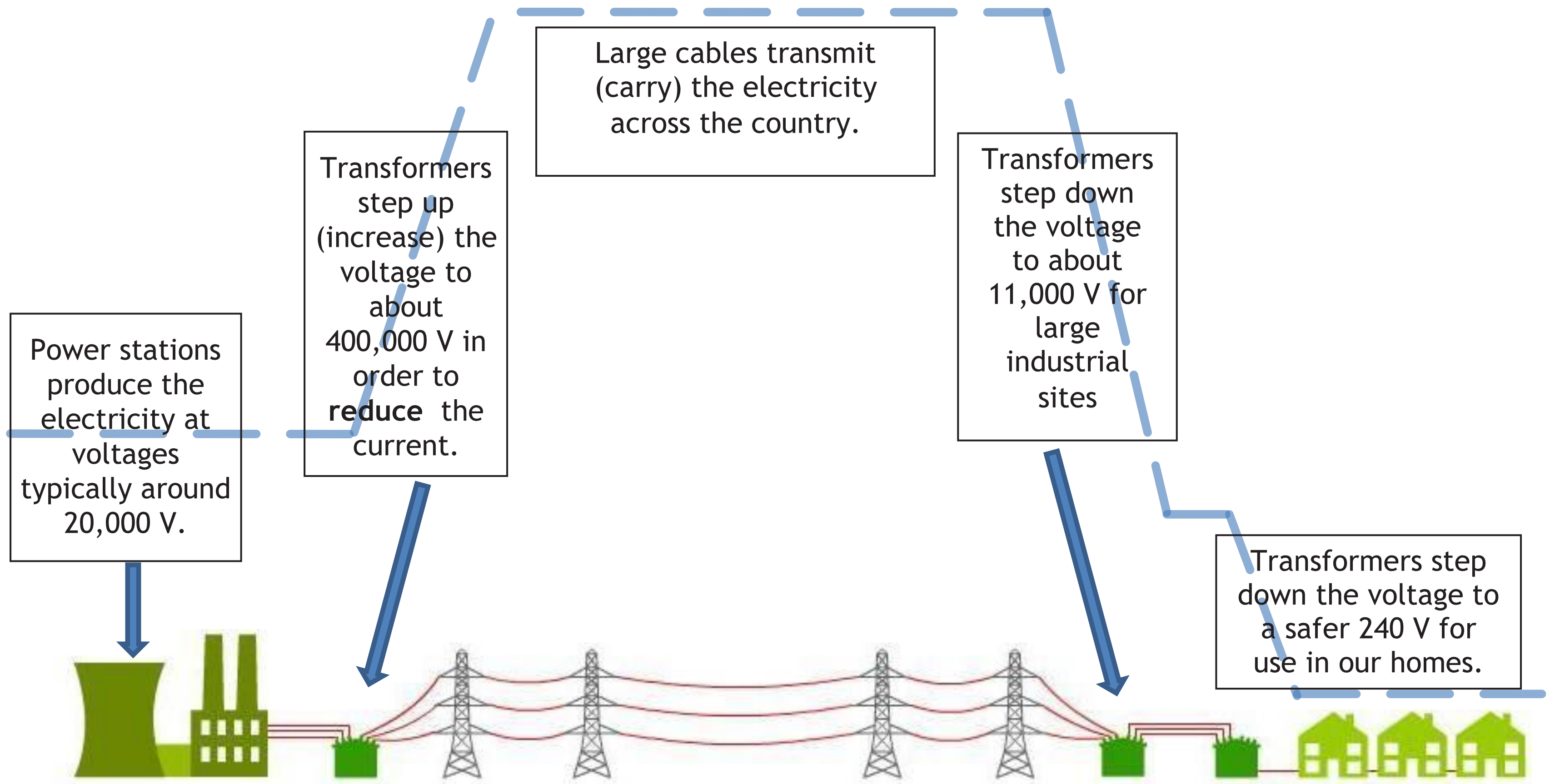
Unit 1 - The National Grid

Overview

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.

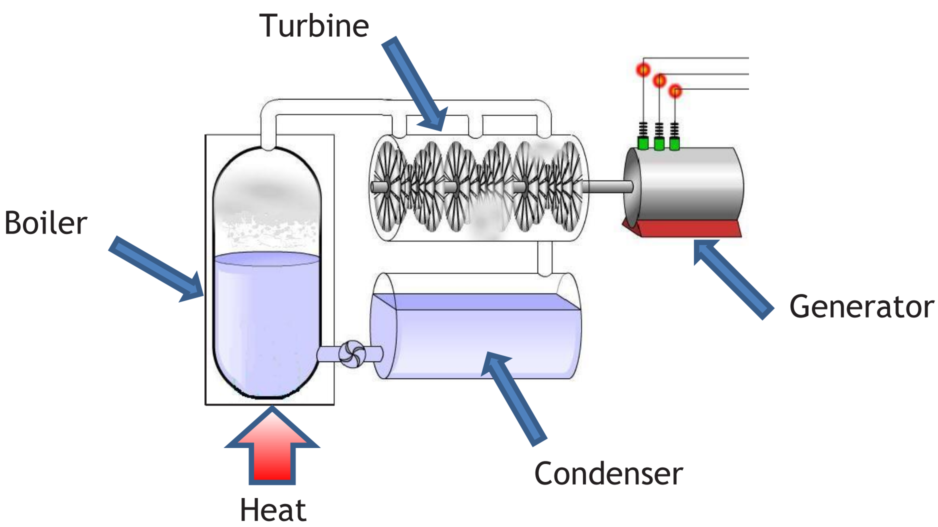
The only other option to produce electricity is **micro-generation** (e.g. solar panels on the roof; small wind turbines in the garden, etc.)



Producing electrical energy

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

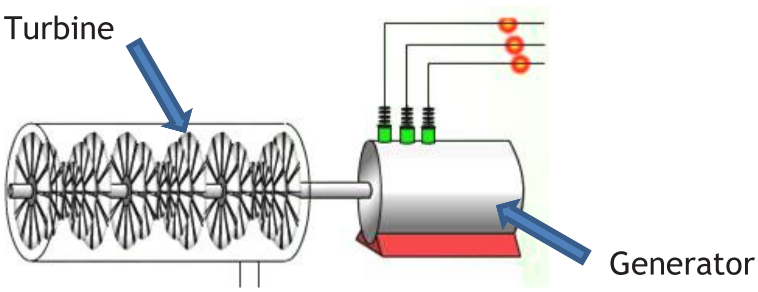
1. Shown below is a typical set-up for most power stations. The fuel is used to provide heat energy to water in a boiler. The water changes to steam which turns the blades of a turbine. The turbine is connected to a generator which then produces electricity.



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

Wylfa Nuclear power station

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. This may involve some calculations like the examples on the bottom of the previous page.

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 for some of the most commonly used ones – here's an example :

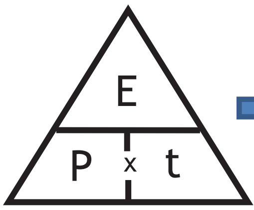
Type	Build cost	Running costs (inc. fuel)	Decomm. costs	Environmental	Socio-economic
Nuclear	High	Medium	Very high	**No CO_2**, but radioactive waste produced	Creates many jobs for decades. Risk with terrorism ?
Coal	Low	Medium	Medium	CO_2 produced	Creates many jobs for decades
Wind	High	Very low	Low	Eye-sore ?	Few jobs created long term
Hydro	High	Very low	Medium	Can affect wildlife + irrigation if dam placed in rivers	Creates many jobs for decades

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 <u>billion</u> ! 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

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



...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 ?

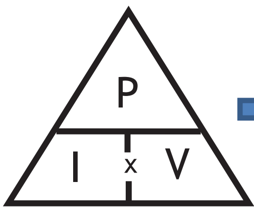
Answer : $E = P \times t = 3000 \times (3 \times 60) = 540\,000$ J

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

$$P = I \times V$$



...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

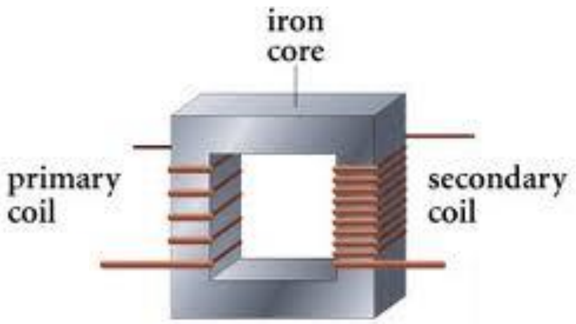
Info. ! *How much electricity flows in a wire is known as electrical <u>current</u>.*

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.

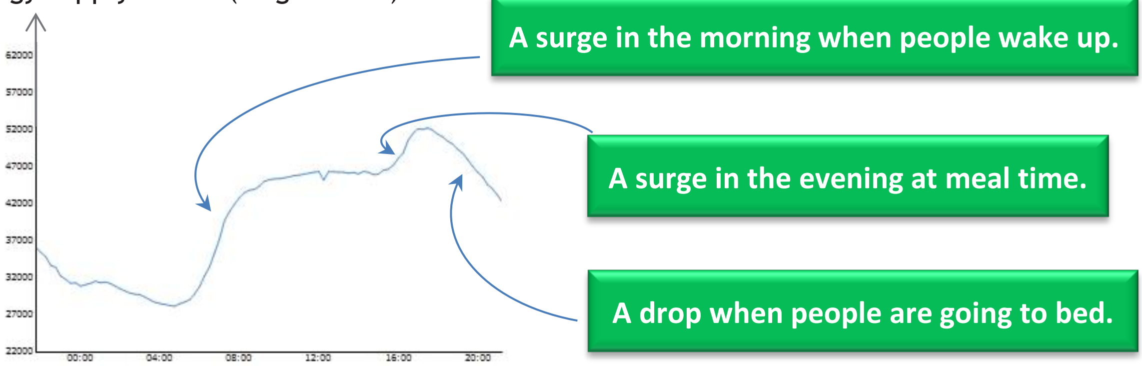
Note : The transformer creates no extra electrical power, so the input power is the same as the ouput power. The equation " Power = current x voltage " (P=IxV) can be used to calculate the effect on the current, when the voltage is changed.

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).

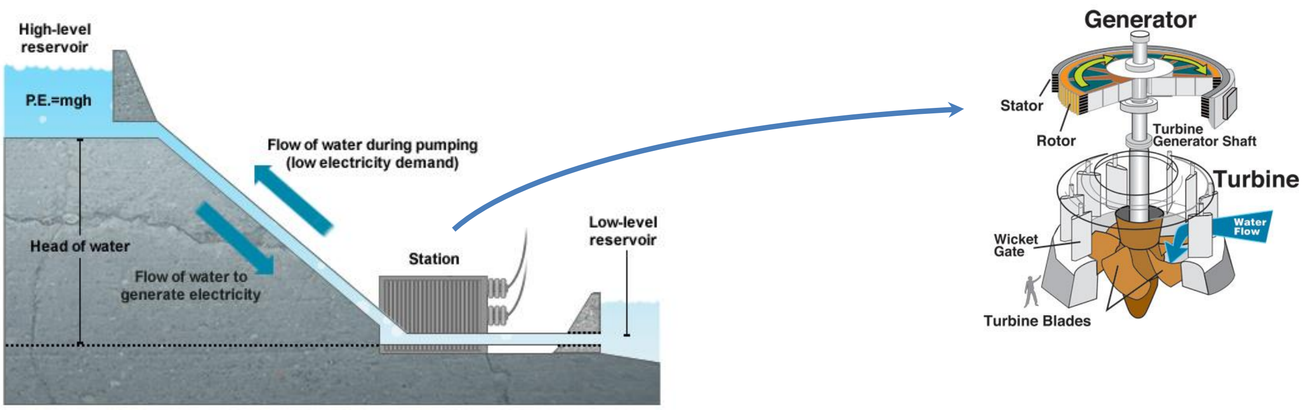


Note that "one-off" special events can cause surges too, as well as day-to-day events, e.g. a popular event at the Olympics; the FA cup final etc. The National Grid try to predict when these occur by looking at the TV listings !

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.

A fast-response hydroelectric power station (pump-storage)



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. Here's the equation for calculating "energy" :

Since $P = \dfrac{E}{t}$, re-arranging ➔ $E = P \times t$ (see page 5 !!)

Normally, the units used are : J W s (Joules, Watts, and seconds)

However, the Joule is much too small for the electricity companies, so they use slightly different units :

E	=	P	x	t
(kWh)		kiloWatts		hours

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

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" :

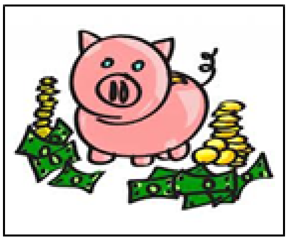
Payback time = cost ÷ savings per year
(in years)

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.

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



You will not 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.

Comparing the costs

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)

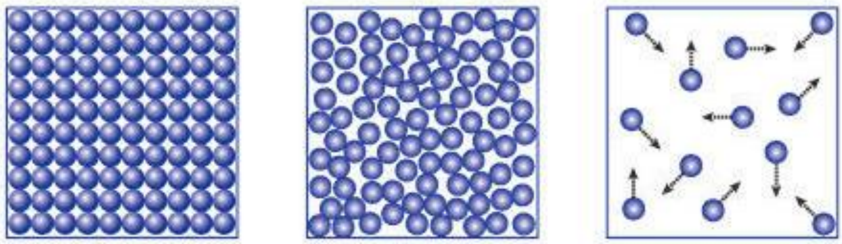
3 x 4 = 12 m^2 (1 mark)

(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).

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:



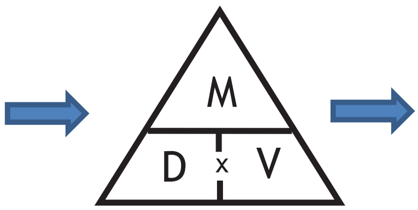
Solid   Liquid   Gas

Here's the equation for calculating density :

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

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

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



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

$$M = D \times V$$

Example

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

Volume of the block = l x w x h = *14 x 4.5 x 2* = ***126 cm³.***

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

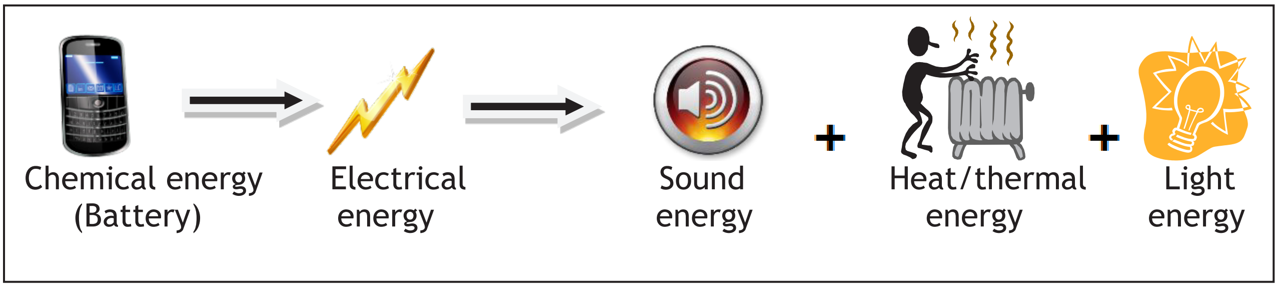
Water has a density of exactly 1 g/cm^3 (or 1000 kg/m^3).
Air has a density of about 0.0013 g/cm^3.

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 m^3 of water weighs about 854 times the same amount of air.

Energy Transfer

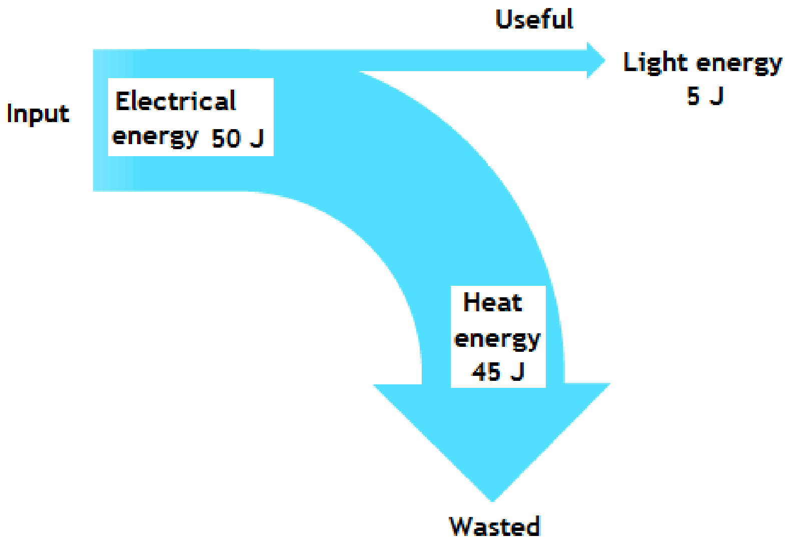
Type of energy	Example
Electrical	Into hairdryer.
Heat	Cooker.
Kinetic	Moving energy - car.
Sound energy	Speaker
Light energy	An object which emits light - LCD screen.
Chemical energy	Stored in food/battery.
Gravitational potential energy	Increases with height above ground - pump storage station.
Elastic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

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

Example: using the data from the Sankey diagram.

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

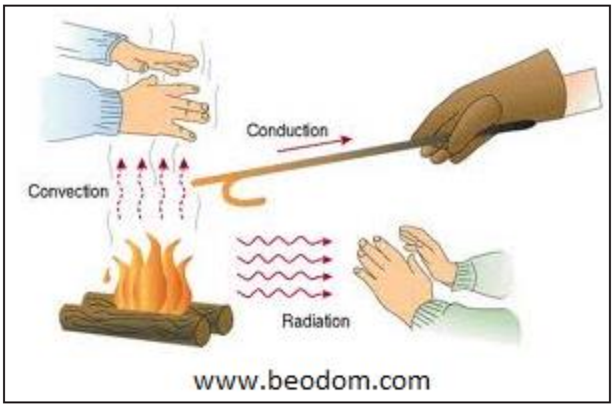
This is very poor and shows that the bulb is not very efficient. You cannot get more than 100%!!!

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.

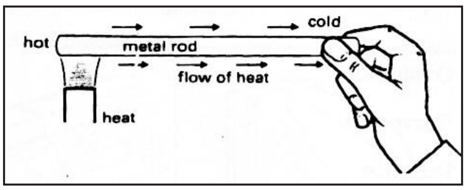


The greater the ***difference in temperature*** the more thermal energy transferred per second e.g. so the temperature of your mug of tea will drop at a greater rate when it is very hot.

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.



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.

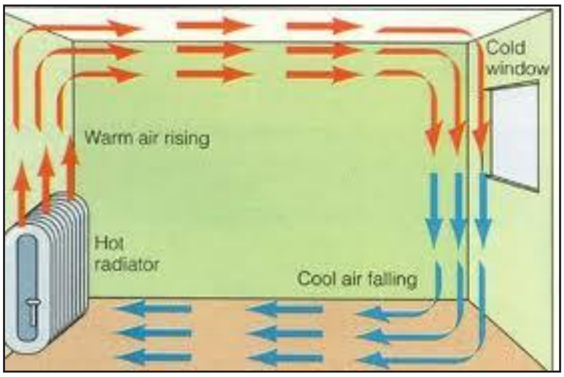
2. The particles speed up

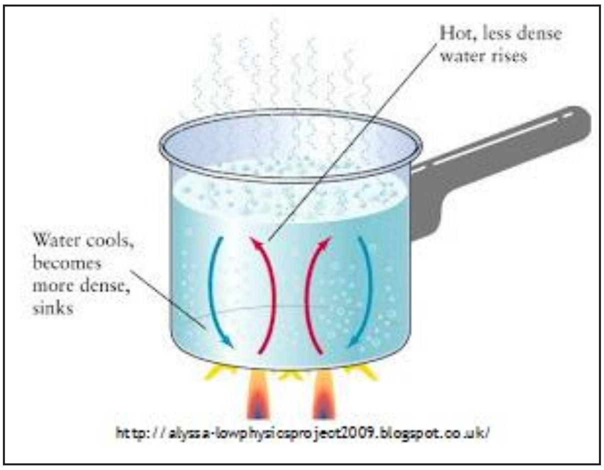
3. Volume of gas/liquid increases. Gas/liquid expands.

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.



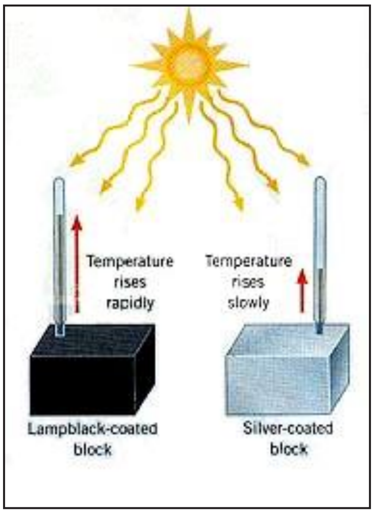


Thermal Radiation (infrared). Any hot object will emit thermal radiation in the form of infrared electromagnetic radiation.

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.



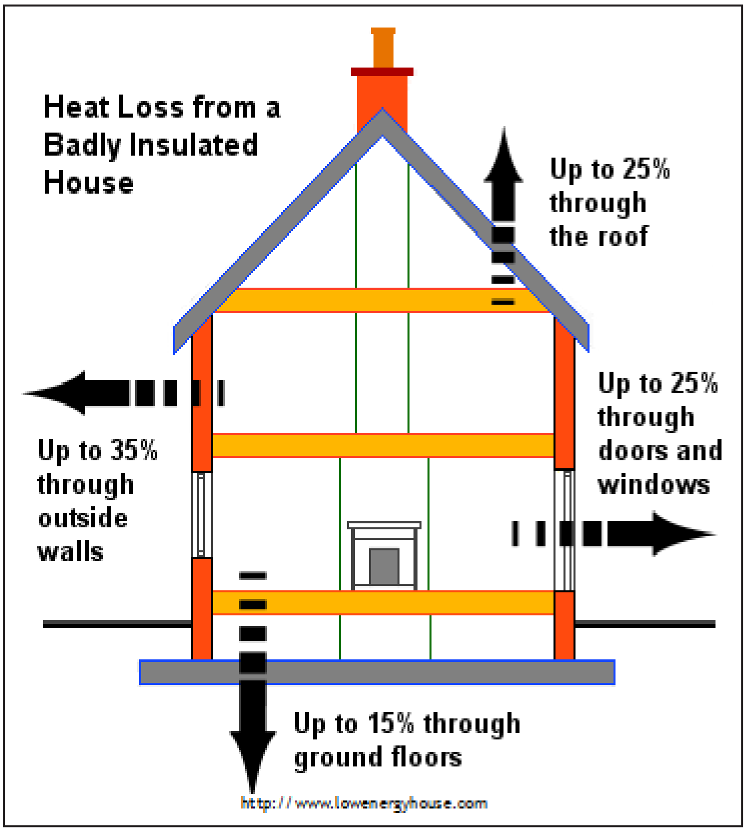
Dull Black	Shiny Black	Colours (dark --> Light)	White	Silver

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

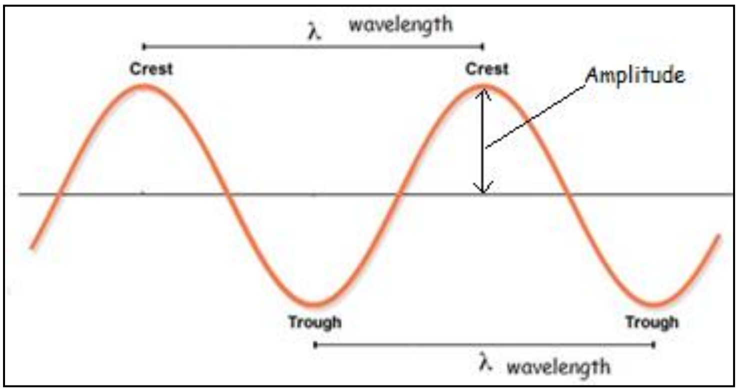
Insulation type/system	How it works.
Double glazing	Two sheets of glass separated by a gap filled with e.g. argon or a partial vacuum. It reduces heat loss through conduction and convection.
Draught proofing	Strips of draught proofing can be fitted around doors and window frames. Draught excluders can 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.

Characteristics of waves. (what can we measure)

Waves transfer energy from one place to another. e.g water waves, light and sound.

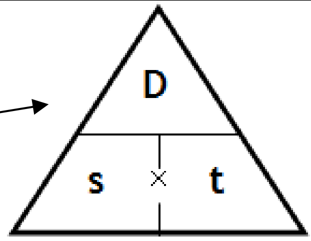


Characteristics	What is it?	Units
1.Wavelength **λ**	The distance from a crest to the next crest or the distance it takes to repeat itself.If there are 10 waves in 5 metres then the wavelength is 0.5m	Metres, m
2. Frequency **f**	The number waves per second. 1 Hz is 1waves per second. If there are 40 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
4. Speed **c**	The distance travelled by the wave in 1 second.	Metres per second, m/s.

Calculations involving waves.

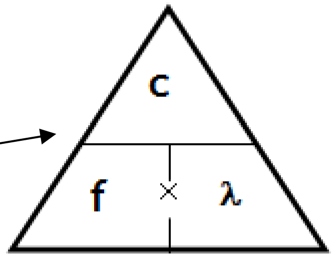
The speed of a wave can be calculated in 2 ways.

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



2. wave speed = frequency x wavelength

$c = f\lambda$



<u>Example 1:</u> 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).

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

<u>Example 2</u>: 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, $\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{2.5}{7.5} = 0.33 \text{ Hz}$

<u>Example 3</u>: 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

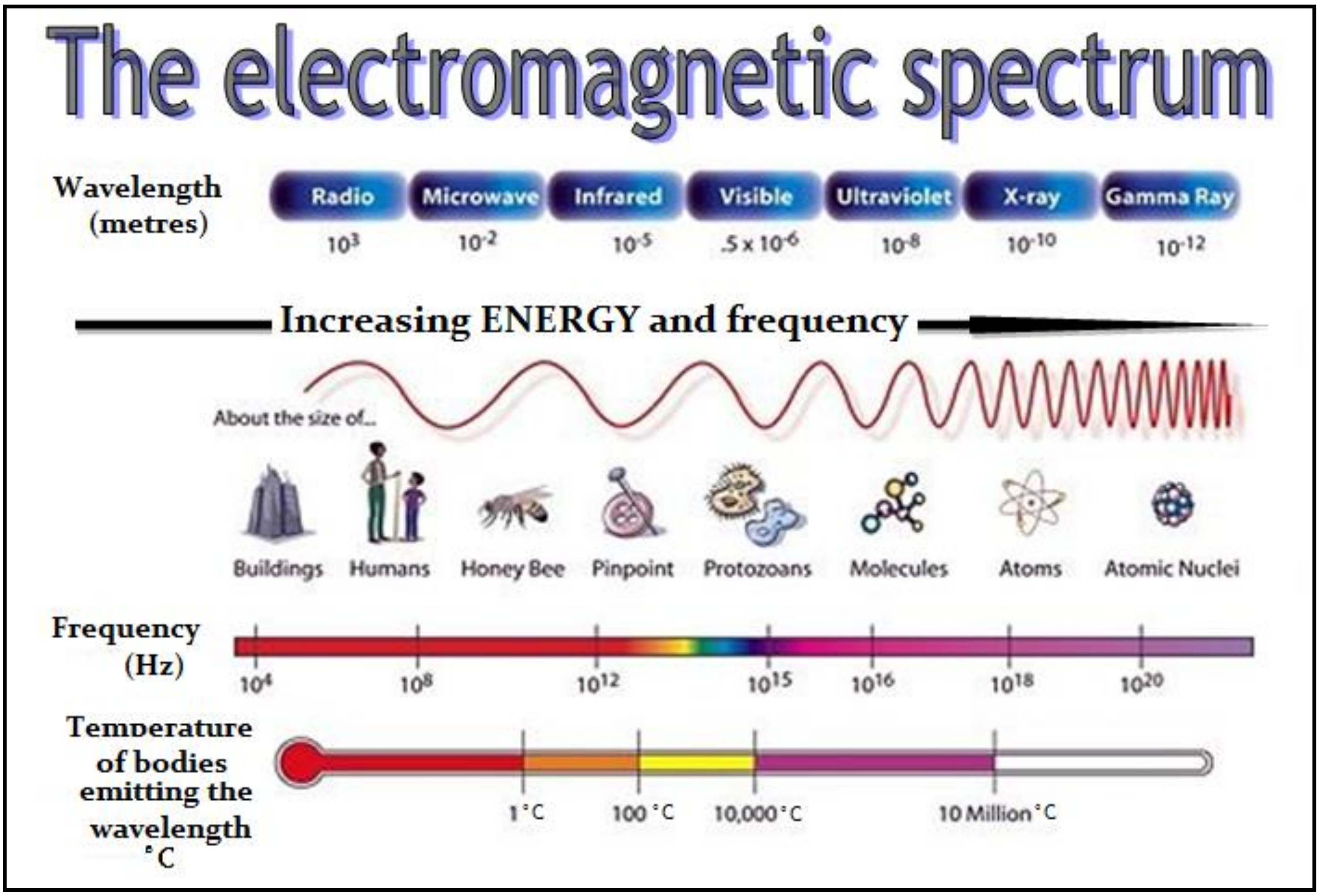
$\text{speed} = \frac{\text{distance}}{\text{time}}$, rearrange

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

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

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.

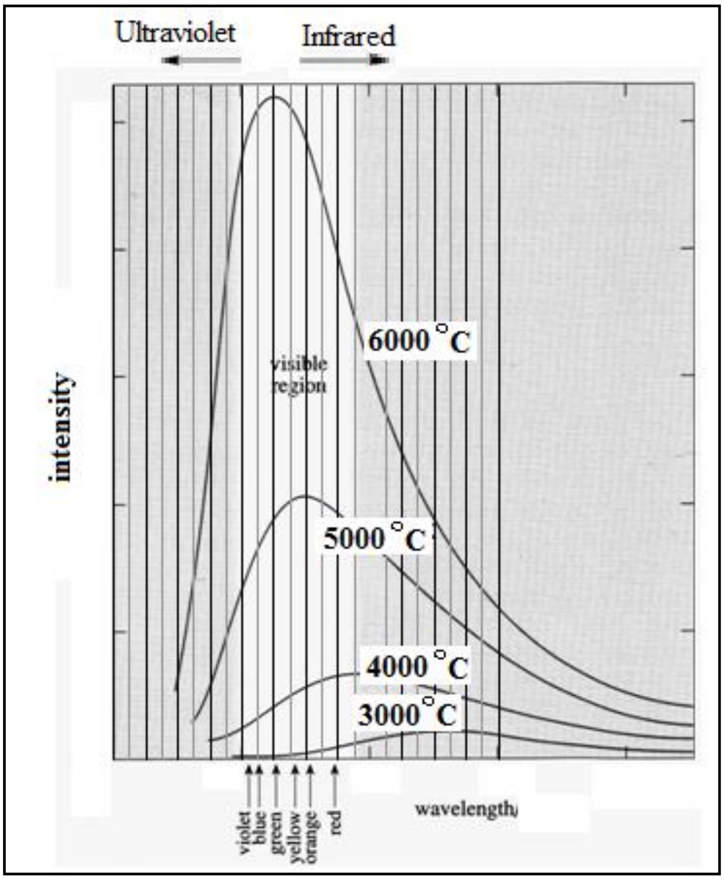
Part of em spectrum	Properties/dangers.	Uses
Radio	Longest wavelength, no known dangers.	Radio and television signals.
Microwave	Short wavelength. Some concern that they pose a health risk to phone users. Absorbed by water molecules.	Heating food, satellite and mobile phone communication.
Infrared (thermal 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.

Radiation emitted by objects. (Higher tier only)

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

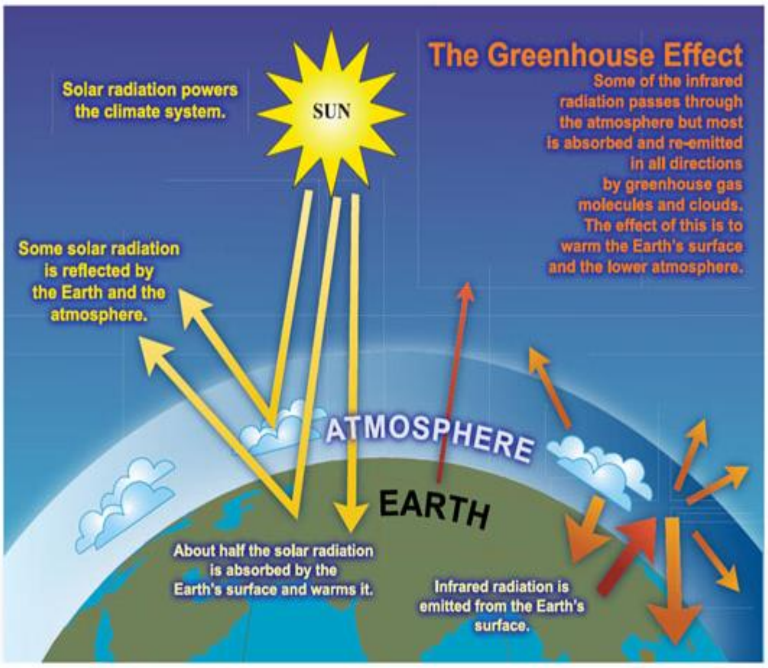
- The **higher the temperature** of an object, the greater the **amount of radiation emitted.** The frequency also increases, and the shorter the wavelength of the peak emission/highest intensity.
- At room temperature objects emit weakly in the infra red.
- An incandescent (giving out light) light bulb (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.



The greenhouse effect. (higher tier only)

1. ***Visible light*** passes through the atmosphere.
2. The Earth absorbs sunlight, and then emits the energy back out as ***infrared/thermal*** radiation.
3. Some of this infrared/thermal radiation makes it into space.
4. Some infrared radiation is absorbed in the atmosphere, by carbon dioxide, methane gas and water vapour.
5. These gases then ***re-emit*** the infrared/thermal radiation.
6. The heat that doesn't make it out through Earth's atmosphere keeps the planet warmer than it would be without the atmosphere which can lead to ***global warming***.



http://www.global-greenhouse-warming.com

Greenhouse gases: *carbon dioxide*, *water vapour*, *methane and CFC's*.

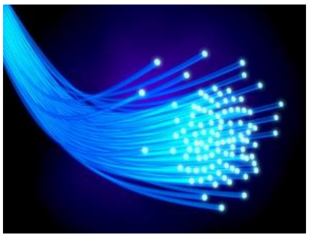
The levels of CO_2 in the atmosphere are increasing because?

1. Burning of fossil fuels.

2. Large areas of forest are being cut down for timber and to gain more farm land.

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 (2×10^8) m/s and can carry more information (1.5 million phone calls through one cable).



The advantages of optical fibre over traditional copper cables are

1.They require fewer boosters to increase strength of the signal.

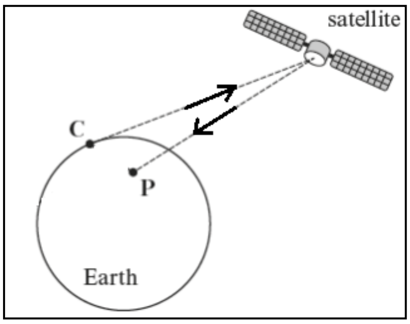
2. More difficult to bug (tap into) the signal.

3. They weigh less.

4. Use less energy.

5. No interference from neighbouring cables.

Satellites.



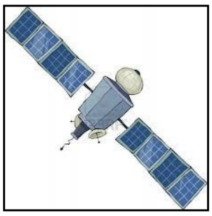
Communication satellites need to be in a **geosynchronous orbit** (36,000 km high) because Satellite needs to be above a fixed point on the Earth so satellite dishes (e.g. sky dish) do not have to be moved.
They use **microwave** radiation to send signals to the satellite

Definition of geosynchronous 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).

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.

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

Time delay: It's possible to calculate the time delay when sending information.



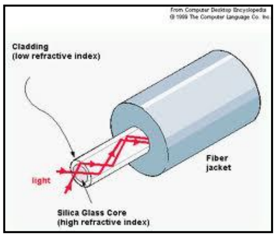
Method 1, satellite: If the distance from the Earth's surface to each satellite is 3.6×10^7 m, what is the total distance the microwaves must travel to go from Wales to Italy?

Total distance (up and down once) = $2 \times 3.6 \times 10^7 = 7.2 \times 10^7$ 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. What is the speed of infrared waves in an optical fibre?



$$70\% \text{ of } 3 \times 10^8 = \frac{70}{100} \times 3 \times 10^8 = 2.1 \times 10^8 \text{ m}$$

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

So there is less time delay with the optical fibre (although the signal will need to be boosted, which can increase the delay time).

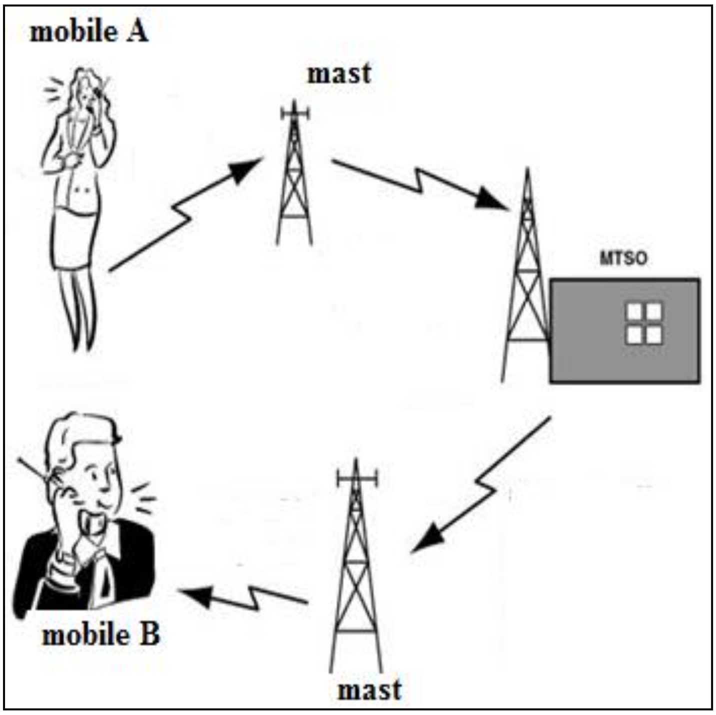
Mobile phones: Mobile phones work by communicating with the nearest phone mast, and then the base station

Your phone is constantly searching for the strongest signal. If there is no signal “no network” appears.

The MTSO (mobile telephone switching station) tracks your movement all the time.

When a friend phones, the MTSO searches to see which mast to use.

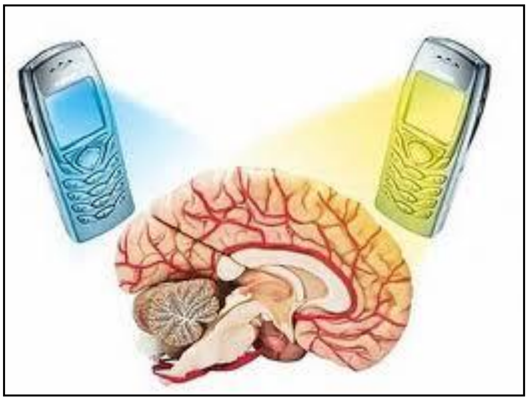
If you move away from the mast the MTSO searches for a new mast.



Which communication method is best?
There are a number of factors to consider: set up cost, maintenance, time delay and the bandwidth.

Mobile phone dangers.

The evidence is not very clear about the dangers of mobile phones. Scientific studies need to have a large sample and also be reproducible (other scientists get similar results) for the data/information to be reliable/dependable.



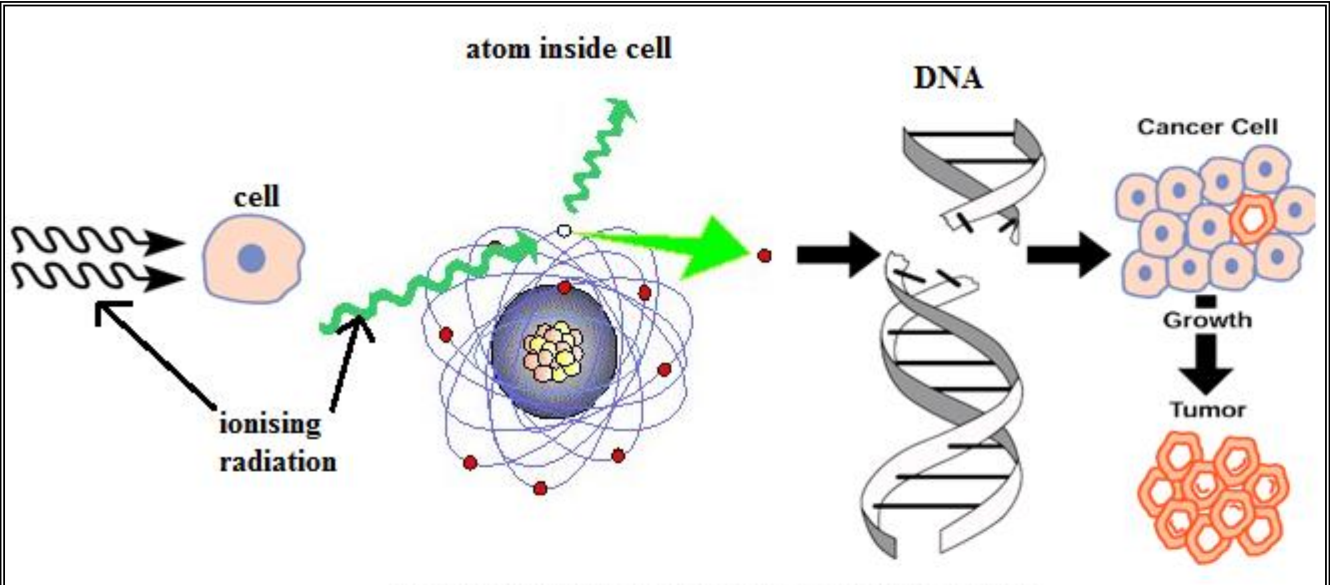
You can reduce the risk by:

- Keep the phone calls as short as possible.
- Using hands-free devices
- Using the phone outside so the signal doesn’t have to be as strong.

Questions on the dangers will be reading a given passage (comprehension) style questions.

Ionising radiation.

Ionising:- some particles and electromagnetic waves (both are radiation) have enough energy to rip electrons away from atoms and molecules. Ions are formed which can interact with cells in the body and ***damage DNA/cells***. This damage can lead to the formation of cancer.

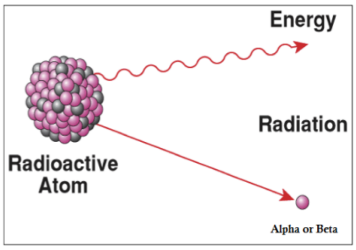


Development of cancer from mutation produced by ionizing radiation.

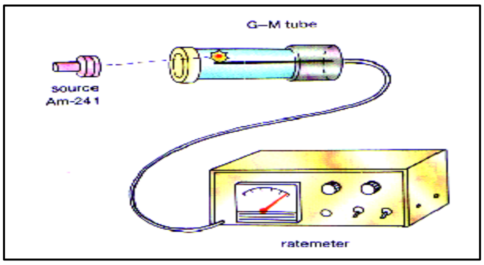
Ionising radiation include: alpha, beta, gamma, x-rays and ultraviolet.

Non-ionising radiation: visible light, infrared, microwave and radio waves.

Radioactive decay:



Some atoms are unstable and so we say that they are radioactive. They try to become stable emitting alpha, beta or gamma radiation. The process of atoms undergoing radioactive decay is totally **random** and **spontaneous**. There is no way of telling **when** or **which** atom will decay in a radioactive material.



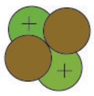
A Geiger counter can be used to measure the ionising radiation. To gain greater accuracy when measuring radioactive decay we must do 2 things:

1. Repeat the experiment and calculate the average.

2.Carry out the experiment over a longer period of time.

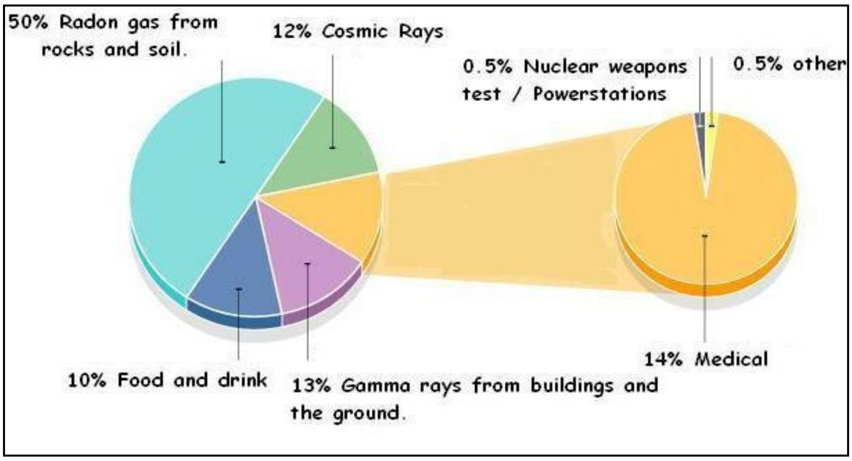
Alpha, beta and gamma radiation.

The 3 types of radioactive emissions from a nucleus.

Properties	**Alpha**	**Beta**	**Gamma**
Symbol	α	β	γ
What is it?	 A helium nucleus (2 protons and 2 neutrons).	 Fast moving electron.	 High energy electromagnetic wave.
Charge	+2	-1	0
Speed	10% speed of light.	50% speed of light.	Speed of light.
What can stop it?	Thin sheet of paper or few cm of air.	Few mm of aluminium or a few metres of air.	Several cm of lead or very thick concrete.
Ionising power.	Very high – most damaging inside the body.	Medium	Low (compared with alpha and beta). Easily passes through the body.

Background radiation.

Background radiation: background radiation is all around as radioactive atoms emit alpha, beta and gamma radiation. Most of the background radiation comes from natural sources. The pie chart shows the sources of background radiation.



Natural sources: Radon, Cosmic radiation (from space), radon, rocks, food and buildings.

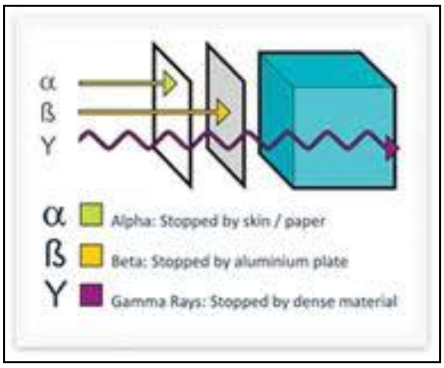
Artificial sources: medical and nuclear industry.

Correcting for background radiation

If the background count was 30 counts per minute (30 count/minute) then if we are measuring the activity of radioactive source we must ***subtract*** the background count rate. If the count rate was therefore measured to be 150 count/minute what is the count rate from the radiation source?

Radiation from source = 150 (total) - 30 (background) = 120 (radiation from source)

<u>**Example question:**</u> an experiment is done to determine the type of radiation emitted by a radioactive material. Various materials are placed between the Geiger tube and the radioactive material. The following information is recorded about the radioactive material. The count rate has ***not been corrected*** for background.



Count without any material in front of source. (count/s)	Count with paper in front of detector. (count/s)	Count with sheet of aluminium in front of detector. (count/s)	Count with thick 20cm of lead in front of detector. (count/s)
250	50	50	0.5

Question: determine the type and amount of each radiation emitted by the radioactive material.

1st point: the count drops from 250 to 50 with a shielding of paper. This indicates the presence of alpha radiation. Count rate alpha = 250 – 50 = 200 count/s.

2nd point: placing aluminium in front has no effect so cannot be beta present.

3rd point: the lead decreases the count/s so must be gamma radiation present.
Count rate gamma = 50 – 0.5 = 49.5 count/s.

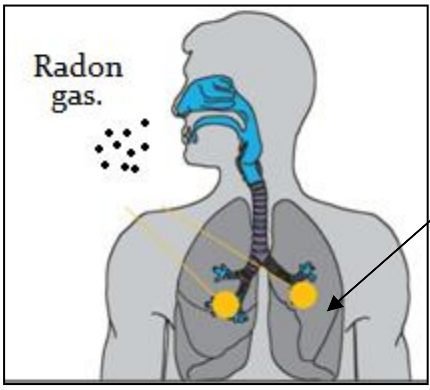
4th point: Background count must be 0.5 count/s. All (almost) gamma radiation should be stopped by 20cm of lead.

Summary: **alpha** = 200 count/s, **beta** = 0 count/s, **gamma** = 49.5 count/s, **background** = 0.5 count/s

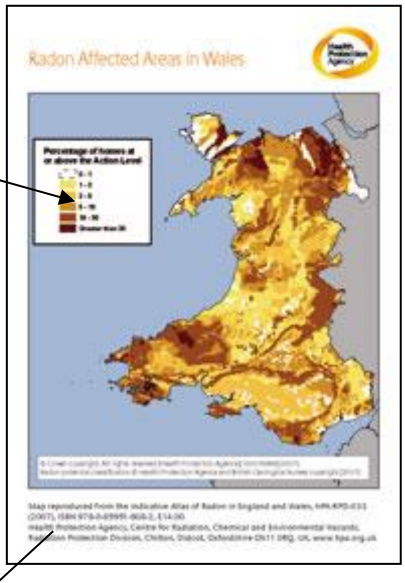
Radon Gas.

Radon gas is formed when ***uranium*** in volcanic rocks like ***granite*** undergoes radioactive decay to form radium and then the radium decays to radon gas. High levels of radon gas can lead to lung cancer.

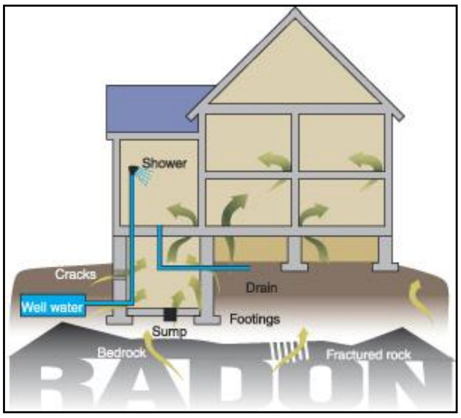
Uranium-238 Solid $\xrightarrow{\alpha}$ Radium 226 Solid $\xrightarrow{\alpha}$ Radon 222 Gas $\xrightarrow{\alpha}$ Polonium 218 Solid



The radon gas is an ***alpha emitter*** which is the worst kind as it the most **highly ionising** and does the most damage if it gets ***inside*** the body.



The dark areas on the map are places with higher levels of radon gas. Radon gas enters your home through the ***gaps/cracks*** in the floor.



If the level of radon is above 200 Bq/m^3, (1 Becquerel is decay per second) then action should be taken to reduce the levels of radon in your home:

1. ***Improve ventilation by opening windows.***
2. ***Fitting air bricks to improve under floor ventilation.***
3. ***Install a fan to extract radon gas from a sump underneath the house.***

Radiation dose.

Measuring the received dose of radiation:
The higher the radiation received can increase your risk of developing cancer. Scientists can measure the dose in units of **sievert** (Sv). One sievert is a large dose and therefore they use **milisievert** (mSv).

The higher the dose received the more damage has been done.

The dose received depends upon two things:

1. **The type of radiation (alpha, beta or gamma)**
2. **The amount of radiation received.**

Over the world the average dose received is 2.4 milisievert (0.0024Sv) a year. Some places in Cornwall receive doses of 7.8 mSv.

Available scientific evidence does not indicate any cancer risk or immediate effects at doses below 100 mSv a year. At low levels of exposure, the body's natural repair mechanisms seem to be adequate to ***repair radiation damage*** to cells soon after it occurs.

Protecting against radiation

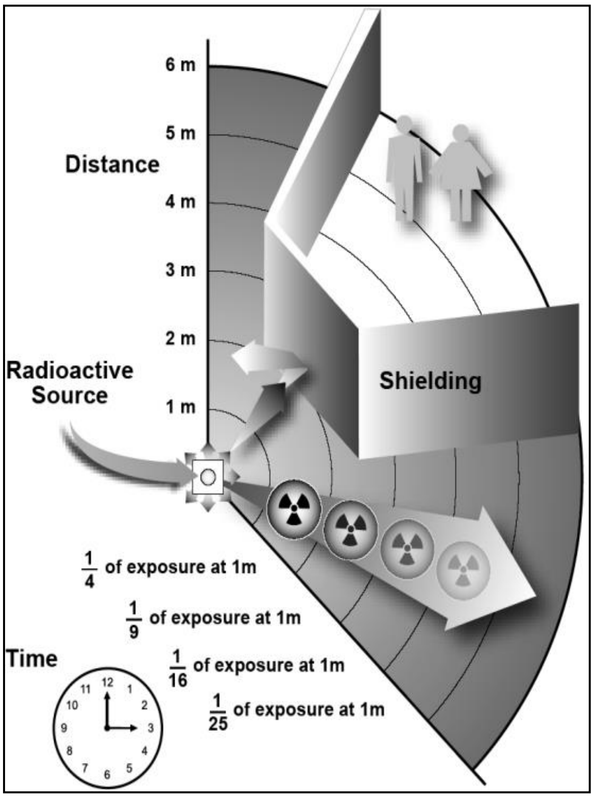
There are ***four ways*** in which people are protected from identified radiation sources:

1. **Limiting time**. In the workplace situations, dose is reduced by limiting exposure time.

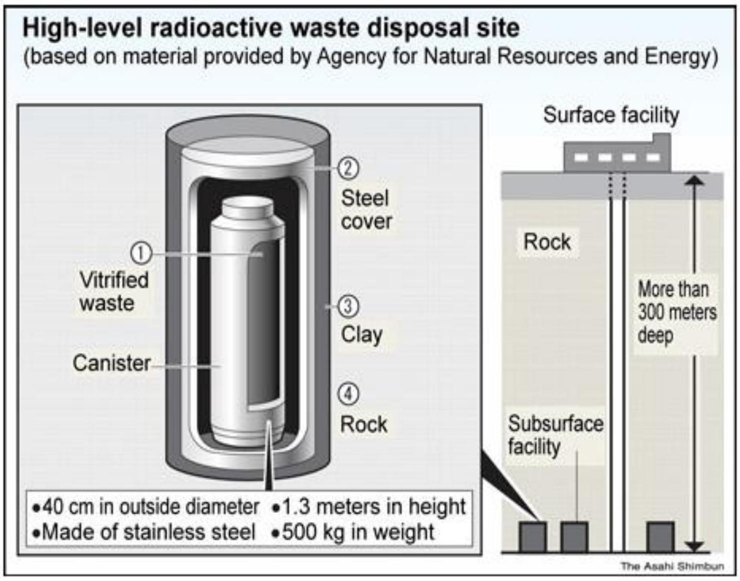
2. **Distance**. The intensity of radiation decreases with distance from its source.

3. **Shielding.** Barriers of lead, concrete or water give good protection from high levels of penetrating radiation such as gamma rays. Intensely radioactive materials are therefore often stored or handled under water, or by remote control in rooms constructed of thick concrete or lined with lead.

4. **Containment.** Highly radioactive materials are confined and kept out of the workplace and environment. Nuclear reactors operate within closed systems with multiple barriers which keep the radioactive materials contained.



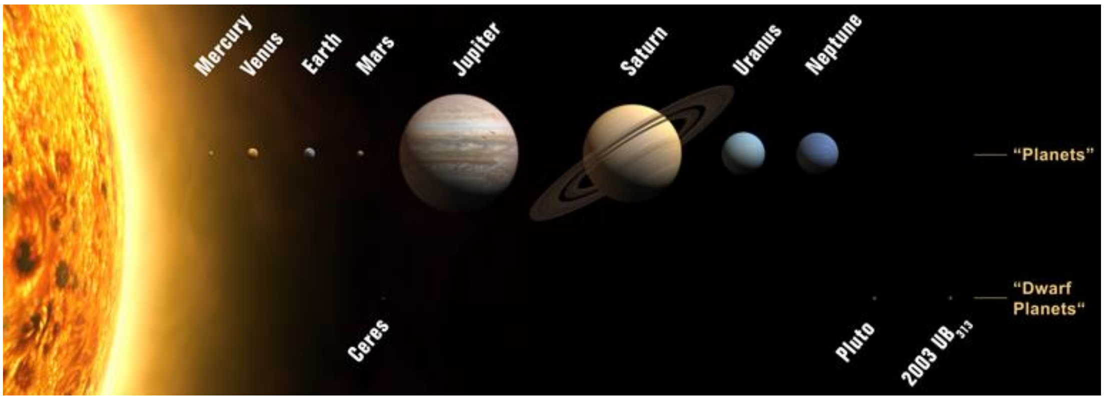
Storing Nuclear Waste



Nuclear waste is produced by the nuclear industry in **nuclear power stations** and ***nuclear medicine***. Nuclear waste is very difficult to get rid of and make safe.
Only **time** can reduce the radiation emitted because they can remain radioactive for a long period of time (**thousands of years** with some materials). It is very ***costly*** to ***process***, ***store*** and ***guard*** the nuclear waste.

Nuclear power stations produce the vast majority of the nuclear waste. Due to the radiation emitted the waste is very hot and so must be cooled. It is then turned into a glass so that it cannot flow. The waste is placed inside steel drums and then sealed in concrete. **Deep underground** is one possible idea for storage. Care must be taken that the waste does not pollute the local water source if it were to leak.

Unit 4 :
The solar system and its place in the Universe



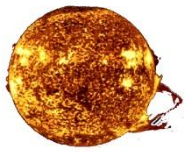
The planets seen above are shown to the correct scale according to their relative sizes, but are far from scale in terms of their distances from the Sun.
(On the scale shown, the Earth should be about 15metres away from the Sun !!)

http://htwins.net/scale2

The Earth – our home !
Diameter = 12,800 km.
The closest object to us in space is the Moon. (It's about 30 Earth diameters away).

X 100

Our star – the Sun. All objects in the solar system orbit around the Sun.
It's about 100 times as big as the Earth.



X 3000

Our solar system.
The picture at the top of this page shows what it contains.

X 40,000

Outside the solar system there's a lot of empty space. The nearest stars are about 4 light years away, and all spaced out about the same distance within the galaxy.

X 10,000

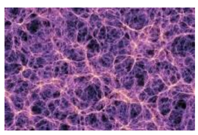
A cluster of stars is known as a galaxy. Our galaxy is called the 'Milky Way'. It's about 90,000 light years across.

X 200

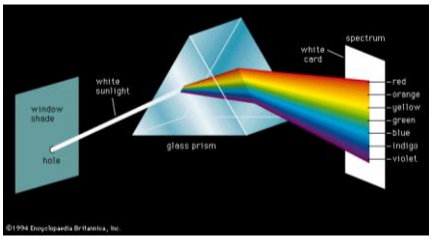
The picture (➔), taken by the Hubble telescope shows a large 'cluster' of galaxies !

X 1000

The known universe is made of many billions of galaxies. The string-like patterns seen are called 'filaments' – colossal clusters of millions of galaxies !



Spectra



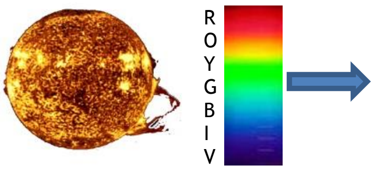
Sir Isaac Newton passed ‘white’ light through a small glass prism, and found that white light is actually a mixture of all the different colours or **wavelengths** in the visible spectrum :

A better device to ‘split-up’ light is a ‘diffraction grating’. The surface of a CD or DVD acts like a diffraction grating – you may have noticed a rainbow effect when you look at them ?

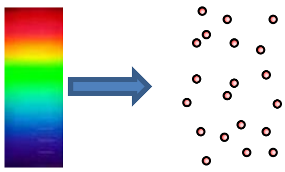
If you want to analyse light from stars or galaxies, you will need a **spectrometer.** This has a diffraction grating that splits all the different wavelengths up in a very precise way.

The picture below shows the Sun’s **spectrum** as you would see it through a spectrometer. If it were in colour, you would see that almost all the colours (or wavelengths) can be seen, but, there are quite a few wavelengths ‘missing (dark lines). Why ?

Red ➔ Green ➔ Blue ➔ Violet

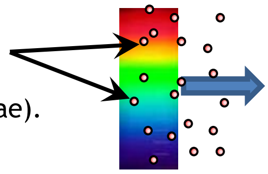


Light produced by a star contains all the (visible) wavelengths.

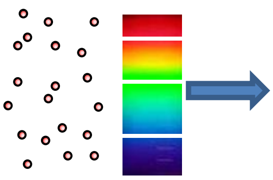


However, this light has to travel through the star’s atmosphere and then through space before it reaches our telescopes.

Dust and gas, either in a star’s atmosphere or in large clouds in space (nebulae).



This dust and gas absorbs some of the wavelengths/colours of the light from the star.



This means that if this light is then looked at through a spectrometer dark lines are seen where there are ‘missing’ wavelengths.

Spectra

These dark lines are known as **absorption lines.**

Each different element can only absorb a certain set of colours. This means that each element has a kind of 'unique fingerprint'. Check out this website :

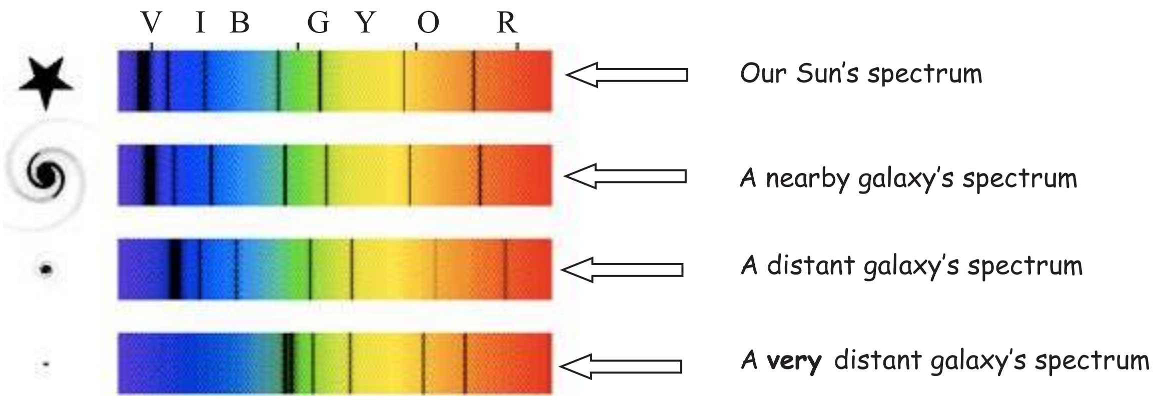
http://jersey.uoregon.edu/elements/Elements.html

Since every different element has its own 'unique fingerprint' of absorption lines, if the position of these lines in a star's spectrum is studied carefully, you can tell which chemicals/elements are present.
Scientists have been using this method since the 19th century to identify the elements in stars and gas clouds in space (nebulae).

When astronomers started looking at the light from stars **within our own galaxy,** they saw that the absorption lines were mainly those produced by **Hydrogen** and **Helium** (the 2 simplest atoms).

The Big Surprize !!

When astronomers analysed the light from **other galaxies** they found the same absorption lines as before (mainly Hydrogen and Helium), but they were all **shifted** towards the red end of the spectrum i.e. **red shifted !**



Edwin Hubble, an American astronomer, studied this curious effect at length.

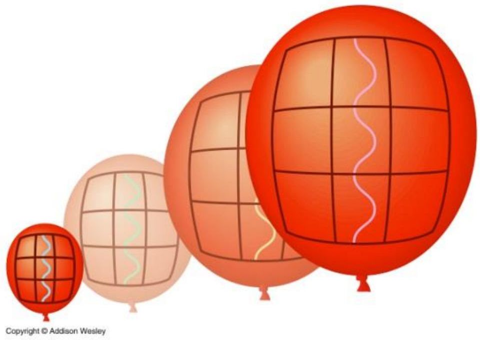
He realised that the further away a galaxy is, the more red-shifted its light appears.

This led him to realise that the universe is expanding, as previously predicted, and that it was therefore much smaller in the distant past, and had a definite beginning - **the Big Bang !**

Edwin Hubble
(1889-1953)

The Big Bang !!

How does the 'cosmological red shift' seen by Hubble show that the Universe is expanding ?



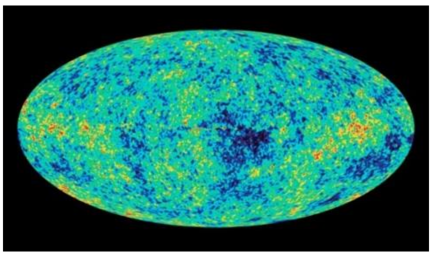
The idea is that if the Universe has been expanding since the Big Bang, then the light waves that have been travelling through it must also have been stretched. If light waves are stretched then their wavelengths will be greater i.e. they will appear red-shifted.

Big Bang Prediction

The Big Bang theory suggests that our Universe began with a massive explosion throwing energy (gamma rays) out in all directions. The Universe, therefore, began in a very hot and very dense state, but has been expanding and cooling since.

This idea of an expanding universe brought about an important prediction :

The enormous 'flash' of light at the beginning of the universe should still be visible today.
However, because the universe has been expanding for billions of years, this light (originally gamma rays) should be severely red-shifted. It should now be microwave radiation and should be seen everywhere in all directions.



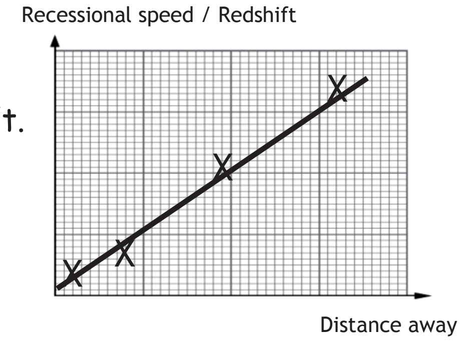
In 1964, 2 scientists, Penzias & Wilson found this background radiation, completely by accident. It's now known as the CMBR (Cosmic Microwave Background Radiation). They both received a Nobel prize in 1978 for their work, since this is very strong, independent evidence for the Big Bang !

The Big Bang !!

Summary

1st - The Big Bang theory was proposed.

2nd -Edwin Hubble's measurements showed that the further away a galaxy is the greater the redshift. This became known as **COSMOLOGICAL REDSHIFT**.
The graph seen ➔ was strong evidence that the Universe is expanding.



3rd – A prediction :- Cosmological Redshift means that the gamma waves from the big bang should have moved to the microwave region of the spectrum by today, and that scientists should be able to see this "background" radiation left over from the Big Bang in all directions.

4th - Penzias a Wilson found the Cosmic Microwave Background Radiation. (CMBR)

5th - The wavelength and temperature of the microwave radiation from the big bang was at the exact temperature that was expected/ predicted by the Big Bang.

Theory	Evidence
The universe is expanding	Cosmological redshift – more distant galaxies have greater redshifts
Large explosion (big bang) at the start.	CMB radiation is the red-shifted gamma rays produced by the Big Bang.