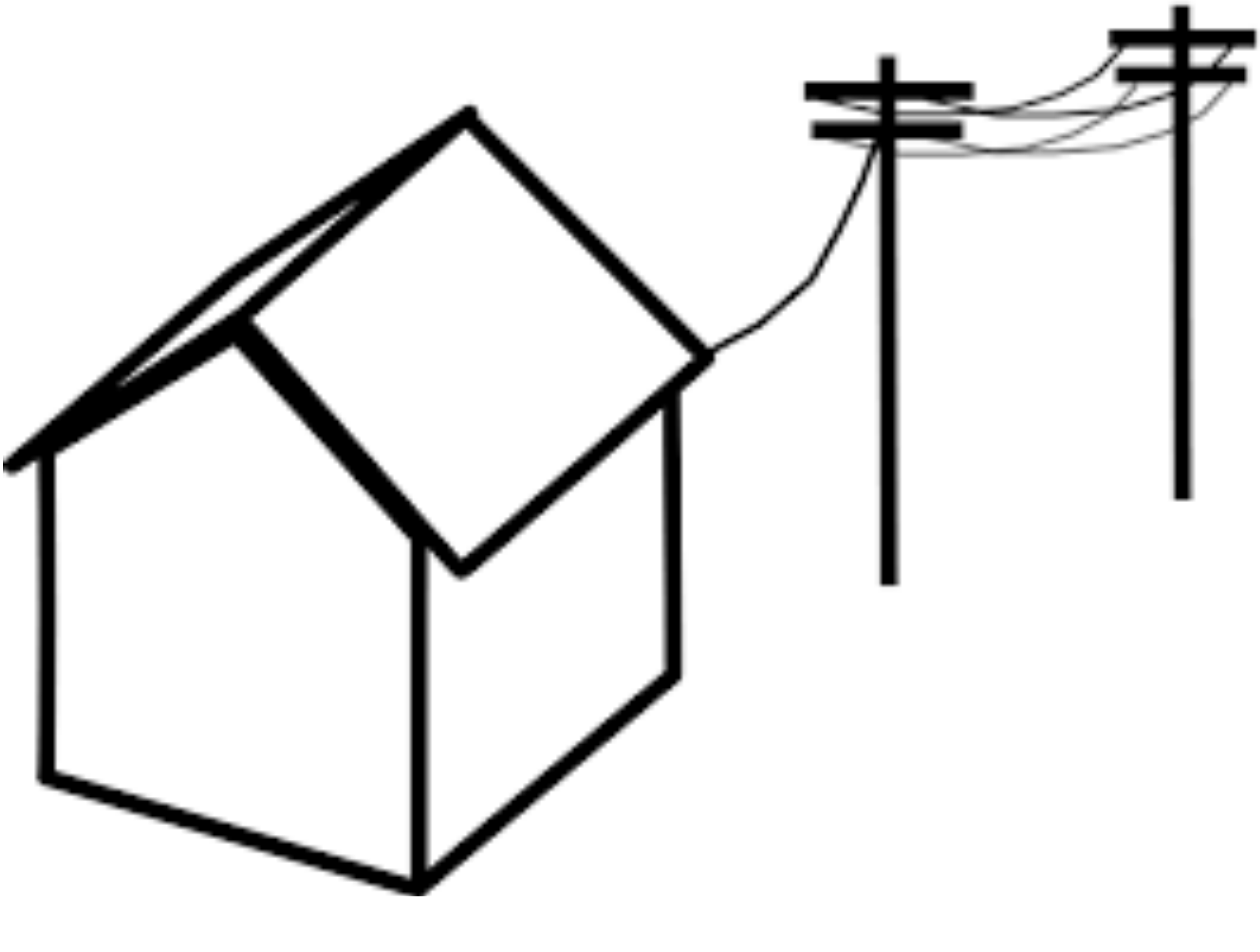
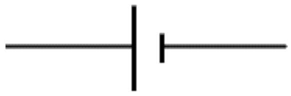
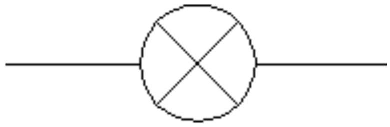
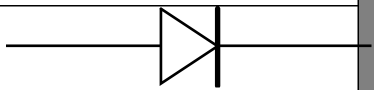
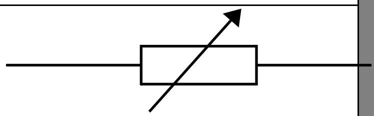
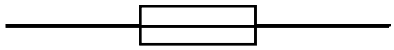
Year 10 Physics



Revision guide

Unit 1.1 - Circuits

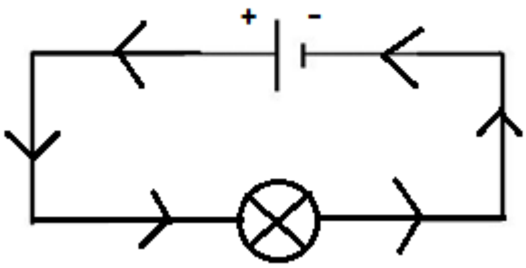
Device	Symbol	Device	Symbol
Wire		Cell / Battery	
Power Supply		Bulb	
Open switch (Off)		Closed switch (On)	
Diode		Resistor	
Variable resistor		Fuse	

Electrical current (I)

Current is the flow of free electrons (negatively charged). As a comparison, think of measuring the amount of water flowing through a pipe.

- Current is described as a measure of the charge that flows past a point every second.

  It flows from **+** to **−**.



- Current is measured in **Amperes, A**.
- It is measured using an **Ammeter connected in series**.

Voltage (V)

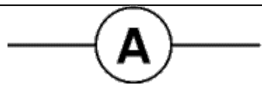
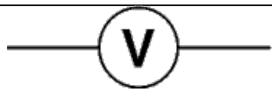
Voltage is a measure of how much electrical energy a certain amount of electrons can transfer as they flow around a circuit. The higher the voltage, the more electrical energy is supplied to the circuit.

- Voltage is measured in **Volts, V**.
- It is measured using a **Voltmeter connected in parallel**.

Resistance (R)

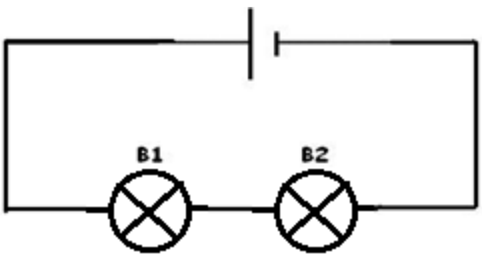
Resistance is a measure of how difficult it is for current to flow through a wire or device. More resistance means less current because it is more difficult for it to flow. Resistance is caused due to the collisions between the free electrons and the atoms/ions in the metal.

- Resistance is measured in **Ohms – Ω.**
- A thin wire has more resistance than a thick wire.

Name	Unit	Measured using	Symbol	Connected in…
Current	***Amps – A***	***Ammeter***		***Series***
Voltage	***Volts – V***	***Voltmeter***		***Parallel***
Resistance	***Ohms - Ω***			

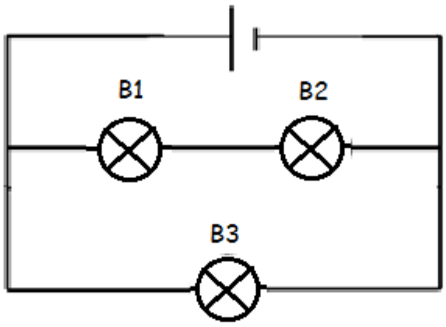
Series and Parallel circuits.

Series circuit: in a series circuit there is only path and the bulbs (B1 and B2) in the diagram below are one after the other. If bulb B1 breaks then B2 will not work/go off.



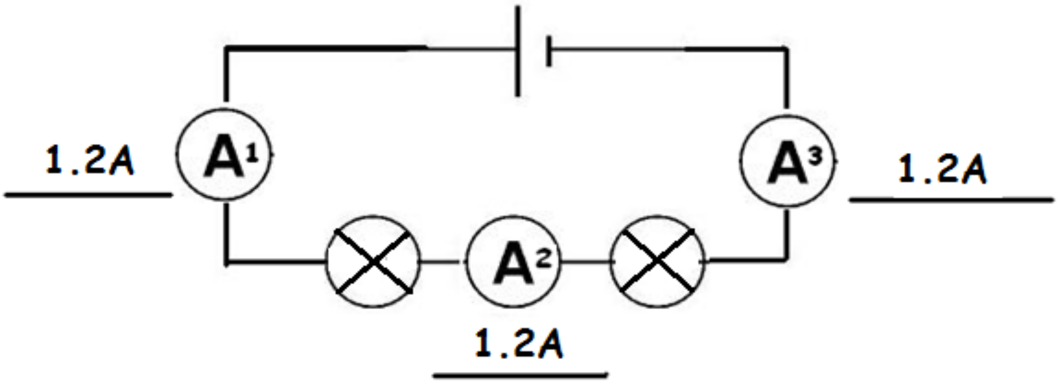
Parallel circuit: in a parallel circuit there is more than one path and the circuit is divided into branches. Bulbs B1 and B2 are in series but B3 is in parallel with them.

If bulb B3 breaks then B1 and B2 will continue to work.



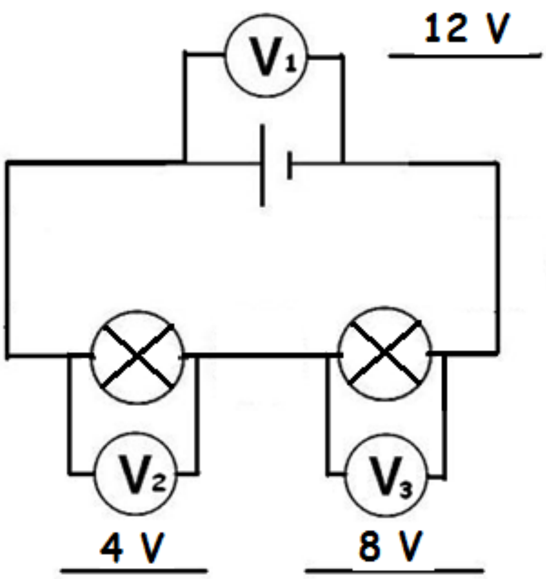
Measuring current and voltage in circuits.

Current in series circuits: ammeters must be connected in series i.e. in the circuit.



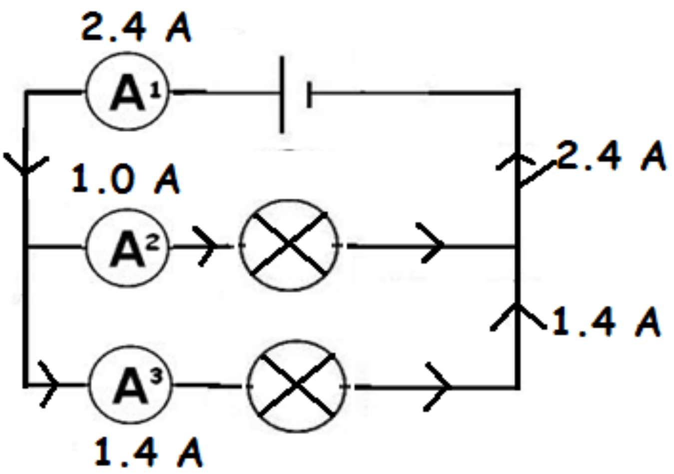
The value of the current is the same at all points ($A_1 = A_2 = A_3$) in the circuit since there is only one path for the current to flow.

Voltage in series circuit: the voltmeters are connected across the component e.g. bulb or battery.



The voltage across both components/bulbs here adds up to the voltage across the supply/battery i.e. ($V_1 = V_2 + V_3$) or (12 = 4 + 8).

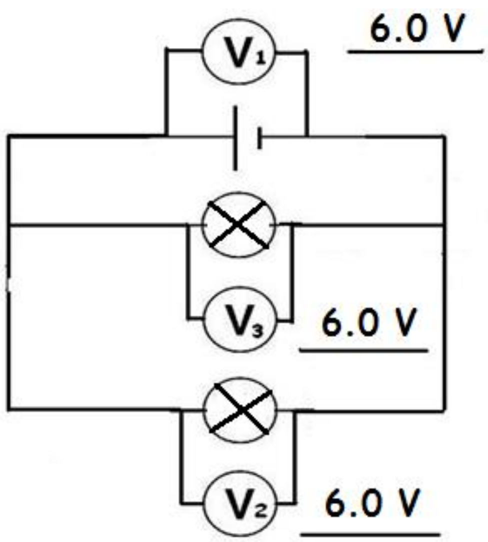
Current in parallel circuits: the ammeter in this series circuit is connected in series.



The value of the current in the two branches adds up to the total current flowing, i.e. ($A_1 = A_2 + A_3$) or (2.4 = 1.0 + 1.4).

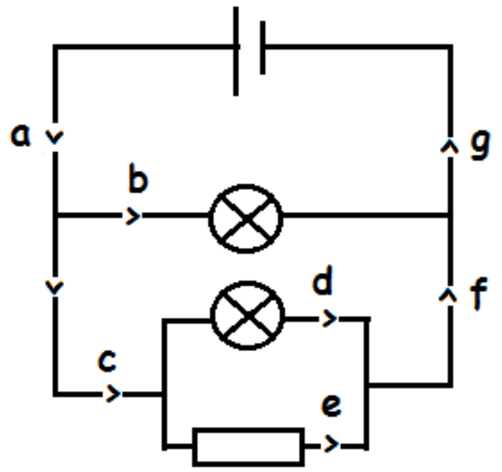
Voltage in parallel circuit: the voltage across all components in parallel is the same.

i.e. ($V_1 = V_2 = V_3$)



Predicting current values.

What is the value of the current at the following points in the circuit.



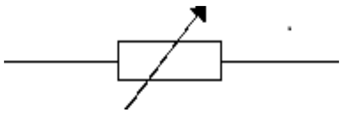
Point	Current (A)
a	3.6
b	2.0
c	
d	1.2
e	
f	
g	

Answers: c = 1.6A, e = 0.4 A, f = 1.6A, g = 3.6A

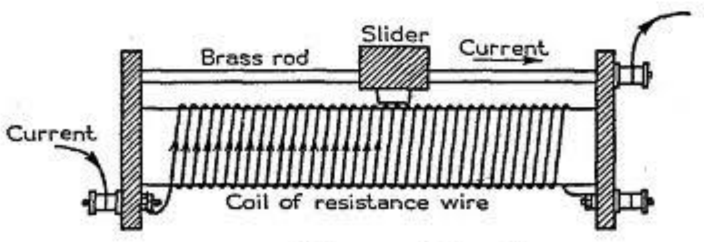
Variable resistors (controlling the current).

In your house the mains voltage is 230V. Not all devices require the same current to operate and some will have two or three settings (like a toaster or hairdryer) so we must have a way of changing/controlling the current required.

A variable resistor (rheostat) is a resistor for which it is possible to alter/vary the resistance. Variable resistors are components that can be put into a circuit to control the current and the voltage e.g. volume control and dimmer switch



If you look at the variable resistor below then the more the slider is over to the right hand side the more wire the current has to go through so the greater the resistance and therefore the current decreases.



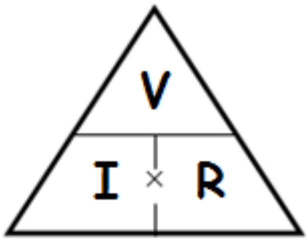
Wire-wound rheostat

Ohm's law

This law describes the relationship between voltage (V), current (I) and resistance (R).

Resistance = $\dfrac{\text{Voltage}}{\text{Current}}$

$$R = \frac{V}{I} \quad \text{or} \quad V = I \times R \quad \text{or} \quad I = \frac{V}{R}$$



Higher tier only

e.g. Calculate the voltage across a 15Ω resistor that carries a current of 1.8A.

$$V = 1.8 \times 15 = 27 \text{ V}$$

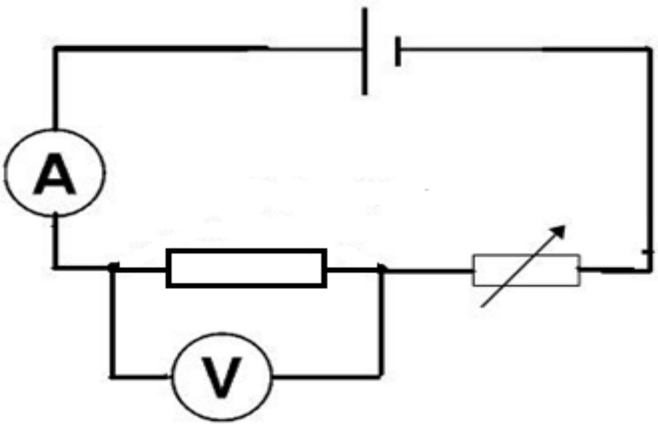
Q1. Calculate the current through a 2kΩ resistor when there is a voltage of 230V across it.

Q2 An electric fire with 4A flowing through it has a voltage of 230V across. Calculate the resistance of the wire in the electric fire.

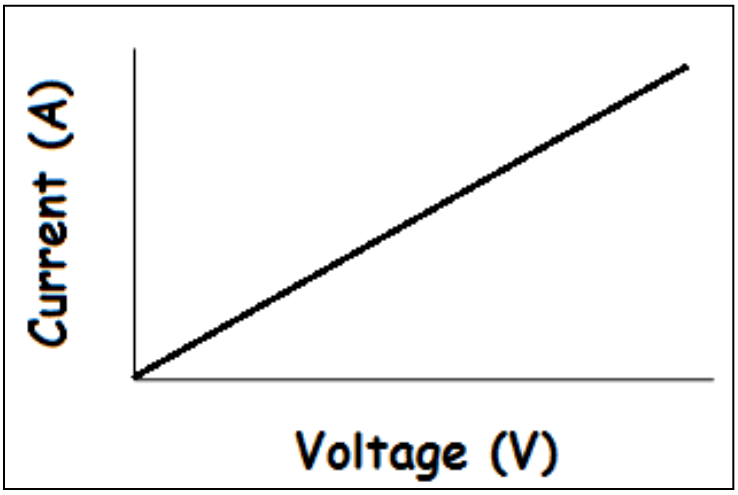
Answers: Q1 = 0.115 A , Q2 = 57.5 Ω

Current – voltage relationship

Resistor or wire at constant temperature. Moving the variable resistor changes the resistance of the circuit so that you can then change and measure the voltage across the resistor/wire and the current flowing through it.



A graph of the voltage and current are plotted. Key features of the graph are:



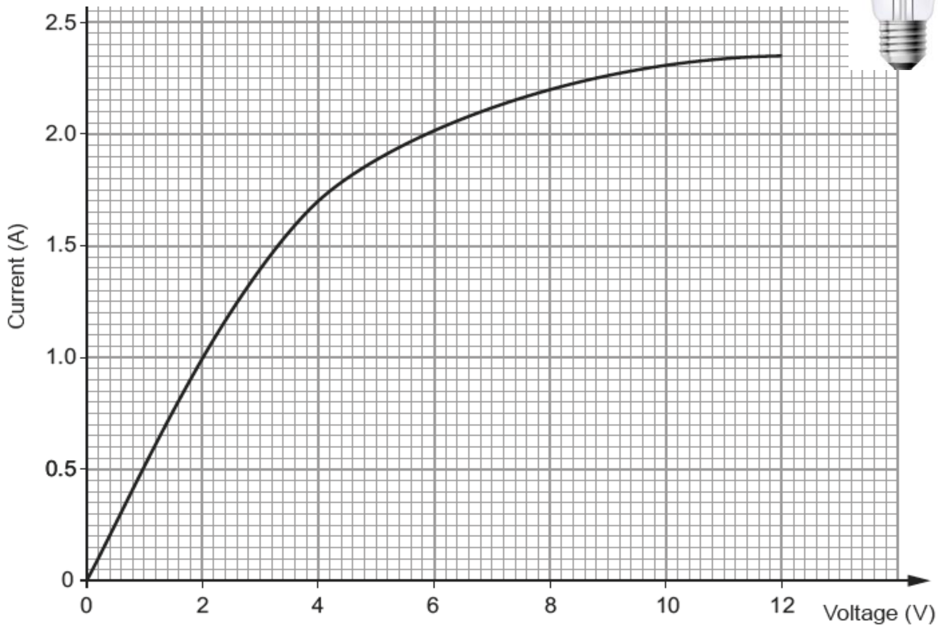
- The graph shows that if the voltage across the wire/resistor is doubled then the current also doubles.
- The relationship between the current and voltage is **directly proportional.** The relationship is only directly proportional if the graph goes through the origin (0,0) and is a straight line.
- This only happens if the **temperature of the wire remains constant.**
- The constant gradient of the graph means that the ***resistance remains constant*** and that the resistor/wire ***obeys Ohm's law.***

<u>Changing resistance</u>

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}} \quad \text{or} \quad R = \frac{V}{I}$$

If the voltage remains constant then if the resistance of ***resistor/wire doubles*** then the ***current will halve.*** This relationship is ***inversely proportional.***

Filament lamp (NOT constant temperature). The same circuit as for the resistor/wire is used, except the resistor is changed for a bulb.



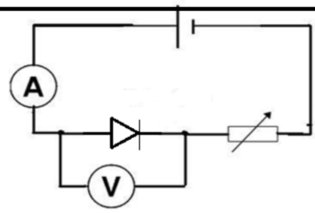
- Up to 2V the current and voltage increase at the same rate because the resistance is constant (constant gradient).
- From 2V to 12V the current increases at a slower rate than the voltage.
  The gradient is not constant so the **resistance is not constant.**

The ***resistance of the lamp increases*** because the temperature of the filament wire is increasing. Therefore the filament lamp does **NOT** obey Ohm's law.

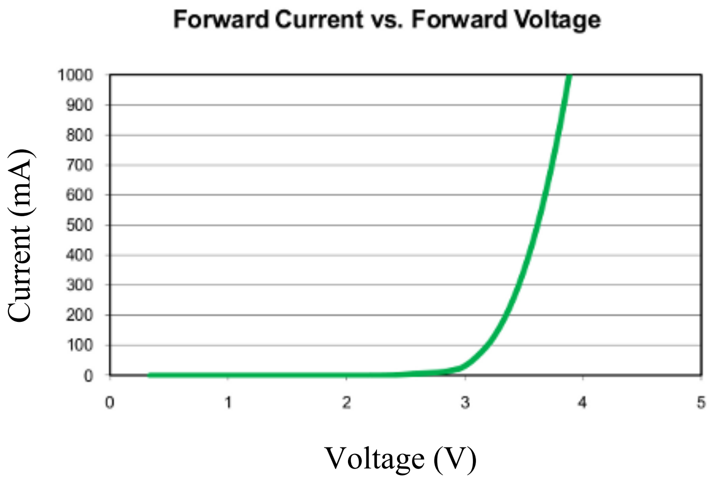
Calculate the resistance of the lamp at (i) 2 V (ii) 12 V.

$R = \frac{V}{I}$ (i) $R = \frac{2.0}{1.0} = 2.00\ \Omega$ (ii) $R = \frac{12.0}{2.35} = 5.11\ \Omega$

Diode (usually a Light emitting diode, LED). The same circuit is used again, except the resistor is changed for a diode ➔.

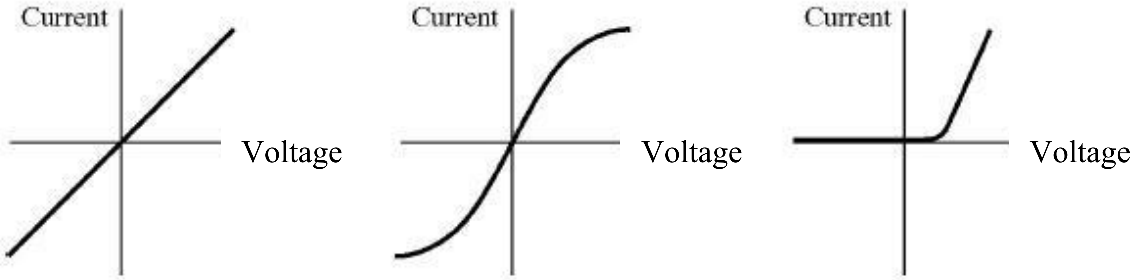


- Up to a certain voltage (2.8V in this case), there's no current at all – any devices connected in series with the LED would be off.
- Above this minimum voltage, the LED starts conducting, and the current increases rapidly (the resistance of the LED is reducing).
- If the LED were connected the opposite way (reversed) then it wouldn't conduct at all – the graph would remain horizontal.



Summary – Current-Voltage graphs

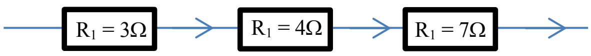
A resistor at constant temperature | A filament lamp | A diode



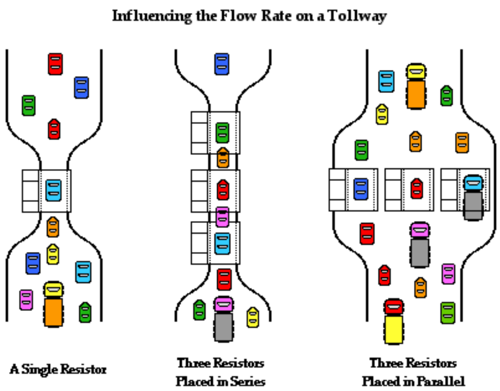
Resistor combinations

Resistors in series

The more resistors that are added in **series**, the greater the resistance. In fact, the total resistance is simply the sum of all the resistors, e.g. $R_T = R_1 + R_2 + R_3 = 3+4+7 = 14\Omega$.



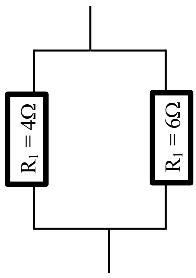
<u>HIGHER TIER ONLY</u>



Resistors in parallel

When resistors are added in **parallel**, the total resistance decreases. If you compare the flow of electricity to the flow of cars through a toll ➔ you can see that more tolls placed in parallel means the cars flow more easily. Likewise, when more resistors are added in parallel, there are more channels for the current to flow through, and hence there's less resistance.

Example : To calculate the total resistance of these ➔ 2 resistors, we use the following equation,



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{6} = \frac{5}{12}$$

$\therefore \quad R_T = 12 / 5 = 2.4\ \Omega$

Use a calculator for these !

Example 2. A 100Ω, 400Ω are connected in parallel with another resistor of 250Ω which is connected in series, Calculate the total resistance.

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{500} \qquad \frac{1}{R} = 0.0125 \qquad \frac{R}{1} = \frac{1}{0.0125} \qquad \therefore \mathbf{R = 80\Omega}$$

Total = 80 + 250 = 330 Ω

Electrical Power.

This is the **rate** (per second) of energy transfer i.e. the amount of energy a device can transfer from one form to another per second. (Hence, $P = E / t$). Power is measured in WATTs, W. In electrical circuits, we can also use the equation,

Power = Voltage x current, $P = V \times I$

Device	Power (W)	Energy transferred every second. (J/s)	Energy transferred into heat every second. (J/s)	Energy transferred into light every second. (J/s)
Filament bulb	60.0	60.0	56.0	4.0
LED bulb	6.0	6.0	0.4	5.6

HIGHER TIER ONLY - Power, current and resistance.

If we want to calculate the power consumption of an electrical component in a circuit but we do not know the voltage then we can do so by combining two equations.

Power = Voltage x Current *substitute* **Voltage = current x resistance**

$P = V \times I$ $V = I \times R$

$$P = V \times I \longrightarrow P = (IR) \times I \longrightarrow P = I^2 \times R$$

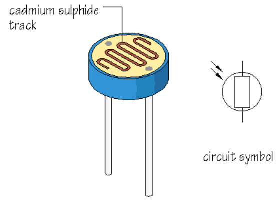
Power = current^2 x resistance

Example: A 2kΩ resistor has a current of 0.80A flowing through it. Calculate the power of the resistor. First we must change 2kΩ into Ω by multiplying by 1000.

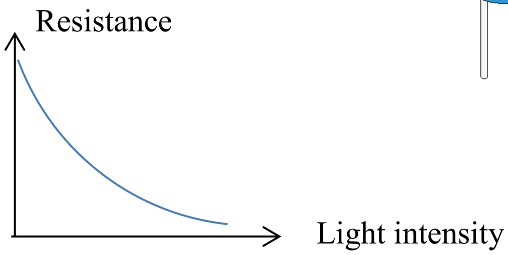
Resistance in Ω = 2 x 1000 = 2000 Ω then,

Power = current^2 x resistance = $0.8^2 \times 2000$ = **1280 W**

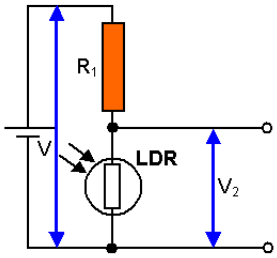
Light dependent resistor, or **LDR**



The LDR is a component that has a resistance that changes when light falls on it. As the intensity of the light is increased so the resistance of the LDR falls.



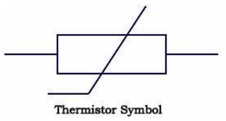
If the LDR is connected as part of a circuit as shown in the diagram then as the light level is increased its resistance falls and the proportion of the input voltage across it will also fall.

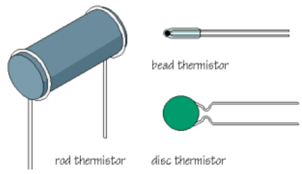


So in the light V_2 is LOW and in the dark V_2 is HIGH.
This type of system is used to automatically switch on street lights, as one example.

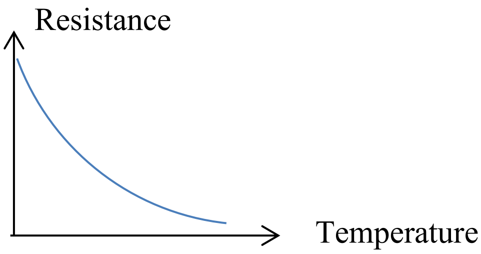
Thermistors (ntc)

A temperature-sensitive resistor is called a **thermistor**. There are several different types:



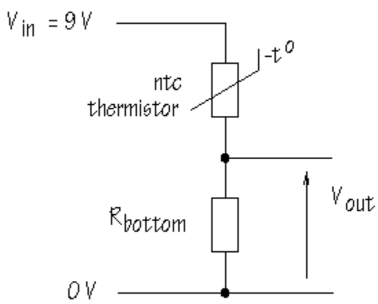


The resistance of most common types of thermistors **decreases** as the temperature **increases** :



Example of the use of a thermistor

How could you make a sensor circuit for use in a fire alarm? You want a circuit which will deliver a HIGH voltage when hot conditions are detected.



So, as the temperature increases, the thermistor's resistance decreases. This means less of the input voltage is now across the thermistor, and more across the resistor (R_{bottom}) – raising the alarm !

Unit 1.2 - The National Grid (Producing electricity)

The National Grid is the system of power stations, cables (& pylons), and transformers that supply electrical energy to our homes, schools, industries etc.

The main benefit of getting our electrical energy from a “grid” like this is that it is very reliable.

The only other option to produce electricity is **micro-generation** (e.g. solar panels on the roof; small wind turbines in the garden, etc.)

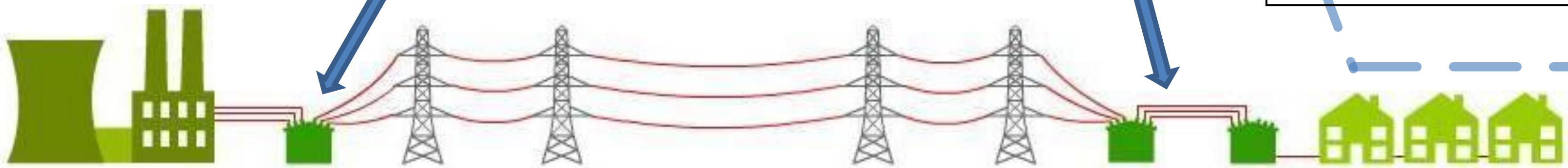
Large cables transmit (carry) the electricity across the country.

Power stations produce the electricity at voltages typically around 20,000 V.

Transformers step up (increase) the voltage to about 400,000 V in order to **reduce** the current.

Transformers step down the voltage to about 11,000 V for large industrial sites

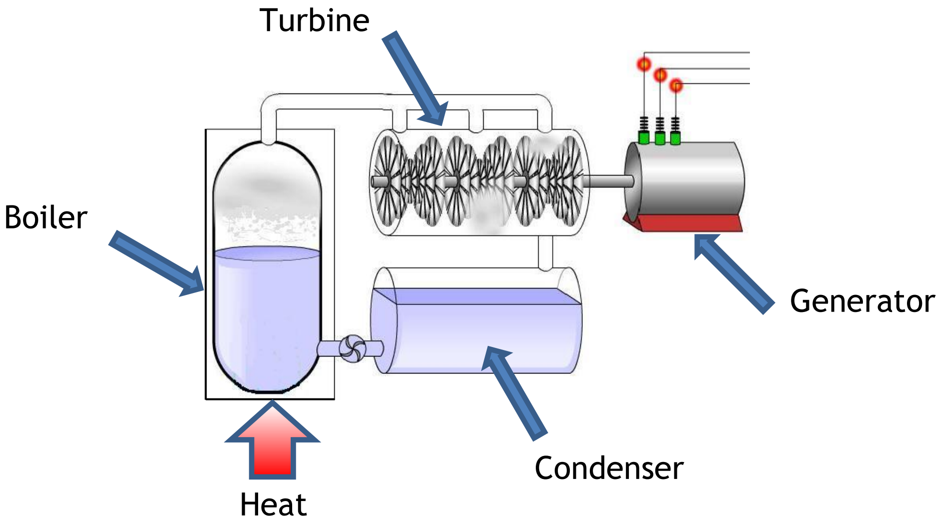
Transformers step down the voltage to a safer 240 V for use in our homes.



Producing electrical energy

There are 3 main ways to produce electricity for use in the national grid.

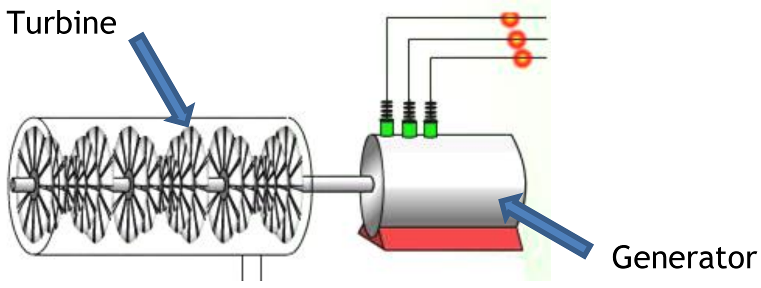
1. Shown below is a typical set-up for most power stations. The fuel is used to provide heat energy to water in a boiler. The water changes to steam which turns the blades of a turbine. The turbine is connected to a generator which then produces electricity.



Coal, oil & gas power stations work like this by burning the fuel.

Note that a nuclear power station also works as shown in the diagram, but that nuclear fuel doesn't "burn" in the usual way, and so doesn't release CO_2.

2. Shown below is a typical set-up for most other types of 'generators', e.g. hydroelectric ; tidal ; wave ; wind.
Water or air strikes the blades of a turbine to make it turn.
The turbine is connected to a generator which then produces electricity.



3. PV (photovoltaic) solar cells convert light energy directly to electrical energy.

Comparing the different power stations

All power stations need an energy **resource**, i.e. a source of energy that can be converted to electrical energy. All these resources are classed as either **renewable** or **non-renewable**.

A renewable resource is a resource we can make more of it in a short amount of time e.g. biomass, or is produced continually e.g. wind or rain (hydroelectricity).

Renewable	Non-renewable
Geothermal	Coal
Solar	Oil
Wind	Gas
Waves	Nuclear
Tidal	
Hydroelectric	
Biomass	

These are fossil fuels. When they are burned to produce heat, they also produce Carbon Dioxide (CO_2). CO_2 is a greenhouse gas that causes global warming.

Costs

One wind turbine

£ 80,000

BARGAIN ??

Wylfa Nuclear power station

£ 2,000,000,000

At first glance it may look like wind power is a much cheaper option, however, to make a fair comparison, we must quote these **commissioning** (build) cost values **per MW (M**ega **W**att) of electricity produced :

Wind farm : Each wind turbine costs £80 000, and produces about 25,000 Watts.
Number of wind turbine needed to make 1 MW = 1,000,000 W ÷ 25,000 W = 40
Total cost = 40 x £80,000 = £3.2 million **per MW**

Nuclear : Total commissioning cost is £2,000 million (£2 billion). Total electrical power produced is about 650 MW.
Therefore, Cost per MW = £2,000 ÷ 650 = £3.1 million **per MW**

So, in fact, the build costs are almost identical ! However, it's not quite this simple . . .
Other costs to consider are : Day-to-day **Running costs, Decommissioning costs** (the safe dismantling of the power station when it becomes too old).

Comparing the different power stations

In the Physics exam., you may be given data, usually in a table, and you will have to compare different power generation systems. Although you are not expected to know all the details for all the different power stations etc., it may be wise to know some basic advantages and disadvantages.

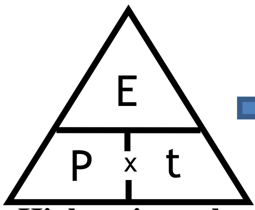
Type	Advantages	Disadvantages
Nuclear	No CO_2, reliable, generate large amounts of electricity and uses small amount of fuel.	Radioactive waste produced which needs to be stored for a long time, high commissioning and decommissioning costs and risks with terrorism.
Coal, Oil and Gas	Generate large amounts of electricity. Can be built in many locations.	CO_2 (global warming) and SO_2 (acid rain for coal) produced, transport of fuel is difficult and getting a secure supply.
Hydroelectric	No CO_2, generate large amounts of electricity, no fuel costs and start up time is short.	Need to flood large area of land, destroy wildlife habitats and building of large dams.
Wind	No fuel, no air pollution.	Eye-sore, unreliable, generate small amount of electricity.
Solar	Cheap to install on buildings, fairly reliable, no air pollution.	Need a lot of panels to generate large amount of electricity and does not work at night.
Geothermal	No air pollution, reliable	Ground source heating needs large area.
Biomass	Can generate large amount of electricity and carbon neutral.	Large areas of land needed to grow trees and plants.
Wave and tidal.	Tidal predictable. No air pollution. Tidal could generate large amounts of electricity	Wave more unreliable as it depends on the wind. Tidal could cause loss of wildlife areas.

Note : *A big debate at the moment is that the decommissioning cost (demolition etc.) for a nuclear power station is much more than originally estimated. Much of this is because the radioactive sections of the reactors stay dangerously radioactive for decades. Some estimates put the decommissioning cost at around £50 billion ! When this is accounted for in the overall costs of a nuclear power station, the price of the electricity is higher than it seems at present.*

Power equations

In general, power refers to how much energy is transferred per second. So, the equation for power is : Power = Energy ÷ time

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



Higher tier only

...and the other two forms of the equation are :

$$E = P \times t$$

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

Energy is measured in **Joules (J)**
Time is measured in **seconds (s)**
Power is measure in **Joules per seconds (J/s)** or **Watts (W)**

Example

If the power of a kettle is 3000 W, and it's on for 3 minutes, how many Joules of energy has it converted ?

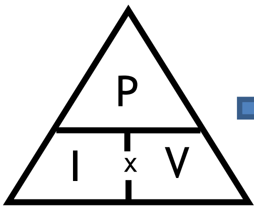
Answer : E = P x t = 3000 x (3x60) = 540 000 J

Look !!! The time must be in **<u>seconds</u>**, not minutes.

In electrical circuits, there's also another equation for power :

Power = current x voltage

$$P = I \times V$$



Higher tier only

...and the other two forms of the equation are :

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

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

Current is measured in **Amps (A)** Voltage is measured in **Volts (V)**

Example

If the power of a hair dryer is 1.2 kW, and it's working on "mains" power (voltage = 240 V) what's the current flowing ?

Answer : I = P / V = 1200 / 240 = 5 Amps (or 5 A)

Transmitting electricity

There are 2 major problems with getting electricity from the power stations to our homes, schools, industries etc :

1. Heat energy is wasted in the cables

2. Electricity can't be stored on a large scale

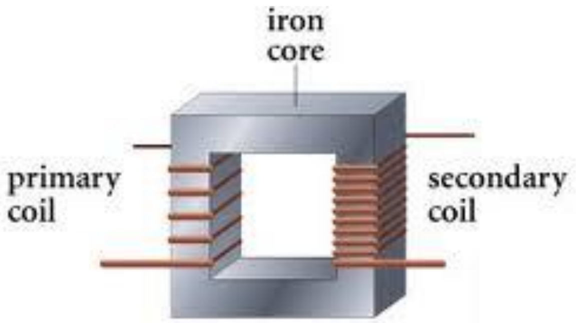
Info. ! How much electricity flows in a wire is known as electrical <u>current</u>.

1. Heat energy is wasted in the cables

Typically, power stations produce electricity with a total current of about 10,000 Amps.
This is a **very** large current, and will cause a lot of heat to be produced in all the wires/cables carrying the electricity around the country !

If nothing were done, there simply wouldn't be enough electrical energy left to work all our devices in our homes.

It's the flow of electricity through wires, i.e. the **<u>current</u>**, that produces heat. So, if we want to reduce the heat produced in wires, we need to keep the current to a minimum. This is how it's done :



A step-up transformer !

Higher voltage → Lower current → Less heat wasted in the wires

So, if the input voltage was, say, 20,000 Volts, and the step-up transformer increased this by a factor of 20 (20,000 x 20 = 400,000 V), then the current would reduce by a factor of 20.

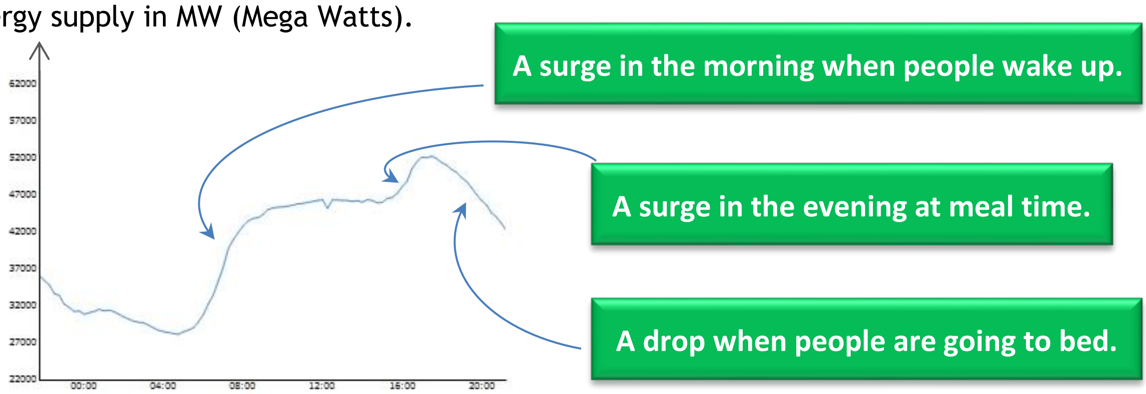
Note : The transformer creates no extra electrical power, so the input power is the same as the output power. The equation " Power = current x voltage " (P=IxV) can be used to calculate the effect on the current, when the voltage is changed.

Transmitting electricity

2. Electricity can’t be stored on a large scale

Since it is **not** practical to store electrical energy on a large scale, the right amount of it must be produced every second of every day. This causes a big headache for the national grid, as it has to try to get the right balance between **supply** (how much is produced) and the **demand** (how much is needed).

Energy supply in MW (Mega Watts).



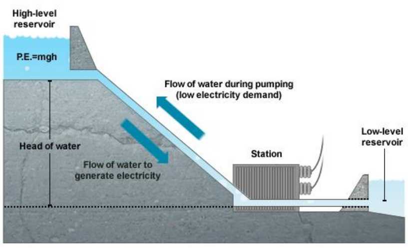
Note that “one-off” special events can cause surges too, as well as day-to-day events, e.g. a popular event at the Olympics; the FA cup final etc. The National Grid try to predict when these occur by looking at the TV listings !

A surge in demand can cause a black-out (no electricity across a large part of the country) unless the National Grid respond very quickly. More electricity is produced within seconds by fast-response power stations like “Electric mountain” in Llanberis, N.Wales – a hydroelectric power station.

When needed they open a few valves, which allow water in the upper lake to flow down through turbines.

Power stations in order of increasing start-up times.

Shortest	----------------------------->		Longest
Hydroelectric	Gas	Coal	Nuclear



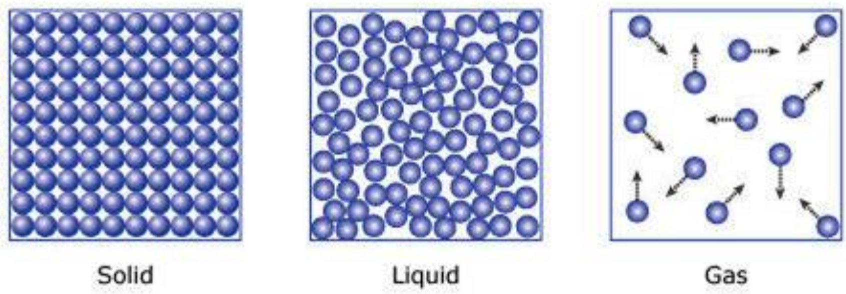
A fast-response hydroelectric power station (pump-storage). Electricity can be imported from other European countries in times of high demand.

Unit 1.3 – Making use of Energy

Density

Density tells us how much mass of a certain material is contained within a certain volume.
The more material in a given volume, the greater the density.

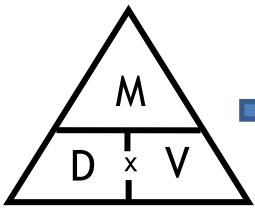
So, in general, solids have high density values whereas gases have very low values:



Here's the equation for calculating density :

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\boxed{D = \frac{M}{V}}$$



Higher tier only

...and the other two forms of the equation are :

$$\boxed{V = \frac{M}{D}} \qquad \boxed{M = D \times V}$$

Example

Calcuate the density of a glass block, length = 14cm, width = 4.5cm, height = 2cm, whose mass = 315g.

Volume of the block = $l \times w \times h = 14 \times 4.5 \times 2 =$ ***126 cm³.***

So, density of block, D $= \frac{M}{V} = \frac{315}{126} =$ **2.5 g/cm³**

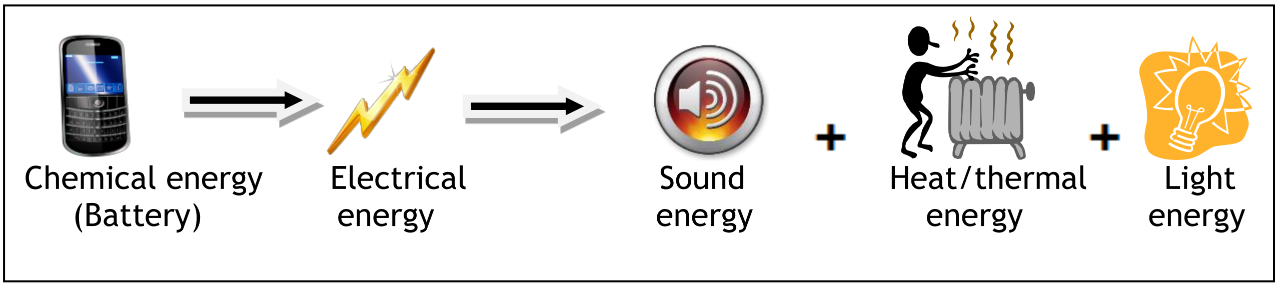
Water has a density of exactly 1 g/cm³ (or 1000 kg/m³).
Air has a density of about 0.0013 g/cm³.

This is why a turbine driven by a certain volume of water is capable of generating more electricity than a turbine driven by the same volume of air.
1 m³ of water weighs about 854 times the same amount of air.

Energy Transfer

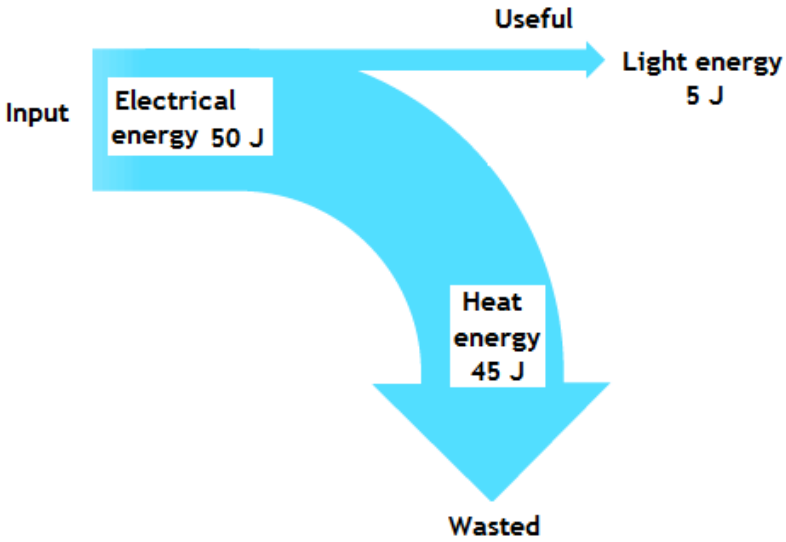
Type of energy	Example
Electrical	Into hairdryer.
Heat	Cooker.
Kinetic	Moving energy - car.
Sound energy	Speaker
Light energy	An object which emits light - LCD screen.
Chemical energy	Stored in food/battery.
Gravitational potential energy	Increases with height above ground - pump storage station.
Elastic potential energy	Stored in stretched elastic band/spring.

Example: energy transfer



Sankey Diagrams

Energy transfers can be shown using **Sankey** diagrams. They show the energy types which are involved and also the amount of energy involved. Below is a Sankey diagram for a filament bulb.



Key points

- Energy input = Energy output: 50 J (input) = 45J + 5 J (output)
- Useful energy is straight on.
- Wasted energy is curved downwards/upwards.
- Width of arrow tells us the amount of energy (to scale)
- Width of arrow is proportional to the amount of energy. They are drawn to scale e.g. 10J = 5mm

Efficiency

Energy efficiency: this is a measure of how much useful energy comes out of a device. It is measured in %.

$$\% \text{ Efficiency} = \frac{\underline{\text{USEFUL energy out (or power) tranfer}}}{\text{TOTAL energy (or power) input}} \times 100$$

Example: using the data from the Sankey diagram.

$$\% \text{ Efficiency} = \frac{5}{50} \times 100 = 10\%$$

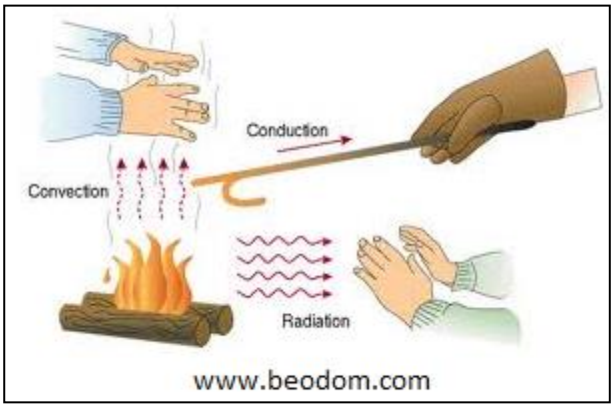
This is very poor and shows that the bulb is not very efficient. You cannot get more than 100%!!!

Coal power station 35% efficient, LED lights are 90% efficient and car engine 40% efficient.

The more efficient a power station is the ***less energy*** that is needed to be burnt so the ***less carbon dioxide*** emitted and also fossil fuels last longer.

Thermal energy (heat) transfer.

Thermal energy moves from **HOT** (High temperature) to **COLD** (lower temperature) (down a temperature gradient) e.g. a hot cup of tea gives out thermal energy to the surroundings.

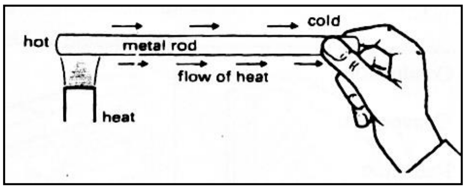


The greater the ***difference in temperature*** the more thermal energy transferred per second e.g. so the temperature of your mug of tea will drop at a greater rate when it is very hot.

3 types of thermal transfer: Thermal energy can be transferred via conduction, convection and radiation.

Conduction: In conduction the thermal energy flows through the object itself. It takes place in solids and liquids.

Conductors: materials which are good at conducting thermal energy e.g. metals like copper. The main reason metals are such good conductors of heat is because they have **free electrons.**



Insulators: materials which are poor at conducting e.g. air, plastic. Many materials which are insulators like wool trap air e.g. jumper.

Convection: Heat flows by convection in **liquids** and **gases** only. Convection cannot occur in solids because the particles are fixed.

This applies to liquids and gases:

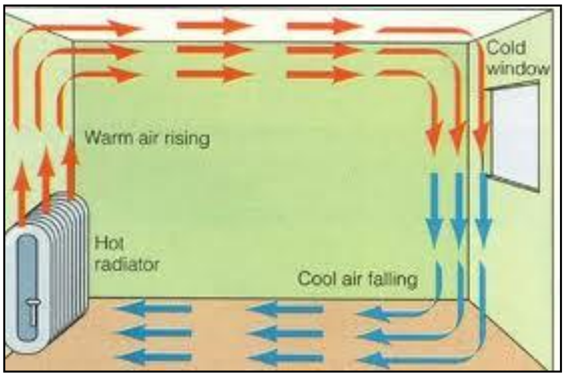
1. When gas/liquid heated.

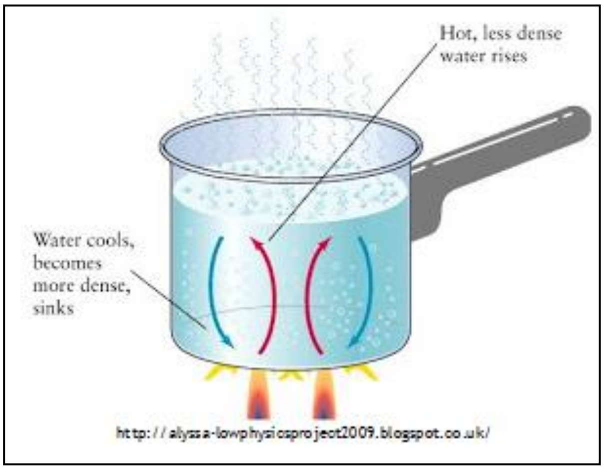
2. The particles speed up

3. Volume of gas/liquid increases. Gas/liquid expands.

4. Density decreases and so gas/liquid rises.

5. Colder, denser gas/liquid falls.





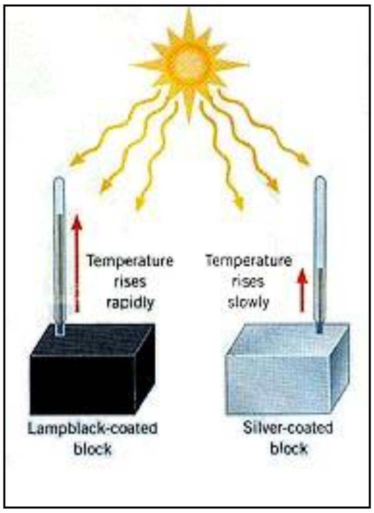
Some materials like foam trap air, which reduces the convection current. This reduces heat loss/transfer through convection.

Thermal Radiation (infrared). Any hot object will emit thermal radiation in the form of infrared electromagnetic radiation.

The higher the temperature of an object the more thermal radiation it will emit. This is the only means of heat transfer through a vacuum (space). Objects can ***emit*** and ***absorb*** heat radiation

Shiny objects are good at reflecting thermal radiation e.g. aluminium foil around food, caravans painted white.

Matt black objects are very good at absorbing/emitting thermal radiation e.g. wood burning stove is painted black and black cars become hotter in the sun.



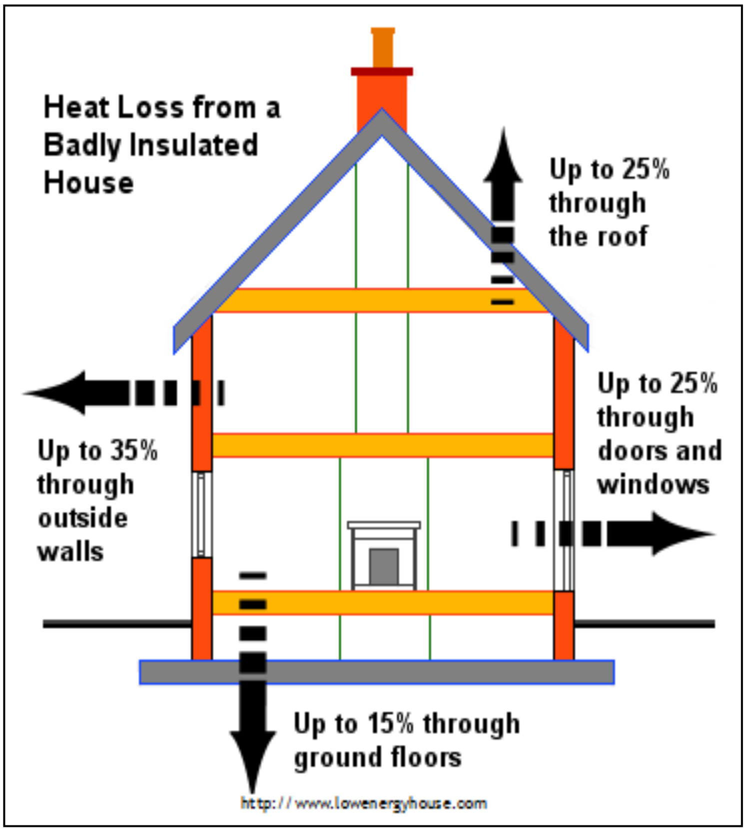
Dull Black | **Shiny Black** | **Colours (dark --> Light)** | **White** | **Silver**

Best Emitter/ Absorber → **Poorest Emitter/ Absorber**

Insulating the house

It is important to try and reduce the thermal energy loss from a house. This will reduce ***energy bills*** (saving money) and also reduce the ***carbon dioxide emissions*** as the result of heating your home. CO_2 is a greenhouse gas which increases global warming.

There are many types/systems of insulation that can be installed in the house to reduce **NOT stop** heat loss. Most of these insulating materials work because they ***trap air*** which is a poor conductor. If the air is trapped heat loss through convection is reduced because warm air cannot rise and cold air cannot fall.



Insulating systems

Insulation type/system	How it works.
Double glazing	Two sheets of glass separated by a gap filled with e.g. argon or a partial vacuum. It reduces heat loss through conduction and convection.
Draught proofing	Strips of draught proofing can be fitted around doors and window frames. Draught excluders can be placed at the bottom of doors. It reduces heat loss through convection.
Loft insulation	Rock wool (mineral wool) can be placed between the rafters in the loft. These materials are good at trapping air. Reduces the heat loss through conduction and convection.
Floor insulation	Fibreboard or mineral wool is placed to reduce heat loss via conduction and convection.
Cavity walls	Walls are built with an inner and outer wall. The gap/cavity can be filled with foam or insulation board which reduces conduction and convection.

Installing wind turbines and solar planes DO NOT reduce heat loss

Note: The higher the temperature of the inside of your house compared to the outside the more energy your house will lose per second because of a greater difference in temperature.

Comparing the costs

There are 2 main energy requirements in the home :

1. Electricity

2. Heat

You will be expected to compare the different energy sources in terms of their cost, their effect on the environment, **payback time**, etc.

"Payback time" is the time it takes to get the money back in energy savings for the money spent on a particular improvement. Here's the equation for calculating "payback time" :

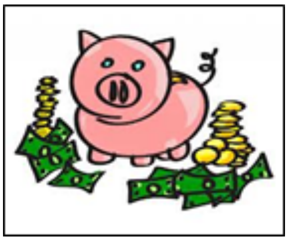
$$\text{Payback time (in years)} = \frac{\text{installation cost}}{\text{annual savings}}$$

Note : This equation is not given in the exam at all, so you'll have to memorise it !!

So, payback time can be calculated by dividing the cost of the system with the saving per year (how much your bill has been reduced).

Example: it costs £4000 to install double glazing in your house. Your energy bills are reduced by £175 per year. How long will it take before the cost of your investment is paid back.

$$\text{Payback time} = \frac{4000}{175} = \quad 22.9 \text{ years.}$$



You will <u>not</u> be expected to remember data about different energy sources, only use what is given in the exam question.

See the example on the next page.

Example from a past paper

1. A householder is considering using a **renewable** energy source to help him save money on electricity bills. He used some information from a local store to draw up the following table.

	Installation cost (£)	Saving per year (£)	Payback time (years)	Maximum power output (W)	Conditions needed
Wind turbine	1 200	600	2	5 400	Average wind speed 4 m/s, (maximum 12 m/s)
Roof top photovoltaic cells (PV) of area 4 m^2	14 000	....	7	1 800	South-facing roof

(a) What is meant by a renewable energy source ? [1]

(b) (i) Complete the table by calculating the saving per year for the roof top Photovoltaic cells (PV). [1]

(ii) Give reasons why the payback times for the wind turbine and roof top photovoltaic cells (PV) may be different from both those shown in the table.[3]

(iii) Calculate the area of roof top photovoltaic cells (PV) needed to produce the same maximum power as a wind turbine.[2]

(c) Explain how the introduction of roof top photovoltaic cells (PV) and wind turbines would benefit the environment. [2]

Answers

(a) Easily replaced / replenished / will not run out / sustainable

(b) (i) [£] 2000

(ii) Wind - variable wind speed (1) Solar - hours of sunshine / roof may not face South or intensity of Sun (1) Fuel costs could change (1)

(iii) 5400 ÷ 1800 = 3 (1 mark)

3 x 4 = 12 m^2 (1 mark)

(c) Reduces CO_2 (1) which reduces the greenhouse effect / global warming (1) or
Less SO_2 (1) which results in less acid rain (1) or
Use less fossil fuels (1) so less extraction needed / less CO_2 / less SO_2 (1)
("less pollution" not accepted as it's not specific enough).

Comparing the cost of different energy sources used in transport

Scenario : You and 2 friends are planning a trip to see your favourite group in concert in Paris ! (One of the parents is driving you there and back !). Each of the 3 families have the same car, but each car uses a different fuel.

Distance from Llanrwst to Paris (one way) = 750km

Fuel type	Cost per litre (£ / l)	Fuel used to travel 100km (l / 100km)
Diesel	1.15	5.46
Petrol	1.13	6.31
Liquid Petroleum Gas (LPG)	0.65	7.41

Use the data below to calculate the fuel costs to drive from Llanrwst to Paris **and back,** for each fuel type.

Step 1 : Calculate the total distance travelled for the journey there **and back.**

Total distance = 750km x 2 = 1500 km

Step 2 : Use the 3rd column to calculate the total amount of fuel used by each type of car.

Diesel

Fuel used = 1500 ÷ 100 = 15
= 15 x 5.46
= 81.9 L

Petrol

Fuel used = 15 x 6. 31
= 94.65 L

LPG

Fuel used = 15 x 7.41
= 111.15 L

Step 3 : Use the 2nd column to calculate the cost of those amounts of fuel.

Cost = amount of fuel x cost per litre
= 81.9 x 1.15 = £ 94.19

Fuel	Amount of fuel (l)	Cost (£)
Diesel	81.9	94.19
Petrol	94.8	107.12
LPG	111.2	72.24

Unit 1.4 - Domestic electricity

Calculating the cost of electricity

When electricity companies need to calculate your electricity bill, they simply count how many "units" (kWh) of electrical energy you've used since your last bill. The Joule is much too small for the electricity companies.

1 kWh is the electrical energy converted by a 1 kW (1000W) appliance used for 1 hour.

The two equations needed to calculate the cost of electricity are:

Units used (kWh) = power (kW) × time (h)

cost = units used × cost per unit

The number of units of electrical energy used are therefore measured in "kilo-Watt-hours"

Once the "number of units" (kWh) has been calculated, it is then easy to calculate the cost of the electricity - see the example below :

Example

If the power of a microwave oven is 850 Watts, and is on for a total of 30 minutes, calculate the cost of the electricity it uses if each unit (kWh) costs 12 pence.

$\text{W} \xrightarrow{\div 1000} \text{kW}$ $\qquad$ $\text{minutes} \xrightarrow{\div 60} \text{hours}$

Units used = P (kW) x t (h) = 0.85 x 0.5 = 0.425 kWh

Cost = 0.425 x 12 pence = 5.1 pence

Converting between kWh and Joules

The 1st step is to change the kilo (k):

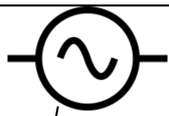
5 kWh x 1000 → 5000 Wh

The 2nd step is to change the hours to minutes and then seconds:

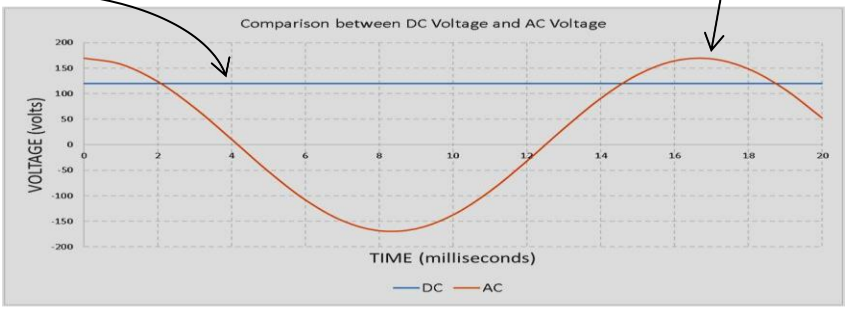
5000 Wh x 60 x 60 = 18,000,000 J

AC/DC

An **alternating current (a.c.)** is one that continuously changes direction.
e.g. Mains electricity is an a.c. supply. The UK mains supply is about 230V and has a frequency of 50Hz.



A **direct current (d.c.)** has a constant direction.
e.g. Cells and batteries.



Electrical Safety

Two wires supply our homes with electricity. One is called

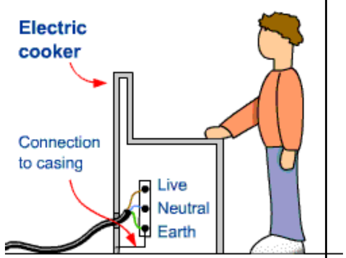
1. **LIVE** (brown), carries the current to the house/appliance at a high voltage. Switches and fuses are placed into the live wire.

2. **NEUTRAL** (blue), completes the circuit and carries the current away at low/zero voltage.

There is one more wire in the home:

3. **EARTH**: (yellow and green) – is a safety wire which can carry current safely into the ground if a fault develops in a metal framed appliance.

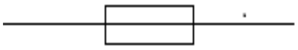
The Earth Wire



If the electrical device has a metal case there is a danger that a person may receive an electric shock if the live wire touches the metal case. This can kill you. To prevent this from happening, the metal case is connected to the earth wire in the plug, which means that the current would go straight the low-resistance earth wire. The strong current would blow the fuse or trip the mcb (miniature circuit breaker) and break the supply/circuit.

Double Insulation

Some appliances have the above symbol. Not only are the wires insulated with a plastic sheath (as usual), but the device has another layer of electrical insulation, e.g. it may have an outer casing that is entirely made of plastic, and so does not need an Earth wire.

The Fuse: 

The wire in the fuse is very thin. If too large a current flows due to a fault in the device, the wire inside the fuse becomes hot and melts or 'fuses'.
This prevents the device from overheating or catching fire.
The fuse will not protect you from an electric shock if you touch the live wire.

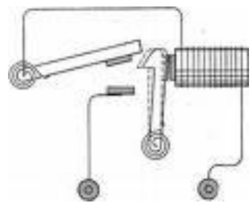
3 common fuses are available: 3A, 5A, and 13A.

Disadvantages of the fuse:

1. A fuse works relatively slowly and therefore you could receive a bad shock before the circuit breaks.
2. It is possible to receive a shock with a current that is too low to break the fuse.
3. A new fuse needs to be inserted every time it blows.

Miniature Circuit Breaker - mcb

There is an electromagnet inside the circuit breaker. When the current becomes large enough the strength of the electromagnet is enough to separate the connections and break the circuit.



- A circuit breaker can be used instead of a fuse.
- It works very quickly (a hundredth of a second).
- A circuit breaker can be reset.

Disadvantage: Exactly like the fuse, it does not protect from electric shocks with a low current. So, you could still receive a shock if you touch the live wire.

Residual Current Circuit Breakers (rccb)

This device is placed in a socket first, and then the equipment is plugged into the device. Its purpose is to protect the user from electric shocks.

Live wire current = neutral wire current → everything working correctly.

If someone accidentally touched the live wire, some of the current would flow through their body to the earth. Then,

Live wire current > neutral wire current → Circuit breaks

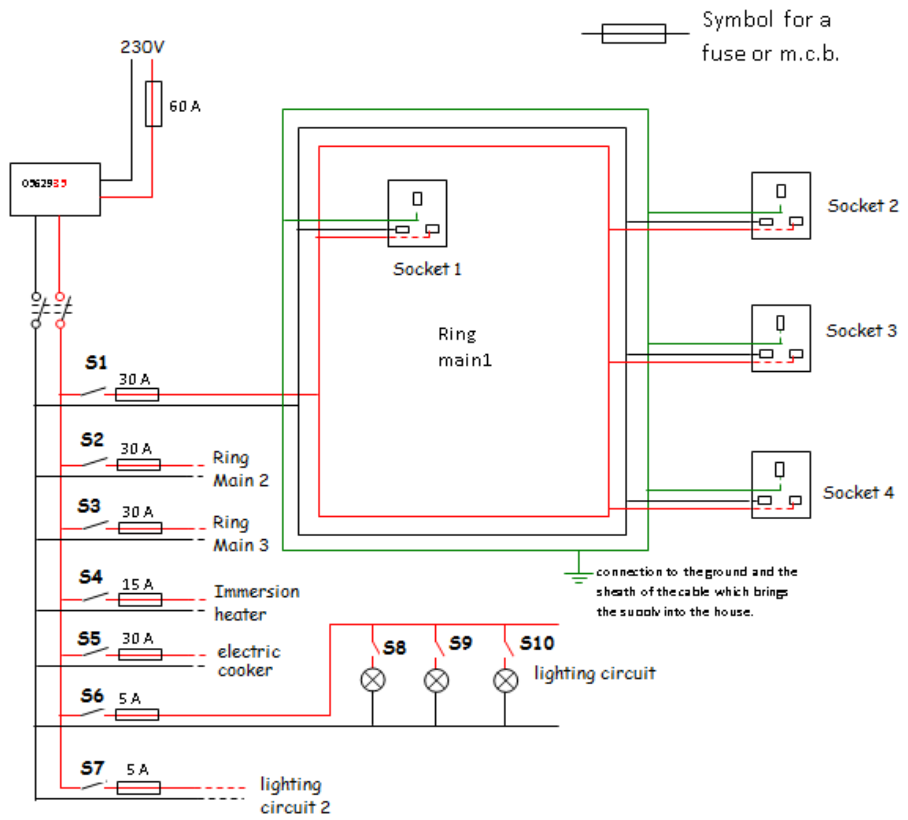
Main Advantages:

- ***Protects the user whereas the mcb protects the appliance***
- Works very quickly (0.001seconds).
- Very sensitive and works with a very small difference in the current (0.003A).
- Can be reset.

Ring Main.

Advantage of a ring main

1. The cables can be made thinner because there are two paths for the current.
2. Each part of the cable carries less current because the current flows both ways.
3. A ring main circuit is more convenient since sockets can be placed anywhere on the ring.
4. Each socket has 230V and they can be operated separately.



1. What is the voltage across socket 1? Answer= 230 V

2. Which switch would you use if you wanted to do maintenance work on ring main1? S1

3. What is the maximum power that could be supplied to the electric cooker?

P = V x I

= 230 x 30

= 6900 W

4. There are 3 identical bulbs in the lighting circuit, and they each require a current of 0.05A. Calculate the total power of the 3 bulbs.

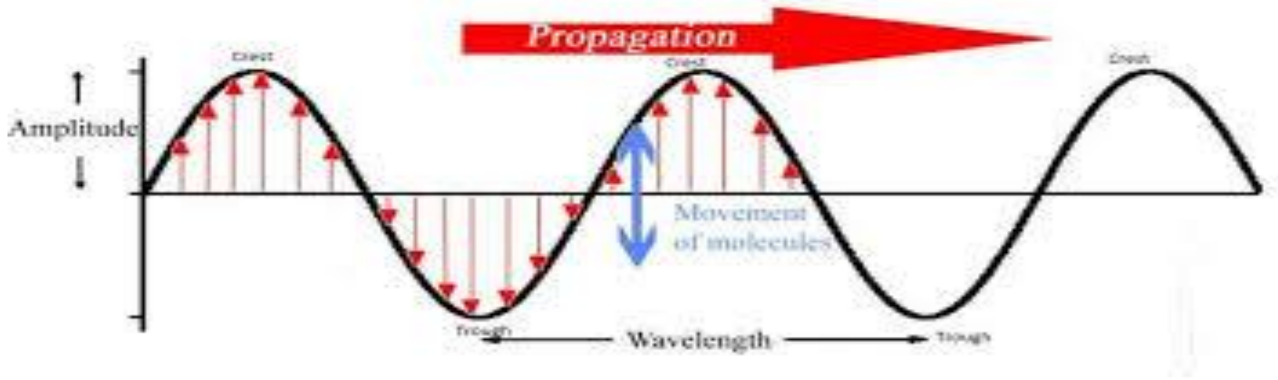
Total current for all bulbs = 0.05 + 0.05 + 0.05 = 0.15 A

Power = voltage x current = 230 x 0.15 = 34.5 W

Unit 1.5 - Waves

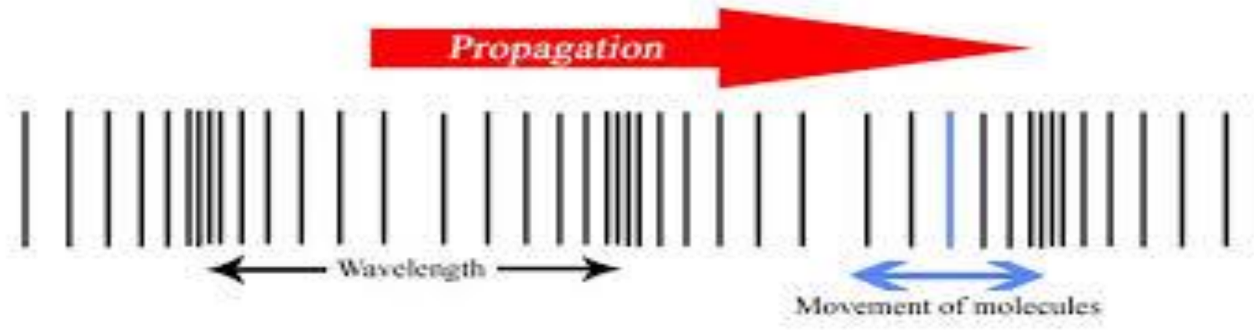
Basic information

Transverse: ***The oscillations of the particles are at right angles (90°) to the direction of travel (propagation) of the wave.***



Examples: All electromagnetic waves (Light, microwaves etc), S-waves,

Longitudinal waves: ***The oscillations of the particles are in the same direction as the wave is moving.***



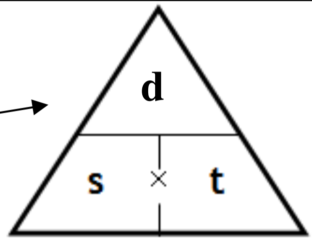
Examples: Sound waves, P-waves

Characteristics	What is it?	Units
1.Wavelength λ	The distance from a crest to the next crest or the distance it takes to repeat itself.If there are 10 waves in 5 metres then the wavelength is 0.5m	Metres, m
2. Frequency **f**	The number waves per second. 1 Hz is 1waves per second. If there are 40 waves in 10 seconds then the frequency is 4 Hz.	Hertz, Hz
3. Amplitude	Distance from the middle of the wave to the crest/top. The greater the amplitude the more energy the wave is carrying.	Metres, m

Calculations involving waves.

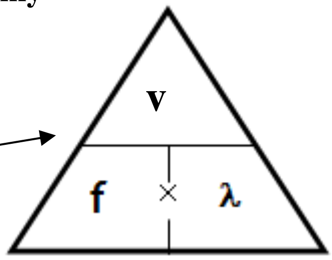
The speed of a wave can be calculated in 2 ways.

1. Speed = $\frac{\text{distance}}{\text{time}}$



Higher tier only

2. wave speed = frequency x wavelength
c = f λ



Higher tier only

Example 1: A gun is fired and person 1200m away hears the shot 4 seconds after the gun is fired, what is the speed of the sound wave? Since distance and time is given we must use the first equation (always show your working).

$$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{1200}{4} = 300 \text{ m/s}$$

Example 2: A water wave moves at a **speed** of 2.5 m/s. Its **wavelength** is 7.5 m. Use the correct equation from to calculate the **frequency** of the wave. We use the 2nd equation since speed and wavelength are given.
Speed = frequency x wavelength

Rearrange the equation, $\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{2.5}{7.5} = 0.33 \text{ Hz}$

Example 3: Light from the sun travel a 150,000,000 km at a speed of 300,000,000 m/s (3×10^8 m/s). Calculate the time in minutes it takes for the light to reach us here on Earth.
We have to units to change here: 150,000,000 km, into metres
150,000,000 km x 1000 = 150,000,000,000 m or 1.5×10^{11} m
speed = $\frac{\text{distance}}{\text{time}}$, rearrang

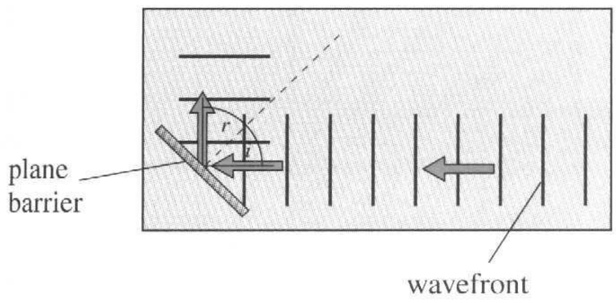
$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{150{,}000{,}000{,}000}{300{,}000{,}000} = \frac{1.5 \times 10^{11}}{3 \times 10^{8}} = 500 \text{ s}$$

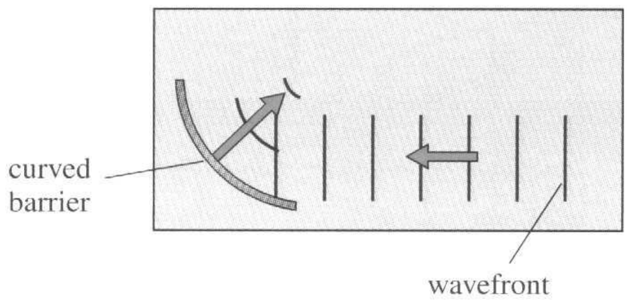
Changing seconds into minutes: $\frac{500}{60} = 8.3$ minutes

Properties of waves

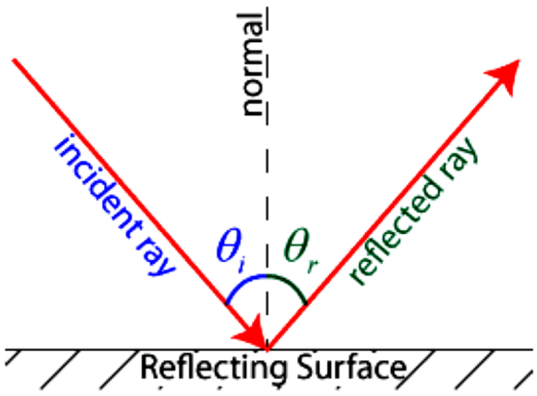
Reflection. As the waves strike a plane (flat) barrier they are reflected. This is very similar for a beam of light reflecting on a plane mirror. If a curved (concave) barrier such as a satellite dish is used, the waves can be made to converge (concentrate) at a point. The angle of incidence and reflection will be equal.

Reflection on a satellite dish.

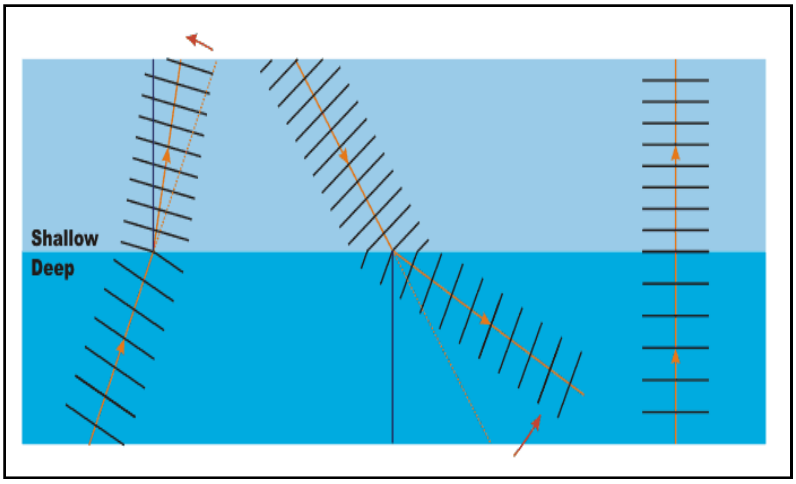




The angle of incidence and reflection will be equal.

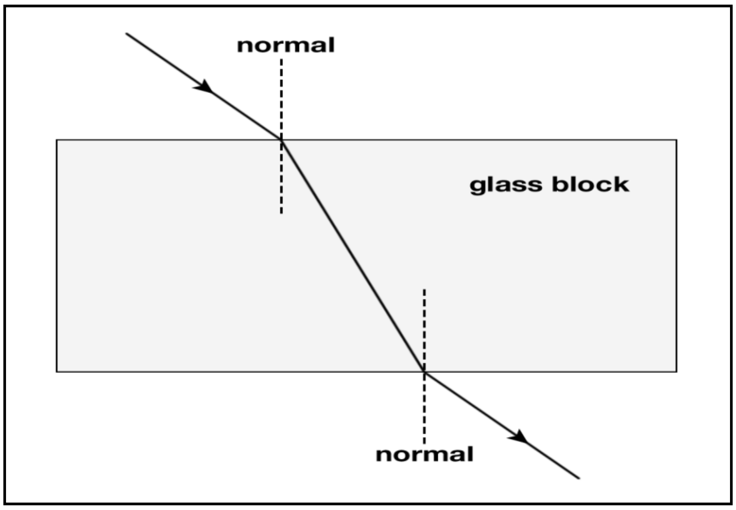


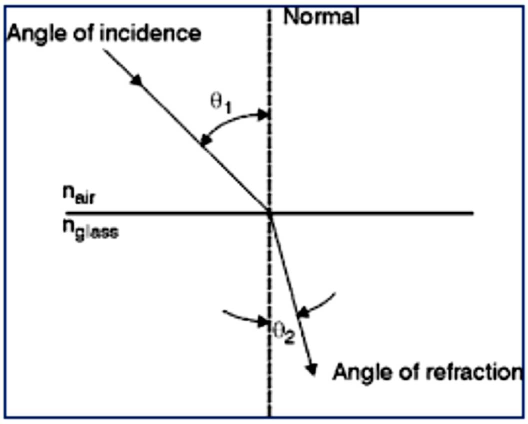
Refraction: Refraction is the change in direction of a wave at the boundary between two materials. This is caused by a change in speed.



Water. This occurs when water waves pass between deep and shallow water. The waves move more slowly in shallow water. The ***frequency of the waves remain constant*** and so the wavelength decreases. When the waves move from shallow to deeper water, their speed increase and they change direction away from the normal

Refraction of Light. When light passes in between materials of different optical densities, it causes the light ray to refract. When the light moves from air to glass it slows down, and bends towards the normal. When the light emerges from the glass block it speeds up and bends away from the normal (opposite direction).

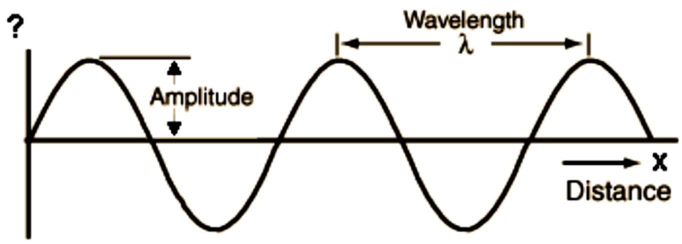




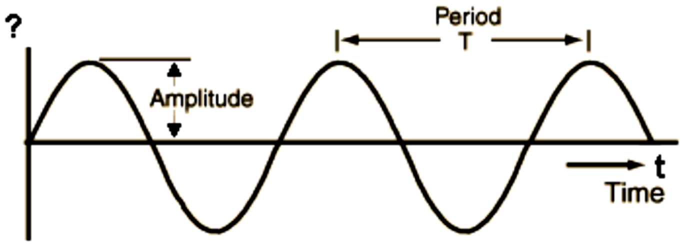
Changes in wavelength are proportional to changes in wave speed. This is true since the frequency remains constant.

Displacement-time and displacement-distance graphs

This graph is a snapshot of the whole wave at an instant in time.

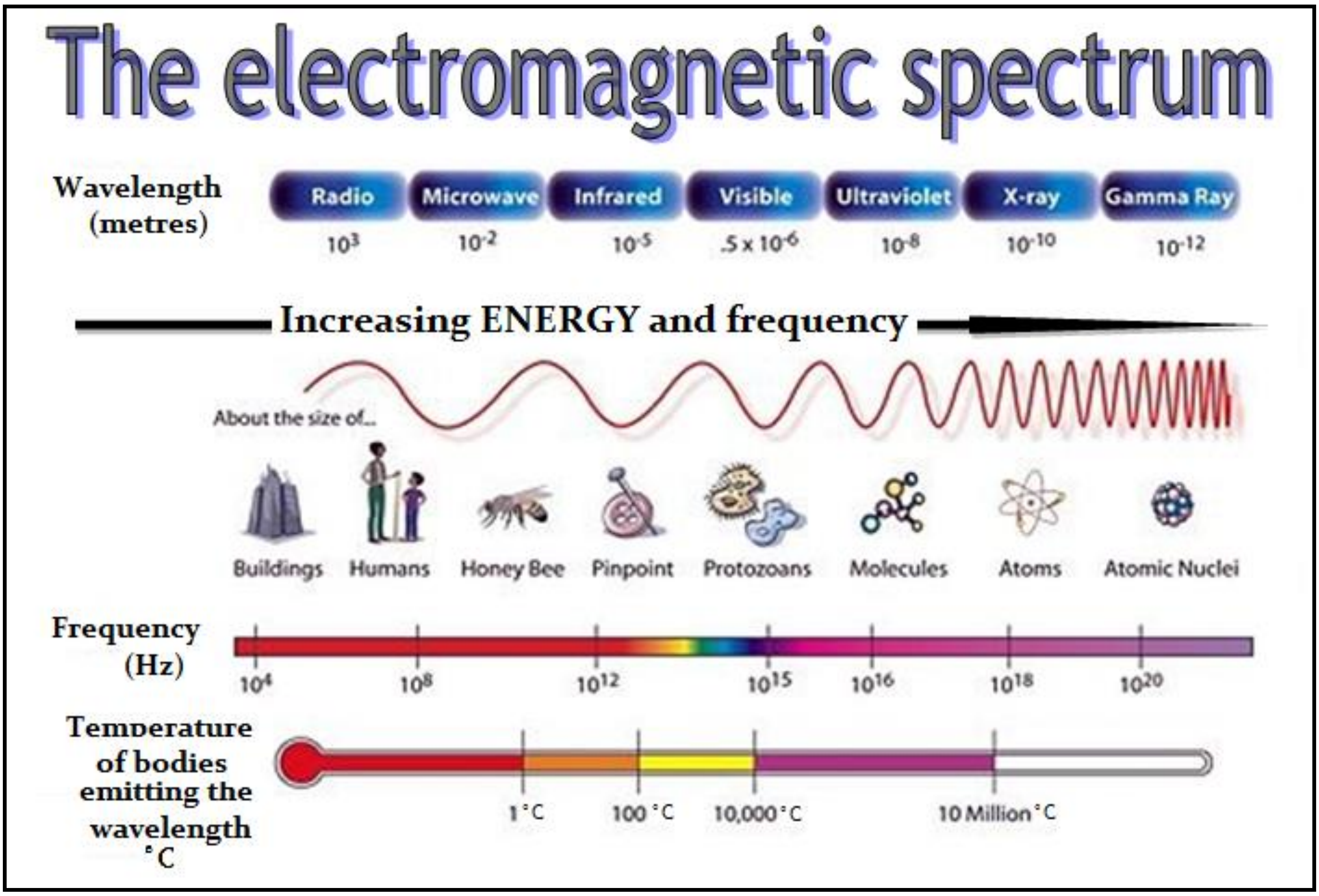


This graph shows the motion/ movement of one particle in the wave over time.



The electromagnetic spectrum.

A family of waves that have similar properties.



The frequency and energy increase from radio to gamma.

The wavelength decreases from radio to gamma.

Note: they do not have to arrange the spectrum in this order, they could do it starting with gamma on the left (it would still have the most energy).

Common properties of the electromagnetic spectrum:

1. **Travels at the same speed in a vacuum. (300,000,000 m/s or 3×10^8 m/s)**

2. **Transfers energy/information from one place to another.**

3. **They are transverse waves.**

Uses of the em spectrum.

Part of em spectrum	Properties/dangers.	Uses
Radio	Longest wavelength, no known dangers.	Radio and television signals.
Microwave	Short wavelength. Some concern that they pose a health risk to phone users. Absorbed by water molecules.	Heating food, satellite and mobile phone communication.
Infrared (thermal radiation)	Longer wavelength than visible light. Can burn if you get too much exposure.	Transmitting information in optical fibres, remote controls and infrared cameras
Visible light	If the light is too bright it can damage the eye/retina.	Photosynthesis. Lasers in CD players.
Ultraviolet	Can ionise cells in the body leading to skin cancer.	Sun tan beds, detecting forged bank notes.
X-rays	They are ionising which can lead to cancer.	Medical imaging, inspection of metal fatigue and airport security.
Gamma	The most ionising in the em spectrum because they have the most energy.	Cancer treatment - killing cancer cells and sterilising medical equipment or food.
Ionising radiation is to interact with atoms and to damage cells by the energy they carry.		

Radiation emitted by objects. (Higher tier only)

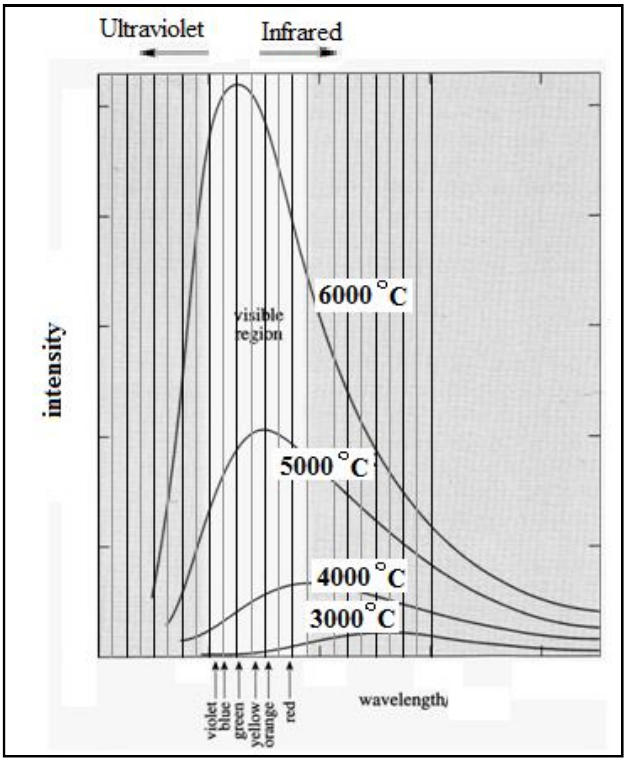
Hot objects emit radiation over a ***wide range of*** wavelengths.

- The **higher the temperature** of an object, the greater the **amount of radiation emitted.** The frequency also increases, and the shorter the wavelength of the peak emission/highest intensity.

- At room temperature objects emit weakly in the infra red.

- An incandescent (giving out light) light bulb (at about 2700°C) filament emits much more strongly – in the visible and infra red.

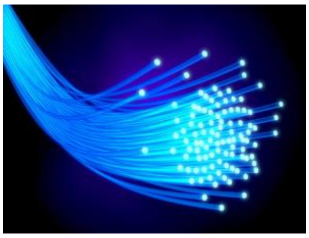
The Sun (at about 5500°C) radiates very strongly/mainly in the visible but also in the infra red and ultra violet.



Comparing forms of communication.

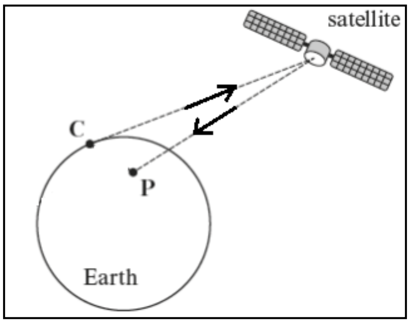
Optical Fibres. The signal is sent using **infrared** light because it can travel further within the cable than visible light. These cables are laid between the continents. The signals travel at 200,000,000 ($2x10^8$) m/s and can carry more information (1.5 million phone calls per cable).

The advantages of optical fibre over traditional copper cables are



1. They require fewer boosters to increase strength of the signal.
2. More difficult to bug (tap into) the signal.
3. They weigh less.
4. Use less energy.
5. No interference from neighbouring cables.

Satellites.

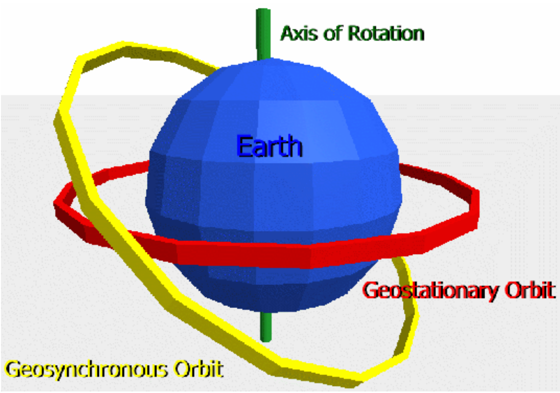


Communication satellites need to be in a **geostationary orbit** (36,000 km high) because Satellite needs to be above a fixed point on the Earth so satellite dishes (e.g. sky dish) do not have to be moved.
They use **microwave** radiation to send signals to the satellite because it can pass through the atmosphere.

To send a signal from C to P, the signal must travel from C to the satellite and relayed back to P. To send a signal a greater distance then more than 1 satellite can be used.

Definition of* geosynchronous *orbit: *has an orbit time of 24 h however the object in this orbit only returns to exactly the same position in the sky after a period of one day.*

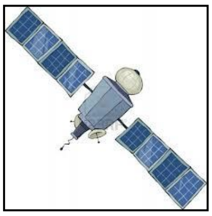
Definition of* geostationary *orbit: the satellite is remains above the same point on the Earth's surface (above equator) and takes 24 hours to complete an orbit (which is the same as the Earth's period of rotation).



The distinction being that while an object in geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position. A base station can be in constant communication with a geostationary satellite but only once every 24 h with a geosynchronous satellite.

Time delay.

Method 1, satellite: If the distance from the Earth's surface to each satellite is 3.6×10^7 m, the total distance the microwaves must travel to go from Wales to Italy is (up and down once) = **2 x** 3.6×10^7 = $\mathbf{7.2 \times 10^7}$ **m**

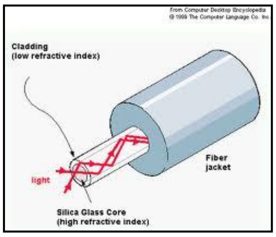


Microwaves are electromagnetic waves so travel at 3×10^8 m/s.

$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{7.2 \times 10^7}{3 \times 10^8} = \mathbf{0.24\ s}$$

Method 2, optical fibres: The distance from Wales to Italy is about 2000 km =

2×10^6 m.



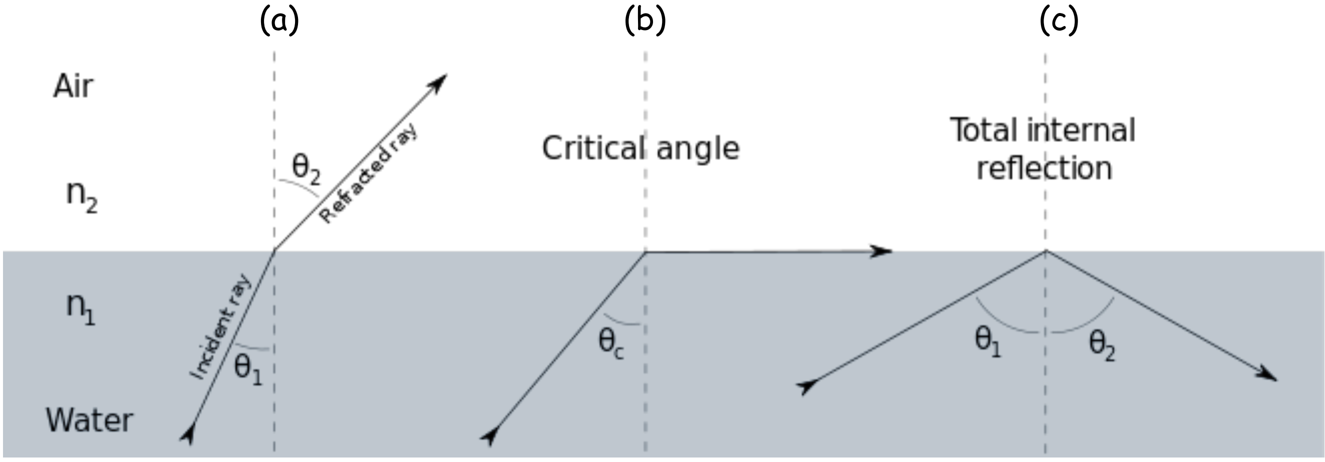
Infrared waves travel at about **70%** of the speed of light in an optical fibre, so, $0.7 \times 3 \times 10^8$ = $\mathbf{2.1 \times 10^8}$ **m**

$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{2 \times 10^6}{2.1 \times 10^8} = \mathbf{0.0095\ s}$$

There is less time delay with optical fibres and they are not affected by the weather.

Unit 1.6 - Total Internal Reflection

Total internal reflection

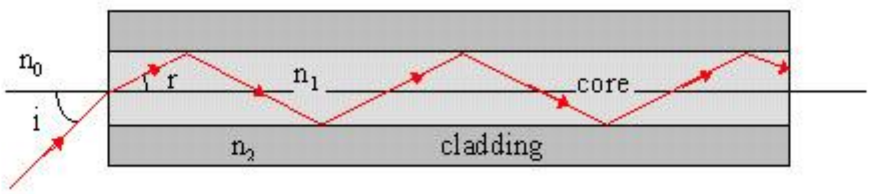


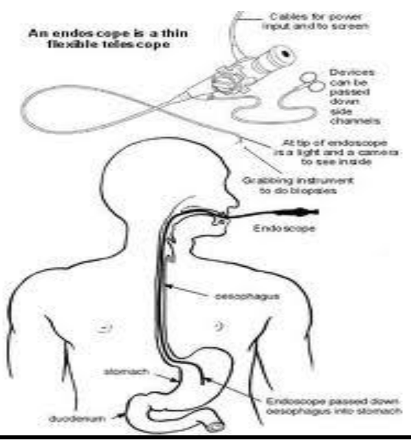
This phenomenon occurs when light moves from a more optically dense material (e.g. water) to a less optically dense material (e.g. air) causing a change in speed.

1. The incident angle θ_1 is ***less than*** the critical angle and so the light ray refracts/ bends away from the normal as it emerges from the water. θ_2 is the **angle of refraction.**
2. The incident angle θ_1 ***equal*** to the critical angle and so the light ray passes along the surface of the boundary.
3. The incident angle is ***greater than*** the critical angle and so the light ray is reflected back into the water - known as ***total internal reflection***. $\boldsymbol{\theta_1 = \theta_2}$

Uses of total internal reflection.

Optical Fibres: these can be used to carry information by using infra-red light. There are many uses from internet, cable TV, phone, some signs



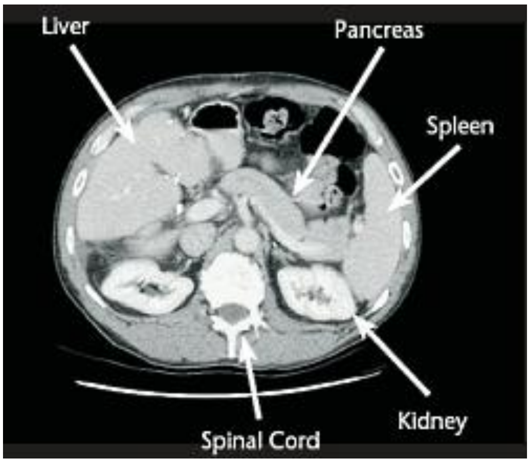


Endoscope: An endoscope is any instrument used to look inside the body. Thousands of optical fibres are bundled together in an endoscope which is inserted into a human body by the doctor. Light can be directed down the fibres even if they are bent, allowing the surgeon to illuminate the area under observation. He/she can then view this from a television camera linked to a monitor.

CT scan (CAT scan)

A **CT scan**, also known as a **CAT scan**, is a specialised X-ray test. It can give quite clear pictures of the inside of your body in 3D. In particular, it can give good pictures of soft tissues of the body which do not show on ordinary X-ray pictures.

CT scans can produce detailed images of many structures inside the body, including the internal organs, blood vessels and bones.



CT scans wouldn't normally be used to check for problems if you don't have any symptoms.
This is because the benefits of screening may not outweigh the risks, particularly if it leads to unnecessary testing.

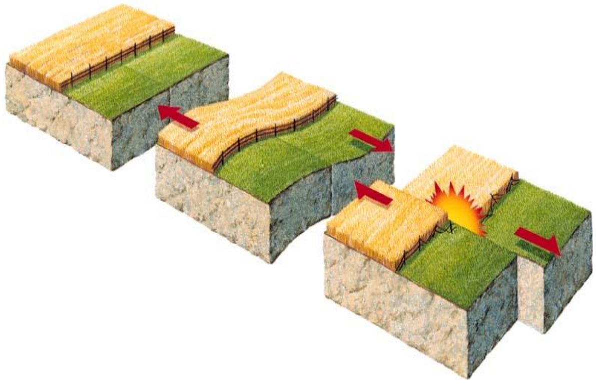
Comparing CT scans and endoscopy

Endoscopy uses optical fibres and CT scans use X-rays. Endoscopy is used to investigate specific areas of the body and it is less harmful than CT scans. CT scans are used to generate more overall images of the body and are a higher risk than endoscopes. CT scans are 3D.

Unit 1.7 - Seismic waves

Seismic waves / Earthquakes

The mechanisms and processes involved when earthquakes occur are extremely complex. However some of the characteristics of earthquakes can be explained:

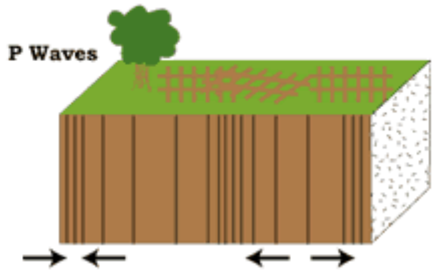


- Over time stresses in the Earth build up (often caused by the slow movements of tectonic plates)

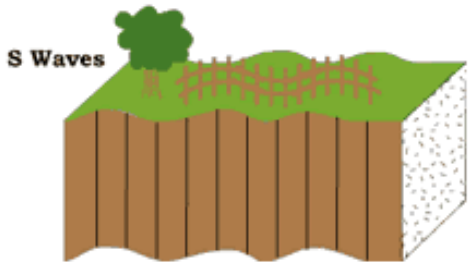
- At some point the stresses become so great that the Earth breaks … an earthquake rupture occurs and relieves some of the stresses (but generally not all) and a lot of **energy** is released.

The 3 types of seismic waves.

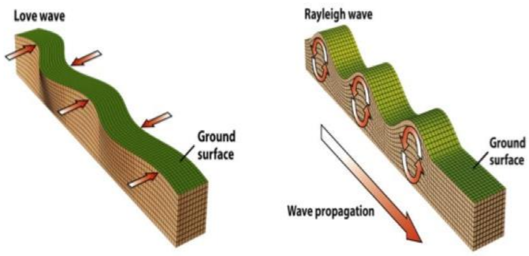
Earthquakes result from P, S and surface waves generated by the release of energy stored in rocks on either side of a fault.



Primary (P) Waves. They are called primary waves because they arrive first. The main characteristics of primary waves are:
- They are longitudinal waves.
- Faster than S waves.
- Can travel through ***liquids*** and ***solids.***



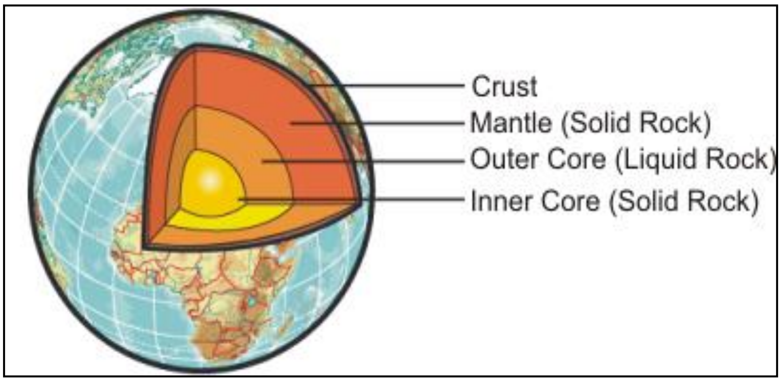
Secondary (S) Waves. They are called secondary waves because they arrive second. The main characteristics of secondary waves are:
- They are transverse waves.
- Travel slower than P waves.
- Can only travel through ***solids.***



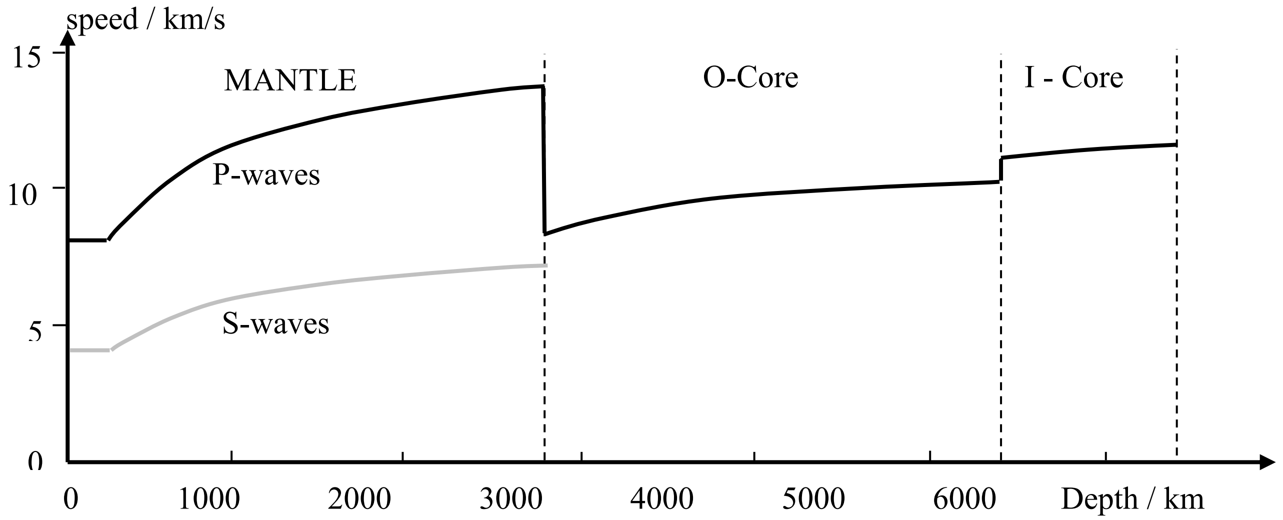
Surface Waves: Travel along the Earth's crust. The main characteristics of surface waves are:
- Have higher amplitudes than P and S waves.
- These usually cause buildings to be knocked down.
- Formed from a combination of P and S waves.
- Generally slowest of the three waves.

The structure of the Earth

The velocity of a P or S wave depends on the physical properties of the rock. In fact, if the velocity of the wave can be measured, it may be possible to predict the type of rock the wave travelled through - indirect detection of rock type.



Speed of P-waves and S-waves:



[Rigidity of the material has a greater effect on speed than density].
Look at the graph and notice that there are no S-waves in the outer core.

This is because S-waves cannot travel in liquids as they are transverse.
Here's a summary :

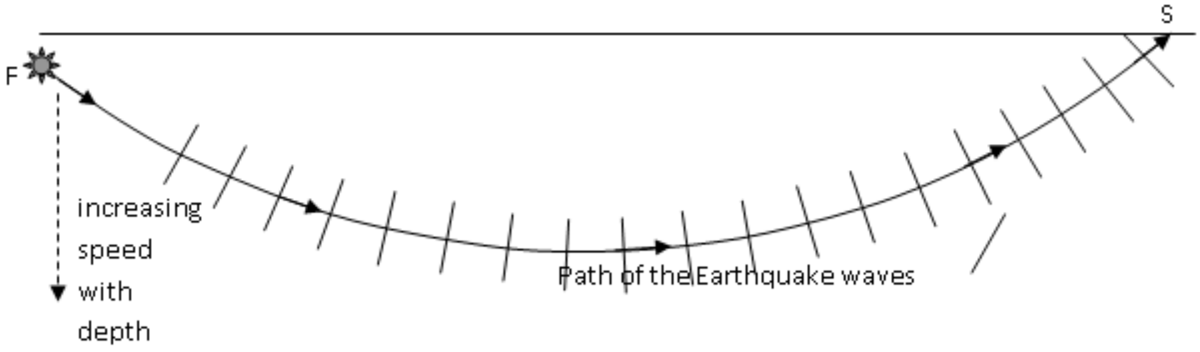
- ***Crust (solid)***: P-waves, S-waves and surface waves.
- **Mantle (solid):** P-waves and S-waves.
- ***Outer core (liquid):*** P-waves only.
- ***Inner core (solid):*** P-waves.

Refraction of seismic waves.

If the speed of the waves changes then the waves will refract and so will change direction

Refraction in the Mantle Over a few hundred km refraction has the following effect – ignoring the curvature of the Earth:

F = earthquake focus S = Seismometer



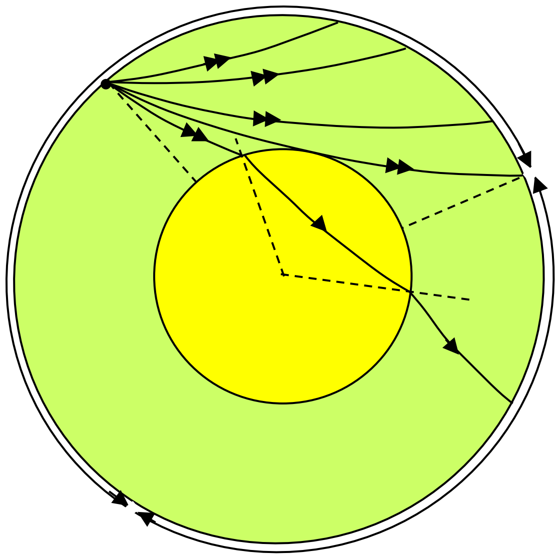
The waves curve because the bottom edge travels faster than the top edge and so it overtakes the top edge. This makes it bend upwards. Note that both P- and S-waves curve like this. They both travel faster the deeper they go into the mantle.

Inside the core.

The waves refract/bend at the core-mantle boundary because they slow down. Inside the core, the waves curve gradually, just like in the mantle, because their speed changes.

(The dotted lines represent the normal which is always at 90° to the boundary).

If the waves pass through the inner core, they refract again. They also ***refract*** as they pass back into the mantle.

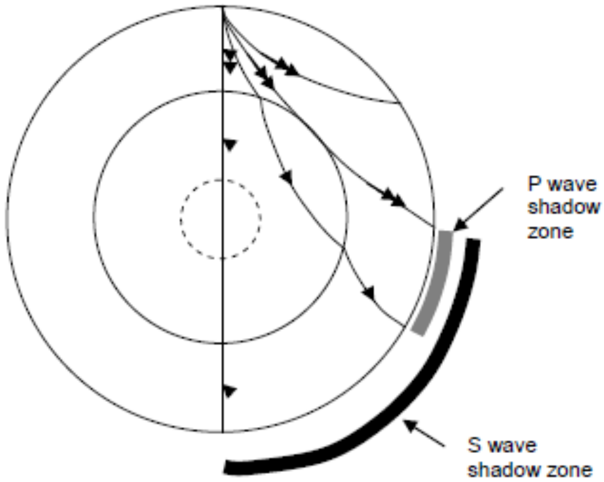


Shadow zones.

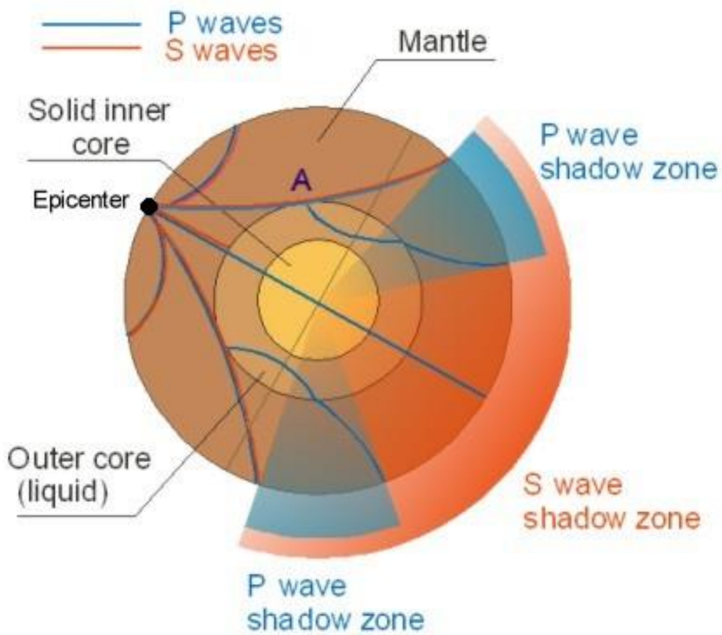
The outer core of the Earth is a liquid. The mantle and the inner core are considered to be solid. Only P-waves can travel through the liquid outer core. By measuring 'P' and 'S' waves after an earthquake at different points across the globe, we can estimate the size of the Earth's liquid outer core.

P and S waves travel **very differently** through the Earth. Initially P and S waves travel in all directions from the epicentre of an earthquake outwards. They are refracted as they travel from the epicentre and follow arcs. However, S waves **cannot** travel through the liquid outer core of the Earth.

1. the large shadow zone for the S waves on the opposite side of the earth from the epicentre.
2. the two smaller shadow zones for P waves



Note that there is a considerable change in speed from the solid mantle to the liquid outer core. By finding the angles at which the P and S waves **both** disappear we can calculate the radius of the liquid core of the earth.

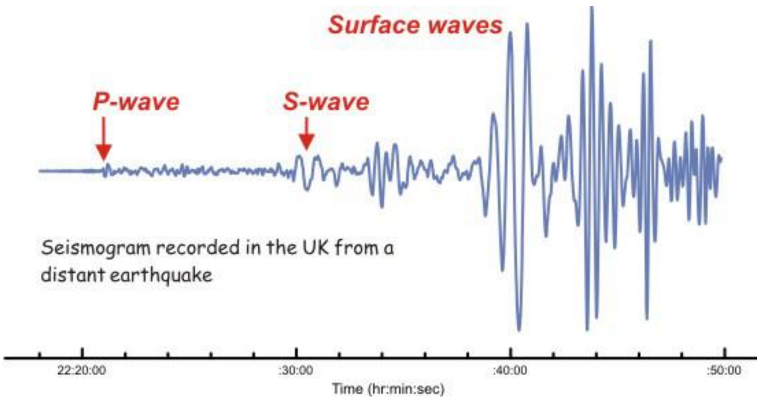


The existence of the ***S shadow zone*** is due to a liquid outer core [at all angles > 104° from the epicentre] shows that there must be a molten layer (liquid) and gives evidence for its size.

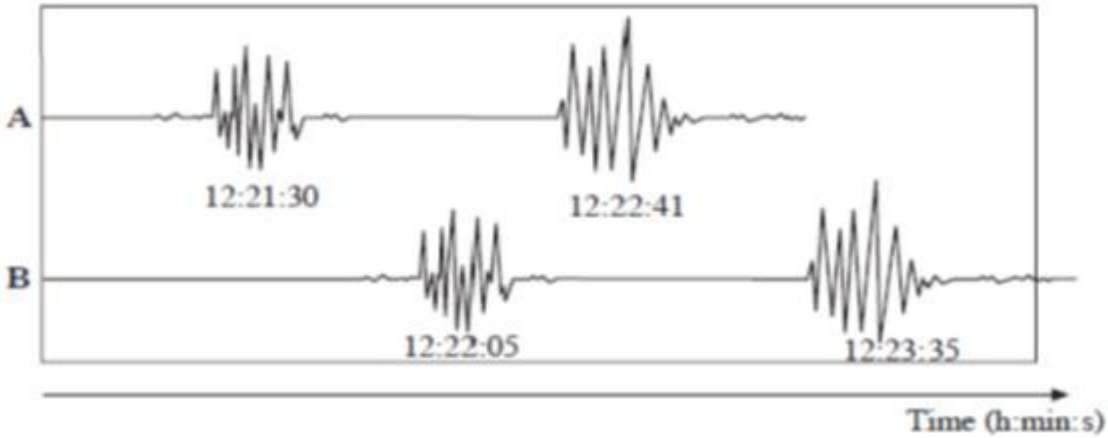
Seismogram.

Seismograms can be used to locate the epicentre of an earthquake.

P-waves arrive first then S-waves followed by the surface wave. The greater the distance from the earthquake to the monitoring station the greater the time lag/gap between the waves. Remember not all monitoring stations will receive the seismic waves due to the shadow zones.



Example question. The diagram shows the first seismic signals received from an earthquake at two monitoring stations A and B.



1. What evidence is shown by the seismic data that suggests A is nearer the epicentre than B?

   Answer: The seismic waves arrive at A before they arrive at B.

2. What evidence suggests P and S waves have travelled with different speeds from the earthquake?

   Answer: P and S waves do not arrive at the same time.

3. The time lag between the arrival of the P and S waves for a seismic station which is 100km from the epicentre of an earthquake is 12s. Calculate the distance of the monitoring station A from the epicentre of this earthquake.

Answer : 1st step is to work out the time gap between P and S waves for station A. Between 12:21 :30 and 12:22:41 there is a 71s gap/delay.

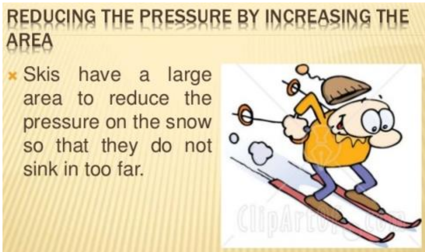
2nd step is to realise that there is a 12s delay for each 100km (as stated). How many times more is 12s than 71s ?

So, 71 ÷ 12 = 5.92 and then 5.92 x 100 = 592km

Unit 1.8 - Gases & the Kinetic Theory

Pressure

Pressure is a measure of how spread out or concentrated a force is on a surface. For example, when walking on soft snow, a person wearing normal shoes is likely to sink into the snow because the force (the person's weight) is acting on a fairly small area. This leads to a relatively high pressure on the snow. If the same person wears snow-shoes, the pressure is less since the same weight is spread over a larger area.



Here's the equation relating force, area and pressure :

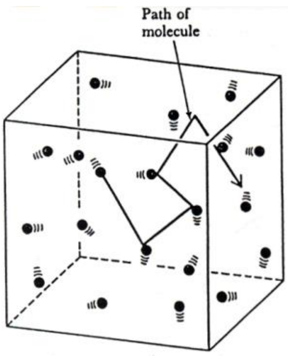
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \qquad\qquad P = \frac{F}{A}$$

where	force, units	newtons, N
	area , units	m^2 (or sometimes cm^2)
	pressure , units	**N/m^2**.

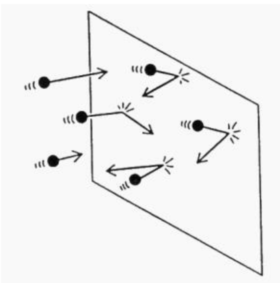
Another common unit for pressure is **Pascal, Pa**, but only if the area is measured in m^2 (rather than cm^2).

The kinetic theory

The kinetic theory is simply the idea that a gas is made from tiny particles that are in constant, random, motion. These particles are assumed to be widely spread and to move in straight lines in between collisions. All collisions are elastic –meaning that **no** kinetic energy is 'lost' during collisions.



A gas may be pictured as a collection of widely spaced molecules in continuous, chaotic motion.



As the molecules of a gas collide with the walls of their container, they exert a force on it. The average force per unit area is the pressure of the gas.

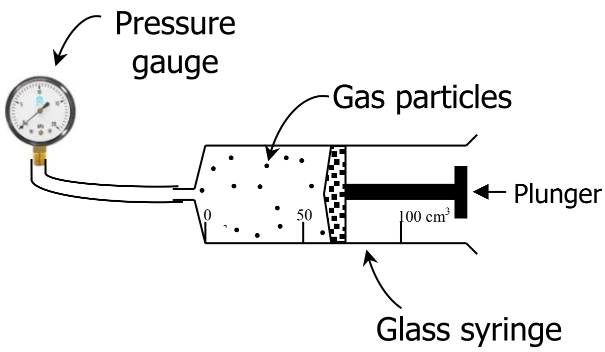
In gases, pressure is created by the gas particles colliding with the inside surface of the container. Every time a particle collides with the inside surface it creates an outward force on the container wall. Millions of such collisions on each square centimetre every second produces outward 'pressure'.

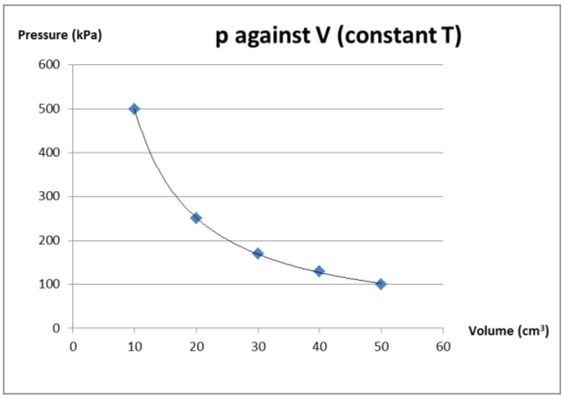
Pressure, Volume & Temperature

A) Relationship between **pressure** and **volume**.

The simple experiment below investigates how changing the volume of a gas affects its pressure. **Temperature is kept constant.**

As the plunger is forced inwards (where the volume decreases), the pressure gauge registers an increase in pressure. The graph on the right shows the results.





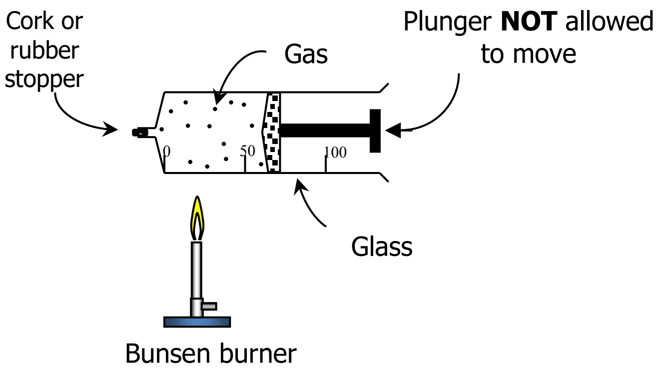
As the volume decreases, the pressure increases. In fact, you can see from the graph that if the volume <u>halves</u>, the pressure <u>doubles</u>. This means that pressure is inversely proportional to the volume, and hence we can write :

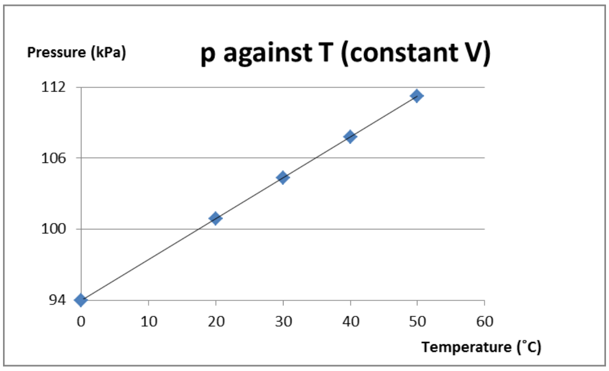
$$p \times V = \text{constant}$$

B) Relationship between **pressure** and **temperature**.

This time the **volume is kept constant.**

As the temperature of the gas is increased, the pressure gauge registers an increase in pressure. The graph on the right shows the results.



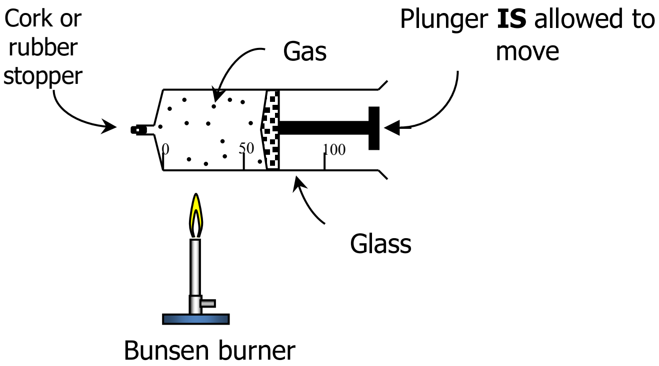


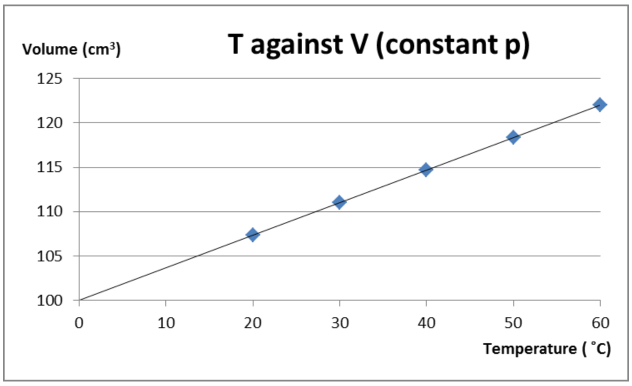
If the temperature is measured in KELVIN rather than degrees Celsius (see later on !), the graph would show that the pressure <u>doubles</u> when the temperature <u>doubles</u>. This means that pressure is directly proportional to the temperature, and hence we can write :

$$\frac{p}{T} = \text{constant}$$

Pressure, Volume & Temperature

C) Relationship between **temperature** and **volume**.
This time the **pressure is kept constant.**
As the temperature of the gas is increased, the volume increases. The graph below shows the results.





If the temperature is measured in KELVIN rather than degrees Celsius (see later on !), the graph would show that the volume doubles when the temperature doubles. This means that volume is directly proportional to the temperature, and hence we can write :

$$\frac{V}{T} = \text{constant}$$

Combining the three results

If we combine all the results/conclusions from the three 'experiments', we get the following result :

$$\boxed{\frac{pV}{T} = \text{constant}} \quad \text{or} \quad \boxed{\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}}$$

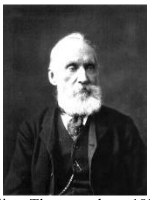
Note
Strictly speaking, this is only true for an "Ideal" gas where the particles don't affect each other **in between** collisions, and their size is extremely small in comparison to their (average) separation.

However, this 'ideal gas equation' works very well in most every-day situations.

Temperature


William Thomson, 1846

Once scientists realised that there is a direct link between the temperature of a gas and the average kinetic energy of the particles in that gas, they also realised that there must be a minimum temperature. This minimum temperature is known as **absolute zero**, and occurs when the (average) kinetic energy of the particles is zero, i.e. they stop moving !


William Thomson, born 1824

This led Lord Kelvin (aka William Thomson) to propose a new scale for temperature :

The Kelvin scale is defined so that zero Kelvin, or '0 K' is the temperature of absolute zero, and that a change of 1 °C is the same as a change of 1 K.

This then means that the freezing point of water is about 273 K, and the boiling point of water is 373 K.

Any equation used in this section only works if the temperature is measured in kelvin, K.

Example

A can of baked beans is mistakenly left sealed and placed in an oven. The air above the beans is initially at room temperature, 18 ˚C, and atmospheric pressure (100kPa). Calculate the pressure of the air inside the can when its temperature reaches 220 ˚C. (Assume there's no change in volume).

First we must convert the temperatures to kelvin using the following information seen on page 2 of the exam. paper :

18 ˚C = 18 + 273 = 291 K
220 ˚C = 220 + 273 = 493K

$$T\,/\,\mathrm{K} = \theta\,/\,°\mathrm{C} + 273$$

Since volume is constant, $\frac{p_1}{T_1} = \frac{p_2}{T_2}$

Re-arranging : $p_2 = \frac{T_2\, p_1}{T_1} = \frac{493 \times 100\,000}{291} =$ **169 415 Pa**

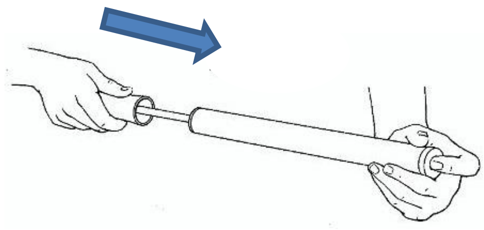
Note : This is likely to cause the can to explode, so do <u>not</u> try this at home !!! ;-)

Variation of pressure with volume or temperature

Explaining a change in pressure due to a change in volume

When the volume of a gas is decreased (i.e. the gas is compressed) the pressure increases.

To visualise this, imaging holding a bicycle pump with the air-hole at the top of the pump blocked – the gas (air) inside the pump is now sealed. If you were to push the piston/handle of the pump inwards, you're decreasing the volume of the air inside. This would cause the pressure of the gas inside the pump to increase - you would feel this trying to push the piston/handle back out.



How can we explain this with the kinetic theory of gases ?

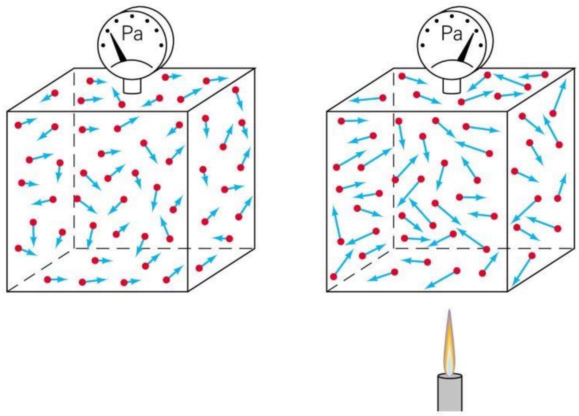
As the volume decreases, the same number of gas particles are moving around in a smaller space, and so they are closer together. If this is done at a constant temperature, the average speed of the particles **stays the same**. However, there are now **more** particles striking each unit area of the inside of the container each second. This therefore means that there is more force acting on the inside surface. Since P = F / A , the pressure will increase.

Explaining a change in pressure due to a change in temperature

When the temperature of a gas is increased the pressure increases.

How can we explain this with the kinetic theory of gases ?

As the temperature increases, the average speed of the particles increases.
This means that the particles strike the inside surface of the container **more often** than before. Also, they strike the inside surface **with greater force** than before**.**
Both these things mean that the particles exert more force on the inside surface.
Since P = F / A , the pressure therefore increases.



(a) Initial temperature (b) Heat added

Specific heat capacity

This is a value given to a particular material that is a measure of **how much heat energy is needed to increase the temperature of 1 kg of substance by 1 ˚C.**

$$\boxed{Q = m\,c\,\Delta\theta}$$

where Q	= heat energy in	units	**Joules, J**
m	= mass	units	**kilograms, kg**
c	= specific heat capacity	units	**J / kg ˚C**
$\Delta\theta$	= change in temperature	units	**˚C**

e.g. water has a specific heat capacity of 4 200 J / kg ˚C this means that 4 200 J of energy is required to increase the temperature of 1 kg of water by 1 ˚C.

Specific latent heat

Specific latent heat of fusion
This is defined as the amount of heat energy needed to change a mass of 1 kg of the substance from a solid at its melting point into a liquid at the same temperature.

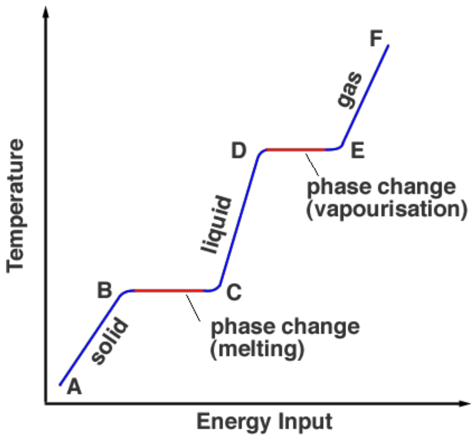
Specific latent heat of vaporisation
The amount of heat energy needed to change a mass of 1 kg of the substance from a liquid at its boiling point into a vapour (gas) at the same temperature.

The equation for specific latent heat is as follows :

$$\boxed{Q = m\,L}$$

where,	Q =	Heat supplied	units	**Joules, J**
	m =	mass	units	**kilograms, kg**
	L =	Specific latent heat	units	**J / kg**

Explaining the graph
All the solid particles are held in place by strong **bonds** (electrostatic forces). Once the temperature of the solid reaches its melting point, the extra (heat) energy flowing into the solid is used to break or weaken these bonds, rather than being used to increase the kinetic energy (and hence temperature) of the particles in the solid. Once all the particles are able to flow past one another the solid has melted into a liquid.



A similar process occurs at the boiling point – once the liquid reaches its boiling point, the heat flowing into the liquid is then used to completely break the bonds still existing between the particles.

Once all bonds are broken, the liquid has then changed to a gas (or vapour).

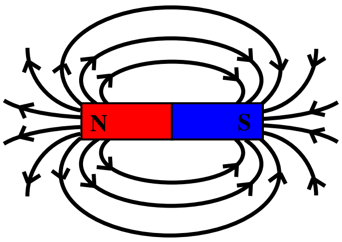
The latent heat of vaporisation has a higher value than the latent heat of fusion, as more bonds are broken.

Unit 1.9 - Electromagnetism

Magnetic fields

A magnetic field is a region where magnetic materials feel a force. Magnetic fields are created by magnets, or current flowing in a wire. Here are some magnetic fields you should know about:

A bar magnet



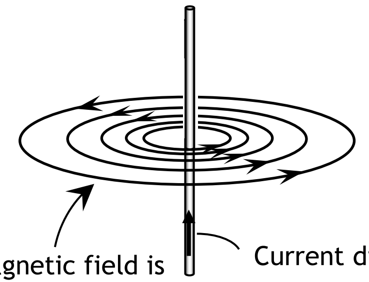
Notice that the magnetic field lines show three things :

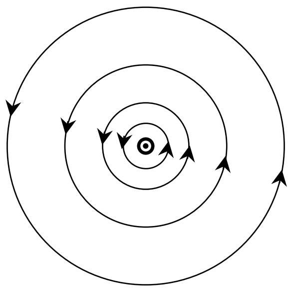
1) The shape of the field

2) The direction – From North to South

3) The strength of the field – the field is stronger where the lines are closer together.

A long, straight wire with a current flowing through it

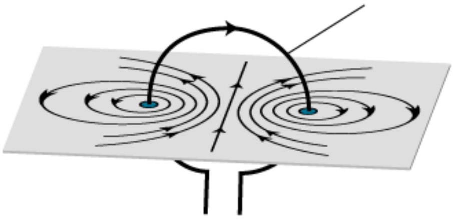




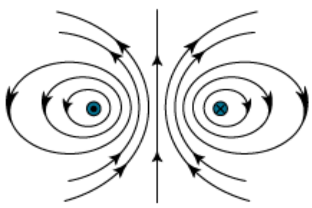
Plan view (bird's-eye)

Notice that the field lines get further apart the further they are from the wire, since the magnetic field is getting weaker.

A flat coil

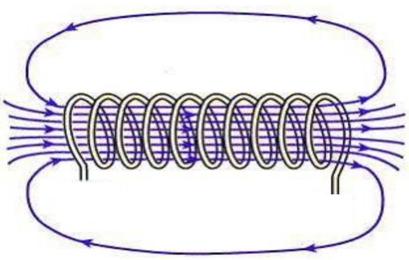


Magnetic field pattern generated by a flat coil



Magnetic field pattern generated by a flat coil (Plan view)

A long coil (solenoid)



Notice that the field lines **inside** the coil are almost straight and parallel – this shows the magnetic field has a constant strength in this region.

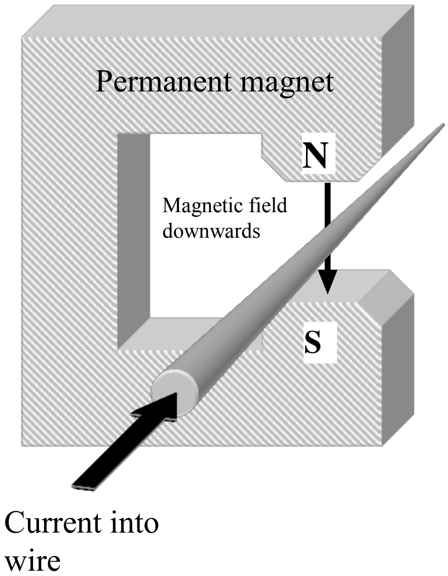
Also, notice that the shape is very similar to that of the magnetic field around a bar magnet.

The Motor Effect

We can use the magnetic effect of electricity to produce movement.

If a current-carrying wire is placed in the magnetic field of a permanent magnet, **two** magnetic fields will exist on top of each other – one due to the permanent magnet, and one from the electricity flowing in the wire.

This produces a **force** on the wire, in exactly the same way a force is produced between two magnets placed close together.



The size of the force on the wire can be increased by doing one of three things :

1. **Increasing the current**
2. **Increasing the magnetic field strength**
3. **Increasing the number of wires in the field**

This leads to the equation :

$$\boxed{F = BIL}$$

F = force on the wire, units Newtons (N)

I = current, units Amps (A)

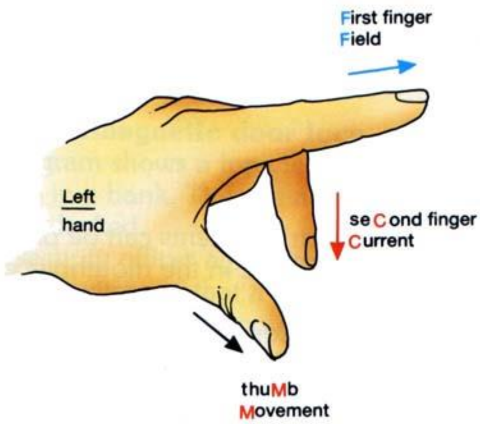
L = length of wire, units metres (m)

B = **magnetic field strength,** units **tesla (T)**

The force produced on a wire can be used to create movement (rotational), and is known as the 'Motor Effect'.

It's possible to predict the direction of the force by using **Fleming's LEFT hand rule.**

If the thumb and first two fingers of the left hand are placed at right angles to each other as shown then . . . .



the **F**irst finger is in the direction of the **F**ield

the se**C**ond finger is in the direction of the **C**urrent

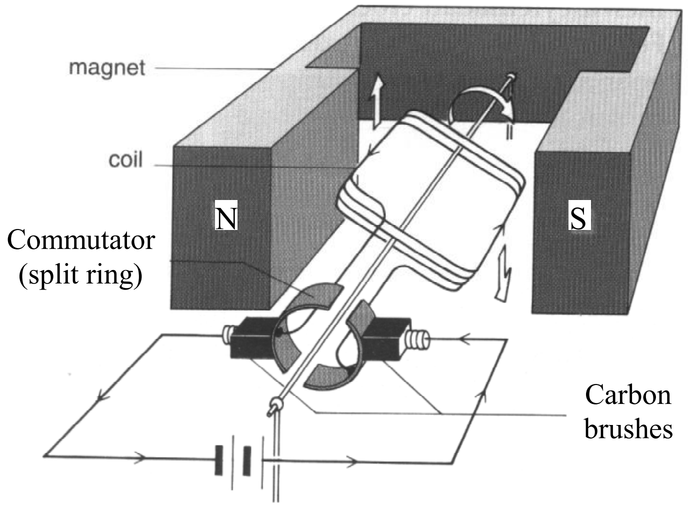
and the thu**M**b is in the direction of **M**otion.

The Motor

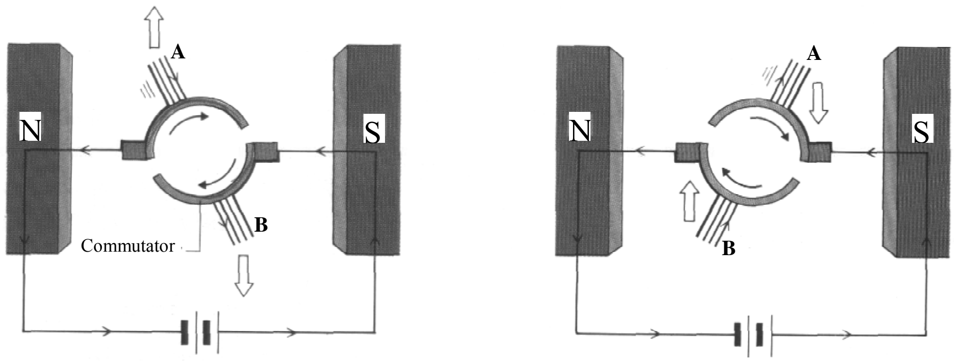
When current passes through the coil, a force acts upwards on one side of the coil, and downwards on the other side.

The overall effect of these forces is to make the coil turn on its axis.

The carbon brushes reduce wear and maintain an electrical connection.

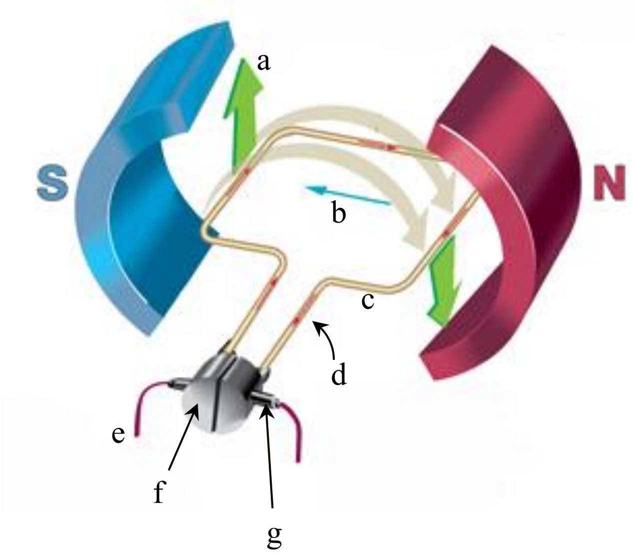


The split ring commutator reverse the current every half turn and ensures that the force on any wire on the left hand side of the motor is always directed upwards, and that the force on the right hand side is always downwards. This makes sure that the coil turns continuously in one direction.



Question : Match each label (1➔7) to the correct part (a➔g) for the simple dc electric motor below :

1. Commutator (Split rings)
2. Voltage in
3. Magnetic field
4. Motion / Force
5. Coil
6. Electric current
7. Brushes

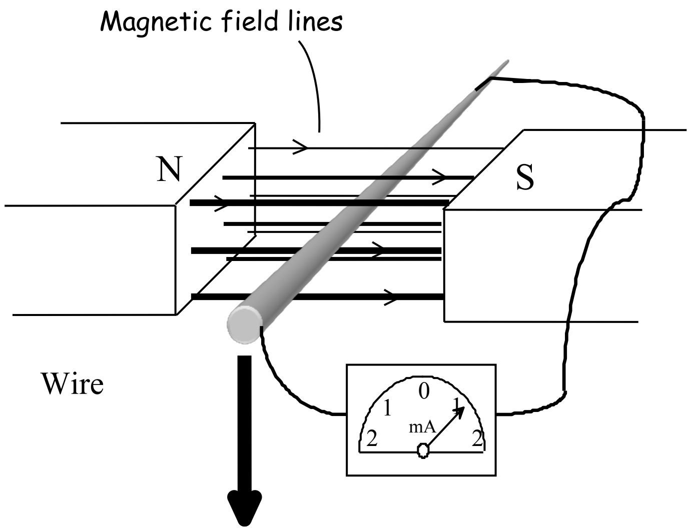


Answer : 1=f, 2=e, 3=b, 4=a, 5=c, 6=d, 7=g

Electromagnetic Induction

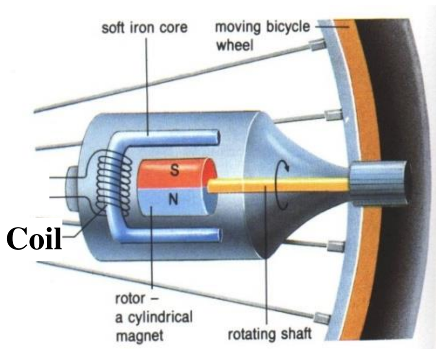
If a metal wire is forced to move through a magnetic field (or a magnetic field is moved through a wire), a **voltage** is produced across the wire.
If this wire is part of a complete circuit, this voltage will push a current around the circiut.

Another way of saying this would be :
"electricity is induced (created) when a wire CUTS through magnetic field lines".

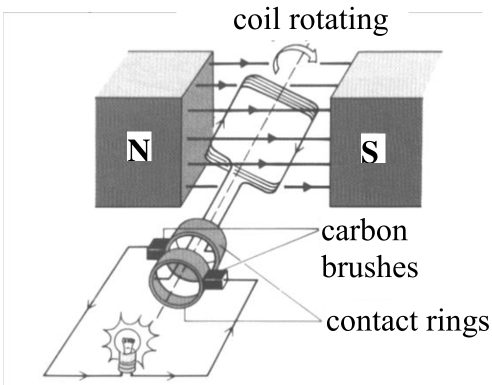


Wire is forced downwards, cutting through the field.

As you can see in the diagrams below, it makes no difference whether it's a magnet turning inside a coil, or a coil turning inside a magnetic field, the effect is the same – electricity is induced in the coil.

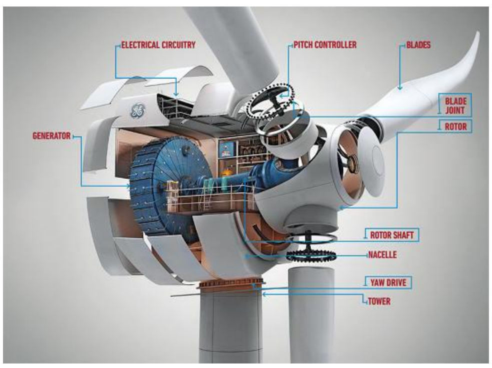


A 'dynamo' on a bicycle wheel

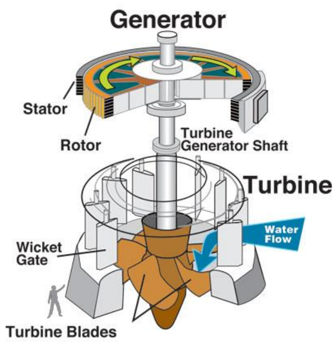


A small generator, e.g. a wind up torch

Generators are a crucial part of all power stations (except for solar PV).
Shown below is a wind turbine – the generator can be seen at the back.



Here's a generator from a hydroelectric power station ➔



Generators

The output voltage/current is **proportional** (doubling one variable doubles the voltage/current) to :

1. **the rate/speed of rotation**
2. **the number of turns on the coil**

and increases if the **magnetic field strength or the area of coil** increases. Including an iron core can also increase the output.

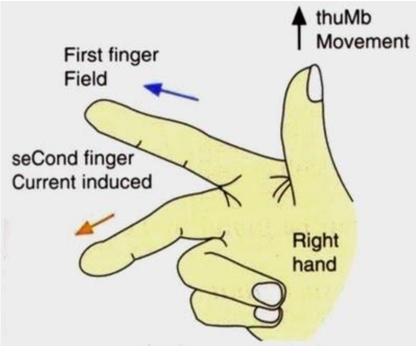
The direction of the induced current can be predicted by using Fleming's **RIGHT** hand rule.

If the thumb and first two fingers of the right hand are placed at right angles to each other as shown then,

the First finger is in the direction of the Field

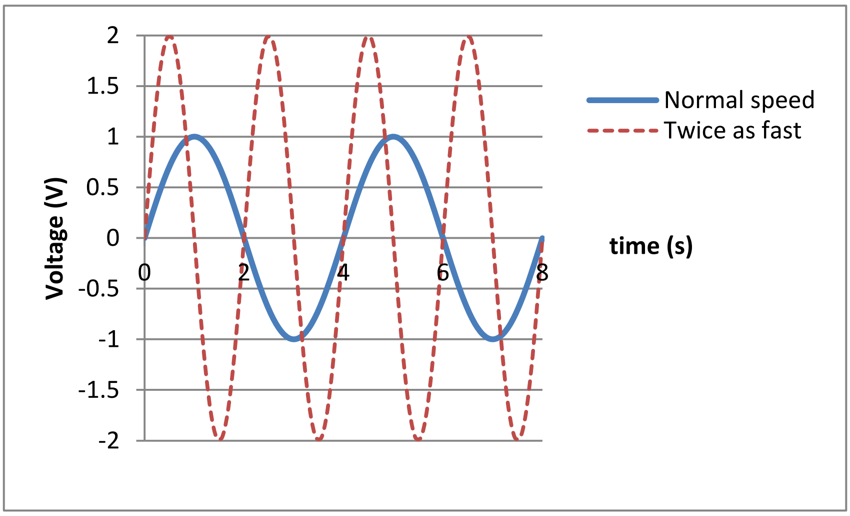
the thuMb is in the direction of Motion

and the seCond finger is in the direction of the Current



What type of output voltage/current is produced by a generator ?

Usually, the circular movement that occurs in generators produces an alternating voltage or current. 'Alternating' means that the current/voltage direction changes regularly. For most generators the circular movement also means that the output current is constantly changing in size – this is explained on the next page.
Here's a graph showing a typical output from a generator :



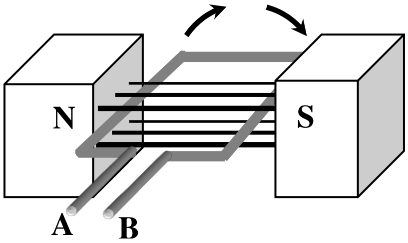
Notice the effect of **doubling** the speed of rotation of the generator.

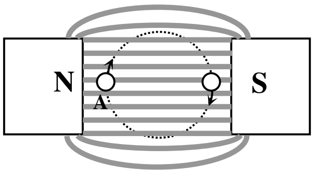
One 'rotation' or cycle takes 2 seconds (rather than 4s).

Also, the peak voltage is now **twice** as large since the coil in the generator is breaking through magnetic field **twice** as quickly – see point 1 at the top of the page !

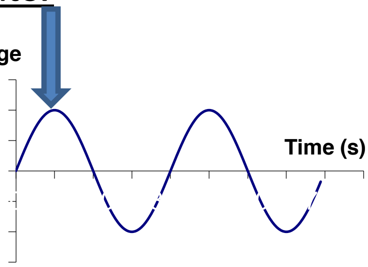
Generators

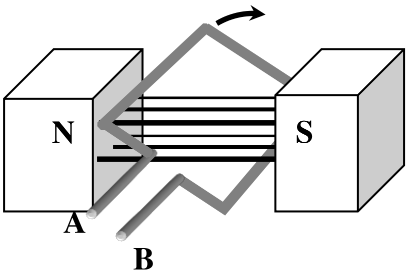
Understanding the shape of the output voltage of a generator

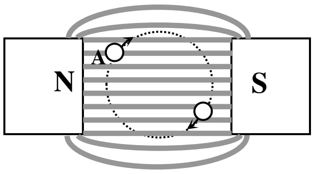




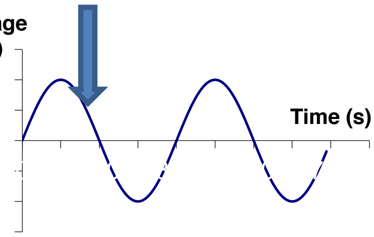
The coil is cutting through magnetic field lines at its greatest rate, and so this is when the maximum voltage/current is produced.

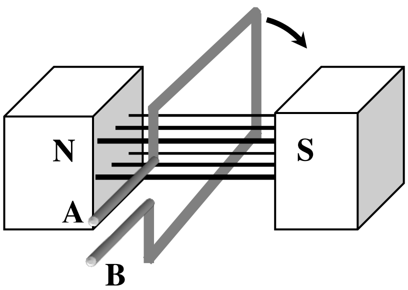


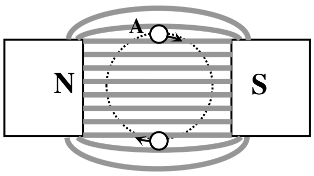




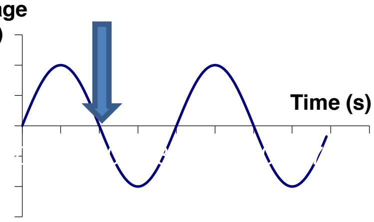
Side "A" of the coil is still cutting **upwards** through magnetic field lines, and so the voltage is still positive. However, because of the angle, the coil isn't cutting the lines as quickly as before, and so there's less voltage.

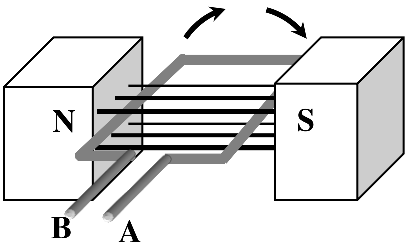


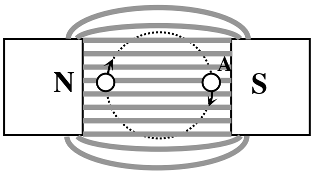




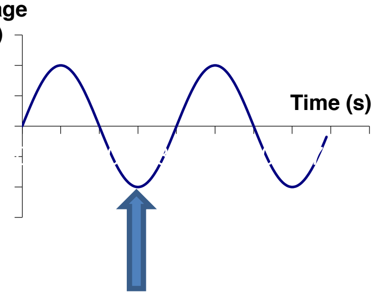
The coil is **not** cutting any field lines – its just moving along with them in the North-South direction.
This means that **NO** voltage is produced.







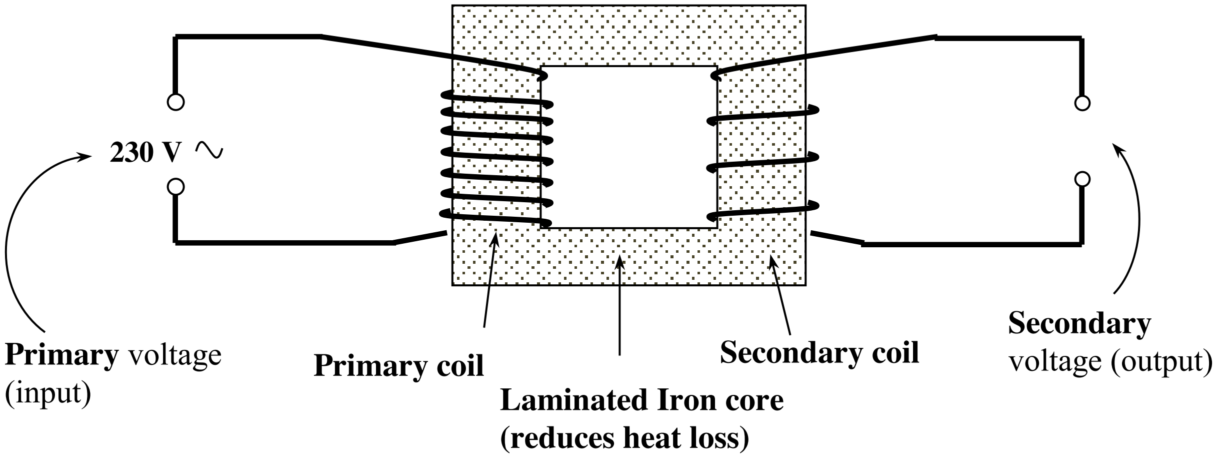
Once again lines are being cut at maximum rate, but side "A" of the coil is now cutting **down** through the magnetic field.
This changes the direction of the voltage.



Using Induction - TRANSFORMERS

A transformer is a device that makes use of the fact that electricity can be created (induced) by a **changing magnetic field**. Transformers are used to increase (step-up) or decrease (step-down) the voltage.

Here's a diagram of a transformer where two separate coils have been wound around two sides of the same piece of solid iron 'core':



← Here's a large transformer in the National grid ……

…… and here's a small transformer – a phone charger →

The explanation for how electricity is created in the secondary coil could be asked for in a "QER"-style examination question. Here's an example of a well-structured answer :

The alternating current in the primary coil creates a changing magnetic field around it. Iron is a magnetic material, and so easily links this magnetic field to the secondary coil. The constantly changing magnetic field around the secondary coil induces a voltage in this coil.

Additionally, whether this output voltage is greater or lesser than the primary voltage depends on the amount of turns in the secondary coil as compared to the primary. For a 100% efficient transformer:

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2}}$$

where
- V_1 = voltage across the primary coil
- V_2 = voltage across the secondary coil
- N_1 = number of turns on the primary coil
- N_2 = number of turns on the secondary coil

Example **:** *The input (primary) voltage of a phone charger is 240V (mains). The output needs to be 4.8 V. Calculate "N_2" (the number of turns on the secondary coil) if N_1 = 2000.*

$$N_2 = \frac{N_1 \times V_2}{V_1} = \frac{2000 \times 4.8}{240} = 40 \text{ turns}$$