Gleniffer High School

National 4

Waves and Radiation

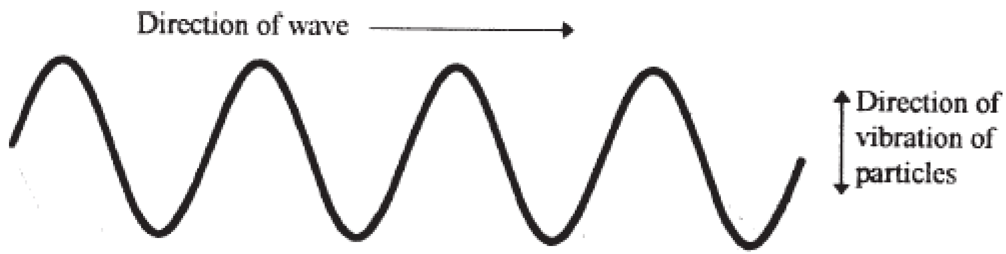
Summary Sheets

WAVE CHARACTERISTICS

Transverse Waves

A **water wave** is a transverse wave. The direction of vibration is at right angles to the direction of wave travel.

In this diagram the water particles move up and down but the wave travels from left to right.

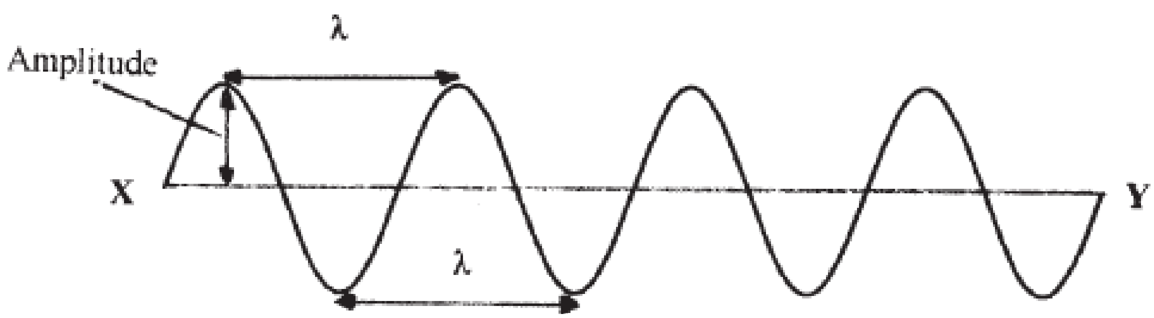


Longitudinal Waves

A **sound wave** is a longitudinal wave. The direction of vibration is in the same direction as the travel of the wave.

Wave Terms

A typical wave diagram is shown below: -



For this wave a number of terms can be measured or calculated.

The **wavelength (λ)** is the horizontal distance between any two corresponding points on adjacent waves.

The **amplitude** is the vertical distance measured from the middle of the wave to the top or to the bottom.

The **frequency (f)** of the wave is the number of waves that pass a point in one second and can be calculated using the following equation:

$$f = \frac{N}{t}$$

where,

f is the frequency of the wave measured in Hertz (Hz)

N is the number of waves

t is the time taken for the waves to pass a point measured in seconds (s)

The **wavespeed (v)** is the speed of the wave and can be calculated using the following equations:

$$v = \frac{d}{t}$$

where,

v is the wavespeed measured in metres per second (ms^{-1})

d is the distance travelled by the wave measured in metres (m)

t is the time taken by the wave measured in seconds (s)

OR

$$v = f\lambda$$

where,

v is the wavespeed measured in metres per second (ms^{-1})

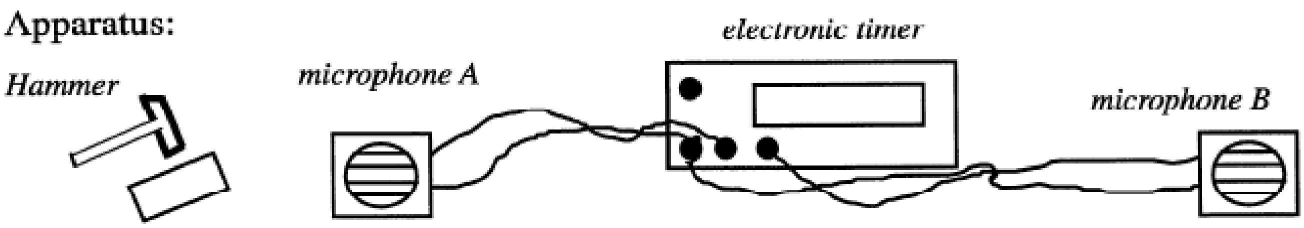
f is the frequency of the wave measured in Hertz (Hz)

λ is the wavelength of the wave measured in metres (m)

Calculating the speed of sound

In a laboratory the speed of sound can be calculated using the formula below.

$$v = \frac{d}{t}$$



A loud sound is made. As the sound reaches microphone A, the timer starts; when the sound waves reach microphone B, the timer stops. The distance between the microphones is measured with a metre stick.

The experiment was repeated five times and the results are shown below.

Distance from microphone A to microphone B = 1 m.

Experiment	1	2	3	4	5
Time (s)	0.0030	0.0029	0.0031	0.0027	0.0029

Average time = 0.0029 s

The speed of sound can be calculated as follows:

v = ?

d = 1 m

t = 0.0029 s

v = d / t

v = 1 / 0.0029

v = 345 ms^{-1}

The speed of sound in air is normally quoted as **340 ms^{-1}**.

Wave Calculations

For wave calculations it is important to write down all the information from the question before selecting the appropriate method for solving the problem.

Example One

A water wave takes 0.2 seconds to travel 1.6 metres. Calculate the speed of the water wave.

t = 0.2 s

d = 1.6 m

v = ?

v = d / t

v = 1.6 / 0.2

v = 8 ms^{-1}

Example Two

A sound wave traveling at 340 ms^{-1}, has a frequency of 2720 Hz. Calculate the wavelength of the wave.

v = 340 ms^{-1}

f = 2720 Hz

λ = ?

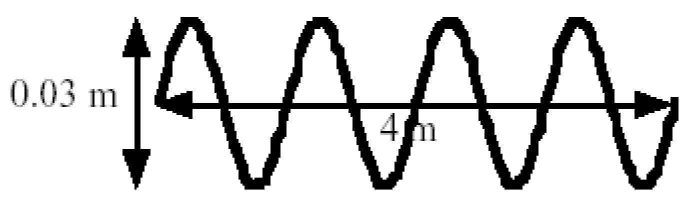
v = f x λ

340 = 2720 x λ

λ = 0.125 m

Example Three

The diagram below represents a wave 0.2 s after it has started.



a) State the amplitude of the wave.
b) State the wavelength of the wave.
c) Calculate the frequency of the wave.
d) Calculate the speed of the wave.

a) Amplitude is defined as the distance from the centre line to the top of the wave. In this case 0.03 / 2 = 0.015 m

b) In this diagram the four complete waves, cover a distance of 4 m. This means that each wavelength must be 4 / 4 = 1 m

c)

f = ?	f = N / t
N = 4	f = 4 / 0.2
t = 0.2 s	f = 20 Hz

d)

d = 4 m	d = v x t
t = 0.2 s	4 = v x 0.2
v = ?	v = 4 / 0.2
	v = 20 ms^{-1}

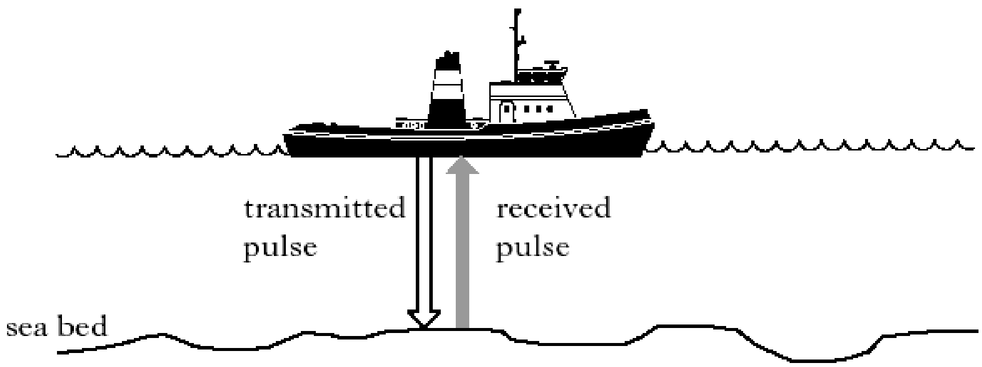
OR

v = ?	v = f x λ
f = 20Hz	v = 20 x 1
λ = 1 m	v = 20 ms^{-1}

Example Four

A ship is carrying out a survey of the seabed using ultrasound waves, which travel at a speed of 1500 ms^{-1} in sea water.

When stationary, the ship transmits and receives pulses of ultrasound waves with a frequency of 30 kHz.



a) Calculate the wavelength of the ultrasound waves.

v = 1500 ms^{-1}

f = 30 kHz = 30,000 Hz

λ = ?

v = f x λ

1500 = 30,000 x λ

λ = 1500 / 30,000

λ = 0.05 m

b) At one point, each ultrasound pulse is received back at the ship 0.36 s after it has been transmitted. Calculate the distance to the seabed.

d = ?

v = 1500 ms^{-1}

t = 0.36 s

d = v x t

d = 1500 x 0.36

d = 540 m

This is the total distance travelled by the pulse.

The distance to the seabed must be 270 m. (540 / 2)

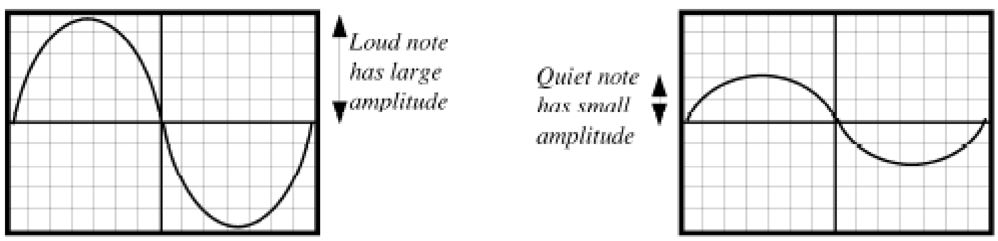
SOUND

Analysing Waveforms

A Cathode Ray Oscilloscope (CRO) is a device that can display a “picture of sounds”. The “picture” can give information about the frequency and amplitude of the sound.

Loud and quiet sounds

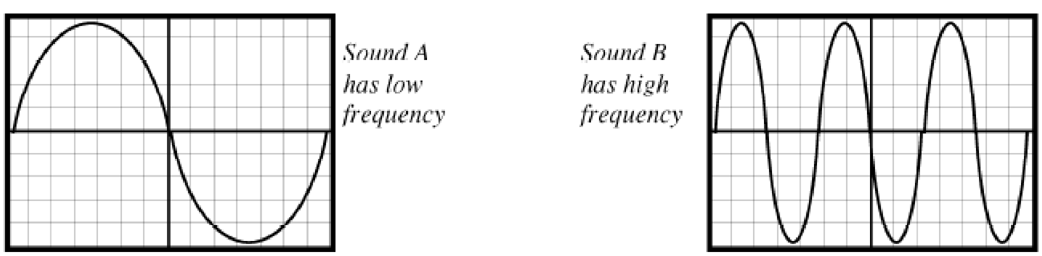
A loud sound transfers more energy so the oscilloscope trace will have a large amplitude. The amplitude of a wave is the distance from the middle of the wave to the top or bottom of the wave.



A soft / quiet sound transfers less energy so the oscilloscope trace will have a small amplitude.

High and low frequency

The effect of changing the frequency of a note can be seen on the oscilloscope screen.



Sound B has a higher frequency than Sound A. Both sounds have the same amplitude.

Noise

Sounds that you do not like or do not want to hear are called noise. If you are forced to hear these noises it is called **noise pollution**. Some examples of noise pollution are:-

- Aircraft
- HGVs
- Pneumatic drills

Loud sounds are the most common type of noise pollution. Loudness of a sound is measured in **decibels (dB)** on a sound level meter.

Some common sound levels are shown below…

Source of noise	Sound Level (dB)
Threshold of hearing	0
Whispers	30
Classroom	60 to 70
Lorry	90
Rock concert	120
Threshold of pain	140

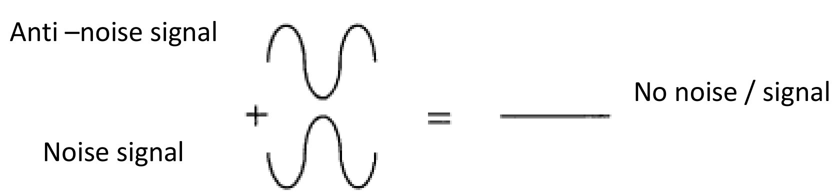
Hearing damage can happen if you regularly listen to sounds above 90 dB. **Ear mufflers** can be used to reduce the sound level. Ear mufflers work by absorbing some of the energy before it reaches your ear.

Noise cancelling headphones can also prevent damage to your hearing. These headphones use electronic components to identify and “cancel out” unwanted background noise.

To cancel out the noise a process called **destructive interference** takes place.

In this process an **anti-noise signal** is added to the **noise signal**. In the diagram below the top signal is the noise signal and the bottom signal is the anti-noise signal.

When the signals are added they **cancel each other out** and this is shown by the straight line after the equals sign.



THE ELECTROMAGNETIC SPECTRUM

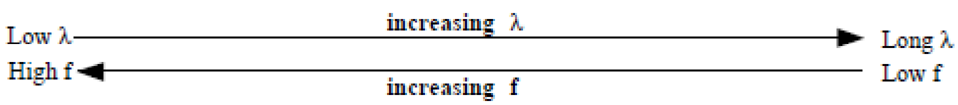
The electromagnetic (EM) spectrum is a family of waves. Like all families the members have lots in common. But each family member is also unique.

The names of the members of the **EM Spectrum** are: -

- Radio
- Microwave
- Infrared
- Visible
- Ultraviolet
- X-ray
- Gamma Ray

All members of the EM Spectrum share two very important characteristics. They travel at the same **speed 3×10^8 ms^{-1}**. (300 million metres per second) They are **transverse waves.**

Although only the visible part can be viewed, all parts can be identified by their frequency or wavelength.



Gamma Ray	X-ray	Ultraviolet	Visible	Infrared	Microwave	Radio

The EM spectrum has many **industrial and medical** applications.

A summary table is shown below.

EM Wave	**Detector**	**Source**	**Application**
Radio	Telescope	Transmitter	Radar
Microwave	Aerial	Transmitter	Mobile phones
Infrared	Photodiode	Lamp	TV remote
Visible light	Eyes	Various	Fibre optics
Ultraviolet	Fluorescent pigments	The Sun	Reduce acne
X-ray	Photographic film	Particle accelerators	Crystallography
Gamma ray	GM Tube	Radioactive nuclei	Tracers

Risks and Safety Procedures

As the frequency of the waves in the EM spectrum increases so does their energy. This makes gamma rays the most dangerous for living cells and radio waves the safest.

Ultraviolet Radiation

Ultraviolet radiation has more energy than visible light and can change the pigmentation (colour) of our skin.

In large doses or with log term exposure it can cause skin cancer as well as damaging the eyes.

To prevent the dangers associated with ultraviolet radiation you should limit your exposure time. A high factor sun cream should be used on any exposed skin, and polarising sunglasses will help prevent damage to your eyes.

X-rays

X-rays have more energy than ultraviolet radiation.

A small dose of X-rays will not cause a severe reaction from your cells. However, daily exposure or a large concentrated dose could result in sickness, hair loss or other types of cell damage.

That is why the person taking your X-ray wears a lead apron and leaves the room when the X-ray machine is operating.

Gamma rays

Gamma rays have more energy than X-rays. They are very penetrating and can pass straight through the human body causing damage to any living cells they meet.

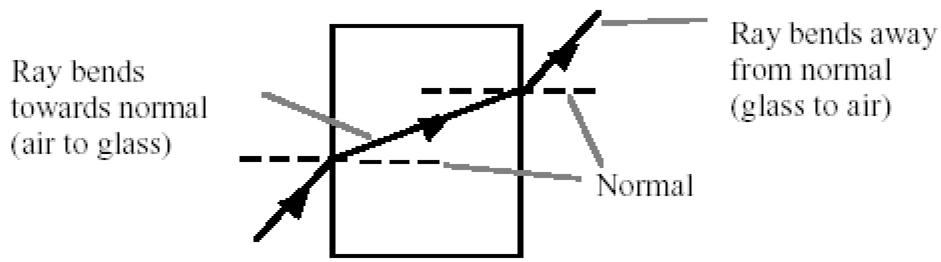
This means that the best way to protect yourself is to avoid exposure to gamma rays…or this could happen:

The ability of gamma rays to damage or even kill living cells can be useful.

Directing gamma rays at cancerous cells will destroy them and gamma rays can be used to sterilise surgical equipment.

REFRACTION of LIGHT

Refraction of visible light can take place whenever visible light enters a new material.



glass block

Refraction is the **change in speed** of a wave that happens when the wave changes from one material to another.

As the above diagram shows, the ray of light has undergone a change in speed when it has changed the material that it is travelling through which has caused also caused a change in direction of the ray of light. The following points should be noted for refraction of light.

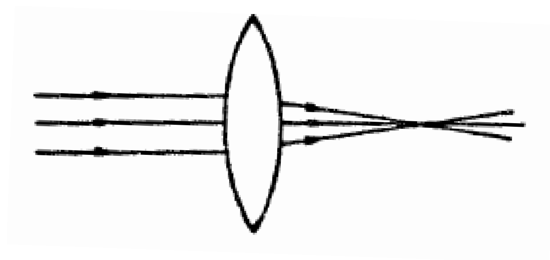
- Light slows down when it enters a denser material e.g. when it travels for air into glass.
- The refracted and incident angles are always measured from the normal line.

Knowledge of the physics of refraction can be used in different contexts, e.g. lenses and fibre optic communication.

Lenses

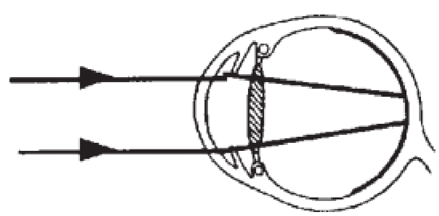
Refraction of light is used in lenses.

When parallel light rays enter a **convex (converging) lens** the refraction that takes place brings the rays of light to a focus or focal point.

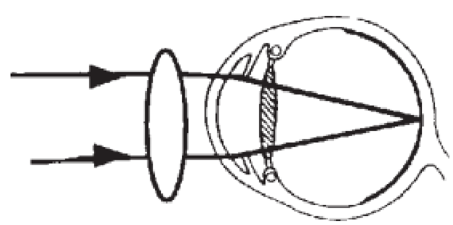


Converging Lens

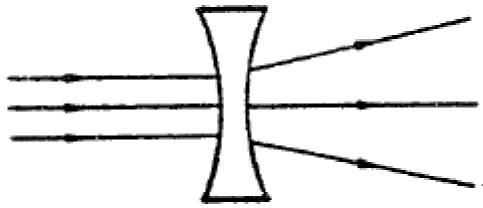
Long-sighted people can see distant objects but have difficulty seeing near objects. The image from a near object would be formed **behind the retina.**



Convex (converging) lenses are used in spectacles when people are long-sighted.

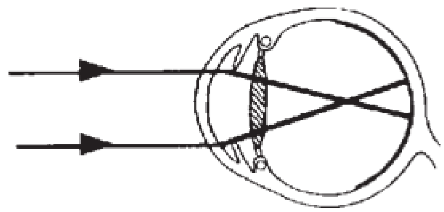


When parallel light rays enter a concave (diverging) lens the refraction that takes place spreads the rays of light out as shown below.

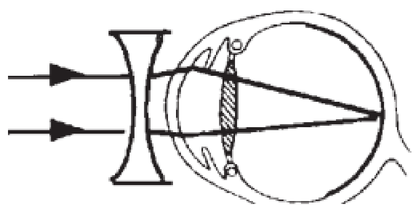


Diverging Lens

People who are **short-sighted** have difficulty seeing distant objects. The image from a distant object would be formed **short of the retina**.

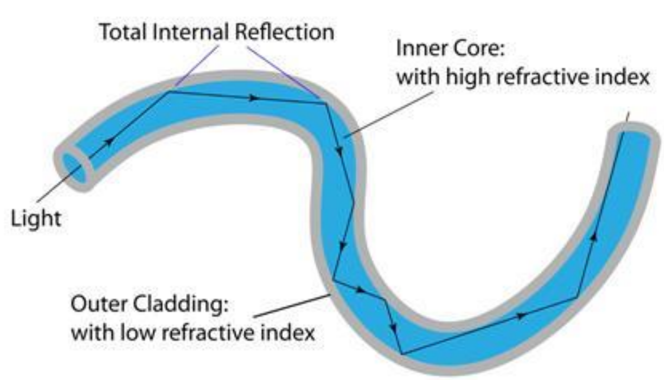


Concave (diverging) lenses are used in spectacles when people are short-sighted.



Optical Fibres

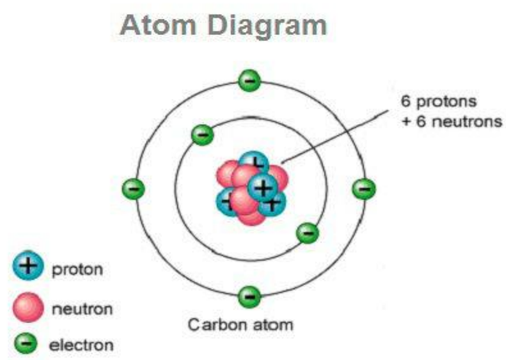
Optical fibres are long, thin, flexible pieces of glass that carry rays of light. The are manufactured in a way that ensures the rays of light do not escape, helping to ensure the message being sent gets communicated successfully from sender to receiver.



NUCLEAR RADIATION

Every substance is made up from atoms.

The nucleus is the central part of an atom. The nucleus contains **protons**, which are positively charged, and **neutrons** which have no charge. Orbiting the nucleus are negatively charged **electrons**.



If the **balance** of protons and neutrons is **incorrect** in a nucleus then it can emit **nuclear radiations** like **gamma** rays, **alpha** particles and **beta** particles.

Although alpha, beta and gamma are all produced by a radioactive nuclei they have very different properties and uses. These are summarised below.

Name	Description	Distance Travels In Air	Absorbed by	Possible Use
Alpha	Slow moving nucleus	A few cm	Paper	Smoke Alarms
Beta	Fast moving electron	Tens of cm	Thin Aluminium	Medical Tracers
Gamma	High energy wave	Many km	Thick Lead	Cancer Treatment

Some atoms have a nucleus that is **naturally radioactive**. An example would be the element **radon,** a gas which occurs naturally in our atmosphere. Radioactive elements can also be **manufactured**. An example would be **plutonium** which is used as fuel in nuclear power stations.

Nuclear power stations often use a process called **nuclear fission** to produce heat energy inside a nuclear reactor.

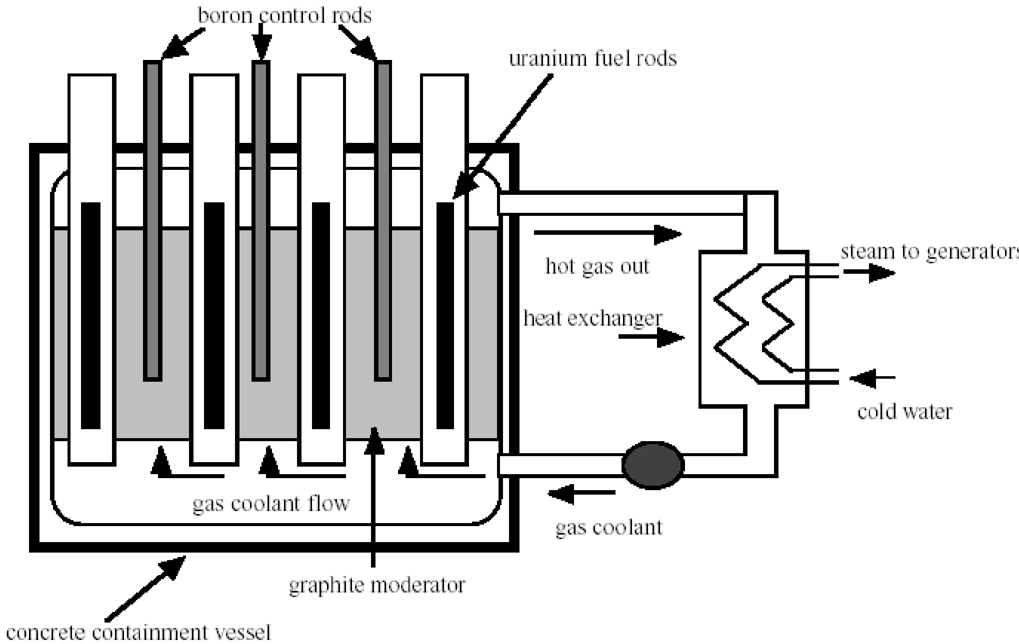
In nuclear fission, a neutron is fired at large nucleus. This causes the large nucleus to split into smaller nuclei and some other particles. During this split lots of heat energy is also released.

Again, further study of nuclear fission forms part of the S4 Physics courses.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{92}_{36}\mathrm{Kr} + ^{141}_{56}\mathrm{Ba} + 3\ ^{1}_{0}\mathrm{n} + \text{energy}$$

By monitoring this chemical reaction a controlled **chain reaction** can be produced inside a **nuclear reactor.**

Nuclear Reactors



Advantages of using nuclear power to generate electricity**:**

- Fossil fuels (coal, oil and gas) are running out, nuclear fuel provide a reliable source for generating electricity.
- A nuclear power station produces the same energy from one tonne of uranium as coal power station would produce from 25 000 tonnes of coal.
- Unlike fossil fuels (coal, oil and gas) nuclear fuel does not release large quantities of the gases (carbon dioxide and sulfur dioxide) which cause acid rain into the atmosphere.

Disadvantages of using nuclear power to generate electricity**:**

- Nuclear power stations produce radioactive waste some of which is very difficult to deal with.
- A serious accident at a nuclear power station is a major disaster, e.g. Chernobyl, as it would release tonnes of radioactive material into the atmosphere.
- When a nuclear power station is no longer in use, it takes a long time for the ground it is built on to be used for any other use.

Radioactive waste

Nuclear power stations produce radioactive waste materials. These waste products are first set in concrete and steel containers then buried deep under the ground or dropped to the bottom of the sea. These types of disposals are very controversial. Some scientists believe the containers will keep the radioactive material safe for a long time; other scientists are worried that the containers will not remain intact for such a long time.

Relationships required for Unit Test are:

frequency = Number of waves ÷ time

$f = N \div t$

wavespeed = frequency x wavelength

$v = f \times \lambda$

distance = speed x time

$d = v \times t$