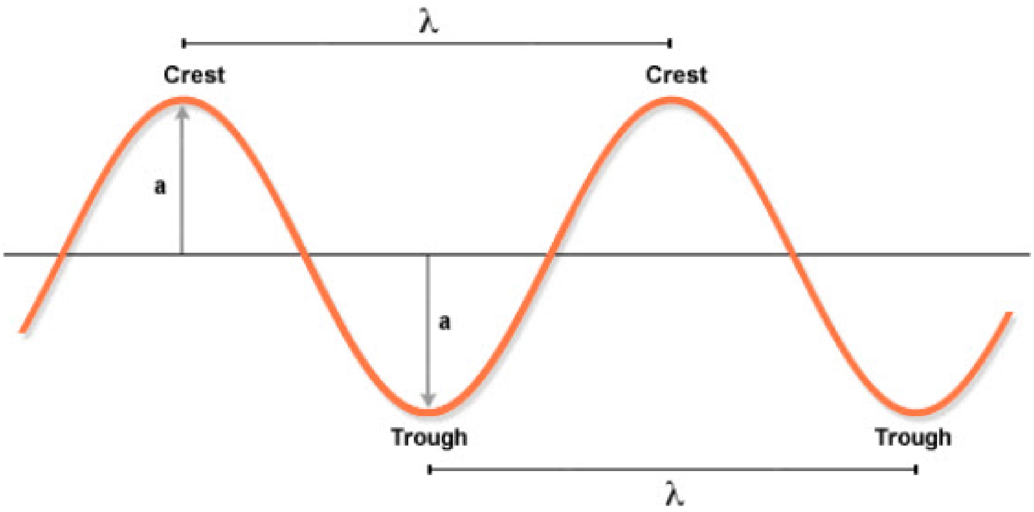
Barrhead High School
Physics Department

National 4 & 5
Physics



Waves and Radiation

National 4/5 Relationships

$E_p = mgh$

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

$Q = It$

$V = IR$

$R_T = R_1 + R_2 + \ldots$

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

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

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

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

$P = IV$

$P = I^2 R$

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

$E_h = cm\Delta T$

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

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

$p_1V_1 = p_2V_2$

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

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

$d = vt$

$v = f\lambda$

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

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

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

$H = Dw_R$

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

$s = vt$

$d = \bar{v}t$

$s = \bar{v}t$

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

$W = mg$

$F = ma$

$E_w = Fd$

$E_h = ml$

Summary of Terms and SI Units continued

Waves

Physical Quantity	Symbol	Unit and Abbreviation
time	t	seconds (s)
Distance	d	metre (m)
Speed	v	metres pes secomd (m/s) or (ms^{-1})
period	T	second (s)
frequency	f	hertz (Hz)
wavelength	λ	metre (m)
angle	θ	degree (°)
critical angle	θ	degree (°)

Radioactivity

Physical Quantity	Symbol	Unit and Abbreviation
activity	A	Becquerel (Bq)
number of nuclei decaying	N	
time	t	seconds (s)
absorbed dose	D	gray (Gy)
radiation weighting factor	W_R	
equivalent dose	H	sievert (Sv)
half-life time	$t_{\frac{1}{2}}$	seconds(s), minutes(min), hour(h), day, year(y)

Prefixes and Scientific Notation

The following are prefixes used to denote multiples and sub-multiples of any unit used to measure a physical quantity

Name	Symbol	Power of 10
tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
kilo	k	10^{3}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Examples

1. 12 GHz = 12×10^{9}Hz = 12,000,000,000Hz
2. 4.7 MΩ = $4.7 \times 10^{6}\Omega$ = 4,700,000Ω
3. 46 km = 46×10^{3}m = 46,000m
4. 3.6 mV = 3.6×10^{-3}V = 0.0036V
5. 0.55 mA = 0.55×10^{-3}A = 0.00055A
6. 25 μA = 25×10^{-6}A = 0.000025A
7. 630 nm = 630×10^{-9}m = 0.000000630m
8. 2200 pF = 2200×10^{-12}F = 0.0000000022F

Learning Outcomes: Wave Parameters and Behaviours

N5 1. State that a wave transfers energy.

N4/5 2. State the difference between a transverse and longitudinal wave and give examples of each.

N4/5 3. Use the following terms correctly in context: wave, frequency, wavelength, speed, amplitude, period.

N4/5 4. Use the equation linking wave period and frequency. ($f = N/t$)

N5 5 I can explain what the period of a wave is and use the equation $T = 1/f$

N4 6. Describe an experiment to measure the speed of sound in air.

N4/5 7. Carry out calculations involving the relationship between distance, time and speed in problems on water waves and sound waves using the equation $v = d/t$.

N4/5 8. Carry out calculations involving the relationship between speed, wavelength and frequency for waves. ($v = f\lambda$)

Wave Parameters and Behaviours

Waves and Energy

N5

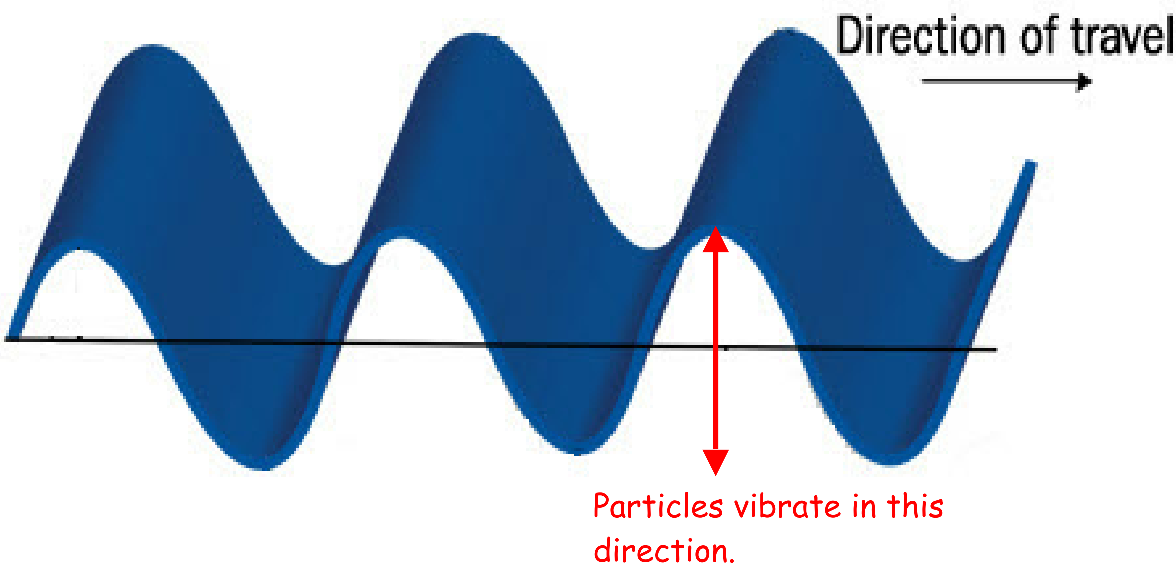
Waves can transfer **energy**, e.g. water waves can transfer energy across the water.

Types of Waves

1. Transverse Waves

N4 & N5

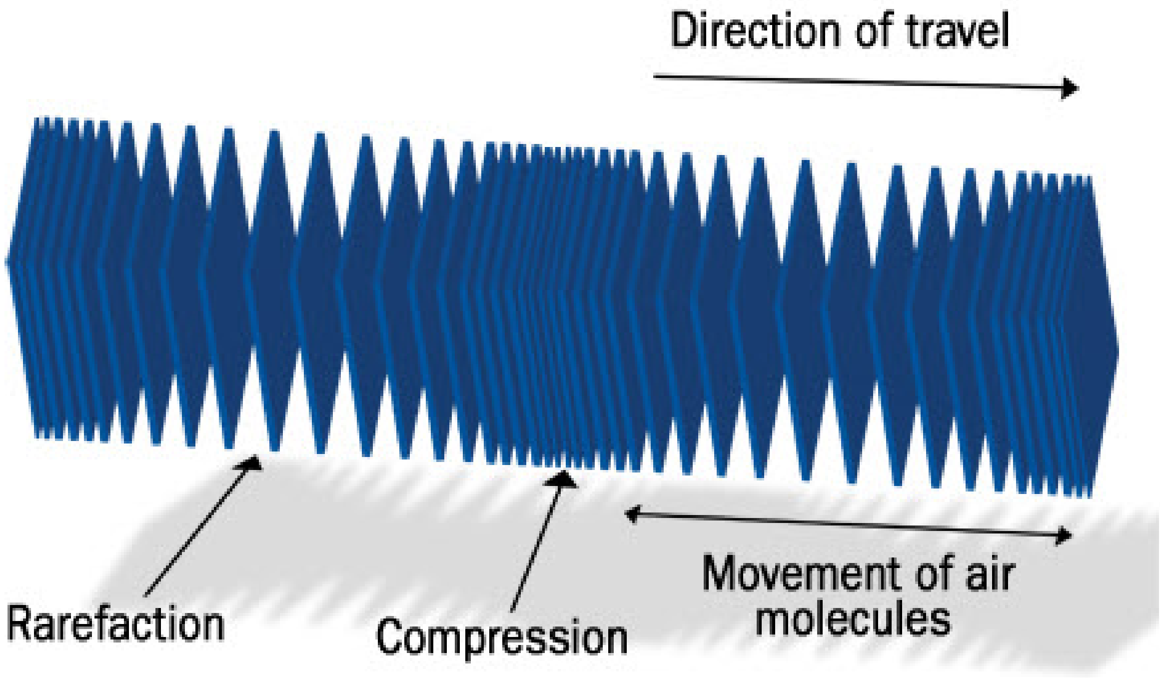
A transverse wave is one in which the particles making up the wave vibrate at 90° to the direction of the wave.



Examples of transverse waves are water waves, light, gamma rays, X-rays and all members of the electromagnetic spectrum.

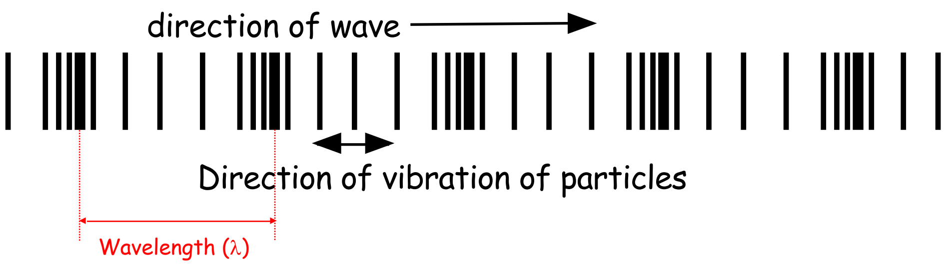
2. Longitudinal Waves

N4 & N5



A longitudinal wave's particles vibrate to and fro along the same line as the direction of the wave. Sound travels as a longitudinal wave.

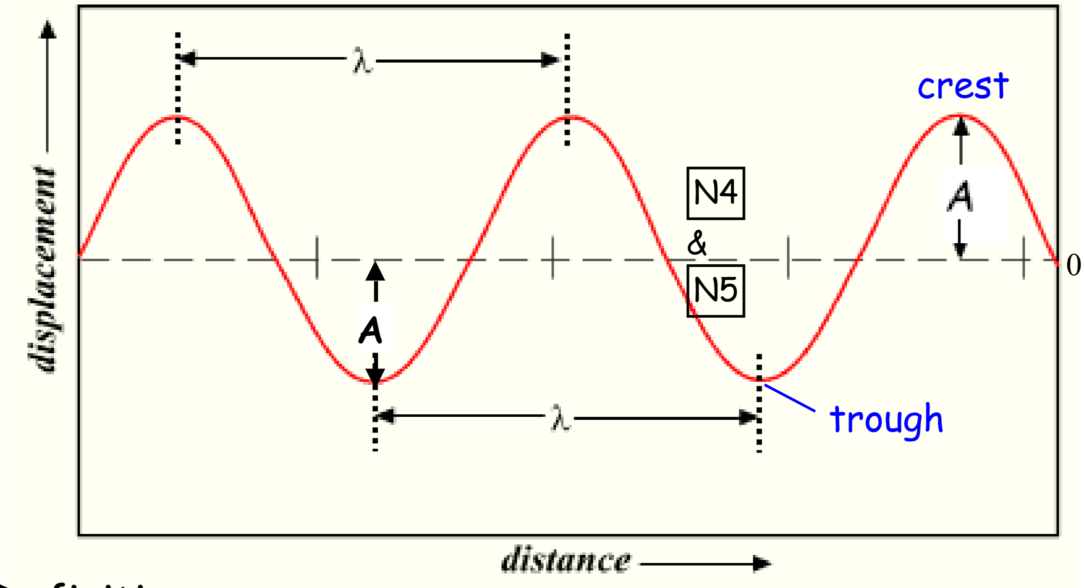
Simplified Diagram



Describing Waves

N4 & N5

Any wave can be described in terms of some basic properties. These are shown in the diagram below.



Definitions

crest = highest point on wave

trough = lowest point on wave

λ = **wavelength** (horizontal distance between adjacent crests or troughs, or the distance between any two corresponding points on the wave)

A = **amplitude** (height of wave from line of zero displacement or half the vertical distance from a trough to crest)

N4 & N5

Frequency(f)

This is the number of waves that pass a point in one second.
It is measured in hertz(**Hz**)

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

Frequency in hertz(Hz)

Number of waves passing a point

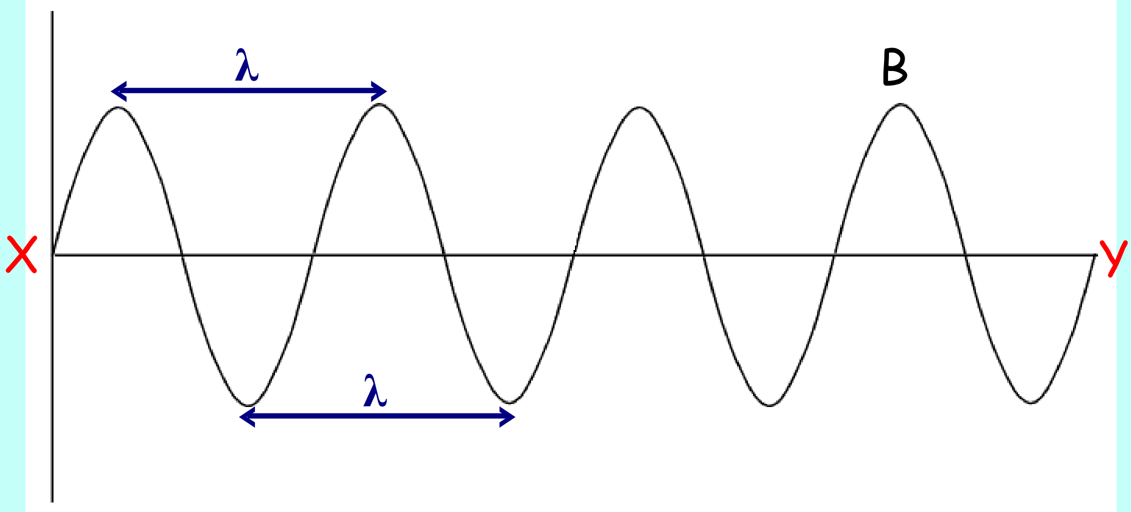
time in seconds(s)

Example

N4 & N5

In the diagram below the distance between X and Y is 10 m.
If 20 waves pass B in 5 s, find :

a) the wavelength
b) the frequency



Solution

a) XY = 4 complete wavelengths

$4\lambda = 10$ m

$\lambda = 10/4 =$ **2.5 m**

b) f = N/t

f = 20/5 **f**

= 4Hz

Period(T)

N5

This is the time it takes one complete wave to pass a point.

Link between Frequency and Period

N5

If one complete wave passes a point in one second the frequency is 1Hz hertz and the period is 2s.

If two complete waves pass a point in one second the frequency is 2Hz and the period is 0.5s.

If three complete waves pass a point in one second the frequency is 3Hz and the period is 0.33s.

If four complete waves pass a point in one second the frequency is 2Hz and the period is 0.25s.

Frequency/Hz	Period(T)/s
1	1
2	0.5
3	0.33
4	0.25

Equation

N5

The equation linking the period and frequency is:

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

Wave Speed

N4 & N5

The speed of a wave is a measure of the distance that the wave disturbance travels in one second.

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

- Speed in metres per second (ms^{-1}) or (m/s)
- Distance travelled in metres (m)
- Time of travel in seconds (s)

Example

N4 & N5

A water wave, produced by a wave machine in a swimming pool, travels from one end of the pool to another in a time of 10 seconds. If the length of the pool is 50 metres, calculate the speed of the wave.

Solution

d = 50 m

t = 10 s

v = ?

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

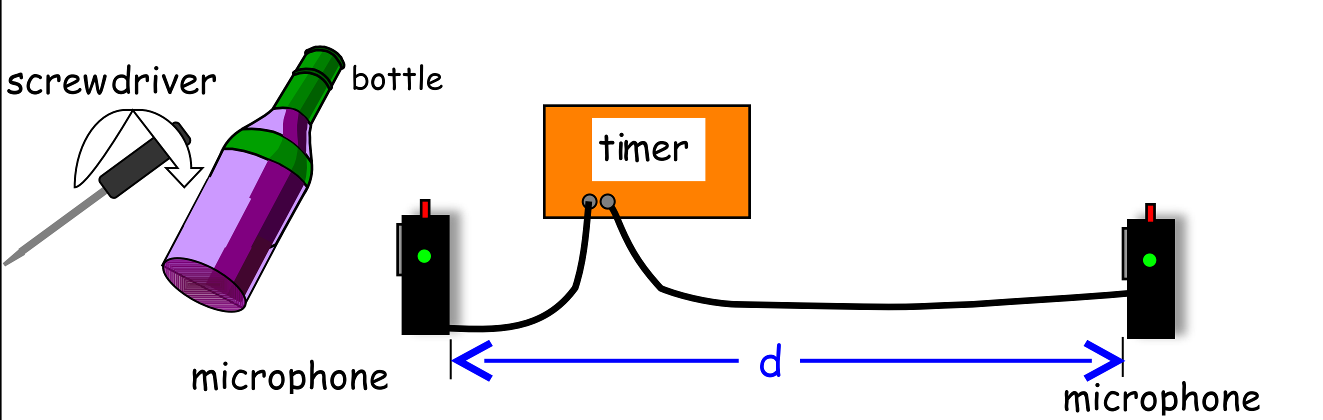
$$v = \frac{50}{10}$$

$$\underline{\mathbf{v = 5\ ms^{-1}}}$$

Measuring the Speed of Sound

N4

The speed of sound in air can be measured using the experiment below.



Method

Measure the distance that the sound travels. This is distance '**d**' between the microphones in diagram below.

Strike the bottle and measure the time it takes for the sound to travel that distance using an electronic timer.

Calculation

Speed can be calculated using the equation:

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

Result

The speed of sound in air at room temperature is found to be **340m/s** .

Example 1

N4 & N5

Two microphones in the speed of sound experiment are 1.5m apart. The reading on the timer after the screwdriver hit the bottle was 4.4ms.

Calculate the speed of sound in air using this information.

Solution

d = 1.5 m
t = 4.4ms = 0.0044s v
= ?

Note: 4.4 ms is 4.4 milliseconds

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

$$\text{speed} = \frac{1.5}{0.0044}$$

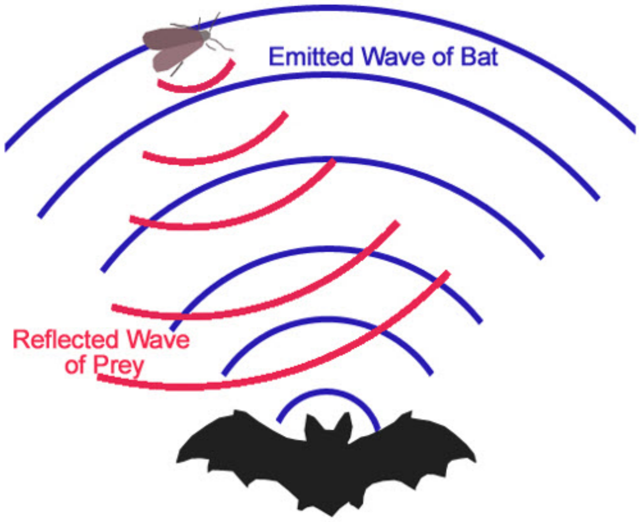
speed = **341 m/s**

Note
Any method used to measure speed must measure both a distance and a time.

Example With Echoes

N4
&
N5

A bat emits a high frequency sound wave and a reflected wave returns to the bat after 0.00666 seconds. Using the speed of sound in air, calculate the distance the moth is from the bat.



Solution

d = ?
t = 0.00666s v
= 340 ms^{-1}

d = v x t
D = 340 x 0.00666s
D = 2.2644 m

To three significant figures this is **2.26m.**

Notice that 2.26m is the distance from the bat to the moth and back again.

The distance from the bat to the moth is half of this.

Final answer = 2.26 / 2
= **1.13 m**

Speed of Sound in Different Materials

N4/5

Material	***Speed in m/s***
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Soft Body Tissue	1500
Water	1500

N4

This information shows that the speed of sound in a gas is less than the speed in liquids and solids. Generally the speed is higher in more dense materials.

The Wave Equation - Another way to calculate the wave speed.

N4 & N5

The equation often used to calculate the wave speed is:

$$V = f\lambda$$

Wave speed in (m/s) or (ms^{-1})

Wave frequency in hertz(Hz)

Wavelength in metres (m)

Derivation of Wave Equation - starting from v = d/t

Extension Work

If the distance travelled is equal to 1λ and this distance is covered in the period time(T) the above equation becomes:

$$v = \frac{d}{t} \quad \frac{\lambda}{T} = \frac{1}{T}\lambda \qquad \text{or} \quad v = f\lambda \quad \text{as} \quad \frac{1}{T} = f$$

Example 1

N4 & N5

Sound travelling in air has a frequency of 9.4 kHz. Calculate the wavelength of the sound wave.

Solution

$v = 340 m/s$

$f = 9.4 \times 10^3 Hz$

$\lambda = ?$

$v = f\lambda$

$\lambda = v/f$

$\lambda = 340/9.4 \times 10^3$

$\lambda = \mathbf{0.036 m}$

Example 2

N4 & N5

Sound travelling through soft body tissue air has a frequency of 45 kHz. Calculate the wavelength of the sound wave.

Solution

$v = 1500$ m/s

$f = 45 \times 10^3$ Hz

$\lambda = ?$

$v = f\lambda$

$\lambda = 1500/45{,}000$

$\lambda =$ **0.033m**

Note: The speed of sound in soft body tissue is found in the table on page 15.

2. Travelling Sound and Oscilloscope Patterns

Learning Outcomes

N4 1. I can state that sound travels as a longitudinal wave and carries energy.

N4 2. I can state that sound is caused by vibrations that travel through materials made up of particles.

N4 3. I can state that sound can travel through solids liquids and gases but not a vacuum because there are no particles in a vacuum to vibrate.

N4 4. I can state some examples of making vibrations to produce sound such as musical instruments, loudspeakers and hearing aids.

N4 5. I can interpret oscilloscope patterns and understand the connection between the loudness of a sound and its amplitude, and the frequency of the sound and the number of waves that appear on the screen.

N4 6. I can state that hearing loss can be helped with the use of hearing aids that increase the amplitude of sound waves but do not change their frequency.

Travelling sound and Oscilloscope Patterns

What Sound is and How it Travels

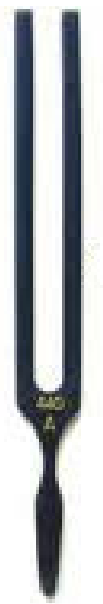
N4

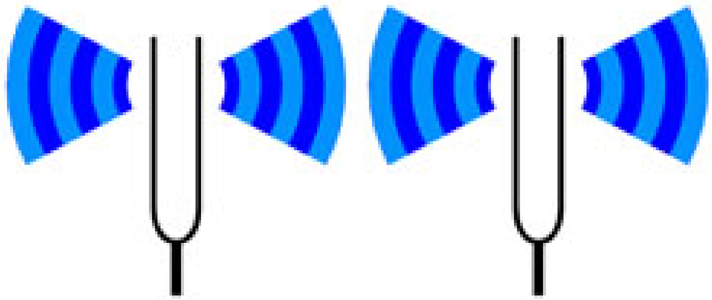
Vibrations

When a vibration occurs, sound waves are produced. These sound waves carry energy from the vibrating object to our ears. These vibrations travel as **longitudinal waves**, enter the ear and allow us to hear the sound.

Producing Sound

N4

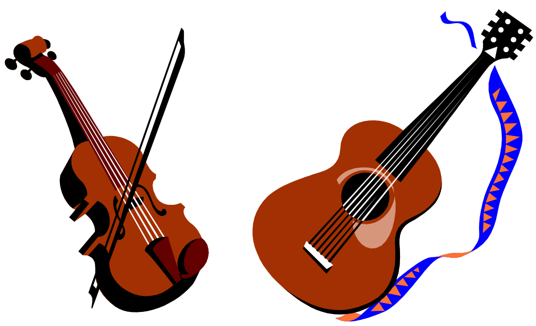




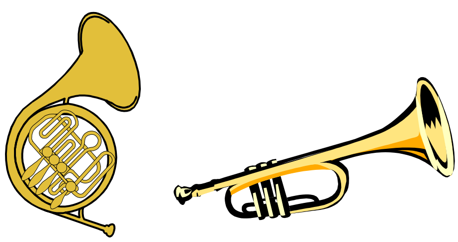
A moving tuning fork vibrates the air around it producing a specific musical note.

Musical Instruments

N4



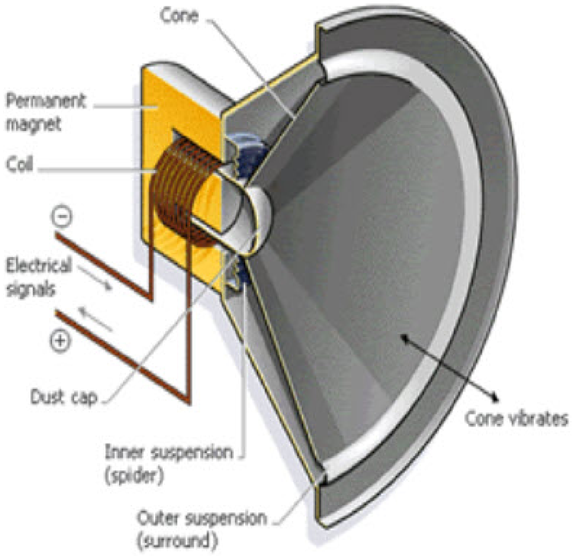
The vibrating string of the cello and guitar produce the sound.



The vibrationg air inside the instrument produces the sound.

Loudspeaker

N4



The speaker cone moves backwards and forwards to vibrate the air.

Headphones and Hearing Aids

N4

Hearing aids contain a small loudspeaker that fit into the opening of the ear. The hearing aid is designed to amplify sounds and

What can sound Travel through?

N4

For people to hear sounds the wave the vibrations to need a substance, containing particles, to travel through. This means that sound can travel through:

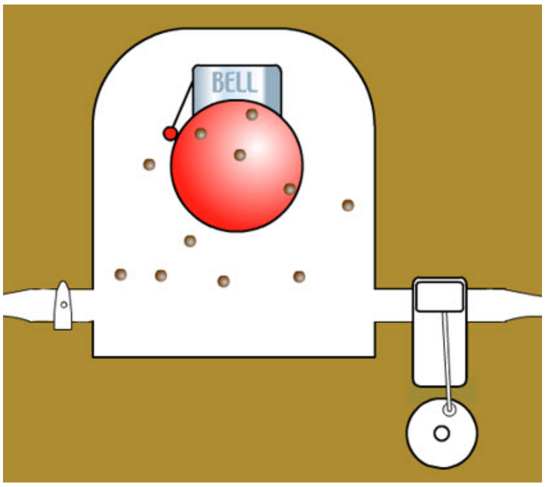
- •Solids
- •Liquids &
- •Gases

Because the particles are closer together in solids and liquids, than in gases, the speed of sound is greater in solids and liquids. The table on page __ gives some examples of the speed of sound in various materials.

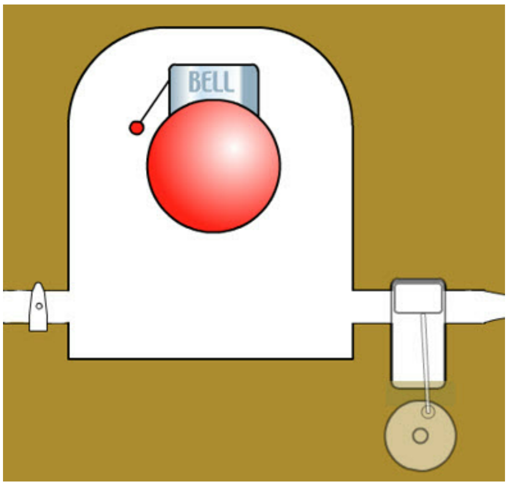
Vacuums

N4

Because there are no particles to vibrate in a vacuum sound cannot travel through a vacuum.



With air particles in the bell jar the sound can be heard outside.



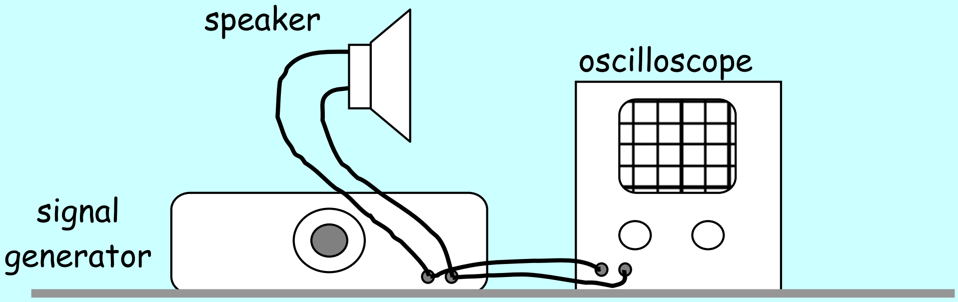
With no air particles in the bell jar the sound cannot be heard outside.

Frequency, Loudness and Oscilloscope Patterns

N4

Examining Sound Waves

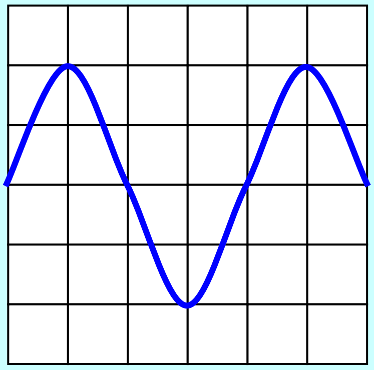
The apparatus shown can be used to examine the sound waves produces from a loudspeaker. The oscilloscope produces a trace or pattern.



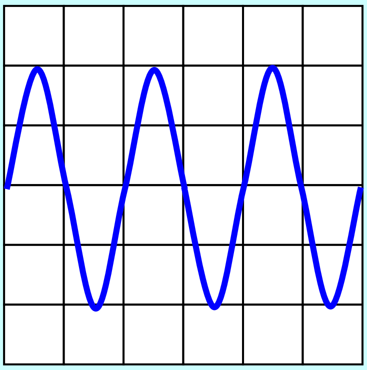
Frequency

N4

Frequency means the number of waves produced per second and is measured in Hertz. The word pitch is also used to describe frequency.



Low Frequency/Pitch



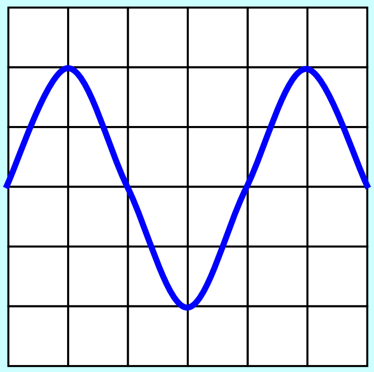
High Frequency/Pitch

More waves are on the screen.

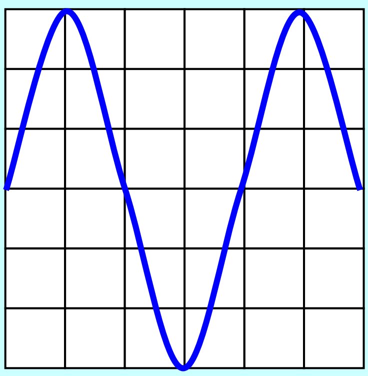
Loudness

N4

The loudness of a sound depends on the amplitude of the sound wave. Loud sounds have a bigger amplitude than quieter sounds.



Quieter Sound



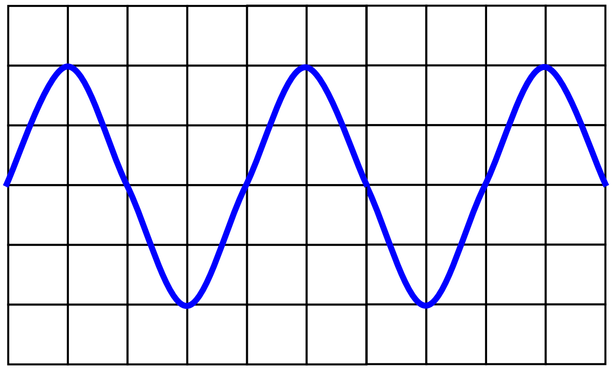
Louder Sound

Bigger waves are on the screen

Hearing Aids

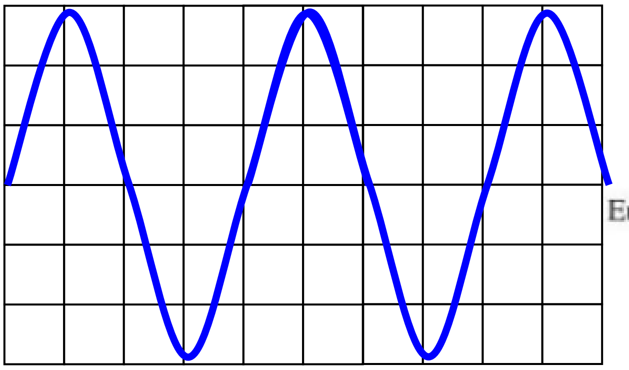
N4

These devices amplify the energy of the sound wave before entering the inner ear.

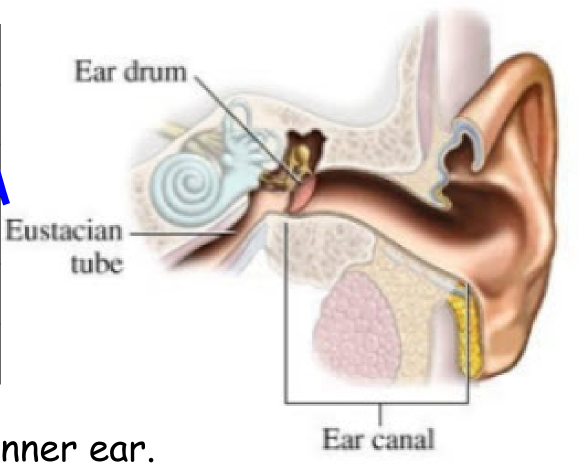


Sound pattern collected by persons ear

Hearing aid amplifies sound.



Amplified sound pattern entering inner ear.



N4

Note

Only the amplitude of the sound is increased. The frequency of the sound remains constant.

Loudness and Frequency of Sound

Learning Outcomes

N4 1. I can state that the loudness of sound is measured in decibels.

N4 2. I can state that loud sounds can damage hearing.

N4 3. I can state that using ear plugs or ear defenders hearing damage can be prevented.

N4 4. I can state what is meant by noise pollution and identify sources of this pollution.

N4 5. I can state the normal frequency range of human hearing.

N4 6. I can explain what is meant by ultrasound and give some uses including:

a) producing images of unborn babies and
b) finding the depth of water
c) fishing vessels detect fish. submarines.

N4 7. I can explain that noise reduction technology works because sound from two different sources can cancel each other out and give some uses of this.

N4 8. I can give some applications of noise reduction technology.

Loudness of Sound

N4

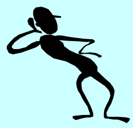
It is important that sound level values are kept to a reasonable level. If the sound level is too high then it is possible that hearing could be damaged.

Sound levels are measured in the unit called the decibel (dB).

N4

Some common sounds with their decibel levels are shown below.

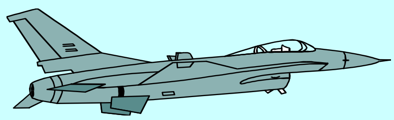
- 0 dB The softest sound a person can hear with normal hearing



- 10 dB normal breathing
- 20 dB whispering at 5 feet
- 30 dB soft whisper
- 60 dB normal conversation
- 80 dB ringing telephone
- 110 dB shouting in ear

- 120 dB thunder

- 150 dB jet engine taking off



Damage to Hearing

N4

Sound levels above 85dB can damage hearing.

Ear defenders should be used in situations where

Noise Pollution

N4

If there is a source of loud noise that causes a disturbance it is known as noise pollution. Some examples of this could be airport noise, roadworks, heavy traffic, and noisy neighbours.

neighbours

drilling

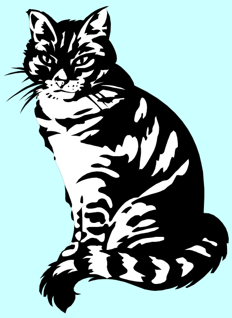
aircraft

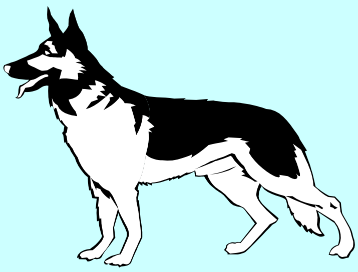
Frequency Range of Hearing

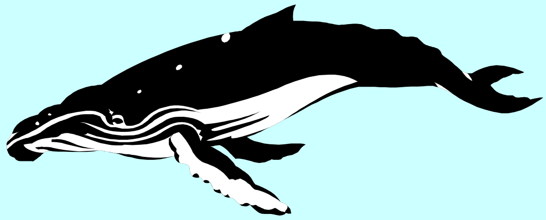
N4

Humans can hear sounds that are inside the frequency range 20 – 20 000 Hz. Frequencies above or below this range cannot be heard.

Other animals are able to hear sounds outside this range.







Cat up to 45 000 Hz   Dog up to 30 000 Hz   Whale up to 80 000 Hz

Ultrasound

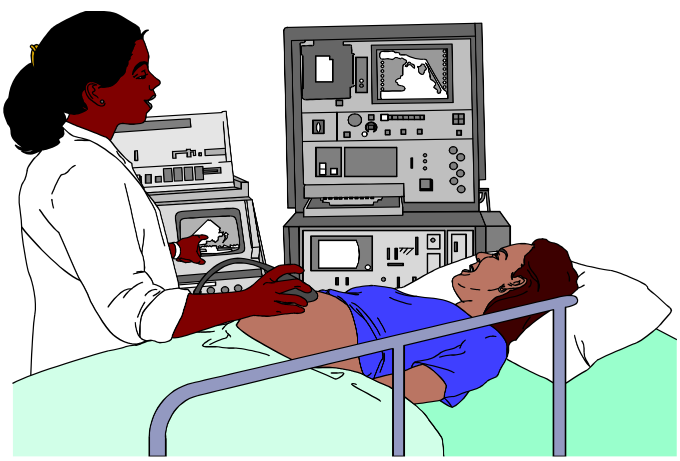
N4

If a sound has a higher frequency than humans can hear [above 20 000 Hz] it is called Ultrasound. Cats, dogs and whales can all hear some ultrasound.

Medical uses of Ultrasound

N4

Ultrasound is used in medicine to **produce images** of unborn babies.



The energy carried by ultrasonic waves can also be used to shatter kidney stones.

Industrial uses of Ultrasound

N4

1. Cleaning Objects in water baths.

Ultrasonic waves vibrate water and remove dirt from objects.

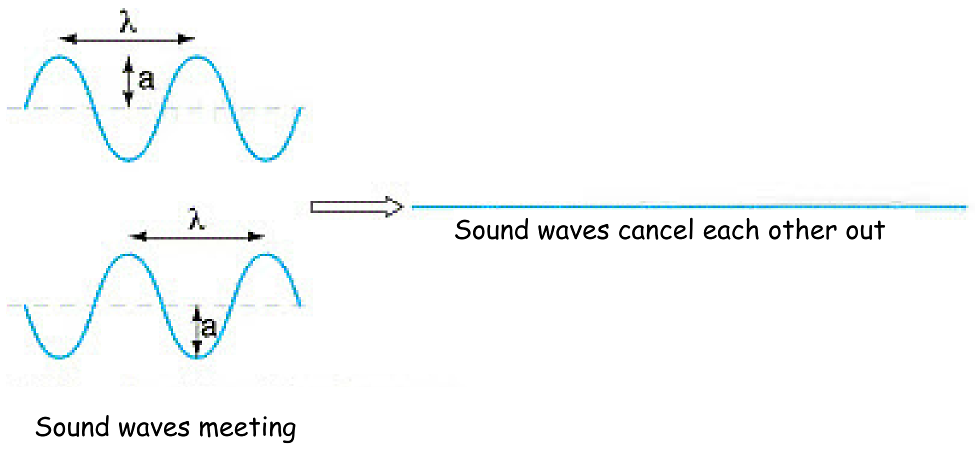
2. Industry :Fishing Boats

Reflections of ultrasound from shoals of fish underwater help fishermen locate fish.

Noise Reduction

N4

When two sound waves meet, they combine and can cancel each other out. This is illustrated in the diagram below.



N4

This cancelling out of sound is used in technology to reduce unwanted background sound.

Some examples of this are described over the page.

Devices using Noise Cancelling Technology

Noise Cancelling Headphones

N4

Pilots wear these devices to cancel out background engine noise.

Humvees

N4

The military also use noise cancelling headsets in vehicles like humvees.

Properties and Behaviour of Light

Learning Outcomes

N4/5

N5

N4/5

N4/5

N4/5

N4/5

N5 1. I am aware that the speed of light depends on the material it is travelling in.

N4 2. I can state that unlike sound, light can travel through a vacuum.

N4 3. I can state that the speed of light is much greater than sound.

N4 4. I can identify situations where the difference in speed of sound and light can be observed.

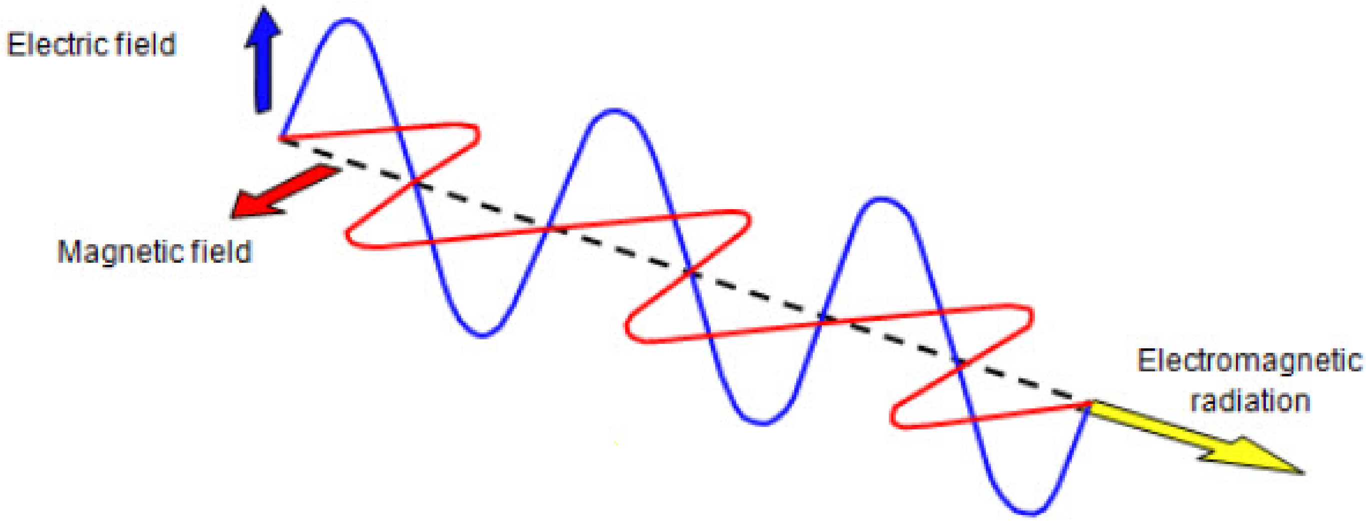
N4/5 5. I can use the equations $v = d/t$ and $v = f\lambda$ to carry out calculations involving light waves in air and glass.

Properties and Behaviour of Light

Type of Wave

N4 & N5

Light is a transverse wave. This means that the waveform disturbance is at right angles to the direction of travel.



Speed of Light

N5

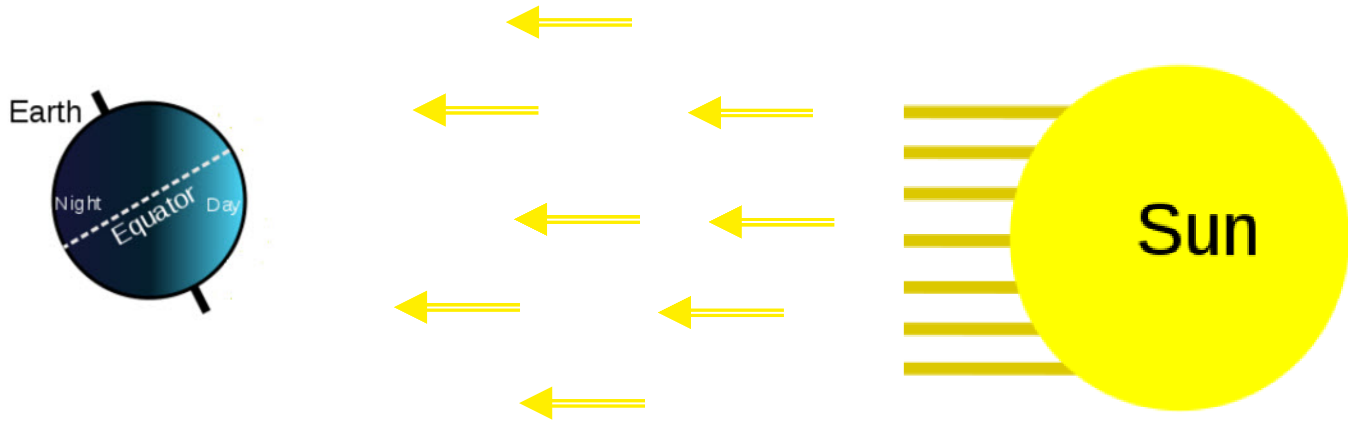
In air light travels at at 300 million ms^{-1} (3.0×10^{8} ms^{-1}).

In glass or perspex the speed of light is about (2.0×10^{8} ms^{-1}).

What light can travel through

N4 & N5

Light can travel through transparent materials and the vacuum of space. Without this ability no light would reach the Earth from the sun.



Speed of Light Compared to Sound

N4 & N5

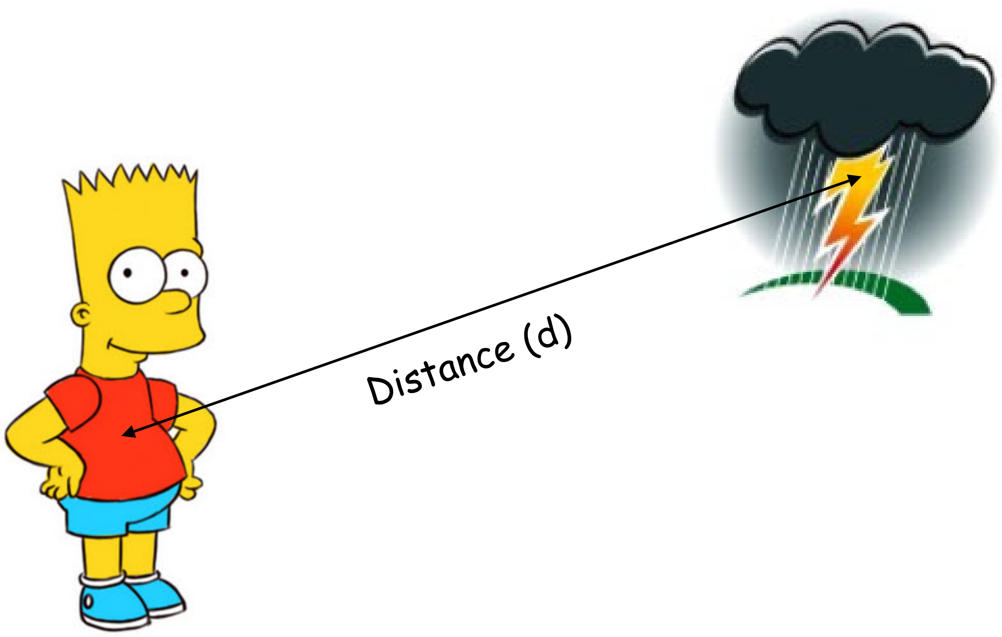
Because the speed of light in air is so much greater than the speed of sound in air the lightning produced by a thundercloud is seen before the sound of the thunder since the speed of light is much greater than the speed of sound.

Example

N4 & N5

A boy notices that in a thunderstorm he sees the flash of lightning 4.0s before he hears the rumble of the thunder. How far away is he from where the thunder and lightning are produced?

Solution



d = ?

t = 4.0 s

v = 340ms^{-1}

d = v x t

d = 340 x 4.0

d = 1360 m

Note: The sound reaches Bart instantly. The delay in hearing the sound is the time the sound travels through the air for, before it reaches his ears.

Reflection, Refraction and Diffraction

Learning Outcomes

N5 1. I can state that the speed of light decreases as it travels from air to glass and this is called **refraction**.

N5 2. I can draw diagrams to show the path of a ray of light as it moves from air and into a transparent material like glass or water from air, or in the opposite direction.

N5 3. I can identify the normal, angle of incidence and angle of refraction in refraction diagrams.

N5 4. I can explain why a straight object, partially submerged in water, appears bent and why objects fully submerged have an apparent depth less than the actual depth.

N4/5 5. I can draw or identify the shapes of converging and diverging lenses.

N4/5 6. I can draw a ray diagram of rays of parallel light passing through lenses and identify the focal point and focal length of a lens.

N4 7. State the meaning of long and short sight.

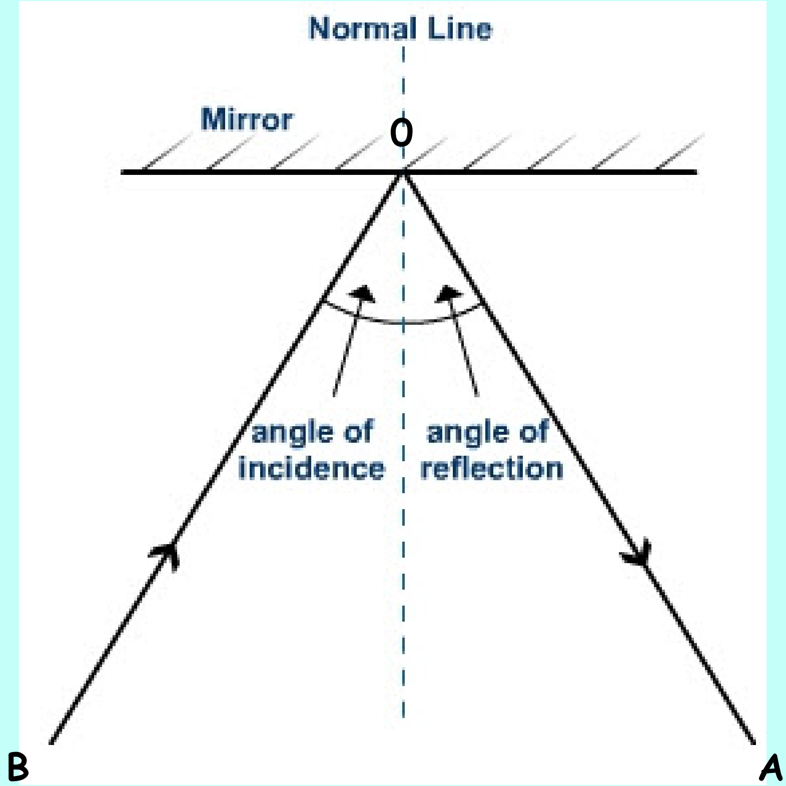
N4 8. Explain the use of lenses to correct long and short sight.

N5 9. I can state that **diffraction** is describes the phenomenon of the the bending of waves around obstacles and the spreading out of waves past small openings.

Reflection of Waves: Revision of Prior Learning

Reflection from a Plane Mirror

The diagram below shows the path of a ray of light when reflected off a mirror. The normal is a line drawn at 90^0 to the mirror.



Law of Reflection

This states that the angle of incidence is equal to the angle of reflection.

$$\angle i = \angle r$$

Note: All EM waves can be reflected

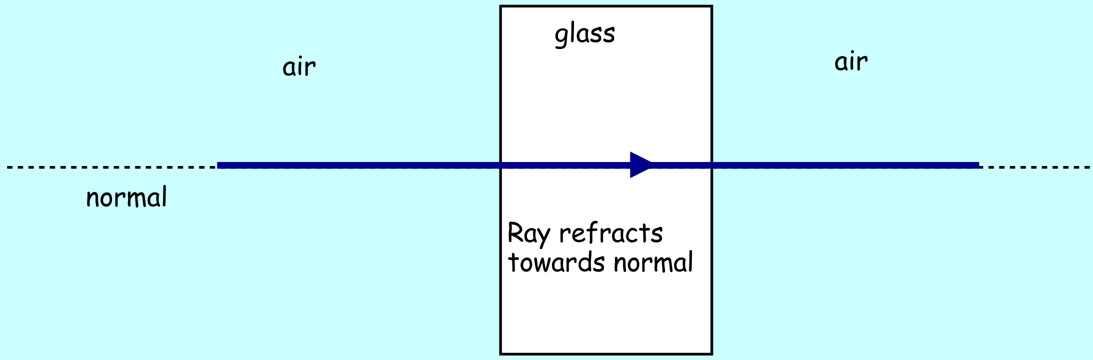
Refraction of Waves

Refraction of Light

N5

The speed of any EM wave decreases when it enters glass. This is called refraction. The speed of the wave, in this case visible light, is less in glass than in the air.

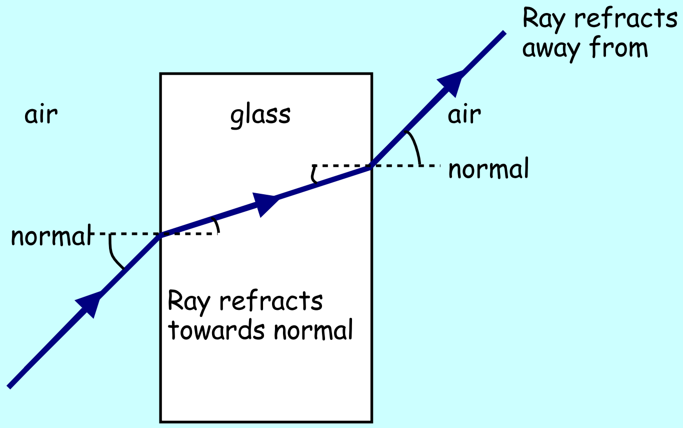
Light Entering and Leaving a Glass Block along the Normal



The light speed decreases as it enters the glass and increases as it leaves. There is no change of direction because it is travelling along the normal.

N5

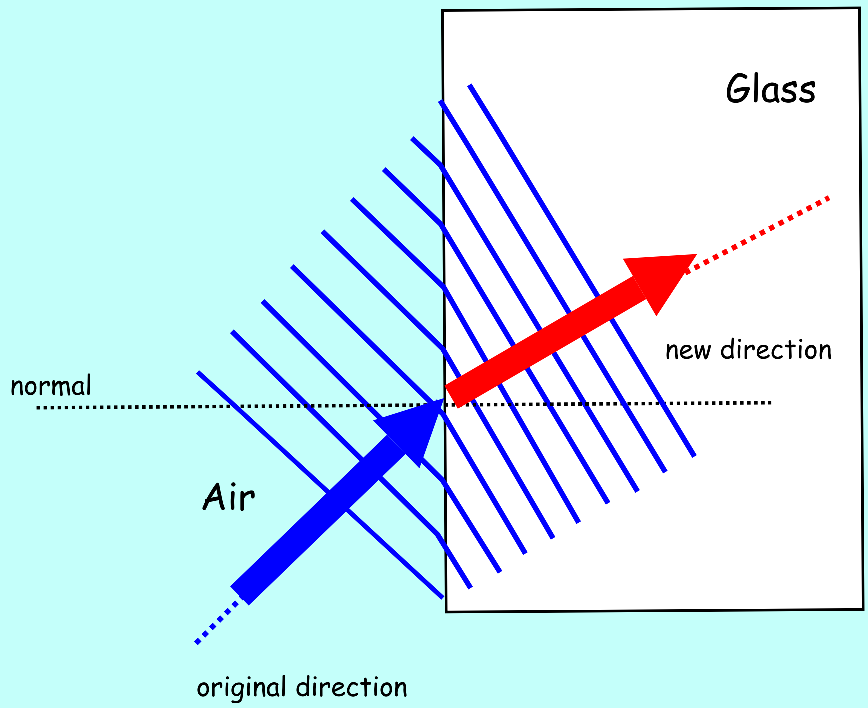
Light Entering and Leaving a Glass Block at an Angle to the Normal



This time the light refracts towards the normal, on entering the glass and away from it on leaving, because of the change in speed.

Wave diagram of Refraction

N5

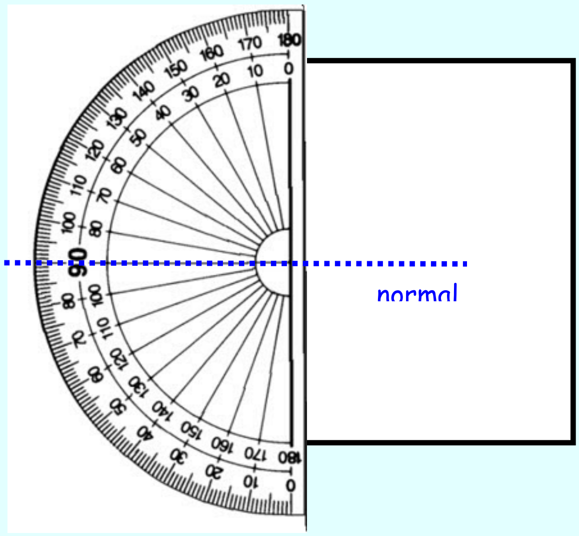


The waves that enter the glass first slow down first. This causes a turning effect as the waves still in the air are travelling at a greater speed. This is illustrated in the diagram. Notice also that the wavelength of the light decreases in the glass block.

Drawing a Normal

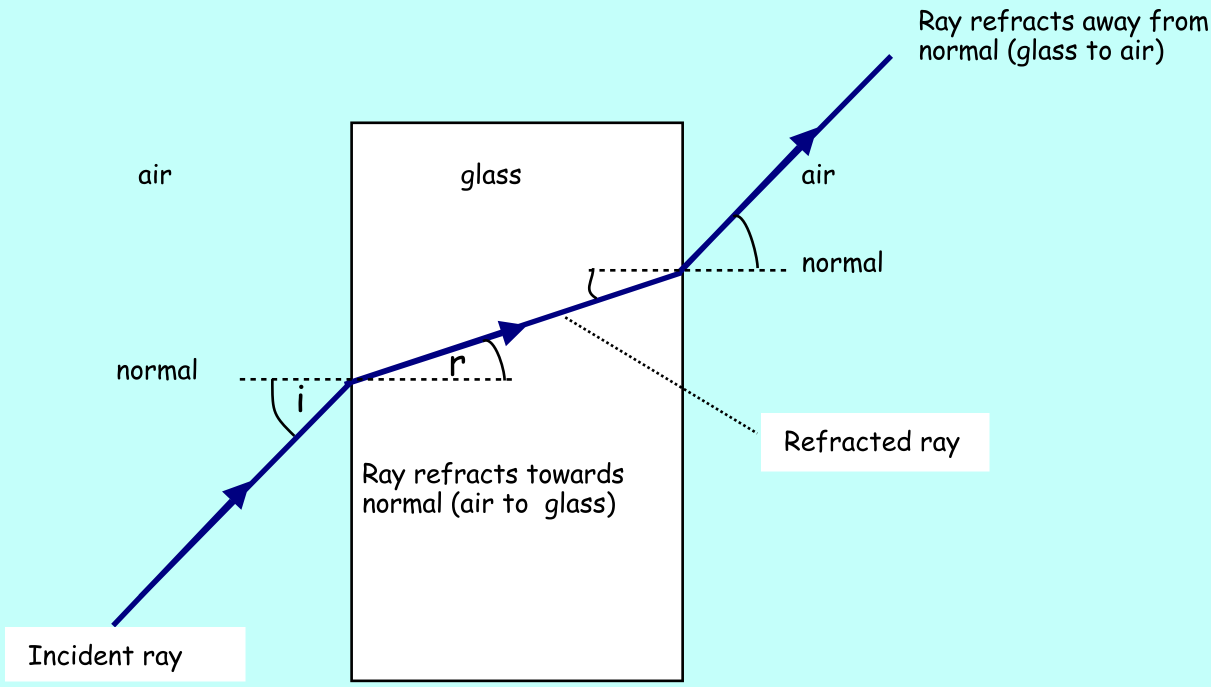
N5

This is a construction line drawn at 90° to the refracting block where the ray enters. To draw this lay a protractor against the edge of the glass block and mark the normal.



Measuring angles

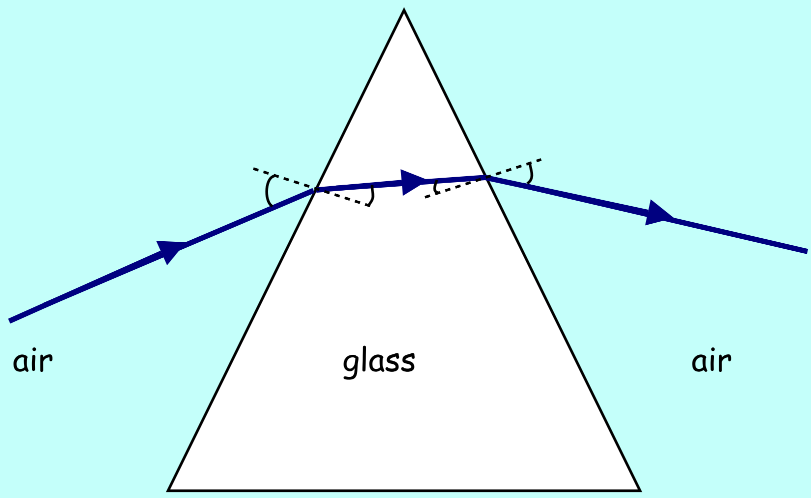
N5



Angles must always be measured between the normal and the ray. The angle between the incident ray and the normal is called the incident angle (i). The angle between the ray and the normal in the glass, at this same boundary, is called the angle of refraction (r).

Triangular Glass Prism and Monochromatic Light Source

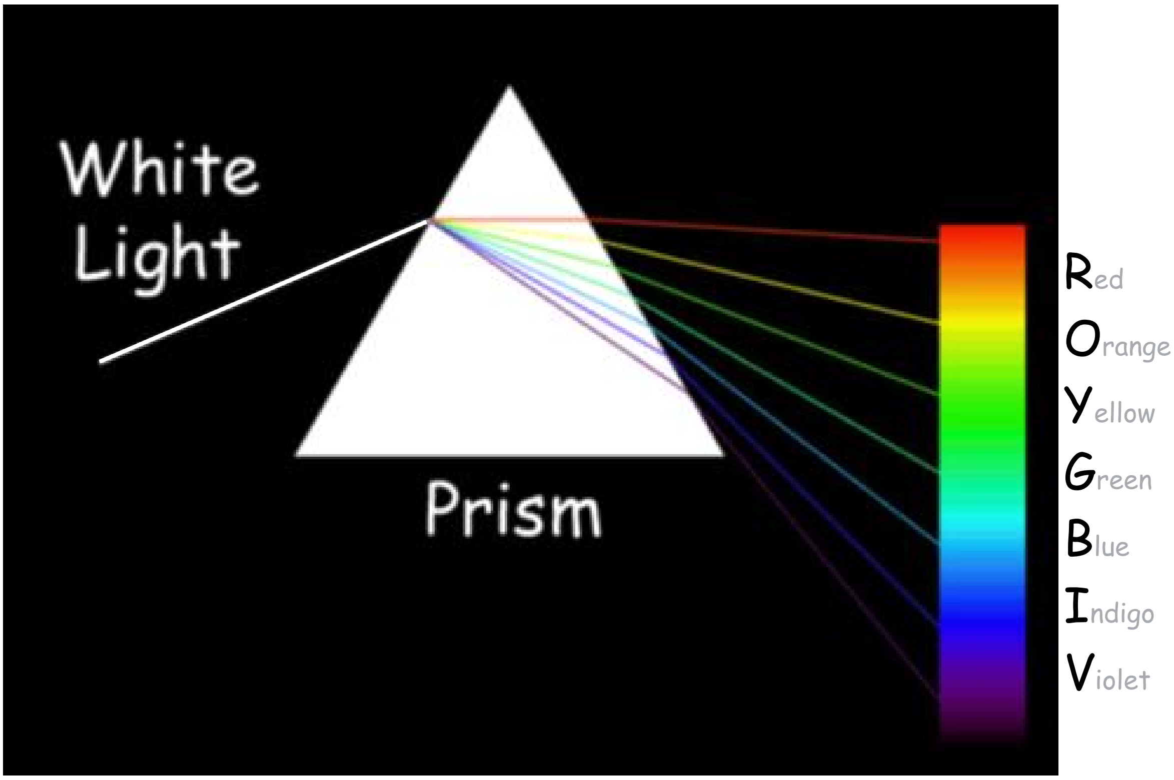
N5



Note: A monochromatic light source has only one wavelength/colour.

Triangular Glass Prism and White Light Source (Additional Information)

A visible spectrum can also be produced using a triangular prism as shown.



Because the refraction effect depends on the wavelength the white light source, made up of many wavelengths, is dispersed into a coloured spectrum. Red light has the longest wavelength and violet has the shortest.

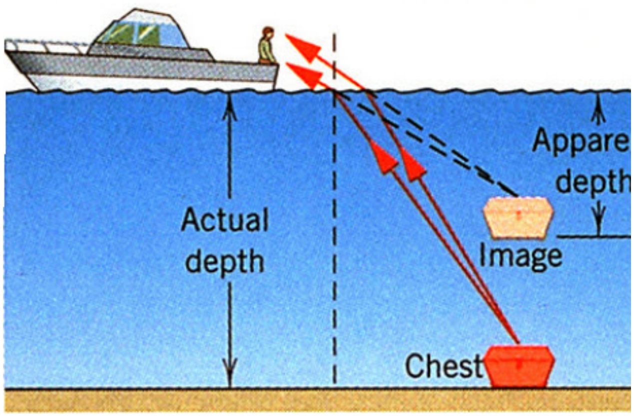
Consequences of Refraction

N5

Straight objects, partially submerged in water, no longer seem straight.

Apparent Depth

N5

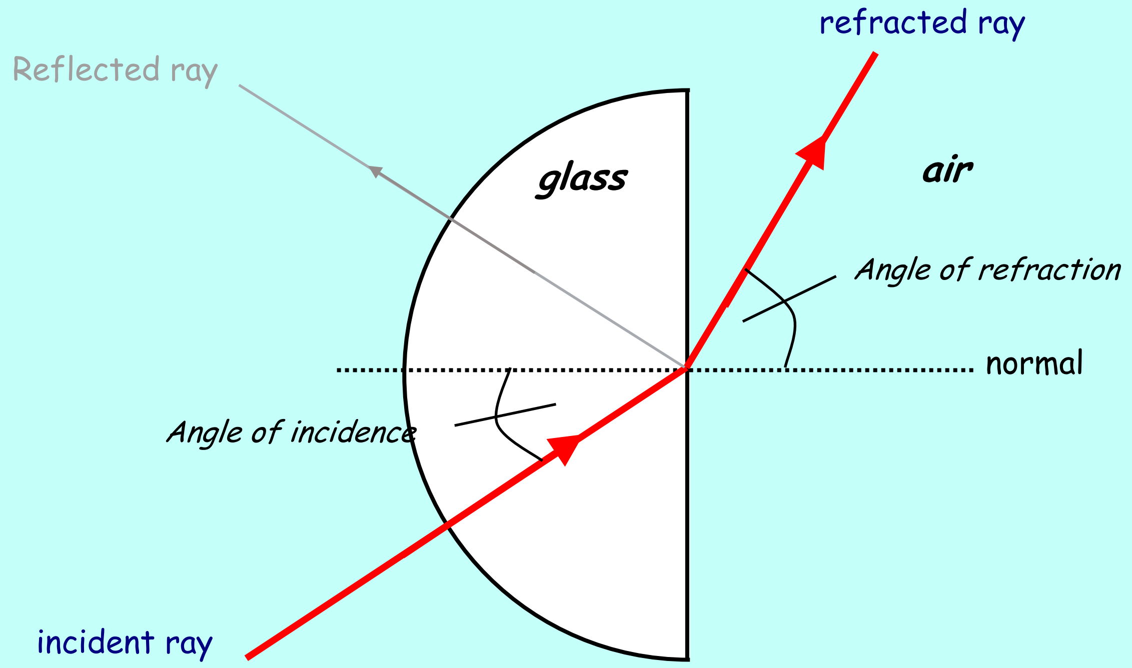


The chest looks at a shallower depth because of the refraction effect at the water air

The fish looks at a shallower depth because of the refraction effect at the water air boundary.

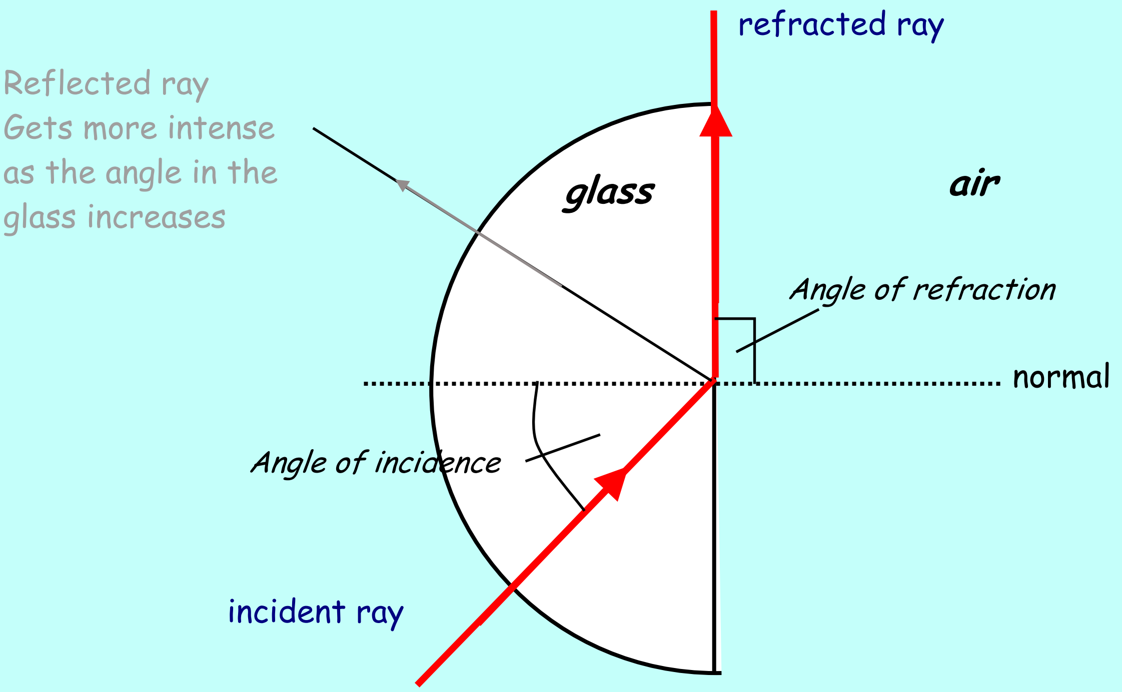
Refraction by Semicircular Glass Block

N5



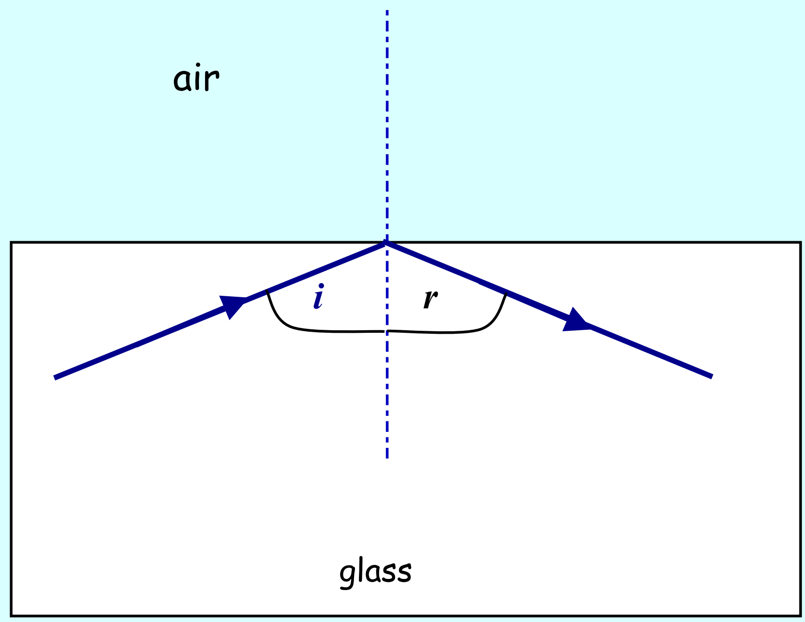
The ray refracts away from the normal as it leaves the block. Also note that a reflected ray is produced and as the angle in the glass is increased it becomes brighter and the refracted ray becomes fainter.

Critical Angle (Extension work not required for N4/5)



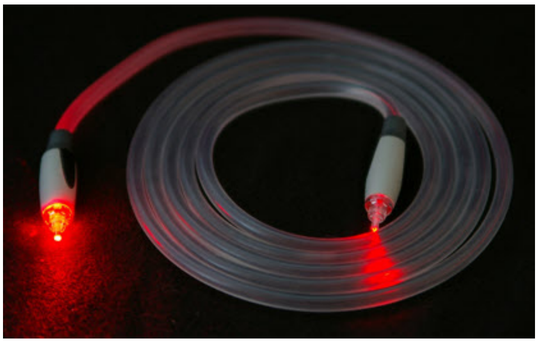
When the angle of refraction in the air is 90° , the incident angle in the glass is called the critical angle. If the angle in the glass is greater than this critical angle, all the light striking the glass air boundary is reflected.

Total Internal Reflection (Not required for N4/5)

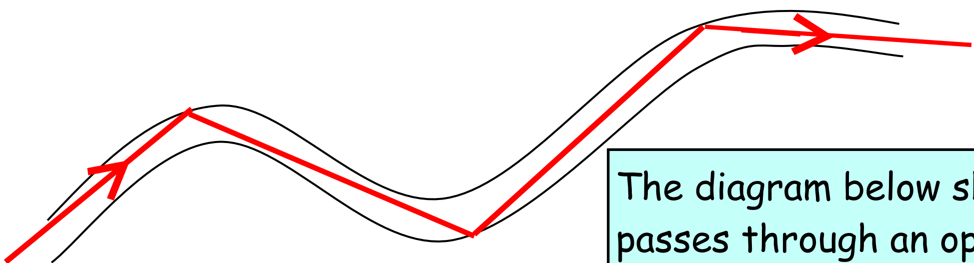


When the incident angle (i) is greater than the critical angle all the light is reflected. This is called **total internal reflection**. The law of reflection applies so $i = r$

Applications of Total Internal Reflection (Not required for N4/5)

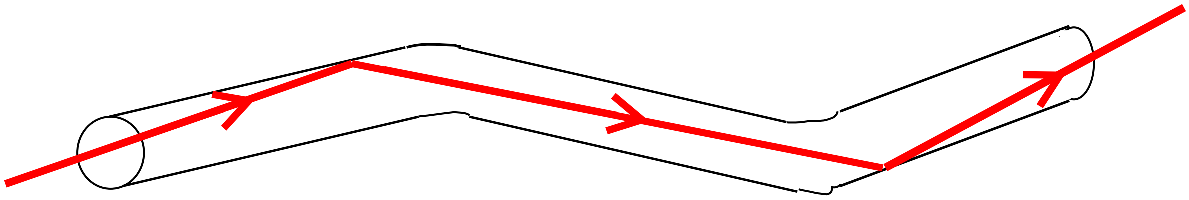


Information is sent in light pulses along the optical fibre made up of thin, flexible strands of glass.



The diagram below shows how light passes through an optical fibre. The light repeatedly totally internally reflects.

More information about Optical Fibres



Facts

The signal passes along the fibre at a speed of almost 200 000 000 ms^{-1}.

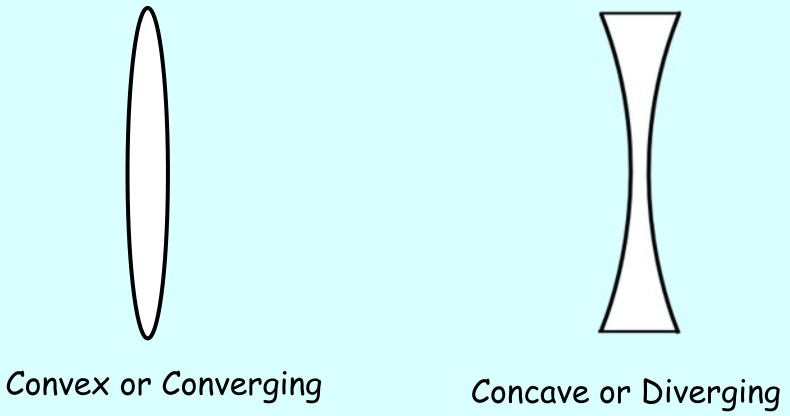
This is slower than the speed that light waves travel through air. However, the rate of data transfer is higher in optical fibres than copper wires.

The angle of incidence at the glass air boundary must be greater than the critical angle.

Refraction by Lenses

Types of Lenses

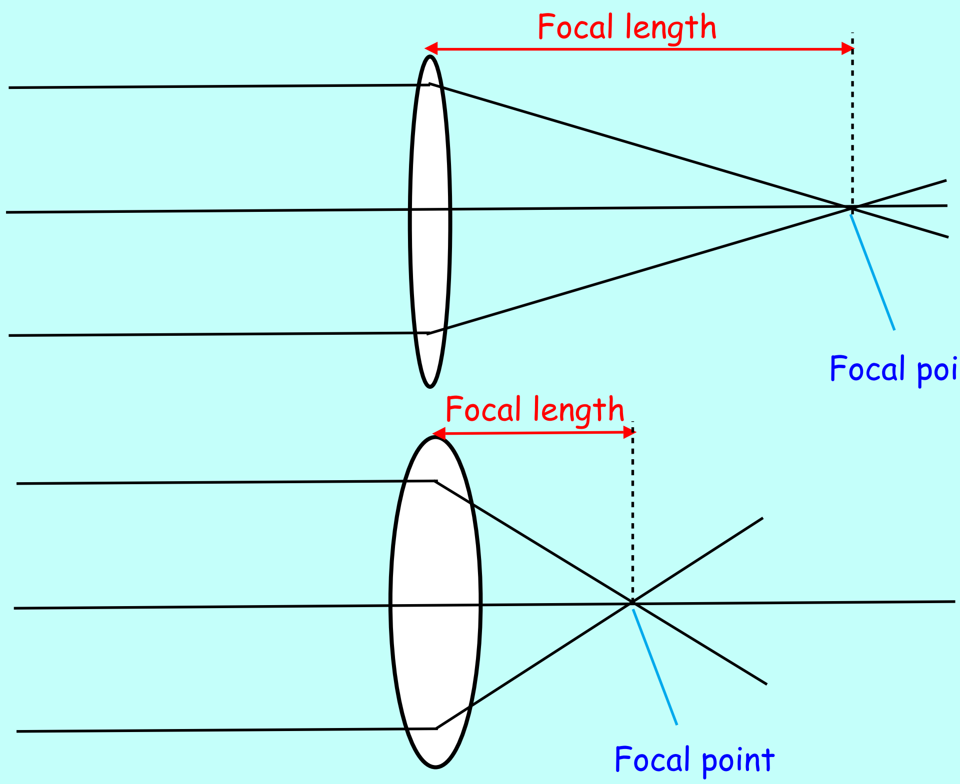
N4 & N5



Lenses are used to refract light.
The ray diagrams below show the effect of converging and diverging lenses on parallel rays of light.

Convex Lens or Converging Lens

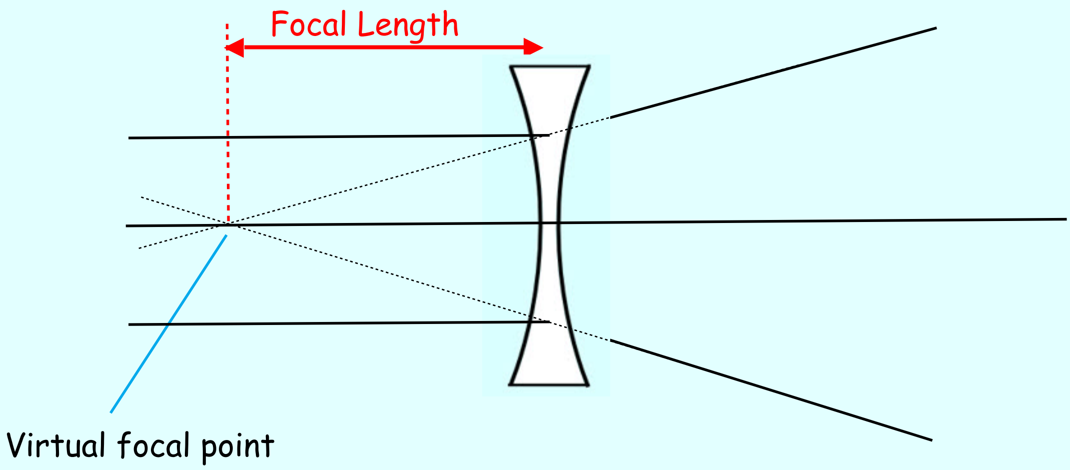
N4 & N5



The lens with more curvature has a shorter focal length.

Concave or Diverging Lens

N4
&
N5

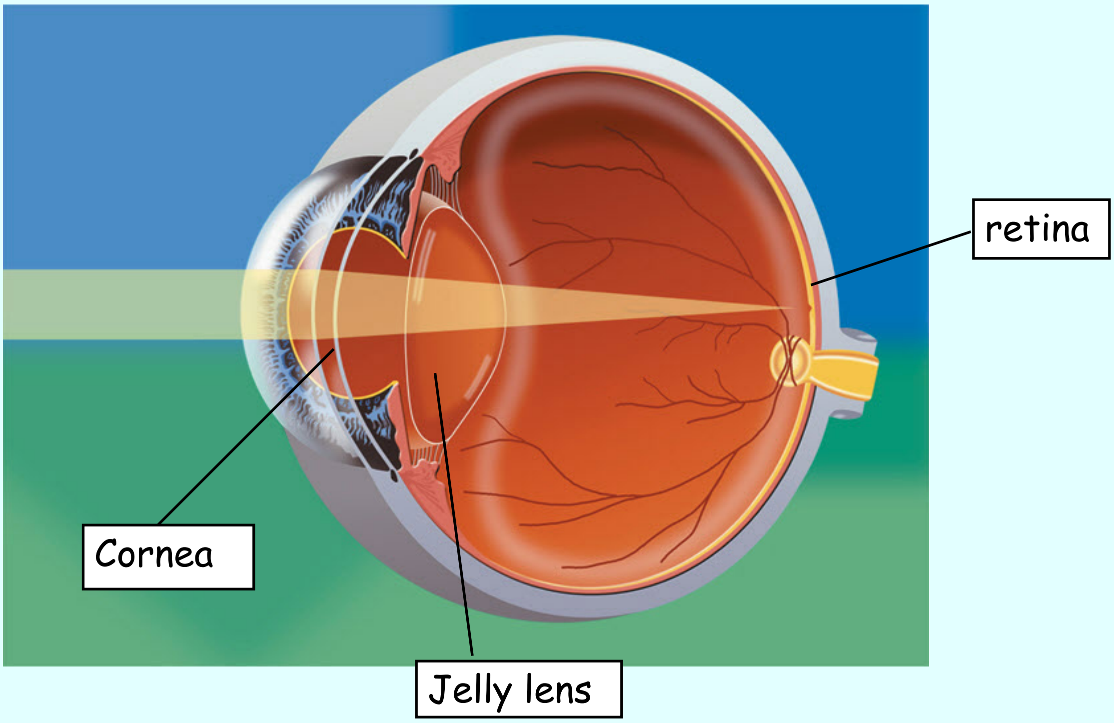


The concave lens diverges the light.

Normal, Long and Short Sight

Normal Vision

N4

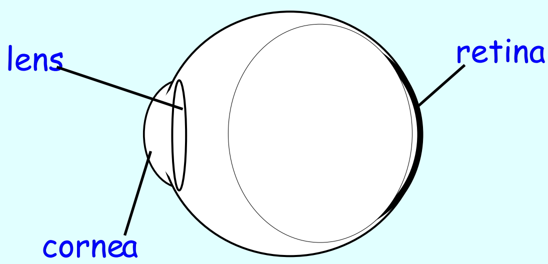


Light enters the eye and is refracted by the cornea and the jelly lens. A sharp image is produced when the light is brought to a focus on the retina. A person with normal sight can bring the light from near and distant objects to a focus on the retina.

Eye Diagram

N4

To the right is a very simple diagram of parts of the eye. The cornea and lens cause the light to change direction. The retina picks up the light and send a signal to the brain which allows us to 'see'.

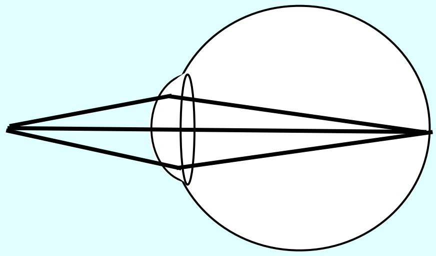


Normal sight

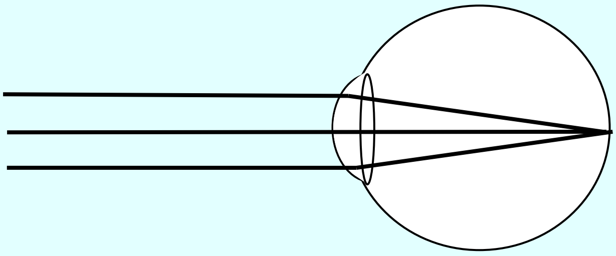
N4

In normal sight any light that enters the eye from near and distant objects is focused on the retina to produce a sharp image. This allows a person to see objects, positioned at different distances from the eye.

Light from a near object enters as diverging rays.



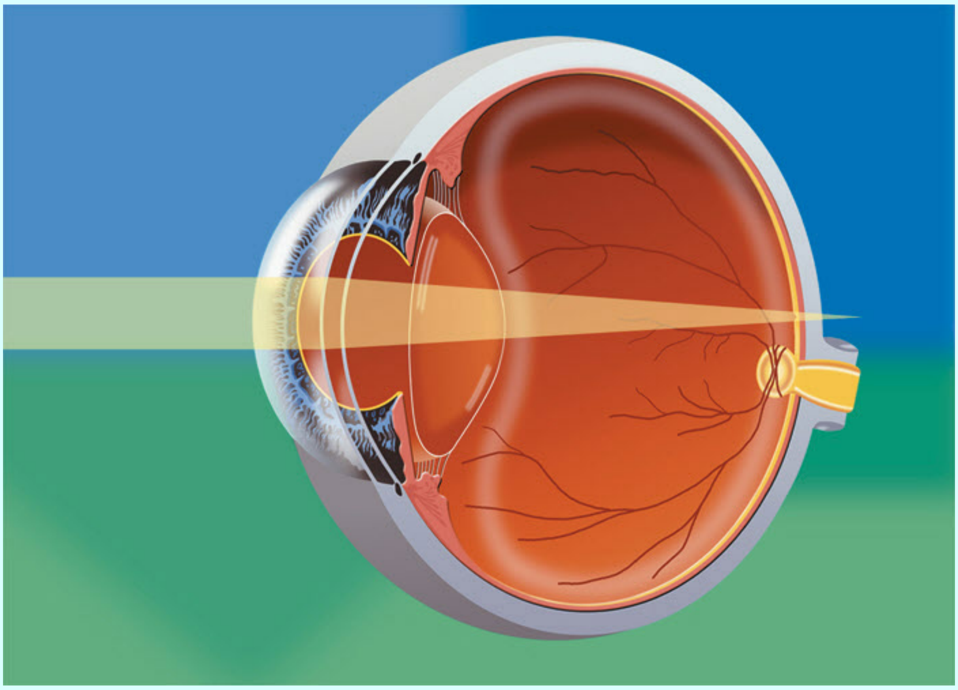
Light from a distant object enters as parallel rays.



No corrective lenses are required.

Long Sight

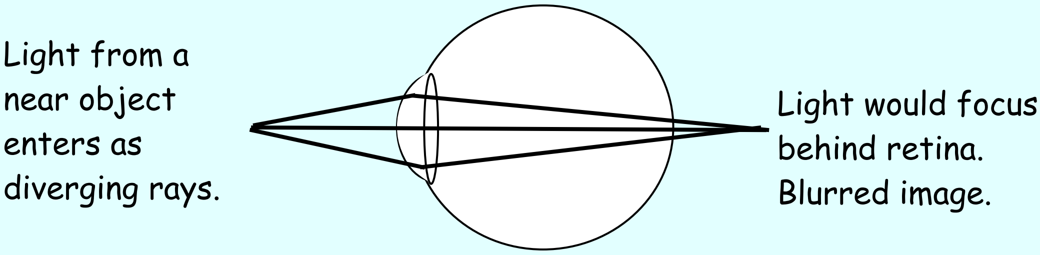
N4

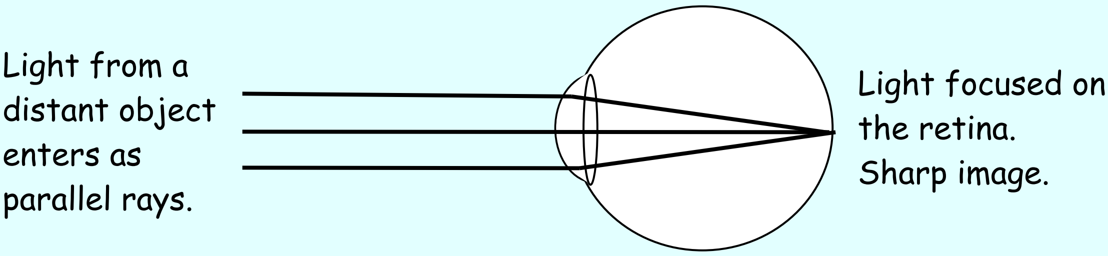


In long sight the light entering the eye from objects near the eye is focused 'long' of the retina. This means the person sees a blurred image of near objects. However, images of distant objects are sharp because the eye has enough refracting power to focus this light on the retina

Diagrams of Long Sight

N4

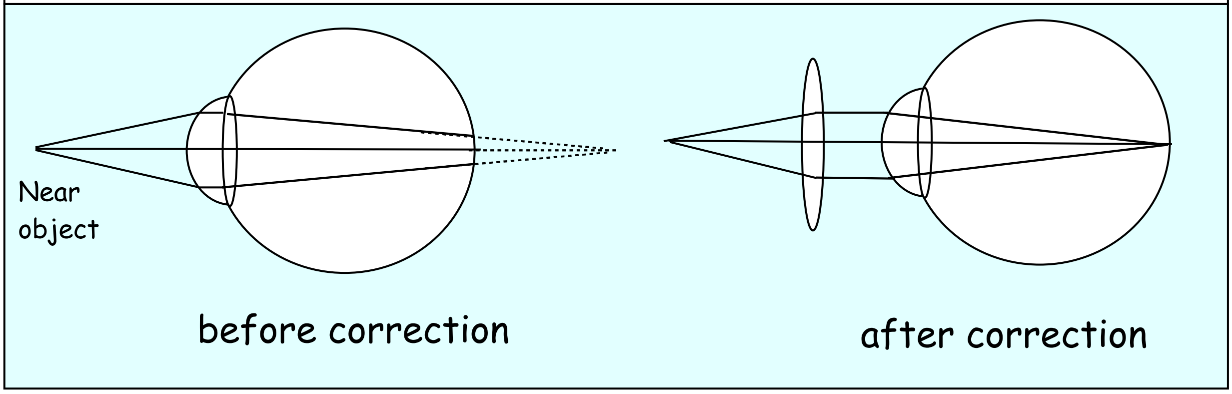




Correction of Long Sight

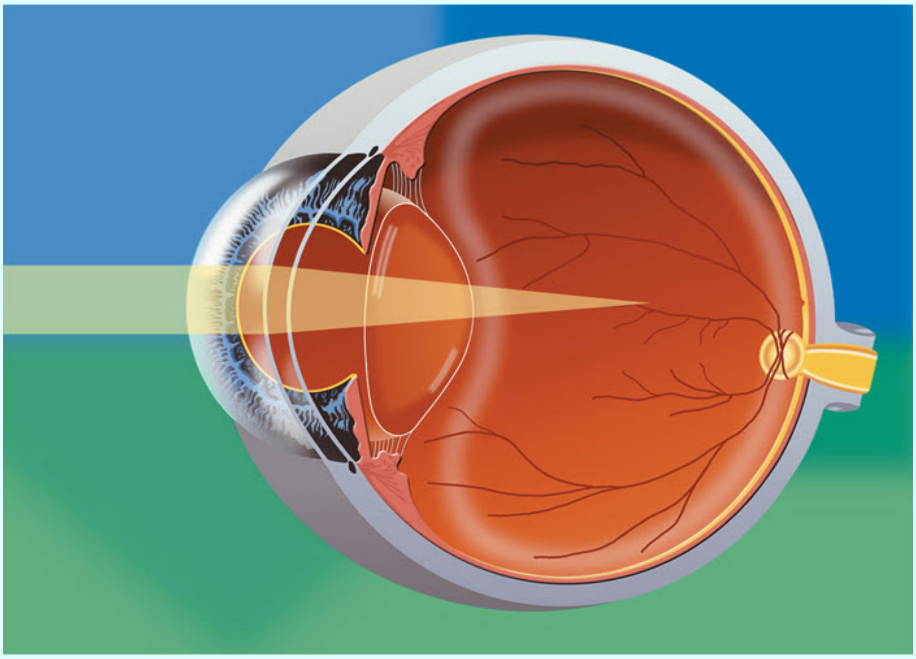
N4

To correct long sight the light must be made to focus on the retina. A converging lens will cause this to happen. A converging lens, of the correct refracting power, is placed in front of the eye.The person will see clearly when light focuses on the retina.



Short Sight

N4

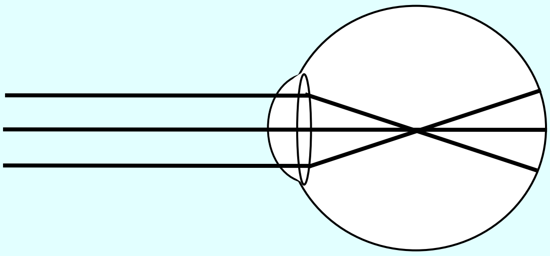


In short sight the light entering the eye from distant objects is focused 'short' of the retina. This means the image of distant objects appears blurred to a person with short sight. However, a short sighted eye can focus the light from near objects on the retina producing a sharp image of these objects.

Diagrams of Short Sight

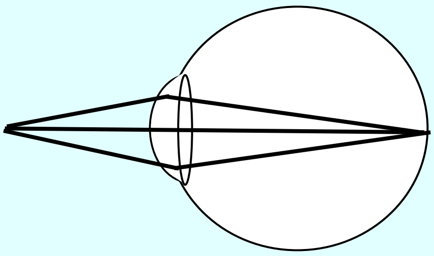
N4

Light from a distant object enters as parallel rays.



Light focused before the retina.
Blurred image

Light from a near object enters as diverging rays.

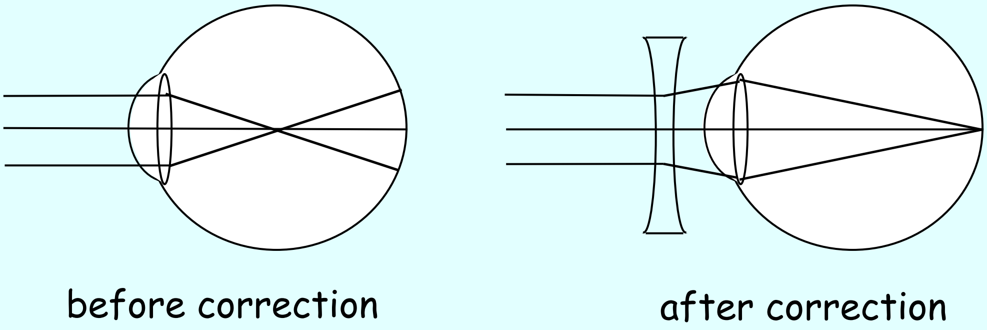


Light focused on the retina.
Sharp image.

Correction of Short Sight

N4

To correct short sight the light must be made to focus on the retina. A diverging lens will cause this to happen. If a diverging lens, of the correct refracting power is placed in front of the eye, the person will see clearly.



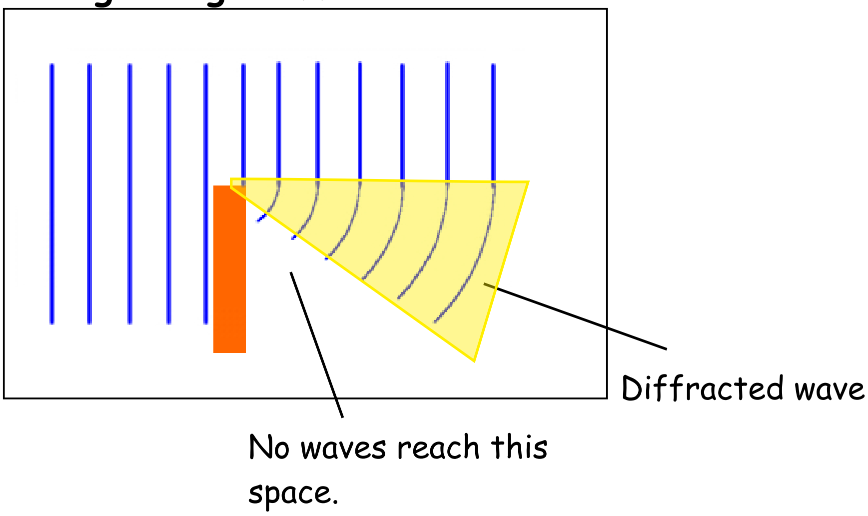
Diffraction of Waves

Another property of waves is diffraction. This is the ability of waves to bend around obstacles or pass through gaps. When the gap is about the same size as the wavelength of the wave, circular wave-fronts are produced that spread out as they move away from the gap.

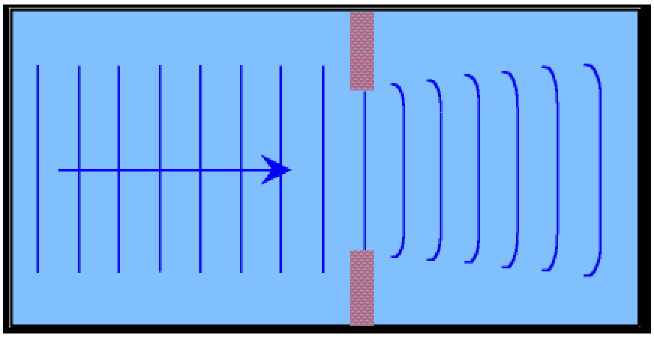
Diffraction of Waves

N5

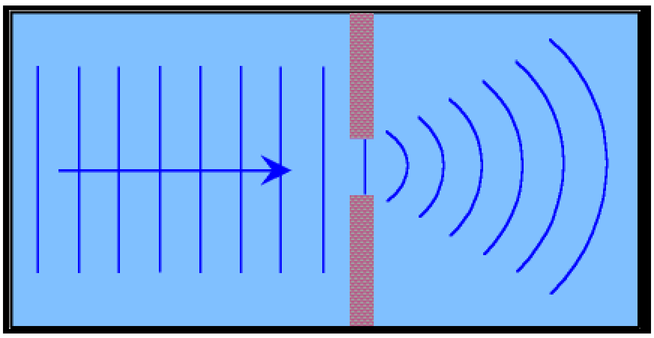
Single Edge diffraction



Diffraction through a gap (double edge diffraction)



When the width of the gap is much greater than the wavelength diffraction effects are less.



When the width of the gap is about the same width as the gap more diffraction occurs.

A very important point in physics is that longer wavelength waves diffract more than shorter wavelength waves.

Learning Outcomes: The Electromagnetic Spectrum

N4/5 1. I can state that Electromagnetic waves are a group of transverse waves.

N5 2. I can arrange electromagnetic waves in order of frequency or wavelength.

N5 3. I can state that EM waves transfer energy and higher frequency EM waves transfer more energy than lower frequency ones.

N5 4. I can state that all EM waves travel at $\mathbf{3 \times 10^8\ ms^{-1}}$ in air.

N5 5. I can use the equations $v = d/t$ and $v = f\lambda$ with EM waves.

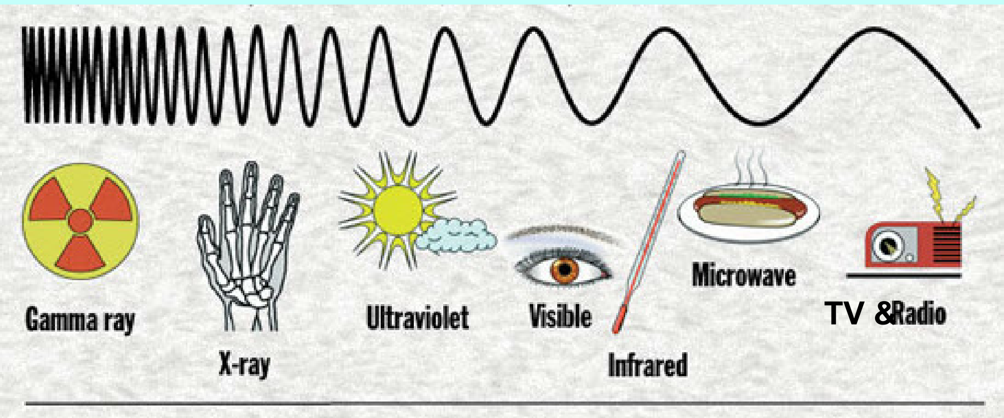
N4/5 6. I can describe sources, applications and uses, detectors and dangers of electromagnetic radiation.

N5 7. With reference to diffraction I can explain why the reception of longer wavelength radio-waves is better than shorter waves in hilly areas.

The Electromagnetic Spectrum

N4 & N5

This is a family of transverse waves with similar properties.



Highest frequency

Short est wavelength

Lowest frequency

Longest wavelength

Electromagnetic waves in order - highest to lowest frequency

N5

- Gamma rays (highest frequency/shortest wavelength)
- X-rays
- Ultraviolet
- visible light
- Infrared
- Microwaves
- TV and radio (lowest frequency/longest wavelength)

Energy of EM Waves

N5

All waves carry energy. The higher the frequency of an EM wave the more energy it carries. Gamma radiation has the highest frequency and therefore has the most energy.

Speed of EM Waves

N5

In air all EM waves travel at 3×10^8 ms^{-1}

EM waves from Space (Background Information)

Unlike sound waves EM waves do not require a material made of particles to travel through. As a result of this they can all travel large distances through the vacuum of space.

Large radio telescopes detect non-visible radio-waves reaching the Earth from space.

Similar Properties of all EM waves

N5

All Em waves can be reflected, refracted and diffracted. Refraction and diffraction are effects that depend on the wavelength of the electromagnetic wave.

- Longer wavelength diffract more than shorter ones.
- Shorter wavelength light refracts more than longer wavelengths.

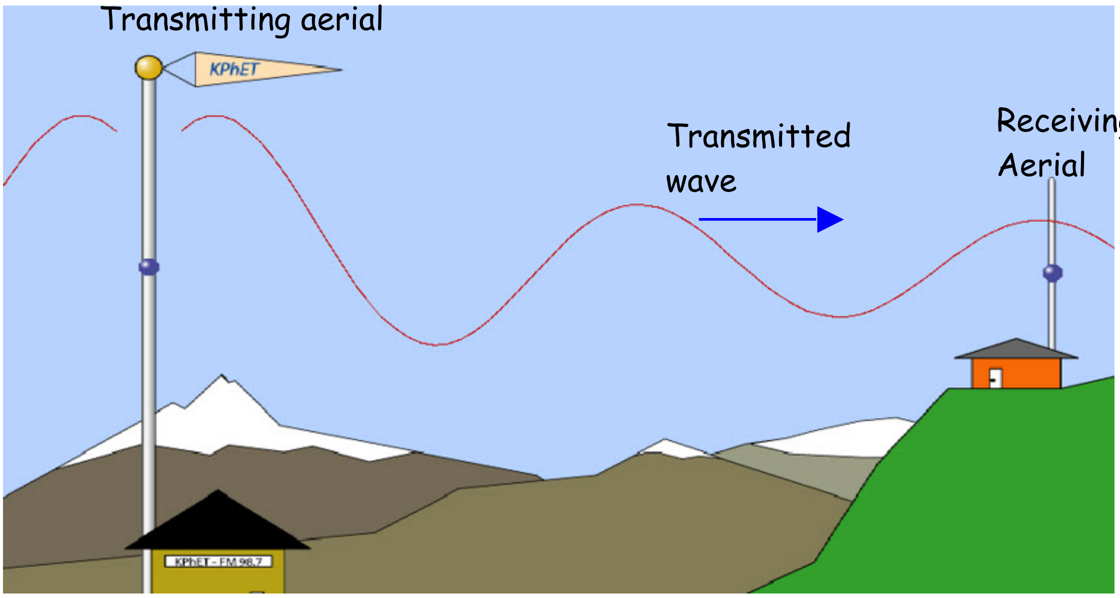
TV and Radio Waves

N4 & N5

These are the longest wavelength and Lowest frequency EM waves. They travel through the air at 3×10^8 ms^{-1} and can be produced by various types of transmitter. They are also given off by stars, sparks and lightning, which is why you hear interference on your radio in a thunderstorm.

Use: To carry video and or audio information.

N4 & N5

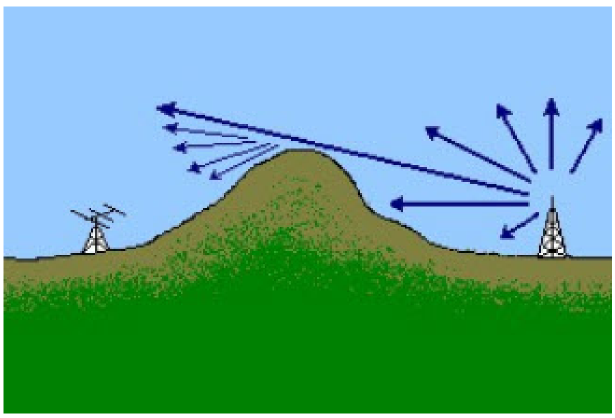


Good reception at the receiving aerial occurs when the transmitted wave reaches the aerial with enough energy to be picked up.

Poor Reception

N5

This can result from the receiving aerial being too far away from the transmitter meaning that the amplitude of the transmitted wave is too small and not carry enough energy to be picked up by the receiving aerial.

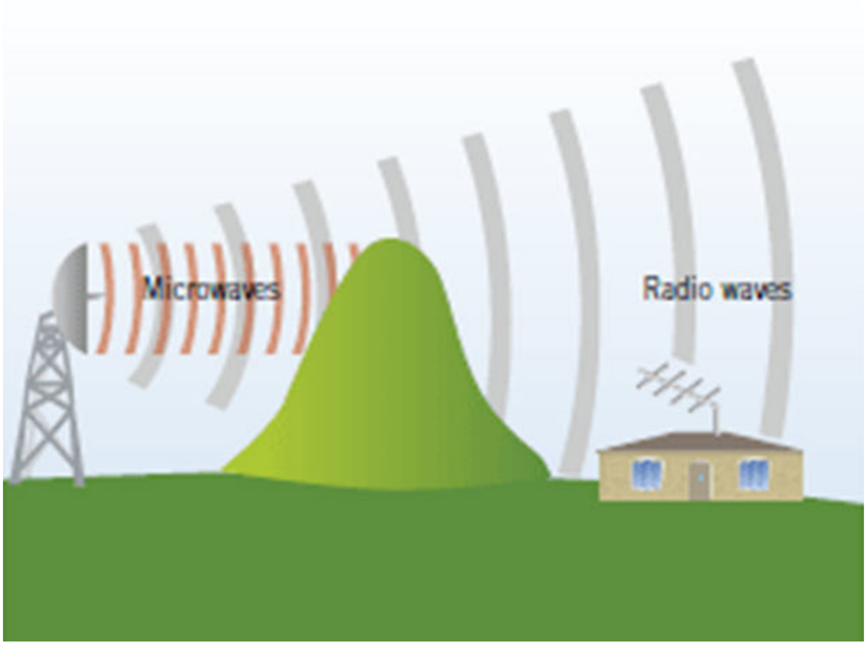


Another reason for poor reception can be physical barriers that absorb the transmitted wave energy. Natural obstacles like hills can result in a loss of reception, particularly of short wavelength higher frequency waves.

Diffraction of Waves around a Hill

N5

As a result of longer wavelength waves diffracting more than shorter wavelengths the reception of long wave radio is better in hilly areas The diagram illustrates that shorter wavelength microwaves cannot diffract as well as the longer wavelength radio waves around the hill.



Dangers of Radio Waves

N4

Large doses of radio waves are believed to cause cancer, leukaemia and other disorders.

Some people claim that the very low frequency field from overhead power cables near their homes has affected their health.

Microwaves

N4 & N5

Microwaves are a form of electromagnetic radiation with a wavelength (λ) of about 3 cm.
They are basically high frequency radio waves,.

Sources of Microwaves

N5

In a mobile phone, they're made by a transmitter chip and an antenna, in a microwave oven they're made by a "magnetron". Stars also give off microwaves.

Detectors of Microwave Radiation

N4 & N5

Microwaves may be detected with solid-state semiconductor diodes.

Uses of Microwaves

N4 & N5

Microwave Oven

Microwaves cause water and fat molecules to vibrate, which makes the substances hot. So we can use microwaves to cook many types of food.

N4 & N5

Mobile Phones

Mobile phones use microwaves, as they can be generated by a small antenna, which means that the phone doesn't need to be very big. The drawback is that, being small, they can't put out much power, and they also need a line of sight to the transmitter. This means that mobile phone companies need to have many transmitter towers if they're going to attract customers.

Speed Cameras and Radar

N4 & N5

How They Work

The most common type of radar works by sending out bursts of microwaves, detecting the "echoes" coming back from the objects they hit, and using the time it takes for the echoes to come back to work out the distance away the object is.

Dangers

N4

Prolonged exposure to microwaves is known to cause "cataracts" in your eyes, which is a clouding of the lens, preventing you from seeing clearly (if at all!)

Recent research also indicates that microwaves from mobile phones can affect parts of your brain - after all, you're holding the transmitter right by your head. Other research is inconclusive, although there is a feeling that you're more vulnerable if you're young and your brain is still growing. So the advice is to keep calls short.

Infrared Radiation (IR)

N4 & N5

Infra red waves have a longer wavelength than red light and a lower frequency.

Sources of IR

N4 & N5

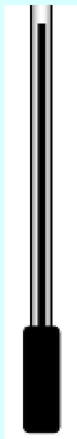
Any hot object emits infrared radiation. This includes stars, lamps, flames and anything else that's warm - including you.

Detectors of Infrared

N4 & N5

Infra red radiation cam be detected by semiconductor devices like photo-transistors. Black bulb liquid in glass thermometers can also be used as a simple detector.

Phototransistor



Blackened bulb thermometer

Thermal Imaging

Thermal imaging cameras can also be used to detect infrared radiation.

Uses of IR Detectors

N4 & N5

Search and Rescue

Infrared radiation is given out by any object that is warmer than its surroundings. This property is used to allow firefighters to use a special camera to find people in smoke filled rooms.

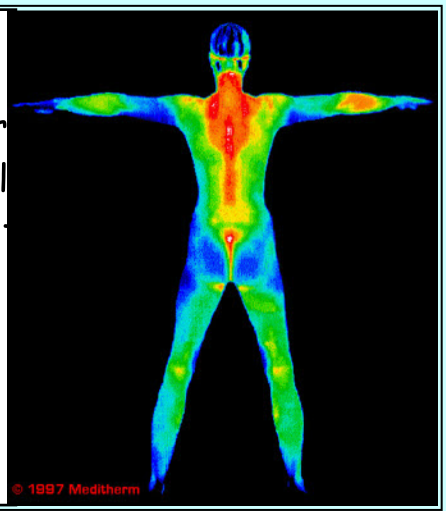
Catering Industry

Lamps producing infrared radiation can be used to help keep food warm.

Medical Uses: Diagnosing Illness and Heat Treatment

Infrared can be used to examine patients, looking at the temperature of different par of their bodies. Often medical problems will cause the temperature of part of the body change.

In medicine infrared lamps are also used to help heal muscle injuries.



Remote Controls

Infra red is also used to transmit the information from remote controls for TVs and dvd players.

Dangers of Infra Red

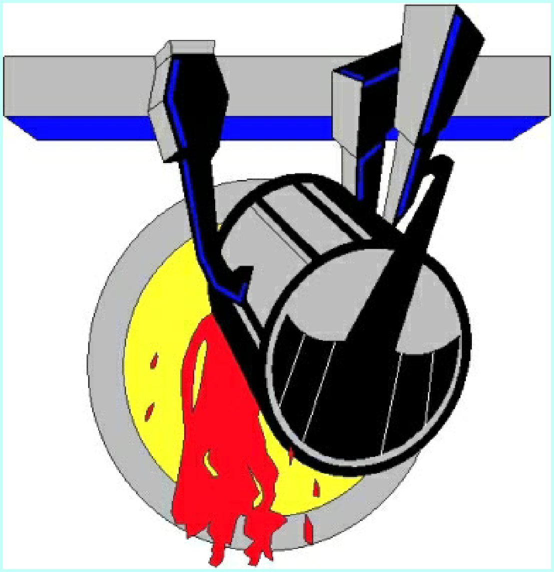
N4

IR radiation will simply heat up any living tissue it touches upon. The only hazard in most cases is that prolonged exposure to a very high level of IR could result in a burn.

High Exposure to IR

N4

Workers who are exposed to close-up, high levels of IR over many years, such as those working with molten glass or steel, have been found to have increased incidences of eye cataracts as a result.



Higher Frequency Shorter Wavelength EM Radiation

N5

The higher the frequency of a wave the more energy it carries. High energy waves can be harmful to living cells.

Biological Damage

N4 & N5

Ultra Violet (UV), gamma radiation and x - rays can kill or damage living cells. Exposure to this type of radiation, in high doses, can cause radiation burns and cancer.

Ultra Violet Radiation (UV)

N5

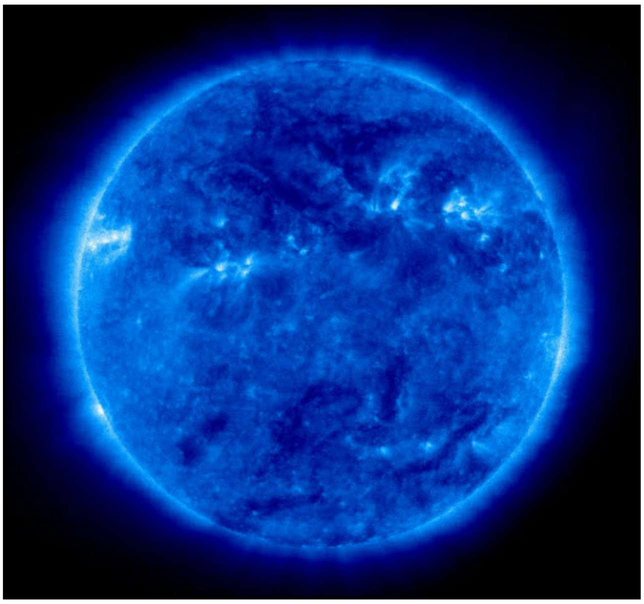
This is radiation with a frequency higher than visible light and a shorter wavelength.

Source of UV

N4/5

The main source of UV radiation on Earth is the sun.

Mercury vapour lamps can by used as an artificial source of UV radiation.



UV (false colour)image of the sun.
UV is invisible to humans.

Detectors of UV

N4 & N5

Ultraviolet radiation will cause fluorescence in certain materials. This fluorescence, or glowing of materials under UV light can be used to detect the presence of UV radiation.

Dangers of UV Radiation

N4

This can cause sunburn and skin cancer.

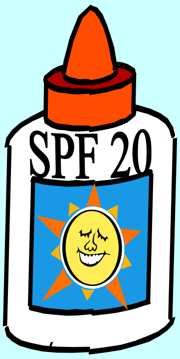
sunburn

Skin Cancer

Protection from UV

N4

Sunburn and skin cancer can be prevented by keeping sunlight exposure as low as possible. This can be done by staying out of direct sunlight, particularly in the middle of the day. Also, the use of protective clothing, including hats, and the use of high sunlight protection factor SPF sunscreens protects the skin. Damage to the eyes can also be prevented by wearing sunglasses that filter out harmful UV rays.



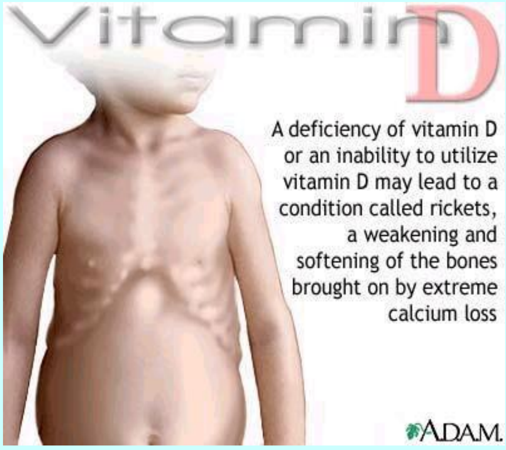
Uses of UV Radiation

Treating acne and vitamin D deficiency

N4 & N5

Ultraviolet radiation (UV) is used to help treat skin complaints such as acne. It is also used to treat patients who have a deficiency in vitamin D.

Although UV can be used as a treatment it is only safe if used under strict medical supervision.



Treating Jaundice

N4 & N5

Jaundice of newborn babies is quite common because of the immaturity of the baby's liver cells and the higher than normal rate of cell breakdown that occurs in the first few weeks of life. This leads to a build up of a naturally occurring substance in the blood called bilirubin .

Treatment with UV radiation

In hospitals lights that emit a limited range of ultraviolet light waves, safe for the newborn's skin can be used in severe cases.

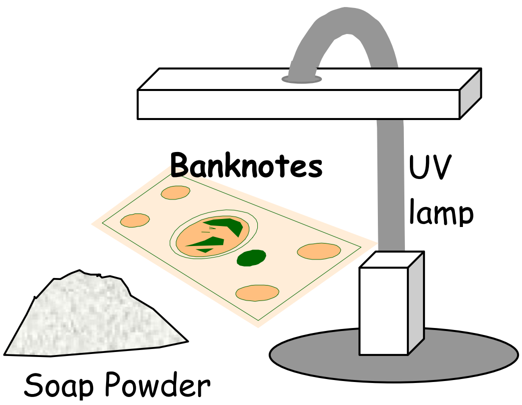
Sterilising water

N4 & N5

The UV light kills germs and bacteria and parasites.

Non Medical Use of UV

N4 & N5



Non medical uses of UV tend to involve fluorescence. This is when materials glow brightly when UV light shines on them. It is used in security markings, banknote identification. Soap powder makers include chemicals that glow to make 'whites whiter'.

X-rays

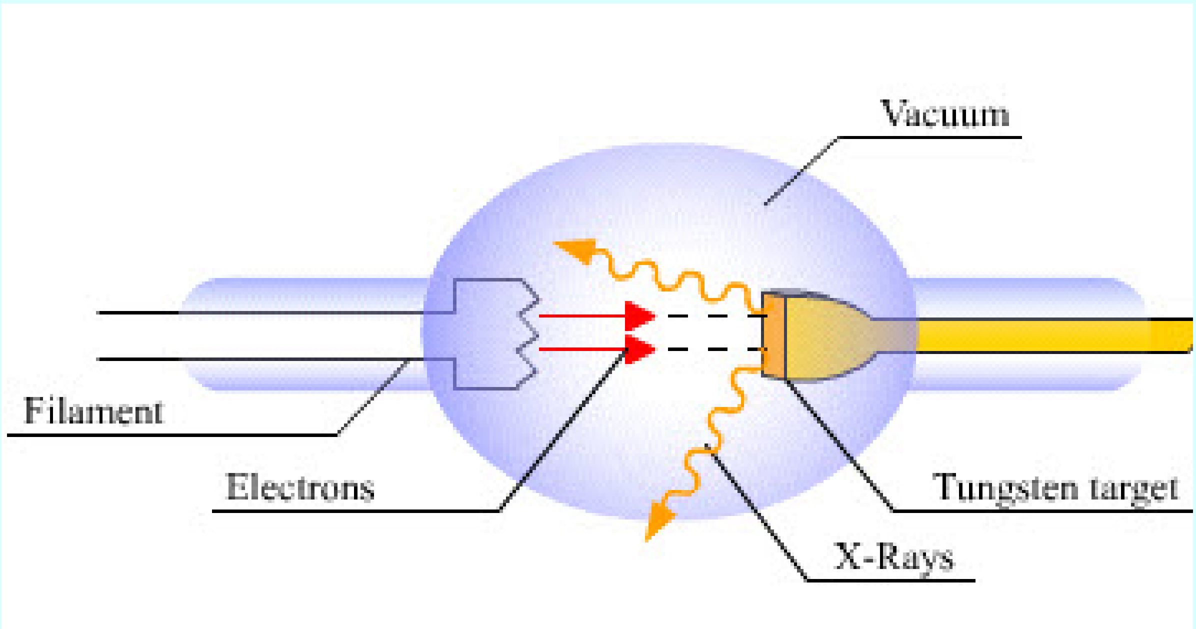
N4 & N5

X-rays are even higher frequency than UV radiation. They carry more energy that UV, can kill or damage living cells and are invisible to the naked eye.

Sources of x - rays

N4/5

X -rays can be produced by accelerating electrons, using a large potential difference, up to high speeds and then colliding them with a metal target. The rapid deceleration of the electron results in the emission of x-rays.



Detecting X-rays

N4 & N5

One way to detect x-rays is by using the fact that x-rays darken photographic film. However, modern detectors used for radiography mostly use digital detectors using semiconductors such as image plates or flat panel detectors. The electronic images produced are digitally stored and can easily be accessed by medical staff.

Medical uses of x-rays

Producing Images of Bones or Tissues

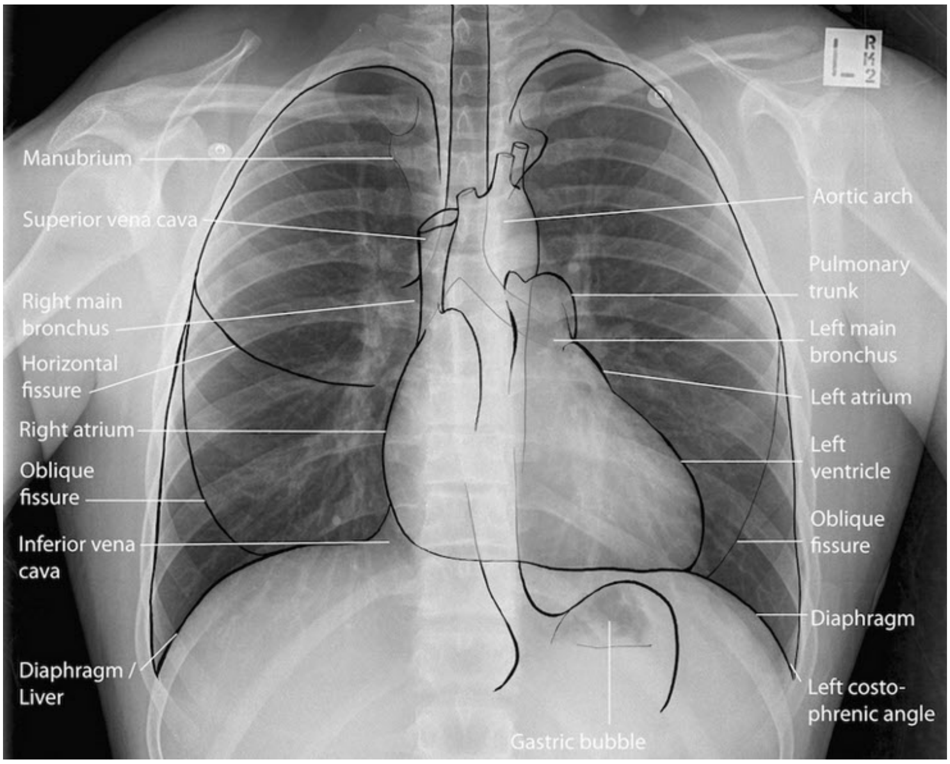
N4 & N5

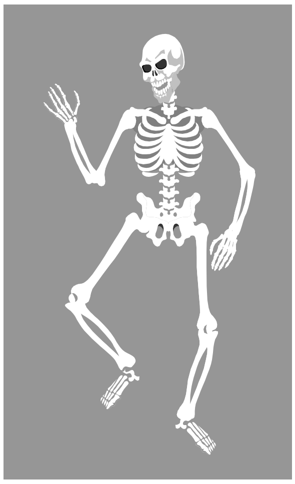
When a medical x-ray is taken the rays are directed towards the part of the body under investigation. Behind this part of the body is photographic film.

The x-rays reach the film blacken it and that part of the developed film will be darker.

As it is more difficult for the rays to pass through dense bone than muscle the film behind the bones is less blackened and the bones show up lighter on the developed film.

The dose of x-rays used is kept low to minimise the damage to healthy cells.





Other Use of X-Rays

Airport Security

N4 & N5

Dangers of x-rays

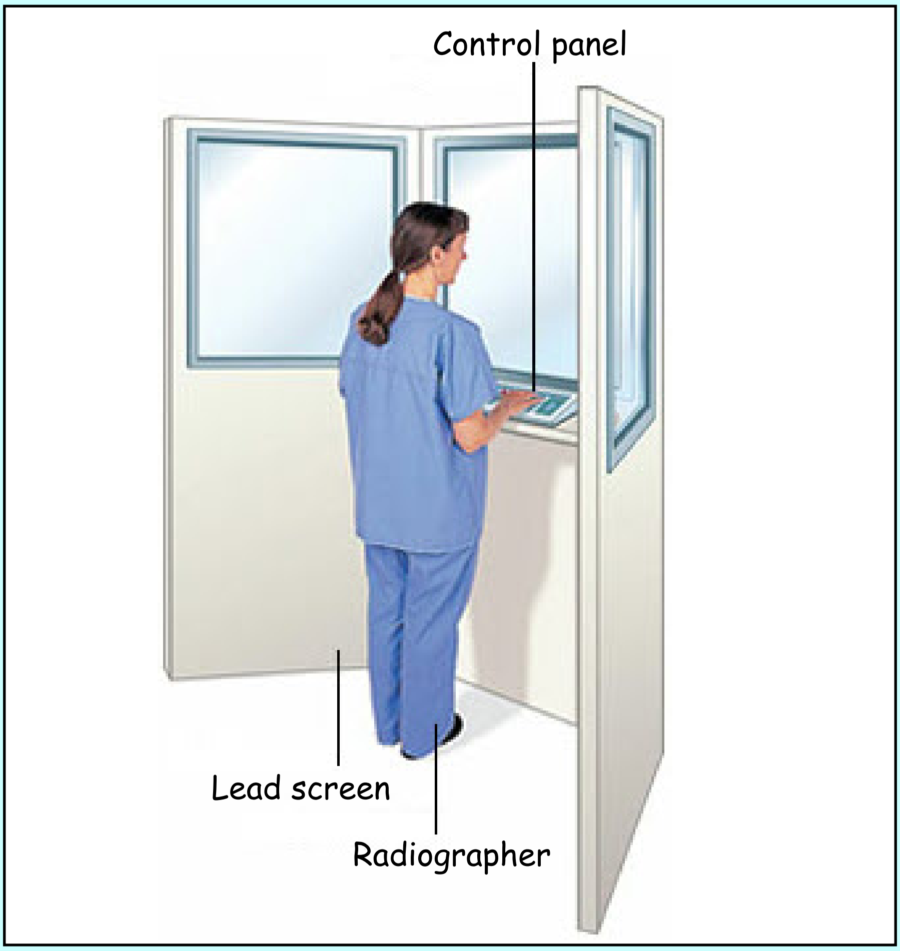
N4 & N5

The high energy of x-ray radiation can kill or damage living cells.

X-ray Operators

N4 & N5

Workers who operate x-ray machines must protect themselves from the damage that can by caused by the x-rays. This is normally done by standing behind lead screens that absorb the energy of the x-rays.

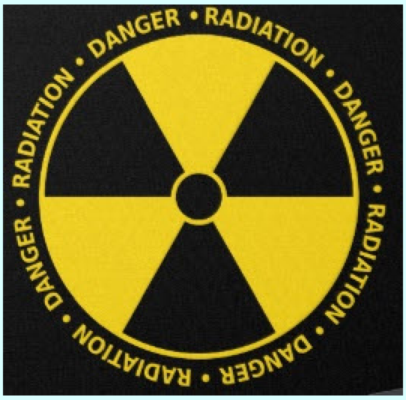


Gamma Radiation

Gamma Rays

N5

Gamma rays are the highest frequency and shortest wavelength electromagnetic radiation and cannot be seen with the naked eye. They are very penetrating and have the highest energy of all the electromagnetic radiations. Because of this they are dangerous and can damage or kill living cells.



Sources of Gamma Radiation

N4 & N5

The main source of this radiation is from the radioactive decay. For example, cobalt - 60, the radioactive form of the element cobalt, decays with the emission of gamma radiation

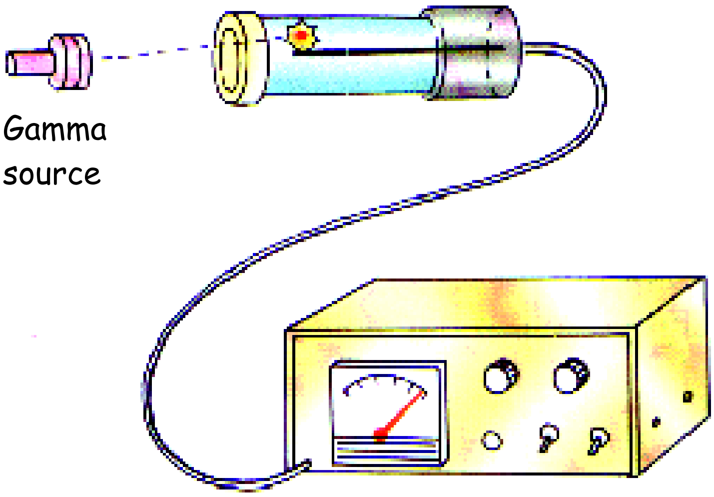
Dangers of Gamma Radiation

N4 & N5

Gamma rays cause cell damage and can cause a variety of cancers .They also cause mutations in growing tissues, so unborn babies are especially vulnerable.

Detection of Gamma Radiation

N4
&
N5



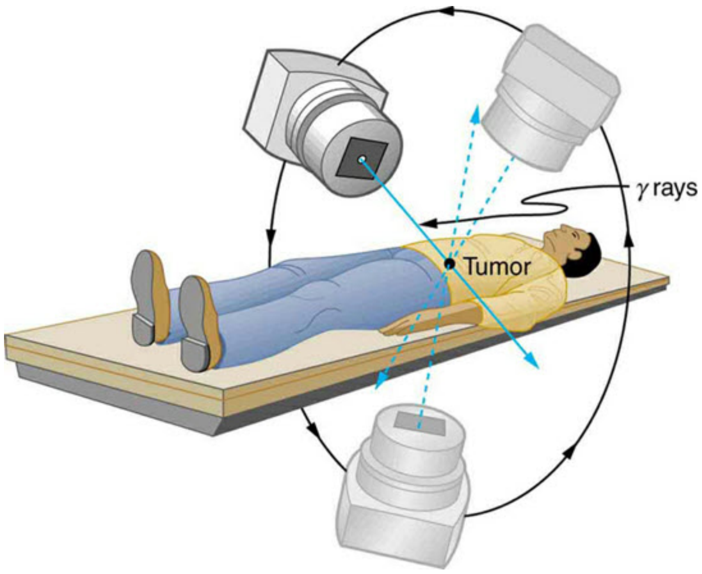
The gamma radiation entering the tube ionises the gas inside. This results in pulses of current that can be measured.

Uses of Gamma Radiation

1. Treating Cancer

N4 & N5

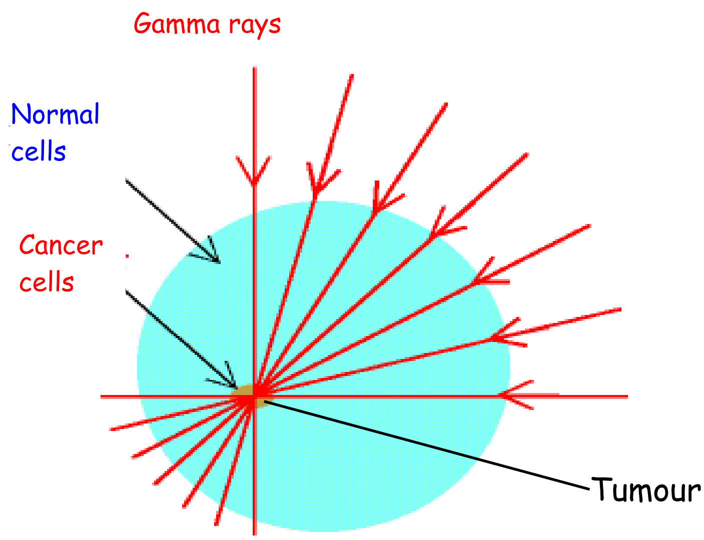
Radiation can be used in the treatment of cancer. The radioactive source, cobalt-60 emits gamma radiation that kills cancer cells. The source is rotated around the body, centred on the cancerous tissue, so the cancerous cells receive radiation all the time. However, as the source is moving the healthy tissue only receives the radiation for a short time and is therefore damaged less and can recover.



Note

High energy x-rays can also be used for this.

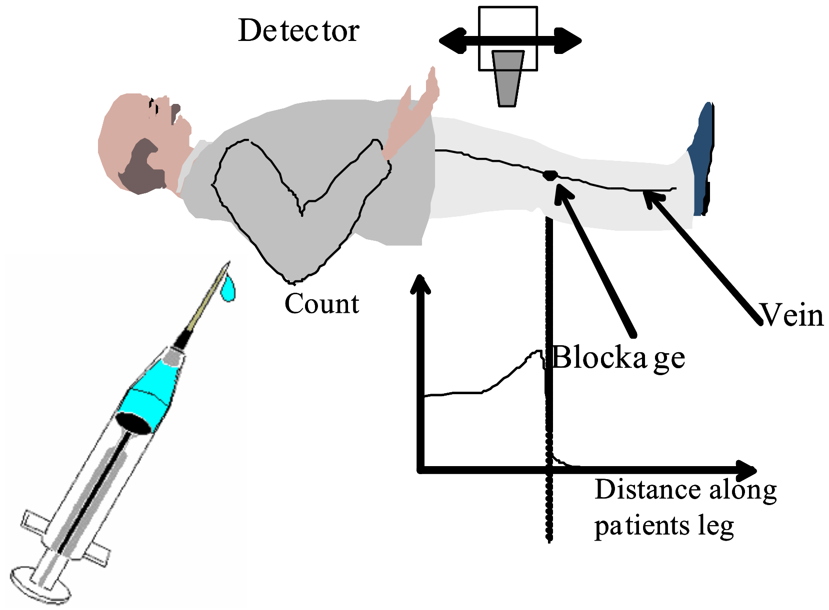
Illustrative Diagram



2. Tracers (1)

N4 & N5

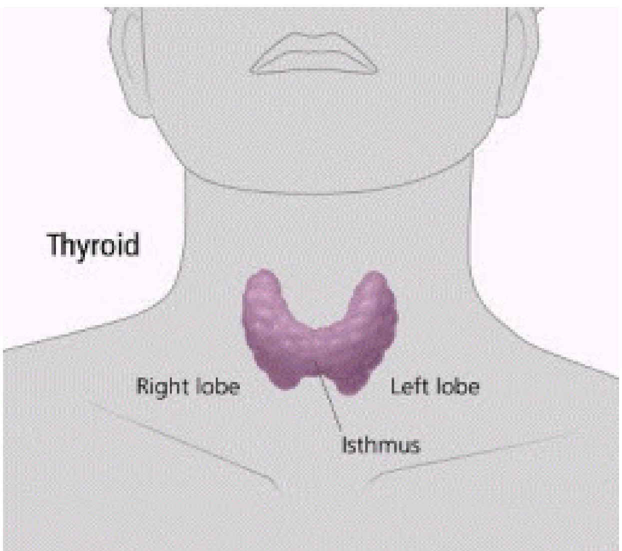
Radioactive tracers that emit gamma radiation help doctors to examine the insides of our bodies. A tracer can be injected into the bloodstream and monitored with a detector outside the body. This can identify blockages where the blood is not flowing as expected.

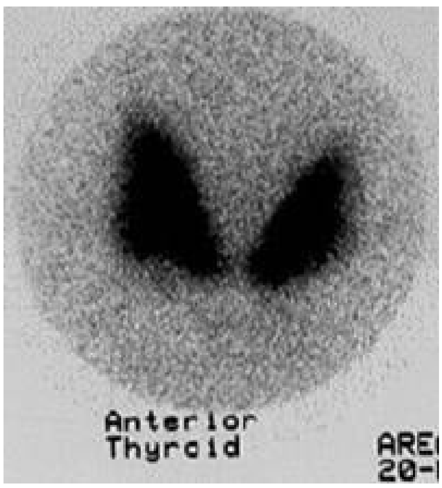


Tracers (2)

N4 & N5

Another tracer, iodine-131, is used to see if our thyroid glands are working properly. The thyroid gland controls the rate at which our body functions. The thyroid gland absorbs iodine, so a dose of radioactive iodine (the tracer) is given to the patient. Doctors can then detect the radioactivity of the patient's throat, to see how well the patient's thyroid is working.





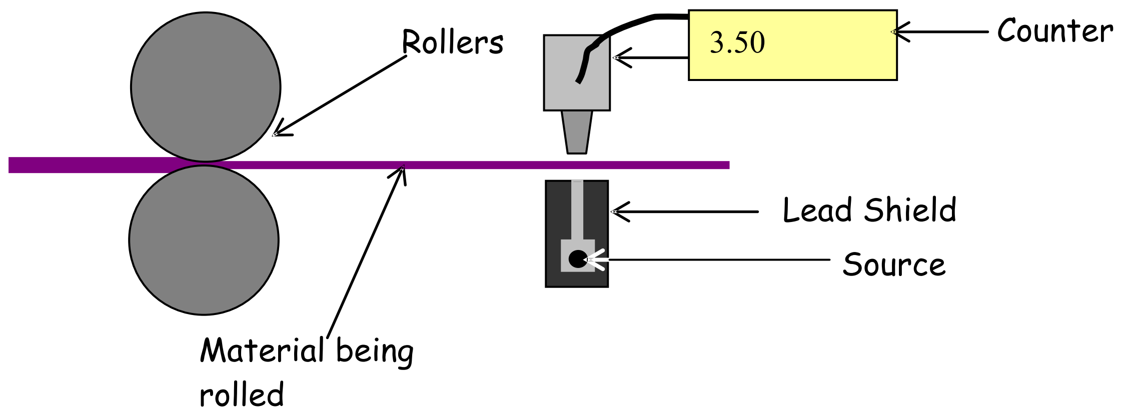
Sterilisation of Medical Equipment

N4
&
N5

Gamma radiation kills harmful living organisms.

Monitoring Material Thickness

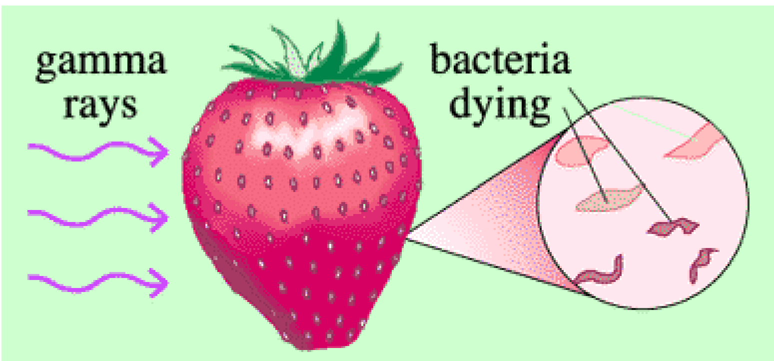
N4 & N5



The detector is placed directly above the source. The meter records the count. If the thickness of the material changes the meter will register a decreased count and the rollers can be adjusted.

Irradiating Food to Increase Shelf Life

N4 & N5



Gamma rays pass through the food killing bacteria making the food last longer before rotting. The food is not left radioactive.

Nuclear Radiation

Learning Outcomes: Ionising Radiations

N5 1. State the three ionising radiations.

N5 2. Describe the nature of these radiations.

N4/5 3. Describe a simple model of the atom which includes protons, neutrons and electrons.

N5 4. State that nuclear radiation is emitted from the decay of an unstable nucleus.

N5 5. State that radiation energy may be absorbed in the medium through which it passes and cause ionisation of atoms.

N5 6. State the range through air and the materials that will absorb alpha, beta and gamma radiation.

N5 7. Explain the term ionisation.

N5 8. State that alpha particles produce much greater ionisation density than beta particles or gamma rays.

N4/5 9. State that everyday exposure to ionising radiation is due to background radiation.

N4/5 10. State the sources of background radiation.

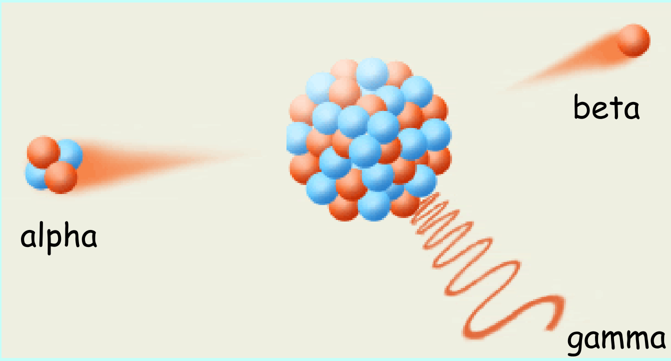
N4/5 11. Describe factors affecting the background radiation level.

Nuclear Radiation

Ionising Radiations

N5

The three ionising radiations are called alpha, beta and gamma. They are all quite different in nature but all cause ionisation.



Alpha particles

N5

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

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

Beta particles

N5

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

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

Gamma rays

N5

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

Symbol: γ

Summary

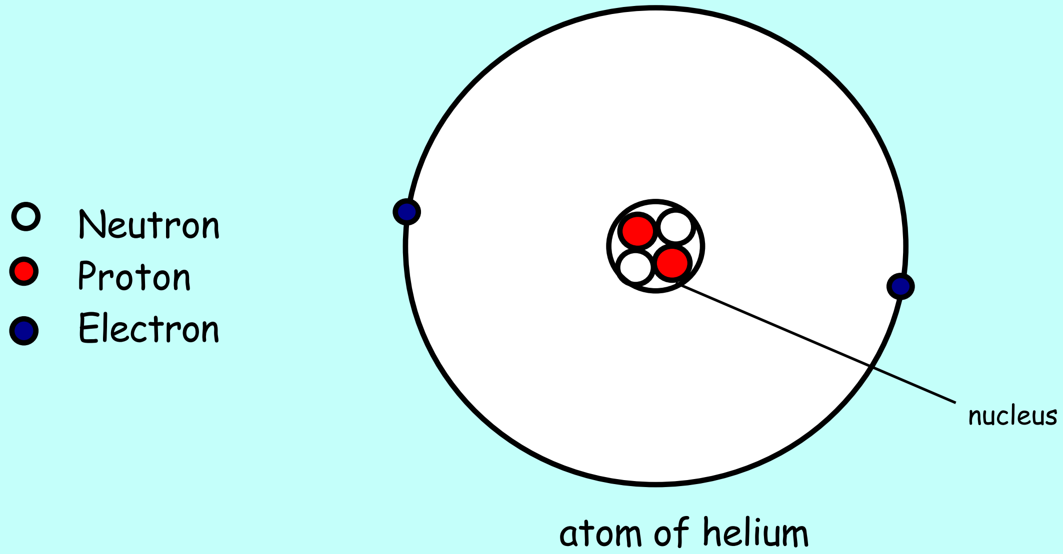
N5

Radiation	Nature	Symbol
Alpha particle	Helium nucleus	${}^{4}_{2}\alpha$
Beta particle	Fast electron	${}^{0}_{-1}\beta$
Gamma ray	High frequency electromagnetic wave	γ

Notice: Gamma radiation has zero mass and zero charge.

The Structure of Atoms and the Nucleus

N4 & N5



Electrons orbit a central nucleus.

The Nucleus

N4 & N5

Inside each atom there is a central part called the **nucleus.** The nucleus contains two particles:

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

Overall the nucleus has a positive charge.

Electrons

N4 & N5

These have a much smaller mass than protons and neutrons, are negatively charged and orbit the nucleus.

Neutral Atoms

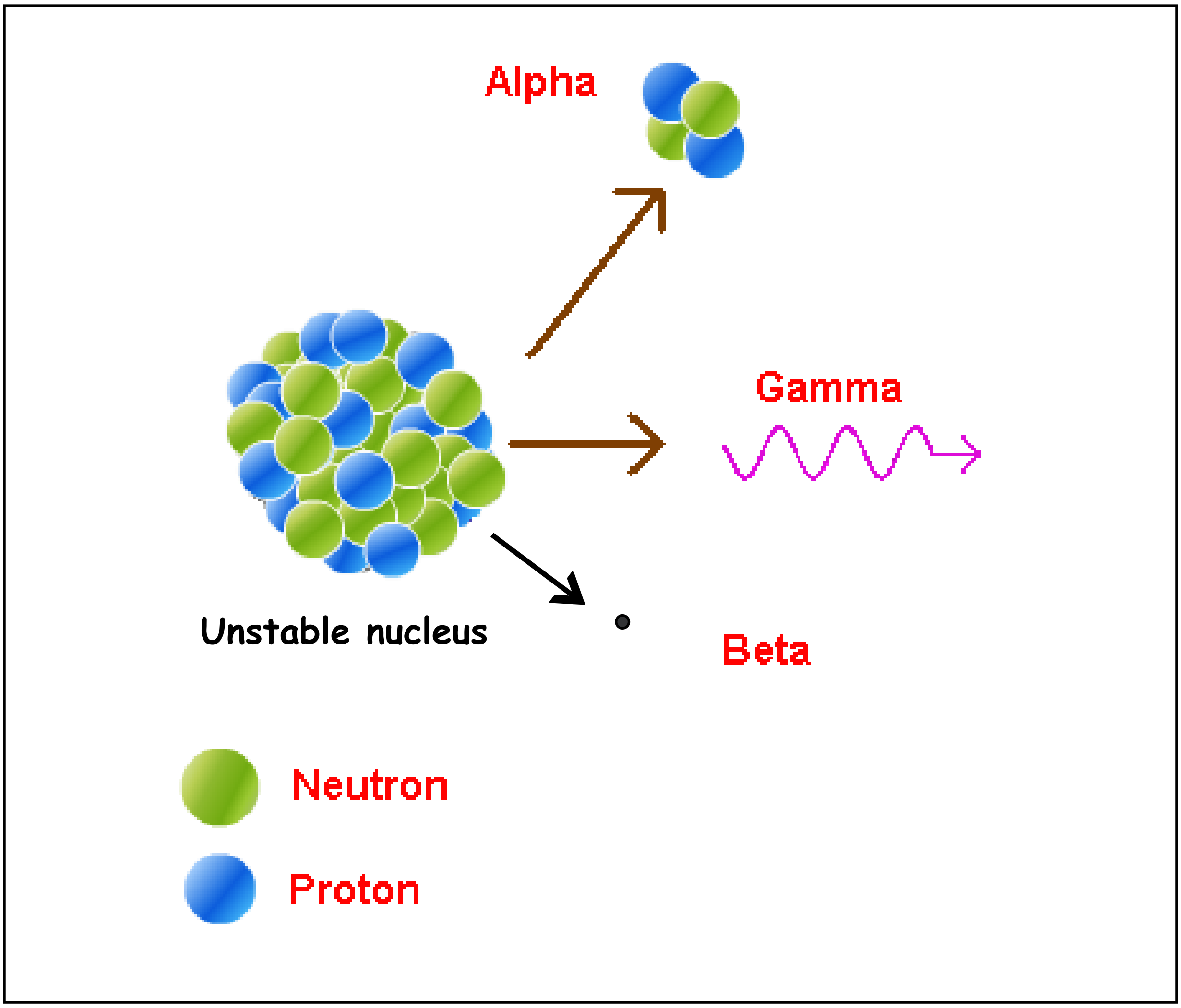
N4 & N5

Overall, the number of positive charges, or protons, is the same as the number of negative charges, or electrons. This gives the atom no overall charge.

Where Radiation Comes From

N4

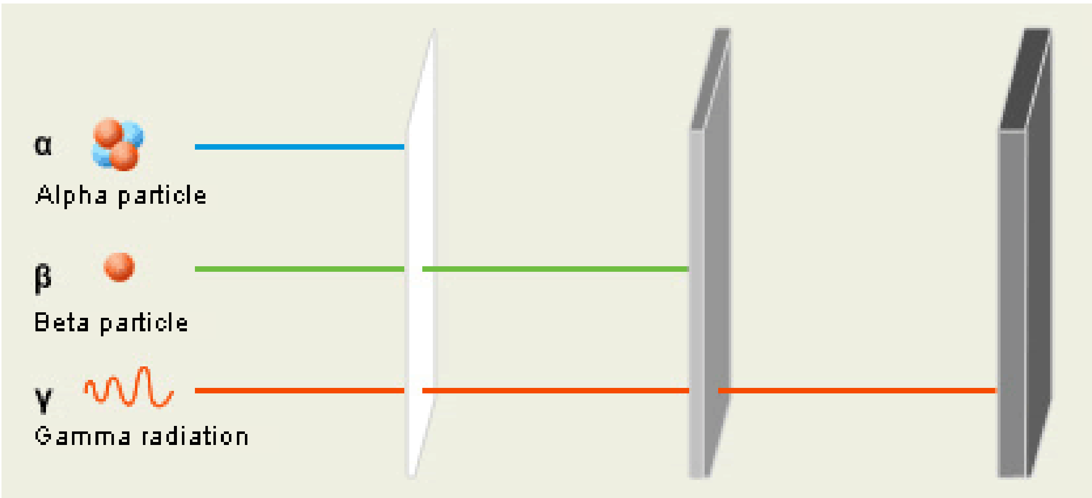
Alpha, beta and gamma radiation are all emitted from the nucleus of unstable elements. When an unstable nucleus disintegrates or decays radiation is emitted. Different nuclei decay to emit specific types of radiation.



Penetration and Absorption of Radiation

N5

As radiation travels through materials its energy gets absorbed. Because of the nature of each radiation the material required to absorb each radiation ranges from a few centimetres of air to thick lead.



paper aluminium lead

Alpha particles

N5

These will travel about 5 cm through the air before they are fully absorbed. They will also be stopped by a sheet of paper.

Beta particles

N5

These can travel several metres through air before being absorbed. The are also absorbed by a sheet of aluminium a few millimetres thick.

Gamma Radiation

N5

This type of radiation can only be stopped by thick dense material like a thick piece of lead.

Absorption and Ionisation

N5

The absorption of radiation energy by a material causes ionisation. This is covered in detail in subsequent pages.

Ionisation

N5

This is the addition or removal of an electron or electrons from a neutral atom. The nucleus of the atom remains unchanged during this process. When an electron is added to an atom a negative ion is formed; when an electron is removed a positive ion is formed.

Ionisation by Radiation

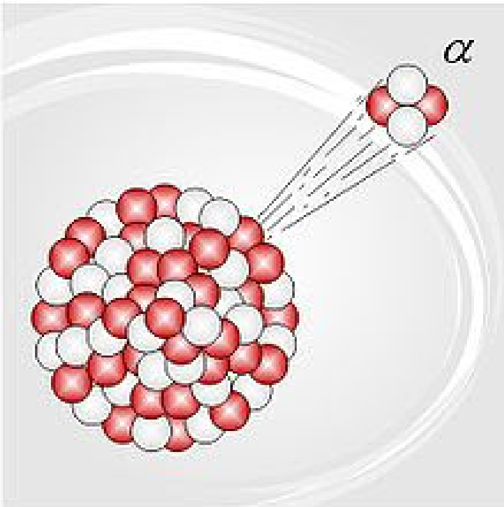
N5

Alpha, beta and gamma radiation have enough energy to knock of electrons from neutral atoms to make positive ions. This is why they are called ionising radiations.

Alpha particles

N5

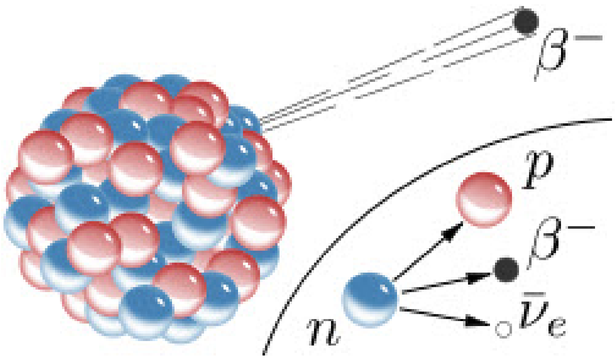
These have **much greater ionisation density** than beta particles or gamma rays. They move much more slowly than beta or gamma radiation. They travel through the air with an initial speed of about 15 million m/s which is 5% of the speed of light.



Beta particles

N5

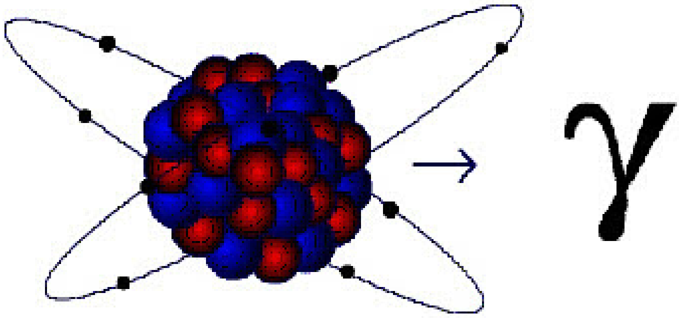
These particles have **a lower ionisation density than alpha** particles. They travel with an initial speed of about 180 million m/s, or about 60% of light-speed



Gamma Radiation

N5

These rays travel at the speed of light and have a very low ionisation density.



Sources of Radiation

Background radiation

N4 & N5

Natural Sources

This is the term used to describe everyday exposure to radiation from sources such as:

- Cosmic rays from space
- Rocks and soil containing traces of radioactive materials
- Radon gas in the atmosphere

Notes:

- Cosmic rays are more intense at high altitudes.
- Granite is more radioactive than brick or sandstone. Areas where there are large amounts of granite have higher background rates, e.g. Aberdeen and Dartmoor.

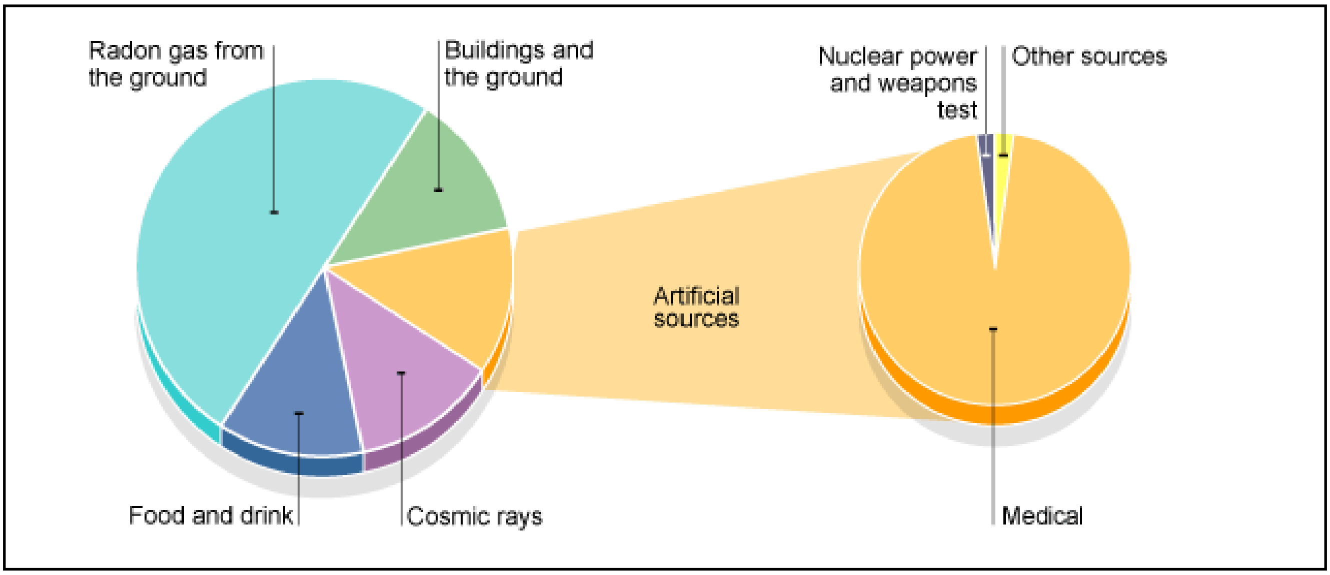
Artificial Sources

N4 & N5

These include radioactive waste from nuclear power stations, plutonium used in nuclear weapons, radioactive fallout from nuclear weapons testing and radioactive isotopes used in medicine.

Pie chart illustrating sources of background radiation

N4 & N5



Nuclear Radiation

Learning Outcomes: Dosimetry

N5 1. State that the activity of a radioactive source is measured in becquerels, where one becquerel is one decay per second.

N4/5 2. State that radiation can kill or damage living cells.

N5 3. State that exposure to radiation can increase the chance of developing cancer.

N5 4. State that the absorbed dose D is the energy absorbed per unit mass of the absorbing material.

N5 5. State that the gray (Gy) is the unit of absorbed dose and that one gray is one joule per kilogram.

N5 6. State that the risk of biological harm from an exposure to radiation depends on:
a) the absorbed dose
b) the kind of radiation, e.g. slow neutron
c) the body organs or tissue exposed.

N5 7. State that a radiation weighting factor W_R is given to each kind of radiation as a measure of its ionising density and therefore biological effect.

N5 8. State that the equivalent dose (H) is the product of D and W_R is measured in sieverts (Sv).

N5 9. Carry out calculations involving the relationship $H = DW_R$.

N5 10. State some ways that radiation workers can reduce their exposure to harmful ionising radiations.

N5 11. State some uses of nuclear radiation. (The use of gamma radiation is also covered in the section on the electromagnetic spectrum.)

Dosimetry

N5

Dosimetry is the measurement and calculation of the radiation dose received by matter and tissue from ionising radiation.

Exposure to a radioactive source will give a dose which is dependent on the activity, duration of exposure, energy of the radiation emitted, distance from the source and shielding.

Activity

N5

The activity, **A**, of a radioactive source is the number of nuclear decays, **N**, **per second**. It is measured in **becquerels.**

N5

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

N: Number of decays

A: Activity in becquerels (Bq)

t: time in seconds (s)

1 becquerel (Bq) = 1 decay per second.

Biological Effect of Radiation

N4/5

Radiation can kill or damage living cells. This can result in illness such as cancer.

Absorbed dose

N5

This measures the transfer of radiation energy to matter. The greater the energy transferred to the matter, the higher the chance there is of ionisation causing damage to the absorbing substance. The absorbed dose, D, is defined as the energy absorbed per unit mass of the absorbing material and is measured in grays, Gy.

N5

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

Energy absorbed in joules (J)

Absorbed dose is measured in grays (Gy)

Absorbing mass in kilograms (kg)

1 gray (Gy) = 1 joule per kilogram.

N5

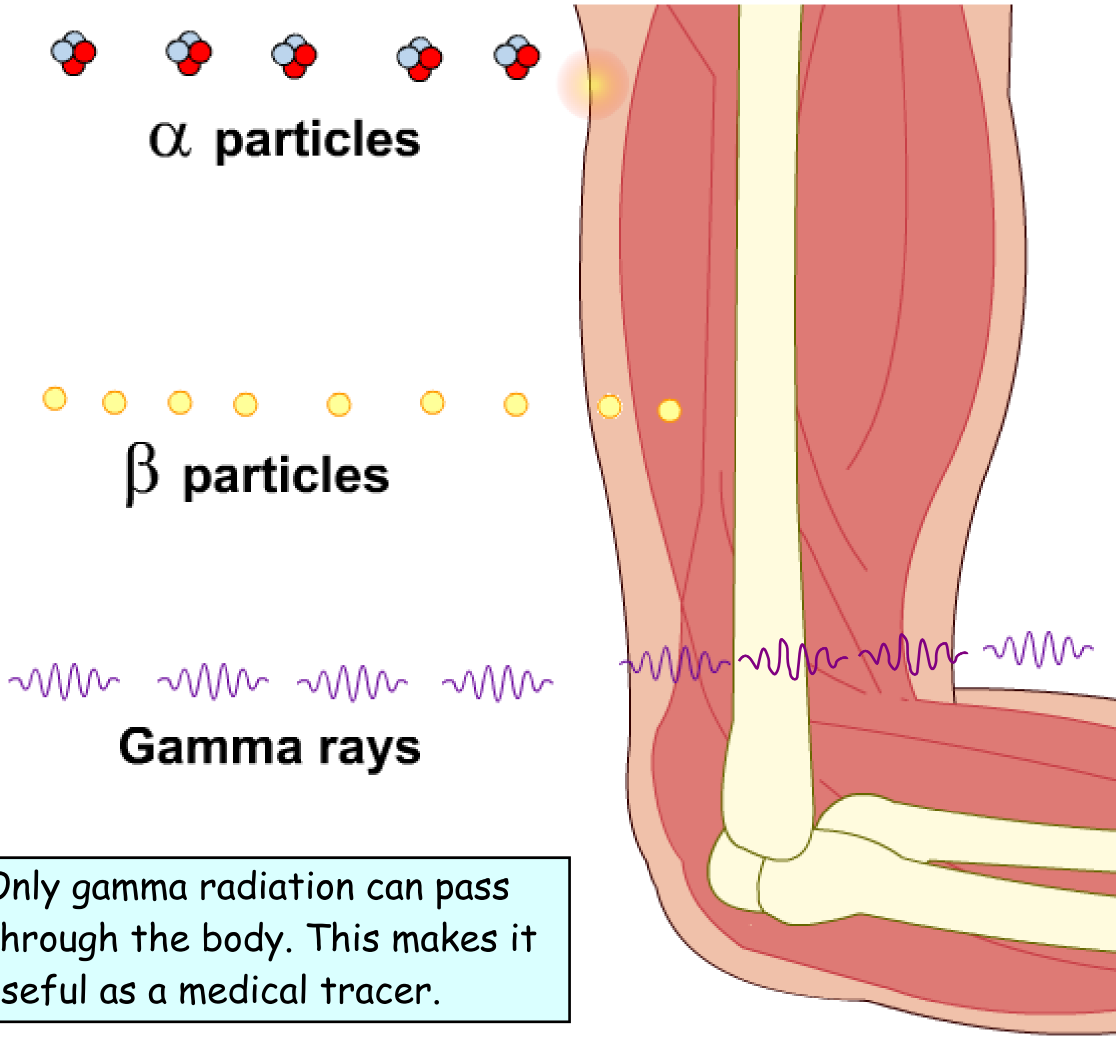
Factors affecting Absorption of Energy

- the nature and thickness of the absorbing substance
- the type of radiation
- the total energy of the radiation absorbed

Alpha radiation is absorbed within a fraction of a mm of tissue. This gives a very high absorbed dose because of the small absorbing mass.

Absorption of Radiation by the Body

N5



Only gamma radiation can pass through the body. This makes it useful as a medical tracer.

Effect of Radiation on the Body

N5

Absorption of ionising radiation by the body damages or kills living cells, increases the chance of developing cancer, and should therefore be avoided by limiting exposure.

N5

Alpha particles

These are absorbed by the surface of the skin.

Beta particles

These are absorbed by a few centimetres of skin and muscle.

Gamma Radiation

This type of radiation is the most penetrating and most passes through the body.

The biological effects of radiation

N5

All ionising radiation can kill or damage cells in the body. There is no minimum amount of radiation which is safe. The risk of biological harm from an exposure to radiation depends on:

- the absorbed dose
- the kind of radiation (α, β or γ)
- the body organs or tissue exposed.

Radiation Weighting Factor

N5

The biological effects, due to a given absorbed dose of radiation, will be different for different types of radiation. To quantify this a radiation weighting factor **W_R** is used. This is a number given to each kind of radiation as a measure of its ionising density and biological effect. Some examples are given below.

W_R	Type of radiation
1	beta particles / gamma rays
10	protons and fast neutrons
20	alpha particles

Equivalent Dose

N5

The **effective equivalent dose** takes into account the relative risks arising from exposure of organs of the body to different types of radiation. It indicates the risk to health from exposure to ionising radiations and is measured in **sieverts** (Sv).

$$H = D \times W_R$$

Equivalent dose measured in sieverts (Sv)

Absorbed dose measured in grays (Gy)

Radiation weighting factor indicating the ionising density.

Typical Exposure levels to radiation

Members of the Public

N5

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

N5

Equivalent Doses from Natural and Artificial Sources

Natural Sources	Annual Dose/mSv	Man Made Sources	Annual Dose/mSv
From Earth	0.4	Medical	0.25
Cosmic	0.3	Weapons(fall out)	0.01
Food	0.37	Occupational	0.01
Buildings(Radon)	0.8	Nuclear Discharges	0.002
Total	**1.87**	**Total**	**0.272**

Workers in the Nuclear Industry

N5

Workers in the nuclear industry are exposed to higher levels of radiation than members of the public. The annual exposure limit for nuclear industry employees is 20 mSv.

Reducing Exposure to Radiation

N5

Radiation workers are at a higher risk of receiving large equivalent doses of radiation. It is therefore important that they take steps to reduce this risk. This is achieved by the following:

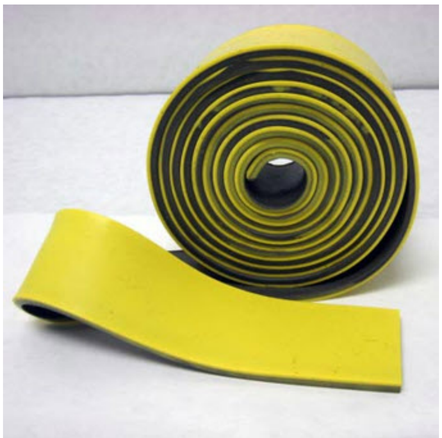
Shielding

N5

Use shielding, by keeping all radioactive materials in sealed containers made of thick lead.

Wear protective lead aprons to protect the trunk of the body.

Any window used for viewing radioactive material should be made of lead glass.



tungsten impregnated silicone

Distance

N5

Keep as far away from the radioactive materials as possible.

Time

N5

Keep the times for which you are exposed to the material as short and as few as possible (dentists often ask you to hold the X-ray film in place while they keep well behind the screen. This may seem unfair - but the dentist takes lots of X-rays over the year and so is at greater risk.)

Safe Practice when Using Radioactive Sources

Radioactive hazard warning sign

N5

- Always use forceps or a lifting tool to remove a source. Never use bare hands
- Arrange a source so that its radiation window points away from the body.
- Never bring a source close to your eyes for examination. It should be identified by a colour or number.
- When in use, a source must be attended by an authorised person and it must be returned to a locked and labelled store in its special shielded box immediately after use.
- After any experiment with radioactive materials, wash your hands thoroughly before you eat. (This applies particularly to the handling of radioactive rock samples and all open sources.)
- In the U.K. students under 16 may not handle radioactive sources.

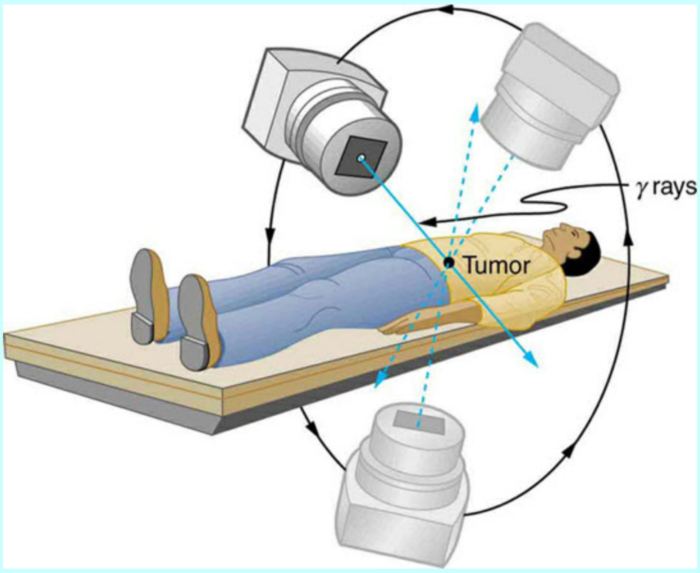
Uses of Nuclear Radiation

Gamma Radiation

N4 & N5

As described in the section on the electromagnetic spectrum, gamma radiation has several uses.

- Treating cancer by killing the cells in a tumour.



- Injected into the body as a medical tracer.
- Irradiating food to kill bacteria and increase its shelf life.
- Monitoring the thickness of sheet material.

Alpha and Beta

N5

These radiations can also be used to treat cancer. Radioactive implants emitting alpha or beta radiation are placed in, or next to the tumour. The radiation energy absorbed by the tumour kills the cancerous cells.

Nuclear Radiation

Learning Outcomes: Half Life and Decay

N5 1. State that the activity of a radioactive source decreases with time.

N5 2. State the meaning of the term ‘half life’.

N5 3. Describe the principles of the method for measuring the half life of a radioactive source.

N5 4. Carry out calculations to find the half life of a radioactive isotope from appropriate data.

Radioactive Decay

N5

As time passes the activity of a radioactive source decreases nuclei decay. This is because the number of unstable nuclei gradually decreases, leaving fewer to decay.

Half-Life

N5

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

Example

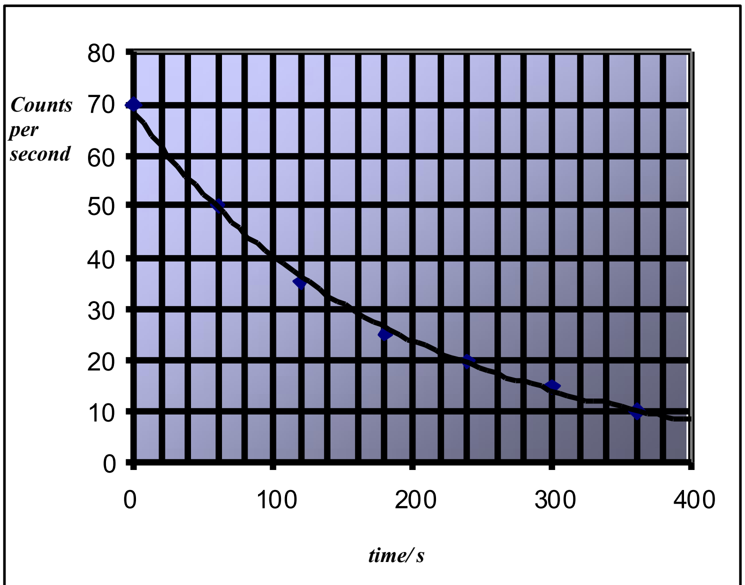
N5

A Geiger-Muller tube and rate-meter were used to measure the activity of radioactive caesium-140 as time passed. The activity of the source was noted every 60 s. The results are shown in the table.

Time/s	0	60	120	180	240	300	360
Count Rate/(counts/s) *corrected for background*	70	50	35	25	20	15	10

By plotting a graph of activity versus time, find the half-life of caesium-140.

Solution



From the graph: The time taken to fall from

70 counts/s to 35 counts/s = 120 s

35 counts/s to 17.5 counts/s= 120 s

Average half life of caesium-140 =

240/2 = **120 s.**

Half Life continued

Half-life values vary widely.

N5

Radionuclide	Half-life
Tellurium-99	6 hours
Iodine-131	8 days
Cobalt-60	5.24 years
Uranium-235	7.1×10^8 years

N5

Example 1

A patient is to be given an injection of iodine-131 in an investigation of her blood. The sample has an initial activity of 8.0kBq. What is the activity after 24 hours?

Solution

$$\text{Number of half lives} = \frac{\text{total time}}{\text{half life time}}$$

$$\text{Number of half lives} = \frac{24}{8} = 3$$

Half life time taken from above table.

$$8.0\text{kBq} \xrightarrow{t_{1/2}} 4.0\text{kBq} \xrightarrow{t_{1/2}} 2.0\text{kBq} \xrightarrow{t_{1/2}} 1\text{kBq}$$

Each arrow represents one half life time.

Final activity = 1kBq

Example 2

N5

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

Solution

80MBq → 40MBq → 20MBq → 10MBq → 5MBq

This takes 4 half-lifes (count the arrows) = 8 days

One half life = 8/4 = 2 days

Nuclear Radiation

Learning Outcomes: Nuclear Reactions

N5 1. Describe, in simple terms, the process of fission.

N5 2. Explain, in simple terms, a chain reaction.

N4 3. State the advantages and disadvantages of using nuclear power for the generation of electricity.

N4 4. Describe the problems associated with the disposal and storage of radioactive waste.

N5 5. Describe in simple terms the process of nuclear fusion.

Nuclear Reactions

Nuclear fission

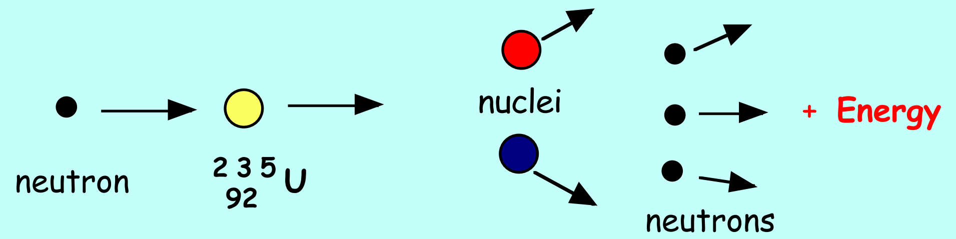
N5

This is the splitting of a large nucleus into smaller nuclei. Other particles and gamma radiation can also be products of this reaction.

Example of Fission

N5

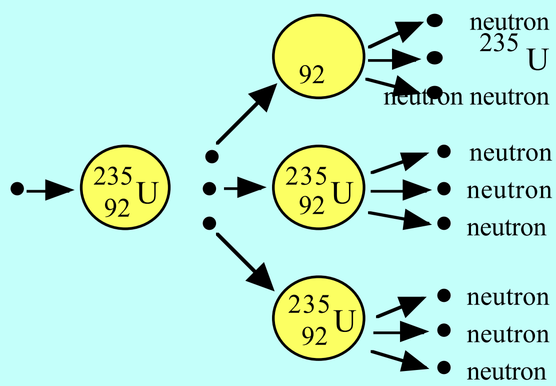
An atom of uranium can be split by a neutron. This can produce two new nuclei plus the emission of neutrons and the release of energy.



Chain reaction

N5

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

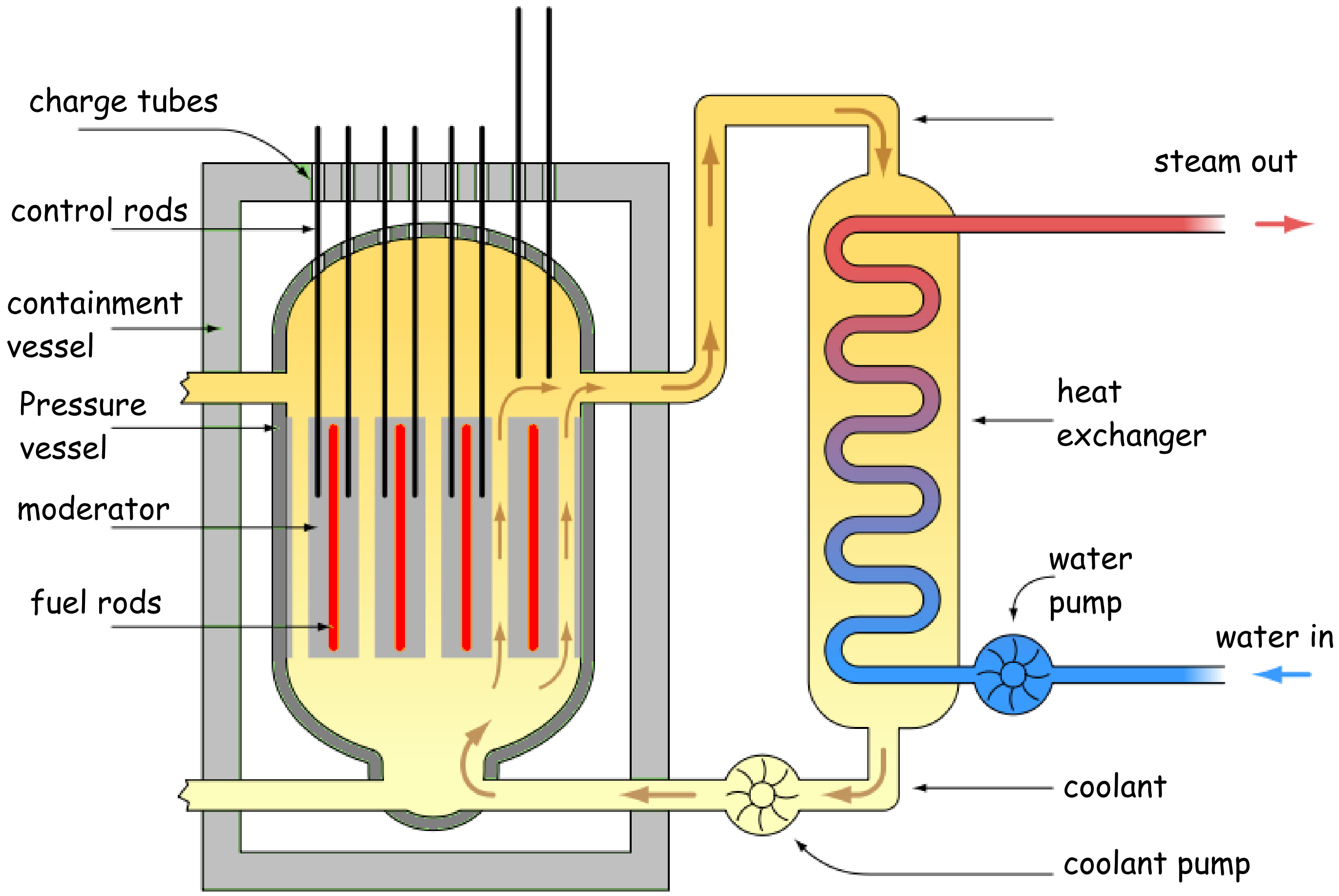


Nuclear Bomb

N5

In a controlled chain reaction, on average only one neutron from each fission will strike another nucleus and cause it to divide. This is what happens in a nuclear power station. In an uncontrolled chain reaction all the neutrons from each fission strike other nuclei producing a large surge of energy. This occurs in atomic bombs.

Nuclear Reactors (Additional information)



- The **fuel rods** are made of uranium-238 enriched with uranium-235 which produce energy by fission.
- The **moderator**, normally made of graphite, has the fuel rods embedded in it. The purpose of the moderator is to slow down neutrons that are produced in fission, since a nucleus is split more easily by slow moving neutrons.
- The **control rods** are normally made of boron, and they control the rate of production of energy. The boron rods absorb neutrons. By lowering them into the reactor, the reaction can be slowed down. In an emergency they are pushed right into the core of the reactor and the chain reaction stops completely.
- A cooling system is needed to cool the reactor and to transfer heat to the boilers in order to generate electricity. British gas-cooled reactors use carbon dioxide gas as a **coolant**.
- The **containment vessel** is made of thick concrete which acts as a shield to absorb neutrons and other radiations.

Nuclear Reactors

Advantages of using nuclear power to produce electricity

N4

- Fossil fuels are running out, so nuclear power provides a convenient way of producing electricity.
- A nuclear power station needs a much smaller mass of fuel compared with a coal or oil-fired power station. A tonne of uranium gives as much energy as 25000 tonnes of coal.
- Unlike fossil fuels, nuclear fuel does not release large quantities of carbon dioxide and sulphur dioxide into the atmosphere,which are a cause of acid rain.

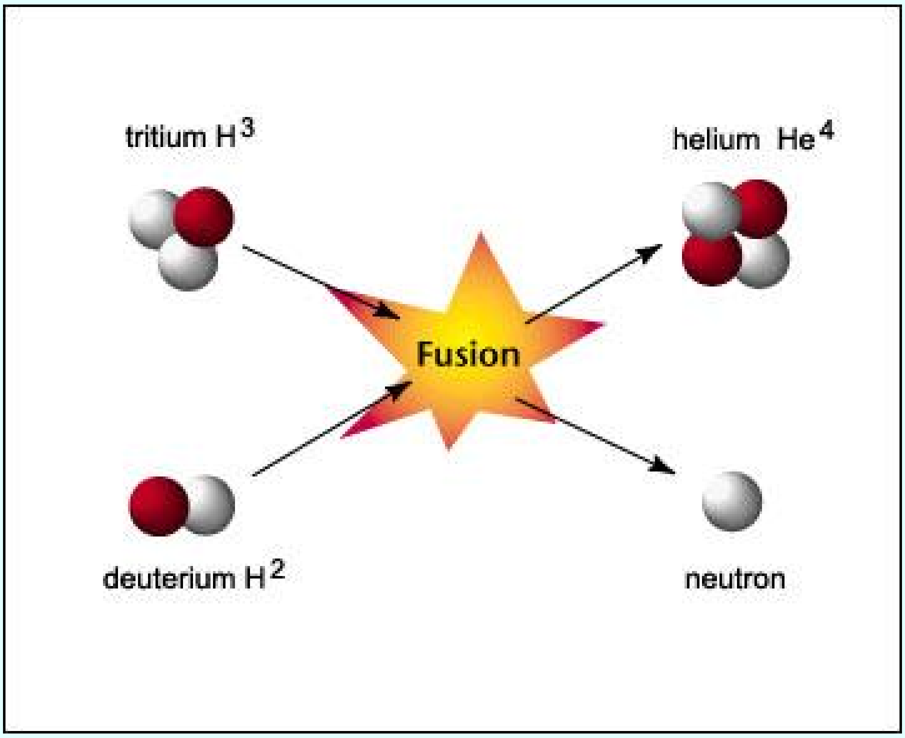
Disadvantages of using nuclear power to produce electricity

N4

- A serious accident in a nuclear power station is a major disaster. British nuclear reactors cannot blow up like a nuclear bomb but even a conventional explosion can possibly release tonnes of radioactive materials into the atmosphere. (The Chernobyl disaster was an example of a serious accident.)
- Nuclear power stations produce **radioactive waste**, some of which is very difficult to deal with.
- After a few decades nuclear power stations themselves will have to be disposed of.

Nuclear fusion

N5



$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{1}_{0}n + ^{4}_{2}He$$

The energy released by the sun and other stars is produced by nuclear fusion.

Nuclear Fusion to Generate Electricity

N5

Very high temperatures are needed to fuse nuclei together and is difficult to achieve. It has been done in research labs, however sustained and controlled fusion has yet to be produced and research in this area continues. Controlled fusion, if achieved would solve the words energy problems in a clean nuclear reaction with no radioactive waste.