

St Ninian's HS



S2 Physics

Medical Physics

Pupil Notes

S2 Medical Physics

The Use of Thermometers

At the end of the section I can:

- State that a thermometer requires some measurable physical property that changes with temperature.
- Describe the operation of a liquid in glass thermometer.
- Describe the main differences between a clinical and ordinary thermometer.
- Describe how body temperature is measured using a clinical thermometer.
- Explain the significance of body temperature in diagnosis of illness.

Thermometry

Body Temperature

Normal body temperature is **37 °C**. This is an average temperature and can vary by 0.5°C either way.

A change of 3°C above, or 2°C below, that temperature can be dangerous and requires medical attention.

Thermometers

All thermometers measure temperature and have a property that changes with temperature.



Liquid-in-glass thermometers

These use the expansion of a liquid to measure temperature. The greater the temperature the greater the expansion of the liquid. As the liquid gets warmer, it expands along the fine glass tube (capillary tube), where there is a scale of numbers marked in °C.

Clinical Thermometers

An ordinary thermometer cannot accurately measure body temperature since;

- the range is too large to measure small temperature changes of the human body.
- the liquid in the tube starts to fall, changing the reading once the thermometer is removed.

In a clinical thermometer;

- the scale ranges from 35 to 42°C.
- keeps the highest reading for ease of use (the little bend in the tube breaks the thread when the liquid cools and contracts). To reset a clinical thermometer it has to be shaken fairly vigorously.
- the glass tube is shaped like a lens to magnify the thin thread of liquid.

S2 Medical Physics

Using Sound

At the end of the section I can:

- Explain the basic principles of a stethoscope as a "hearing aid" and label the main parts of a stethoscope.
- State that high frequency vibrations, beyond the range of human hearing, are called ultrasounds
- Define ultrasound in terms of its frequency.
- Give an example of the use of ultrasound in medicine.

Using Sound

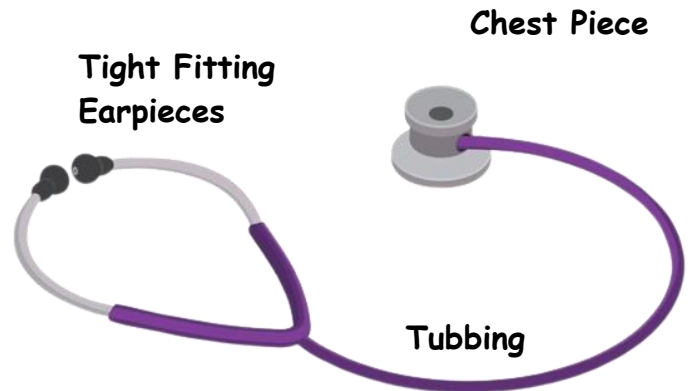
The Stethoscope

The stethoscope is a hearing aid which allows a doctor or nurse to listen to sounds made within the body. It is most often used to listen to the heart and the lungs.

The main parts of a modern stethoscope are shown:

Stethoscopes can be used to determine a patient's BPM (beats per minute)

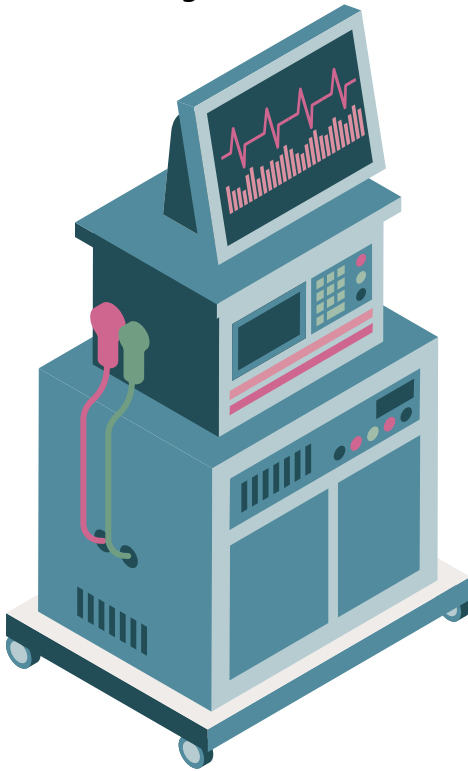
A normal resting heart rate for adults ranges from 60 to 100 beats per minute.



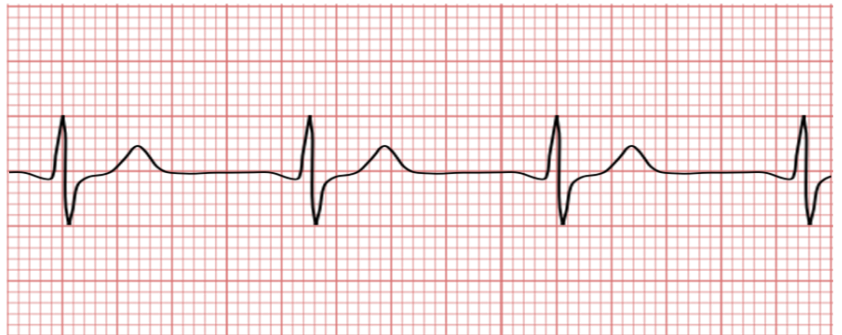
Electrocardiograms

Electrocardiograms also known as ECGs are another way of monitoring heart rate.

They use electrodes to monitor electrical signals going through a patient's heart. If a patient has a regular heart beat a signal such as that below will be generated:



Heart rate = $300 \div (\text{number of large squares in one R-R interval})$



Ultrasound

Different sounds have different frequencies (reminder: frequency is the number of waves per second). Young people can hear sounds with frequencies which range from 20 to 20 000 Hz. Frequencies above 20 000Hz are called **ultrasound**.

Medical Application:

1. Scanning the body

Ultrasound can be used to image the body. When these higher frequency ultrasonic waves are sent out by a transmitter and hit an object, some of the waves will pass through the object while some will be reflected. These waves will take different times to return to a receiver and a computer can use them to produce an image.



A typical scan can check on the progress of a baby in the womb or check the functioning of the valves in the heart.

2. Treating kidney stones

Kidney stones can be shattered by these high frequency sound waves.

Prefixes

To reduce the problem of very long numerical measurements uses a standard set of abbreviations to cut down the numbers that need to be written.

For example:

20 000 Hz can be written as 20 kHz or 20×10^3 Hz

Prefix	Symbol	Power
micro	μ	$\times 10^{-6}$
milli	m	$\times 10^{-3}$
kilo	k	$\times 10^3$
Mega	M	$\times 10^6$

This table shows you all the prefixes you may need to know



S2 Medical Physics

Light and Sight

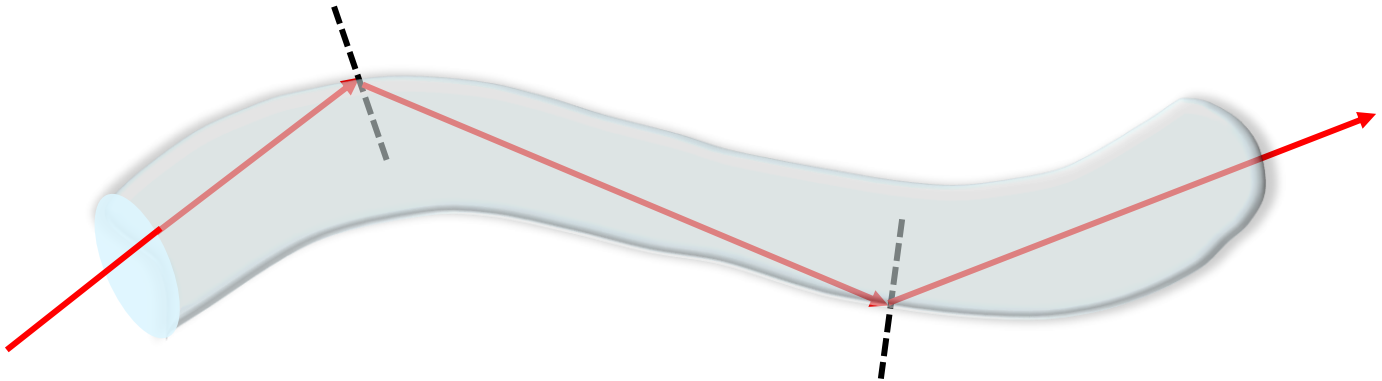
At the end of the section I can:

- Describe what is meant by total internal reflection.
- Explain the use of fibre optics in the endoscope (fibroscope).
- State that refraction is the change in the speed of light as it passes from one material to another.
- Draw diagrams to show the change in direction with regards to the normal as light passes from air to glass and glass to air.
- Draw the shapes of concave and convex lenses.
- Describe the focusing of light on the retina of the eye.
- State the meaning of long and short sight
- Explain the use of lenses to correct long and short sight
- Describe a simple experiment to find the focal length of a spherical convex lens.

Light and Sight

Optical Fibres

When light is shone inside a thin piece of glass it undergoes a process known as **total internal reflection**.



One application which uses total internal reflection is the optical fibre. A optical fibre is a long, thin strand of glass. The principle of total internal reflection is used to transmit light rays through the optical fibre.

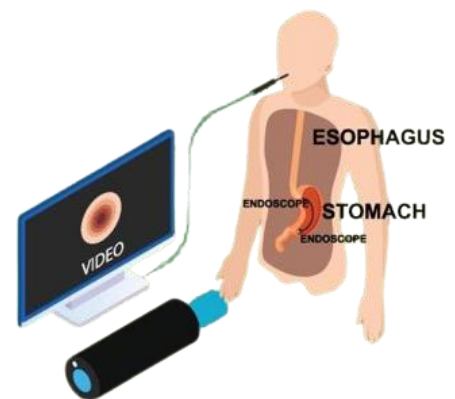
Endoscopes and Optical Fibres

Optical fibres are used in endoscopes.

In an endoscope there are two bundles of optical fibres;

- one supplies light into the patient's body
- one transmits the image back to a computer

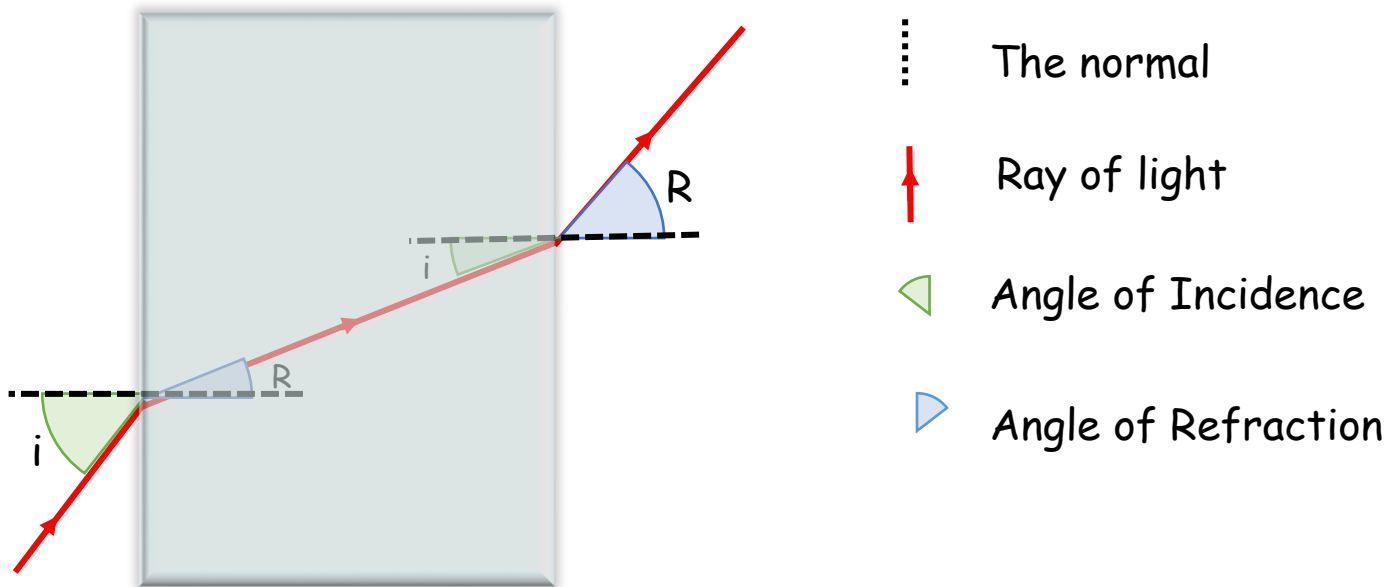
ENDOSCOPY



An endoscope enables doctors to see inside the patient's body without having to perform open surgery, this reduces the risk of patients' being subject to infection and longer term discomfort.

Refraction

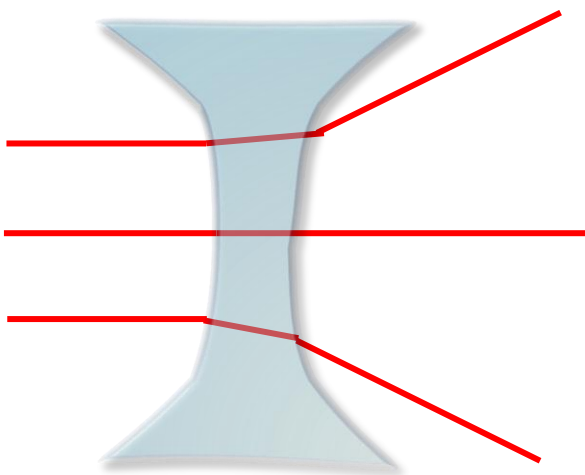
When light passes from one material to another material with a different density its speed will change. This change of speed is known as **refraction**.



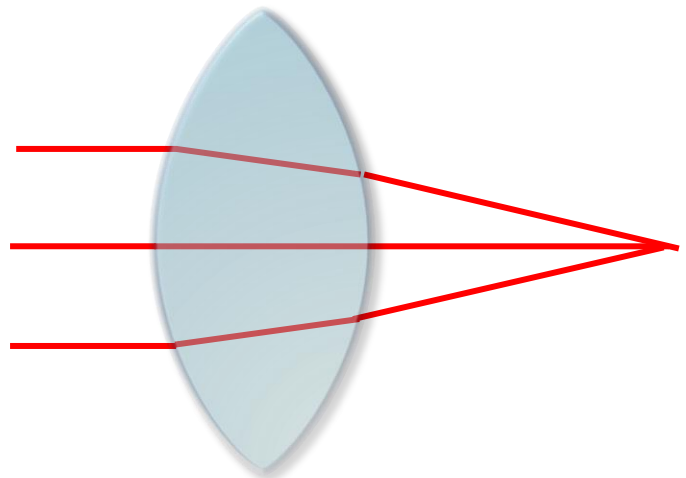
Lenses

Different shapes of glass cause light to refract in different waves. There are two shapes of glass (lenses) that are important to medical Physics:

Concave Lens:



Convex Lens:

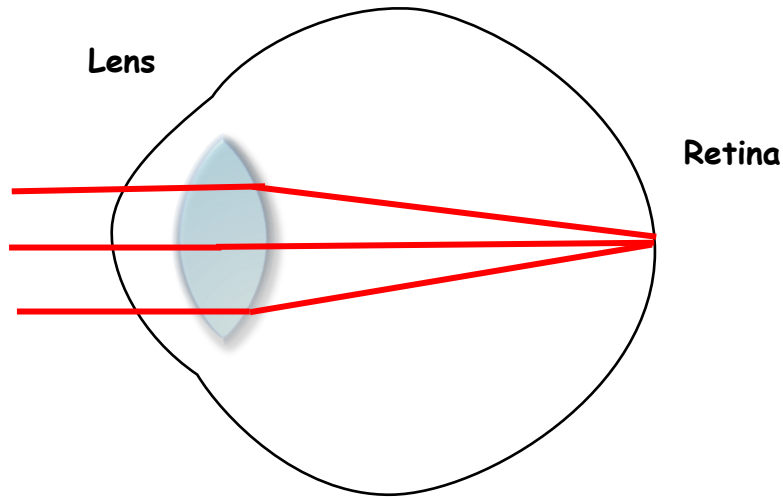


Also known as **diverging** lens
concave lenses cause the light to
"spread out"

Also known as **converging** lens
convex lenses cause the light to focus onto a
focal point.

The eye

The eye contains a convex lens. This is essential to ensure good vision as it helps to focus light upon the retina, the layer of light sensitive cells at the back of the eye.



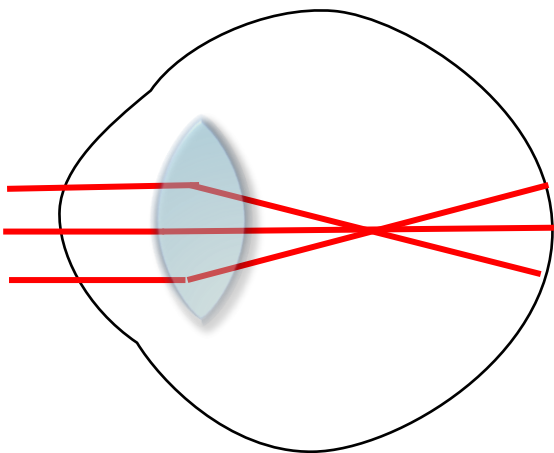
The lens in the eye changes in thickness to accommodate light travelling from varying distances.

Eye defects

Eye defects are conditions which prevent light from focusing on the retina perfectly.

There are two main eye defects that we will look at:

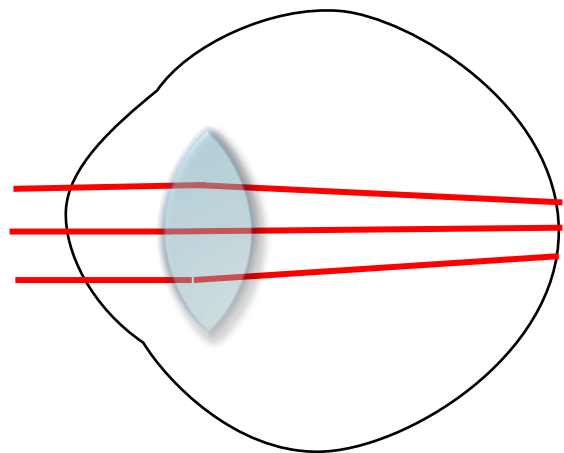
Short-sight:



The light comes to a focus before the retina.

This person **can** focus on nearby objects but **cannot** see distant objects clearly.

Long-sight:



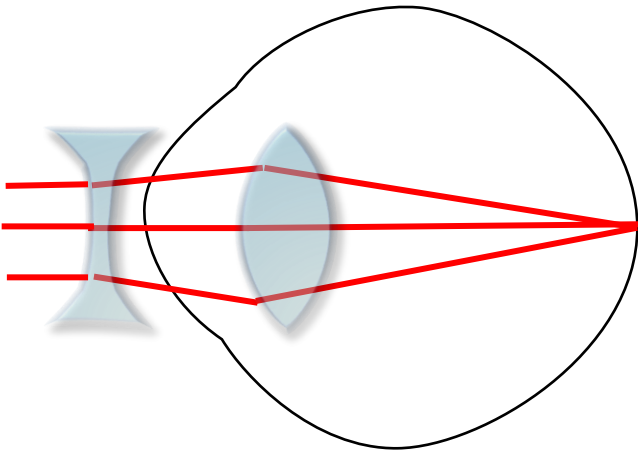
The light comes to a focus after the retina.

This person **can** focus on distant objects but **cannot** see nearby objects clearly.

Correcting eye defects

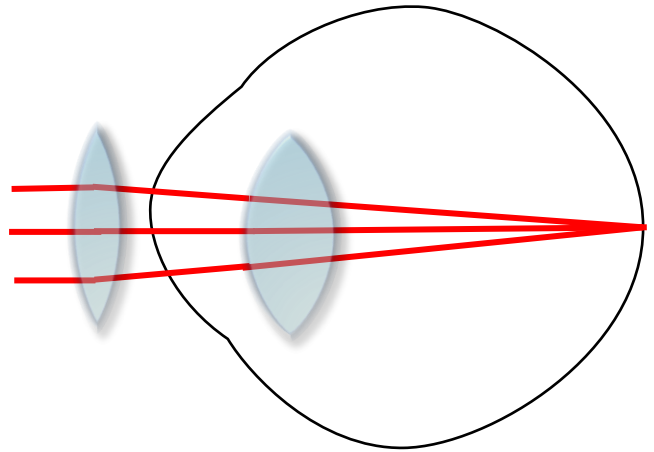
Eye defects can be corrected using lenses (glasses). Different lenses are used for each defect:

Short-sight:



A concave lens makes the rays diverge before entering the eye focusing the light on the retina

Long-sight:

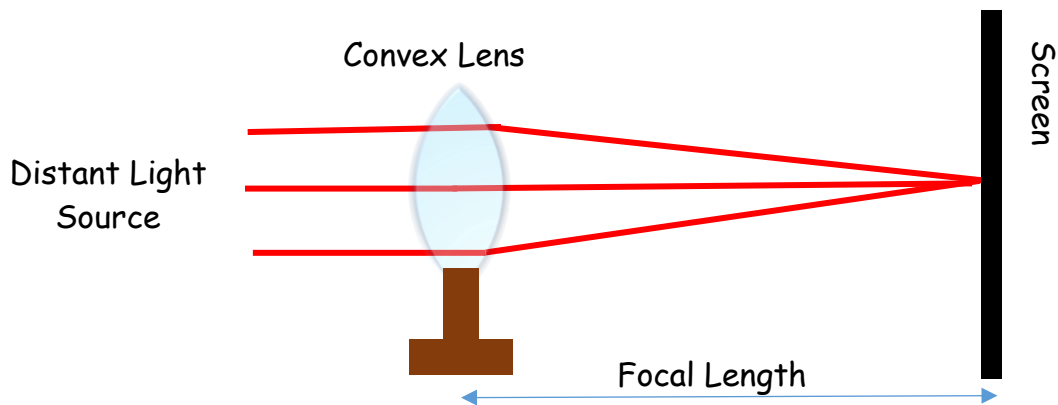


A convex lens makes the rays converge before entering the eye focusing the light on the retina

Focal Length Investigation

Focal Length can be measured by completing the following:

1. A screen is placed opposite a distant light source. The lens is placed in front of the screen:



2. The lens is moved slowly away from the screen toward the light source until a sharp image of the source is focused on the screen.
3. A ruler is used to measure the distance between the lens and the screen. This is the focal length.

Lens with a smaller diameter have a greater focal length.

S2 Medical Physics

Using the Spectrum

At the end of the section I can:

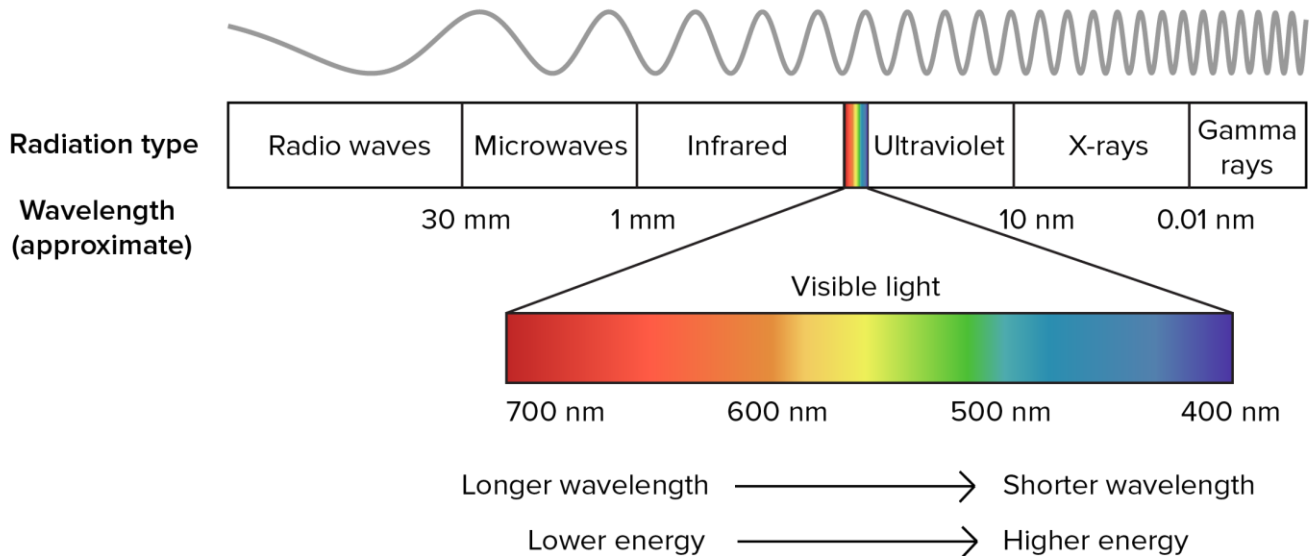
- State in order of increasing frequency the bands of the electromagnetic spectrum.
- Give examples of medical applications for each band of the electromagnetic spectrum.
- State that the higher the frequency of electromagnetic radiation the greater the energy of the wave.
- State that all radiations in the electromagnetic spectrum travel at the speed of light.

Using the Spectrum

The Electromagnetic Spectrum

The Electromagnetic Spectrum is a range of transverse waves which travel at $3 \times 10^8 \text{ m/s}$ in a vacuum.

In order of increasing frequency, the bands of the electromagnetic spectrum are:



Medical Applications

Many Medical Devices make use of the electromagnetic spectrum:

Radio Waves: Used in MRI Scans, a diagnostic test that can create detailed images of organs inside the body.

Microwaves: Used in microwave ablation, a treatment that uses heat from microwave energy to destroy cancer cells.

Infrared: Infrared therapy can be used to relieve muscle pain and tension.

Visible Light: Medical lasers have a variety of uses such as tattoo removal, eye surgery and tumour removal.

Ultraviolet: Can be used to treat certain skin conditions such as psoriasis, vitiligo, and skin tumours of cutaneous T-cell lymphoma.

X-rays: X-ray machines are used to see inside the human body. X-rays pass through tissue like skin and muscle and are absorbed by the film underneath. Dense tissue like bone blocks the X-rays leaving an image of the skeletal structure.

Gamma Radiation: Gamma cameras ([see below](#)) are another way of seeing inside the body.

S2 Medical Physics

Nuclear Radiation

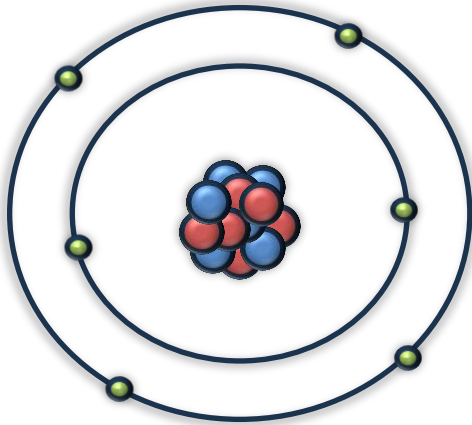
At the end of the section I can:




- State that radiation can kill living cells or change the nature of living cells.
- Describe one medical use of radiation based on the fact that radiation can destroy cells (e.g. instrument sterilisation, treatment of cancer).
- Describe one medical use of radiation based on the fact that radiation is easy to detect.
- State that radiation energy may be absorbed in the medium through which it passes.

Introduction to Nuclear Radiation

The Atom

Radiation occurs when atoms are unstable. Atoms are the smallest possible particles of the elements which make up everything around us.



-  Proton (positive charge)
-  Neutron (neutral charge)
-  Electron (negative charge)

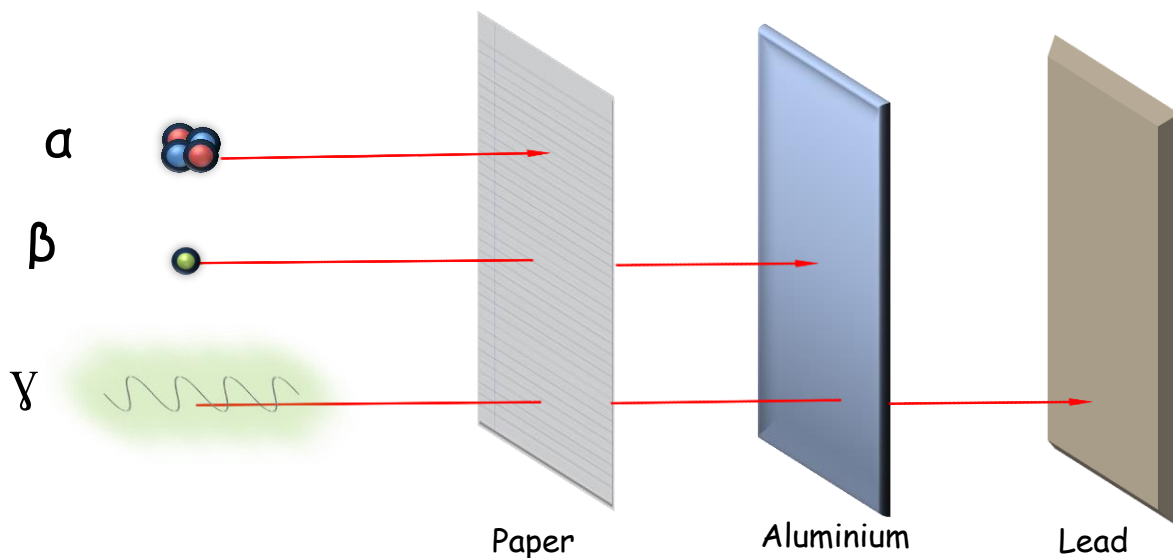
When elements are unstable they are called radioisotope and they release radiation.

Ionising Radiation

Ionisation is the additional or removal of electrons from an atom,

There are 3 types of ionising radiation:

- Alpha, α Alpha particles are positively charged, relatively slow and heavy.
- Beta, β Beta particles are negatively charged, fast and light.
- Gamma, γ Gamma rays are waves, not particles. This means that they have no mass and no charge.



The Biological Effects of Radiation

All ionising radiation can cause damage to the body.

The risk of biological harm from an exposure to radiation depends on:

1. the absorbed dose
2. the kind of radiation
3. the body organs or tissue exposed



Equivalent Dose

The body tissue or organs may receive the same absorbed dose from alpha or gamma radiation, but the biological effects will be different.

To solve this problem a weighting factor, (w_r) is used. This is a number given to each kind of radiation as a measure of its biological effect.

When scientists try to work out the effect on our bodies of a dose of radiation they prefer to talk in terms of **equivalent dose** which is given by:

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

$$\text{Equivalent Dose (Sv)} \rightarrow H = D \times w_r \leftarrow \text{Weighting factor}$$

\uparrow
Absorbed Dose (Gy)

Example Problem:

A medical physicist receives an absorbed dose of 0.20 Gy of X-ray radiation. **Calculate** the equivalent dose received by this worker.

$$H = D \times w_r \leftarrow \text{Formula } \checkmark$$

Shopping List:

$$H = ?$$

$$D = 0.20$$

$$w_r = 1 \text{ (from the table above)}$$

$$H = 0.20 \times 1 \leftarrow \text{Sub-in } \checkmark$$

$$H = 0.2 \text{ Sv} \leftarrow \text{Answer with units } \checkmark$$

Equivalent Does cont.

The following can be done to reduce the equivalent dose:

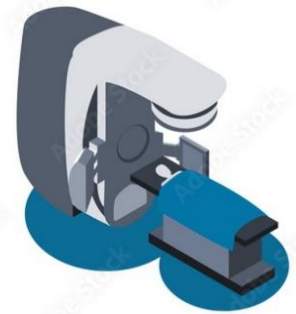
1. Use shielding, keep radioactive materials in sealed lead containers. Wear protective lead aprons.
2. Keep as far away from a radioactive source as possible.
3. Limit the exposure time.

Medical Applications of Radiation

Nuclear Radiation has multiple uses within medicine such as:

Treating Cancer

Radiotherapy is the treatment of cancers by radiation. Cancers are growths of cells which are out of control. The object of the radiation treatment is to cause damage to the cancer cells which stops them reproducing. The tumour then shrinks. Unfortunately, healthy cells can also be damaged by radiation. This means the amount of radiation has to be very accurately calculated and the radiation must be aimed very accurately at the tumour.



Sterilising Instruments



Gamma radiation can kill cells. This can be used to kill bacteria on instruments leaving them sterile. The instruments are wrapped up inside a package and exposed to a heavy dose of radiation, which kills all germs inside the pack. The package does not need to be opened until it is required for use. So it stays sterile.

The Gamma Camera

A radiopharmaceutical is used which acts as a tracer. The advantage of the radiopharmaceutical is that the radiation can be detected outside the body. It is injected into the blood and provides a trace of the inside of the body, the kidney, which is viewed with a special camera called a gamma camera which detects the radiation passing from the body. Gamma is chosen since alpha or beta would be absorbed by tissue and would not be detected outside the body.