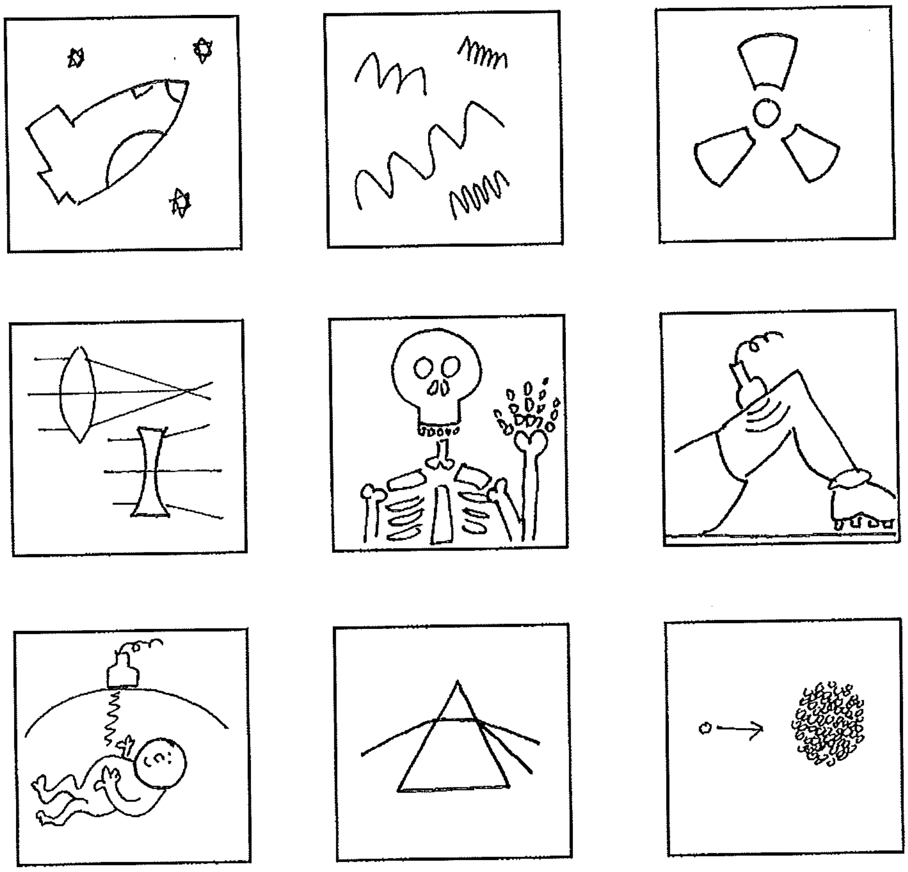
NQ 5 Physics

Unit 1

Waves and Radiation



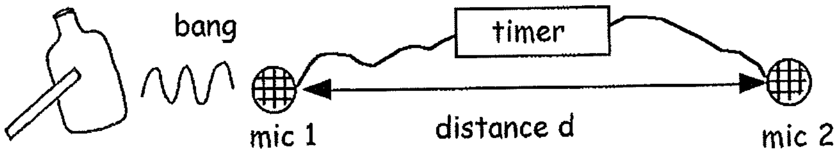
Summary Notes

NQ5	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 ___________.
Measure the distance between microphones using a __________.



Make a loud ___________. When sound gets to microphone 1 the timer ____________ When sound gets to microphone 2 the timer _____________.

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

The speed of sound in air is __________m/s.

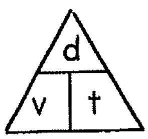
The speed of light in air is _____________________m/s or 3x10☐ m/s

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

2. Wave speed, - distance and time.

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

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

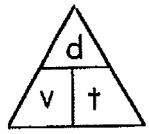


quantity	units
distance	m
time	
speed	

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

d= ?
v = 340m/s
t = 0.6s

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



$$d = v\,t$$

$$d = 340 \times 0.6$$

$$d = 204\text{m}$$

3. <u>Scientific Notation</u>

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

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

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

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

$0.005 = 5 \times 10^{\square}$

$0.000000047 = 4.7 \times 10^{\square}$

4. <u>Converting Numbers</u>

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 $4 \times 10^{\square}$ m

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

5.7cm = 5.2 $\div$100 or $5.2 \times 10^{\square}$ m

6.2ms = 6.2 $\div$ 1000 or $6.2 \times 10^{\square}$ s

4μm = 4 $\div$ 1,000,000 or $4 \times 10^{\square}$ m

5. Converting Time to seconds

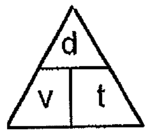
ms = ÷ by 1000 or x 10^{-3} s   5.6ms = 5.6×10^{-3} s

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?

$v = 3\times10^{8}$ m/s
d= 2.5km = 2.5×10^{3} m
t = ?

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



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

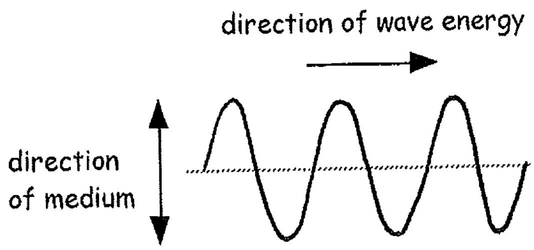
$$t = \frac{2.5 \times 10^{3}}{3 \times 10^{8}}$$

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

6. Transverse and Longitudinal Waves

Transverse Waves

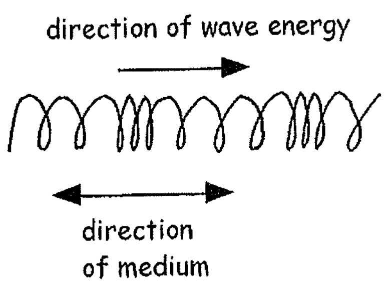
The medium the wave passes through vibrates at ________ angles to the direction the wave travels.



Examples of a transverse wave are ____________ and ____________ waves

Longitudinal Waves

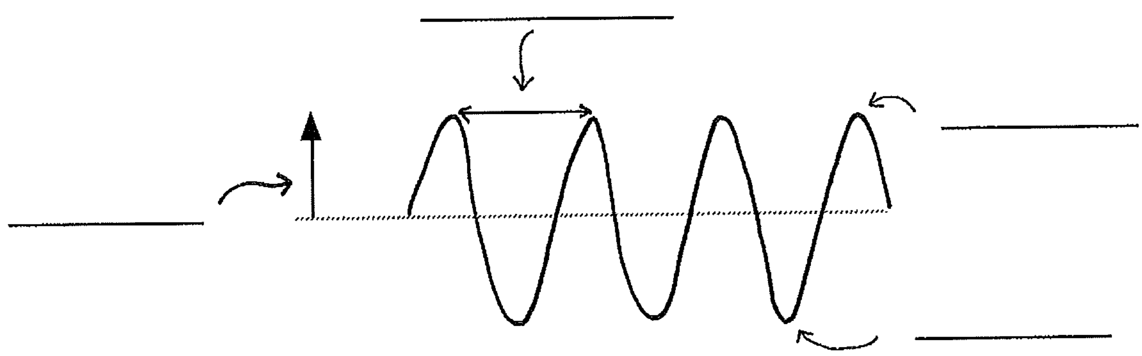
The medium the wave passes through vibrates back and ___________ in the ___________ direction the wave travels



An example of a longitudinal waves is ______________.

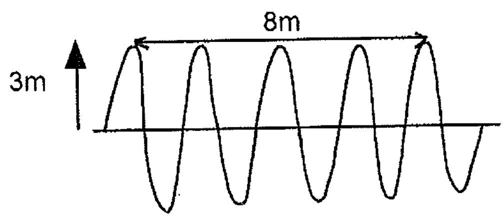
7. Wave words

(1) We use the following terms to describe parts of a wave.



Quantity	Symbol	Unit	Unit symbol	Definition
Wavelength		metre		The__________ between any 2 repeating points on the wave
Frequency	f			The number of waves passing a point in ________ second
Amplitude			m	The __________of the wave from the middle line

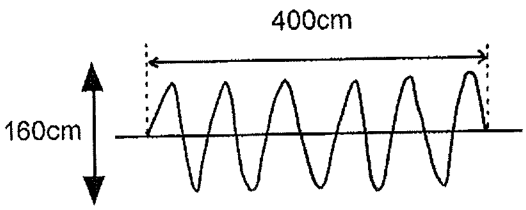
Example 1 Look at this water wave.



(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

8. Calculating frequency

To calculate the frequency of a wave from the number of waves passing in a certain time.

$$\text{frequency} = \frac{\text{Number of waves}}{\text{time in seconds}} \qquad f = \frac{N}{t}$$

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

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

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

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

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

Example 16 water waves pass a point in 80s. What is the frequency?

f = ?
No of waves = 16
time = 80s

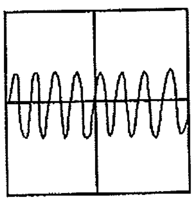
$$f = \frac{\text{Number of waves}}{\text{time in seconds}}$$

$$f = \frac{16}{80}$$

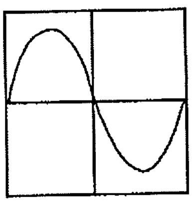
$$f = 0.2\text{Hz}$$

9. Pictures of Sound waves

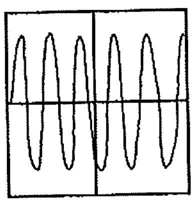
We can display sound waves on an oscilloscope screen.



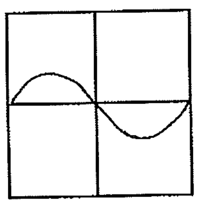
Quiet / loud
High / low
frequency sound



Quiet / loud
High / low
frequency sound



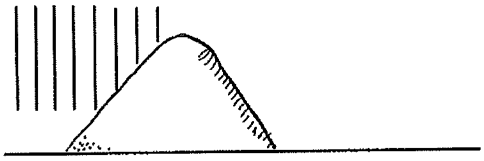
Quiet / loud
High / low
frequency sound



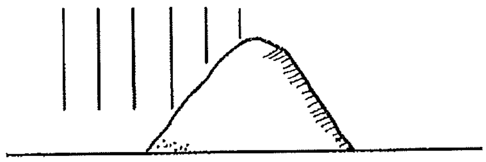
Quiet / loud
High / low
frequency sound

10. Diffraction

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



short wavelengths

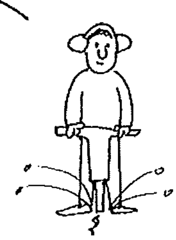


long wavelengths

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

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

11. Sound Level (Loudness)



(1) The larger the amplitude the __________ the sound. Sound level or loudness is measured in units called _______________ or ______ for short.

Quiet conversation is ____dB.. Danger Level is ____dB.

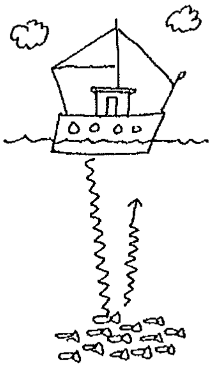
A loud Disco is _____dB. Loud sounds can damage your _______________.

Wear _______ protectors to protect your hearing.

Noise _________________ is any sound which can ruin your environment.

12. Ultrasound

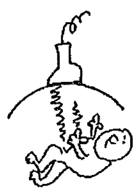
(1) Humans can hear sound waves with frequencies between _____ and __________Hz.



Frequencies above 20,000Hz are called _______________.

When ultrasound travels from one medium into another some of it _____________ back.

We can use this fact to create pictures of unborn ____________, to find fish in the _______ and cracks in ___________.



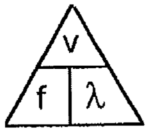
It can also be used to break up _________ stones.

13. Speed, frequency and wavelength

(1) Wave speed, wavelength and frequency.

speed = frequency x wavelength

or $v = f\lambda$



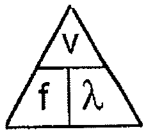
quantity	units
frequency	Hz
wavelength	
speed	

Example A <u>sound</u> wave has a frequency of 12kHz.

(a) What is the wavelength of the wave?

$\lambda = ?$
$v = 340 m/s$
$f = 12 kHz = 12 \times 10^3$ Hz

$v = f\lambda$



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

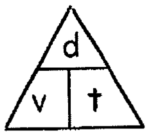
$\lambda = \frac{340}{12 \times 10^3}$

$\lambda = 0.028 m$

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

$t = ?$
$v = 340 m/s$
$d = 6.8 km = 6.8 \times 10^3$ m

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



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

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

$t = 24.1 s$

B. Electromagnetic Spectrum

14. Electromagnetic family

(1) The electromagnetic spectrum describes a range or family of waves which all travel as ______________________ waves at a speed of _____________.

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

Radio	TV			Visible light		X -Rays	

R_YG_IV

⟶ frequency ____________ ⟶

⟶ wavelength ____________ ⟶

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

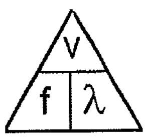
(3) Some more useful prefixes

nano = x 10$^{\square}$ m   eg   678nm = 678 x 10$^{\square}$ 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 ______________ so they are good at ______________ round hills and buildings,. This makes them ideal for carrying radio and ______ programmes to your house.

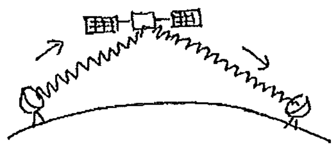
____

____

____

____

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



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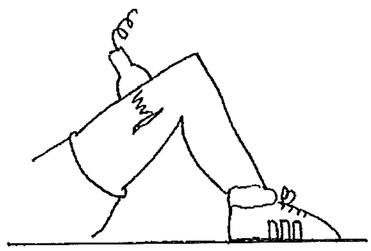
(3) **Infra red** radiation is the scientific name for __________. It can be detected by a thermometer. In medicine it can be used in heat treatment to speed up the healing of damaged ______________ tissue. In industry it can be used to _______ paint. Rescue services use ______________ imaging cameras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



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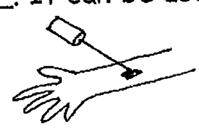
(4) **Visible light** is made up of a range of different ______________. Red has a ______________ wavelength than blue light. A concentrated beam of visible light of one colour is called a ________________ beam. It can be used to remove _____________ marks and ______________. It can be used to ________________________tumours.



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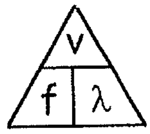
Example The frequency of a microwave is 2870MHz. Calculate its wavelength.

$\lambda = ?$
$v = 3 \times 10^{8}$ 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

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

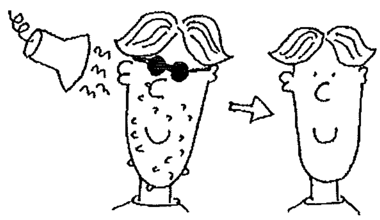
$$t = \frac{d}{v}$$

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

$$t = 0.003s$$

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

UV light can be used to treat skin conditions like ______________. Special ______________ chemicals can be painted on important items as ______________ markings. These markings only show up under ________________________ light.



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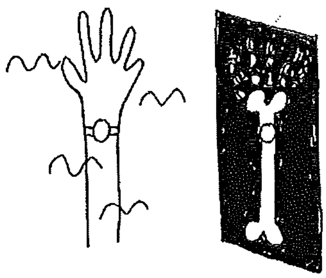
(6) X rays pass through most tissue and cause photographic film to turn ____________. However X rays are absorbed by ____________ in your body. So photographic film behind bones stays white. This allows X ray ____________ to be taken of your body.



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

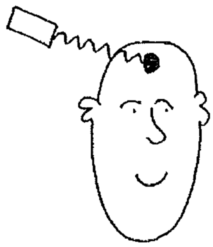
____

____

____

____

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



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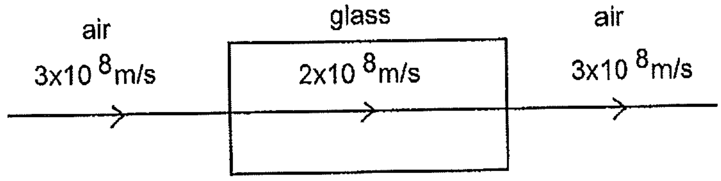
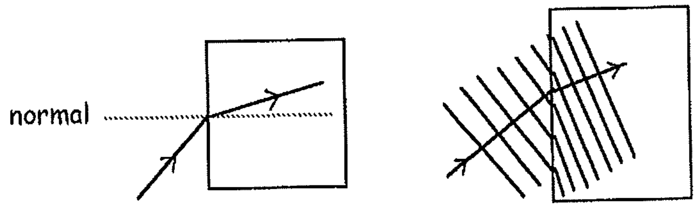
16. Refraction

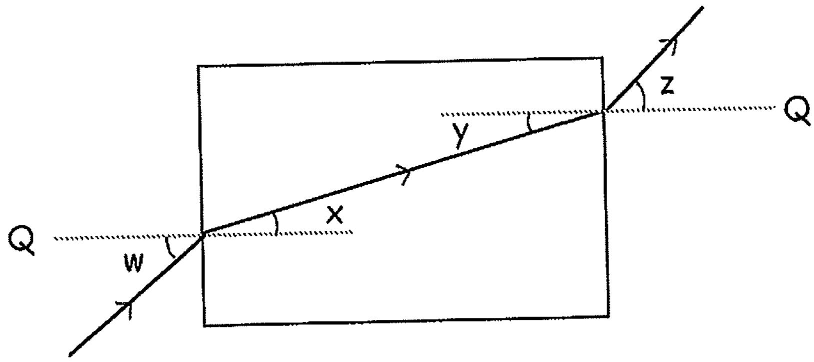
(1) Refraction is the process where the ____________ of a wave changes as it travels from one medium into a different medium (ie air into glass).



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



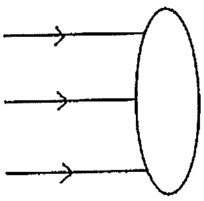
(3) Here is a diagram showing a beam of light travelling from air into a glass block then back into air.



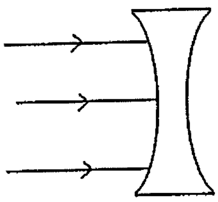
line Q is drawn at _____ to the boundary. It is called the ______________.
All ____________ are measured **from** the normal **to** the ray of light .

angle w = angle of ____________	angle y = angle of ____________
angle x = angle of ____________	angle z = angle of ____________

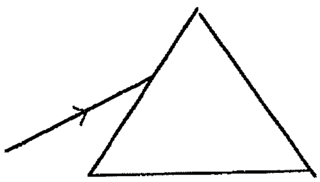
(4) Copy and complete the path of light through these 3 common lenses.
Name the first two lenses.



____________lens

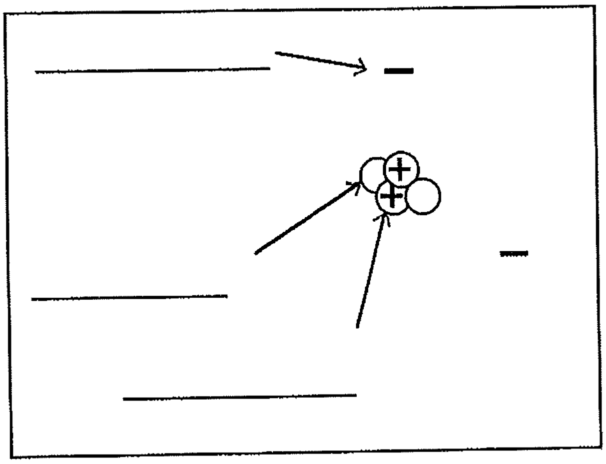


____________lens



C. Nuclear Radiation

17. The atom



(1) An atom has a tiny central ____________ made up of positive ____________ and ______________ which have no charge. Flying around the nucleus are tiny particles called __________ which have a ______________ charge.

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

Most atoms are electrically neutral because they have equal numbers of positive ____________ and negative ______________.

18. Nuclear radiation

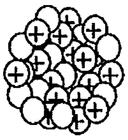
(1) Small atoms are stable because they have fairly similar numbers of protons and ______________. However very big atoms like Uranium have a big imbalance. Uranium has _____ protons and _____ neutrons. To become more stable the nucleus can throw off ____ types of radiation. We call these 3 types NUCLEAR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

Radiation	Symbol	Picture	Nature	Nucleus Symbol
Alpha	α		2______ and 2 ________. It is a Helium _________	^{4}He
Beta		—	A fast moving __________	
Gamma			An electromagnetic __________	

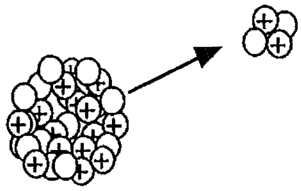
(2) If there are no electrons in the nucleus, where does this beta particle come from?
Well, a neutron turns into a ____________ and an electron and the electron is released as a ________ particle.

19. Decay

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



radioactive atom



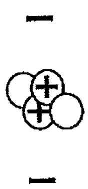
radioactive atom decaying

Gamma emission usually happens along side alpha and beta emission.

Any material containing radioactive atoms is called a source.

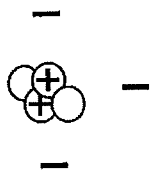
20. Ionisation

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



neutral atom
2 +ve protons
and
2 -ve electrons

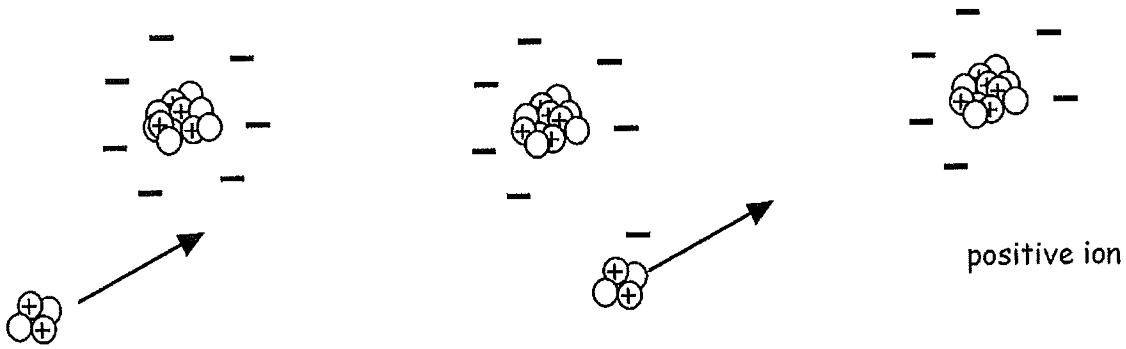
Atom loses an electron and becomes a ___________ ion with a charge of ___



Atom gains an electron and becomes a ____________ ion with a charge of ____

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

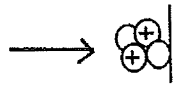
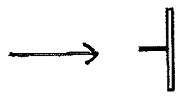
(3) Alpha particles cause the most ionisation because they are the biggest of the three nuclear radiations. Also, because it has a _______________ charge it can attract the _______________ off an atom without actually colliding with it. Beta and Gamma cause much less ionisation.



atom being ionised by an ___________particle

21. Absorption

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

Alpha particles	Stopped by ______cm of air or a thin sheet of _______________.	
Beta particles	Stopped by _____m of air or a _______ sheet of _________________.	
Gamma radiation	Stopped by a thick block of ______________.	

(2) Radiation can be detected by a _________________________ tube or by _________________________________film
Radiation causes photographic film to turn black.

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

22. Uses and Applications of Nuclear Radiation.

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

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

In industry _________ radiation can be used to judge the _______________ of paper or foil. Radioactive tracers can also be used to study the flow of liquids along ____________.

Other Uses.

____

____

____

____

____

23. Background Radiation

(1) Background radiation is the radiation which is ______________ us all the time. It can come from n_____________ sources or m_______ made sources. Here are some sources of Background radiation.

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

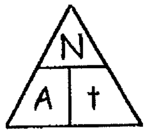
(2) Background radiation can be measured using a ______________________ tube and a counter. When measuring the activity of a source we must make sure we take into account ______________________ radiation.

24. Dosimetry - Measuring Radiation.

(1) Activity

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

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



Quantity	Units
Activity No of decays time	

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

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

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

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

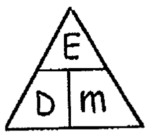
$$A = \frac{2400}{180}$$

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

(2) Absorbed Dose

Absorbed Dose, D, tells you how much radioactive energy 1____ 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 Energy mass	

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

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 ________________ effect that radiation has on a body. Equivalent Dose takes into account the ________________ Dose and the type of ________________ which you are exposed to.
The unit for Equivalent Dose is the ________________ or ____ for short.

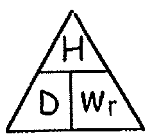
We take into account the type of radiation by multiplying the Absorbed Dose by a ________________ factor, w_r. Each radiation causes a different amount of ionisation so has a different ________________ factor.

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

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

Equivalent Dose = Absorbed Dose x Weighting ___________

$$H = D \times w_r$$



Quantity	Units
Dose Equivalent	
Absorbed Dose	
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

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		800
Carbon and Potassium in body.		370
Cosmic rays from space		300
Medical (x-rays, CT scan etc)		250
Fallout from weapons testing		10
Nuclear waste		2
Aeroplane trips		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 __________________ sources than from __________________.

26. Safety in dealing with radiation

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

1. S__________________ the source with an appropriate absorber like ____________.
2. Limiting the t______________ you are exposed to radiation
3. Putting a big d__________________ between you and the source.

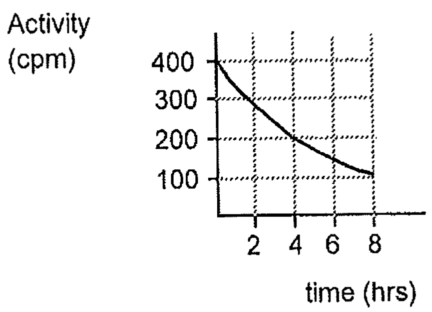
(2) If you do have to handle radioactive sources

1. Always use f______________ or t____________ when lifting a source.
2. Never bring a source close to your ______________.
3. Store in a l____________ lined l______________ box.
4. Always ______________ your hands after using sources.

27. Half Life

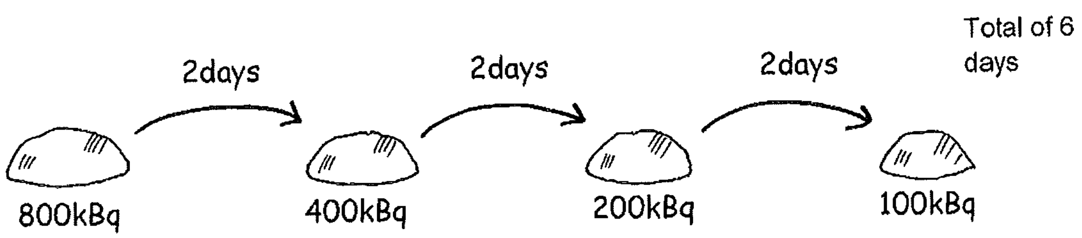
(1) A source may contain billions of radioactive atoms. As time goes by the atoms decay and become ______________. So the Activity of all sources ________________ with time.

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



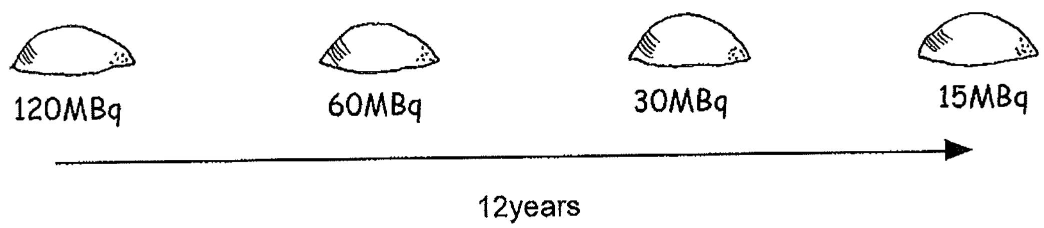
Half life = __________

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?

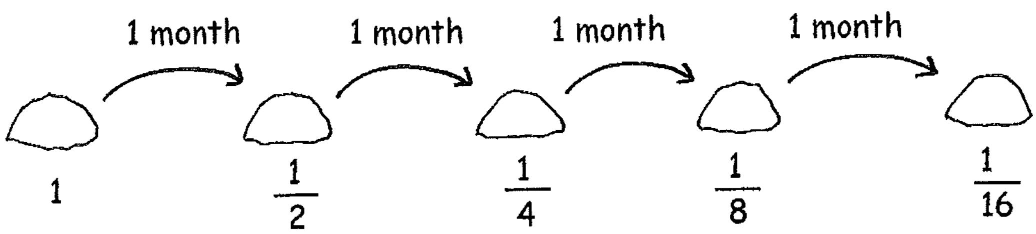


Activity has halved 3 times in 12 years. Therefore the half life = $\frac{12}{3}$ = 4 years

(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 ______________ of the original activity , then after another half life the activity would be an ________________ 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.

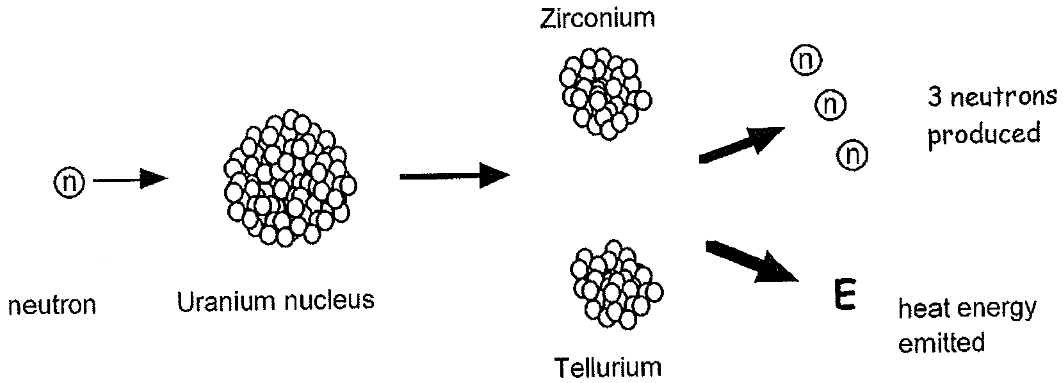
(29) Taking Background radiation into account.

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

30. Nuclear Reactions

1. Nuclear Fission.

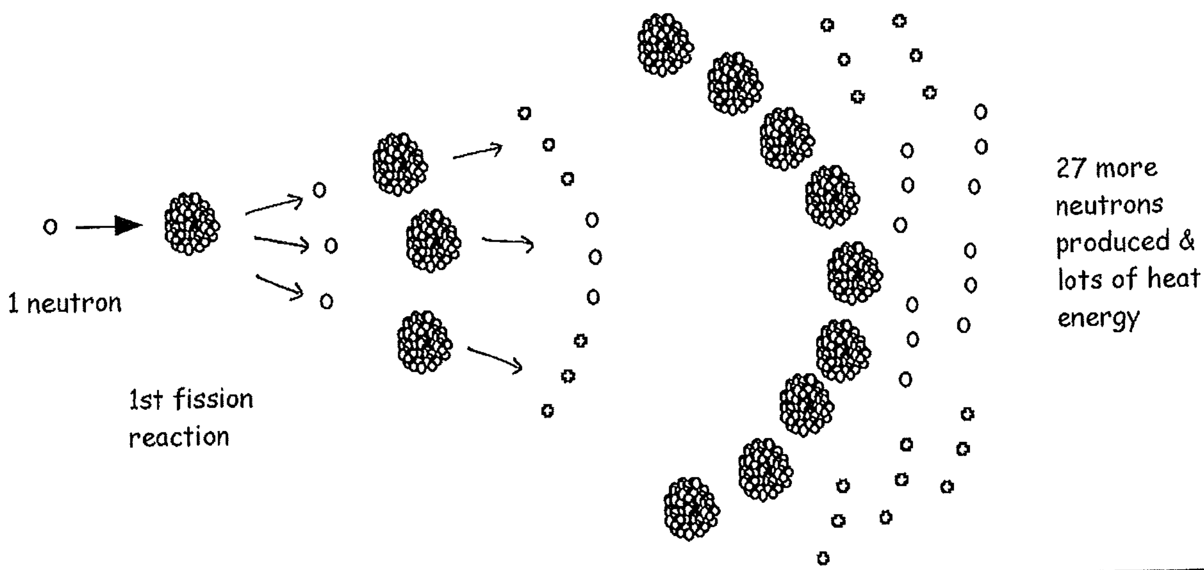
(1) In a nuclear fission reaction a neutron is fired at a large unstable U_________________ nucleus. The Uranium nucleus absorbs the neutron and _________ into two smaller nuclei. When the nucleus splits some neutrons are emitted. But more importantly the mass of the particles after the reaction is ___________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



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

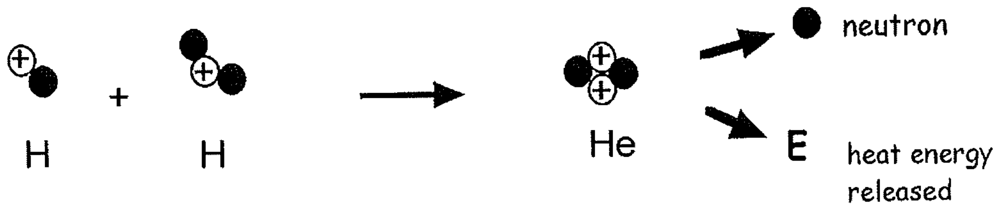
2. Chain Reaction

The neutrons which are released caused 3 more ______________ reactions which produce _______ more neutrons which cause __________ more fission reactions. This is called a ________________ reaction and as a result a huge amount of ___________ energy is created very quickly.



3. Nuclear Fusion

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

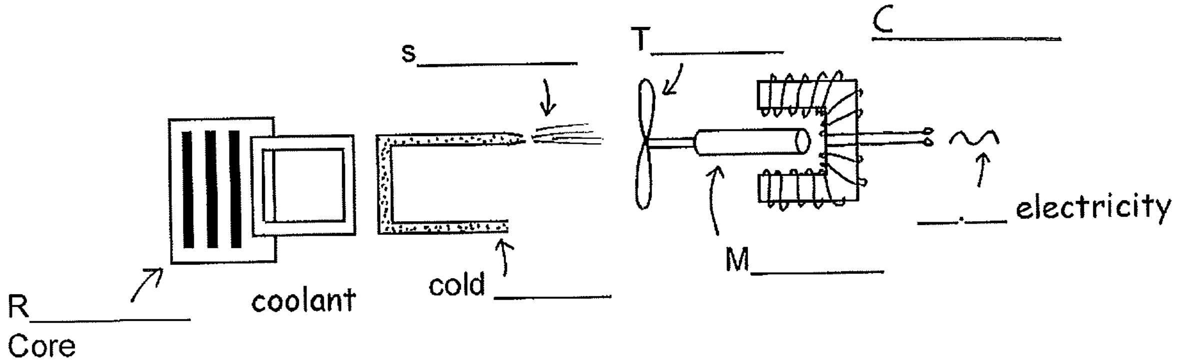


As in the fission reaction, the mass of the particles after the reaction is ________ than the mass of the particles before the reaction. This lost mass is turned into ___________energy.

4. Nuclear Power Station - Using the Heat Energy

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

The Nuclear Reactor



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

(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.

5. Pros and Cons of Generating Electricity from Nuclear Fission

(1) Advantages of Nuclear Fission Power

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

2. The supply of electricity is very ______________.

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

(2) Disadvantages of Nuclear Fission Power

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

2. Nuclear waste has to be stored safely for __________________ of years. This is very ___________________.

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

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

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 ________________________________ gases or ___________________________ waste

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

(2) Disadvantage of fusion compared to fission.

1. The fusion process requires temperatures similar to the core of the ________ to fuse the nuclei together. Creating temperatures this high is very ___________________________________.

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

NQ5 Physics	Waves and Radiation	Contents