attracts the iron armature. The armature rotates towards the electromagnet, pushing the contacts together. This switches on the large current in the output circuit.

This type of relay circuit is used in the ignition of a car.

# Generating Electricity

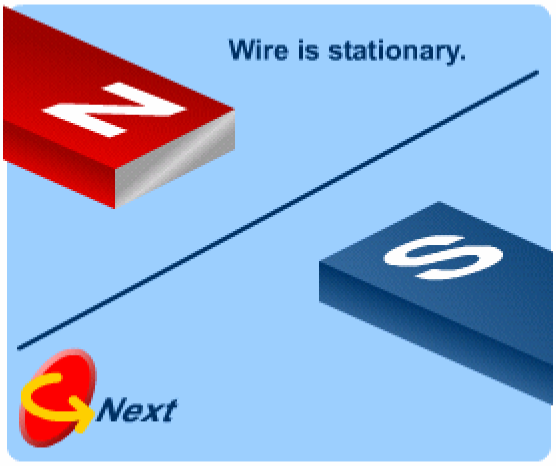
## Creating currents

You can see that any current in a magnetic field will produce a force, which may make something move.

The opposite affect is that if a wire is moved in a magnetic field, a voltage is produced, and if there is a complete loop, a current will flow. This is how electricity is generated.

**There are two main ways to generate electricity:**

**1. Moving a wire in a magnetic field:**

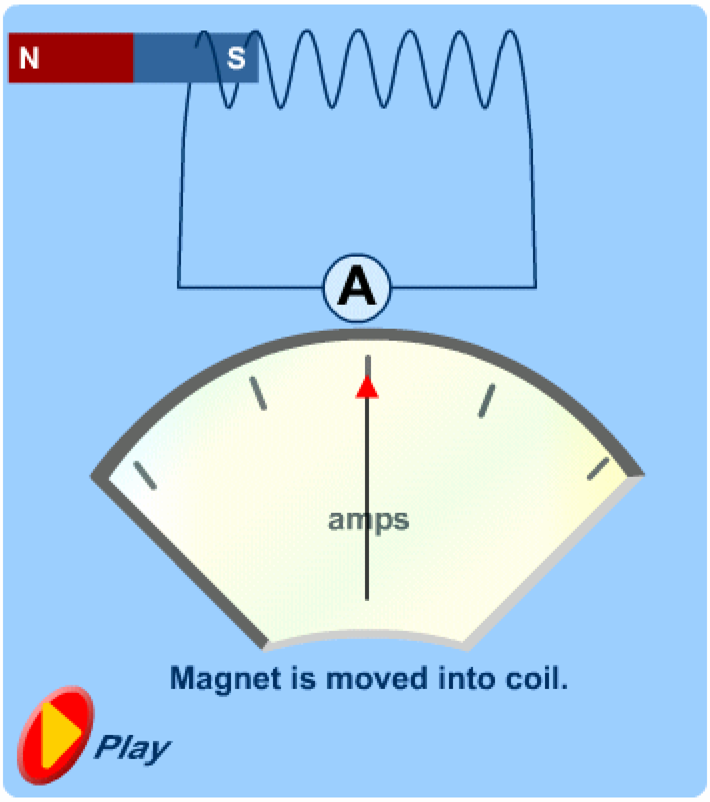



- If the wire is moved in the opposite direction, the current will flow the other way.

- If the wire is moved faster, a larger current will flow.

- If the wire is stationary, no current will flow.

**2. Moving a magnet in a coil of wire:**




- If the magnet changes direction, the current will flow the other way.

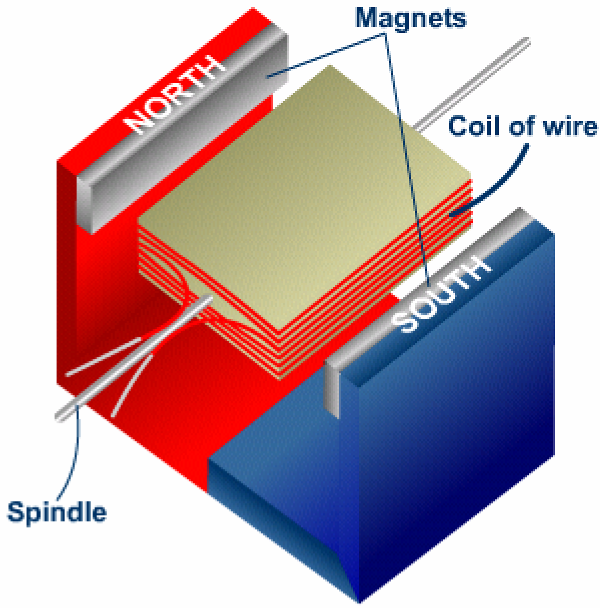
- If the magnetic poles are swapped around, the current will flow the other way.

- If the magnet moves faster, a larger current will flow.

- If the magnet is stationary, no current will flow.

## Generating electricity

In industry, electricity is generated by spinning a coil of wire in a magnetic field.




**To increase the voltage or current generated:**

**1.** Spin the coil faster.

**2.** Put more loops on the coil.

**3.** Use a stronger magnetic field.

**4.** Use a coil with a larger area.

When a current is generated we say that it has been **induced** in a conductor.

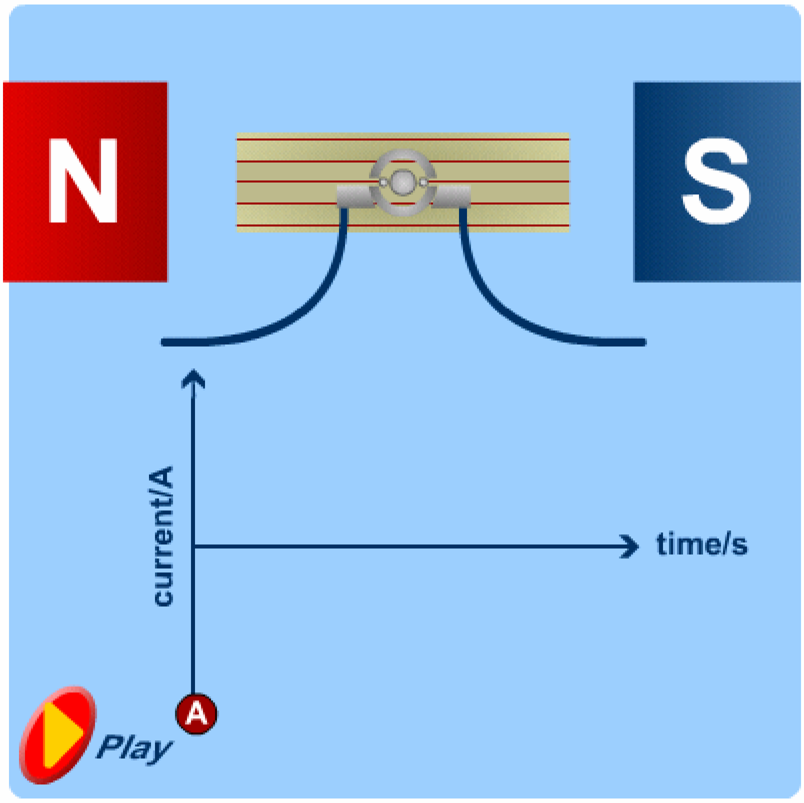
**Note:** A voltage is always induced when a conductor moves in a magnetic field, but a current is only induced if there is a **complete circuit** for it to flow around.

In the diagram, you can see that there are carbon brushes and slip rings.

The carbon brushes act as contacts with the slip rings, so that the current can always flow from the coil to an external circuit.

**Why is alternating current produced?**

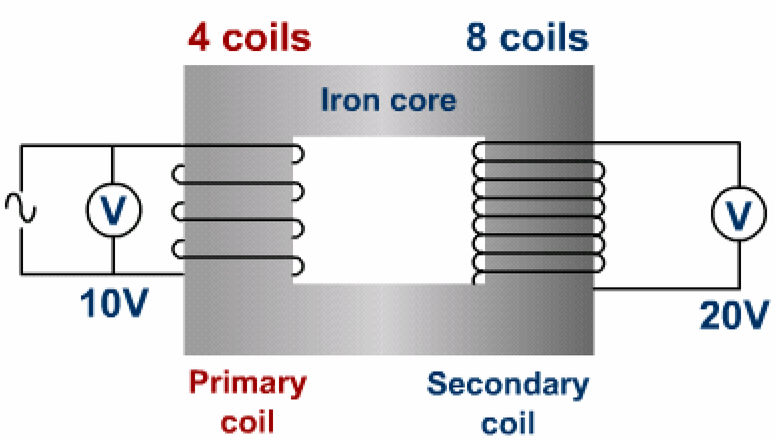
The current produced is an alternating current as during each rotation, each side of the coil moves up and down in the magnetic field. This change in direction produces a change in direction of the current.




## Transformers

**Transformers** are able to change the voltage of an alternating current. This is used on the national grid. The larger the voltage, the lower the amount of wasted heat energy in the cables. However, these large voltages are too dangerous to use in the home, so transformers are used to reduce the voltage to a safe level.

An alternating current has a changing magnetic field around it. This changing magnetic field can induce a current in another nearby conductor. This is how a transformer works.



The alternating current in the primary coil has a changing magnetic field around it. This changing field induces an alternating current and voltage in the secondary coil. The size of this voltage depends on the difference in the number of loops on the coils.

**Calculating the size of the output voltage**

**You can work out the size of the voltage using the following equation:**

$$\frac{\text{Voltage across the primary coil}}{\text{Voltage across the secondary coil}} = \frac{\text{Number of loops on the primary coil}}{\text{Number of loops on the secondary coil}}$$

This means that if there are twice as many loops on the secondary coil, then twice the voltage will be across the secondary coil, and so on.

**Have a go filling in the following table:**

| Number of loops on primary coil | Number of loops on secondary coil | Voltage in (V) | Voltage out (V) |
|---|---|---|---|
| 100 | 200 | ______ | 10 |
| 25 | 100 | 1 | ______ |
| 100 | ______ | 10 | 5 |
| ______ | 200 | 50 | 100 |
| 200 | 800 | 60 | ______ |

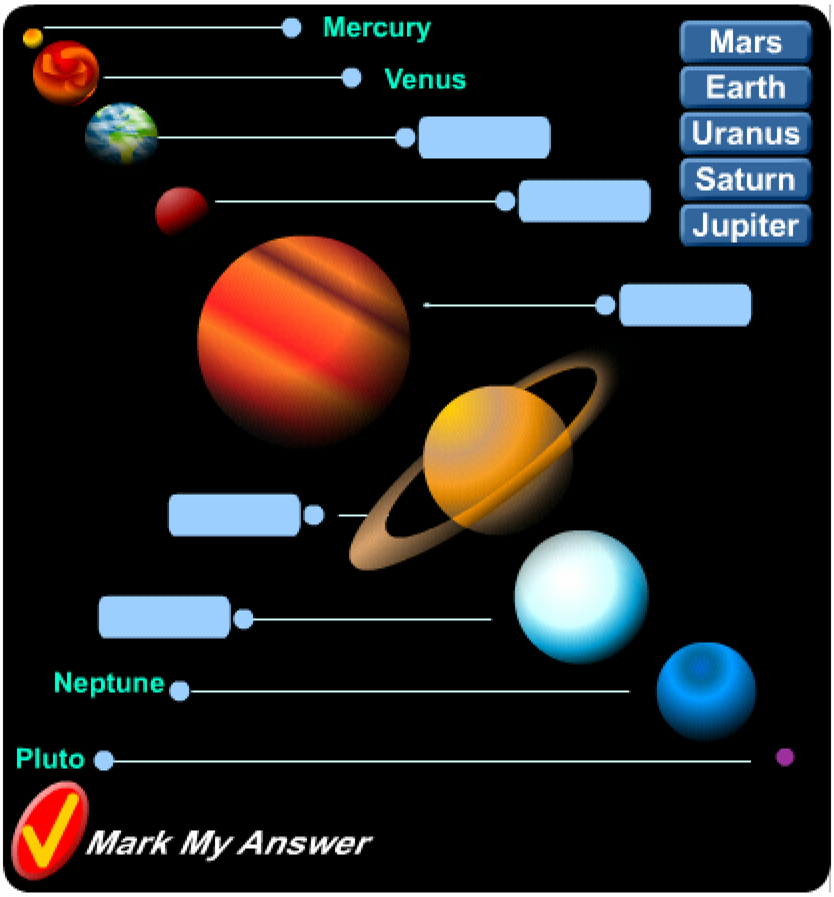
*Mark Answer*

# The Solar System

## The Planets

The **Solar System** is made up of the nine planets, including the Earth, that orbit (go round) the Sun.

**See whether you can name them on the diagram below:**

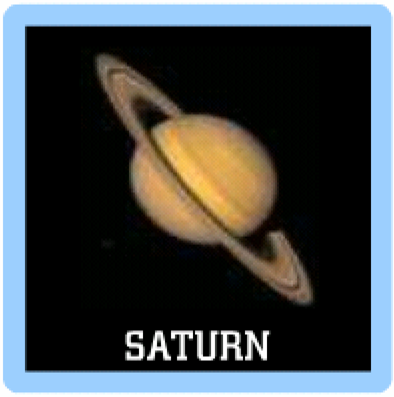



The four inner planets are called **terrestrial planets** and are small rocky planets.



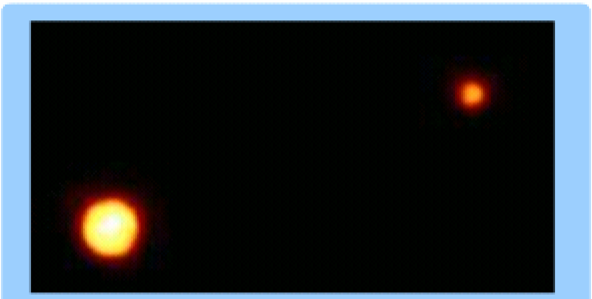

Between Mars and Jupiter, there is an asteroid belt, which may be the remains of a planet.


The next four are called gas giants and are large planets made up of gas.



Pluto is a very cold lump of rock, with a moon - Charon - nearly as large as Pluto.


Pluto and Charon

### Some facts about the solar system

**Decide whether the following facts are true or false:**

| | | |
|---|---|---|
| The further a planet is from the sun, the less energy it receives in the form of light and heat. | True | False |
| The orbits of the planets are circular. | True | False |
| Saturn is the only planet to have rings. | True | False |
| The sun is a star. | True | False |
| Mercury has no atmosphere. | True | False |
| Venus is the hottest planet in the solar system. | True | False |
| Humans have visited mars. | True | False |
| Jupiter is the largest planet in the solar system. | True | False |
| Jupiter has a big red spot. | True | False |

Mark Answer

The moon orbits the earth in 28 days and the Earth orbits the sun in 365¼ days. Each planet takes a different amount of time to orbit the sun.

# Orbits and circular motion

As mentioned above, the planets move in near circular orbits called **ellipses**.

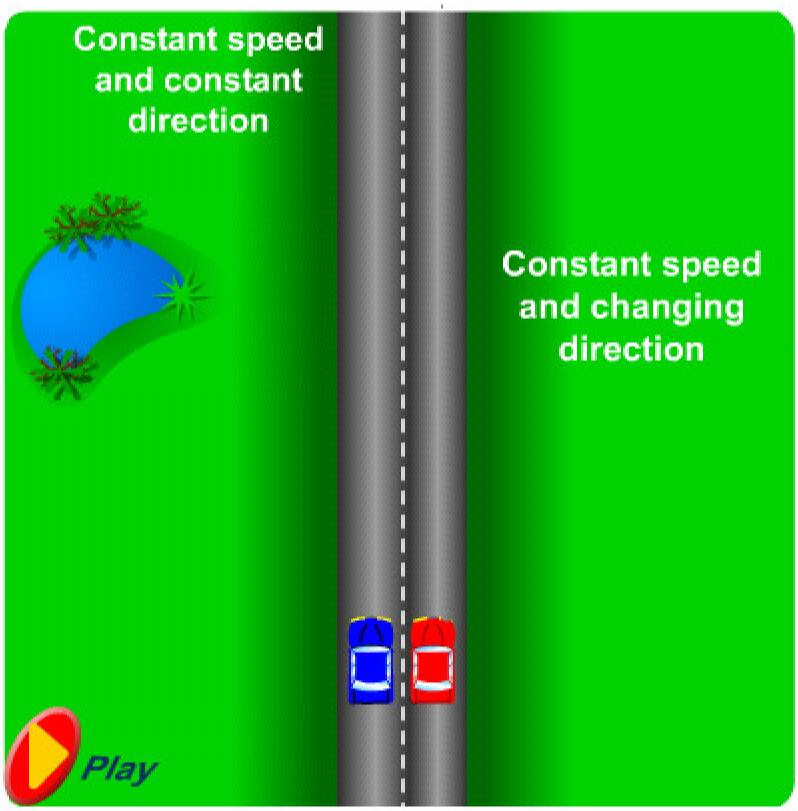
Objects will only move in a circle if there is a force acting on them. The force in this case is caused by the gravitational attraction between masses. This is also the force that keeps the moon in orbit round the Earth and your feet on the ground.

**But why must there be a force for objects to travel in a circle?**

## Speed and velocity

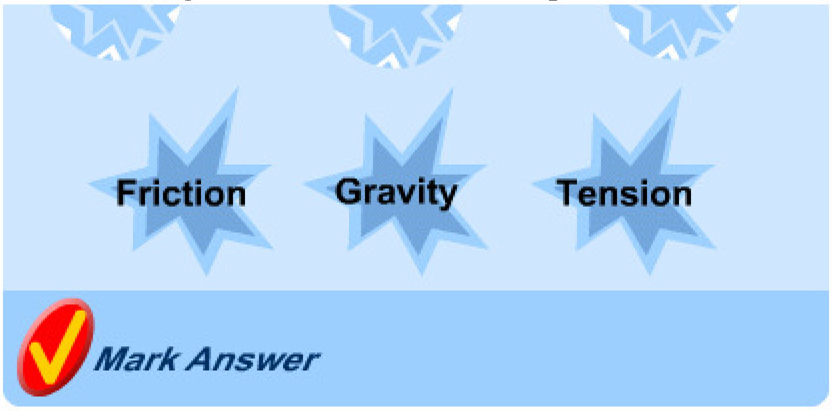
**Velocity is speed with direction.** If a car has driven off at 30mph, it would be very hard to find it after an hour, but if you knew it had driven at 30mph northwards for an hour, it would be very easy to find.

Below is a brief demonstration to show this. You will see three different journeys of the same two cars. For each journey, the blue car drives due north at the same constant speed and so always ends up in the same place. The red car however, drives with constant speed, but with changing direction and so ends up in a different place every time.



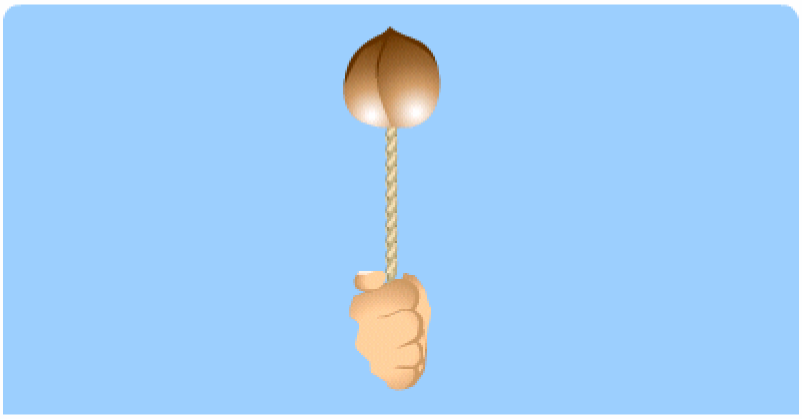

If something is going in a circle, its velocity is changing, even if its speed is constant. This is because it is changing direction. If the velocity is changing the object must be accelerating. We know from Newton's Laws that something will only accelerate when a force is being applied.

We call the force that keeps things moving in a circle a **centripetal force.** A centripetal force can be provided in a number of ways. **See whether you can identify which of the forces below provides the force in each**




Notice that the centripetal force always acts towards the centre of the circle.

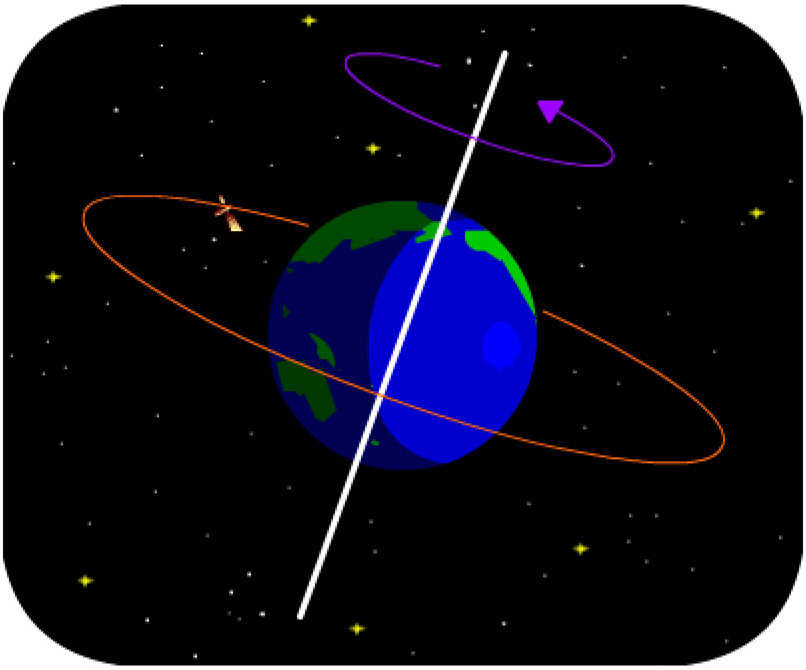
Help the hammer thrower below release the hammer at the right time. Remember, as soon as the centripetal force is removed the object will travel in a straight line.



### Satellites

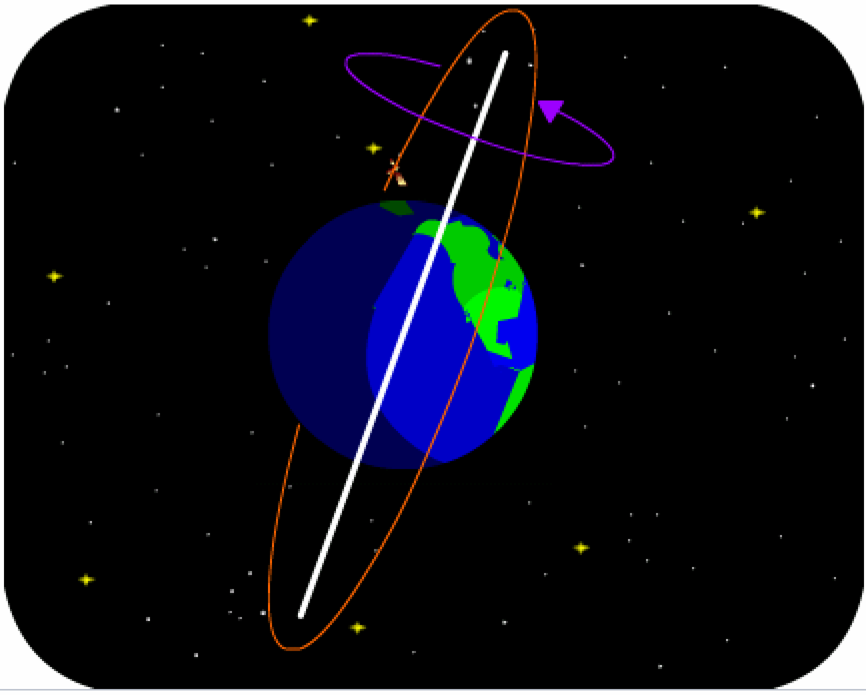
Satellites are also held in orbits around the Earth by the gravitational attraction of the Earth. There are two main types of satellites:

1. **Geo-stationary orbit satellites:**



The satellite rotates around the Earth once every 24 hours, so it is able to stay over one point on the Earth. This is useful for communications, as microwaves can be directed at the satellite, which then sends them back to a different point on the Earth. The satellite is always in the same position relative to the Earth.

**2. Polar orbit satellites:**



The satellite can orbit the Earth many times in a day and see the whole Earth as it travels. The Earth is rotating as the satellite orbits, so the satellite sees a different part of the Earth each time it goes around. These satellites are used for weather forecasting and for spying.

# The Earth

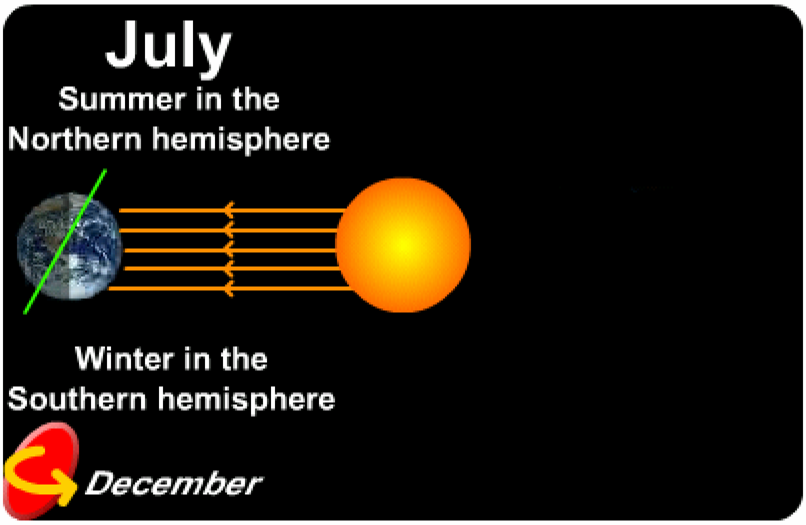
## The seasons

The Earth has seasons because it rotates on an axis, which is tilted.

**The seasons change two significant things on the earth:**

**1.** The length of the day and night.

**2.** The temperature and weather, due to the intensity of the sun.




In July, the Northern Hemisphere is tilted towards the Sun and so has the warmer weather. The North Pole is in constant daylight because it is never in the Earth's shadow. England has longer days during the summer because it is facing the sun for longer.

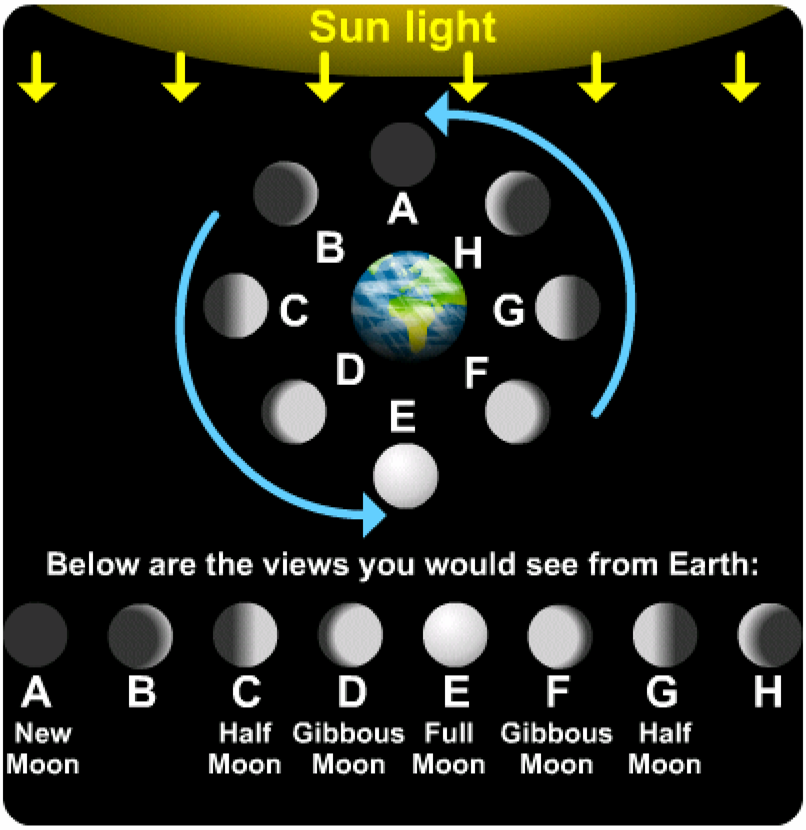
In December, the Northern Hemisphere is now tilted away from the Sun. The days are shorter and the North Pole is in constant night as it is always in the Earth's shadow as the world rotates. In England, the Sun still rises in the East and sets in the West, but now it is always lower in the sky, making the shadows longer.

The Sun is more intense in the summer as the electromagnetic waves from the sun land on a smaller area, whereas in the winter, the same waves are spread over a larger area, making them less intense.

## The phases of the moon

The moon orbits the Earth every 28 days. As it goes around, it is caught in the shadow of the Earth, this is why we see different amount of the moon as the month goes by. During a full moon, the Earth is not in the way between the sun and the moon. During a new moon, the moon is in the Earth's shadow, which is why very little of the moon can be seen.

**There are eight phases of the moon:**




# Tides

The moon and the Sun cause the sea to have tides. This is because of the gravitational attraction between the Sun, moon and water in the sea. The moon has the biggest effect, as it is closer to the Earth. The highest tides, called **spring tides,** occur when the moon and the Sun are pulling in the same direction. When the Sun and the moon are pulling in directions at 90 degrees to each other, the high tides are at their smallest. These are called **neap tides.**

# The Universe

Our solar system is a collection of planets orbiting a star. Our Sun is gravitationally bound to a huge collection of other stars. This collection of stars is called a **galaxy.** Our galaxy is called the Milky Way. There are lots of galaxies in the Universe.

## The life of the Universe

There are various theories in existence about how the Universe started and what will happen to it. Most cultures have creation myths to explain the beginning of the Universe.

Most scientists today believe in a theory called the **Big Bang.**

### The Big Bang theory

There is evidence that the Universe is expanding.

This evidence is found when we look at the electromagnetic radiation emitted from other galaxies. It is normally **red-shifted.** This means the wavelength of the electromagnetic radiation appears longer than it actually is.

This is a result of an effect known as the **Doppler Effect.** This effect makes waves appear to have a longer wavelength if their source is moving away from you. It also means the wavelength will appear shorter if something is moving towards you. You can hear this when a police car goes past you, with its siren on. As the car approaches you, the noise is a higher pitch than when the car is moving away from you.

One explanation for this is that all the energy and mass in the Universe all started in the same place and exploded apart. This flung all matter outwards and even now scientists believe it is still all moving away from the initial explosion.

Just after the Big Bang, scientists believe everything was energy, but soon after, the energy began to turn into mass making small particles - like the electron. It would have been incredibly hot at the start, but cooled down as it expanded. Scientists have measured the background temperature of the Universe with a satellite and found it to have a temperature just a couple of degrees above absolute zero (-273 degrees Celsius). Eventually, protons were able to join with electrons and hydrogen was made. This led to the birth of the first stars.

We think the Universe is between 11 billion and 18 billion years old, but scientists often change their estimate.

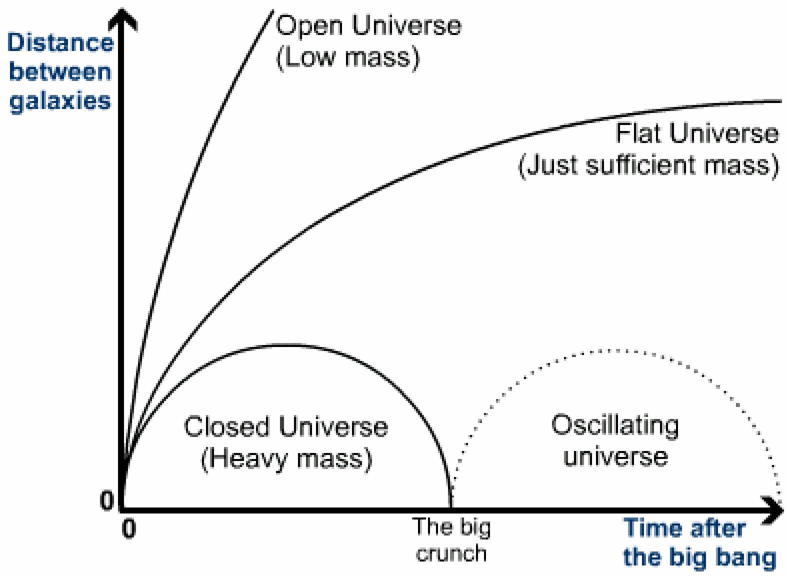
## How will it end?

**Scientists are still arguing about this, but there are three main possibilities:**

**1.** If there is too much matter in the Universe, the gravitational attraction between all the masses will eventually pull all the galaxies back together into a big crunch. This is called a **closed universe.** This may lead to another Big Bang setting up an **oscillating universe** that keeps expanding and contracting.

**2.** If there is not enough matter in the Universe, everything will keep moving apart forever. This is called an **open universe.**

**3.** If there is just the right amount of matter in the Universe, the expansion of the Universe will slow down until it is expanding so slowly that it will appear the Universe has stopped expanding. This is called a **flat universe.**



# Life of Stars

Scientists worked out a fairly long time ago that the Sun couldn't be powered by chemical reactions because it would have used up all its energy long before life was formed. It wasn't until nuclear reactions were understood that they could work out what was going on inside the Sun.

From this they were able to work out the life of a star.

## The life of a star

Stars start off in the same way, but their end depends on how much mass they have.

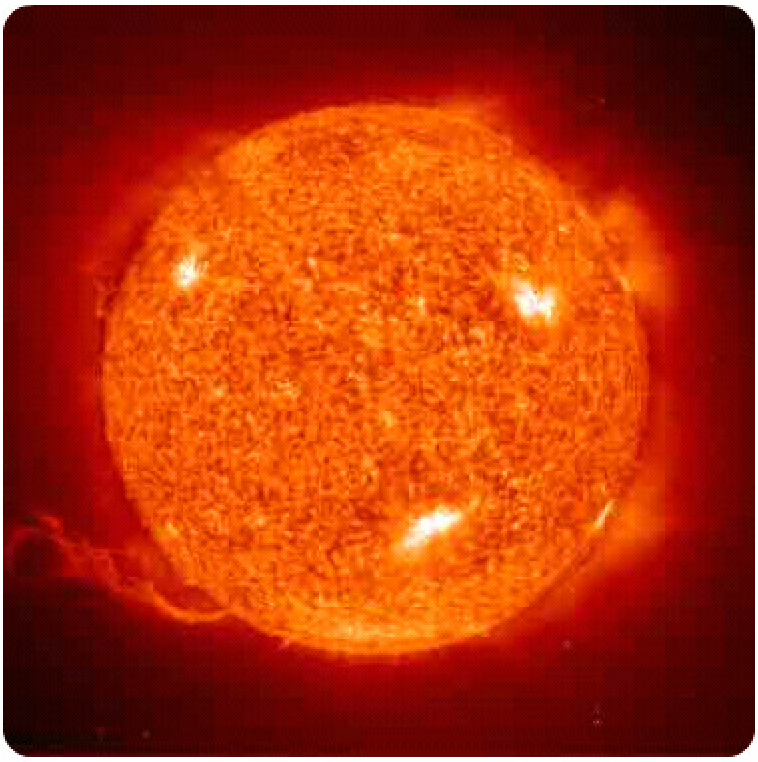
**Step 1:**

Gravitational attraction pulls hydrogen atoms together. The initial star will be big and cold. As it pulls its mass closer together, the hydrogen atoms will start to fuse together to make helium atoms. This is called **nuclear fusion.** A huge amount of energy is released during nuclear fusion, compared with a chemical reaction. (Don't confuse this reaction with nuclear fission, which they use to generate electricity.)

**The picture below shows a birthplace for stars:**

**Step 2:**

The star will settle down into middle age. The outward pressure, caused by the highly energetic nuclear reactions taking place in the star, just cancels out the gravitational attraction pulling the star in on itself. A star spends most of its lifetime like this. **Our sun is at this stage in its development.**



**Step 3:**

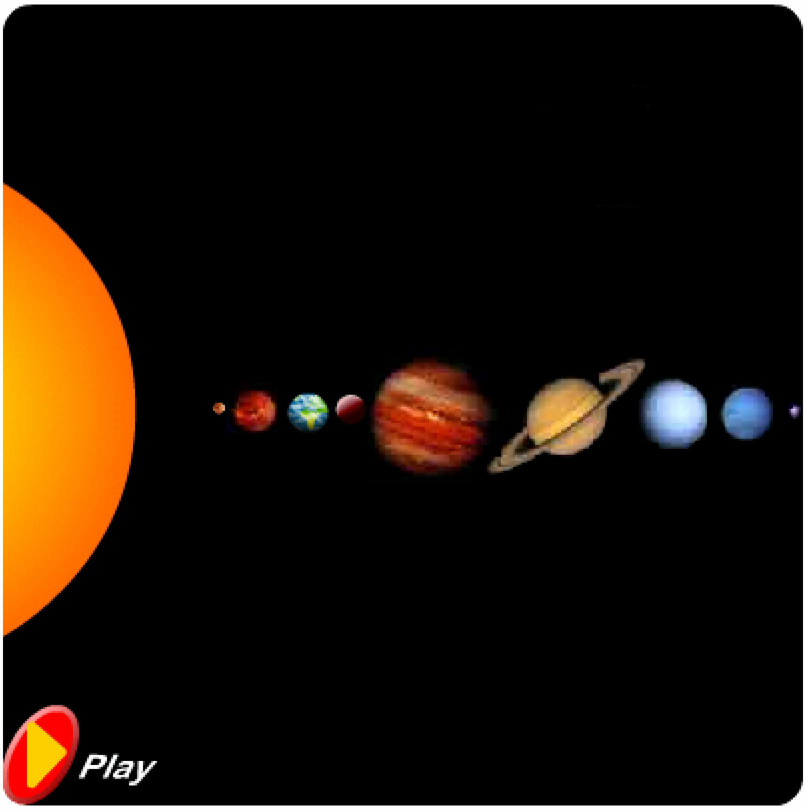
Eventually, the hydrogen in the star is used up. When this happens, the star starts to collapse under its own gravitational attraction.

There is no longer enough outward pressure from nuclear reactions to stop the star collapsing, this causes the star to become unstable.

A sudden surge of radiation is emitted, which causes the star to expand massively.

**This will happen to our Sun in about 5 billion years time - it will then expand to the orbit of Mars.**

**The animation below shows this process:**



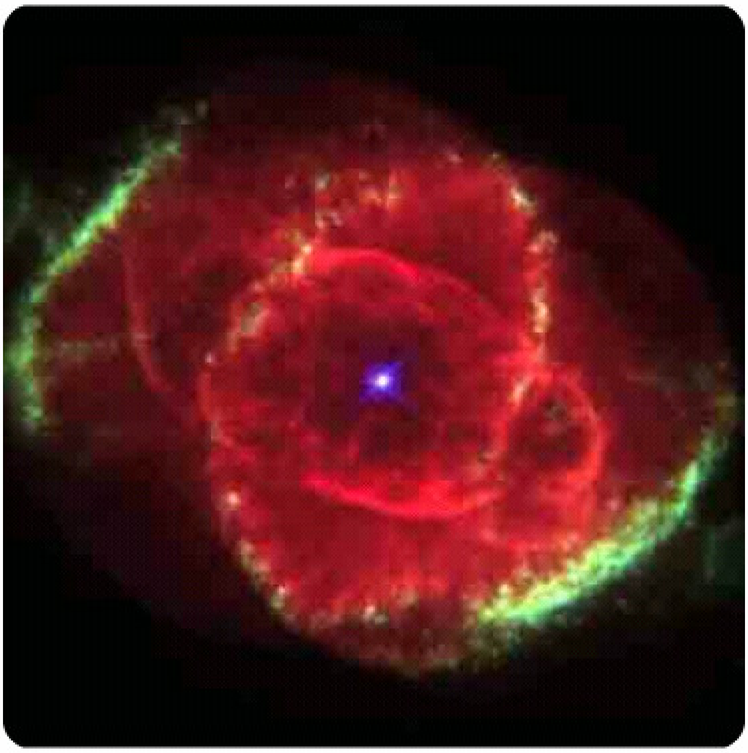

The Star is now a **red giant.** It will stay like this for a long time with helium nuclei joining together to make heavier elements.

What happens next depends on how heavy the star is.

## Life of low mass stars

Once helium fusion has stopped, the core of the star will collapse under its gravitational attraction. The outer layers are thrown outwards to form something called a planetary nebula.

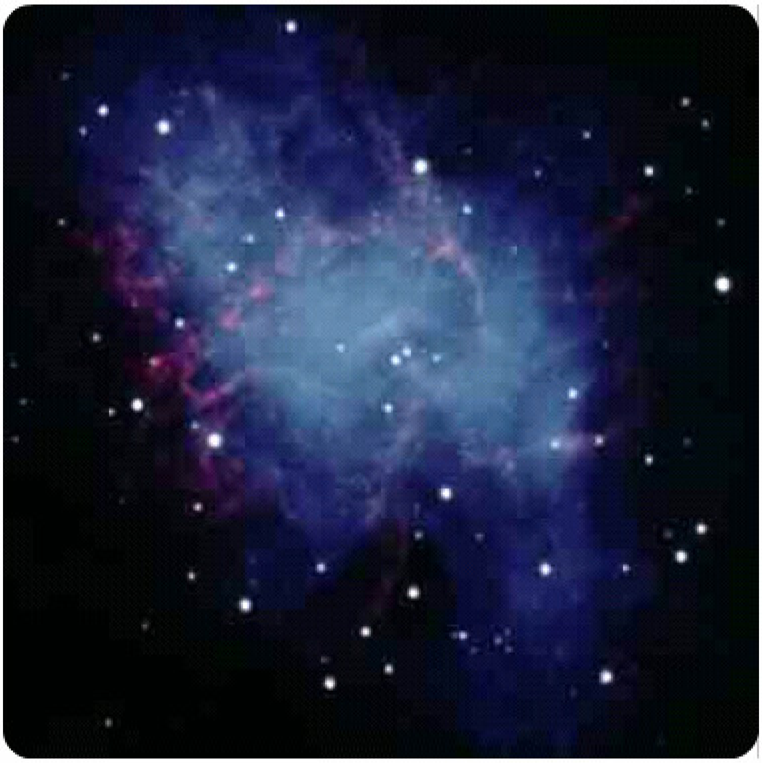
The core of the star shrinks until it becomes something known as a **white dwarf** star:



## Life of large mass stars

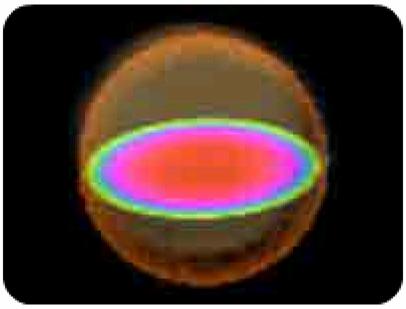
These stars have shorter life spans than smaller stars. They become red giants very quickly (in fact, they are called **red super giants** because they are so big).

**When they explode, they cause a supernova:**



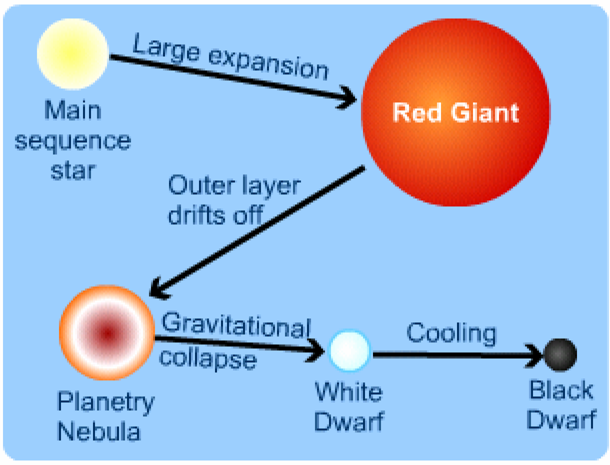
The collapsed core will either form a **neutron star** - where the gravitational attraction has pulled everything together so much all the particles have turned in to neutrons, or a **black hole** - which is so dense, even light can not escape from its gravitational field. Neutron stars are formed if the star's mass is between 1½ and 3 times the mass of our sun. A black hole is formed if the star's mass is over 3 times the mass of our Sun.

**A neutron star:**



**A black hole:**

**The following diagram shows the life of a star:**



static electricity.mht
basic circuits.mht
Electricity at Home.mht
Describing waves.mht
Reflection of waves.mht
Refraction of waves.mht
Dispersion and total internal reflection.mht
Diffraction of waves.mht
Sound waves.mht
Uses of sound waves.mht
Electromagnetic spectrum.mht
Information carrying.mht
What Can Forces Do.mht.mht
Newton's Laws.mht
Behaviour of Solids.mht
Forces and Pressure.mht
Moments.mht
Types of Energy Transfers.mht
How Does Heat Energy Move.mht.mht
How Can We Stop Heat Moving.mht
Non-Renewable Energy Sources.mht
Alternative Energy Sources.mht
Work And Energy.mht
Kinetic Energy.mht
Gravitational Potential Energy.mht
Work Done By Unbalanced Forces.mht
Power And Efficiency.mht
Introduction.mht
Atomic equations and Isotopes.mht
Radiation.mht
Types of Radiation.mht
Half-Life.mht
Nuclear Power.mht
Magnetism.mht
Electromagnetism.mht
Uses of Electromagnetism.mht
Generating Electricity.mht
The Solar System.mht
The Earth.mht
The Universe.mht
Life of Stars.mht

## Management Team:

**Theodore Mason**, Managing Director

Theodore Mason was born in Italy, coming to the UK to study at the University of Bristol. He is a trained Chartered Accountant. He worked with KPMG as an auditor and later an IT consultant. Theo is the founder of S-cool Limited and has overall responsibility for S-cool's strategic direction.

**Nicholas Glossop**, Director of Education

Nick Glossop qualified and worked as a mechanical engineer before becoming a teacher. He spent time as a Head of Physics and also held a number of pastoral roles. Nick has overall responsibility for the educational content and value of S-cool products.

**Judge Singh**, Operations Director

Judge Singh is a trained Chartered Accountant. During the seven years he worked for KPMG, Judge focused on IT consultancy and had formal training in project management. Judge specialises in the review and control of large IT projects.

## Our clients include:

>lsc Leading learning and skills

department for education and skills

Arcadia Group Limited

BARCLAYS

vodafone

EDS

KPMG

logicaCMG

MARKS & SPENCER

NAO NATIONAL AUDIT OFFICE

REUTERS

ROYAL AIR FORCE RISE ABOVE THE REST

TATE & LYLE

Dixons Stores Group