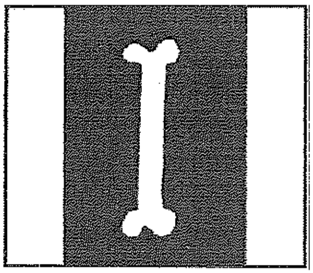
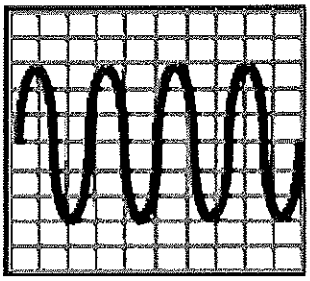
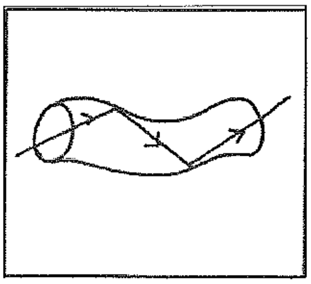
Our Lady's High School

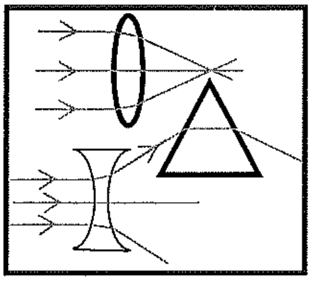
North Lanarkshire Council

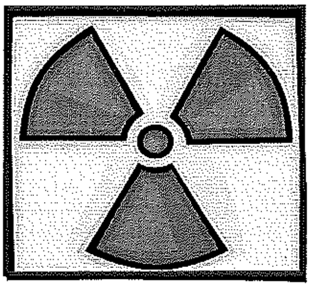
S3 Physics

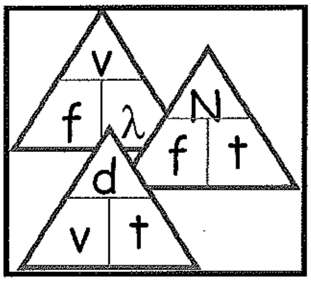


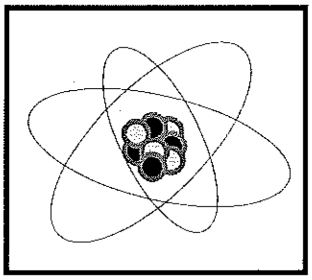


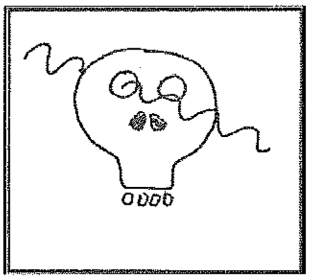


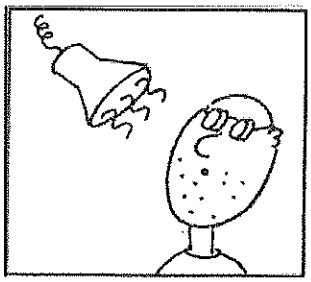












Waves & Radiation

Summary Notes

2018

S3 Physics – Waves and Radiation Key Areas

Wave Parameters and Behaviours

- ☐ I can state that energy can be transferred as waves.
- ☐ I can define frequency, period, wavelength, amplitude and wave speed.
- ☐ I can state the difference between a transverse and a longitudinal wave.
- ☐ I can classify these waves as either transverse or longitudinal: sound, electromagnetic radiation and water.
- ☐ I can determine the frequency, period, wavelength, amplitude and wave speed for transverse and longitudinal waves.
- ☐ I can solve problems using $d = v\,t$, $v = f\lambda$, $f = \frac{N}{t}$ and $T = \frac{1}{f}$ including sonar/ultrasound and echoes.
- ☐ I can describe what is meant by diffraction.
- ☐ I can describe the differences between long wave and short wave diffraction and apply these to complete diagrams and explain differences in radio and television reception.

Electromagnetic Spectrum

- ☐ I can state the names of the seven bands of the electromagnetic spectrum and put them in order of frequency and wavelength.
- ☐ I can give an example of a typical source, detector and application for each of the seven bands in the electromagnetic spectrum.
- ☐ I can state how the energy associated with a form of radiation is linked to its frequency.
- ☐ I can state the speed at which all radiations in the electromagnetic spectrum travel.
- ☐ I can classify all radiations in the electromagnetic spectrum as transverse waves.

Refraction of Light

- ☐ I can define refraction in terms of wave speed.
- ☐ I can state how the wavelength and frequency of a ray change during refraction.
- ☐ I can identify and/or draw the normal, incident ray, refracted ray, angle of incidence and angle of refraction on a diagram.
- ☐ I can state how the angle in air and the angle in the medium compare for a refracted ray and apply this to complete a ray path.

- ☐ I can apply my knowledge of refraction to investigate real life applications e.g. lenses and fishing.

Nuclear Radiation

- ☐ I can draw the symbols for a voltmeter, an ammeter and an ohmmeter can connect them correctly to measure voltage, current and resistance.
- ☐ I can state what is meant by alpha, beta and gamma radiation.
- ☐ I can state what will absorb alpha, beta and gamma radiation.
- ☐ I can describe what is meant by ionisation.
- ☐ I can compare the ionising effect of alpha, beta and gamma radiation.
- ☐ I can define activity in terms of number of nuclear disintegrations and time.
- ☐ I can solve problems using $A = \frac{N}{t}$.
- ☐ I can explain why ionising radiation can be dangerous for living cells.
- ☐ I can explain some safety precautions for working with nuclear radiation including exposure measurement.
- ☐ I can define absorbed dose and equivalent dose.
- ☐ I can solve problems using $D = \frac{E}{m}$ and $H = D\,w_R$.
- ☐ I can define equivalent dose rate.
- ☐ I can solve problems using $\dot{H} = \frac{H}{t}$.
- ☐ I can compare the equivalent dose due to a variety of natural and artificial sources.
- ☐ I can give examples of sources of background radiation.
- ☐ I can state the average UK background radiation level in terms of annual effective equivalent dose.
- ☐ I can state the exposure safety limits for both a member of the public and a radiation worker in terms of additional annual effective equivalent dose.
- ☐ I can describe some practical applications of nuclear radiation including electricity generation, cancer treatment and other industrial and medical uses.
- ☐ I can define half-life.
- ☐ I can describe an experiment to measure the half-life of a radioactive material.
- ☐ I can use a graph, table or data to calculate half-life.
- ☐ I can describe the process of nuclear fission including chain reactions.
- ☐ I can describe the process of nuclear fusion including plasma containment.

- [ ] I can describe the role of fission and fusion in the generation of energy.

Units, Prefixes and Scientific Notation

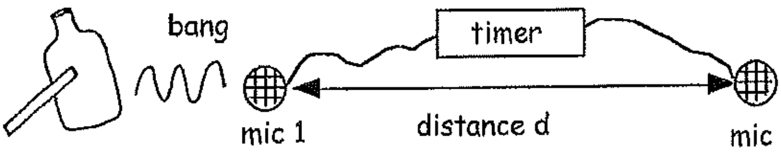
- [ ] I can state and use appropriately the name, symbol, unit and unit symbol for all physical quantities in the National 5 Physics course.
- [ ] I can define and use appropriately the following unit prefixes: nano (n), micro (μ), milli (m), kilo (k), mega (M), and giga (G).
- [ ] I can use scientific notation appropriately.
- [ ] I can state the final answer to a calculation with an appropriate number of significant figures.

	Unit 1 Waves and Radiation	Summary Notes

A. Sound Waves

1. The speed of sound and light

(1) To measure the speed of sound. Connect two microphones to a timer.
Measure the distance between microphones using a Metre stick



Make a loud sound. When sound gets to microphone 1 the timer starts When sound gets to microphone 2 the timer stops.

$$\text{speed of sound} = \frac{\text{distance between mic 1 and 2}}{\text{time to travel from mic 1 to 2}}$$

The speed of sound in air is 340 m/s.

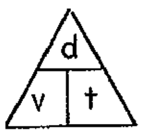
The speed of light in air is 300,000,000 m/s or 3×10^{8} m/s

Light is much faster than sound. In a thunder storm the light and sound are made at exactly the same time. We see the light first because the light signal travels faster than the sound, so it gets to us first.

2. Wave speed, - distance and time.

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

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

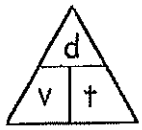


quantity	units
distance	m
time	s
speed	ms^{-1}

Example 1 How far would a sound wave travel in 0.6s?

d= ?
v = 340m/s^{-1}
t = 0.6s

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



$d = v\ t$

$d = 340 \times 0.6$

d = 204m

3. Scientific Notation

$2300000 = 2.3 \times 10^{6}$

$4560000000 = 4.56 \times 10^{9}$

$300,00,000 = 3 \times 10^{8}$

$806000 = 8.06 \times 10^{5}$

$0.005 = 5 \times 10^{-3}$

$0.000000047 = 4.7 \times 10^{-8}$

4. Converting Numbers

Useful prefixes - these make writing big and small numbers much easier.

kilo or k = $\times$ 1000 or $\times 10^{3}$

Mega or M = $\times$ 1,000,000 or $\times 10^{6}$

cm = $\div$ by 100 or $\times 10^{-2}$

milli or m = $\div$ by 1000 or $\times 10^{-3}$

micro or μ = $\div$ by 1,000,000 or $\times 10^{-6}$

4km = 4 $\times$1000 or 4×10^{3} m

12.6Mm = 12.6 $\times$ 1000000 or 12.6×10^{6} m

5.7cm = 5.2 $\div$ 100 or 5.2×10^{-2} m

6.2ms = 6.2 $\div$ 1000 or 6.2×10^{-3} s

4µm = 4 $\div$ 1,000,000 or 4×10^{-6} m

5. Converting Time to seconds

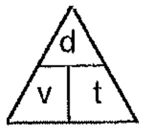
ms = ÷ by 1000 or x 10^{-3} s   5.6ms = 5.6 x 10^{-3} s

minutes to seconds	x minutes by 60
hours to seconds	x hours by 60 then by 60
days to seconds	x days by 24 the by 60 then by 60

Example   How long would it take a light wave to travel 2.5km?

v = 3x10^8 m/s
d= 2.5km = 2.5x10^3 m
t = ?

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



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

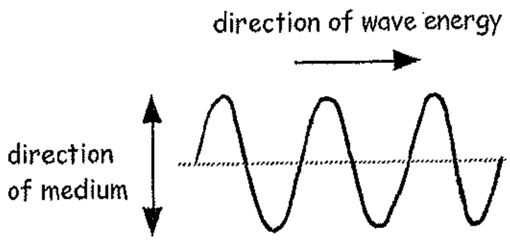
$$t = \frac{2.5 \times 10^3}{3 \times 10^8}$$

$$t = 0.000008\text{s}$$

6. Transverse and Longitudinal Waves

Transverse Waves

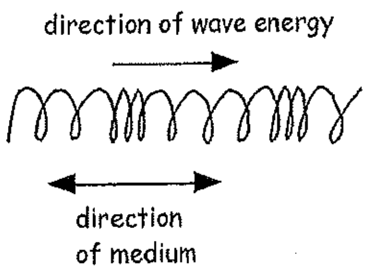
The medium the wave passes through vibrates at right angles to the direction the wave travels.



Examples of a transverse wave are water and radio waves

Longitudinal Waves

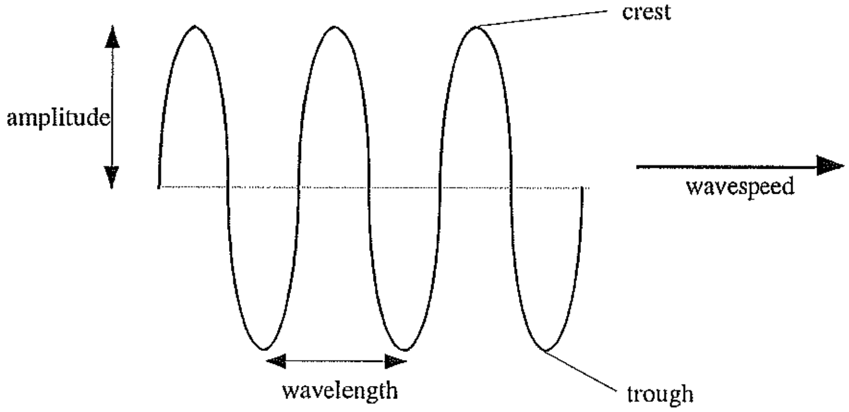
The medium the wave passes through vibrates back and forth in the same direction the wave travels



An example of a longitudinal waves is sound .

Wave Terms

Waves carry **energy** from place to place and therefore they can be used to transmit signals.



Frequency, f - Number of waves passing a point each second. Hertz (Hz)

$$\text{frequency} = \frac{\text{number of waves}}{\text{time (in seconds)}}$$

Wavespeed, v - Distance travelled by a wave in one second. metres per second (m/s)

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Amplitude - Size of maximum disturbance from centre (zero) position. -

Wavelength, λ - Distance from one point on a wave to the same point on the next wave. metres (m)

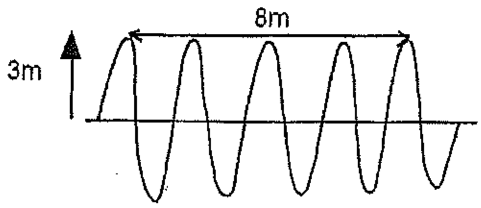
Period, T - Time taken for one wave to pass a point. seconds (s)

$$\text{period} = \frac{\text{time}}{\text{number of waves}}$$

$$T = \frac{1}{f} \quad \text{or} \quad f = \frac{1}{T}$$

8.

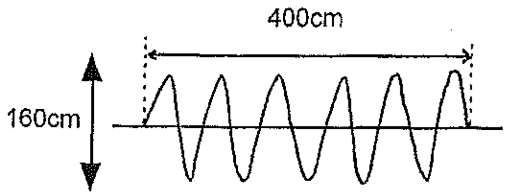
Example 1 Look at this water wave.



(a) What is its amplitude?
(b) What is its wavelength?

(a) Its amplitude = 3m
(b) Its wavelength = $\frac{8}{4}$ = 2m

Example 2 Look at this sound wave.



(a) What is its amplitude?
(b) What is its wavelength?

(a) Its amplitude = $\frac{160cm}{2}$ = 80cm

(b) Its wavelength = $\frac{400cm}{5.5}$ = 72.7cm

Example 600 waves pass a point in 2mins. What is the frequency?

f = ?
No of waves = 600
time 2mins = 120s

$$f = \frac{\text{Number of waves}}{\text{time in seconds}}$$

$$f = \frac{600}{120}$$

$$f = 5Hz$$

What is the period of the wave?

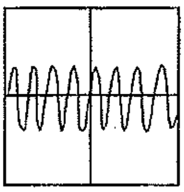
$$T = \frac{1}{f}$$

$$T = \frac{1}{5}$$

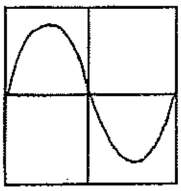
$$T = \underline{0.2\ s}$$

9. Pictures of Sound waves

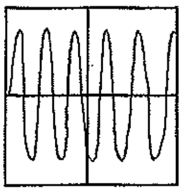
We can display sound waves on an oscilloscope screen.



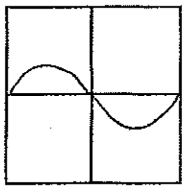
Quiet / loud
High / low
frequency sound



Quiet / loud
High / low
frequency sound



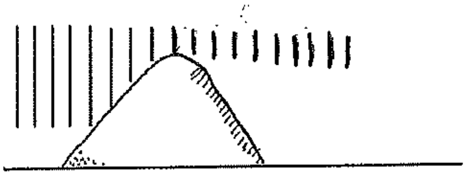
Quiet / loud
High / low
frequency sound



Quiet / loud
High / low
frequency sound

10. Diffraction

(1) All waves will bend around obstacles placed in their way. This bending effect is called diffraction. The longer the wavelength of the waves the more they diffract. Complete diagrams



short wavelengths

long wavelengths

A wave with a wavelength of 4m will diffract more than a wave of wavelength 2m

A wave of frequency 1000Hz will diffract less than a wave of frequency 50Hz.

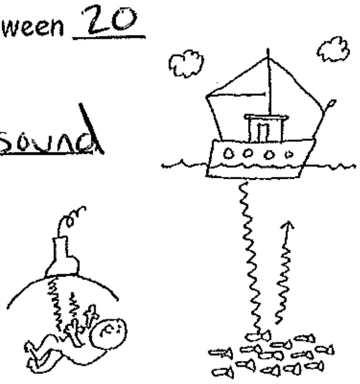
11. Sound Level (Loudness)

(1) The larger the amplitude the louder the sound.
Sound level or loudness is measured in units called decibels or dB for short.
Quiet conversation is 60 dB., Danger Level is 80 dB.
A loud Disco is 110 dB. Loud sounds can damage your hearing.
Wear ear protectors to protect your hearing.
Noise pollution is any sound which can ruin your environment.

12. Ultrasound

(1) Humans can hear sound waves with frequencies between 20 and 20,000 Hz.

Frequencies above 20,000Hz are called ultrasound



When ultrasound travels from one medium into another some of it reflects back.
We can use this fact to create pictures of unborn babies, to find fish in the sea and cracks in pipes.

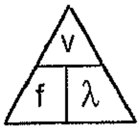
It can also be used to break up kidney stones.

13. Speed, frequency and wavelength

(1) Wave speed, wavelength and frequency.

speed = frequency x wavelength

or $v = f\lambda$



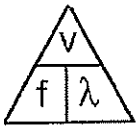
quantity	units
frequency	Hz
wavelength	m
speed	ms^{-1}

Example A sound wave has a frequency of 12kHz.

(a) What is the wavelength of the wave?

$\lambda = ?$
$v = 340ms^{-1}$
$f = 12kHz = 12 \times 10^{3}$ Hz

$v = f\lambda$



$$\lambda = \frac{v}{f}$$

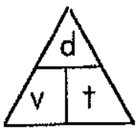
$$\lambda = \frac{340}{12 \times 10^{3}}$$

$\lambda = 0.028m$

(b) How long will it take the sound wave to travel 6.8km?

$t = ?$
$v = 340m.s^{-1}$
$d = 6.8km = 6.8 \times 10^{3}$ m

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



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

$$t = \frac{6.8 \times 10^{3}}{340}$$

$t = 24.1s$

B. Electromagnetic Spectrum

14. Electromagnetic family

(1) The electromagnetic spectrum describes a range or family of waves which all travel as transverse waves at a speed of 3×10^8 ms^{-1}

(2) Here is the electromagnetic spectrum. Fill in the names of the missing waves.

Radio	TV	Micro-waves	infra red	Visible light	ultra violet	X -Rays	Gamma Rays.

R_YG_IV

→ frequency increasing →
→ wavelength decreasing →
→ energy increasing →

Radio waves have the longest wavelength. Gamma rays have the shortest wavelength and therefore the highest frequency. Violet light has a shorter wavelength than red light. As the frequency of the wave increases the wave has more energy. In the spectrum the waves which diffract the most are Radio waves because they have the longest wavelengths

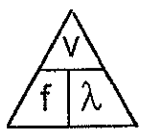
(3) Some more useful prefixes

nano = $\times 10^{-9}$ m   eg   678nm = 678×10^{-9} m

Example A ray of infra red radiation has a wavelength of 1400nm. What is its frequency?

f = ?
$v = 3 \times 10^8$ m/s
$\lambda = 1400\text{nm} = 1400 \times 10^{-9}$ m

$v = f\lambda$



$$f = \frac{v}{\lambda}$$

$$f = \frac{3 \times 10^8}{1400 \times 10^{-9}}$$

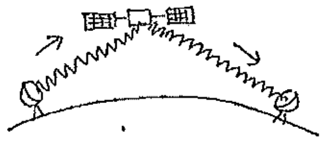
$$f = 2.14 \times 10^{14} \text{ Hz}$$

15. Electromagnetic family - Names and Applications.

(1) **Radio and TV** waves have long wavelength so they are good at diffracting round hills and buildings,. This makes them ideal for carrying radio and TV programmes to your house.

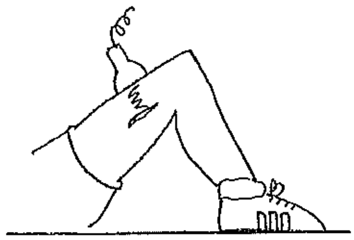
detected by an aerial and a receiver

(2) **Microwaves** are used to carry signals up to satellites in space.



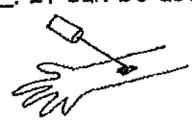
detected by an aerial and a receiver

(3) **Infra red** radiation is the scientific name for heat. It can be detected by a thermometer. In medicine it can be used in heat treatment to speed up the healing of damaged muscle tissue. In industry it can be used to dry paint. Rescue services use thermal imaging cameras to find people in dark or smoky places.



detected by a photodiode and a meter.

(4) **Visible light** is made up of a range of different colours. Red has a longer wavelength than blue light. A concentrated beam of visible light of one colour is called a laser beam. It can be used to remove birth marks and tatoos. It can be used to vapourise tumours.

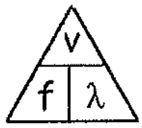


detected by the retina of the eye, photodiode and meter, photographic film

Example The frequency of a microwave is 2870MHz. Calculate its wavelength.

$\lambda = ?$
$v = 3 \times 10^8$ m/s
$f = 2870MHz = 2870 \times 10^6$ Hz

$v = f\lambda$



$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{3 \times 10^8}{2870 \times 10^6}$$

$$\lambda = 0.1m$$

Example How long would it take a beam of infra red radiation to travel 980km?

$t = ?$
$v = 3 \times 10^8$ m/s
$d = 980km = 980 \times 10^3$ m

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

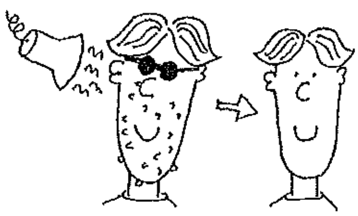
$$t = \frac{d}{v}$$

$$t = \frac{980 \times 10^3}{3 \times 10^8}$$

$$t = 0.003s$$

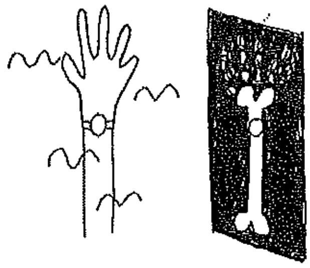
(5) Most of our **ultraviolet** radiation comes from the Sun. It gives us our tan in summer, but too much can damage the skin or even worse cause skin cancer.

UV light can be used to treat skin conditions like acne. Special fluorescent chemicals can be painted on important items as security markings. These markings only show up under ultra violet light.



detected by fluorescent materials and photographic film

(6) <u>**X rays**</u> pass through most tissue and cause photographic film to turn black. However X rays are absorbed by bones in your body. So photographic film behind bones stays white. This allows X ray photographs to be taken of your body.



A Computer Aided Tomography or CAT scanner allows pictures of slices through your body to be taken. This allows a detailed 3 D image to be built up.

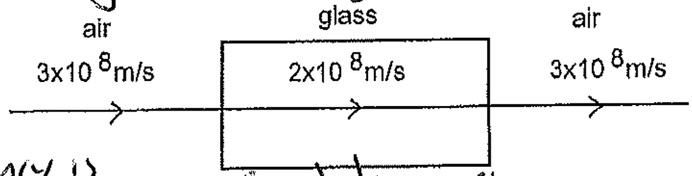
Detected by photographic film.

(7) **Gamma rays** can be used to kill cancer cells in your body. Chemicals emitting gamma radiation can be injected into your blood stream. A Gamma camera picks up the gamma radiation being emitted by the chemical and creates an image of blood flow in your body. This is called a tracer.

Detected by a Geiger counter, photographic film

16. Refraction

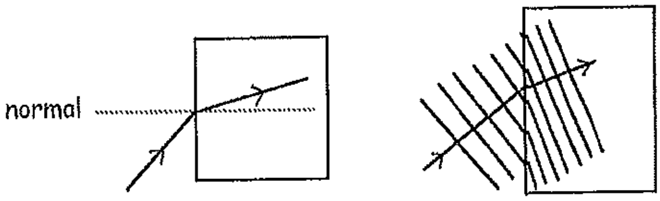
(1) Refraction is the process where the speed of a wave changes as it travels from one medium into a different medium (ie air into glass).
The wavelength also changes



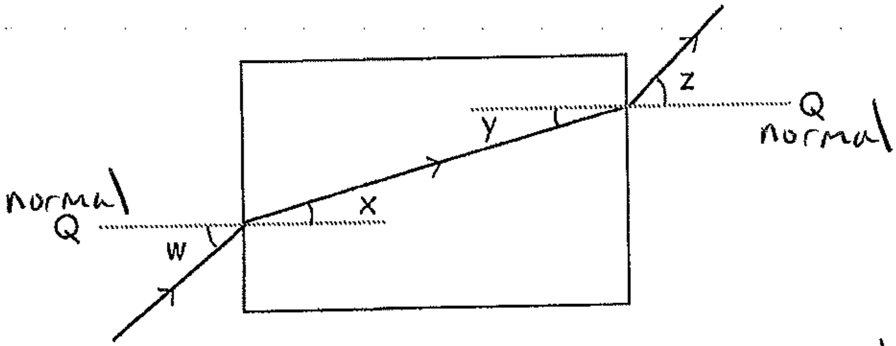
Frequency is unchanged.

Speed decreases
wavelength decreases

(2) If the light travels at an angle to the normal from one medium into another its direction also changes.



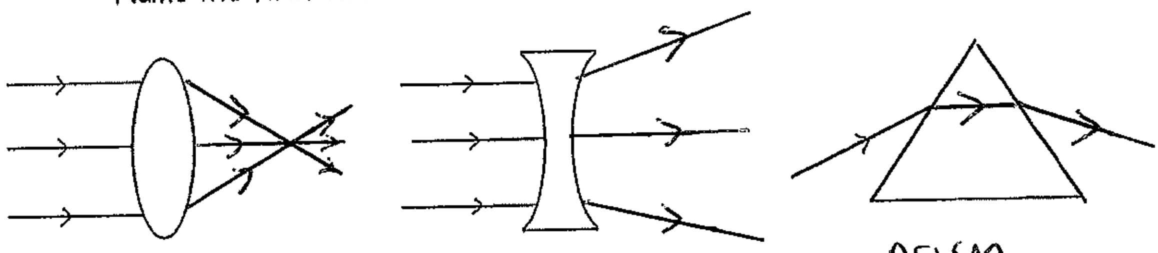
(3) Here is a diagram showing a beam of light travelling from air into a glass block then back into air.



line Q is drawn at 90° to the boundary. It is called the normal.
All angles are measured **from** the normal **to** the ray of light .

angle w = angle of incidence	angle y = angle of incidence
angle x = angle of refraction	angle z = angle of refraction

(4) Copy and complete the path of light through these 3 common lenses.
Name the first two lenses.

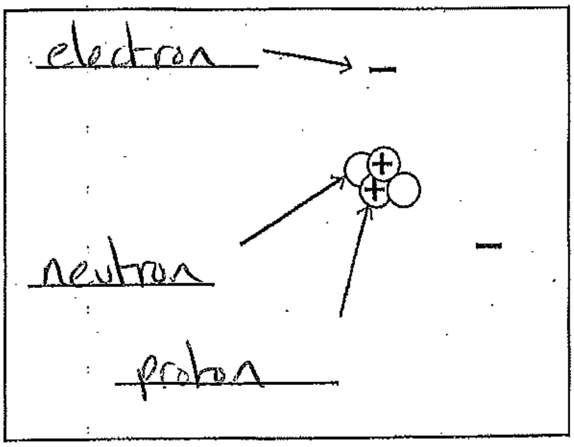


Convex lens   concave lens   prism

C. Nuclear Radiation

17. The atom

(1) An atom has a tiny central nucleus made up of positive protons and neutrons which have no charge.
Flying around the nucleus are tiny particles called electrons which have a negative charge.



As an atom gets bigger it has more protons, neutrons and electrons.

Most atoms are electrically neutral because they have equal numbers of positive protons and negative electrons.

23. Background Radiation

(1) Background radiation is the radiation which is around us all the time. It can come from natural sources or man made sources. Here are some sources of Background radiation.

Source	Natural / Manmade
Cosmic rays	N
Rocks/soil	N
Human Body	N
Industry	M
Chest X ray	M
Dental X ray	M
1 flight over Atlantic	N

(2) Background radiation can be measured using a Geiger-Müller tube and a counter. When measuring the activity of a source we must make sure we take into account background radiation.

22. Uses and Applications of Nuclear Radiation.

(1) In medicine nuclear radiation can be used to kill cancer cells. A gamma source can be injected into your body and be used as a radioactive tracer to study the flow of blood around your body. Because radiation can kill cells it can be used to sterilise medical equipment by killing bacteria.

In our homes alpha radiation is used in smoke detectors. Some of the food you eat might have been irradiated by gamma radiation to kill bacteria and prolong its shelf life.

In industry beta radiation can be used to judge the thickness of paper or foil. Radioactive tracers can also be used to study the flow of liquids along pipes.

Other Uses.

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____

____

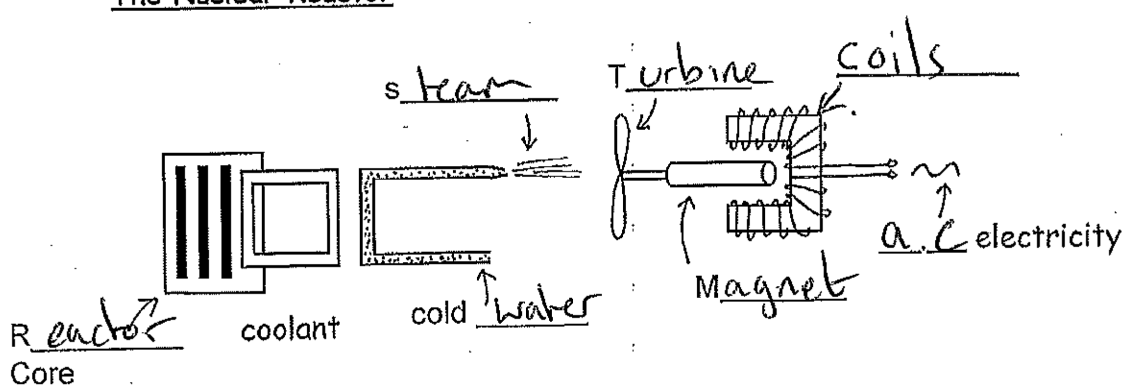
____

____

4. Nuclear Power Station - Using the Heat Energy

(1) The heat energy produced is used to create electricity. A fluid called the coolant flows through the reactor core and absorbs the heat energy. The coolant then passes near to pipes containing cold water. The cold water absorbs this heat and is turned to super heated steam. The steam is fired out of a nozzle and hits the turbine blades. These blades spin and turn a magnet which sits inside a coil of wires. This moving magnet causes or induces an electric current in the coil.

The Nuclear Reactor



(2). At present electricity produced from nuclear fission reactors accounts for 30 % of all the electricity made in Scotland.

6. Nuclear fission versus nuclear fusion

(1) Advantages of fusion compared to fission.

1. The fusion reaction is a very clean process. It does not produce greenhouse gases or radioactive waste

2. The fuel is a type of hydrogen atom which is in plentiful supply in sea water.

(2) Disadvantage of fusion compared to fission.

1. The fusion process requires temperatures similar to the core of the Sun to fuse the nuclei together. Creating temperatures this high is very difficult and expensive.

If scientists can get fusion working at lower temperatures then we will have a clean, cheap and renewable energy source.

5. Pros and Cons of Generating Electricity from Nuclear Fission

(1) Advantages of Nuclear Fission Power

1. The fission process produces no greenhouse gases which are partly responsible for global warming.

2. The supply of electricity is very reliable.

3 A small amount of fuel creates a large amount of electricity.

(2) Disadvantages of Nuclear Fission Power

1. The fission reaction produces nuclear waste which remains dangerous for thousands of years.

2. Nuclear waste has to be stored safely for thousand of years. This is very difficult.

3. Although normally very safe, catastrophic failure due to earthquakes, tsunamis or terrorism could cause dangerous emissions of radiation into the atmosphere and water supply.

4. Nuclear power stations are expensive to build and expensive to decommission once they have come to the end of their lives.

18. Nuclear radiation

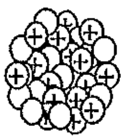
(1) Small atoms are stable because they have fairly similar numbers of protons and neutrons. However very big atoms like Uranium have a big imbalance. Uranium has 92 protons and 146 neutrons. To become more stable the nucleus can throw off 3 types of radiation. We call these 3 types NUCLEAR radiation, because they come from the nucleus of the atom.

Radiation	Symbol	Picture	Nature	Nucleus Symbol
Alpha	α		2 protons and 2 neutrons. It is a Helium nucleus	^{4}He
Beta	β	—	A fast moving electron	$^{0}_{-1}e$
Gamma	γ		An electromagnetic wave	$^{0}_{0}\gamma$

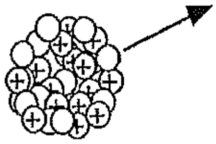
(2) If there are no electrons in the nucleus, where does this beta particle come from?
Well, a neutron turns into a proton and an electron and the electron is released as a beta particle.

19. Decay

When a nucleus has emitted a piece of radiation we say that it has decayed
This diagram shows a radioactive nucleus decaying by emitting an alpha particle.



radioactive atom




radioactive atom decaying

Gamma emission usually happens along side alpha and beta emission.

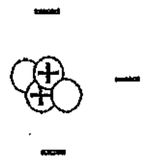
Any material containing radioactive atoms is called a source.

20. Ionisation

(1) If an atom loses or gains electrons we say it has become a charged ion.
This process is called ionisation.

neutral atom
2 +ve protons
and
2 -ve electrons

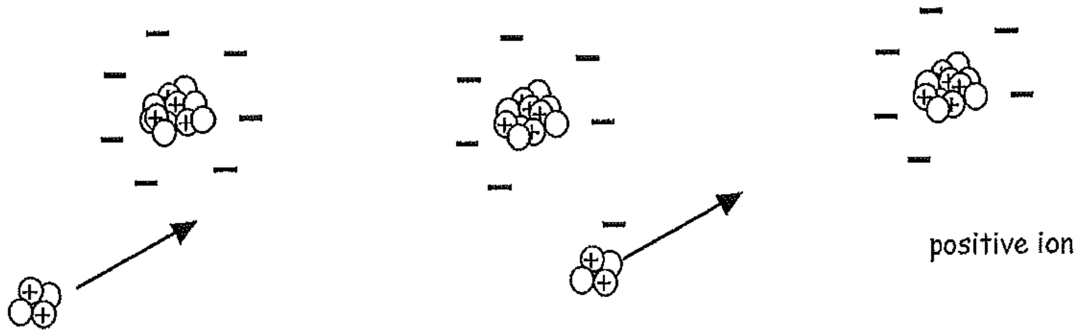
Atom loses an electron
and becomes a
positive ion
with a charge of +1



Atom gains an electron
and becomes a
negative ion
with a charge of -1

(2) Ionisation can be caused by nuclear radiation. Alpha , beta and gamma are called ionising radiations as they can ionise the atoms they come close to or collide with.

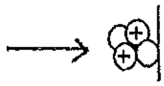
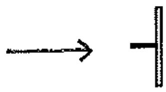
(3) Alpha particles cause the most ionisation because they are the biggest of the three nuclear radiations. Also, because it has a positive charge it can attract the electrons off an atom without actually colliding with it. Beta and Gamma cause much less ionisation.



atom being ionised by an alpha particle

21. Absorption

(1) When a material stops a radioactive particle or wave moving we say it has absorbed the radiation. The following table shows what absorbs alpha, beta and gamma radiation

Alpha particles	Stopped by few cm of air or a thin sheet of paper.	
Beta particles	Stopped by few m of air or a thin sheet of aluminium.	
Gamma radiation	Stopped by a thick block of lead.	

(2) Radiation can be detected by a Geiger-Müller tube or by photographic film
Radiation causes photographic film to turn black.

counter GM tube

(3) Radiation is dangerous to humans because it can damage healthy cells by ionising the atoms which make up the cells. A group of damaged cells is called a tumour.

26. Safety in dealing with radiation

(1) Radiation is dangerous so it is important we avoid too much exposure to it by

1. shielding the source with an appropriate absorber like lead.
2. Limiting the time you are exposed to radiation
3. Putting a big distance between you and the source.

(2) If you do have to handle radioactive sources

1. Always use forceps or tongs when lifting a source.
2. Never bring a source close to your eyes.
3. Store in a lead lined lockable box.
4. Always wash your hands after using sources.

Background radiation.

Rocks and soil contain traces of radioactive materials, mainly uranium-238, thorium-232 and their daughter products radium, and potassium-40. Granite is more radioactive than brick or sandstone. Areas where there are large amounts of granite have higher background rates, e.g. Aberdeen and Dartmoor.

Annual effective equivalent dose limits

For the public, exposure should not exceed **5 mSv** in any year and should not exceed 1 mSv per year on a long term basis.

Radiation workers are permitted higher doses, because:

- they are unlikely to be either old and infirm or young and vulnerable
- they will be subject to regular medical examination
- they will have their exposure monitored.

25. Comparing Risk

We now have a quantity which allows us to compare the biological harm different sources can cause. This table indicates the Equivalent Dose an average person receives each year from different sources.

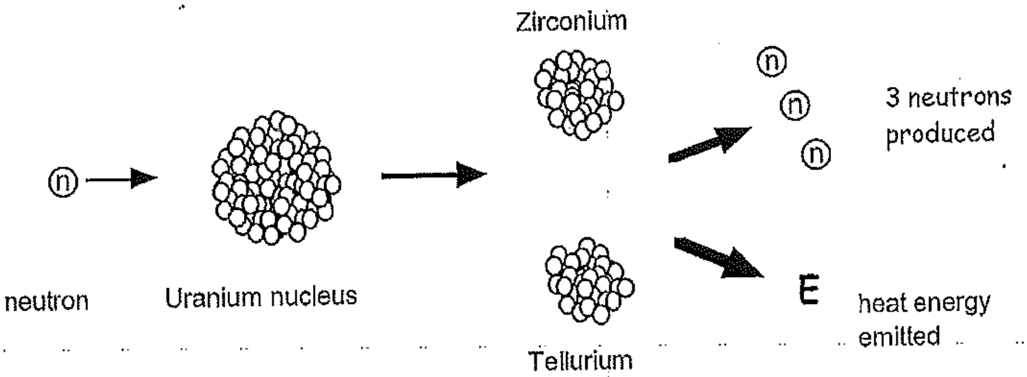
Source	Natural / Man made	Annual Dose (μSv)
Rocks and Soil	N	800
Carbon and Potassium in body.	N	370
Cosmic rays from space	N	300
Medical (x-rays, CT scan etc)	M	250
Fallout from weapons testing	M	10
Nuclear waste	M	2
Aeroplane trips	N	11

The total dose is still very small and will cause very little harm to the average person. However from the table we run a greater risk of biological harm from natural sources than from Man-Made sources.

30. Nuclear Reactions

1. Nuclear Fission.

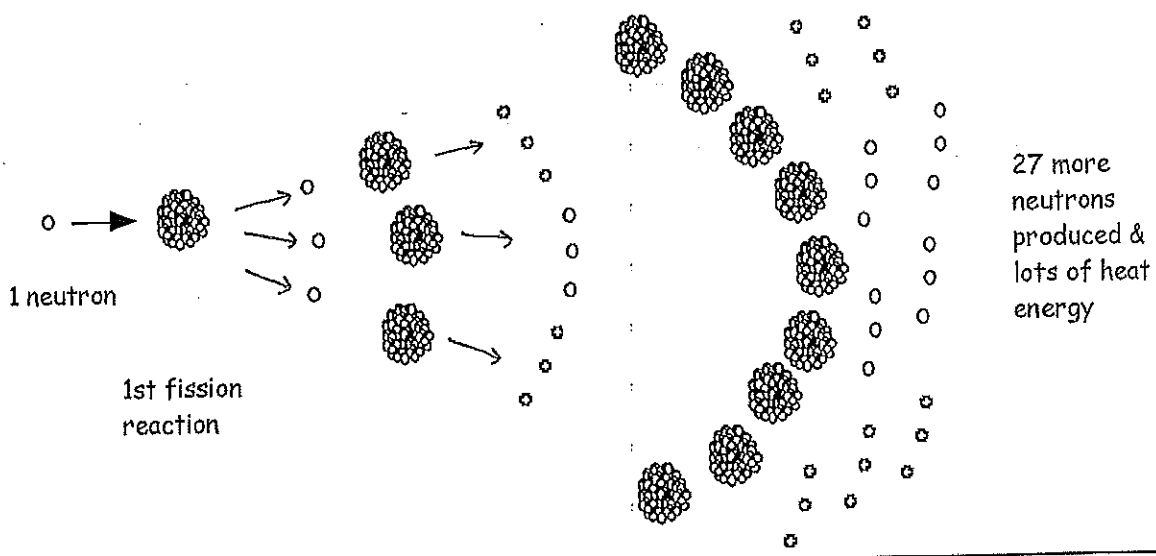
(1) In a nuclear fission reaction a neutron is fired at a large unstable Uranium nucleus. The Uranium nucleus absorbs the neutron and splits into two smaller nuclei. When the nucleus splits some neutrons are emitted. But more importantly the mass of the particles after the reaction is less than the mass of the particles before the reaction. This lost mass is turned into heat energy.



(2) The fission products Tellurium and Zircoium are called daughter products or fission products and are very radioactive.

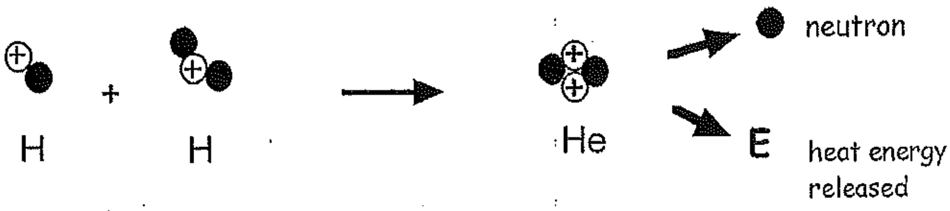
2. Chain Reaction

The neutrons which are released caused 3 more fission reactions which produce 9 more neutrons which cause 9 more fission reactions. This is called a chain reaction and as a result a huge amount of heat energy is created very quickly.



3. Nuclear Fusion

In a fusion reaction two small nuclei join or fuse together to produce a larger nuclei. A neutron and heat energy are also released.



As in the fission reaction, the mass of the particles after the reaction is less than the mass of the particles before the reaction. This lost mass is turned into heat energy.

(3) The lost mass involved in both a fission and fusion reaction is converted to energy. The amount of energy converted from this lost mass is given by Einstein's famous equation

$$E = mc^2$$

where m = the lost mass c = speed of light.

Nuclear Fission equation

Induced nuclear fission of Uranium producing Barium,.Krypton, neutrons and energy

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

Nuclear Fusion equation

Two deuterium atoms combine to produce Helium- 3, Hydrogen and energy.

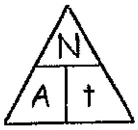
$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{1}H + ^{1}_{1}H$$

24. Dosimetry - Measuring Radiation.

(1) Activity

The activity of a radioactive source tells us the number of decays happening in one second. Activity is measured in Becquerels or (Bq) for short.

$$\text{Activity} = \frac{\text{No of decays}}{\text{time in seconds}}$$



Quantity	Units
Activity	Bq
No of decays	—
time	s

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

Example A radioactive source emits 2400 alpha particles in 3minutes. What is its activity?

A = ?
N = 2400
t = 3mins = 180s

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

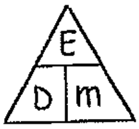
$$A = \frac{2400}{180}$$

$$A = 13.3\text{Bq}$$

(2) Absorbed Dose

Absorbed Dose, D, tells you how much radioactive energy 1kg of body tissue absorbs. It is measured in Grays (Gy).

$$\text{Absorbed Dose} = \frac{\text{Energy absorbed}}{\text{Mass of tissue}}$$



Quantity	Units
Absorbed dose	Gy
Energy	J
mass	kg

$$D = \frac{E}{m}$$

Example A 70kg scientist absorbs 0.41J of radiation. What is the absorbed Dose?

D = ?
E = 0.41J
m = 70kg

$$D = \frac{E}{m}$$

$$D = \frac{0.41}{70}$$

$$D = 0.006Gy$$

(3) **Equivalent Dose**

The Equivalent Dose, H, is a term which tells you the biological effect that radiation has on a body. Equivalent Dose takes into account the absorbed Dose and the type of radiation which you are exposed to.
The unit for Equivalent Dose is the Sievert or Sv for short.

We take into account the type of radiation by multiplying the Absorbed Dose by a weighting factor, w_r. Each radiation causes a different amount of ionisation so has a different weighting factor.

Radiation	w_r
beta particles	1
gamma	1
fast neutrons	10
alpha particles	20

Alpha particles have a weighting factor of 20. This tells us that they cause 20 times more ionisation than gamma or beta radiation.

Equivalent Dose = Absorbed Dose x Weighting factor.

$$H = D \times w_r$$

Quantity	Units
Dose Equivalent	Sv
Absorbed Dose	Gy
weighting factor	—

Example	A man receives an absorbed dose of 0.15Gy of alpha particles. What is the equivalent dose he experiences?

$H = ?$
$D = 0.15Gy$
$w_r = 20$

$H = D \times w_r$

$H = 0.15 \times 20$

$H = 3\ Sv$

(4) *Equivalent Dose Rate* $\dot{H}$ *(H dot)*

This is given by the equation $\dot{H} = \frac{H}{t}$

The units of dose equivalent rate can be: mSv h^{-1}, mSv yr^{-1}, etc.

Example

In a year a worker receives the following exposures to radiation:
30 mGy of γ *radiation and 400* μ *Gy of fast neutrons.*

What is his equivalent dose rate for the year?

$H = D \times W_R$

Gamma	$H = 30 \times 10^{-3} \times 1$	=	$30 \times 10^{-3}\ Sv$
Fast neutrons	$H = 400 \times 10^{-6} \times 10$	=	$4 \times 10^{-3}\ Sv$

Total equivalent dose = 34 mSv and equivalent dose rate = 34 mSv yr^{-1}.

Background radiation

Man has always been exposed to a continual 'background' of radiation.

The average annual effective equivalent dose is approximately **2.0 mSv**, although this can vary from place to place.

Main contributing factors	Annual equivalent dose
Cosmic radiation	0.3 mSv
Radioactivity from rocks, soil, buildings	0.3 mSv
Radioactivity in human body	0.4 mSv
Inhaled Radon and daughter products	1.0 mSv

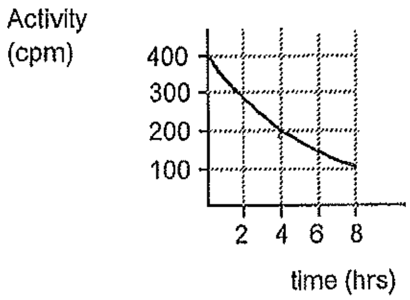
Primary cosmic rays (mostly protons) lose energy, by collisions in the atmosphere, and produce **secondary cosmic rays**, of γ-rays, electrons and neutrons that may reach the Earth's surface.

Cosmic rays are more intense at high altitudes.

27. Half Life

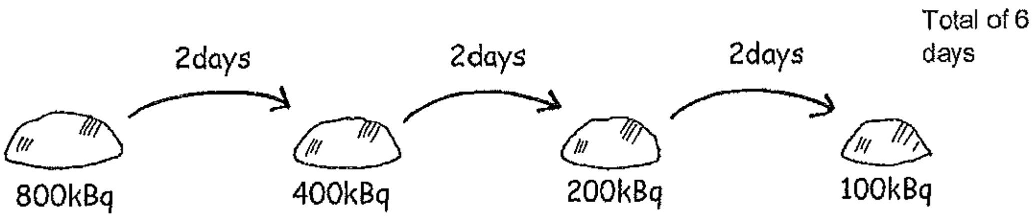
(1) A source may contain billions of radioactive atoms. As time goes by the atoms decay and become stable. So the Activity of all sources decreases with time.

(2) The half life of a source is the time it takes the activity of a source to fall to half of its previous value.



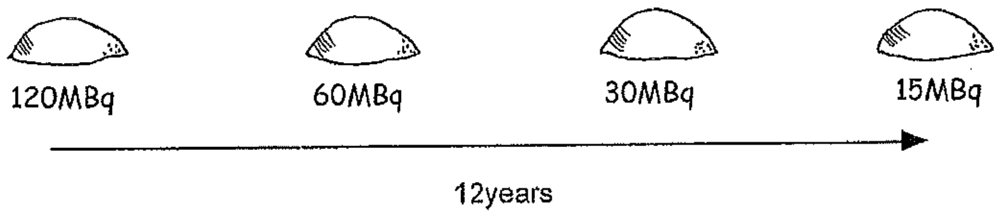
Half life = 4 hours.

Example The activity of a source is 800kBq and its half life is 2days. What is the activity after 6 days.



So the activity halves 3 times in 6 days. The final activity is 100kBq

Example The activity of a source is 120MBq. 12 years later the activity is 15MBq. What is the half life of the source? So how many time does its activity half in these 12 years?

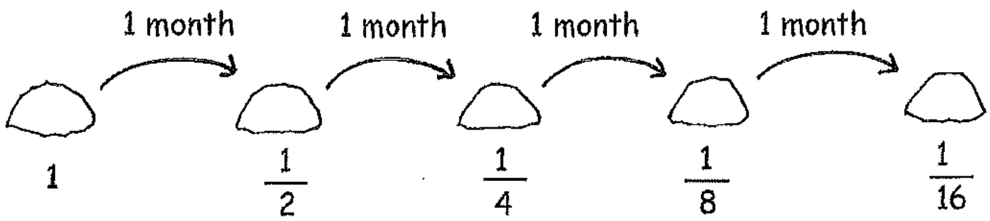


Activity has halved 3 times in 12 years. Therefore the half life = $\frac{12}{3}$ = 4 years

(28) Fractional activity.

Instead of talking about the actual activity after a period of time we can describe the source as having a certain fraction of its activity left.
So after 1 half life the activity would have dropped to half its first value. Another half life later we would be down to a quarter of the original activity , then after another half life the activity would be an eighth of the original.

Example. The half life of a source is 1 month. What fraction of the activity is left after 4 months? We call the original activity 1.
So we will half the original activity 4 times



So the activity will have fallen to $\frac{1}{16}$ of the original after 4 months.

(29) Taking Background radiation into account.

When measuring the activity of an unshielded source it is important that you measure the background radiation. This number must be subtracted from all the readings you take.