Gleniffer High School

National 5

Waves and Radiation

Summary Notes

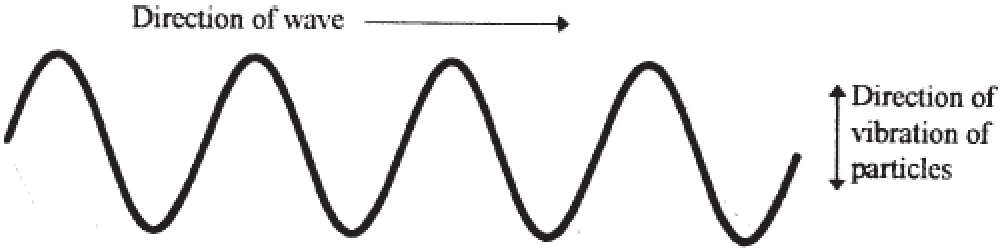
Name: ______________________________

National 5 Waves and Radiation Summary Notes

WAVE PARAMETERS and BEHAVIOURS

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.

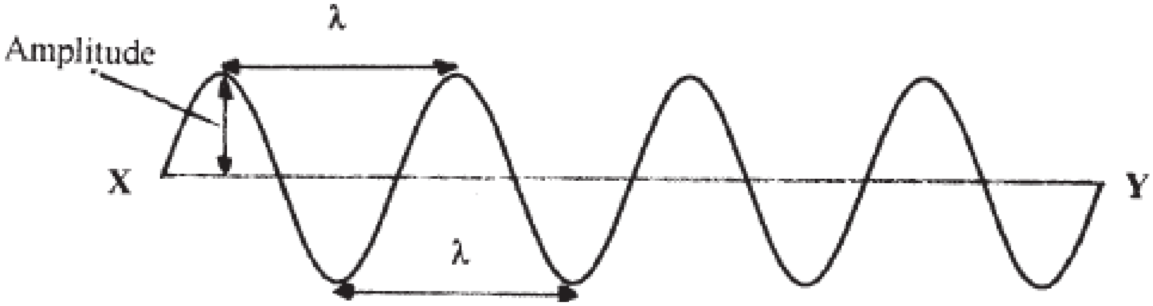


Longitudinal Waves

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

Wave Calculations

A typical wave diagram is shown below: -



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

The **frequency (f)** of the wave is the number of waves that pass a point in one second.

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.

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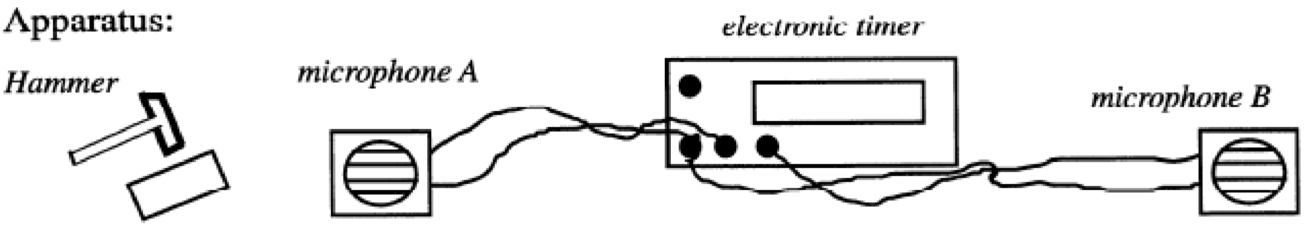
Calculating the speed of sound

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

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



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 = 1m.

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

Average time = 0.0029s

The speed of sound can be calculated as follows:

speed = v = ?
distance = d = 1m
time = t = 0.0029s

d = v x t
1 = v x 0.0029
v =1 / 0.0029
v = 345ms^{-1}

The **speed of sound in air** is normally quoted as **340ms^{-1}** and will appear on your data sheet for assessments.

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It is also possible to find the speed of the wave by using the wave equation.

wavespeed = frequency x wavelength

Which is often written as:-

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

where,

v = wave speed measured in ms^{-1}

f = frequency measured in Hz

λ = wavelength measured in m

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

Example One

A water wave takes 0.2 seconds to travel 1.6metres. What is the speed of the water wave?

$t = 0.2$ s $d = 1.6$ m $v = ?$

speed = distance ÷ time

$v = d / t$

$v = 1.6 \div 0.2$

$v = 8\ ms^{-1}$

Example Two

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

$v = 340\ ms^{-1}$ $f = 2720$ Hz $\lambda = ?$

wavespeed = frequency x wavelength

$v = f \times \lambda$

$340 = 2720 \times \lambda$

$\lambda = 0.125$ m

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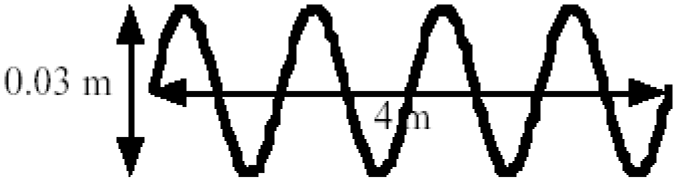
Example Three

The diagram below represents a wave 0.2s 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 0.03m / 2 = 0.015m

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

c) Frequency is the number of waves per second. In this case four waves have been made in 0.2s. In one second there would be five times as many waves.
So the frequency is 5 x 4 = 20Hz.

d)
d = 4m
t = 0.2s
v = ?

d = v x t
4 = v x 0.2
v = 4 / 0.2
v = $20ms^{-1}$

OR

v = ?
f = 20Hz
λ = 1m

v = f x λ
v = 20 x 1
v = $20ms^{-1}$

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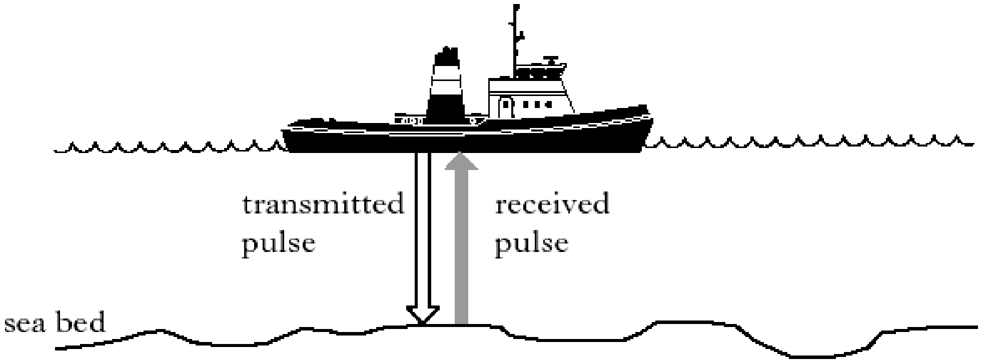
Example Four

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 30kHz.



a) Calculate the wavelength of the ultrasound waves.

$v = 1500 ms^{-1}$
$f = 30KHz = 30{,}000Hz$
$\lambda = ?$

$v = f \times \lambda$
$1500 = 30{,}000 \times \lambda$
$\lambda = 1500 / 30{,}000$
$\lambda = 0.05m$

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

$d = ?$
$v = 1500 ms^{-1}$
$t = 0.36s$

$d = v \times t$
$d = 1500 \times 0.36$
$d = 540m$

This is the total distance travelled by the pulse.
The distance to the seabed must be 270m. (540 / 2)

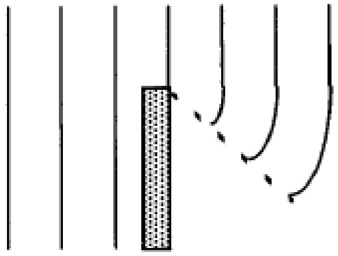
National 5 Waves and Radiation Summary Notes

Diffraction

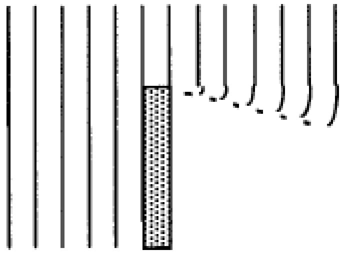
The ability of a wave to bend around an object is known as diffraction.

Waves which have a longer wavelength produce more diffraction than waves with a shorter wavelength.

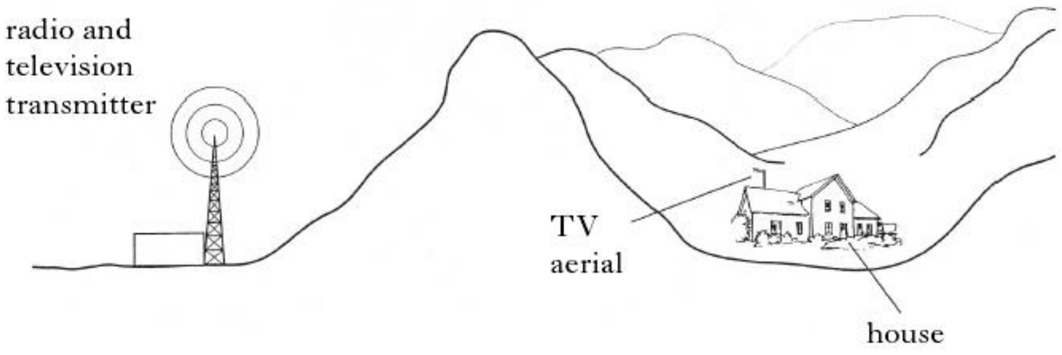
Long wavelength diffraction



Short wavelength diffraction



This property of waves has many applications. For example, in telecommunications it is easier to receive a longer wavelength radio wave behind a hill than a shorter wavelength TV wave. The house in the following diagram would have a good quality radio signal but a poor quality TV signal from the transmitter.



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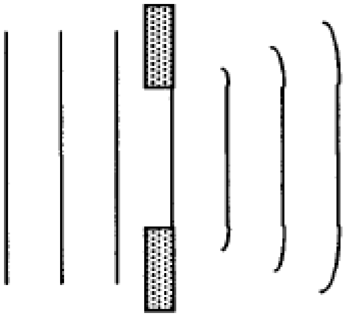
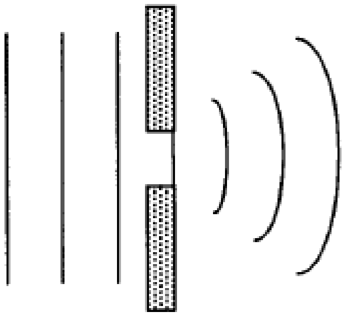
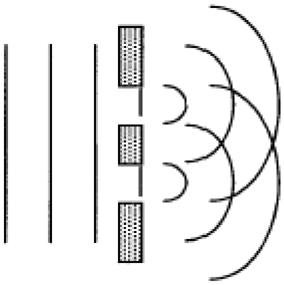
Diffraction can also happen when waves travel between objects.



In this diagram the gap between the objects is much bigger than the wavelength of the waves. But if a gap size is chosen that is very similar to the wavelength of the waves it is possible create circular waves.



If multiple gaps are used the circular waves will overlap to produce an **interference pattern.**



Only waves can demonstrate interference patterns.

It is interference that creates the rainbow effect when an oil film covers water and interference is used when creating flat surfaces for precision mirrors and lens.

The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	Section One	Section Two
2015	7	3
2016	8, 9 and 10	4c)i)
2017	8, 9 and 10	4
2018	20	10
2019	17, 18 and 19	9 a) and b)

THE ELECTROMAGNETIC SPECTRUM

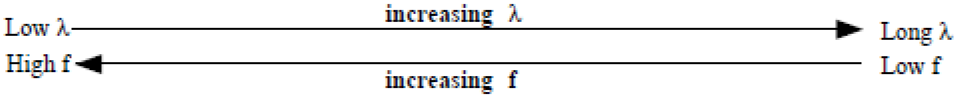
The electromagnetic (EM) spectrum is a family of waves. Like all families the members have lots in common. But each family member is also unique.

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 x 10^8ms^{-1}**. (300million 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.

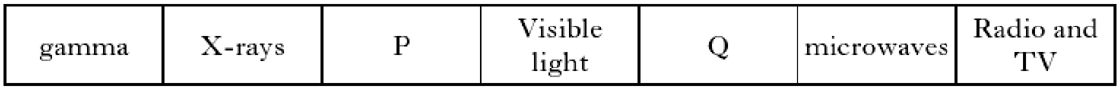
A summary table is shown below.

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

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. However, the high energy associated with gamma rays can be used in medical applications such as sterilising surgical instruments.

Example

The diagram below represents the electro magnet spectrum.



gamma	X-rays	P	Visible light	Q	microwaves	Radio and TV

Electromagnetic spectrum

a) Name the radiations represented by P and Q.

P – ultraviolet
Q – infrared

b) Which of the two radiations, P or Q, has the greater energy? Explain your answer.

P has the greater energy because it is nearer the gamma end of the spectrum and this is the end with the highest frequency. When a radiation has a high frequency it will correspond to a high energy value.

c) Name a non-medical use for radiation P.

P could be used for detecting counterfeit bank notes.

d) Name a medical use for radiation Q.

Q could be used for treating muscle injuries.

Example (continued)

e) Which of the two radiations, P or Q has the greater wavelength?
Q has the greater wavelength.

f) If the wavelength of Q is 6 x 10^{-9}m, calculate the frequency of this radiation.

$v = 3 \times 10^8 ms^{-1}$
$f = ?$
$\lambda = 6 \times 10^{-9} m$

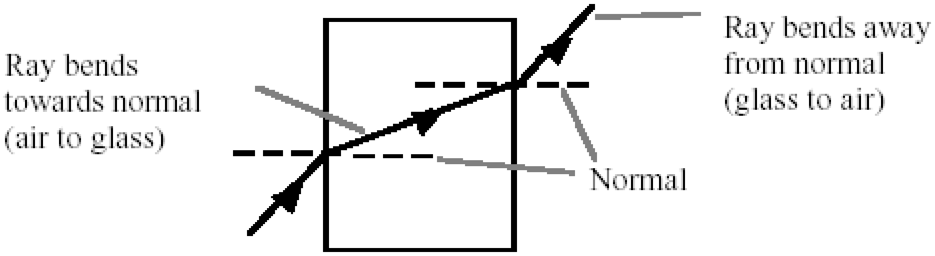
$v = f \times \lambda$
$3 \times 10^8 = f \times 6 \times 10^{-9}$
$f = 3 \times 10^8 / 6 \times 10^{-9}$
$f = 5 \times 10^{16} Hz$

The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	Section One	Section Two
2015	8	No examples
2016	No examples	4 not c)i)
2017	11	12a)i)
2018	21	11a) and b)
2019	No examples	10

REFRACTION of LIGHT

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



glass block

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

- Light slows done 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.
- The wavelength of the light will decrease when it enters a denser material, e.g. when it travels from air into glass.
- Frequency does not change when a light passes into a new material.

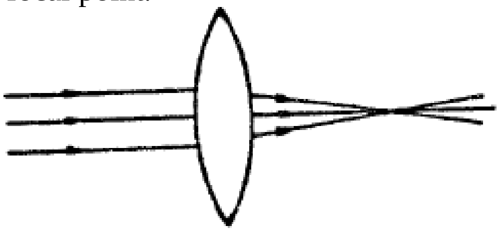
The measure of the refractive effect that a material has on light is known as its **refractive index.** The greater the refractive index the greater the effect on the ray of light.

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

The next two sections – Lenses and Critical Angle - help explain these uses but are mainly included in these notes as useful background reading for N5 and as preparation for the Higher course.

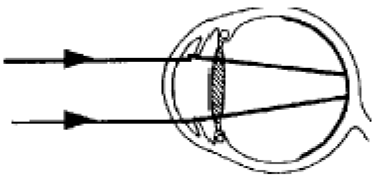
Lenses

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.

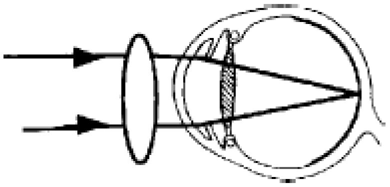


Converging Lens

Long-sighted people have difficulty seeing objects that are close to their eyes. Converging lenses can be used to fix this problem.

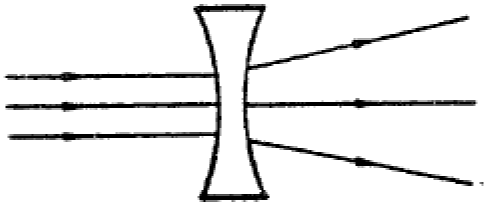


Light would focus beyond retina.



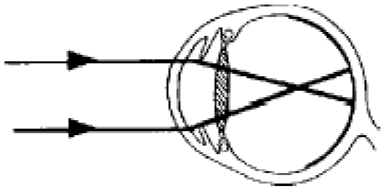
With a lens, focus is on the retina.

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

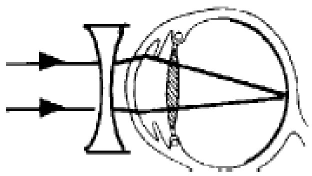


Diverging Lens

Short-sighted people have difficulty seeing objects that are far away from their eyes. Diverging lenses can be used to fix this problem.



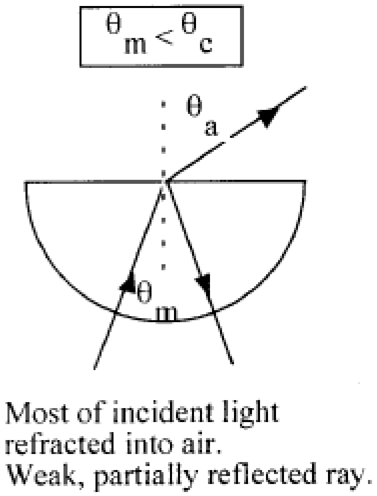
Light will focus short of the retina.



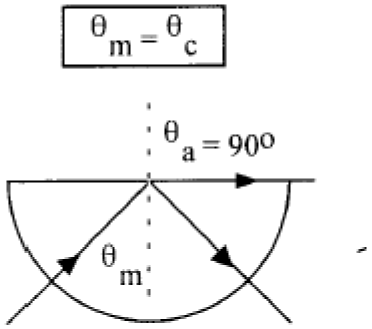
With a lens, focus is on the retina.

Critical Angle

When light travels from a material of high refractive index (denser material) to one of lower refractive index (less dense) it bends away from the normal. This happens when light travels from glass to air.

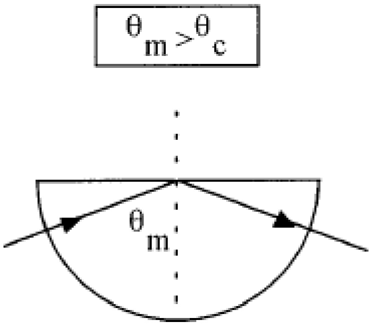


If the angle within the material, Θ_m, is increased, a point is reached where the angle, Θ_a, becomes 90^0.
The angle in the material which causes this is called the **critical angle, Θ_c**.



Light refracted into air at 90^o
Partially reflected ray stronger.

If the angle in the material is greater than the critical angle, then no light is refracted and only reflection takes place. This is known as **total internal reflection**.



No light refracted into air.
All light reflected back into medium.
Total internal reflection occurs.

Optical fibres – long, flexible pieces of glass **-** use the principle of total internal reflection. The rays of light always strike the internal surface of the glass at an angle greater than the critical angle.

Commercial optical fibres have a high refractive index in their core which is surrounded by a cladding of lower refractive index. This ensures that total internal reflection takes place.

The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	**Section One**	**Section Two**
2015	No examples	5 not d)
2016	11	6
2017	12	No examples
2018	No examples	11c)
2019	20	11

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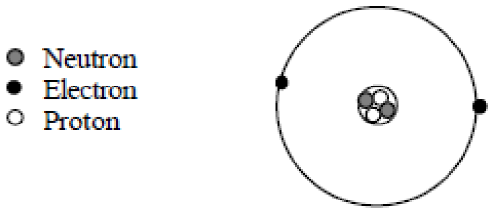
NUCLEAR RADIATION

Atoms

Every substance is made up of atoms. Each element is made up of the one kind of atom, sometimes these atoms are combined together to form molecules.
Inside each atom there is a central part called the **nucleus.** The nucleus contains two particles:

protons: these have a positive charge
neutrons: these have no charge.

Surrounding the nucleus are negatively charged **electrons**.
An uncharged atom will have the same number of protons and electrons.
Consider the element helium, which has two neutrons and two protons in the nucleus, and two electrons surrounding the nucleus. This can be represented as:



atom of helium

Ionisation

Atoms are normally electrically neutral but it is possible to add electrons to an atom or take them away. When an electron is added to an atom a negative ion is formed; when an electron is removed a positive ion is formed. **The addition or removal of an electron or electrons is called ionisation.** It is important to remember that the nucleus remains unchanged during this time.

Ionising Radiations

There are some atoms which have unstable nuclei which throw out particles to make the nucleus more stable. These atoms are called **radioactive**. The particles thrown out cause ionisation and are called ionising radiations.
There are three types of ionising radiation:

Alpha particles are the nuclei of helium atoms. They have 2 neutrons and 2 protons in the nucleus and are therefore positively charged.

Symbol: $^{4}_{2}\alpha$

Beta particles are fast moving electrons. They are special electrons because they come from within the nucleus of an atom. They are caused by the break up of a neutron into a positively charged proton and a negatively charged electron.

Symbol: $^{0}_{-1}\beta$

Gamma rays are caused by energy changes in the nuclei. Often the gamma rays are sent out at the same time as alpha or beta particles. Gamma rays have no mass or charge and carry energy from the nucleus leaving the nucleus in a more stable state.

Symbol: γ

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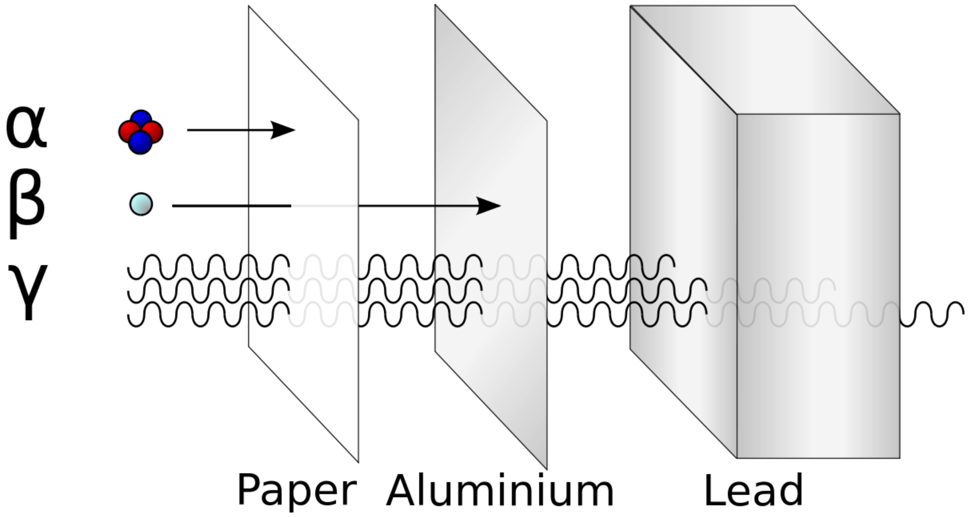
Properties of Radiation

Alpha particles will travel a few centimetres through air before they are fully absorbed. They will be stopped by a sheet of paper. Alpha particles produce a much greater ionisation density than beta particles or gamma rays.

Beta particles can travel tens of centimetres through air and will be stopped by a thin sheet (few millimetres in thickness) of aluminium. Beta particles have a much lower ionisation density than alpha particles.

Gamma rays can only be stopped by a very thick piece (tens of centimetres in thickness) of lead or concrete. Gamma rays travel at the speed of light and have the lowest ionisation density.

These properties can be seen in the following diagram.



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Background radiation

Background radiation is the name given to radiation that is always present in our atmosphere. Everyone is exposed to this radiation. Background radiation can come from **natural sources** and from **man-made sources**. A list of sources and their contributions to background radiation is given below.

- Radon gas
- Soil and rocks
- Cosmic rays
- Nuclear power
- Nuclear weapons
- Medical uses
- Food and drink

Natural	Annual dose (mSv)	Man-made	Annual dose (mSv)
Radon	0.8	Medical	0.25
Soil and rocks	0.4	Nuclear weapons	0.01
Food and drink	0.37	Nuclear power	0.002
Cosmic rays	0.3		

This shows that natural sources make a significantly greater contribution than man-made sources to background radiation.

The current measurements for background and safety limits for the UK are:

Background radiation level is 2.2mSv per year
Safety limit for the public is 1mSv per year
Safety limit for a radiation worker is 20mSv per year

Knowledge of these figures is required for the final exam.

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Radiation Calculations

The following equations can be used to measure exposure to radiation:

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

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

$$H = Dw_r$$

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

Activty

The Activity (A) of a radioactive source is the number of disintegrations (decays) per second and is measured in Becquerels (Bq).

Example

In a radioactive source 24000 nuclei disintegrtae in one minute. Calculaalte the activity of the source.

A = ?
N = 24000
t = 1 x 60 = 60s

A = N/t
A = 24000/60
A = 400Bq

Absorbed dose

When radiation reaches the body or our tissues it is absorbed. This is called the Adorbed Dose (D). The aborbed dose is measured in Grays (Gy) where one Gray is equal to one joule of energy absorbed by one kilogram of tissue.

Example

A part of the body of mass 0.5kg is exposed to radiation. The energy absorbed is 0.3J. calculate the absorbed dose received by this part of the body.

D = ?
E = 0.3J
m = 0.5kg

D = E/m
D = 0.3 / 0.5
D = 0.6Gy

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Equivalent Dose

All ionising radiation can cause damage to the body. The risk of biological harm from an exposure to radiation depends on:

- the absorbed dose, D, which is the energy absorbed per unit mass
- the type of radiation
- the body organs or tissues exposed

This means that two different organs exposed to the same absorbed dose of alpha or gamma will experience a different biological effect. To solve this problem a radiation weighting factor, w_r, is given to each type of radiation. Some examples are given below.

Radiation Weighting Factor w_r	Type of Radiation
1	Beta particles
1	Gamma rays
10	Fast neutrons
10	Protons
20	Alpha particles

When Physicists calculate the effect on our bodies the absorbed dose and the radiation weighting factor are combined in the following equation to give the dose equivalent.

Dose equivalent = absorbed dose x radiation weighting factor

$$H = D \times w_r$$

where,

H – the dose equivalent is measured in Sieverts(Sv)
D – the absorbed dose is measured in Grays (Gy)
w_r – the radiation weighting factor is just a number and has no units

Example One

A worker in the nuclear industry receives the following absorbed doses.

- 30mGy from gamma rays
- 300μGy from fast neutrons

Calculate her equivalent dose.

For gamma

$H = ?$
$D = 30\text{mGy} = 30 \times 10^{-3}\text{Gy}$
$w_r = 1$

$H = D \times wr$
$H = 30 \times 10^{-3} \times 1$
$H = 30 \times 10^{-3}\text{Sv}$
$H = 30\text{mSv}$

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Example One (continued)

For fast neutrons
$H = ?$
$D = 300\mu Gy = 300 \times 10^{-6} Gy$
$w_r = 10$

$H = D \times w_r$
$H = 300 \times 10^{-6} \times 10$
$H = 3000 \times 10^{-6} Sv$
$H = 3mSv$

Her equivalent dose is (30 + 3) mSv = 33mSv

Example Two

A health worker is exposed to two types of radiation 180minutes. The absorbed doses she receives 10μGy of alpha radiation and 25μGy of gamma radiation. Calculate her equivalent dose rate per hour.

For alpha
$H = ?$
$D = 10\mu Gy = 10 \times 10^{-6} Gy$
$w_r = 20$

$H = D \times wr$
$H = 10 \times 10^{-6} \times 20$
$H = 200 \times 10^{-6} Sv$
$H = 200\mu Sv$

For gamma
$H = ?$
$D = 25\mu Gy = 25 \times 10^{-6} Gy$
$w_r = 1$

$H = D \times w_r$
$H = 25 \times 10^{-6} \times 1$
$H = 25 \times 10^{-6} Sv$
$H = 25\mu Sv$

Her equivalent dose is (200 + 25) μSv = 225μSv

Equivalent dose rate is calculated using:

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

As 180minutes is 3hours her equivalent dose rate = $225 \times 10^{-6} / 3 = 75\mu Svhr^{-1}$

Applications

Nuclear radiations have a wide variety of applications including nuclear power stations, car manufacturing and many medical uses.

In nuclear power stations the reactors are fuelled by a nuclear chain reaction. Car manufacturers use nuclear radiation for quality control on the thickness of car body parts. In medicine radioactive iodine is used in the treatment of thyroid cancers and gamma rays can be used to sterilise surgical instruments.

However, you must remember that over exposure to nuclear radiations can damage living cells.

National 5 Waves and Radiation Summary Notes

Half-life

The activity of a radioactive source is measured in Becquerel (Bq), and it is defined as the number of decays per second.

However, radioactive decay is a random process. This means that for a radioactive source, it can never be predicted when an atom is about to decay. In any radioactive source, the activity decreases with time because the number of unstable atoms gradually decreases leaving fewer atoms to decay.

The half-life of a radioactive source is the time for the activity to fall to half its original value.

Example One

The activity of a source falls from 80MBq to 5MBq in 8days. Calculate its half-life.

Solution

$$80 \rightarrow 40 \rightarrow 20 \rightarrow 10 \rightarrow 5$$

Each arrow represents one half-life. There are four arrows, so in 8days there are four half-lives.

The half-life will be 8 / 4 = 2days.

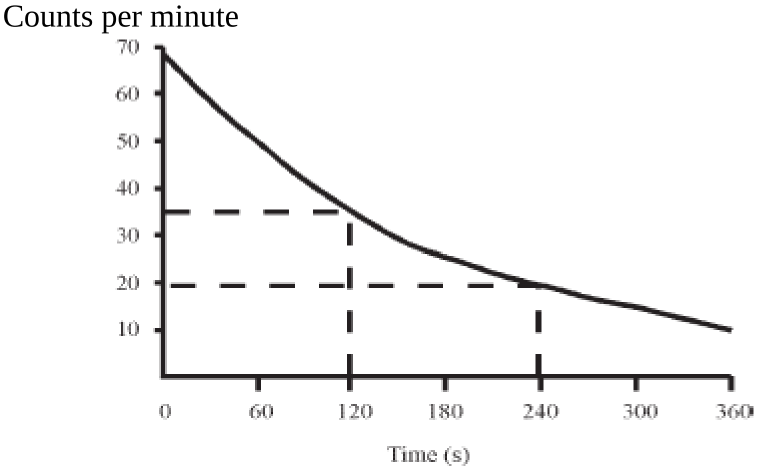
National 5 Waves and Radiation Summary Notes

Example Two

A Geiger-Muller tube and a ratemeter were used to measure the half-life of Cs-140. The count rate was noted every 60seconds. The results are shown in the table:

Time (s)	0	60	120	180	240	300	360
Count rate (counts per minute)	70	50	35	25	20	15	10

By plotting a suitable graph, find the half-life of Cs-140.



In graph type examples a number of results should be taken from the graph before the half-life is stated.

For the above graph the time taken for the count rate to fall from 70 counts per minute to 35 counts per minute is 120s. When other results are analysed, for example, the time taken for the count rate to fall from 35 counts per minute to 17.5 counts per minute is also approximately 120s.

When enough examples have been taken from the graph we can state that the half-life for the Cs-140 will be 120s.

The next four pages help explain further uses of nuclear radiation and are also useful background reading for N5 and as preparation for the Higher course.

National 5 Waves and Radiation Summary Notes

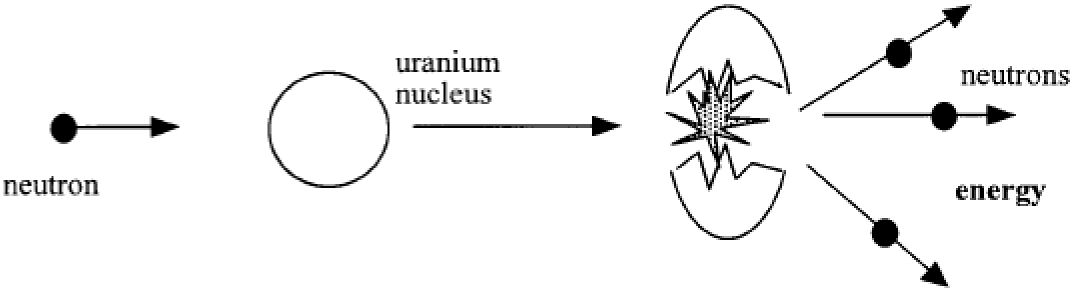
Nuclear Fission

Nuclear fission occurs when heavy elements (those with a significantly greater mass than iron) disintegrate to form two elements with smaller masses.

$$^{238}_{92}\text{U} \rightarrow \, ^{92}_{36}\text{Kr} + \, ^{141}_{56}\text{Ba}$$

This **spontaneous fission** reaction would also produce 5 neutrons and release energy.

The unstable isotopes that undergo spontaneous fission are rarely found on Earth but it is possible to split a stable heavy nucleus by using neutron bombardment.

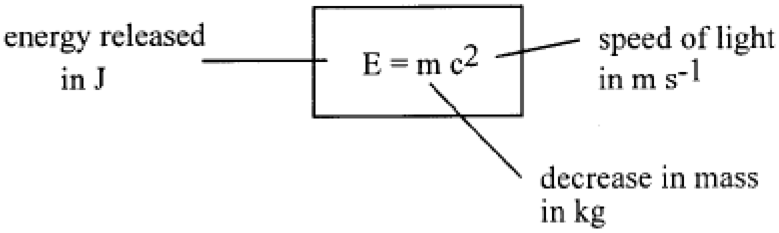


An equation for this **induced fission** process is shown below.

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

The nuclear equation shows that the atomic number and mass number before the reaction are the same as the atomic number and mass number after the reaction. However a detailed analysis of the total mass before and after the reaction reveals that the mass before is greater than the mass after.

Einstein suggested that the mass difference was equivalent to the value of energy produced from the reaction. Einstein summed up this relationship in his famous equation.



National 5 Waves and Radiation Summary Notes

Example
Calculate the energy released from the following nuclear reaction, if there is a decrease in mass of 3.25 x10^{-28}kg during the reaction.

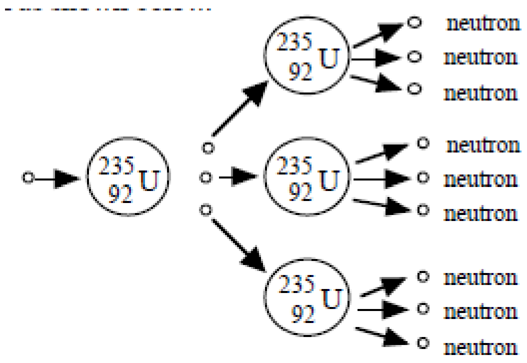
$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{137}_{56}\mathrm{Ba} + ^{97}_{42}\mathrm{Mo} + 2\,^{1}_{0}\mathrm{n} + \text{energy}$$

Solution
E = ?
m = 3.25 x10^{-28}kg
c = 3 x 10^{8}ms^{-1}

$E = mc^2$
$E = 3.25 \times 10^{-28} \times (3 \times 10^{8})^2$
$E = 2.9 \times 10^{-11}$J

This may seem like a very small value of energy. However, this is just from one nucleus and this type of reaction would take place in a **nuclear reactor** where millions of such reactions would take place in a **controlled chain reaction**.

Once a nucleus has divided by fission, the neutrons that are emitted can strike other neighbouring nuclei and cause them to split releasing energy each time. This results in what is called a chain reaction, as shown below.



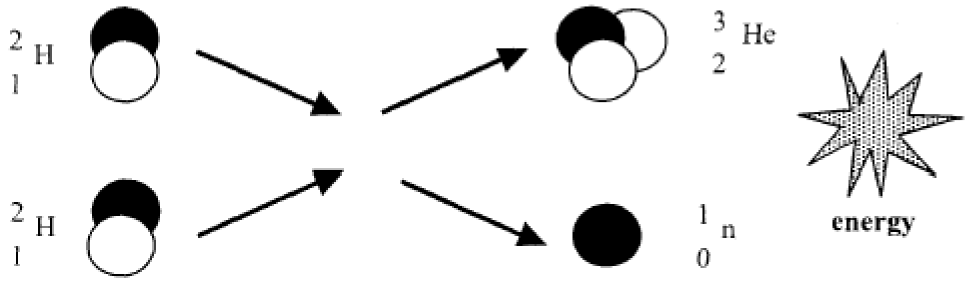
In a controlled chain reaction, on average only one neutron from each fission will strike another nucleus and cause it to divide. This is what happens in a **nuclear power station**.

In an **uncontrolled chain reaction** all the neutrons from each fission strike other nuclei producing a large surge of energy. This occurs in **nuclear bombs**.

National 5 Waves and Radiation Summary Notes

Nuclear Fusion

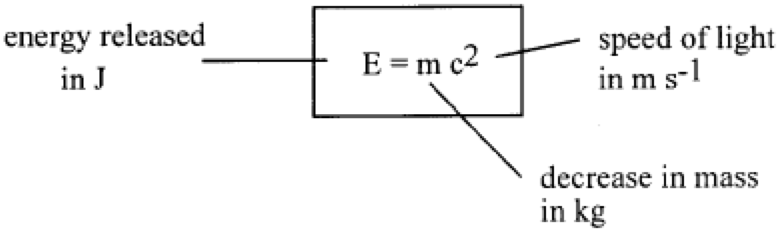
Nuclear fusion occurs when two low mass nuclei fuse together to form a more massive nuclei.



The equation for this **nuclear fusion** process is shown below.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n + \text{energy}$$

The nuclear equation shows that the atomic number and mass number before the reaction are the same as the atomic number and mass number after the reaction. However a detailed analysis of the total mass before and after the reaction reveals that the mass before is greater than the mass after.
So Einstein's famous equation can be used for nuclear fusion reactions as well.



Example
Calculate the energy released from the above fusion reaction, if there is a decrease in mass of 4.0 x10^{-28}kg during the reaction.
Solution
E = ?
m = 4.0 x10^{-28}kg
c = 3 x 10^{8}ms^{-1}

$E = mc^2$
$E = 4.0 \times 10^{-28} \times (3 \times 10^{8})^2$
$E = 3.6 \times 10^{-11}$J

Nuclear fusion is the process that takes place in **stars**.
Fusion reactions require extreme temperatures and are not currently able to release more energy than they take in.

National 5 Waves and Radiation Summary Notes

Radioactive Decay

Elements in the periodic table can be identified by their **atomic number**. However, it is possible to have different versions of the same element. Each different version is known as an **isotope**.

Most isotopes of most elements are stable because they contain the correct numbers of protons and neutrons. However, some isotopes of elements can be unstable because they contain too many or too few neutrons. These isotopes will decay by the emission of nuclear particles to form more stable isotopes of other elements.

Two common types of particle that are emitted by unstable isotopes are alpha particles and beta particles.

In alpha decay, the unstable isotope emits 2 protons and 2 neutrons. This is equivalent to emitting a Helium nucleus. This type of nuclear decay can be written as follows.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

In this case an unstable isotope Uranium-238 has been changed to Thorium-234 by the emission of the alpha particle (Helium nucleus).

In beta decay, inside the unstable isotope a neutron in the nucleus is changed into a proton and an electron. The electron is the emitted beta particle. This type of nuclear decay can be written as follows.

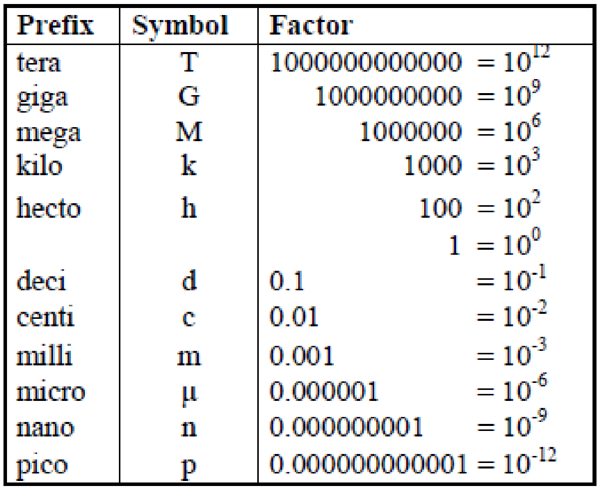
$$^{210}_{82}\mathrm{Pb} \rightarrow {}^{210}_{83}\mathrm{Bi} + {}^{0}_{-1}\mathrm{e}$$

In this case the unstable isotope Lead-210 has been changed to Bismuth-210 by the emission of a beta particle (an electron).

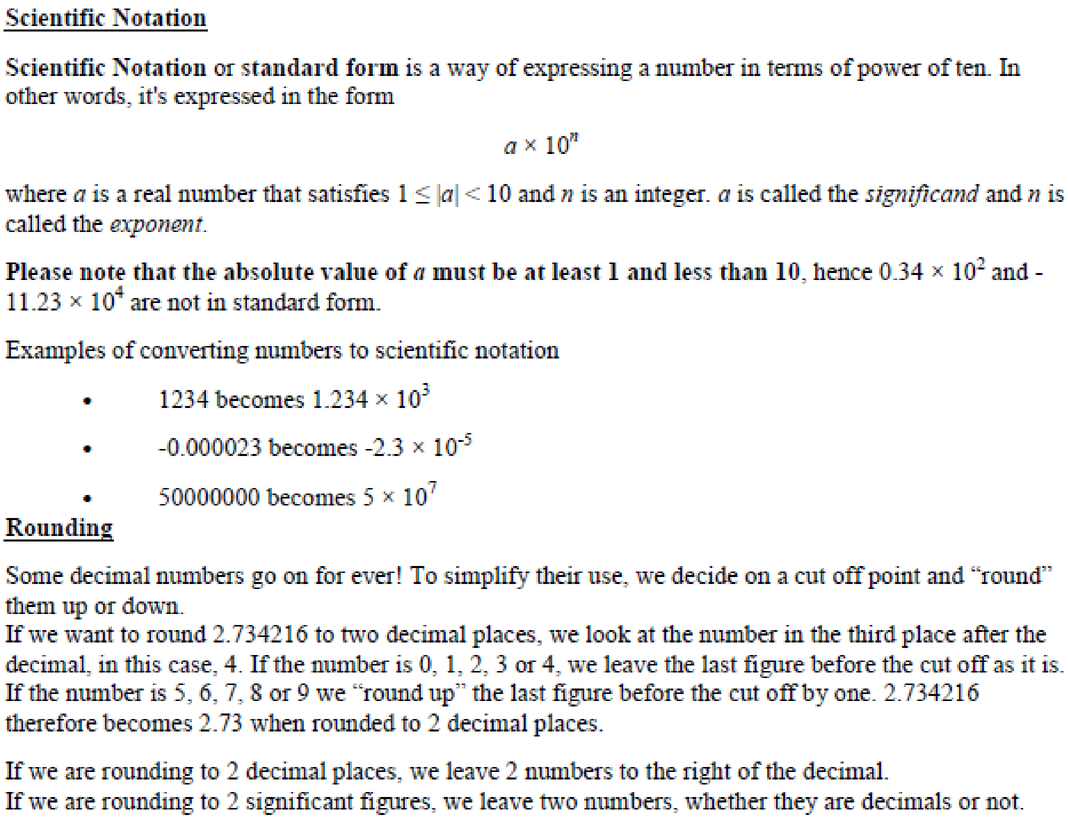
The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	Section One	Section Two
2015	9, 10, 11, 12 and 13	6 and 13a)
2016	12 and 13	7 and 8
2017	13	6 and 7
2018	23, 24 and 25	12 and 13
2019	21, 22, 23, 24 and 25	12

National 5 Waves and Radiation Summary Notes



Prefix	Symbol	Factor
tera	T	1000000000000 = 10^{12}
giga	G	1000000000 = 10^{9}
mega	M	1000000 = 10^{6}
kilo	k	1000 = 10^{3}
hecto	h	100 = 10^{2}
		1 = 10^{0}
deci	d	0.1 = 10^{-1}
centi	c	0.01 = 10^{-2}
milli	m	0.001 = 10^{-3}
micro	µ	0.000001 = 10^{-6}
nano	n	0.000000001 = 10^{-9}
pico	p	0.000000000001 = 10^{-12}



Scientific Notation

Scientific Notation or **standard form** is a way of expressing a number in terms of power of ten. In other words, it's expressed in the form

$$a \times 10^{n}$$

where a is a real number that satisfies $1 \leq |a| < 10$ and n is an integer. a is called the *significand* and n is called the *exponent*.

Please note that the absolute value of a must be at least 1 and less than 10, hence 0.34×10^{2} and -11.23×10^{4} are not in standard form.

Examples of converting numbers to scientific notation

- 1234 becomes 1.234×10^{3}
- -0.000023 becomes -2.3×10^{-5}
- 50000000 becomes 5×10^{7}

Rounding

Some decimal numbers go on for ever! To simplify their use, we decide on a cut off point and "round" them up or down.
If we want to round 2.734216 to two decimal places, we look at the number in the third place after the decimal, in this case, 4. If the number is 0, 1, 2, 3 or 4, we leave the last figure before the cut off as it is. If the number is 5, 6, 7, 8 or 9 we "round up" the last figure before the cut off by one. 2.734216 therefore becomes 2.73 when rounded to 2 decimal places.

If we are rounding to 2 decimal places, we leave 2 numbers to the right of the decimal.
If we are rounding to 2 significant figures, we leave two numbers, whether they are decimals or not.

National 5 Waves and Radiation Summary Notes

$$E_p = mgh$$

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

$$Q = It$$

$$V = IR$$

$$R_T = R_1 + R_2 + \ldots$$

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

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

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

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

$$P = IV$$

$$P = I^2 R$$

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

$$E_h = cm\Delta T$$

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

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

$$p_1V_1 = p_2V_2$$

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

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

$$d = vt$$

$$v = f\lambda$$

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

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

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

$$H = Dw_R$$

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

$$s = vt$$

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

$$s = \bar{v}t$$

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

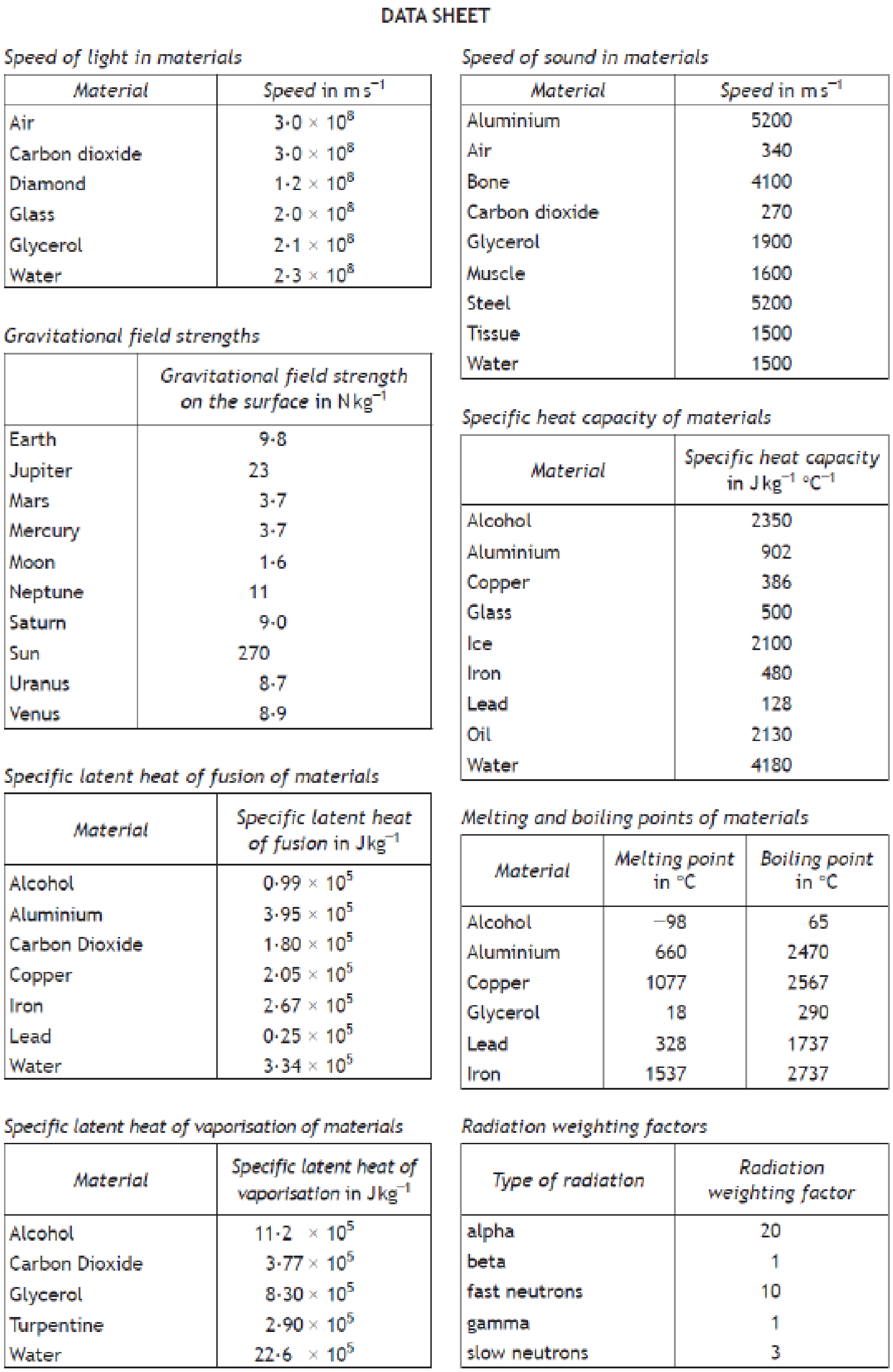
$$W = mg$$

$$F = ma$$

$$E_w = Fd$$

$$E_h = ml$$

National 5 Waves and Radiation Summary Notes



DATA SHEET

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