National 5 Physics

Waves and Radiation

Notes

Name……………………………………………………………

Key Area Notes, Examples and Questions

Other Notes

Key Area: Wave Parameters and Behaviour

Success Criteria

1.1 I know that energy can be transferred by waves.

1.2 I can explain what is meant by a longitudinal wave and a transverse wave and can give examples of each.

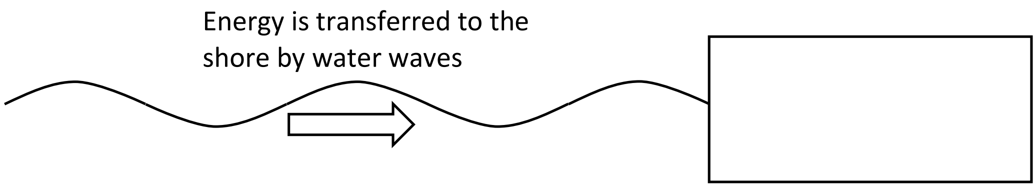
1.3 I understand the terms crest, trough, null position, amplitude, wavelength, frequency, period and wave speed.

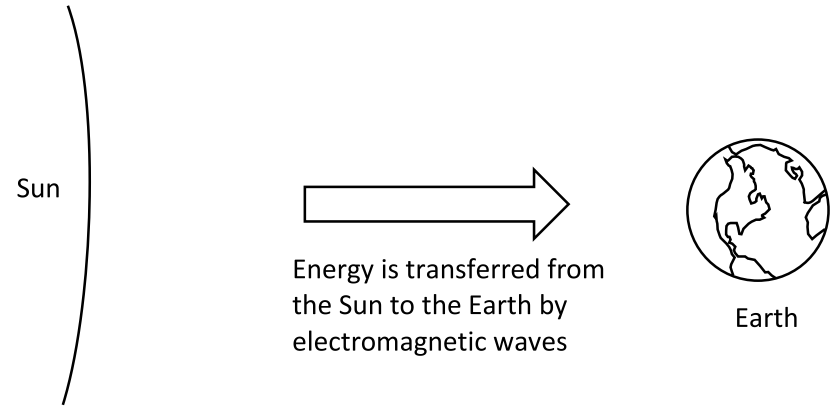
1.4 I can solve problems involving frequency, period, wave speed, wavelength, distance, number of waves and time.

1.5 I can explain what is meant by diffraction and can draw diagrams to explain situations where diffraction occurs.

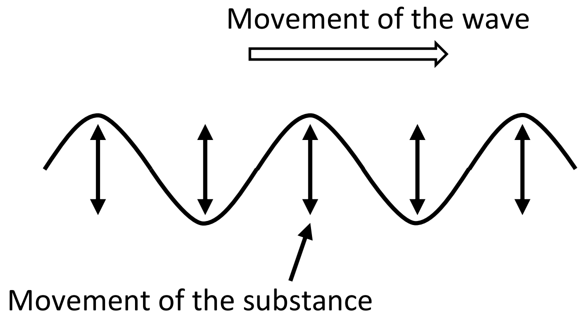
1.1 I know that energy can be transferred by waves.

Waves move energy from one place to another. They consist of an oscillation in a material or field without the transfer of the material itself.





1.2 I can explain what is meant by a longitudinal wave and a transverse wave and can give examples of each.



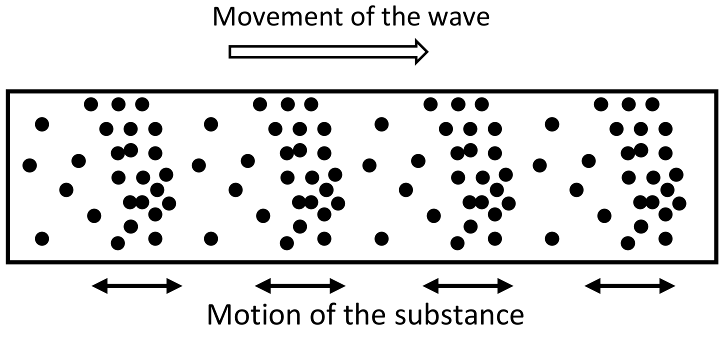
For a transverse waves the substance vibrates perpendicular to the direction of motion of the wave.

Examples of transverse waves

Water surface waves

All electromagnetic waves; radio, microwave, infrared etc.

earthquake S-waves



For a longitudinal wave the substance vibrates parallel to the direction of motion of the wave.

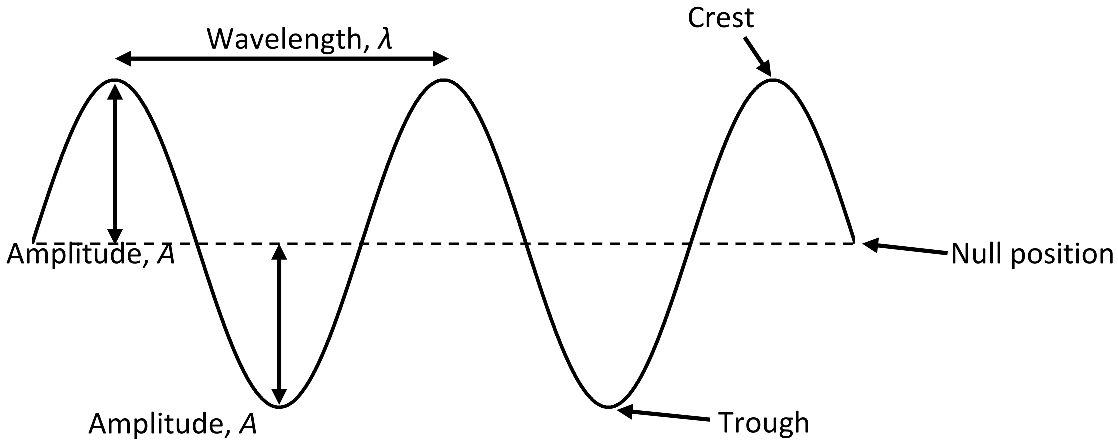
Examples of longitudinal waves

Sound waves

earthquake P-waves.

Waves and Radiation Problem Book page 1 questions 1 to 4

1.3 I understand the terms crest, trough, null position, amplitude, wavelength, frequency, period and wave speed.



Amplitude is the distance between a crest or trough and the null position of the wave. Measured in metres.

Crest the highest point of the wave

Trough the lowest point of the wave

Null position the middle point of the wave.

Wavelength the distance between two adjacent crests or two troughs or two other corresponding points. Measured in metres.

Period is the time it takes for one wave to move past a point. Measured in seconds.

Frequency is the number of waves arriving or leaving at a point per second. Measured in Hertz.

Wave speed the distance travelled by the wave per second. Measured in metres per second.

Waves and Radiation Problem Book page 1 questions 5

1.4 I can solve problems involving frequency, period, wave speed, wavelength, distance, number of waves and time.

Frequency and Period

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

Period (s) → T; Frequency (Hz) → f

<u>Example</u>

Find

a. The period of a wave of frequency 10Hz.

b. The frequency of a wave of period 0.2s

<u>Solution</u>

a. $f = 10\text{Hz}$
$T = ?$

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

$$T = \frac{1}{10}$$

$$T = 0.10\text{s}$$

b. $f = ?$
$T = 0.2\text{s}$

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

$$0.2 = \frac{1}{f}$$

$$f = \frac{1}{0.2}$$

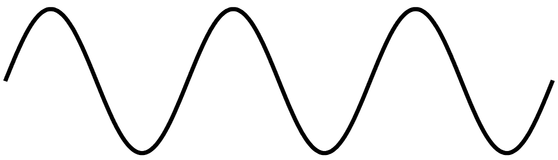
$$f = 5\text{s}$$

Frequency, number of waves and time

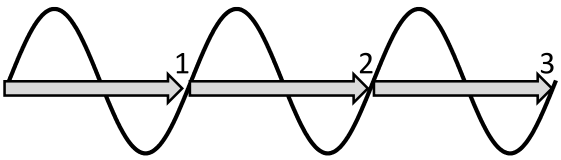
Frequency (Hz) → $f = \frac{N}{t}$ ← Number of waves; ← Time (s)

> Note
> This relationship is not on the exam relationship sheet.

Example
The wave below was produced in in 4.0s. Find the frequency of the wave.



Solution
Count the number of waves.



$N = 3$ waves
$t = 4.0$s

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

$$f = \frac{3}{4.0}$$

$$f = 0.75\text{Hz}$$

Waves and Radiation Problem Book pages 1 to 4 questions 6 to 16.

Wave speed, frequency and wavelength

Wave speed (ms^{-1}) → $v = f\lambda$ ← Wavelength (m)

↖ Frequency (Hz)

<u>Example</u>
Sound waves travel at 340ms^{-1}. Find the wavelength of a 440Hz sound wave.

$v = 340\text{ms}^{-1}$
$f = 440\text{Hz}$
$\lambda = ?$

$$v = f\lambda$$
$$340 = 440\lambda$$
$$\lambda = \frac{340}{440}$$
$$\lambda = 0.772\text{m}$$

Waves and Radiation Problem Book pages 4 and 5 questions 17 to 24.

Wave speed, distance and time

Wave speed (ms^{-1}) → $v = \frac{d}{t}$

Distance (m) → d

Time (s) → t

<u>Example</u>
In 1883 the world's loudest explosion occurred when the volcano Krakatoa exploded. It was heard 4800km away in Australia. Calculate how long after the eruption the sound was heard in Australia.

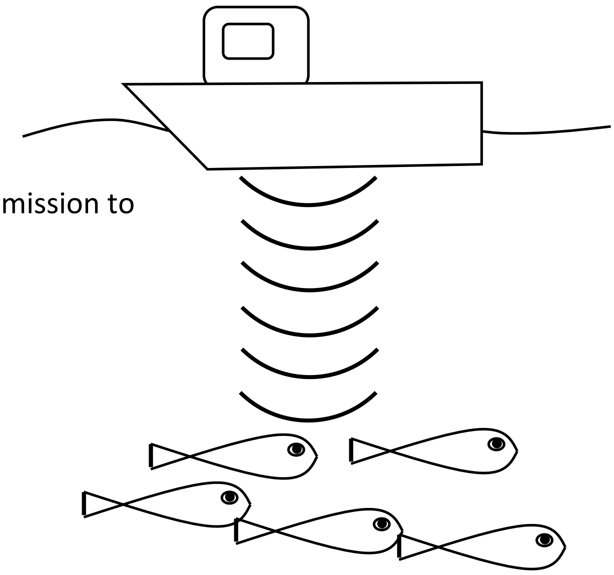
<u>Solution</u>
$v = 340\text{ms}^{-1}$ – look this up in the data sheet.

$d = 4800\text{km} = 4800 \times 10^3\text{m}$

$t = ?$

$$v = \frac{d}{t}$$
$$340 = \frac{4800 \times 10^3}{t}$$
$$t = \frac{4800 \times 10^3}{340}$$
$$t = 14{,}100\text{s}$$

Example



A fishing boat uses sonar to find fish. Equipment on the boat sends sound waves down through the water and times how long it takes for the reflection from the fish to return. If the time taken from transmission to return is 0.04s how deep are the fish?

Solution

$t = 0.04\text{s}$

$v = 1500\text{ms}^{-1}$ - from the data sheet

$d = ?$

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

$$1500 = \frac{d}{0.04}$$

$$d = 1500 \times 0.04$$

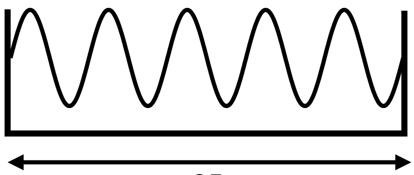
$$d = 60\text{m}$$

This is the distance travelled by the sound when it moves from the boat to the fish and back to the boat again. The depth of the fish is half this distance.

$$\text{Depth} = \frac{60}{2} = 30\text{m}$$

Example

The wave below is produced in a 25m swimming pool and travels the length of the pool in 10 seconds. Find the frequency of the wave.



Solution

$\text{Number of waves} = 5 - \text{count them}$

$$\lambda = \frac{25}{5} = 5\text{m}$$

$$v = \frac{d}{t} = \frac{25}{10} = 2.5\text{ms}^{-1}$$

$$v = f\lambda$$

$$2.5 = f \times 5$$

$$f = \frac{2.5}{5}$$

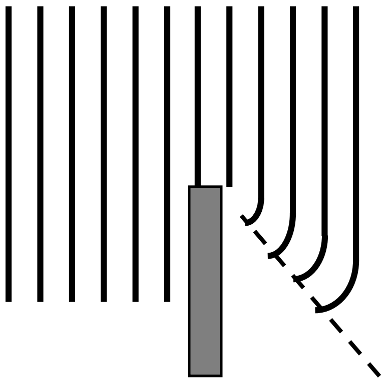
$$f = 0.5\text{Hz}$$

Waves and Radiation Problem Book pages 5 and 6 questions 25 to 31.

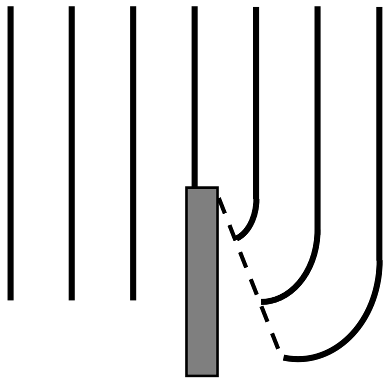
1.5 I can explain what is meant by diffraction and can draw diagrams to explain situations where diffraction occurs.

Diffraction is the bending of a wave around an object or when passing through a gap. Longer wavelengths diffract more than shorter wavelengths.

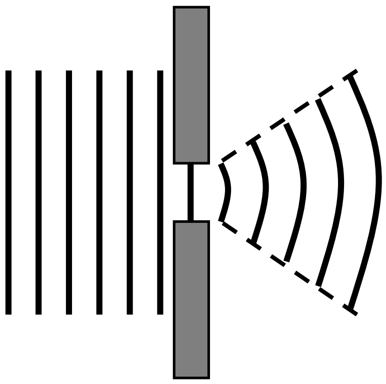
Diffraction around an obstacle
Short Wavelength



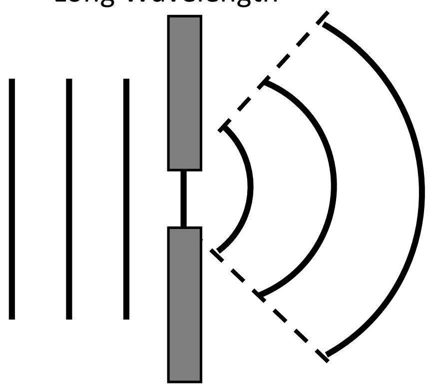
Diffraction around an obstacle
Long wavelength



Diffraction through a gap
Short Wavelength

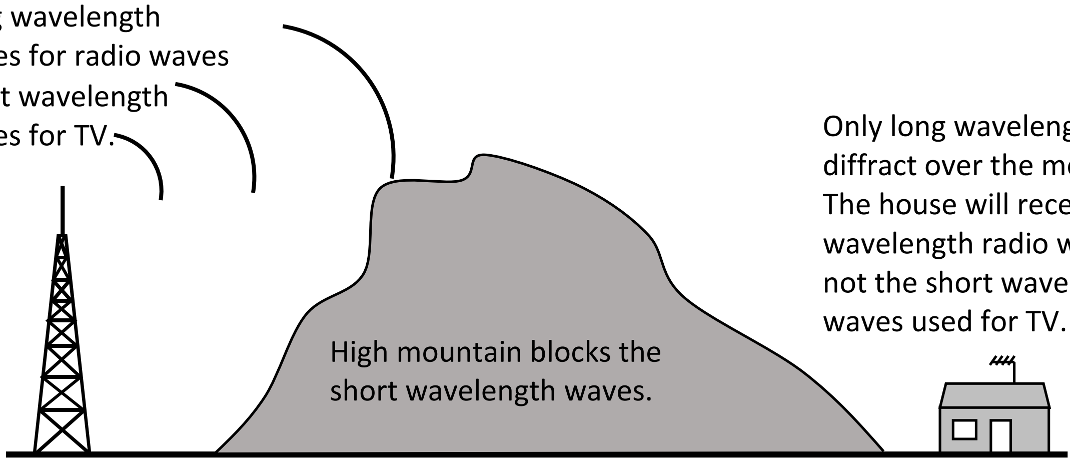


Diffraction through a gap
Long Wavelength



The transmitter transmits

- Long wavelength waves for radio waves
- Short wavelength waves for TV.



Only long wavelength waves diffract over the mountain. The house will receive the long wavelength radio waves but not the short wavelength waves used for TV.

Waves and Radiation Problem Book page 6 questions 32 to 34.

Key Areas: Electromagnetic Spectrum

Success Criteria

2.1 I know the correct order of the bands of the electromagnetic spectrum and the relative wavelength, frequency and energy of the bands.

2.2 I know that all wavelengths of radiation in the electromagnetic spectrum travel at the same speed in a vacuum.

2.3 I can state some detectors of electromagnetic radiation.

2.4 I can give some applications of the electromagnetic spectrum.

2.1 I know the correct order of the bands of the electromagnetic spectrum and the relative wavelength, frequency and energy of the bands.

A spectrum of light containing all the wavelengths of visible light is produced when white light is split by a prism. There are other wavelengths beyond the red and violet which are not visible. The **electromagnetic spectrum** consists of all the bands of radiation from radio to gamma rays. The electromagnetic spectrum is continuous from long wavelength, low frequency, low energy radio waves to short wavelength, high frequency, high energy gamma rays.

Low Frequency → High Frequency

Low energy → High energy

Radio	Microwave	Infrared	Visible	Ultraviolet	X-rays	Gamma Rays

Long Wavelengths ← Short Wavelengths

2.2 I know that all wavelengths of radiation in the electromagnetic spectrum travel at the same speed in a vacuum.

In a vacuum and in air all wavelengths in the electromagnetic spectrum travel at $3.0 \times 10^{8} \mathrm{ms}^{-1}$. You do not need to remember this number as it is in the data sheet. See the last page of these notes. You only need to remember that they all travel at the same speed.

Since all the radiation in the electromagnetic spectrum are waves the relationships $v = f\lambda$ and $v = \frac{d}{t}$ can be used so solve problems involving the speed of electromagnetic waves.

Example

A mobile phone uses a frequency of 1900MHz. Find

a. The wavelength used by the mobile phone.

b. The time it takes a signal to travel from the phone to a mobile mast 3.0km away.

Solution

a.

$v = 3.0 \times 10^8 \text{ms}^{-1}$ - from the data sheet

$f = 1900\text{MHz} = 1900 \times 10^6\text{Hz}$

$\lambda = ?$

$$v = f\lambda$$

$$3.0 \times 10^8 = 1900 \times 10^6 \times \lambda$$

$$\lambda = \frac{3.0 \times 10^8}{1900 \times 10^6}$$

$$\lambda = 0.16\text{m}$$

b.

$d = 3.0\text{km} = 3.0 \times 10^3\text{m}$

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

$$3.0 \times 10^8 = \frac{3.0 \times 10^3}{t}$$

$$t = \frac{3.0 \times 10^3}{3.0 \times 10^8}$$

$$t = 1.0 \times 10^{-5}\text{s}$$

Waves and Radiation Problem Book pages 15 to 17 questions 51 to 57.

Waves and Radiation Problem Book page 20 question 64.

2.3 I can state some detectors of electromagnetic radiation

The following table gives some detectors for the different bands in the electromagnetic spectrum

Band of the Electromagnetic Spectrum	Detector
Radio	Aerial
Microwave	Aerial
Infrared	Pyloelectric sensor, PIN photodiode
Visible	CCD and CMOS sensors, photodiode
Ultraviolet	CCD and CMOS sensors
X-rays	Photographic film, scintillation counter
Gamma Rays	Geiger counter, scintillation counter

2.4 I can give some applications of the electromagnetic spectrum.

Band of the Electromagnetic Spectrum	**Application**
Radio	Broadcast Radio, mobile phones, astronomy
Microwave	Mobile phones, cooking, radar
Infrared	Heating, remote control, optical fibre communications, thermograms
Visible	Seeing, photography etc.
Ultraviolet	Sun tan, setting fillings, security pens
X-rays	Looking for broken bones
Gamma Rays	Cancer treatment, sterilising medical instruments

Waves and Radiation Problem Book pages 17 to 19 questions 58 to 64.

Key Area: Refraction of Light

Success Criteria

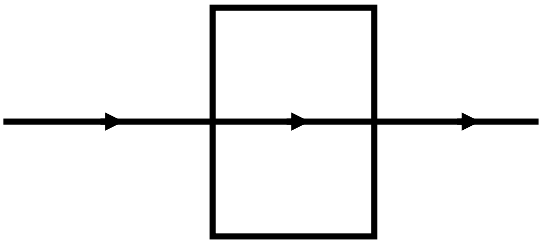
3.1 I understand what is meant by refraction.

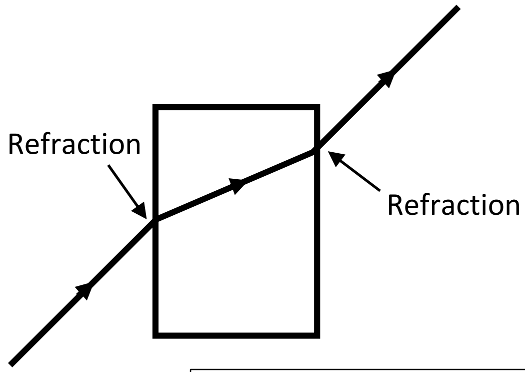
3.2 I can identify on a ray diagram; the angle of incidence, normal and the angle of refraction.

3.3 I know the change in angle when a light ray moves from air into another material and from another material into air.

3.1 I understand what is meant by refraction.

As light moves from one substance to another its speed and wavelength both change. Refraction is defined as the change in direction of light as it passes from one medium to another due to the light changing speed.

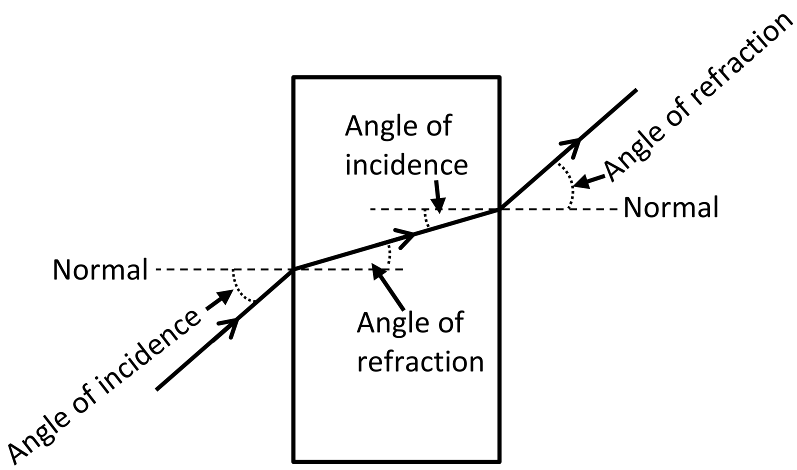




When light is incident on the material at 0° then there is no change in direction. When at any other angle, the light ray will change direction.

Note as diffraction and refraction are similar words you must be able to spell them correctly.

3.2 I can identify on a ray diagram; the angle of incidence, normal and the angle of refraction.



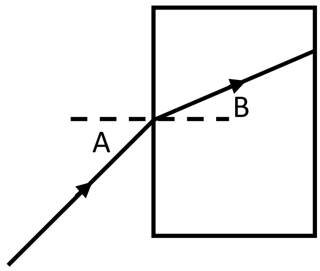
Normal – This is an imaginary line at 90° from the surface of the material. Angles are measured from this line.

Angle of incidence, *i* – This is the angle between the incident ray and the normal line.

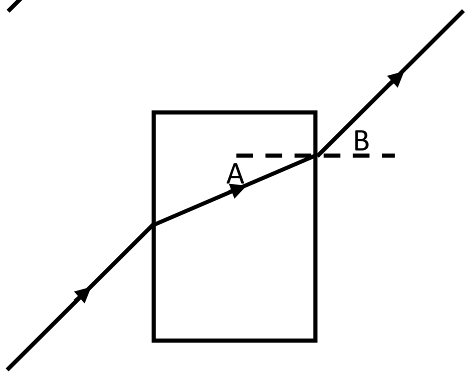
Angle of Refraction, *r* – The is the angle between the refracted ray and the normal line.

3.3 I know the change in angle when a light ray moves from air into another material and from another material into air.

When a light ray moves from air into another material the ray bends towards the normal line. Angle B is smaller than angle A.



When a light ray moves from another material into air the ray bends away from the normal line glass. Angle B is larger than angle A.



Waves and Radiation Problem Book pages 9 to 21 questions 38 to 44.

Key Area: Nuclear Radiation

Success Criteria

4.1 I understand a model of the atom containing protons, neutrons, electrons and a nucleus.

4.2 I know that some isotopes are unstable and decay to form more stable nuclei by emitting alpha, beta and gamma radiation.

4.3 I can describe ionisation.

4.4 I know of the danger of ionising radiation to living cells and the to measure exposure to radiation.

4.5 I can give the relative effect of the ionisation of alpha, beta and gamma radiation.

4.6 I can give the relative penetration of alpha, beta and gamma radiation with example of the types of material which block each type of radiation.

4.7 I can use the relationship $A = \frac{N}{t}$ to solve problems involving activity, number of nuclear disintegrations and time.

4.8 I understand the term background radiation

4.9 I can solve problems involving absorbed dose, equivalent dose, energy mass and radiation weighting factor.

4.10 I can solve problems involving equivalent dose rate, equivalent dose and time.

4.11 I can compare equivalent doses due to a variety of natural and artificial sources.

4.12 I know that effective equivalent dose is the sum of equivalent doses.

4.13 I can state exposure safety limits for the public and for workers in radiation industries.

4.14 I am aware of applications of nuclear radiation.

4.15 I can state the definition of half-life of a radioactive material.

4.16 I can describe an experiment to determine the half-life of a radioactive material.

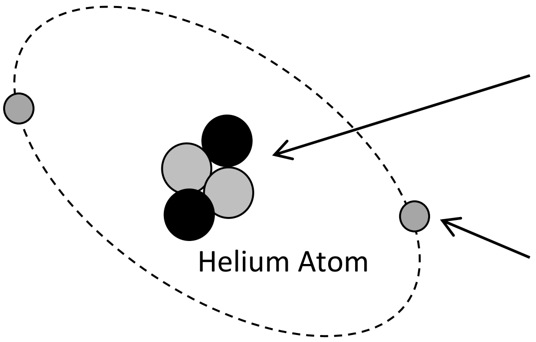
4.17 I can use graphical or numerical data to determine the half-life of a radioactive material.

4.18 I can describe fission and fusion nuclear processes for the generation of energy.

4.19 I explain plasma containment in nuclear fusion.

4.1 I understand a model of the atom containing protons, neutrons, electrons and a nucleus.

All atoms consist of a small dense nucleus in the centre containing protons and neutrons. Electrons are outside the nucleus and move around the nucleus.



Protons are positively charged particles.
Electrons are negatively charged particles.
Neutrons are neutral.

These particles (protons and electrons) have an equal charge but opposite signs.

The number of protons in the nucleus determines the type of atom. e.g. Hydrogen always has one proton, Mercury always has 80 protons and iron always has 26 protons.

The number of neutrons in the nucleus can vary e.g. Hydrogen can have one, two or three neutrons in its nucleus. Atoms with the same number or protons in their nucleus but different numbers of neutrons are called isotopes.

The number of protons equals the number of electrons in a neutral atom. If an electron is added or removed from an atom it is then called and ion.

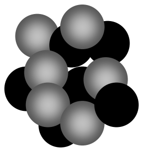
Waves and Radiation Problem Book page 24 questions 68 and 69.

4.2 I know that some isotopes are unstable and decay to form more stable nuclei by emitting alpha, beta and gamma radiation.

Some isotopes of atoms are unstable and can decay to a more stable state by emitting either alpha (α), beta (β) or gamma (γ) radiation.   All atoms with more than 82 protons in their nucleus are unstable i.e. they are radioactive.

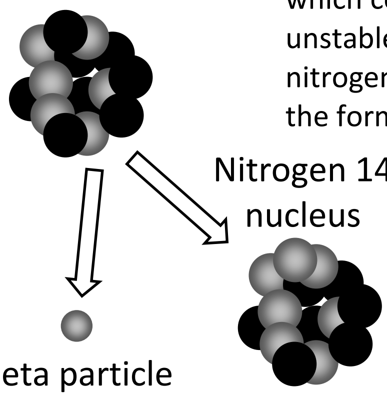
Example

Carbon 12 nucleus



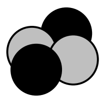
The most common type of carbon is carbon 12 which contains 6 protons and 6 neutrons in its nucleus. This is a stable form of carbon and does not emit nuclear radiation.

Carbon 14 nucleus



A much less common type of carbon is carbon 14 which contains 6 protons and 8 neutrons. This is an unstable form of carbon and will, over time, decay to nitrogen. In decaying it will emit nuclear radiation in the form of a beta particle.

The three types of radiation produced as unstable nuclei decay are given in the table below.

Radiation	Type	Symbol
Alpha particle	Helium nucleus (2 protons and 2 neutrons) 	α
Beta particle	Fast electron 	β
Gamma ray	High frequency electromagnetic wave 	γ

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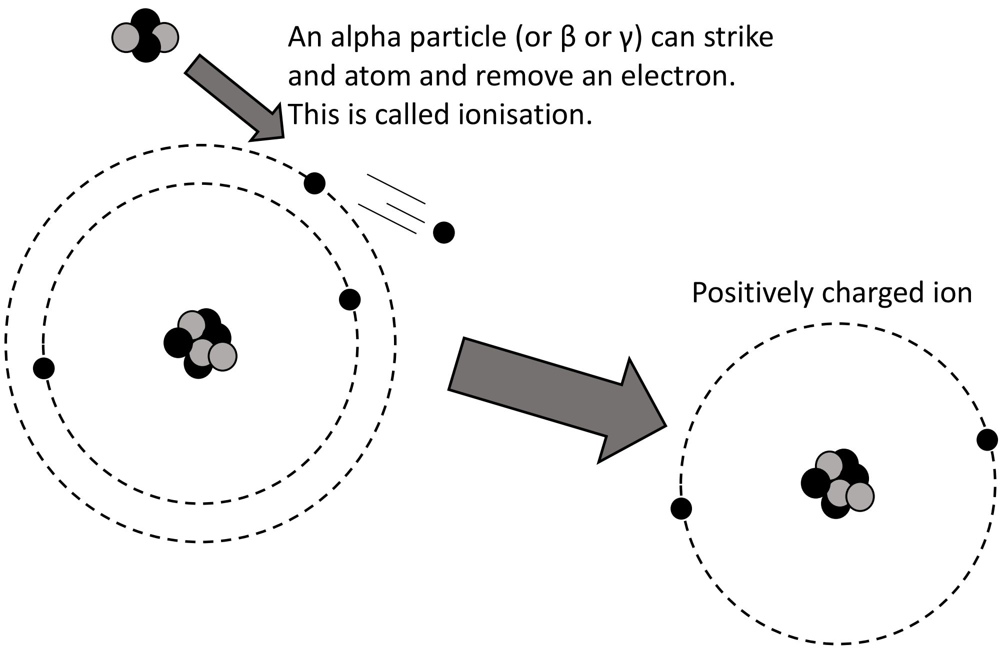
4.3 I can describe ionisation.

When alpha, beta or gamma radiation strikes an atom it can remove one or more of the electrons. This leaves a positively charged ion.

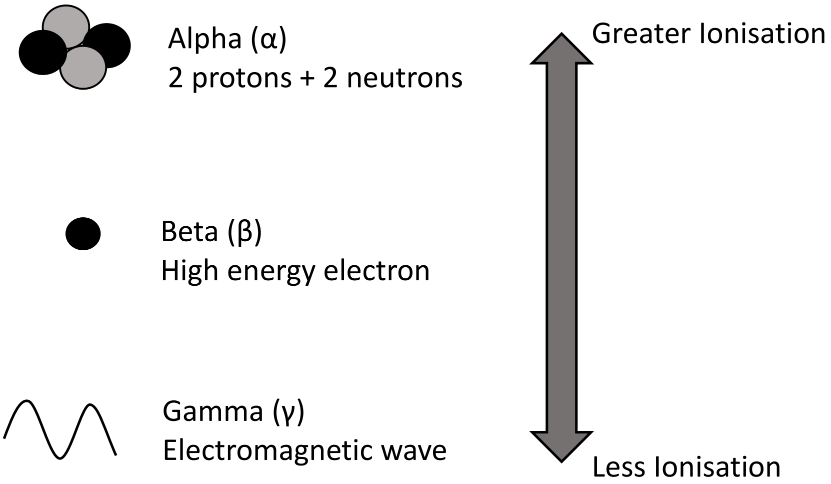


4.4 I know of the danger of ionising radiation to living cells and the to measure exposure to radiation.

When Ionisation happens in biological tissue the molecule containing the atom can break apart destroying the molecule. This can be harmful to the organism especially if the molecule involved is DNA. In order to control the damage done by radiation it is necessary for exposure to be measured.

4.5 I can give the relative effect of the ionisation of alpha, beta and gamma radiation.

Alpha particles cause more ionisation than other types of radiation because they are more massive and have sufficient energy to ionise multiple atoms. Beta causes less ionisation as it is less massive but is still a fast moving particle. Gamma causes less again as it is a wave not a particle and has lower energy that beta or alpha.



4.6 I can give the relative penetration of alpha, beta and gamma radiation together with examples of the types of material which block each type of radiation.

Alpha, beta and gamma can be absorbed by material blocking their path.

Radiation		Stopped by
Alpha	Less penetration	A few centimetres of air A sheet of paper
Beta	↕	Several metres of air Sheet of Aluminium
Gamma	Greater penetration	Several centimetres of lead

Waves and Radiation Problem Book page 24 and 25 questions 69 to 73.

4.7 I can use the relationship $A = \frac{N}{t}$ to solve problems involving activity, number of nuclear disintegrations and time.

Radioactive decay is a random process. It is not possible to tell when any individual atom will decay. However, as there are huge numbers of atoms in any sample of a radioactive material, the rate at which they decay will be approximately constant. The number of decays per second is called the activity. The activity of a radioactive material is given by

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

Activity (Bq) → A

N ← Number of disintegrations

t ← Time (s)

Example

In a radioactive sample, there are 2.3×10^6 decays in 12 minutes. Find the Activity of the source.

Solution

$A = ?$

$N = 2.3 \times 10^6$ decays

$t = 12 \text{ minutes} = 12 \times 60 = 720\text{s}$

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

$$A = \frac{2.3 \times 10^6}{720}$$

$$A = 3200\text{Bq}$$

Waves and Radiation Problem Book page 25 questions 74 to 77.

4.8 I understand the term background radiation

Background radiation comes from material in the surroundings. Some background radiation comes from natural sources and some from artificial sources. Natural sources account for around 85% of background radiation and artificial sources around 15%.

Natural Sources	**Artificial Sources**
Some types of rocks e.g. granite Cosmic rays Radon gas Internal sources e.g. carbon-14 and potassium-40	Nuclear power Nuclear testing Building materials Diagnostic x-rays and nuclear medicine

Waves and Radiation Problem Book page 26 question 78.

4.9 I can solve problems involving absorbed dose, equivalent dose, energy mass and radiation weighting factor.

When radiation is absorbed by a tissue the dose received depends on the energy delivered by the radiation and the mass of the tissue absorbing the radiation.

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

Absorbed Dose (Gy) → D

Energy (J) → E

Mass (kg) → m

<u>Example</u>
A radiation workers hand of mass 550g absorbs 0.40μJ from radiation. Calculate the absorbed dose.

<u>Solution</u>

$D = ?$

$E = 0.40\mu\text{J} = 0.4 \times 10^{-6}\text{J}$

$m = 550\text{g} = 0.550\text{kg}$

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

$$D = \frac{0.40 \times 10^{-6}}{0.550}$$

$$D = 7.3 \times 10^{-7}\text{Gy}$$

Waves and Radiation Problem Book pages 26 and 27 questions 79 to 82.

The absorbed dose does not consider the type of radiation absorbed. Each type of radiation causes different amounts of ionisation and carries different amounts of energy. To assess the damage caused to tissue these must be taken into account. This is done by calculating the equivalent dose (*H*) which is obtained by multiplying the absorbed dose by a radiation weighting factor (w_R). The weighting factor depends on the type of radiation. This gives the relationship

$$H = Dw_R$$

Equivalent Dose (Sv) → H

Radiation weighting factor (See the data sheet) → w_R

Absorbed Dose (Gy) → D

Example
The hand of the radiation worker in the previous example is irradiated by beta particles. Calculate the equivalent dose.

Solution

$H = ?$

$D = 7.3 \times 10^{-7}\,\text{Gy}$

$w_R = 1$ Take the value of w_R from the data sheet.

$H = Dw_R$

$H = 7.3 \times 10^{-7} \times 1$

$H = 7.3 \times 10^{-7}\,\text{Sv}$ ← Note the change in unit from Grays to Sieverts sheet

Waves and Radiation Problem Book pages 27 and 28 questions 83 to 89.

4.10 I can solve problems involving equivalent dose rate, equivalent dose and time.

Radioactive materials irradiate tissue over a period of time. To take into account the time period, the equivalent dose (*H*) can be expressed as equivalent dose rate ($\dot{H}$). This means that an equivalent dose can be found for a given exposure time if equivalent dose rate known.

$$\dot{H} = \frac{H}{t}$$

Equivalent Dose rate (Svs^{-1} or Svhr^{-1}) → $\dot{H}$

Equivalent Dose (Sv) → H

Time (seconds or hours) → t

Example
A radioactive source gives an equivalent dose rate of 40μSvhr^{-1}. Find the equivalent dose if a worker is exposed to this source for 2.0 hours.

Solution

$\dot{H} = 40\mu\text{Svhr}^{-1} = 40 \times 10^{-6}\,\text{Svhr}^{-1}$

$H = ?$

$t = 2.0$ hours

$\dot{H} = \frac{H}{t}$

$40 \times 10^{-6} = \frac{H}{2.0}$

$H = 2.0 \times 40 \times 10^{-6}$

$H = 80 \times 10^{-6}\,\text{Sv}$

You could also do this problem without changing $40\mu\text{Svhr}^{-1}$ to $40 \times 10^{-6}\text{Svhr}^{-1}$. This would give the equivalent dose in micro-Sieverts rather than Sieverts.

4.11 I can compare equivalent doses due to a variety of natural and artificial sources.

The table below shows some equivalent doses from artificial and natural sources.

Source of exposure	Equivalent Dose (mSv)
Dental x-ray	0.005
100g of Brazil nuts	0.01
Chest x-ray	0.014
Transatlantic flight	0.08
Nuclear power station worker average annual occupational exposure (2010)	0.18
UK annual average radon dose	1.3
CT scan of the head	1.4
UK average annual radiation dose	2.7
USA average annual radiation dose	6.2
CT scan of the chest	6.6
Cosmic rays	0.33
Eating one banana	0.00001

Source: Public Health England

4.12 I know that effective equivalent dose is the sum of equivalent doses.

When exposed to more than one type of radiation the sum of all the equivalent doses from each radiation give the effective equivalent dose.

$$\text{Effective Equivalent Dose} = \text{Sum of Equivalent Doses}$$

Example

A worker in a nuclear industry receives the following equivalent doses:

- γ–radiation 150μSv
- Slow neutrons 1200μSv
- Fast neutrons 900μSv.

Find the effective equivalent dose.

Solution

$$\text{Effective Equivalent Dose} = \text{Sum of Equivalent Doses}$$

$$\text{Effective Equivalent Dose} = 150 + 1200 + 900$$

$$\text{Effective Equivalent Dose} = 2250\mu\text{Sv}$$

4.13 I can state exposure safety limits for the public and for workers in radiation industries.

In the radiation industries, the following effective equivalent dose limits apply

- Annual exposure limit for nuclear industry employees is 20mSv.
- Annual effective dose limit for a member of the public is 1mSv.
- Average annual background radiation in the UK is 2.2mSv.

4.14 I am aware of applications of nuclear radiation.

Some examples are;

- Smoke detectors to give early warning of fires.
- Tracers for monitoring the thickness of materials.
- Medical tracers to image parts of the body
- Sterilizing medical equipment
- Generation of electricity
- Geological dating of rocks
- Radiocarbon dating
- Treatment of cancer
- Sterilizing food

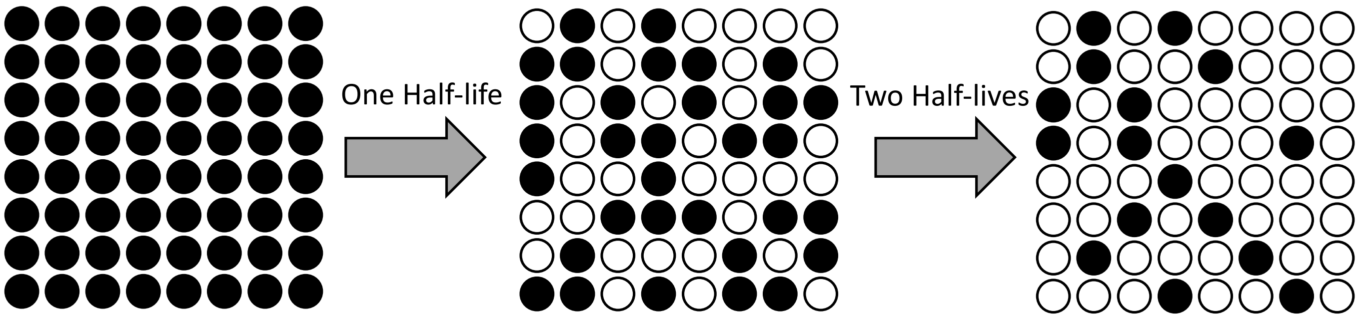
Waves and Radiation Problem Book pages 28 and 30 questions 90 to 92.

4.15 I can state the definition of half-life of a radioactive material.

As radioactive nuclei decay the number of remaining nuclei decreases. The definition of half-life is

- Half-life is the **time** taken for half of the radioactive nuclei to decay.

<u>Example</u>

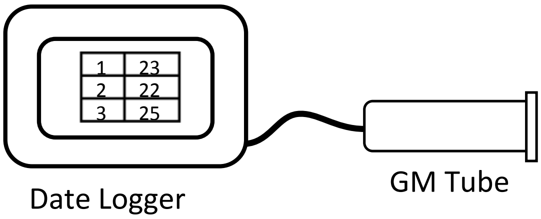


Initially
At time t = 0
Number of original atoms = 64

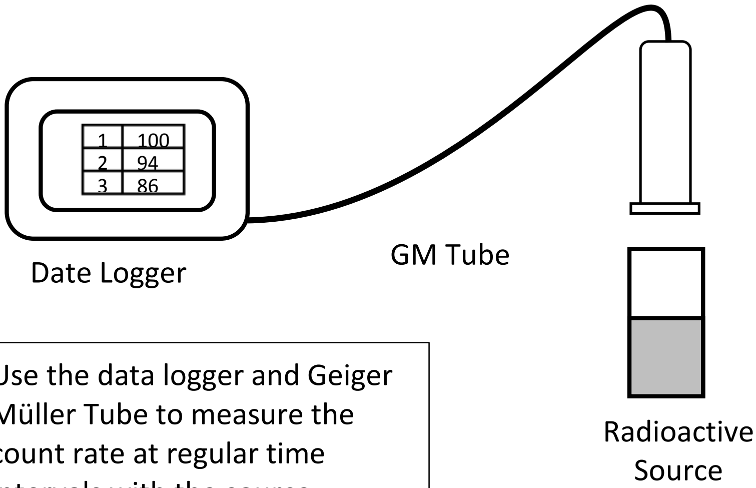
After One Half-life
At time t = 1 half-life
Number of original atoms = 32

After Two Half-lives
At time t = 2 half-lives
Number of original atoms = 16

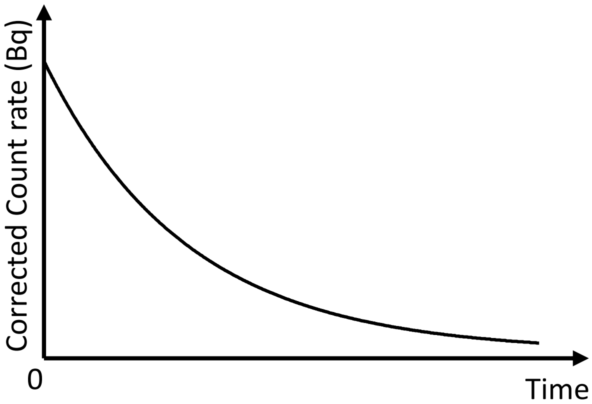
4.16 I can describe an experiment to determine the half-life of a radioactive material.



- Use the data logger and Geiger Müller Tube to measure the count rate several times with no source present.
- Find the mean value of background radiation count rate.



- Use the data logger and Geiger Müller Tube to measure the count rate at regular time intervals with the source



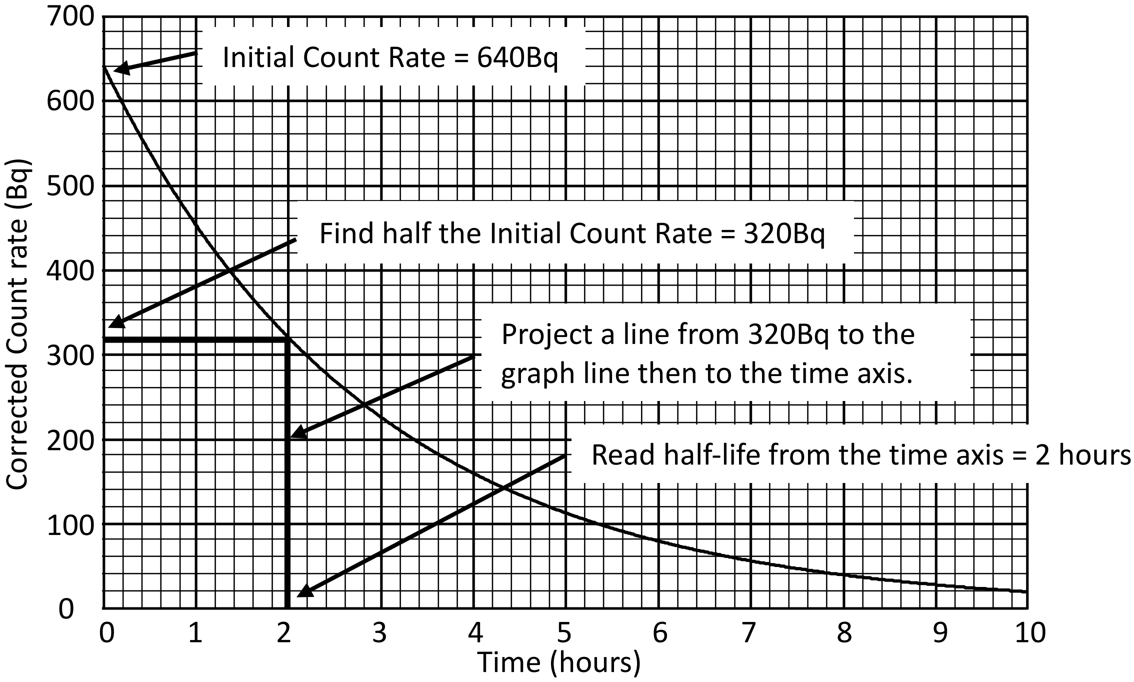
- Subtract the background count rate from all the readings with the source present to obtain the corrected count rate.
- Plot a graph of corrected count rate against time.
- Use the method in section 4.17 to find the half-life.

4.17 I can use graphical or numerical data to determine the half-life of a radioactive material.

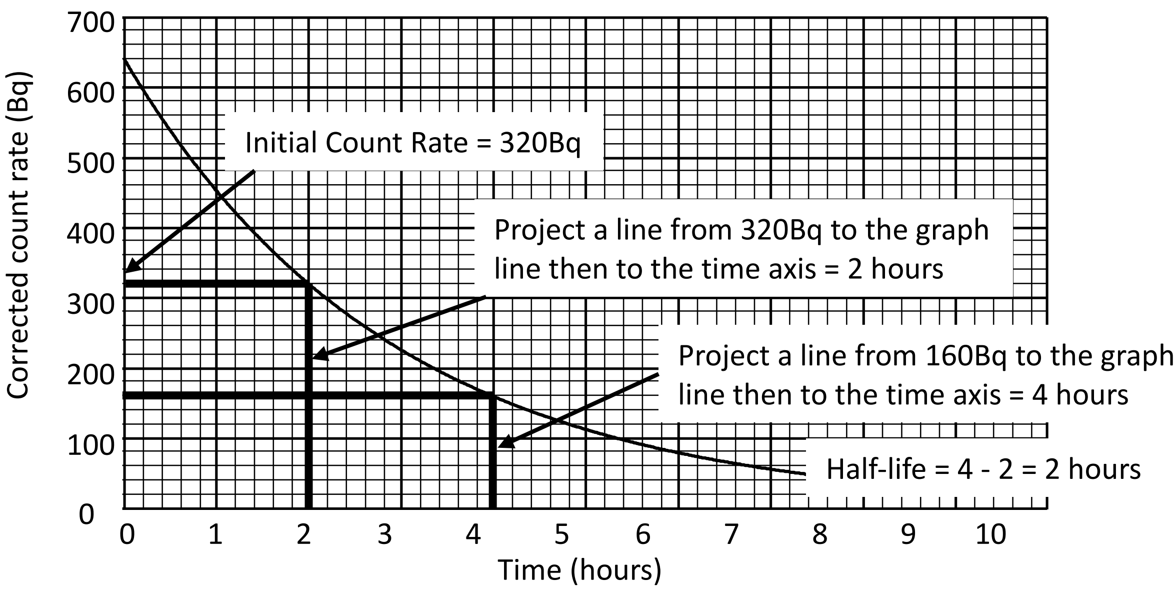
Half-life from a Graph

The graph below shows a plot of corrected count rate over ten hours. Follow the steps shown on the graph to find the half-life of the radioactive source.

The corrected count rate is the count rate minus the background radiation count rate.



Half-life can also be calculated from any initial value of corrected count rate.



Half-life from Numerical Data

Problems involving the half-life of a radioactive material can also be solved using numerical data without plotting as a graph.

Example 1

A radioactive source has a half-life of 15 minutes. If the original activity is 400Bq what would be the activity after 1 hour.

Solution 1

1 hour = 60 minutes

$$\text{Number of half lives} = \frac{60}{15} = 4 \text{ half lives}$$ ← Find the number of half-lives

Keep halving for 4 half-lives

$$400 \xrightarrow{1 \text{ half-life}} 200 \xrightarrow{2 \text{ half-lives}} 100 \xrightarrow{3 \text{ half-lives}} 50 \xrightarrow{4 \text{ half-lives}} 25$$

The activity after 1 hour is 25Bq.

Example 2

The activity of radioactive source starts at 200Bq and after 12hours has fallen to 25Bq. Find its half-life.

Solution 2

Keep halving until 25Bq is reached

$$200 \xrightarrow{1 \text{ half-life}} 100 \xrightarrow{2 \text{ half-lives}} 50 \xrightarrow{3 \text{ half-lives}} 25$$

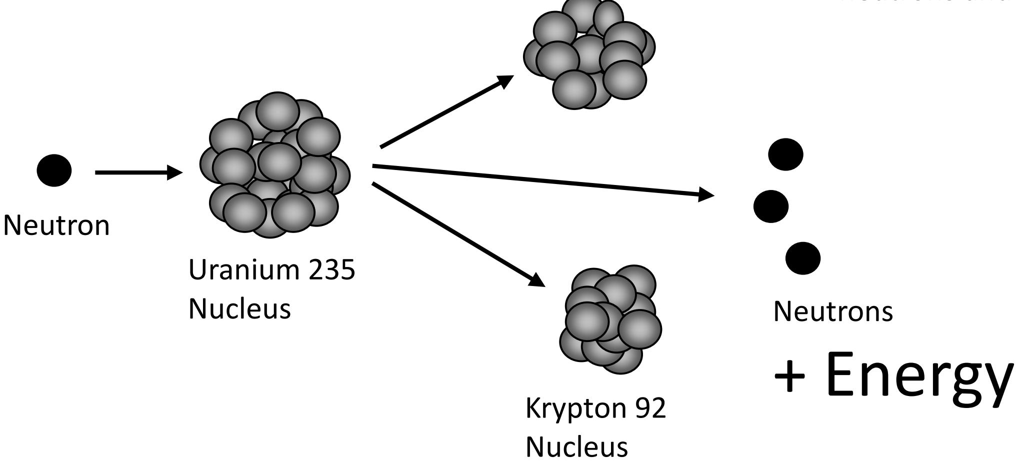
There are three half-lives in 12 hours. The half-life is $\frac{12}{3} = 4\text{hours}$.

Waves and Radiation Problem Book pages 30 and 31 questions 93 to 100.

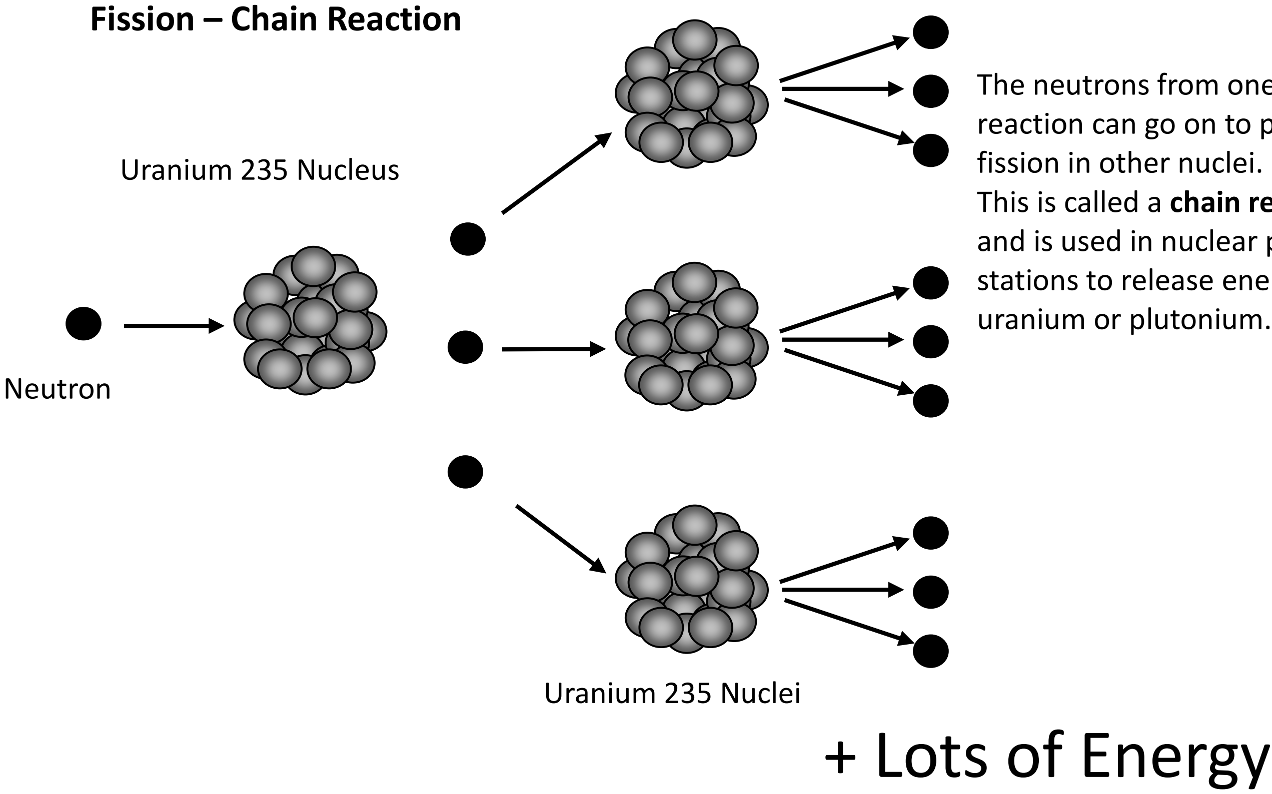
4.18 I can describe fission and fusion nuclear processes for the generation of energy.

Fission

In fission, a large nucleus is split into two smaller nuclei. This releases more neutrons and large amounts of energy.

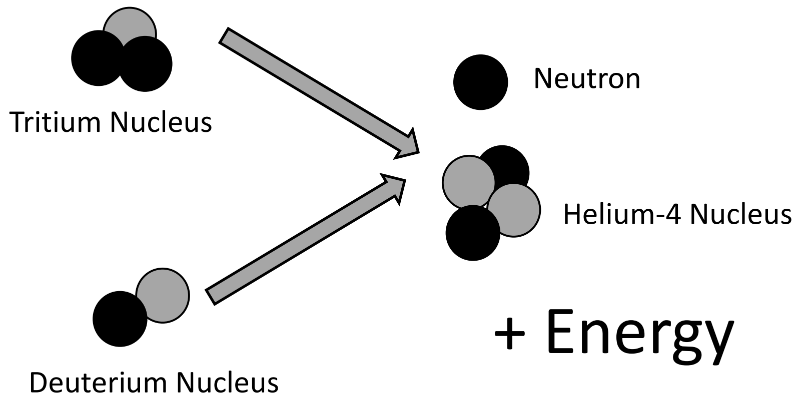


Fission – Chain Reaction



The neutrons from one fission reaction can go on to produce fission in other nuclei.
This is called a **chain reaction** and is used in nuclear power stations to release energy from uranium or plutonium.

Fusion



In fusion two smaller nuclei fuse together to form one larger nucleus. This releases large amounts of energy.
All energy generation using fusion is currently experimental.

The energy released in fission and fusion reactions are used to heat water to steam. This steam is used to turn a turbine which turns an electrical generator.
Currently all nuclear power stations use fission to generate electricity.

> **Note**
> **Fission** and **Fusion** are both similar words for different nuclear processes. It is important that you spell these words correctly in any tests.

Waves and Radiation Problem Book pages 32 and 33 questions 101 to 107.

4.19 I explain plasma containment in nuclear fusion.

The main issue around the production of energy from nuclear fusion is the containment of the very hot plasma required for the nuclear reactions to occur.
There are several approaches to plasma containment in nuclear fusion. The two main ones are

- Magnetic confinement
- Inertial confinement

Magnetic Confinement
The hot plasma is confined by magnetic fields within a torus shaped container. The magnetic field keeps the hot plasma from touching the sides of the torus which would cool the plasma and stop the fusion reactions. The plasma within the torus is heated by induction to the required high temperature.

Inertial Confinement
Small pellets containing around 10milligrams of deuterium and tritium and compressed and heated by lasers to achieve fusion temperatures. The time for the fusion reaction is so short that the inertia of the deuterium and tritium keeps them sufficiently close together for fusion to occur.

Quantities, Units and Multiplication Factors

Quantity	Quantity Symbol	Unit	Unit Abbreviation
Absorbed Dose	*D*	Gray	Gy
Activity	*A*	Becquerel	Bq
Amplitude	*A*	metre	m
Angle of incidence	*i*	Degree	°
Angle of refraction	*r*	Degree	°
Energy	*E*	Joule	J
Equivalent Dose	*H*	Sievert	Sv
Equivalent Dose Rate	$\dot{H}$	Sievert per second Sievert per hour	Svs^{-1} $Svhr^{-1}$
Frequency	f	Hertz	Hz
mass	*m*	kilogram	kg
Mass	*m*	kilogram	kg
Number of waves	*N*	-	-
Period	*T*	Second	s
Time	*t*	Second	s
Wave Speed	*v*	metre per second	ms^{-1}
Wavelength	*λ*	metre	m

Prefix Name	Prefix Symbol	Multiplication Factor
Pico	p	$\times 10^{-12}$
Nano	n	$\times 10^{-9}$
Micro	µ	$\times 10^{-6}$
Milli	m	$\times 10^{-3}$
Kilo	k	$\times 10^{3}$
Mega	M	$\times 10^{6}$
Giga	G	$\times 10^{9}$
Tera	T	$\times 10^{12}$

You **WILL NOT** be given the tables on this page in any tests or the final exam.

Relationships Sheet

You will be given this sheet in all tests and the final exam.

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$Q = It$

$V = IR$

$R_T = R_1 + R_2 + \ldots$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

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

$P = IV$

$P = I^2R$

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

$E_h = cm\Delta T$

$p = \frac{F}{A}$

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

$p_1V_1 = p_2V_2$

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$d = vt$

$v = f\lambda$

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

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

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

$H = Dw_R$

$\dot{H} = \frac{H}{t}$

$s = vt$

$d = \bar{v}t$

$s = \bar{v}t$

$a = \frac{v - u}{t}$

$W = mg$

$F = ma$

$E_w = Fd$

$E_h = ml$

DATA SHEET

You will be given this sheet in all tests and in the final exam.

Speed of light in materials

Material	*Speed* in m s^{-1}
Air	$3{\cdot}0 \times 10^8$
Carbon dioxide	$3{\cdot}0 \times 10^8$
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	$2{\cdot}1 \times 10^8$
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths

	Gravitational field strength on the surface in N kg^{-1}
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in J kg^{-1}
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon Dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Iron	$2{\cdot}67 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in J kg^{-1}
Alcohol	$11{\cdot}2 \times 10^5$
Carbon Dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials

Material	*Speed* in m s^{-1}
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	*Specific heat capacity* in J kg^{-1} °C^{-1}
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3
X-rays	1