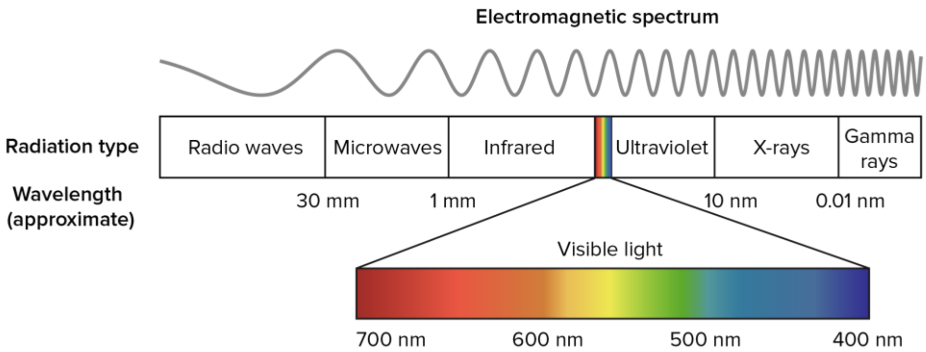
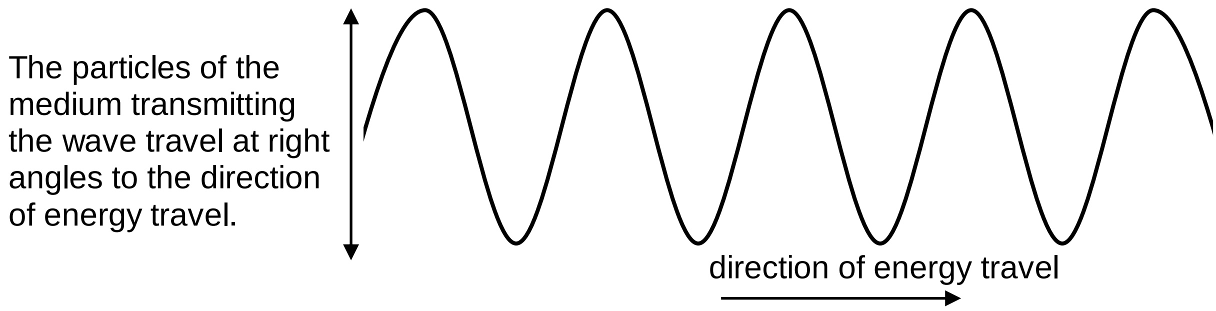
Waves and Radiation
National 5 Physics



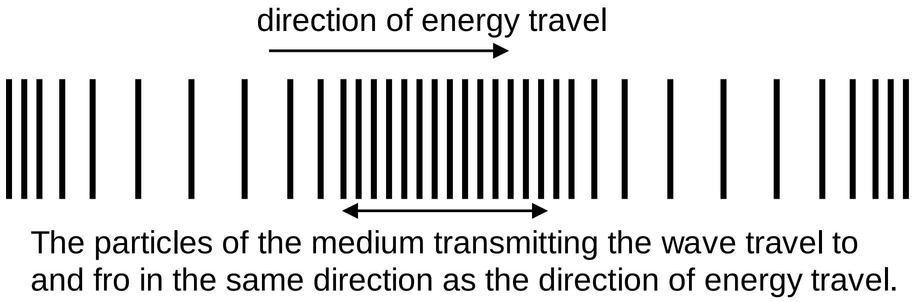
Wave Parameters and Behaviours

Longitudinal and transverse waves
Waves transfer energy from one place to another. There are two types of wave.

Transverse wave. Examples of a transverse wave are water waves and light. The particles of the medium carrying the wave move at right angles to the direction of energy travel.



Longitudinal wave. An example of a longitudinal wave is sound. The particles of the medium carrying the wave move parallel to the direction of energy travel.



Wave definitions

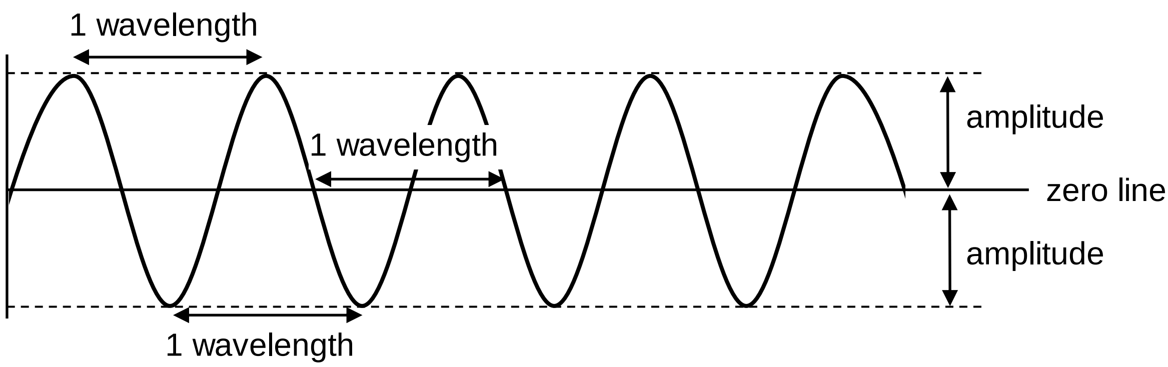
period - time taken for one wave to pass a point.

frequency - number of waves each second.

amplitude - distance from the mid line to a wave crest or wave trough.

wavelength - the distance between the point on a wave and the identical point on the next wave.

wave speed - distance the wave travels each second.



The period of the wave can be calculated using the formula:

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

where T = period of the wave
f = frequency of the wave

Calculating wave speed using frequency and wavelength
The speed of a wave can be calculated if you know its wavelength and frequency.

Use the equation wave speed = frequency × wavelength

$$v = f\lambda$$

where v = speed of wave measured in metres per second ($m\ s^{-1}$)
λ = wavelength measured in metres (m)
f = frequency measured in hertz (Hz)

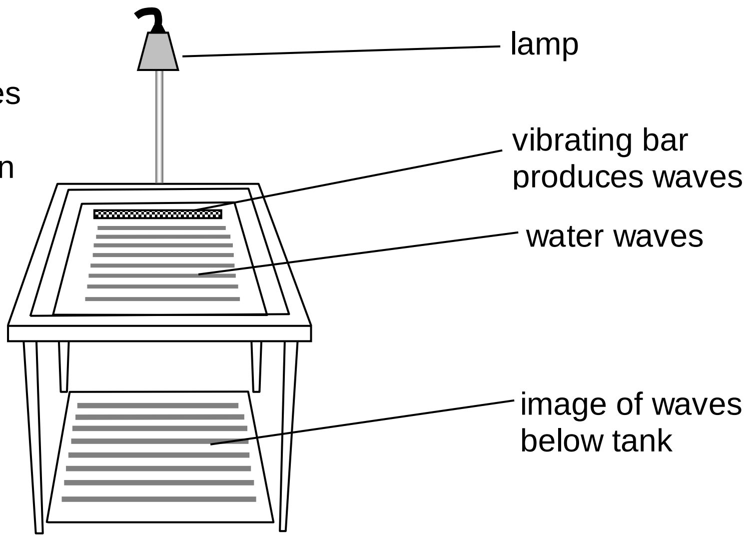
Calculating wave speed using distance and time
The speed of a wave can also be calculated from the distance it travels in a given time.

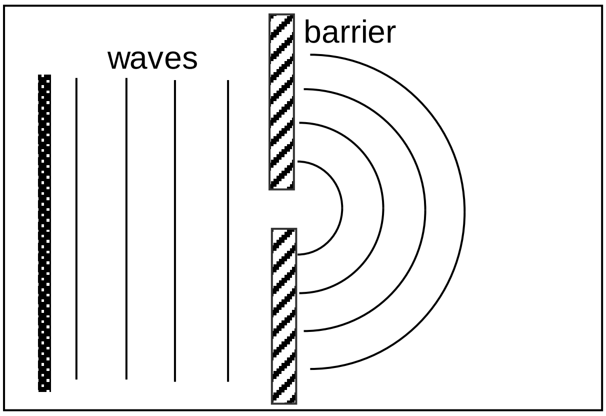
Use the equation $$\text{wave speed} = \frac{\text{distance wave travels}}{\text{time taken}}$$

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

where v = speed of wave measured in metres per second ($m\ s^{-1}$)
d = distance wave travels in metres (m)
t = time taken for wave to travel given distance (s)

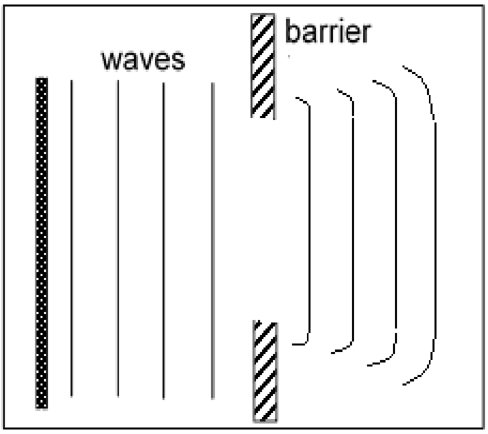
Waves and Diffraction
The behaviour of water waves can be examined using a ripple tank like the one shown opposite.



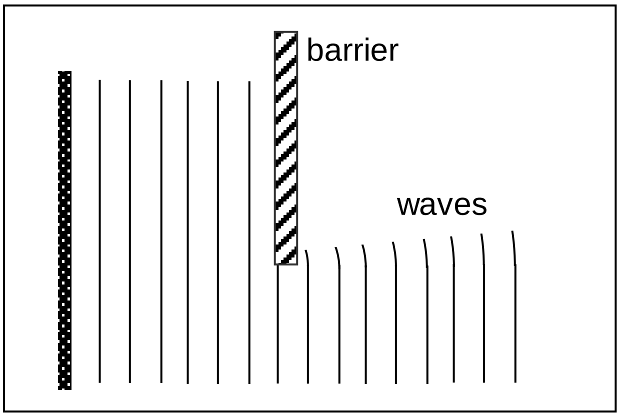


A vibrating bar produces a series of plane or straight waves. If these meet a barrier with a small gap in it, the waves appear on the other side as circular waves centred on the gap.

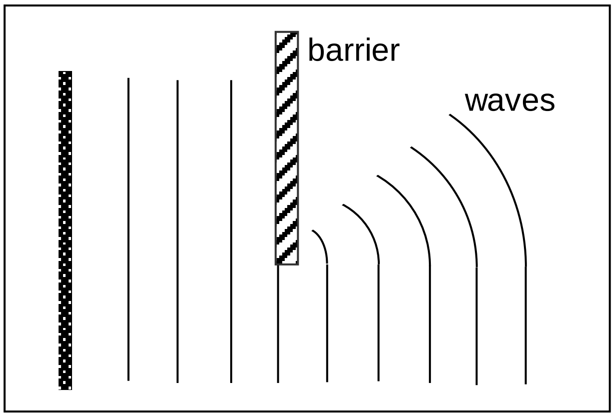
The effect of waves bending when they meet obstacles is called diffraction.



If the gap is larger than the wavelength then the waves are straight in the middle and only bend behind the barrier (in the shadow of the barrier).

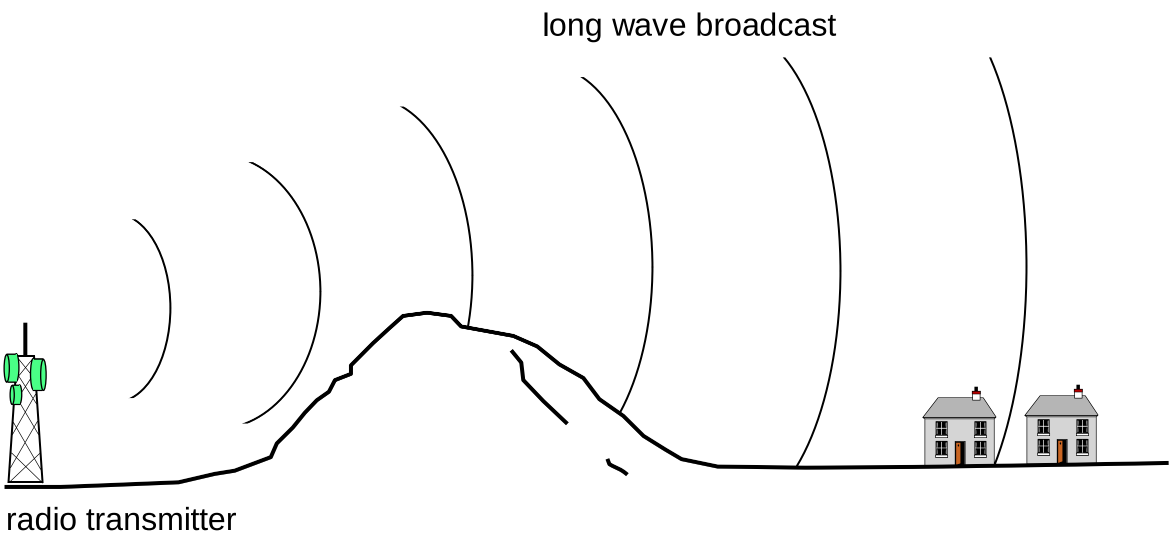


When waves meet the edge of a barrier they will diffract around it. Shorter wavelengths do not diffract much.



Waves with a longer wavelength diffract more.

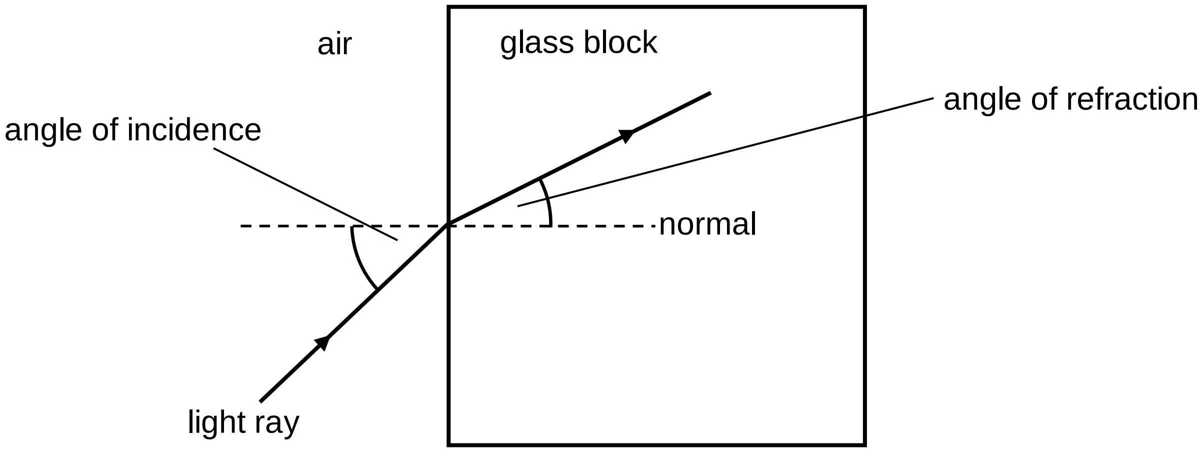
Radio waves will diffract around an object such as a large building or a hill. Short wave, higher frequency broadcasts, such as television waves, will be blocked by a hill. Longer wave broadcasts such as radio broadcasts, are able to bend around the hill as shown below.



Light

Refraction of light

A ray of light enters a glass block as shown. The normal is a line at 90° to the glass surface.



When light travels from one medium to another, from air to glass for example, the wave undergoes certain changes.

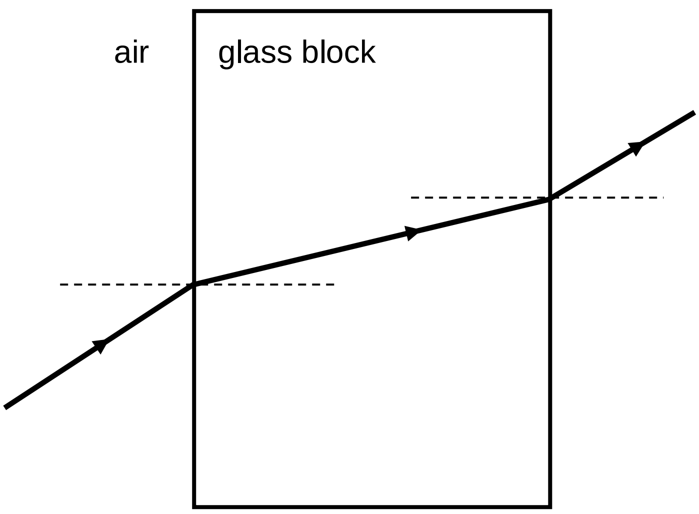
Travelling from air into glass the ray of light:

- slows down.
- its wavelength decreases.
- it refracts or bends towards the normal if it enters the block at an angle.
- its frequency remains unchanged.

Travelling from glass into air the ray of light:

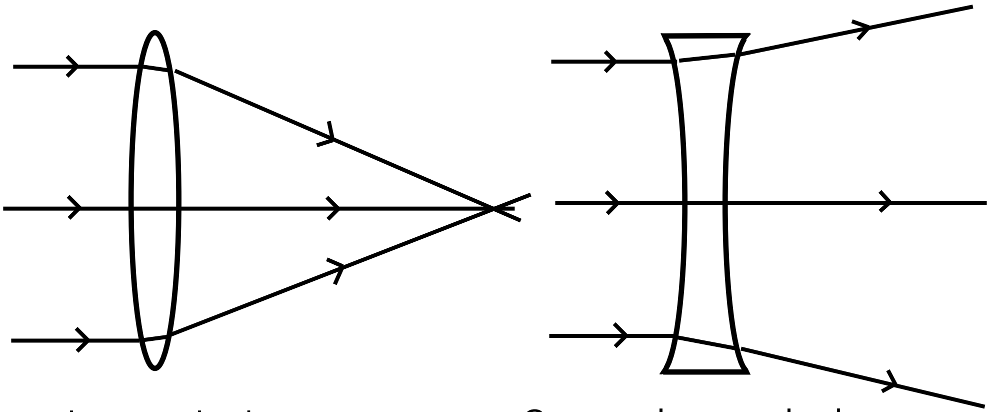
- speeds up.
- its wavelength increases.
- it refracts or bends away from the normal if it leaves the block at an angle.
- its frequency remains unchanged.

Light passing through a glass block will emerge parallel with the incident beam though offset due to the refraction effect. This is why a straw in a glass of water appears bent when you look at it.



Applications of Refraction

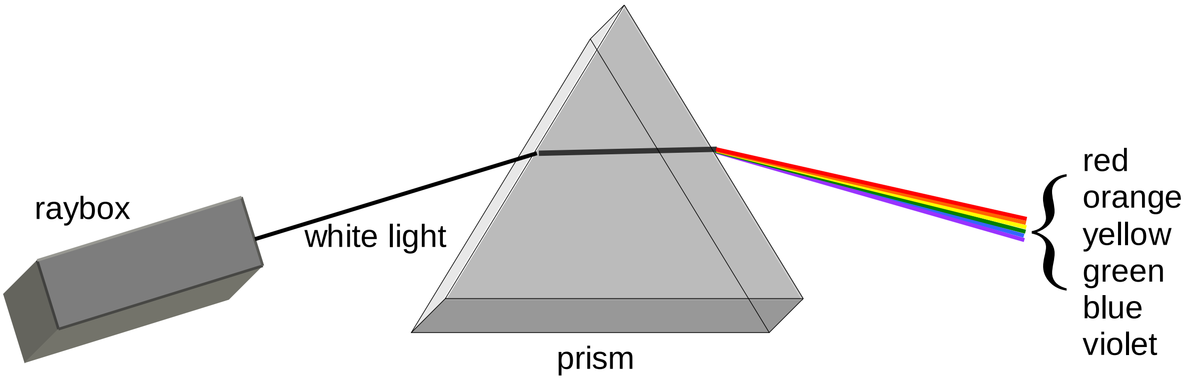
When light enters a glass shape its path will alter (unless it passes along the normal in which case it does not change direction). This can be made use of in lenses. They can be either convex or concave as shown below.



Convex lenses, also known as converging lenses, bring parallel rays of light to a focus

Concave lenses, also known as diverging lenses, cause parallel rays of light to spread out

The refraction of light is also responsible for the colours seen when white light is split into its component colours when it enters a prism.



Red light is refracted least by the prism and violet the most giving the order shown above (remembered using the pneumonic – **R**ichard **O**f **Y**ork **G**ave **B**attle **V**ainly.)

Electromagnetic Spectrum

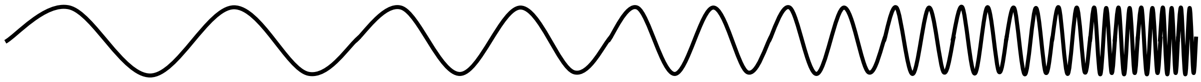
The Electromagnetic Spectrum

The electromagnetic spectrum consists of a family of waves, one of which is light. They all travel with the speed of light i.e. 3×10^8 m s^{-1}. Their properties vary however, depending upon the frequency and wavelength of the waves. All the waves are transverse and are able to travel through a vacuum.

The higher the frequency of the waves in the spectrum, the more energy they carry. This is why high frequency waves such as X-rays and gamma radiation are the most dangerous.

low frequency
long wavelength

high frequency
short wavelength



Radio and TVwaves	microwaves	infrared	visible light	ultraviolet	X-rays	gamma radiation

Radio and TV waves

Radio and TV waves are all around us. These have the longest wavelength of any wave in the electromagnetic spectrum. They are detected by a receiver tuned to the particular frequency of the wave – whether it is a TV signal or a radio signal. The waves carry information which can be decoded by the receiver to produce sound or visual images.

Microwaves

Microwaves have a shorter wavelength than radio and TV waves. They are often used in telecommunication and in mobile telephones. In high doses they could present some danger, for example excessive use of a mobile phone close to the head. Microwaves can also be used in microwave ovens where they cause water molecules in food to vibrate and generate heat.

Infrared Radiation

Any object which is hotter than its surroundings will emit infra red radiation. It can be detected with special cameras or infrared film. Infrared can be used to treat muscle injuries and thermal images can be used to help diagnose disease.

Infra red photography can also help identify where houses are losing heat or where overhead electric cables are overheating due to a fault.

Visible Light

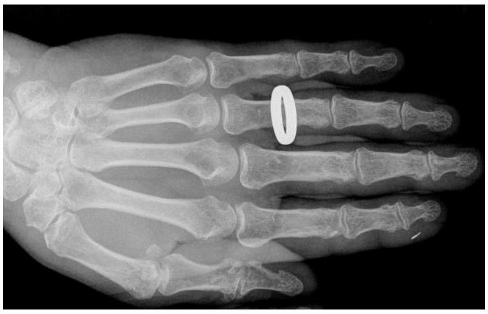
Visible light is the electromagnetic radiation we are most familiar with. It is detected by our eyes and the colour we see depends upon the wavelength or frequency of the light.

Ultraviolet light

Ultraviolet light comes from the Sun or can be produced by special lamps. It causes our skin to tan but it can also be dangerous and cause severe skin damage including skin cancer.

Ultraviolet light causes certain materials to fluoresce or glow. It can be used to show up security marking or special dyes used to print genuine bank notes.

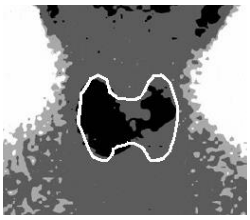
X-rays



X-rays have the ability to pass through the human body. They can be detected by photographic film. These properties are made use of in hospitals when X-ray pictures are taken of patients. Dense tissue like bone blocks the X-rays most and these show up as pale on the images whilst soft tissue appears darker. A metal object will appear white as it completely blocks the x-rays

Gamma Radiation

Gamma radiation is potentially the most dangerous of the electromagnetic radiations but even it can be put to use in medicine. A gamma emitting liquid is injected into the patient.



The radioactive liquid can be used to show up blood flow or tumours or particular organs such as the thyroid gland.

The picture opposite shows the thyroid gland of a patient taken with a gamma camera.

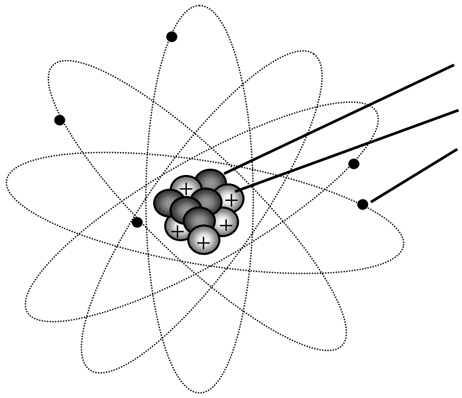
Gamma radiation can also be used to destroy tumours inside a patient's body. A beam of radiation is directed at the tumour from several different directions. The tumour receives a full dose but surrounding healthy tissue a lesser dose.

The electromagnetic spectrum
Calculations involving waves from the electromagnetic spectrum can be solved using the two formula met earlier i.e.

$$v = f\lambda \qquad \text{and} \qquad v = \frac{d}{t}$$

Nuclear Radiation

Types of radiation
All nuclear radiation comes from the atom. An atom consists of protons (positively charged) and neutrons (no charge) surrounded by orbiting electrons (negatively charged).



There are three types of nuclear radiation; alpha and beta which are particles and gamma radiation which is a wave and part of the electromagnetic spectrum.

Alpha radiation is a helium nucleus and consists of 2 protons and 2 neutrons giving it a positive charge. Beta radiation is a fast moving electron which is ejected from the nucleus of an atom when a neutron splits into a proton and electron. it has a negative charge.

Gamma radiation has no charge as it is part of the electromagnetic spectrum. It has a very short wavelength and very high energy.

The properties of the three types of ionising radiation are given in the table below.

Type of radiation	*alpha*	*beta*	*gamma*
Symbol	α	β	γ
Consists of	2 protons and 2 neutrons	a fast moving electron	a wave, part of the electromagnetic spectrum
Blocked by	thin sheet of paper or a few cm of air	about 3 mm of aluminium	about 3 cm of lead
Ability to ionise	strong	weak	weak

Ionisation occurs when radiation causes the atom to become charged. This can happen when an atom captures an electron to become negatively charged or an electron is knocked off an atom to leave it positively charged.

The more a radiation is able to ionise the more likely it is to cause damage to living cells. Alpha is the most dangerous in this respect, but it is also the least able to enter the body unless swallowed or breathed in.

Activity of a Source

A radioactive substance contains many nuclei which undergo decay in a random manner. The ACTIVITY of a source is the number of decays per second.
Activity can be calculated using the formula:

$$\text{activity} = \frac{\text{number of nuclei decaying}}{\text{time in seconds}} \qquad A = \frac{N}{t}$$

where A = activity in becquerels (Bq)
N = number of nuclei decaying
t = time in seconds (s)

Activity is measured in becquerels and 1 Bq is equivalent to 1 decay per second.

Background Radiation

Background radiation is radiation which is present all the time. It can come from either man made sources or from naturally occurring sources.

Man made sources include building materials, radioactive material used in medicine and radioactive materials used in smoke detectors or luminous watches.

Smoke alarms contain a radioactive source which is used in the detection of the smoke.

Natural sources of radiation includes cosmic radiation from outer space, rocks and minerals such as granite, radon gas from underground and even the food we eat.

Absorbed and Equivalent Dose
The effect of radiation on the human body is measured by absorbed dose and equivalent dose.

When alpha, beta or gamma radiation is absorbed by the human body its energy is deposited in the absorbing tissue. This is measured by the absorbed dose which is the energy absorbed per unit mass of the absorbing material.

$$\text{absorbed dose} = \frac{\text{energy}}{\text{mass}} \qquad D = \frac{E}{m}$$

where D = absorbed dose in grays (Gy)
E = energy in joules (J)
m = mass in kilograms (kg)

One gray is equivalent to one joule of energy being absorbed per kilogram of body tissue.

Equivalent Dose
Human tissue can be harmed by radiation. The amount of damage done will depend upon the size of the absorbed dose and the type of radiation being absorbed, whether it is alpha, beta, gamma neutrons or X-rays.

The equivalent dose is measured in sieverts. The sievert is a unit which applies a weighting factor, W_R, to the absorbed dose so that the type of radiation can be taken into account.

$$\text{equivalent dose} = \text{absorbed dose} \times \text{weighting factor}$$

$$H = D\,W_R$$

where H = dose equivalent in sieverts (Sv)
D = absorbed dose in grays (Gy)
W_R = weighting factor

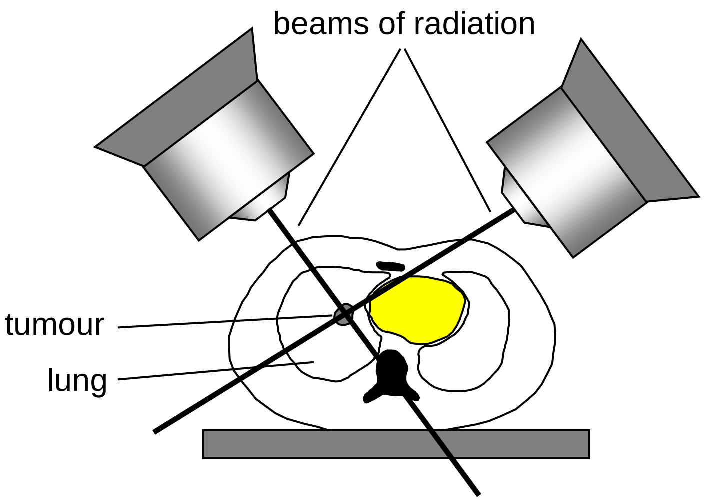
Some weighting factors are shown below. Alpha particles have a high weighting factor due to their strong ionising effect which causes more damage to cells.

Type of radiation	*weighting factor, W_R*
X-rays	1
gamma rays	1
beta particles	1
slow neutrons	5
fast neutrons	10
alpha particles	20

Applications of Nuclear Radiation
Nuclear radiation is used in medical applications to help diagnose and treat disease as well as in industrial applications.

Medical uses

- used to treat tumours by killing the cancer cells present in the tumour. A beam of gamma radiation is fired into the patient from several angles. The tumour being treated is targeted by every beam and receives a full dose of radiation. Surrounding healthy tissue receives a much weaker dose.



- radioactive liquid can be injected into a patient and its path around the body traced using special instruments.
- radiation can be concentrated in certain organs in the body and this helps a doctor to diagnose or treat disease.
- can sterilise medical instruments by destroying any organisms on them.

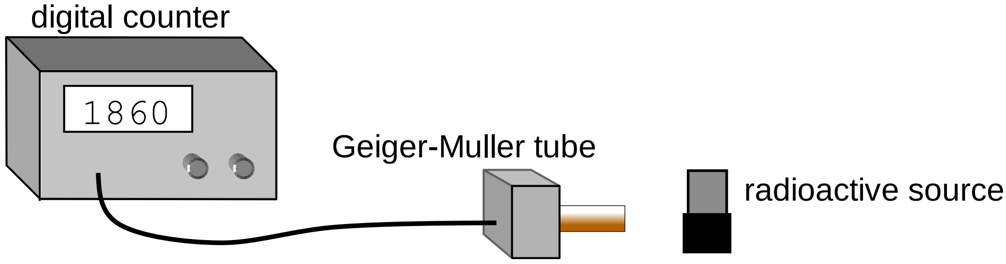
Industrial uses

- used in smoke detectors.
- can be used in control processes in manufacturing e.g. to measure the thickness of a material by the amount of radiation absorbed.
- tracing leaks and cracks in pipes.

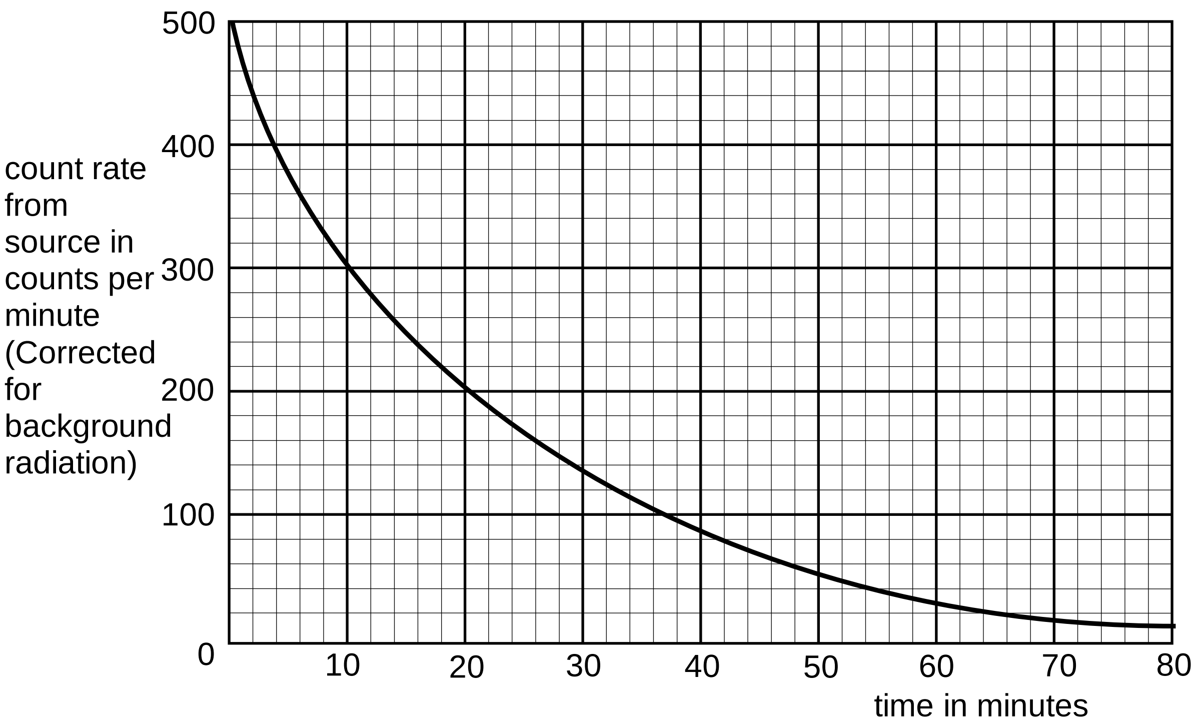
Half-life
Over time, the activity of a source will decrease. The rate at which a radioactive source loses its radioactivity is measured by its half-life. Half-life is defined as the time it takes for activity of the source to decrease to half of its original value.

A radioactive source with a long half-life will remain radioactive for much longer than one with a short half life. The half-life of a source can range from fractions of a second to thousands of years.

The half-life of a source can be found experimentally by measuring its activity over a period of time using a geiger counter as shown below.



The activity of the source is measured over a period of time. The background count is first measured with no source in place and this is deducted from all the readings. The graph below is typical and shows the decrease in activity with time.



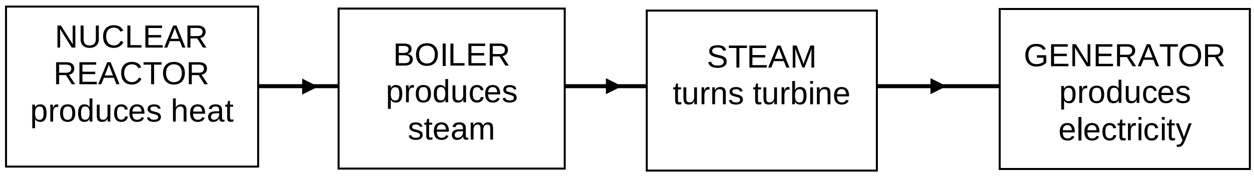
The count rate halves approximately every 16 minutes.

The half life can also be found by simple calculation. If a substance has an activity of 80 000 Bq and a half life of 15 minutes, its activity will have reduced to 5000 Bq after 60 minutes.

80 000 Bq
↓ 15 minutes
40 000 Bq
↓ 30 minutes
20 000 Bq
↓ 45 minutes
10 000 Bq
↓ 60 minutes
5000 Bq

Nuclear power

Nuclear reactors use uranium as a source of energy. The uranium is stored in fuel rods inside the reactor and a process called nuclear fission takes place where atoms split and release heat energy.



The heat energy released from the nuclear reactions is used to turn water into high pressure steam. The steam drives a turbine which then rotates the generator to produce electricity.

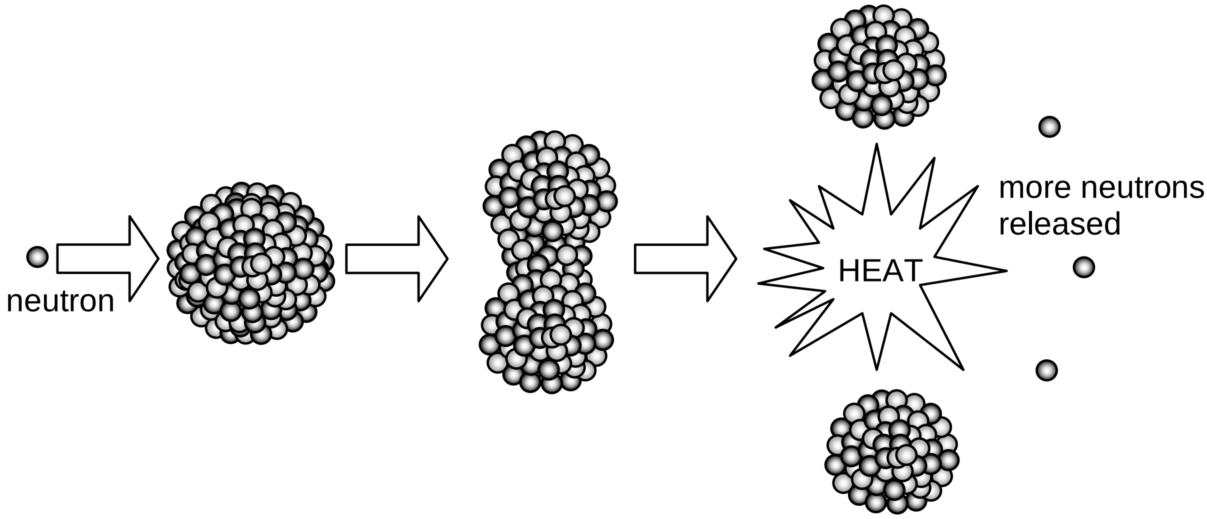
Nuclear Fusion and Fission

Nuclear reactions are one of two types—nuclear fusion or nuclear fission.

Nuclear fusion takes place when two small nuclei collide and join together to create a larger nucleus. This also causes heat energy to be released. This is the same atomic reaction that takes place in the Sun.

Nuclear fission takes place when a neutron collides with a large unstable nucleus. This causes it to split into two smaller nuclei. At the same time it releases more neutrons and a quantity of heat.

In a nuclear reactor the neutrons go on to produce further fission reactions though the number of these is controlled to limit the amount of heat produced. This is called a chain reaction.



Advantages of Nuclear Power

- A small amount of radioactive material can produce a lot of energy.
- Nuclear reactors do not produce carbon dioxide, sulphur dioxide or other pollutants.
- Nuclear reactors can supply large amounts of energy, replacing power stations powered by fossil fuels.
- The fuel for nuclear reactors will last for some time.

Disadvantages of Nuclear Power

- Waste from nuclear reactors must be stored underground for a long time until the radiation emitted decreases.
- Nuclear reactors are expensive to build and the time from deciding to build one and it being operational can be many years.
- Leaks of radioactive materials can have a major impact on the surrounding environment.

Precautions to take when handling radioactive substances

Precautions should always be taken when handling radioactive substances.

- always use forceps to lift a radioactive source.
- always point the source away from the body.
- always wear suitable lead lined gloves.
- never eat or drink where radioactive sources are being handled.
- always wash your hands after handling radioactive sources.

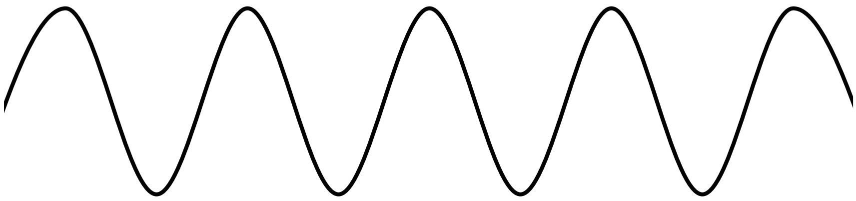
Wave Parameters and Behaviours

Longitudinal and transverse waves

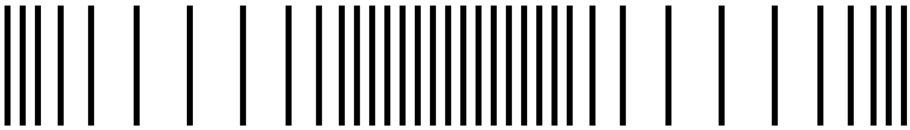
1. Waves provide a way of transferring energy. Give two examples of waves and state the energy they transfer.

2. Look at the two diagram s below. State which represents a longitudinal wave and which a transverse wave.

Wave A



Wave B



3. Describe how you could use a ‘Slinky’ spring to demonstrate:
(*a*) a transverse wave
(*b*) a longitudinal wave.

4. State which of the waves below are longitudinal waves and which are transverse waves

water waves light sound radio waves x-rays

Wave speed, frequency, wavelength, period and amplitude

5. Copy and complete the table to define some properties of waves.

Property	***Symbol***	***Unit***	***Definition***
Amplitude	none	m	(*a*)
(*b*)	λ	m	The horizontal distance between the point on a wave and the identical point on the next wave.
Frequency	f	(*c*)	The number of waves per second.
Period	T	(*d*)	The time it takes for one wave to pass a point.
Speed	v	$m\ s^{-1}$	(*e*)

6. State an equation that links frequency and the period of a wave.

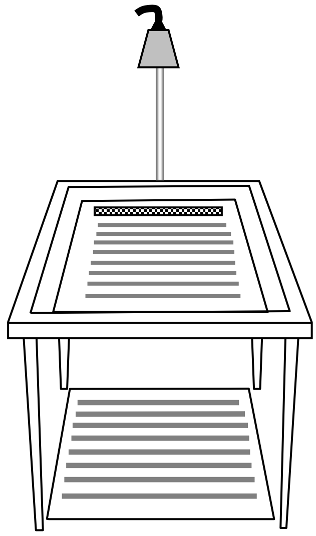
7. Calculate the period of waves which have a frequency of 10 hertz.

8. What is the period of water waves with a frequency of 0·25 hertz?

9. Waves have a period of 0·2 seconds. Calculate their frequency.

10. Waves a period of 0·01 seconds. Calculate their frequency.

11. Ripples are produced on a ripple tank like the one shown opposite. Calculate the frequency when:



(*a*) 10 waves pass a point in 2 s;

(*b*) 18 waves pass a point in 6 s;

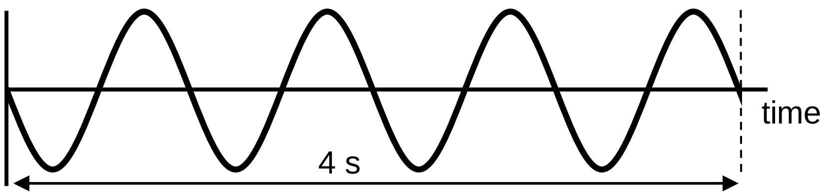
(*c*) 4 waves pass a point in 4 s;

(*d*) 100 waves pass a point in 20 s;

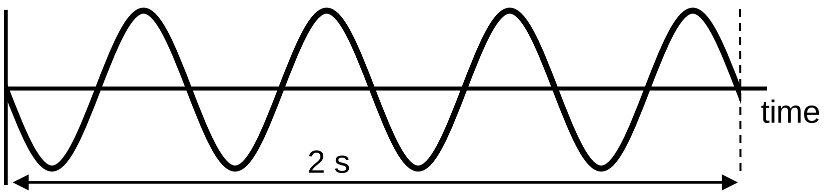
(*e*) 5 waves pass a point in 10 s.

12. Look at the diagram s of waves below. From the information provided, find the frequency of the waves.

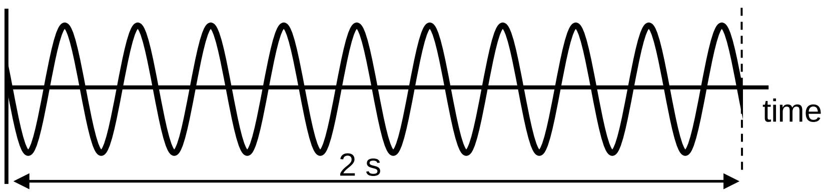
(*a*)



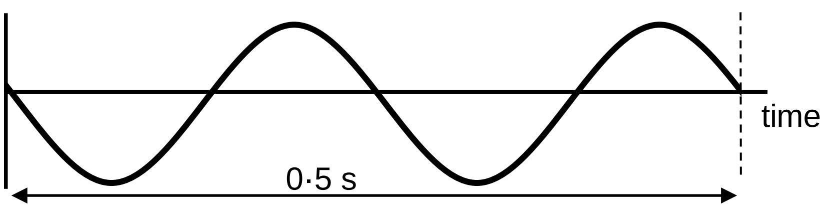
(*b*)



(*c*)

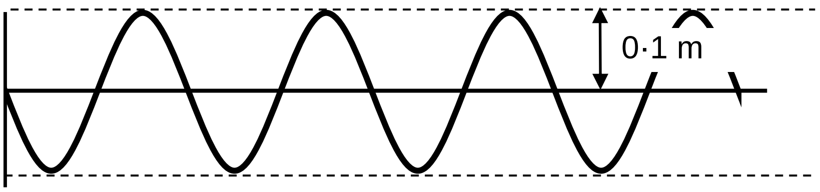


(*d*)

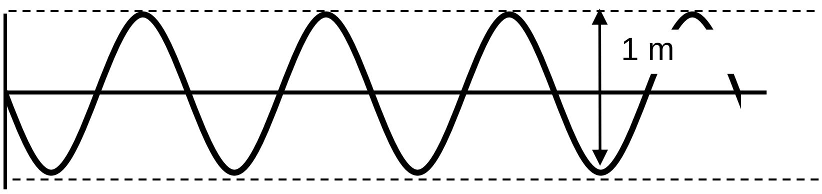


13. Use the information provided on the diagram s below to find the amplitude of each wave.

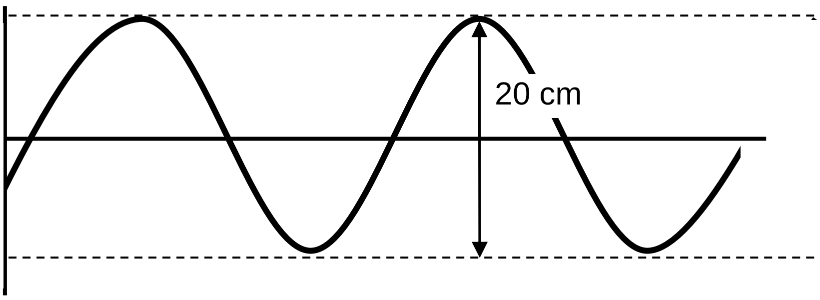
(*a*)



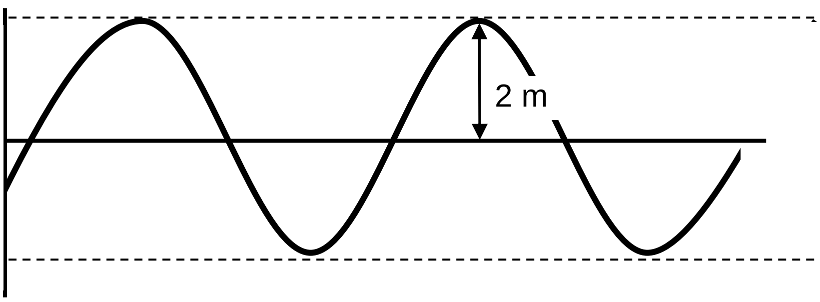
(*b*)



(*c*)



(*d*)



14. A loudspeaker vibrates at a frequency of 256 Hz to produce the note we call "middle C"

(*a*) How many waves does it produce in one second?

(*b*) How many waves does it produce in one minute?

15. Longitudinal waves are sent along a slinky spring. Four waves pass a point in 2 s. What is the frequency of the waves.

16. An alarm on a phone produces a tone with a frequency of 500 Hz. How many waves will be produced in:

(*a*) 1 s;

(*b*) 5 s;

(*c*) 0·1 s?

Calculating wave speed using frequency and wavelength

17. State an equation that links wave speed, frequency and wavelength.

18. Calculate the missing values in the table below.

Wave speed	***Frequency***	***Wavelength***
(*a*)	10 Hz	2 m
(*b*)	0·5 Hz	10 m
4 m s^{-1}	2 Hz	(*c*)
50 m s^{-1}	10 Hz	(*d*)
340 m s^{-1}	(*e*)	5 m
2 m s^{-1}	(*f*)	10 m
3×10^{8} m s^{-1}	200 kHz	(*g*)
3×10^{8} m s^{-1}	(*h*)	100 m
(*i*)	$6{\cdot}0 \times 10^{14}$ Hz	500×10^{-9} m

19. A frequency meter is used in a laboratory to measure frequency. When used to find the highest frequency a student can hear it displays 17 000 Hz. Calculate the wavelength of the sound wave if sound travels at 340 m s^{-1}.

20. A note played on a piano has a wavelength of 0·25 m. Calculate its frequency if sound waves travel at 340 m s^{-1}.

21. Water waves travelling along a canal have a wavelength of 2·0 m and a frequency of 0·5 Hz. Calculate their speed.

22. A speedboat produces waves with a frequency of 2·0 Hz and a wavelength of 3·0 m. Calculate the speed of the waves.

23. Calculate the wavelength of each of the following radio stations broadcast in Aberdeen. Radio waves travel at 3×10^8 m s^{-1}.

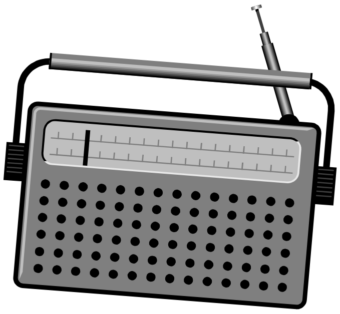
(*a*) FM Radio Scotland - 93·1 MHz

(*b*) FM Northsound One - 96·9 MHz

(*c*) FM Original - 106·8 MHz

(*d*) MW Absolute Radio - 1215 kHz

(*e*) LW BBC Radio 4 - 198 kHz



24. Red light has a wavelength of 700 nanometres or 700×10^{-9} m. Calculate the frequency of red light if it travels at a speed of 3×10^8 m s^{-1}.

Calculating wave speed using distance and time

25. State an equation that links wave speed, distance and time.

26. Calculate the missing values in the table below.

Speed	***Distance***	***Time***
(*a*)	40 m	5 s
(*b*)	4 m	0·2 s
340 m s^{-1}	1700 m	(*c*)
5 m s^{-1}	2 km	(*d*)
340 m s^{-1}	(*e*)	8 s
2 m s^{-1}	(*f*)	10 s

27. A wave travels at 1·5 m s^{-1}. Calculate the time it will take to travel 30 m.

28. Very high waves produced in the ocean due to earthquakes are called tsunamis. A tsunami travelled from Sumatra to Somalia, a distance of 6000 km, in 7 hours. Calculate the speed of this wave in metres per second.

29. How long would it take a sound wave to travel from one end of a football pitch to the other if it is 105 m long? (Speed of sound in air is 340 m s^{-1}).

30. A surfer rides along the crest of a wave for a distance of 48 m in 12 s. Calculate their speed.

31. Light travels through space at 3×10^8 m s^{-1}.

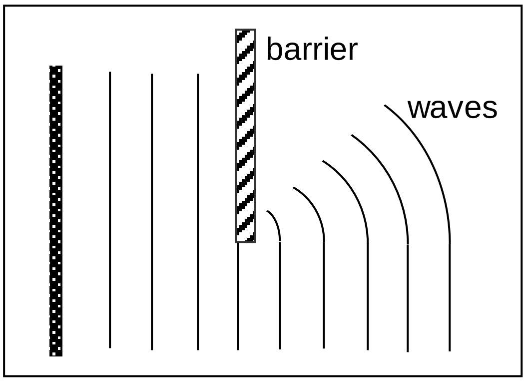
(*a*) The moon is $3{\cdot}8 \times 10^8$ m from Earth. Calculate the time it will take for light reflected from the moon to reach Earth.

(*b*) The Sun is an average of is $1{\cdot}5 \times 10^{11}$ m from the Earth. Calculate the time it will take for light from the Sun to reach Earth.

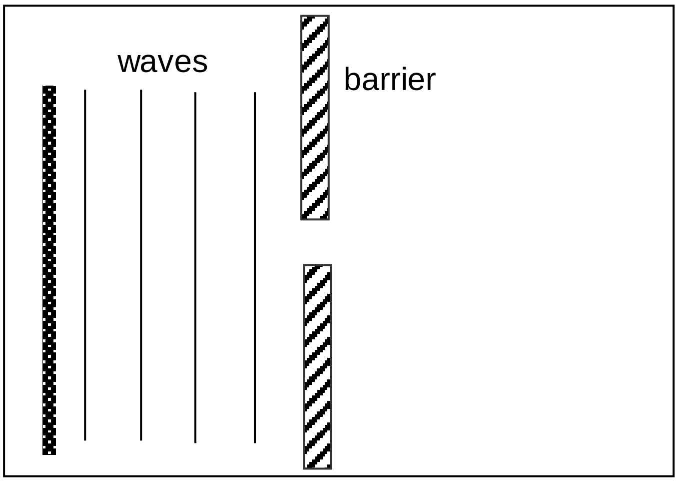
Diffraction of waves

32. The pattern shown opposite is seen on a ripple tank.

What name is given to the effect of the barrier on the water waves?



33. Copy and complete the diagram below for waves on a ripple tank to pass through a gap in a barrier.



34. (*a*) What is the bending of waves called?

(*b*) Copy and complete the following sentence:

Waves which have a __________ wavelength bend more than waves which have a __________ wavelength.

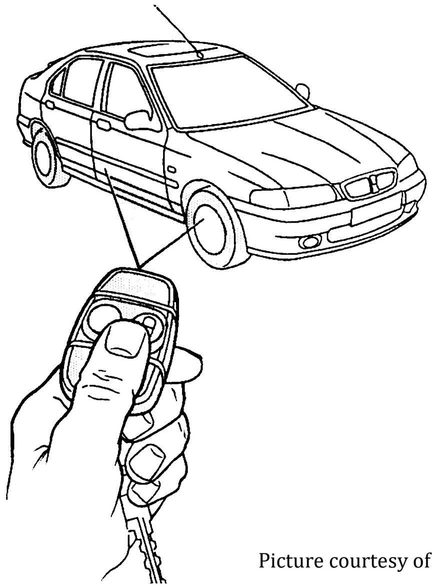
Extension Questions

35. A pupil uses his mobile phone on the way home from school to call his friend. The receiver which picks up the signal from his mobile phone is 9 km from the pupil.

(*a*) Calculate the time it will take the radio wave to reach the receiver if the radio was travel at 3×10^{8} m s^{-1}.

(*b*) The radio wave is transmitted with a frequency of 1800 MHz. Calculate the wavelength of the **radio wave**.

36. Drivers often use remote controls to lock and unlock their car doors. The controller emits a radio wave which will operate the door locks.



Picture courtesy of Rover Group Ltd.

(*a*) What is the speed of radio waves in air?

(*b*) The radio wave from the transmitter has a frequency of 433 MHz. Calculate the wavelength of the wave.

(*c*) If someone stands in front of the transmitter, the locks still operate. Discuss how diffraction may explain this including the effect of the wavelength on the radio wave.

37. Read the passage below about waves then answer the questions which follow.

If you stand at the corner of a building you cannot see your friend who may be just around the corner. You will be able to hear them if they speak though. Why is this? It is due to a phenomenon called diffraction. Waves have the ability to bend around objects. How much diffraction takes place depends upon the wavelength of the waves and the size of the object. Sound waves have a wavelength much greater than light so are able to bend around the wall whilst light waves cannot.

Earth bund beside the M40

The bending of waves around objects can be useful but can also cause problem s. Depending upon the wavelength of sounds, it is possible to get acoustic (sound) shadows in the same way as you can get light shadows. Special barriers, called bunds, can be built between busy roads and houses which could be mounds of earth or heavily built fences. They will reduce the noise of traffic but lower frequency 'rumbles' can still diffract over the top of these barriers.

TV signals and high frequency radio broadcasts have wavelengths of a few metres which means that the waves are unable to diffract around large buildings or hills. This can mean poor reception for those living behind the obstacle. Long wave (LW) radio however, has a wavelength of around a kilometre. This means that radio stations using long wave signals can be easily received where other stations cannot.

(*a*) What name is given to the bending of waves around an obstacle?

(*b*) Explain why it is possible to hear someone around the corner of a building even though you can't see them.

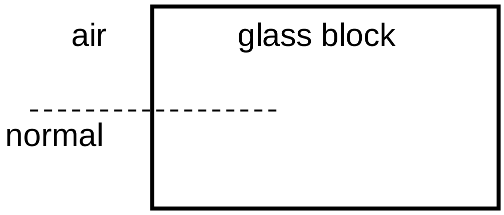
(*c*) Why do sound barriers at the sides of roads not cut out all noise?

(*d*) There is only a single transmitter for the whole of the UK for Radio 4 LW. Why must there be many local transmitters for Radio 4 broadcast on high frequency FM?

Light

Refraction of light

38. What angle does the normal make with the surface of a glass block?



39. Copy and complete the following sentences using the words below.

decreases towards away from less than
greater than increases

(*a*) When a light ray enters a glass block from air it refracts ______________ the normal.

(*b*) When a light ray leaves a glass block into air it refracts ______________ the normal.

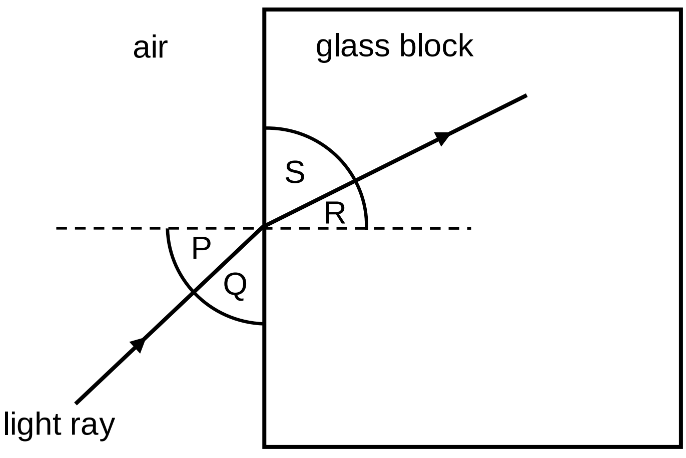
(*c*) When light enters a glass block from air its speed ______________ .

(*d*) When light leaves a glass block and enters air its speed ______________ .

(*e*) When a ray of light travels from air into glass, the angle of refraction is _______________ the angle of incidence.

(*f*) When a ray of light travels from glass into air, the angle of refraction is _______________ the angle of incidence.

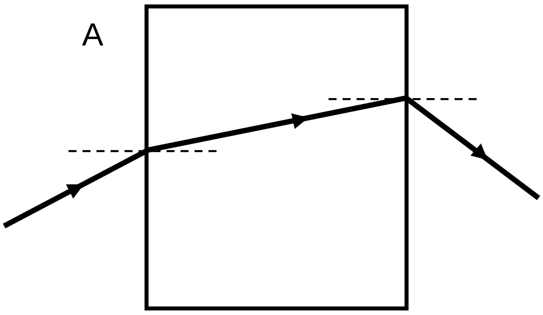
40. Which of the angles in the diagram below (P, Q, R or S) represents:

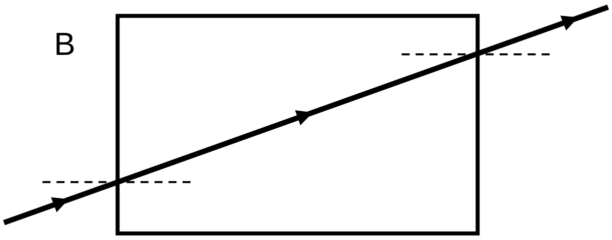


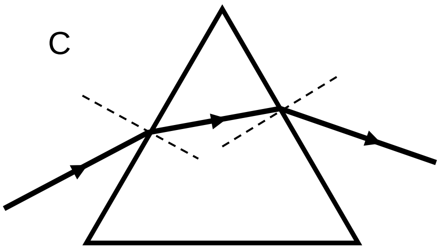
(*a*) the angle of incidence;

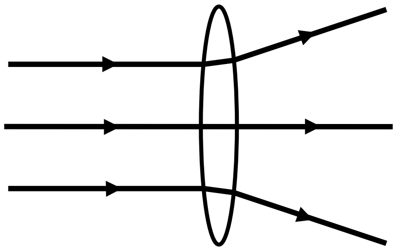
(*b*) the angle of refraction.

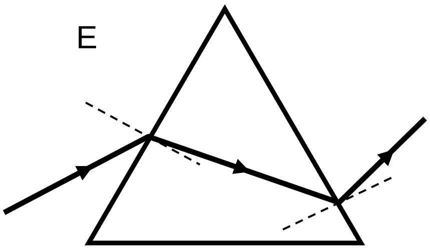
41. A ray of red light is shone into a number of glass blocks as shown below. State which correctly show the path of the ray of light.

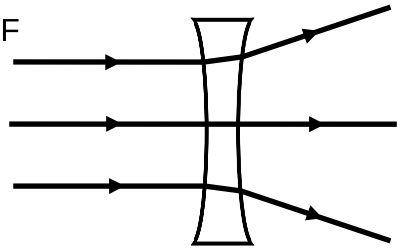
A


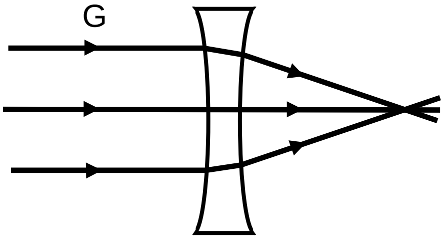
B


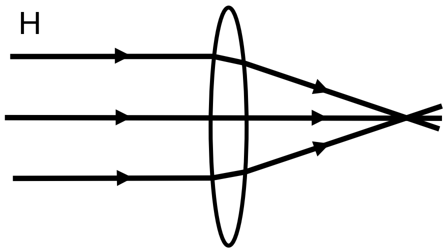
C


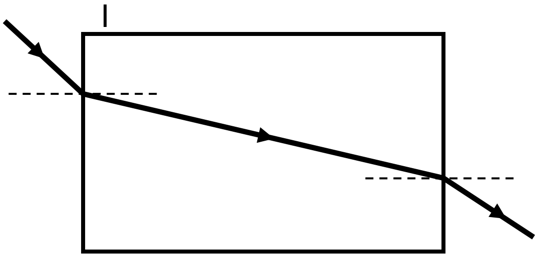
D


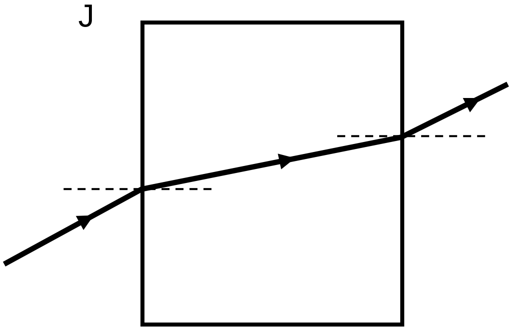
E


F


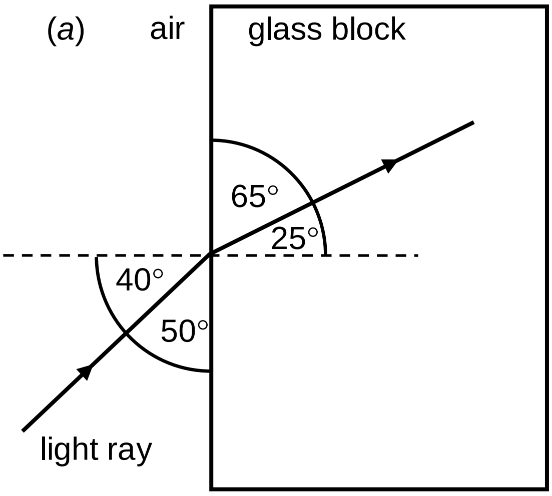
G


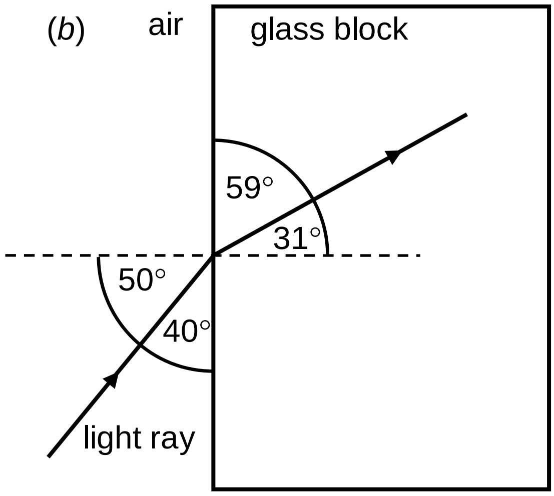
H


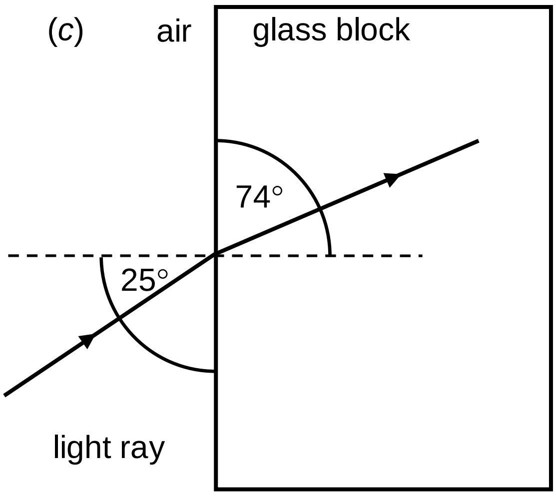
I


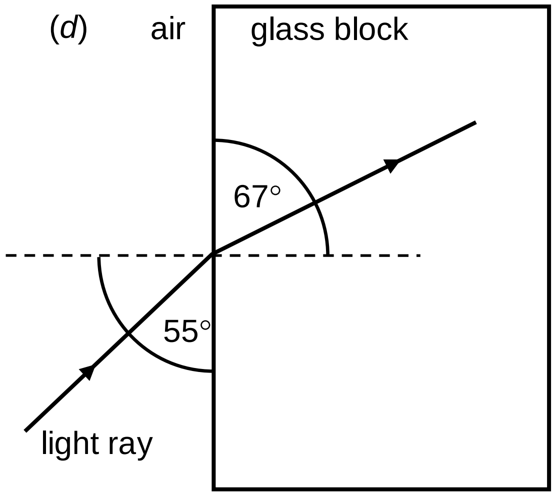
J


42. Identify the angle of incidence and the angle of refraction in the following examples.



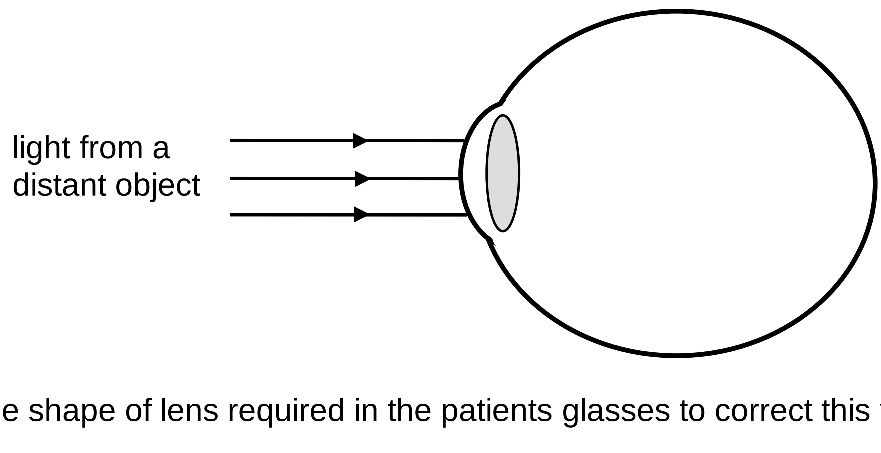






43. An optician prescribes a pair of glasses for a patient who is short sighted.

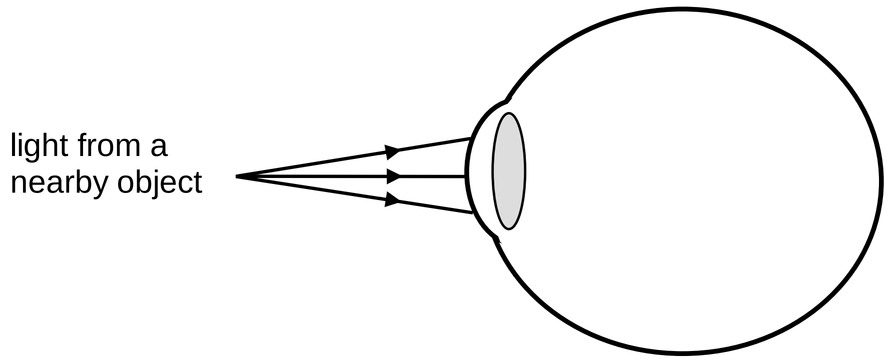
(*a*) Copy the diagram below and complete the rays to show how the patient has blurred vision when viewing a distant object



(*b*) State the shape of lens required in the patients glasses to correct this vision defect.

44. An optician prescribes a pair of glasses for a patient who is long sighted.

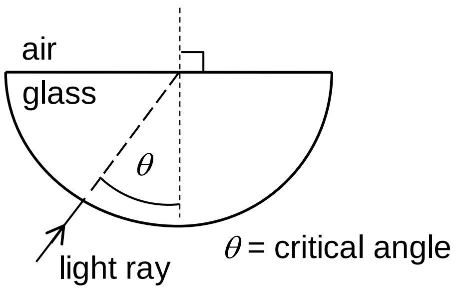
(*a*) Copy the diagram below and complete the rays to show how the patient has blurred vision when viewing a nearby object



(*b*) State the shape of lens required in the patients glasses to correct this vision defect.

45. Explain what is meant by total internal reflection, saying when it will occur.

46. Rays of light are shone into a semi-circular glass block like the one shown opposite.



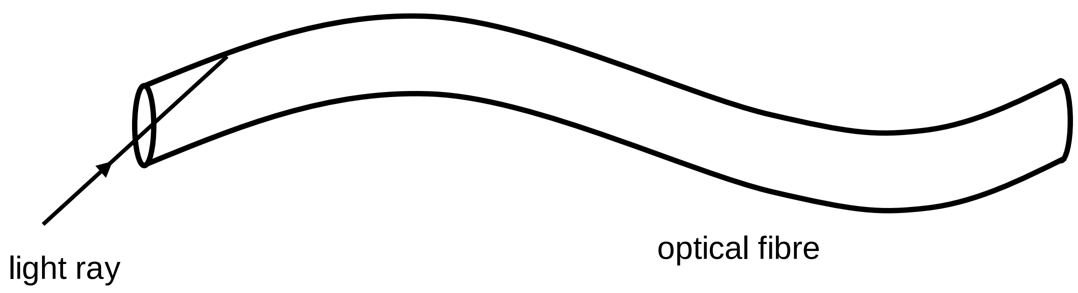
The angle θ represents the critical angle for the glass block. Describe what would be seen if a ray of light were shone in towards the centre of the block:

(*a*) at an angle below the critical angle;

(*b*) at the critical angle;

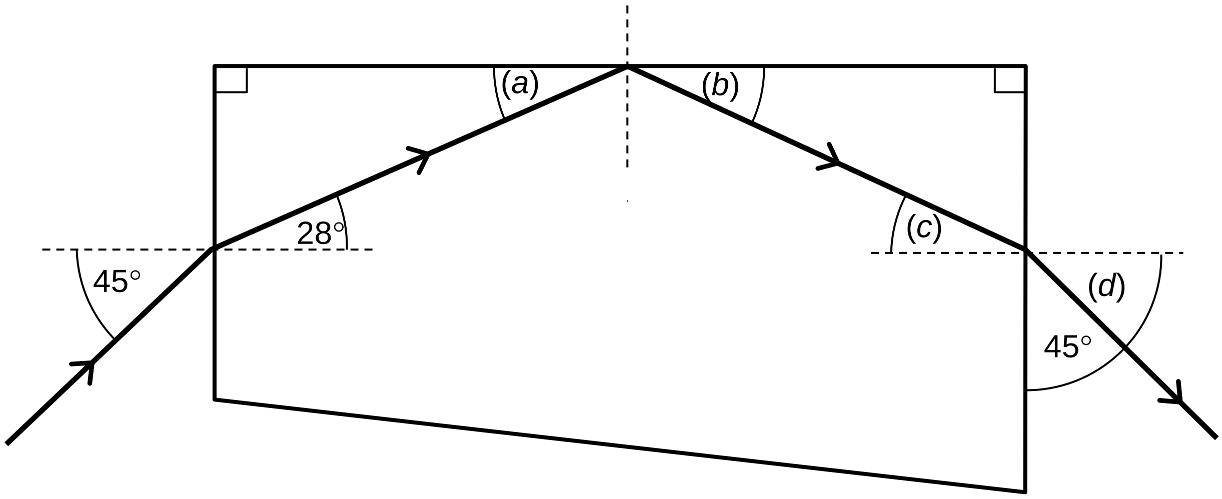
(*c*) at an angle above the critical angle.

47. An optical fibre uses total internal reflection to transmit light along its length. Copy and complete the sketch below to show this.

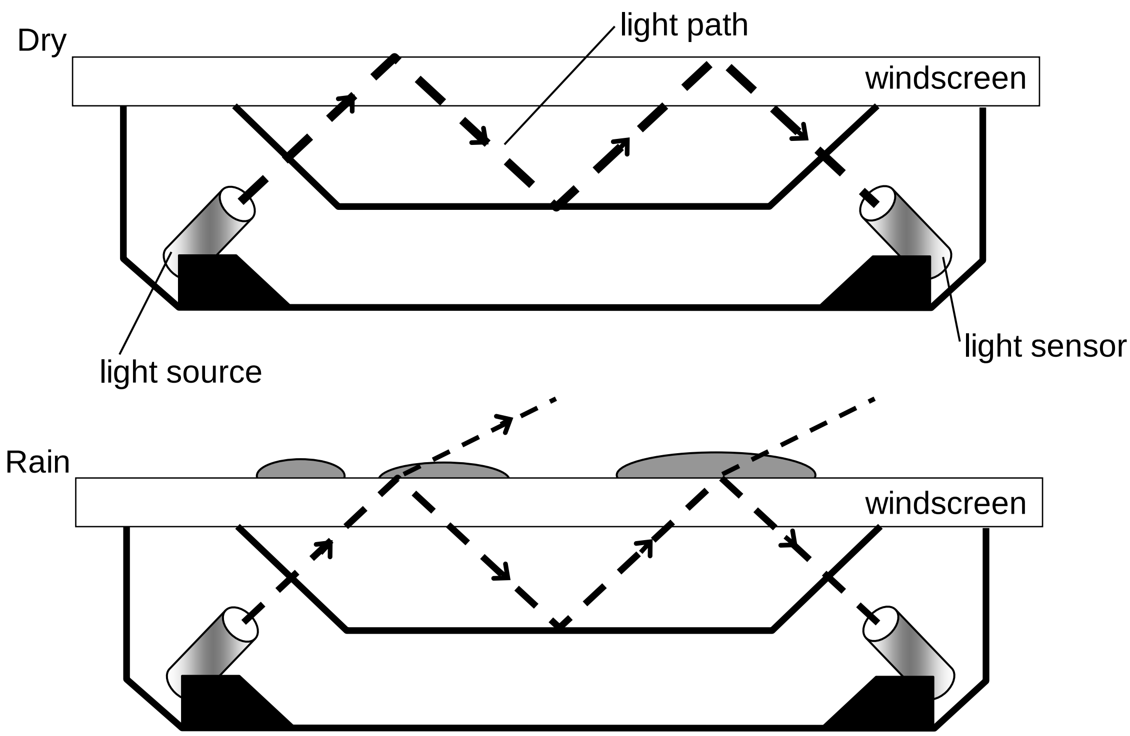


Extension Questions

48. Light enters a glass block shown below. Use your knowledge of refraction and geometry to calculate the angles the light makes till it escapes from the block.



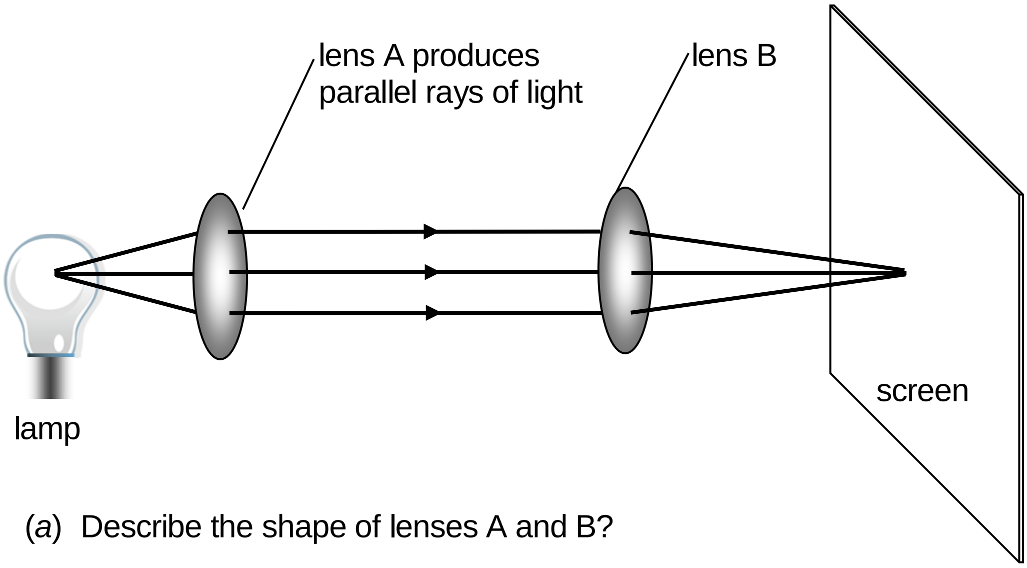
49. Some modern cars have automatic windscreen wipers which are activated when it rains. The heavier the rain the more frequently they operate. A sensor placed on the inside of the windscreen directs a beam of light towards the windscreen at the critical angle for glass to air. The light is reflected back into a sensor which measures the light intensity. When it rains, the droplets of water on the glass causes some light to be refracted out rather than reflected.



(*a*) What name is given to the effect when light is reflected from the windscreen in dry conditions?

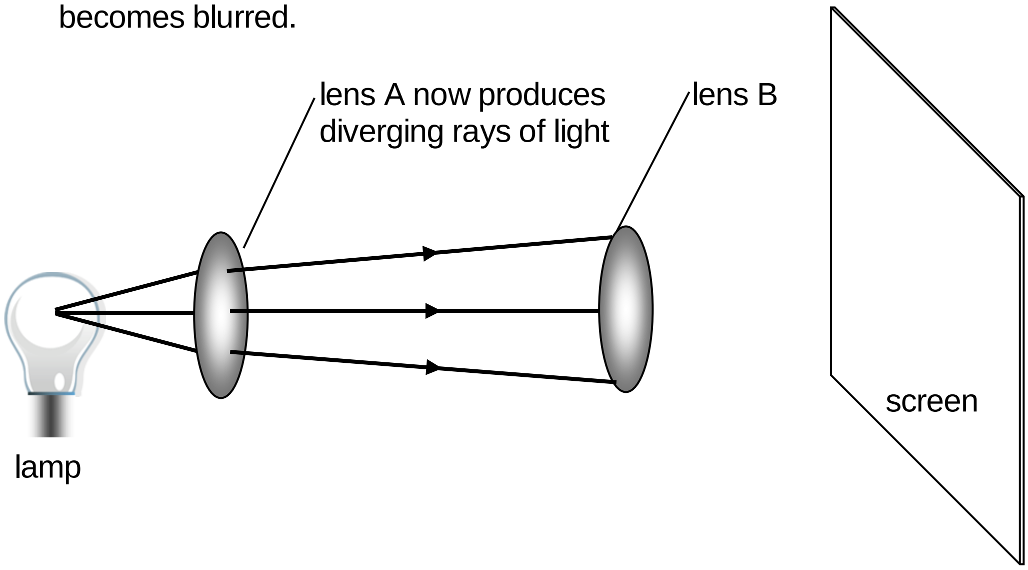
(*b*) How will the light intensity falling on the sensor change as the amount of rain increases? Give reasons for your answer.

50. Light from a lamp is shone through two lenses onto a screen as shown below.



(*a*) Describe the shape of lenses A and B?

(*b*) Lens A is now moved so that the rays emerging from it are travelling as shown below. As a result the image on the screen becomes blurred.



In which direction will the screen have to be moved to obtain a sharp image once again?

(*c*) A pupil, who has poor vision, holds the lens in front of his eye and finds that it becomes sharper. What eye defect does the pupil suffer from?

Electromagnetic Spectrum

The electromagnetic spectrum

51. The electromagnetic spectrum is shown below.

radio and TV waves	microwaves	infrared radiation	visible light	ultraviolet radiation	X-rays	gamma radiation

(*a*) At what speed do waves in the electromagnetic spectrum travel at?

(*b*) The Sun emits both visible light and X-rays. If they are emitted at the same time, which will reach the Earth first?

(*c*) Which waves in the electromagnetic spectrum have:

(i) the longest wavelength;

(ii) the highest frequency;

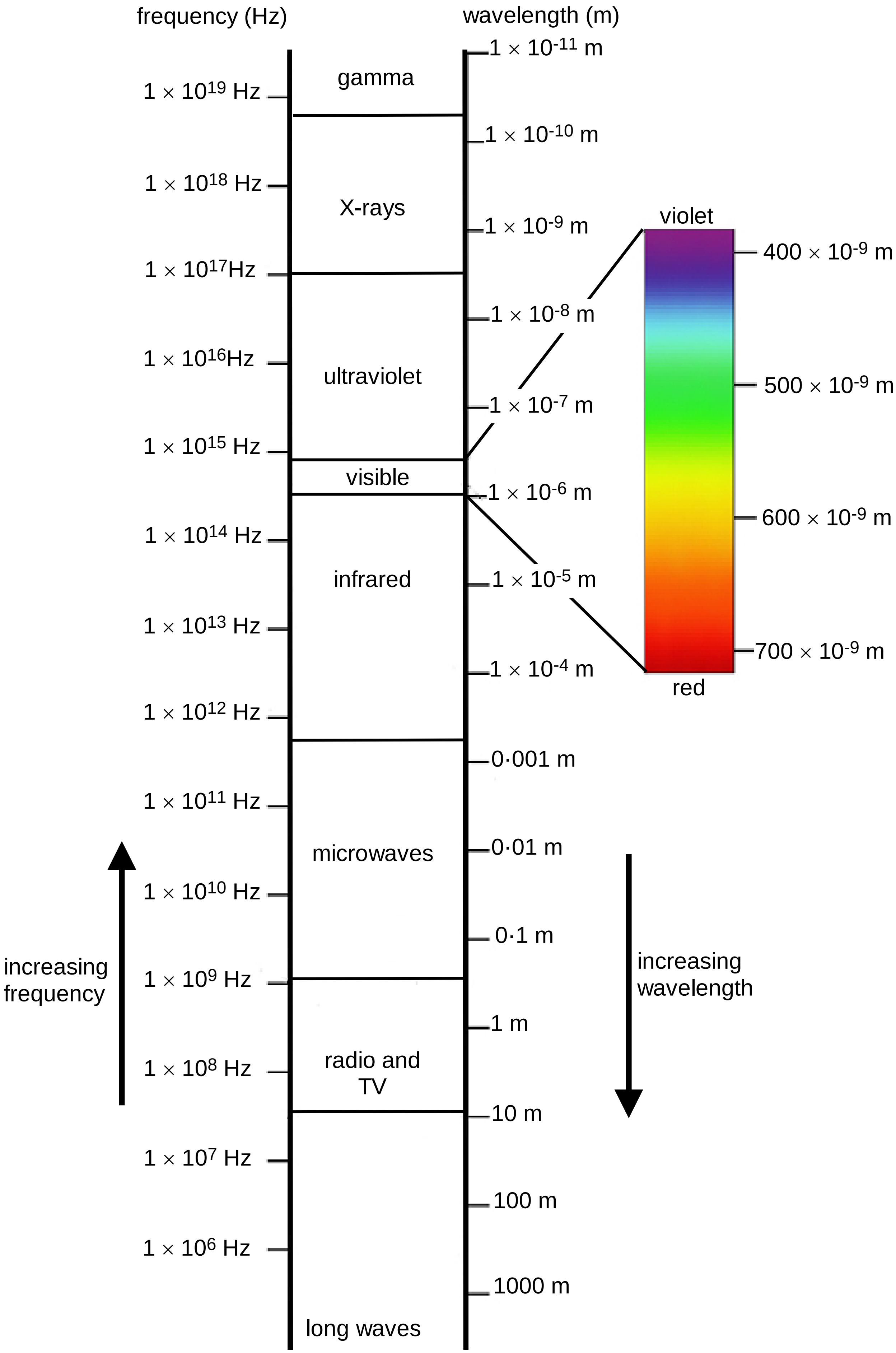
(iii) the shortest wavelength;

(iv) the lowest frequency?

52. The table below lists the frequency and wavelength of waves found in the electromagnetic spectrum. Copy the table and complete by calculating the missing values. Use the diagram on the next page to identify the part of the electromagnetic spectrum the wave belongs to.

	Wave frequency	***Wavelength***	***Type of wave***
(*a*)	3×10^{19} Hz		
(*b*)	$4{\cdot}3 \times 10^{14}$ Hz		
(*c*)	3×10^{10} Hz		
(*d*)	$7{\cdot}5 \times 10^{14}$ Hz		
(*e*)		3×10^{-8} m	
(*f*)		3×10^{-10} m	
(*g*)		3 m	
(*h*)		300 m	
(*i*)		1×10^{-5} m	

52 (continued)



53. An ultraviolet lamp has a frequency of 1×10^{15} Hz. Calculate the wavelength of the light if it travels at 3×10^{8} m s^{-1}.

54. A radio station broadcasts its radio signal at a frequency of 97·7 MHz.

(*a*) What speed do the radio waves at?

(*b*) Calculate the wavelength of the waves.

(*c*) Calculate the time it takes the radio waves to travel 100 km?

55. An infrared source emits waves with a wavelength of 100 μm. Calculate the frequency of these waves.

56. Gamma rays travel from the Sun at a speed of 3×10^{8} m s^{-1}.

(*a*) Calculate the time it takes for the rays to reach Earth if the Sun is $1{\cdot}5 \times 10^{11}$ m away.

(*b*) Calculate the frequency of the gamma rays if they have a wavelength of 3×10^{-12} m.

57. A mobile phone network uses microwaves with a frequency of 1800 MHz.

(*a*) Calculate the wavelength of the microwaves.

(*b*) Calculate the time it takes for the waves to travel from the phone to a receiving mast 5 km away.

Applications of the electromagnetic spectrum

58. The table below gives types of electromagnetic radiation and possible source or detector Match the letters and numbers to correctly link them together.

Wave	***Source or detector***
(*a*) radio & TV	1 – sun bed
(*b*) microwave	2 – glow stick
(*c*) infrared	3 – Geiger counter
(*d*) visible light	4 – mobile phone
(*e*) ultraviolet	5 – radio one transmitter
(*f*) x ray	6 – toaster
(*g*) gamma ray	7 – photographic plate

59. Mobile phones use waves to transmit information.

(*a*) Name the radiation adjacent to microwaves which have a longer wavelength than microwaves.

(*b*) Name the radiation adjacent to microwaves which has a shorter wavelength than microwaves.

(*c*) Part of the microwave spectrum can have applications other than communication. Name one of these.

(*d*) Other waves in the electromagnetic spectrum are also used for communication in optical fibres. Name this radiation.

60. Infra red radiation is part of the electromagnetic spectrum.

(*a*) Name a possible source of infrared radiation.

(*b*) How can infrared radiation be detected?

(*c*) Describe one use of infrared radiation.

61. The sign shown below is often displayed where there is the risk of exposure to high intensity ultraviolet light.

(*a*) How can ultraviolet light be detected?

(*b*) Explain why ultraviolet light can pose health risks for people who sunbathe.

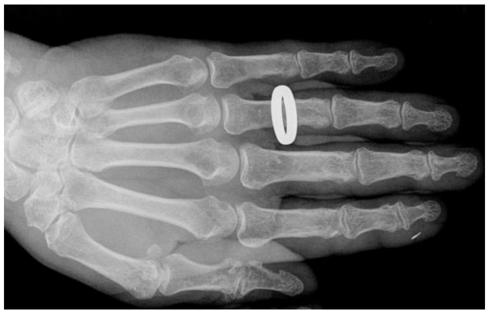
(*c*) Ultraviolet light can have uses. Describe one medical and one non-medical use for ultraviolet light.

62. X rays are used in hospitals to help with the diagnosis of a patient.

(*a*) When the X-rays are taken, the staff are in a separate room from the patient. Why is this necessary?

(*b*) Doctors avoid taking X-rays in young patients. Why would they do this?

(*c*) The picture opposite shows an X-ray of a hand wearing a gold ring. Explain why the ring shows up so clearly.



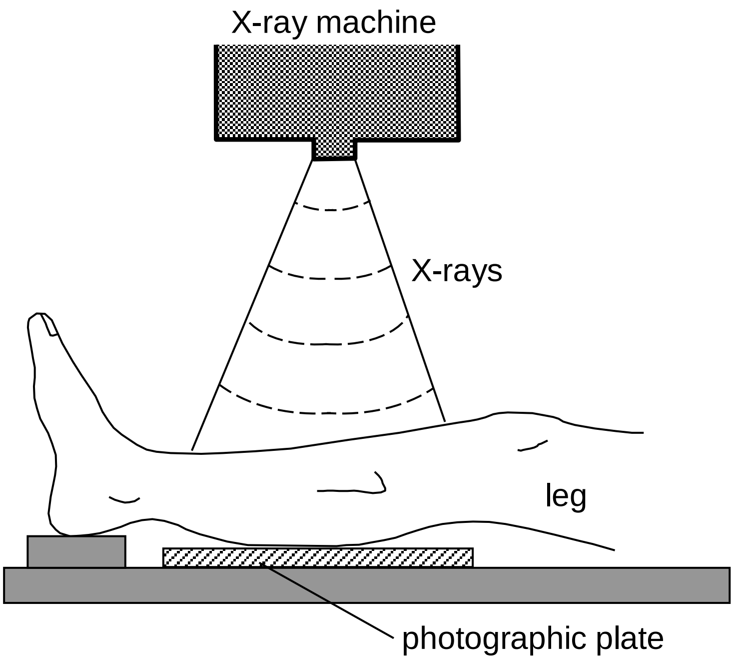
63. A patient with a broken leg has an X-ray picture taken of their leg.

(*a*) Explain why the image of the bone appears on the film.

(*b*) The X-rays have a wavelength of 1×10^{-10} m. Calculate their frequency.

(*c*) If the patient were a pregnant woman, the doctor would be reluctant to use X-rays to examine the break. Explain why.

(*d*) What alternatives are available to a doctor if she did not want to use X-rays?



Frequency and energy

64. Copy and complete the passage which follows using the words below.

higher **energy** **low** **longer** **shorter**

Waves from the electromagnetic spectrum will transfer __________ from one place to another. The amount of energy the waves carry depends upon the frequency or wavelength of the waves. The __________ the frequency or __________ the wavelength, the more energy they carry. Waves with a __________ wavelength and a __________ frequency carry less energy.

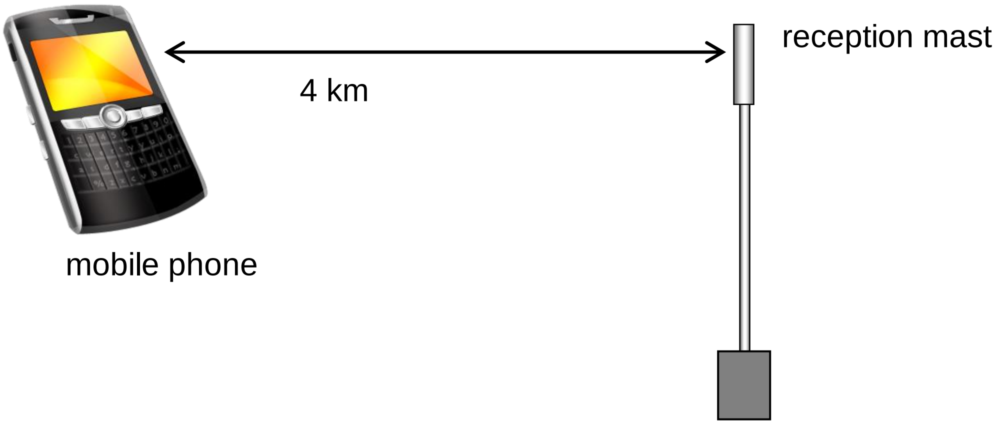
65. Ultraviolet light can be grouped into uv A and uv B. Uv A has typical wavelengths of 3×10^{-7} m whilst uv B has wavelengths of 4×10^{-7} m.

(*a*) Show by calculation, which of the two types of uv has the highest frequency.

(*b*) Which of the two types will cause most damage to our skin? Give reasons for your answer.

Extension Questions

66. A pupil uses a mobile phone to keep in touch with family and friends. It communicates with the reception mast using microwaves with a frequency of 900 MHz.



(*a*) Calculate the wavelength of the microwaves being used.

(*b*) Name the two waves on the electromagnetic spectrum with:

(i) a higher frequency;

(ii) a lower frequency.

(*c*) Calculate the time it takes for the microwaves to travel between the phone and the reception mast.

(*d*) Concern has been expressed about the dangers from microwave radiation of holding the phone close to the users head. Explain why there would be more concern about phones which use a higher frequency of microwave.

(*e*) Microwaves are also used to communicate with satellites in orbit around the earth. It takes the microwave signal 0·12 s to travel from earth to the satellite. Calculate its distance away.

67. Read the passage below about waves then answer the questions which follow.

Electromagnetic radiation belongs to the electromagnetic spectrum (or EM spectrum). Unlike sound waves which need a medium to travel through, EM waves can travel through a vacuum. They also differ from sound waves as they are transverse waves rather than longitudinal waves.

The EM spectrum ranks radiation from waves with the longest wavelength and lowest frequency through to waves with the shortest wavelength and highest frequency. The shorter the wavelength, the more energy the waves can carry and so the more dangerous they are. This is why gamma rays and X-rays can cause considerable harm to our bodies yet radio and TV waves do not.

Radio waves have very long wavelengths which can be as long as a football pitch. They are created when electrons move within a conductor. Touching the terminals of a cell or battery together will create sparks which produce radio waves but unlike the radio stations we listen to, they are not all at the one frequency but over random frequencies. These would be picked up as static on a radio.

At higher frequencies on the EM spectrum are microwaves and infrared radiation. Infra red radiation absorbed by the body is felt as heat and all objects emit infrared radiation. The hotter the object the more infrared it emits. This is used in infrared photography which can be used to detect heat escaping from houses or areas of poor blood circulation in the body as these are cooler than surrounding tissue. Infrared radiation is just below the visible spectrum and some animals, such as snakes, can detect this to find prey in total darkness.

The visible spectrum is radiation that we can see with our eyes, red having the longest wavelength and violet the shortest. Ultraviolet light is found at frequencies higher than visible light. Ultraviolet light can cause damage to our skin if we are exposed to too much. Fortunately, the ozone layer in the atmosphere filters out most of the ultraviolet radiation reaching the Earth.

X-rays have a higher frequency than ultraviolet light and can penetrate through our bodies. This makes them useful for taking pictures of internal organs, broken bones etc. Some shoe shops in the 1950's had machines that used X-rays to produce an image of the bones in the foot so that the shop assistant could check if the shoe fitted properly! As soon as it was realised that people were being exposed to dangerous and unnecessary X-rays the use of the machines stopped.

Gamma rays have the highest frequency of all EM waves. They will destroy living cells but this property can be put to good use. Gamma rays are used to sterilise surgical instruments and carefully controlled burst of gamma radiation can be used to treat cancer tumours.

Now answer the questions below.

(*a*) State two differences between sound waves and waves from the EM spectrum.

(*b*) Give an example of an EM wave which can damage our bodies.

(*c*) Explain why waves with a very short wavelength from the EM spectrum are more dangerous.

(*d*) How are radio waves generated?

(*e*) What would you hear on a radio if you connected the terminals of a battery together?

(*f*) How do some animals use infrared radiation?

(*g*) What prevents most of the ultraviolet radiation reaching the Earth's surface?

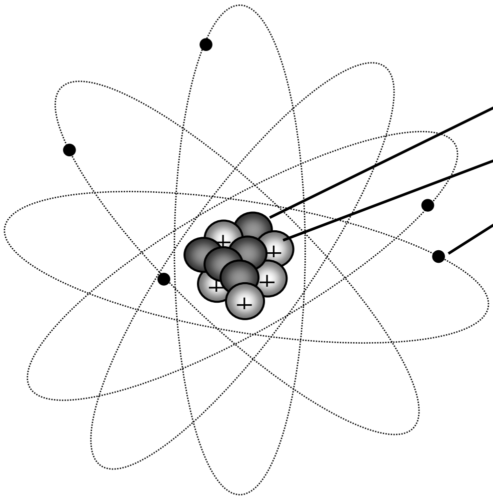
(*h*) Why was the use of X-ray shoe fitting machines discontinued?

(*i*) State two uses of gamma radiation.

Nuclear Radiation

Properties of Radiation

68. The diagram below represents and atom. Name the parts labelled (*a*), (*b*) and (*c*).



69. An atom is described as being neutral. What does this tell you about the numbers of electrons and protons in the atom?

70. Nuclear radiation is often described as '*ionising radiation*'. State what happens when nuclear radiation ionises and atom to produce ions.

71. Copy and complete the paragraph on nuclear radiation using the words given below.

air wave electron positive lead strongly

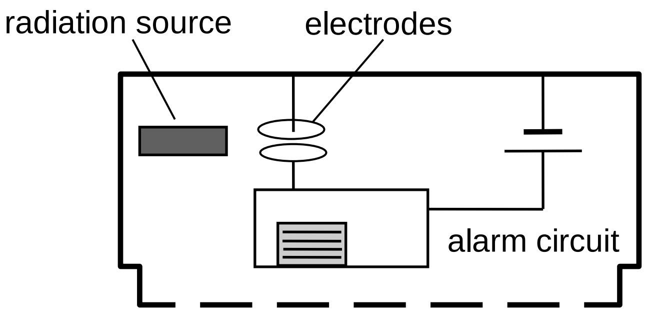
nucleus helium paper negative weakly

There are three different types of nuclear radiation – alpha, beta and gamma. Alpha radiation is a ___________ nucleus and has a ___________ charge. It is a ___________ ionising radiation so will damage cells if it gets into the body. Fortunately, it is blocked by a thin sheet of ___________ or a few centimetres of ___________. Beta radiation is a fast moving ___________ from the break up of a proton in an atom's ___________ . It has a ___________ charge and requires 3 millimetres of aluminium to block it. The last type is gamma radiation which is not a particle but a ___________ and part of the electromagnetic spectrum. Gamma requires 3 centimetres of ___________ to block its path. Beta and gamma are ___________ ionising radiations and do not ionise as strongly as alpha radiation.

72. The table below lists the three types of nuclear radiation and their properties. Copy and complete the table. Blocked by Ability to ionise

Radiation	***What it is***	***Blocked by***	***Ability to ionise***
alpha	2 protons and 2 neutrons	(*a*)	(*b*)
beta	(*c*)	about 3 mm of aluminium	(*d*)
(*e*)	a wave, part of the electromagnetic spectrum	(*f*)	weakly ionises

73. A smoke alarm uses a radioactive source to produce ionisation of the air in the detector. These ions cross between the electrodes and a small current flows. If smoke from a fire enters the alarm the amount of ionisation will decreases. This is detected by an electronic circuit and the alarm is activated.



(*a*) Explain what is meant by the term *ionisation*.

(*b*) Why is an alpha producing radioactive source used rather than one which produces gamma or beta radiation?

74. What is the name given to the unit of radioactive decay which represents one decay per second?

75. In a sample of radioactive material there are 2×10^6 decays each second. Find the samples activity in Becquerels?

76. A sample of radioactive material has an activity of 5 kBq. How many decays will take place in 1 hour?

77. A radioactive isotope used in industry has an activity of 0·4 MBq. Calculate the umber of decays which take place in 15 seconds?

78. (*a*) What is meant by the term '*background radiation*'?

(*b*) The table below lists a number of sources of background radiation. Copy and complete the table by putting a tick in the appropriate column to show whether the radiation is natural or man-made. The first is done for you.

Source	***Natural***	***Man-made***
Building materials		✓
Nuclear medicine		
Nuclear power stations		
Cosmic radiation		
Granite rock		
Radon gas		
Bananas		
Water		
Tobacco		
Smoke detectors		
Luminous watches		

Absorbed Dose and Equivalent Dose

79. (*a*) Write an equation linking absorbed dose, energy and mass.

(*b*) State the unit used to measure absorbed dose.

80. Calculate the missing values in the table below.

Absorbed Dose	***Energy***	***Mass***
(*a*)	5×10^{-6} J	1×10^{-2} kg
(*b*)	0·1 mJ	0·004 kg
50×10^{-6} Gy	(*c*)	0·5 kg
5×10^{-6} Gy	(*d*)	30 g
2×10^{-6} Gy	0·5 μJ	(*e*)
10 mGy	1×10^{-2} J	(*f*)

81. A mass of 0·4 kg absorbs 500 μJ of energy. Calculate the absorbed dose.

82. A patient is undergoing radiotherapy treatment. The tumour they suffer from has a mass of 0·03 kg and it absorbs 0·5 J of energy. Calculate the absorbed dose?

83. (*a*) State the formula which relates absorbed dose with equivalent dose.

(*b*) State the unit used to measure equivalent dose.

84. (*a*) The following table gives the weighting factor for certain types of radiation.

Type of radiation	***Weighting factor, w_R***
X-rays	1
gamma rays	1
beta particles	1
slow neutrons	5
fast neutrons	10
alpha particles	20

Why do different types of radiation have a different weighting factor.

(*b*) Suggest a reason why alpha radiation has the highest weighting factor.

85. Using the table above, find the absorbed equivalent dose for the following radiation exposures.

	Absorbed dose	***Type of radiation***
(*a*)	10 μGy	alpha particles
(*b*)	3 mGy	slow neutrons
(*c*)	50×10^{-6} Gy	fast neutrons
(*d*)	5×10^{-6} Gy	beta particles
(*e*)	2×10^{-6} Gy	X-rays
(*f*)	10 μGy	gamma rays

86. A student breaks his arm during a PE lesson. The break is x-rayed and the absorbed dose he receives is 20 μGy. Calculate the equivalent dose he receives. (Use the weighting factors given in the table in question 78.)

87. Calculate the equivalent dose if someone received an absorbed dose of 10 mGy from slow neutrons.

88. A technician with a mass of 60 kg absorbs 200 μJ of alpha radiation.

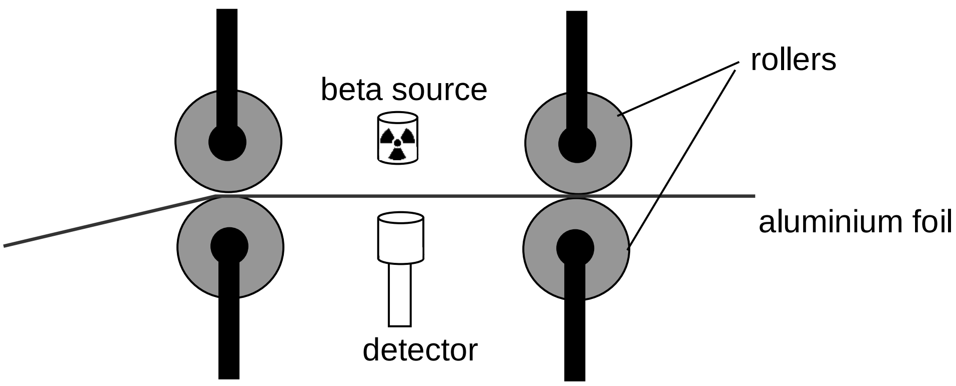
(*a*) Calculate the absorbed dose she receives.

(*b*) Calculate the equivalent dose she receives.

89. A patient receives an absorbed dose of 10 μGy from fast neutrons. Calculate the equivalent dose received.

Applications of nuclear radiation

90. A manufacturer of tin foil uses an automatic thickness monitoring system which uses nuclear radiation. The pressure applied to the rollers will determine the thickness of the foil - the greater the pressure the thinner the foil. The radiation passing through the foil will vary with the thickness of the foil.



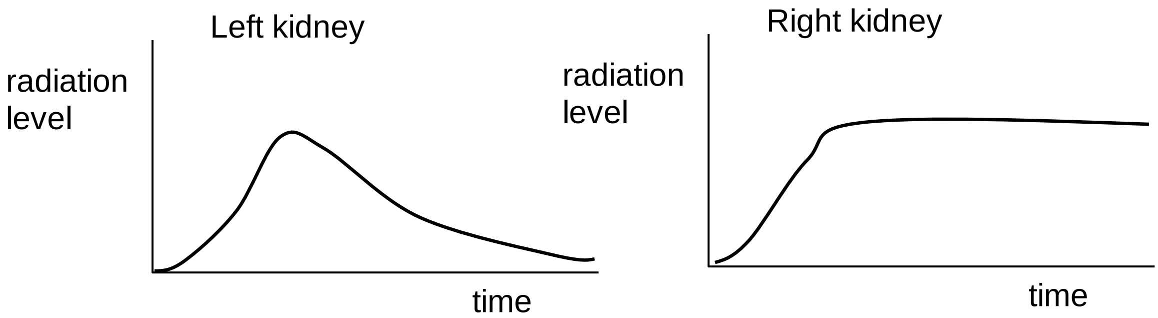
(*a*) Why is beta radiation used rather than alpha or gamma radiation?

(*b*) The count rate of the beta radiation decreases. What does this mean has happened to the thickness of the foil?

(*c*) How will the roller pressure be altered if the foil is found to be too thin?

91. A doctor uses radioactive tracers to check the flow of blood through a patient's kidneys. One kidney is functioning normally and the other is blocked.
A radioactive liquid which emits gamma radiation, is injected into the patients bloodstream. The level of radiation emitted from the kidney increases then falls for a normal kidney but increases and remains steady for a blocked kidney.

The two graphs below show the radiation levels for each kidney.

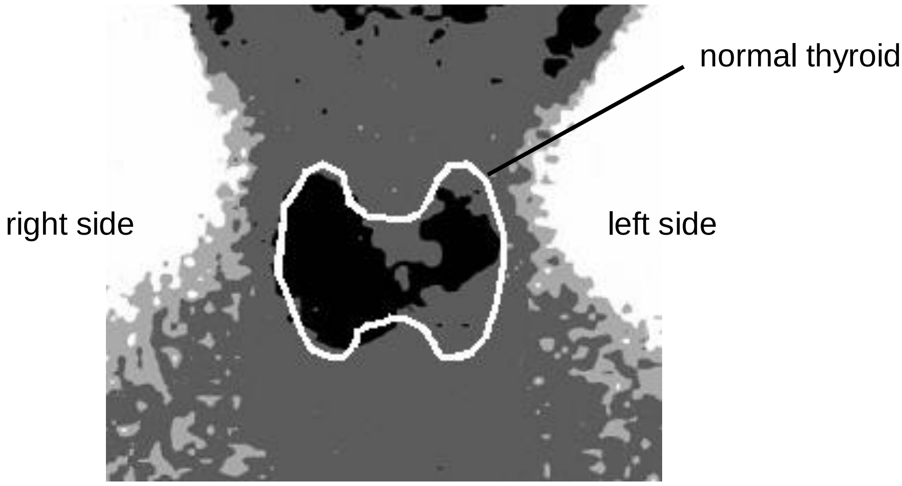


(*a*) Give two reasons why a gamma emitter is used rather than an alpha emitter as the radioactive source.

(*b*) Examine the graphs above and state which kidney is blocked.

(*c*) Why will the level of radiation in the patient slowly decrease?

(*d*) Iodine is naturally absorbed by the thyroid gland found in the neck. Radioactive iodine is injected into a patient and a gamma camera used to produce an image of their thyroid area. The image produced is shown below. The normal size and location of the thyroid is outlined.

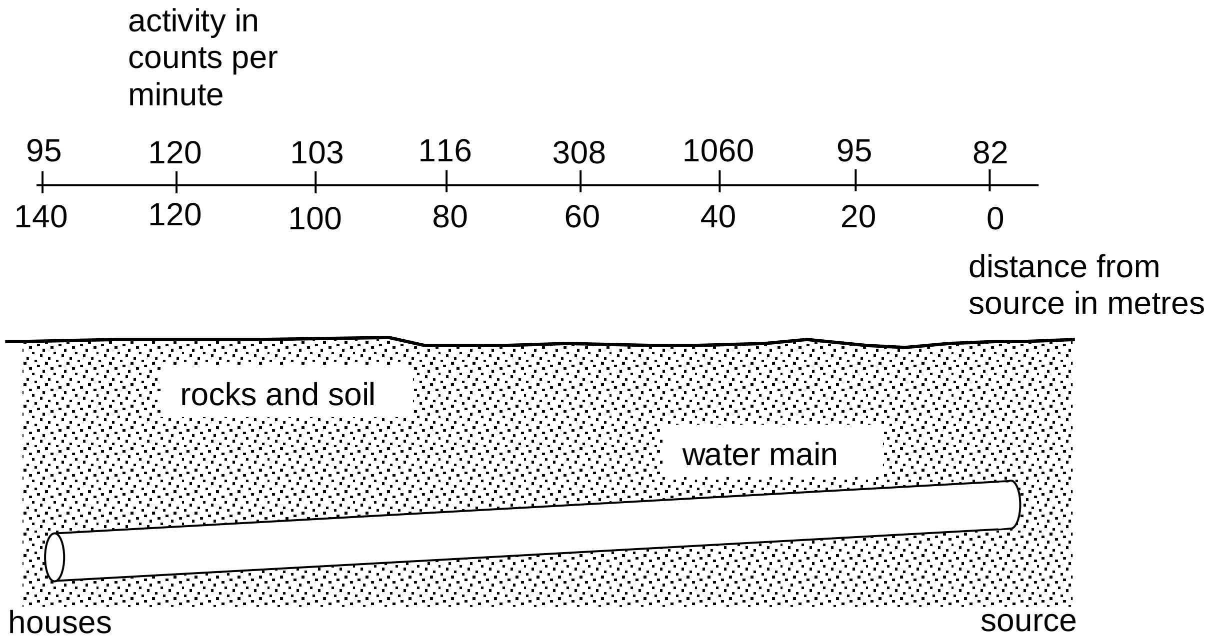


(i) What information does the image from the gamma camera give about the absorption of the radioactive iodine?

(ii) The radioactive iodine injected into the patient is prepared shortly before use. Why are larger batches not produced and stored.

92. A long section of underground water main has developed a leak. To find its location some radioactive liquid is added to the water flowing through the pipe and levels of radioactivity measured in the area above the pipe.

The diagram below shows the radiation levels in counts per minute.



(*a*) Why are the water supplies to houses supplied by the pipe disconnected during the test?

(*b*) Suggest the distance from the source where the leak might be.

(*c*) Why must a gamma emitting source be used for this test?

Half-life

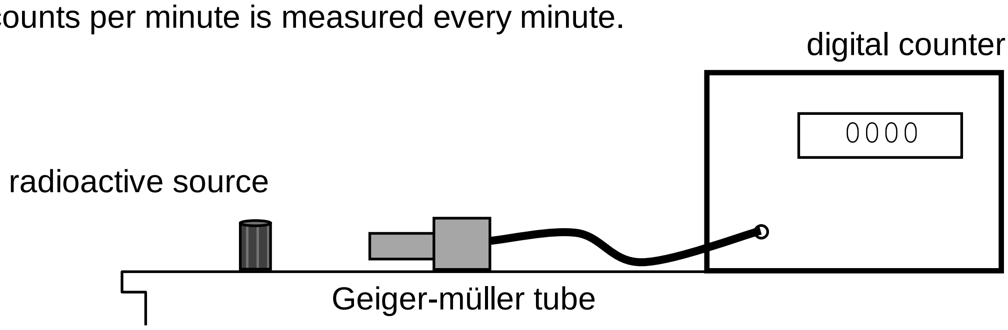
93. State the meaning of the term '*half-life*'.

94. The activity of a radioactive sample decreases from 4000 counts per minute (c.p.m.) to 125 c.p.m. over a period of 40 minutes. Calculate the half-life of the source?

95. A radioactive source has a half-life of 8 hours. If the source has an initial activity of 32 000 Bq, find its activity after 2 days.

96. A radioactive sample has a half life of 2 days. Calculate the time it will take for its activity to drop to one sixteenth of its original value.

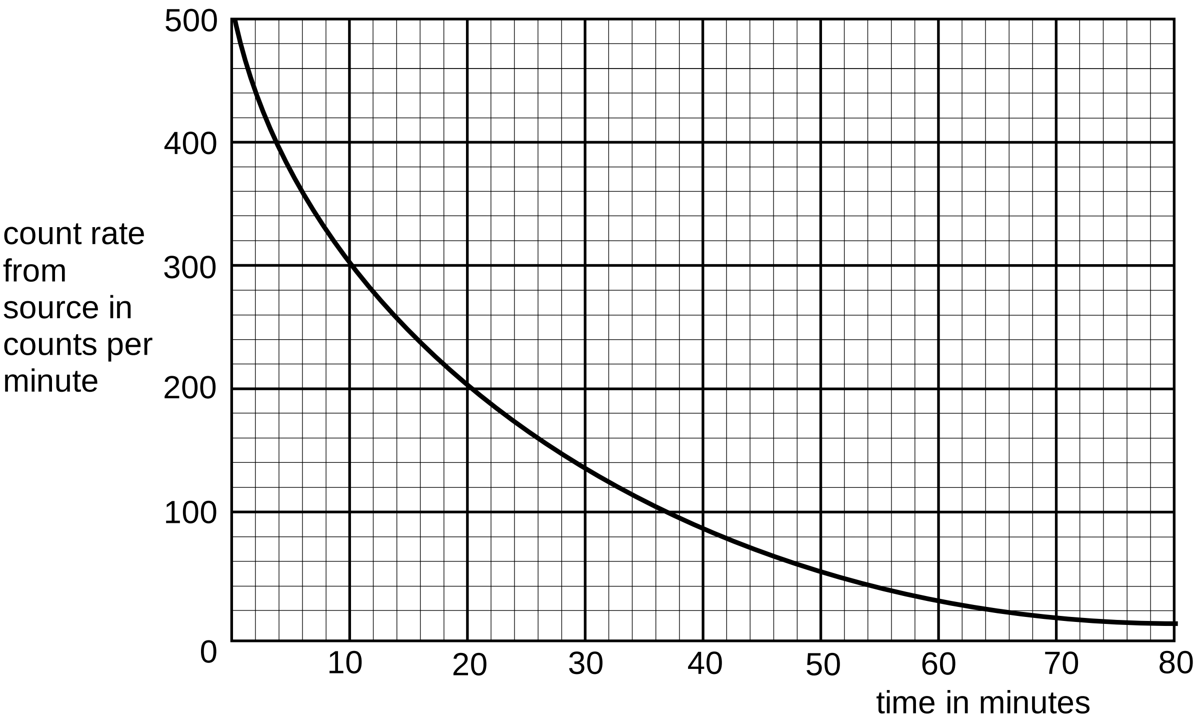
97. An experiment can be carried out to measure the half-life of a radioactive sample. The apparatus is shown below. The radioactive sample is placed in front of a Geiger-müller tube connected to a counter. The activity of the sample in counts per minute is measured every minute.



(*a*) Before the experiment, readings are taken for background radiation. What is background radiation?

(*b*) Will the readings for background radiation be added to or deducted from the experimental readings?

(*c*) A graph of the experimental results is shown below. Use the graph to calculate the half-life of the source.



98. A radioactive isotope has a half-life of 15 hours. 256 g of the isotope is placed in a sealed container. What mass of the isotope will remain radioactive after 60 hours?

99. A radioactive isotope contains 640 million atoms of the isotope. How many isotope atom s will remain after 6 half-lives have passed.

100. A radioactive rock with a half life of 8000 years has an activity of 20 MBq. What will be the activity after 40 000 years?

Nuclear power

101. Copy and complete the following paragraph using the words below.

uranium **neutron** **heat** **split**

smaller **neutrons** **large**

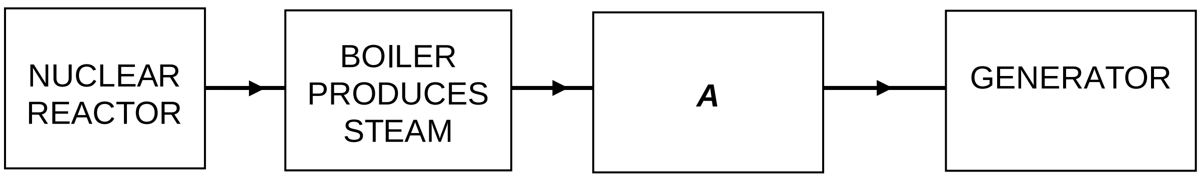
Nuclear fission takes place when a _____________ collides with a _____________ unstable nucleus of _____________. This causes it to ___________ into two _____________ nuclei. At the same time it releases more _____________ and a quantity of _____________.

102. Copy and complete the following paragraph using the words below.

heat **Sun** **small** **larger**

Nuclear fusion takes place when two _____________ nuclei collide and join together to create a _____________ nucleus. This also causes _____________ energy to be released. This is the same atomic reaction that provides the energy for the _____________.

103. Look at the block diagram of a nuclear power station below.



(*a*) Name the part labelled **A**.

(*b*) Heat is produced by the nuclear reaction. What happens to this heat?

(*c*) Describe the purpose of the generator.

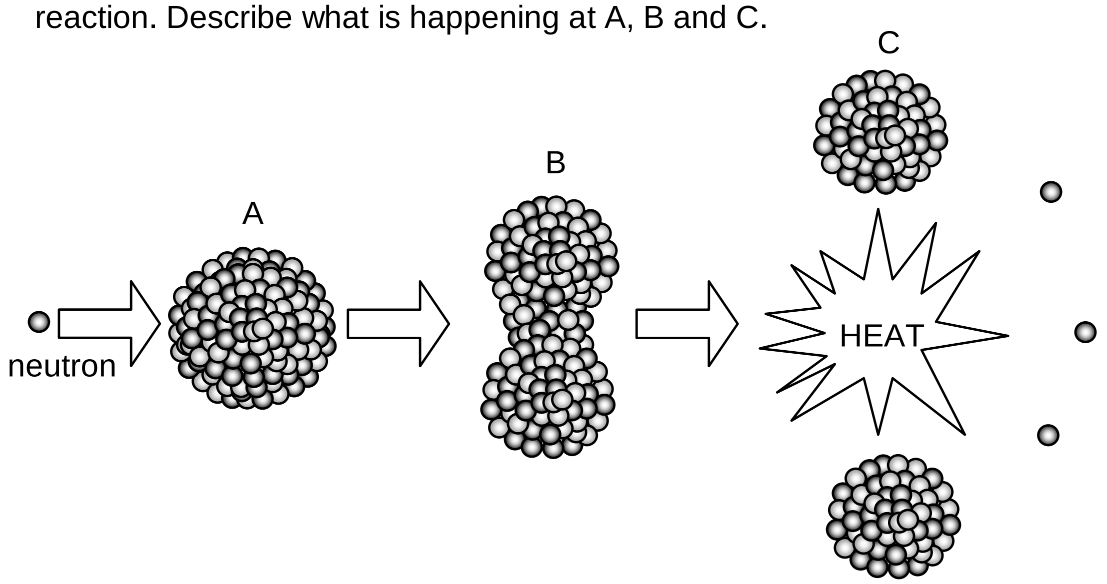
(*d*) What energy conversion takes place in the nuclear reactor?

104. (a) Explain the difference between a nuclear fission reaction and a nuclear fusion reaction.

(*b*) State which of these two reactions, fission or fusion, is used in a nuclear power station.

105. A chain reaction takes place in the core of a nuclear reactor. Explain what is meant by a chain reaction

106. The diagram below represents the sequence of events in a nuclear fission reaction. Describe what is happening at A, B and C.

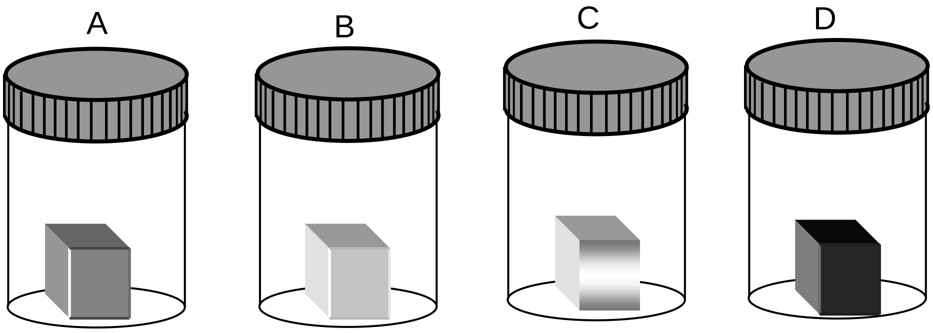


107 Listed below are some statements relating to the generating of electricity using nuclear reactors. For each statement, say whether you think it is true or false.

1. The vast majority of radiation we are exposed to comes from space and the ground beneath our feet.
2. Nuclear power stations will run out of fuel in just a few years.
3. Waste from nuclear reactors must be stored underground for a long time until the radiation emitted decreases.
4. Nuclear reactors use the process of nuclear fission to produce heat.
5. Nuclear reactors can be built very quickly.
6. Nuclear reactors produce a large amount of sulphur dioxide which produces acid rain.
7. Most of the radiation we are exposed to comes from nuclear power stations.
8. Nuclear reactors cannot generate enough electricity to meet high power demands like industry.
9. Nuclear reactors produce large volumes of greenhouse gases.
10. All the nuclear reactors in the world are the same type as the one that exploded in Chernobyl.

Extension Questions

108 Four samples of radioactive material are isolated and tested for their penetrating properties.



The following information is obtained after conducting experiments on each of the samples.

	Radiation blocked by		
Sample	***Sheet of paper***	***3 millimetres of aluminium***	***3 centimetres of lead***
A	No	Partial	Yes
B	Yes	Yes	Yes
C	No	No	Yes
D	No	Yes	Yes

(*a*) Which sample or samples emitted beta radiation only?

(*b*) Which sample or samples emitted alpha radiation only?

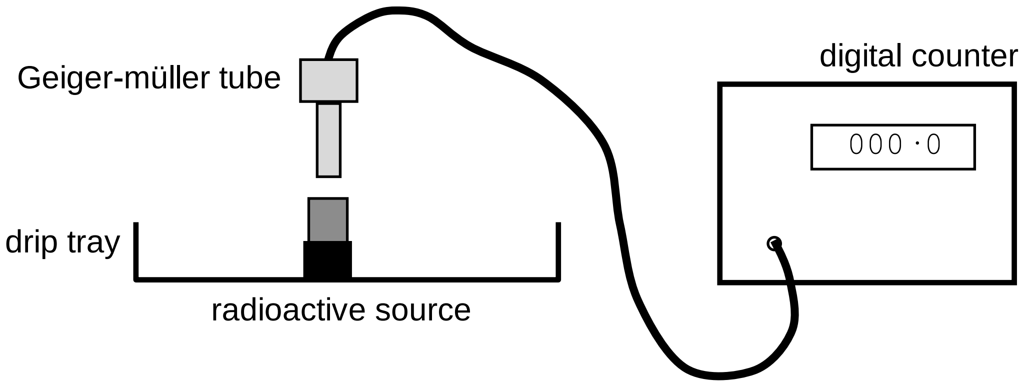
(*c*) Which sample or samples emitted gamma radiation only?

(*d*) Which sample or samples emitted more than one kind of radiation?

(*e*) (i) 128 000 nuclei decay in a radioactive sample every 32 seconds. Calculate the activity of the sample.

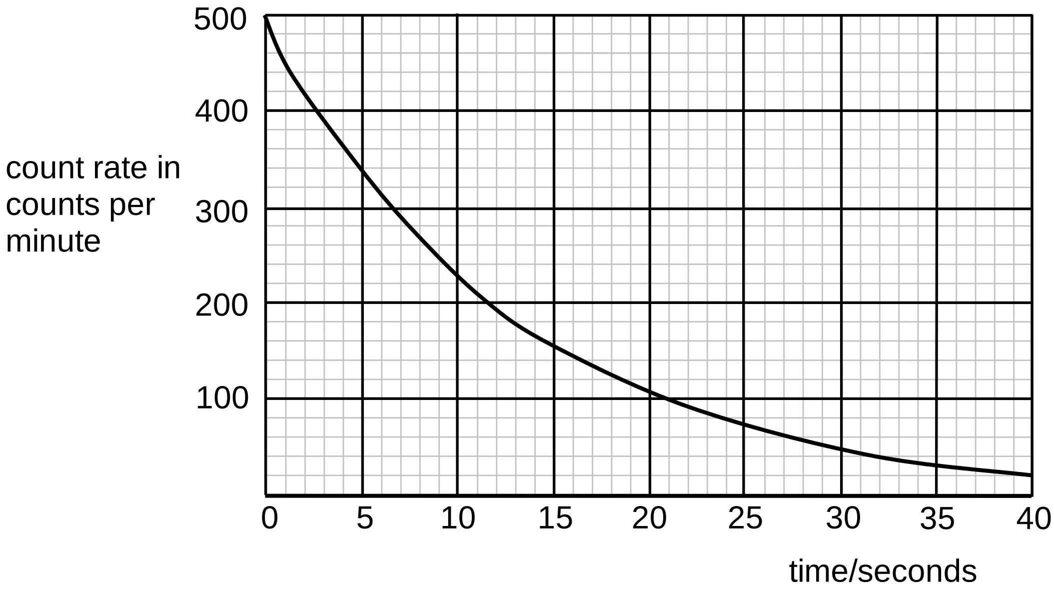
(ii) The sample has a half-life of 3 hours. Calculate the activity of the sample after 12 hours.

109 An experiment is set up to measure the half-life of a radioactive source. The source is placed in a drip tray and a Geiger-müller tube placed above it. This is connected to a digital counter.



(*a*) The results are corrected for background radiation. Name three sources of background radiation.

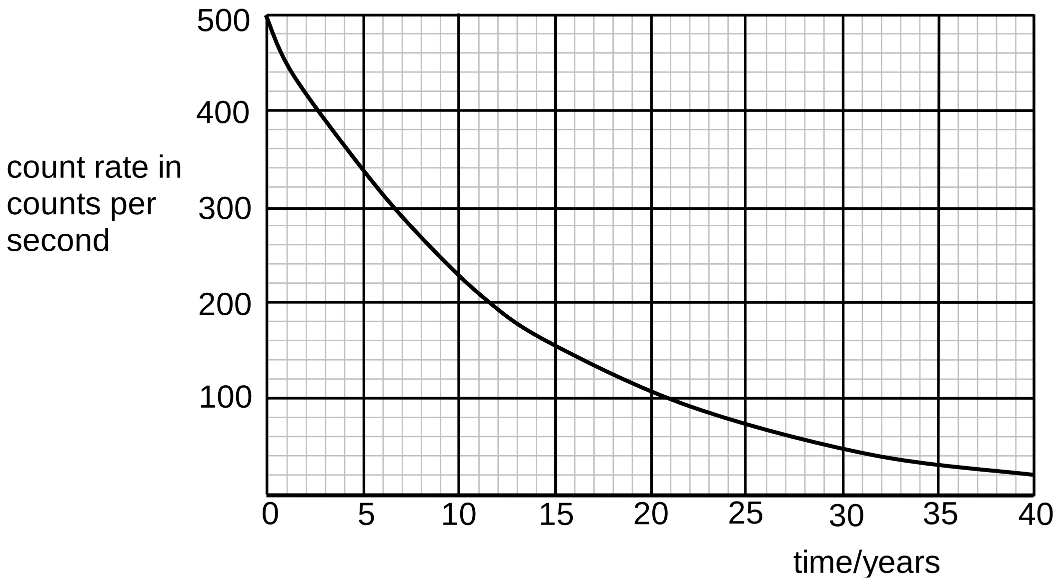
(*b*) The graph below is produced from the results of the experiment. Find the half-life of the source.



(*c*) A drip tray is placed under the source as a safety precaution. Explain why this is done.

(*d*) In the experiment above the source has a relatively short half-life. Waste from nuclear reactors can have a very long half-life. How is this waste dealt with?

110. An experiment is carried out to find the half-life of a radioactive source. The graph produced from the results of this experiment are shown below.



(*a*) State the meaning of the term "*half-life*".

(*b*) Find the half-life of this radiation sample from the graph above.

(*c*) Geiger-Müller tubes can be used to measure the amount of radiation produced by a source. Radiation entering the tube ionises the gas inside the tube. Explain what is meant by the term *ionisation*.

(*d*) A radioactive form of carbon is absorbed by all living things. Once the animal or plant dies, the level of radioactivity slowly falls. The half-life of the carbon is 6000 years.

Some ancient human remains are tested and the count rate is found to be 8000 counts per minute. Calculate the age of the bones if the original count rate would have been 32 000 counts per minute.

Wave Parameters and Behaviours

Longitudinal and transverse waves

1. Sound wave – transfers sound energy, water wave – kinetic energy.

2 Wave A is a transverse wave and Wave B is a longitudinal wave.

3. (*a*) Stretch the spring and move sideways, back and fore at right angles to length of spring.
(*b*) Stretch the spring and move spring back and fore in direction of spring.

4. Water waves – transverse, Light – transverse, Sound – longitudinal, Radio waves – transverse, X-rays – transverse.

Wave speed, frequency, wavelength and amplitude

5. (*a*) The distance from the mid line to a wave crest or wave trough.
(*b*) Wavelength.
(*c*) Hz
(*d*) s
(*e*) The distance travelled by a wave each second.

6. f = 1/T

7. 0·1 s

8. 4 s

9. 5 Hz

10. 100 Hz

11. (*a*) 5 Hz
(*b*) 3 Hz
(*c*) 1 Hz
(*d*) 5 Hz
(*e*) 0·5 Hz

12. (*a*) 1 Hz
(*b*) 2 Hz
(*c*) 5 Hz
(*d*) 4 Hz

13. (*a*) 0·1 m
(*b*) 0·5 m
(*c*) 10 cm or 0·1 m
(*d*) 2 m

14. (*a*) 256. (*b*) 15 360

15. 2 Hz

16. (*a*) 500
(*b*) 2500
(*c*) 50

Calculating wave speed using frequency and wavelength

17. $v = f \times \lambda$

18. (*a*) 20 m s^{-1}
(*b*) 5 m s^{-1}
(*c*) 2 m
(*d*) 5 m
(*e*) 68 Hz
(*f*) 0·2 Hz
(*g*) 1500 m
(*h*) 3×10^6 Hz
(*i*) 3×10^8 m s^{-1}

19. 0·02 m

20. 1360 Hz

21. 1 m s^{-1}

22. 6 m s^{-1}

23. (*a*) 3·2 m
(*b*) 3·1 m
(*c*) 2·8 m
(*d*) 247 m
(*e*) 1515 m

24 $4{\cdot}3 \times 10^{14}$ Hz

Calculating wave speed using distance and time

25. $d = v \times t$

26. (*a*) 8 m s^{-1}
(*b*) 20 m s^{-1}
(*c*) 5 s
(*d*) 400 s
(*e*) 2720 m
(*f*) 20 m

27. 20 s

28. 238 m s^{-1}

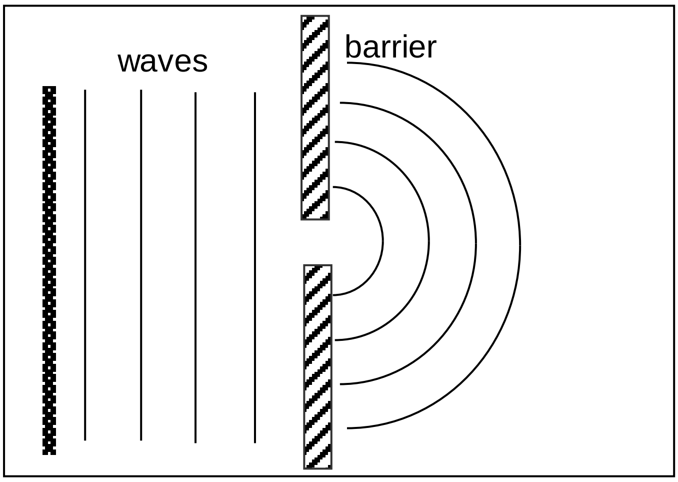
29. 0·3 seconds

30. 4 m s^{-1}

31. (*a*) 1·27 s
(*b*) 500 s

32. Diffraction

33.



34. (*a*) Diffraction

(*b*) Waves which have a **long** wavelength bend more than waves which have a **short** wavelength.

Extension Questions

35. (*a*) 0·00003 s
(*b*) 0·17 m

36. (*a*) 3×10^8 m s^{-1}
(*b*) 0·7 m
(*c*) Waves bend around the person to reach the car.

37. (*a*) Diffraction
(*b*) Sound can diffract around the corner of the building.
(*c*) Low frequency sound is able to diffract over the top of the barrier.
(*d*) The LW broadcasts can bend around obstacles whilst the high frequency FM cannot.

Light

Refraction of light

38. 90°

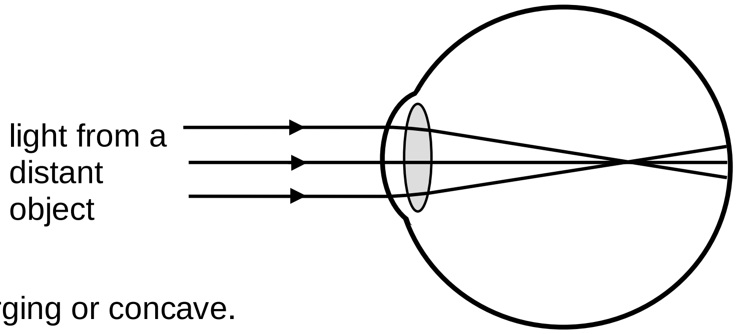
39. (*a*) Towards.
(*b*) Away from.
(*c*) Decreases.
(*d*) Increases.
(*e*) Less than.
(*f*) Greater than.

40. (*a*) P
(*b*) R

41. C, F, H, I, J

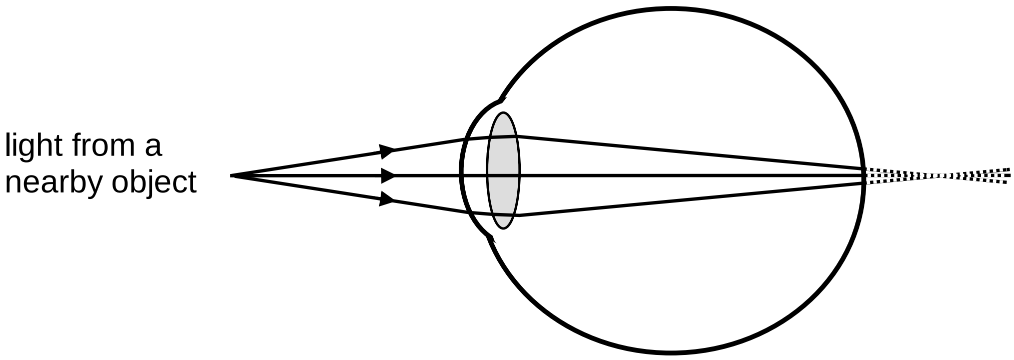
42. (*a*) angle of incidence = 40°, angle of refraction = 25°
(*b*) angle of incidence = 50°, angle of refraction = 31°
(*c*) angle of incidence = 25°, angle of refraction = 16°
(*d*) angle of incidence = 35°, angle of refraction = 23°

43. (*a*)



(*b*) Diverging or concave.

44. (*a*)

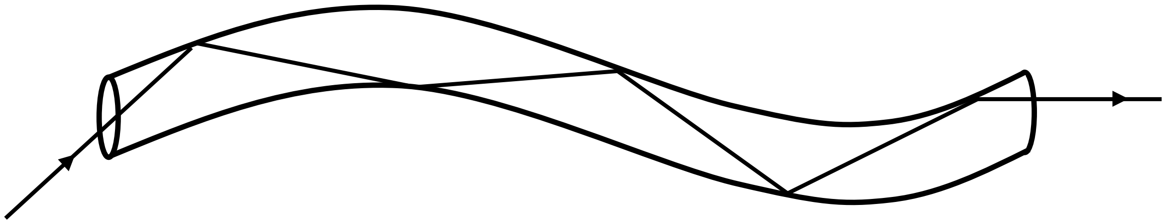


(*b*) Convex or converging.

45. Occurs when a ray of light tries to escape from a glass to air and the angle of incidence is greater than the critical angle. The ray is reflected back into the glass.

46. (*a*) Ray refracts out of block with some reflection.
(*b*) Ray refracts at 90° along block face with some reflection.
(*c*) Ray totally reflects back into block.

47.



48. (*a*) 28°
(*b*) 28°
(*c*) 28°
(*d*) 45°

49. (*a*) Total internal reflection.
(*b*) It will decrease as some of the light has been refracyed out of the windscreen.

50. (*a*) Convex or converging.
(*b*) Backwards.
(*c*) Long sight.

Electromagnetic Spectrum

The electromagnetic spectrum

51. (*a*) 3×10^8 m s^{-1}
(*b*) At the same time.
(*c*) (i) Radio and TV waves.
(ii) Gamma radiation
(iii) Gamma radiation.
(iv) Radio and TV waves

52.

	Wave frequency	*Wavelength*	*Type of wave*
(*a*)	3×10^{19} Hz	**1×10^{-11} m**	**Gamma radiation**
(*b*)	$4·3 \times 10^{14}$ Hz	**$6·97 \times 10^{-7}$ m**	**Red light**
(*c*)	3×10^{10} Hz	**0·01 m**	**Microwaves**
(*d*)	$7·5 \times 10^{14}$ Hz	**4×10^{-7} m**	**Violet light**
(*e*)	**$1·0 \times 10^{16}$ Hz**	3×10^{-8} m	**Ultraviolet**
(*f*)	**$1·0 \times 10^{18}$ Hz**	3×10^{-10} m	**X-rays**
(*g*)	**$1·0 \times 10^{8}$ Hz**	3 m	**Radio and TV**
(*h*)	**$1·0 \times 10^{6}$ Hz**	300 m	**Long wave**
(*i*)	**$3·0 \times 10^{13}$ Hz**	1×10^{-5} m	**Infrared**

53. 3×10^{-7} m

54. (*a*) 3×10^{8}
(*b*) 3·1 m
(*c*) 0·0003·s

55. 3×10^{12} Hz

56. (*a*) 500 s
(*b*) 1×10^{20} Hz

57. (*a*) 0·17 m
(*b*) $1·7 \times 10^{-5}$ s

58. (*a*) 5
(*b*) 4
(*c*) 6
(*d*) 2
(*e*) 1
(*f*) 7
(*g*) 3

59. (*a*) Radio and TV waves.
(*b*) Infrared.
(*c*) Heating food in a microwave oven.
(*d*) Visible or Infrared.

60. (*a*) A hot object.
(*b*) An infrared camera or infrared sensitive film. It will also cause objects which absorb it to warm up.
(*c*) Thermographs, treating muscle injuries, remote controls, burglar alarm activators.

61. (*a*) Using materials which fluoresce (glow) under ultraviolet light.
(*b*) It can cause skin cancer.
(*c*) Can be used in the treatment of skin diseases or to security mark objects.

62. (*a*) Frequent exposure to X-rays would be harmful.
(*b*) X-rays are more likely to damage cells which are actively dividing, such as in a young child.
(*c*) It completely blocks more of the X-rays.

63. (*a*) The bone blocks the X-rays reaching the film.
(*b*) 3×10^{18} Hz
(*c*) X-rays could harm the foetus.
(*d*) Ultrasound.

64. Waves from the electromagnetic spectrum will transfer **energy** from one place to another. The amount of energy the waves carry depends upon the frequency or wavelength of the waves. The **higher** the frequency or **shorter** the wavelength, the more energy they carry. Waves with a **longer** wavelength and a **low** frequency carry less energy.

65. (*a*) Uv A = 1×10^{15} Hz, uv B = $7{\cdot}5 \times 10^{14}$ Hz so uv A has the higher frequency
(*b*) Uv A as the higher frequency radiation carries more energy.

Extension Questions

66. (*a*) 0·33 m
(*b*) (i) Two from: infrared, visible light, ultraviolet, x-rays or gamma radiation.
(ii) TV and radio and long waves
(*c*) $1{\cdot}3 \times 10^{-5}$ s
(*d*) High frequency waves carry more energy.
(*e*) $3{\cdot}6 \times 10^{7}$ m

67. (*a*) Sound waves are longitudinal waves and cannot travel through a vacuum. Waves from the EM spectrum are transverse and can travel through a vacuum.
(*b*) Ultraviolet, X-rays and gamma radiation.
(*c*) They carry more energy.
(*d*) When electrons move in a conductor.
(*e*) Static.
(*f*) To ‘see’ when there is no light.
(*g*) The ozone layer in the atmosphere filters it out.
(*h*) It can be harmful.
(*i*) Sterilising medical instruments, destroying cancer cells.

Nuclear Radiation

Properties of Radiation

68. (*a*) Neutron.
(*b*) Proton
(*c*) Electron

69. They are equal in number.

70. When alpha or beta particles pass another atom, they tend to pull electrons off it leaving it with a positive charge.

71. There are three different types of nuclear radiation – alpha, beta and gamma. Alpha radiation is a **helium** nucleus and has a **positive** charge. It is a **strongly** ionising radiation so will damage cells if it gets into the body. Fortunately, it is blocked by a thin sheet of **paper** or a few centimetres of **air**. Beta radiation is a fast moving **electron** from the break up of a proton in an atom's **nucleus**. It has a **negative** charge and requires 3 millimetres of aluminium to block it. The last type is gamma radiation which is not a particle but a **wave** and part of the electromagnetic spectrum. Gamma requires 3 centimetres of **lead** to block its path. Beta and gamma are **weakly** ionising radiations and do not ionise as strongly as alpha radiation.

72. (*a*) Sheet of paper or 3 cm of air.
(*b*) Strongly ionises.
(*c*) Fast moving electron.
(*d*) Weakly ionises.
(*e*) Gamma.
(*f*) 3 cm of lead.

73. (*a*) When alpha or beta particles pass another atom, they tend to pull electrons off it leaving it with a positive charge.
(*b*) It is good at ionising the air.

74. Becquerel.

75. 2×10^6 Gy

76. $1{\cdot}8 \times 10^7$

77. 6×10^6

78. (*a*) Background radiation is present all time, either from natural sources or man-made sources.

(*b*)

Source	*NATURAL*	*MAN-MADE*
Building materials		✓
Nuclear medicine		✓
Nuclear power stations		✓
Cosmic radiation	✓	
Granite rock	✓	
Radon gas		✓
Bananas	✓	
Water	✓	
Tobacco		✓
Smoke detectors		✓
Luminous watches		✓

Absorbed Dose and Equivalent Dose

79. (*a*) Absorbed dose = energy/mass

(*b*) Gray (Gy).

80. (*a*) 5×10^{-4} Gy

(*b*) 0·025 Gy

(*c*) $2{\cdot}5 \times 10^{-5}$ J

(*d*) $1{\cdot}5 \times 10^{-7}$ J

(*e*) 0·25 kg

(*f*) 1 kg

81. $1{\cdot}25 \times 10^{-3}$ Gy

82. 17 Gy

83. (*a*) Equivalent dose = absorbed dose × weighting factor.

(*b*) Sievert (Sv)

84. (*a*) Some form s of radiation are more harmful than others to living tissue.

(*b*) It strongly ionises so will cause greatest disruption and damage to living cells.

85. (*a*) 2×10^{-4} Sv

(*b*) 0·015 Sv

(*c*) 5×10^{-4} Sv

(*d*) 5×10^{-6} Sv

(*e*) 2×10^{-6} Sv

(*f*) 10×10^{-6} Sv

86. 20 μSv

87. 0·05 Sv

88. (*a*) 3·3 μJ
(*b*) 66 μj

89. 100 μSv

Applications of nuclear radiation

90. (*a*) Alpha will be blocked by the aluminium foil while gamma will pass straight through unaffected.
(*b*) It has become thicker.
(*c*) It would be reduced.

91. (*a*) Gamma radiation can escape from the body, alpha radiation is very harmful within the body.
(*b*) The right kidney.
(*c*) Radioactivity decreases with time.
(*d*) (i) The left side of the thyroid has not absorbed the radioactive iodine (as well).
(ii) The radioactivity of the iodine may decrease to a low level before it is used.

92. (*a*) So that householders do not receive radiation in their water.
(*b*) About 40 metres.
(*c*) Only gamma will be able to travel through the rocks and soil to the surface.

Half-life

93. It is the time taken for the activity of the source to decrease to half its original value.

94. 8 minutes.

95. 500 Bq

96. 8 days.

97. (*a*) Radiation from natural or man-made sources that is always present.
(*b*) Deducted.
(*c*) Approximately 16 minutes

98. 16 g

99. 10 million

100. 625 kBq

101. Nuclear fission takes place when a **neutron** collides with a **large** unstable nucleus of **uranium**. This causes it to **split** into two **smaller** nuclei. At the same time it releases more **neutrons** and a quantity of **heat**.

102. Nuclear fusion takes place when two **small** nuclei collide and join together to create a **larger** nucleus. This also causes **heat** energy to be released. This is the same atomic reaction that provides the energy for the **Sun**.

103. (*a*) Turbine.
(*b*) It is used to produce steam.
(*c*) It converts the kinetic energy of the turbine into electricity.
(*d*) Nuclear energy into heat.

104. (*a*) Fission occurs when a large nucleus splits in two, releasing energy. Nuclear fusion occurs when two small nuclei combine together to form a larger nucleus, again releasing energy.
(*b*) Fission.

105. Neutrons are released by nuclear fission which go on to produce more fission which releases more neutrons and so on.

106. A A neutron strikes a large nucleus which becomes unstable.
B The nucleus splits into two smaller nuclei.
C Heat is released along with more neutrons.

107.
1. **TRUE** – Most radiation comes from cosmic rays from space and from radon gas escaping from underground rocks.
2. **FALSE** – Estimates vary, but there is sufficient nuclear fuel, in the form of uranium, to last for at least a hundred years. Newer types of nuclear reactors could make this last a lot longer.
3. **TRUE** – Radioactive waste from nuclear reactors remains radioactive for a long tome so needs to be stored underground till the radiation levels decrease enough.
4. **TRUE** - Nuclear fission is currently used though scientists are working on using nuclear fusion to produce energy.
5. **FALSE** - Nuclear reactors take many years to plan and build so can’t be built quickly.
6. **FALSE** - Nuclear reactors do not produce any sulphur dioxide.
7. **FALSE** – Only a tiny fraction of the overall background radiation comes from nuclear power stations though there have been some major disasters such as Chernobyl power station in Russia which blew up as a result of workers switching off safety mechanism s.
8. **FALSE** – Industry can create demands for large quantities of energy but like fossil fuelled power stations, this can be supplied by nuclear power stations.
9. **FALSE** - Nuclear reactors do not produce any greenhouse gases.

10. **FALSE** – None of the nuclear power stations in the west are of the type that exploded in Chernobyl.

Extension Questions

108. (*a*) D
(*b*) B
(*c*) C
(*d*) A
(*e*) (i) 4000 Bq
(ii) 250 Bq

109. (*a*) Cosmic radiation, radon gas, rocks, medical radioactivity etc.
(*b*) Approximately 8·5 seconds
(*c*) Any spillages are kept enclosed.
(*d*) It is buried underground in sealed containers.

110. (*a*) It is the time taken for the activity of the source to decrease to half its original value.
(*b*) Approximately 9 minutes
(*c*) When alpha or beta particles pass another atom, they tend to pull electrons off it leaving it with a positive charge.
(*d*) 12 000 years.