S3 PHYSICS WAVES AND RADIATION SUMMARY NOTES

WAVES AND SOUND

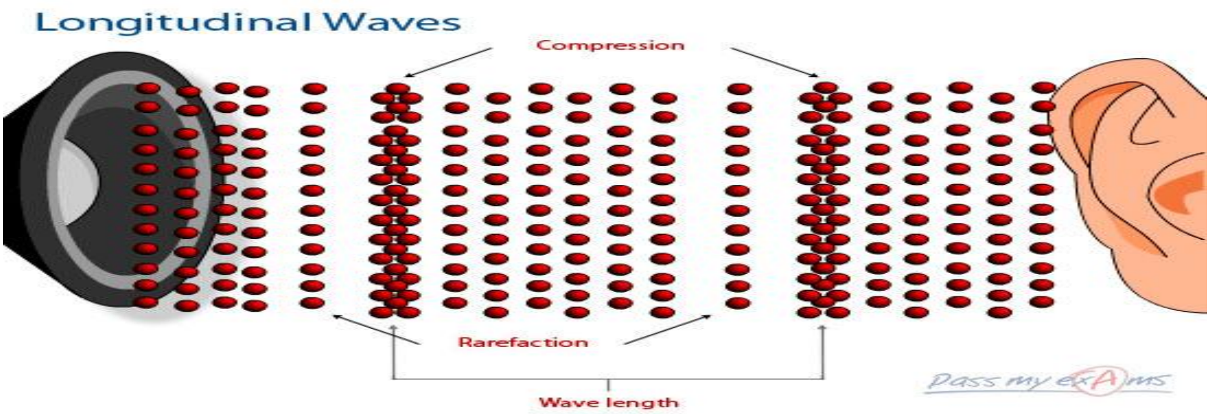
Types of Waves

In **longitudinal waves** the **vibration of the particles** is in the **same direction** as the **direction of energy transport**.

In **transverse waves** the **vibration of the particles** is at **right angles** to the **direction of energy transport**.

Sound is an example of a **longitudinal** wave.

Light, water waves and waves on a string are examples of **transverse** waves.



How do we hear sound?

As the **diaphragm of the speaker vibrates** back and forth it di**sturbs the surrounding air molecules**. The air molecules then pass on the disturbance to adjacent air molecules. In this way the originating disturbance from the speaker travels through air (the medium) via the air molecule as a sound wave.

As the air molecules move in the same direction as the wave, sound waves are therefore longitudinal waves.

The **wavelength** of a sound wave is the distance between successive **compressions** or **rarefactions** as shown in the diagram above.

In order for sound to be heard it **requires a medium (material) to pass through**.

Sound can travel through solids liquids and gases at different speeds.

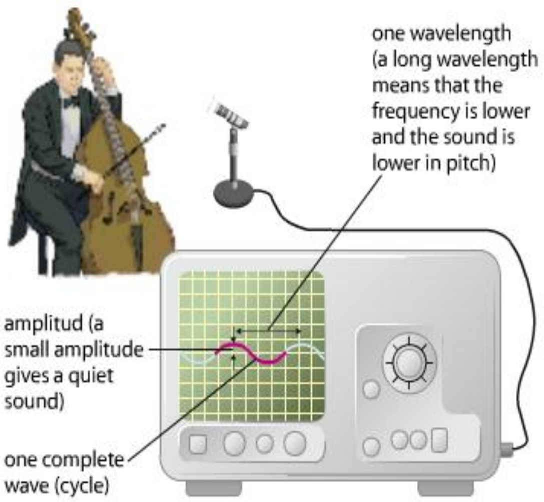
This is because of **how close the particles** in these materials are and their ability to pass on the sound vibrations

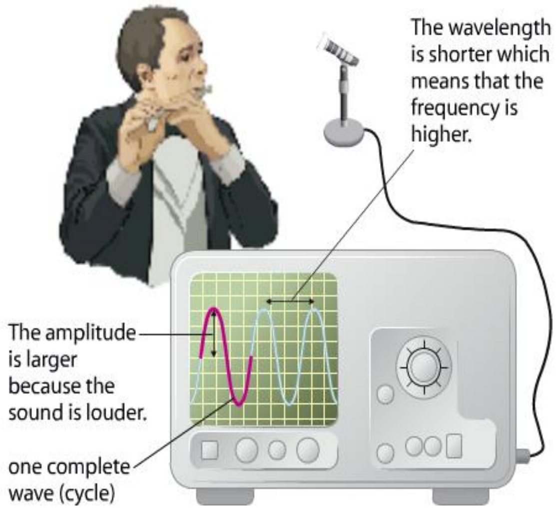
<u>Detecting Sound</u>

Scientists use **microphones to detect sounds**.

If a microphone is attached to an **oscilloscope**, you can see a picture of the **sound wave** produced.

By looking at the wave (or trace) on the oscilloscope screen, scientists can make comments about the **amplitude** (volume) and **frequency** (pitch) of the sound.





As the length of a medium gets smaller, the sound it produces gets higher.

This means that as length decreases, the frequency increases.

With the increase in mobile technology most of our day to day communications are completed using **waves.**

The **Waves** pass through the air, wires or fibre optics.

We need to understand how to describe a wave so that we are able to talk about **waves** in a meaningful way.

Parts of a Wave

Part	Symbol	Unit	Description
Wavelength	λ	m	**It is the distance between two successive points on a wave in phase.**
Amplitude	***A***	m	**It is measured from the centre line to the crest or trough. It is a measure of how much energy a wave carries.**
Frequency	***f***	Hz	**This is how many waves are produced each second. This is the same as the number of waves that pass a point in one second.**
Period	***T***	S	**This is the time to produce one wave.**
Wavespeed	***v***	m/s	**This is the distance a wave travels in one second.**

Wave Equations

We can find the speed (***v***) of a wave by measuring how far the wave travels (distance, ***d***) in a known time interval (time, ***t***). This uses the formula:

$$d = v \times t$$

It is also possible to calculate the speed of a wave if we know the wavelength (***λ***) and frequency (***f***) of the wave. This uses the formula:

$$v = f \times \lambda$$

The frequency of a single wave can be expressed as the relationship between the frequency and the time taken for one wave, the period of a wave, (***T***):

$$T = 1 / f$$

Similarly, the frequency of a number of waves (***N***) passing a given point in a fixed time (***t***) can be expressed as:

$$f = N / t$$

Measuring the Speed of Sound

Light travels extremely fast. In fact, the **speed of light** in a vacuum (3×10^8 m/s, or 300000000 m/s) is the fastest speed **anything** in the universe can travel at.

Sound travels much slower through air. We can use this difference between the speed of light and the speed of sound to attempt to measure the speed of sound in air using a variety of methods.

Direct Method:

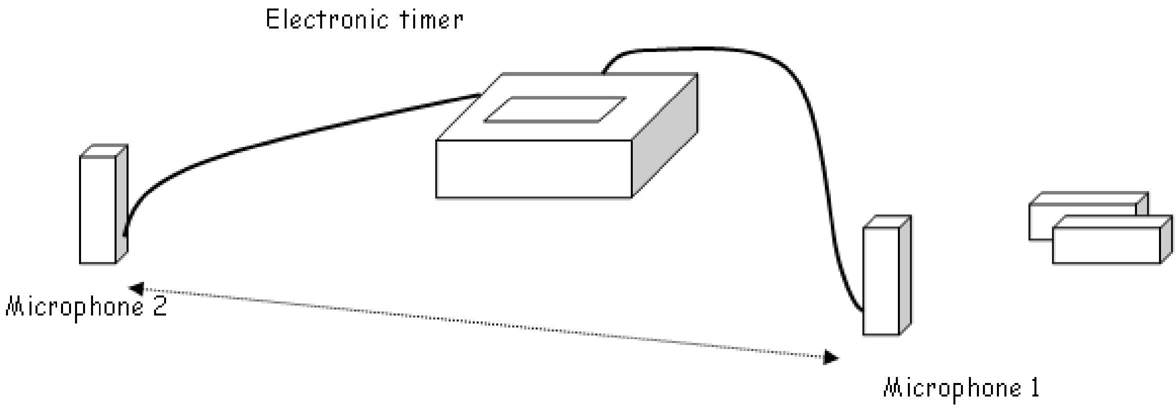
Measure the distance between yourself and the blocks.

Start the watch when you see the blocks hitting each other.

Stop the watch when you hear the sound.

Repeat this three times

Electronic Method



The timer is set so that it will record **fast times**.

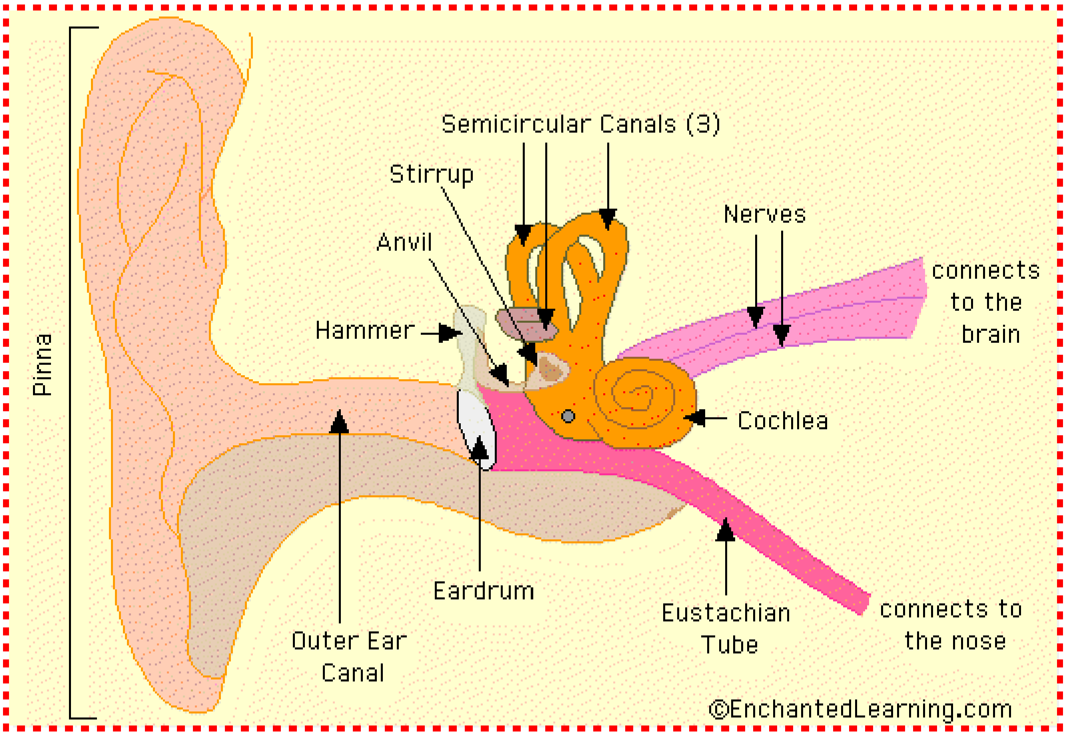
When the two woods blocks are hit together. The timer will show the time it takes for the sound to travel between the two microphones in milliseconds.

Your teacher will carry this procedure out three times. Record the results in your jotter.

Human ear and Hearing

The human ear has two functions: **hearing and balance**. The ear has three main parts: the **outer**, **middle** and **inner ear**. The outer ear is the part you can see and opens into the ear canal. The **eardrum separates the ear canal from the middle ear**. Three **small bones** in the middle ear **transmit sound vibrations to the inner ear**.

The inner ear contains the **cochlea** which **converts the vibrations into electrical signals**. These electrical signals pass along the nerve to the brain. The **semicircular canals** in the ear have nothing to do with hearing. They are **required for balance**.



- **Ear Canal**—the open passage through which sound waves travel to the middle ear.
- **Eardrum**—a taut, circular piece of skin that vibrates when hit by sound waves
- **Malleus (Hammer), Incus (Anvil), Stapes (Stirrup)**—tiny bones that vibrate to amplify sound waves.
- **Cochlea**—coiled, fluid-filled structure of the inner ear that contains hair cells called cilia. Cilia sway in response to sound waves, transmitting signals toward the brain.
- **Semicircular Canals**—fluid-filled structures in the inner ear that detect movement and function as balance organs.
- **Auditory Nerve**—bundle of nerve cells that carry signals from the sensory fibers to the brain.

Humans have a limited range of frequencies that we can hear.

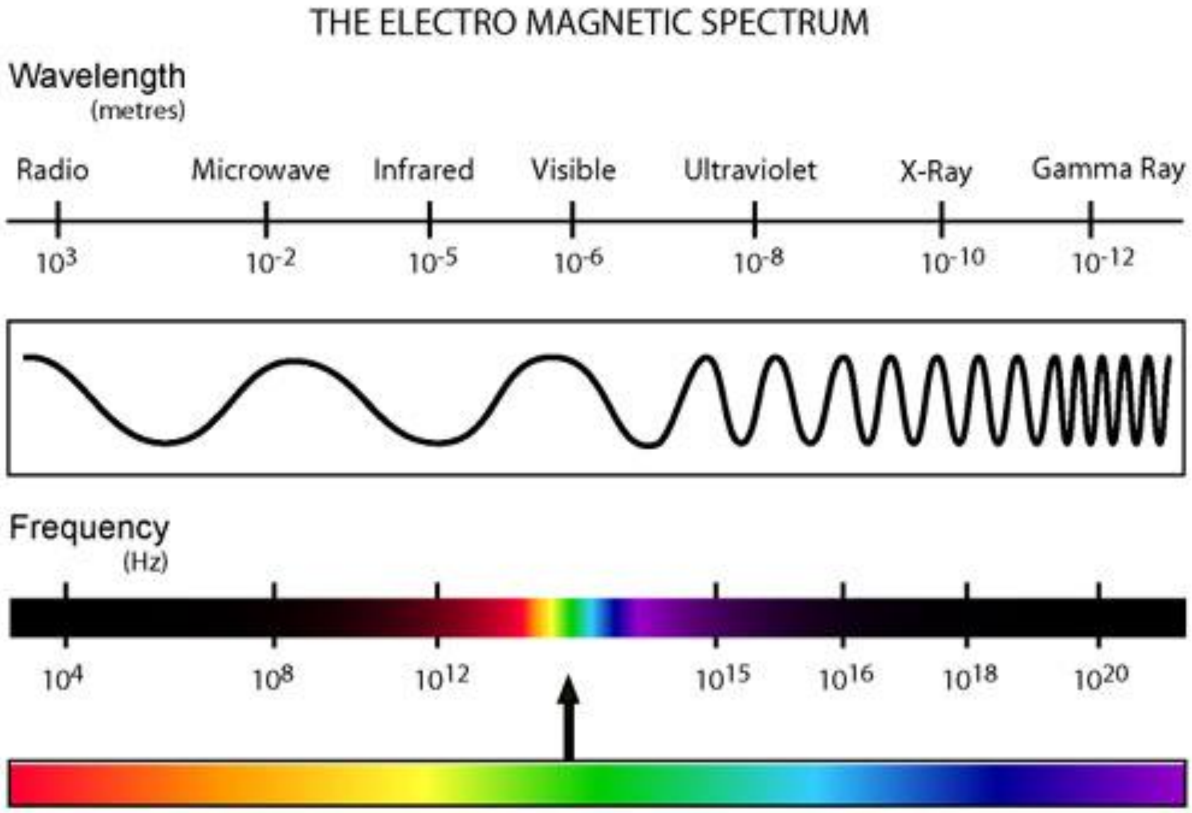
Anything above this range is called **Ultrasound**

Anything below this range is called **Infrasound**

When listening to music, you hear sounds of many frequencies. On average, humans can detect frequencies between **20 Hertz** and **20000 Hertz**.

These are **audible** frequencies for humans. As we get older, the upper limit gradually **reduces** to about 15 000Hz.

ELECTROMAGNETIC SPECTRUM

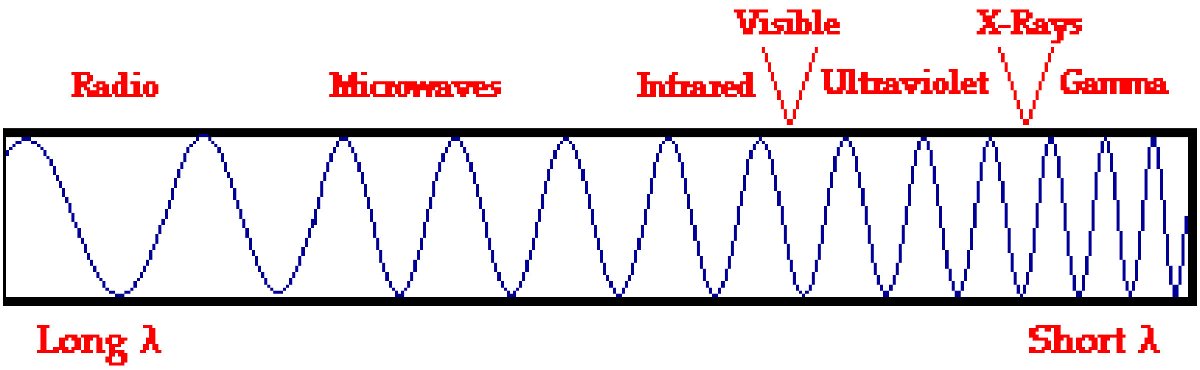


The electromagnetic (or EM) spectrum is a family of waves.

Electromagnetic waves do not require particles to travel which means they can travel in space (a vacuum)

All Electromagnetic waves travel at the speed of light: 300,000,000 m/s .

The 7 members of the EM spectrum are arranged in order of wavelength from biggest to smallest:



Since EM radiation travels as a wave, we can describe it in terms of wavelength (l), frequency (f) or energy (E).

RADIO WAVES

Velocity in air: 300,000,000 m/s

Wavelength Range: 1mm- 1000m

Frequency: below 300000000000Hz

Uses of radio waves:

- Television
- Walkie Talkies
- Radio
- Satellites

Radio waves diffract well around obstacles as they are long wavelength waves

Radio waves are easily detected using an aerial and receiver.

Microwaves

Velocity in air: 300,000,000 m/s

Wavelength Range: 1mm- 25 µm

Frequency: $3x10^{11}$ - 10^{13} Hz

Microwaves are detected by an aerial and receiver

Microwaves can be used to heat food, for satellite communications (including mobile phones) and for RADAR.

Infra-Red

Also known as radiated heat

Velocity in air: 300,000,000 m/s

Wavelength Range: 25um - 750nm

Frequency: $1x10^{13}$ - $4x10^{14}$ Hz

Emitted by

– Sun and stars (Near)
– TV Remote Controls
– Everything at room temp or above

Detected by

– Infrared Cameras

- Photodiodes
- (TVs, VCRs)
- (Your skin)

Heat to heal

Heat can be used to speed up the healing process of certain types of muscle/ tissue injuries. Infra red lamps are used to treat the affected area

Heat to diagnose

Some tumours give off more heat than surrounding tissue. This heat can be detected as infra red radiation using a thermo gram, an infra-red picture.

Visible Light

Velocity in air: 300,000,000 m/s

Wavelength Range: 750nm - 400 nm

Frequency: 4×10^{14} - 7.5×10^{14} Hz

Emitted by

- The sun and other astronomical objects
- Laser pointers
- Light bulbs

Detected by

- Cameras (film or digital)
- Human eyes
- Plants (red light)
- Telescopes

The colours of visible light correspond to different wavelengths of electromagnetic radiation

The correct order of the spectrum can be remembered in different ways

Richard Of York Gave Battle In Vain

Ultraviolet (UV)

Velocity in air: 300,000,000 m/s

Wavelength Range: 400nm - 1nm

Frequency: $1 \times 10^{15} – 1 \times 10^{17}$ Hz

Emitted by

- The sun (A)
- Tanning booths (A)
- Black light bulbs (B)
- UV lamps

Detected by

- Space based UV detectors
- Phosphorescent paints
- UV Cameras
- Flying insects (flies)

Medical Use

U.V. light can be used to sterilise medical equipment and treat some skin conditions like acne by killing bacteria.

Police Use

UV light can be used to detect forged banknotes and stolen property.

Forensic scientists also use UV to detect fingerprints, hair and bodily fluids that would be invisible to the naked eye

Over-exposure to UV radiation can cause skin damage (like sunburn and premature aging) which can lead to skin cancer.

Hazards of UV Radiation

These include skin damage (sun burn and premature ageing) that can lead to skin cancer.

How can you protect yourself from UV damage

- Wear a high SPF sunscreen or sunblock
- Stay in the shade when the sun is at its highest
- Cover up in the sun

- Wear sunglasses to protect your eyes
- Use UV beads to monitor sun exposure
- Don't use sunbeds

X-rays

Velocity in air: 300,000,000 m/s

Wavelength Range: 1nm - 1pm

Frequency: $1 \times 10^{17} - 1 \times 10^{20}$ Hz

Emitted by

- – Astronomical objects
- – X-ray machines
- – CAT scan machines
- – Older televisions
- – Radioactive minerals
- – Airport luggage scanners

Detected by

- – Space based X-ray detectors
- – X-ray film (photographic film)
- – CCD detectors

- X rays pass through "light" atoms such as skin.
- X rays are stopped by "heavy" atoms like bones or metal.
- Photographic film turns black when hit by X rays

Uses of X rays

- CAT Scanners
- Security at airports
- CHANDRA X-ray observatory
- Hazards of X-rays

X-rays can change the nature of cells in the body and over exposure can lead to cancer developing.

As a precaution X-rays are not performed on pregnant women unless deemed clinically necessary.

Gamma Rays

Velocity in air: 300,000,000 m/s

Wavelength Range: < 1×10^{-12} m

Frequency: 1×10^{20} – 1×10^{24} Hz

Emitted by

- Radioactive materials
- Exploding nuclear weapons
- Gamma-ray bursts
- Solar flares

Detected by

- Gamma detectors and astronomical satellites
- Medical imaging detectors (gamma cameras)

Treating cancer (radiotherapy)

Radioactive tracers:

-Medical: to allow organs in the body to show up on a scan

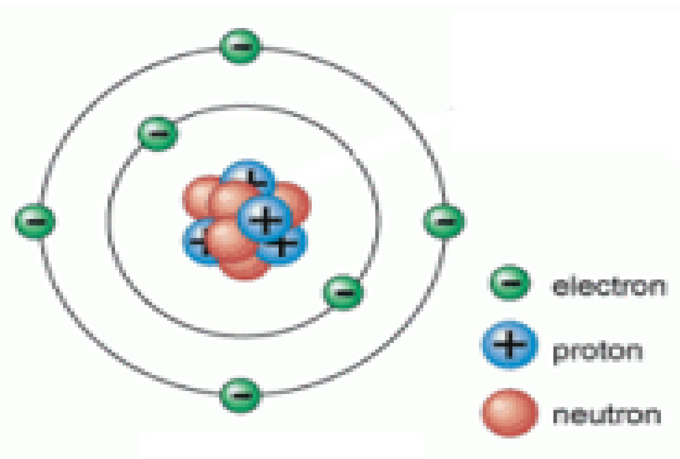
-Industrial: to detect cracks in water and gas mains

-Agricultural: to evaluate the benefits of fertilizers in plants

NUCLEAR RADIATIONS

The atom:

- In physics, we consider an atom to be made of three main particles:
- Protons
- Neutrons
- Electrons



Protons are found in the _nucleus_

Electrons _orbit__ the __nucleus__

Neutrons are found in the ___nucleus___

When we talk about the different charges of the particles in the atom, there is an easy way to remember them.

Protons = __Positive__

Neutrons = _Neutral__

Electrons = _Negative___

Radioactivity

In some elements like Uranium, the nuclei are unstable. We say these atoms are radioactive. They then release their excess energy by emitting particles and waves

Types of Radiation

Alpha

- Symbol: α
- Particles or Waves?: Particles
- Made from: 2 Protons and 2 Neutrons (its a helium nucleus)
- Charge: Positive

Beta

- Symbol: β
- Particles or Waves?: Particles
- Made from: Electrons
- Charge: Negative

Gamma

- Symbol: γ
- Particles or Waves?: Waves
- Made from: High energy E-M waves
- Charge: No charge (waves don't have a charge)

Sources of Radiation

Some sources of radiation are "Natural".

This means that they occur in nature and we do not make them radioactive.

Natural Radioactive Sources:

- Cosmic Rays
- Rocks
- Natural Gases (Radon)
- Living Beings

Some sources of radiation are "Artificial".

This means that they are man-made and we make them radioactive.

Artificial Radioactive Sources:

- Nuclear Waste
- Nuclear Weapons Testing
- Nuclear Medicine
- Nuclear Power Plants

<u>Nuclear Activity</u>

Within a nuclear source, there are millions of **Nuclei.**

Each one has a chance to emit nuclear particles and waves (alpha, beta and gamma)

It is **impossible** to predict when one will emit radiation...

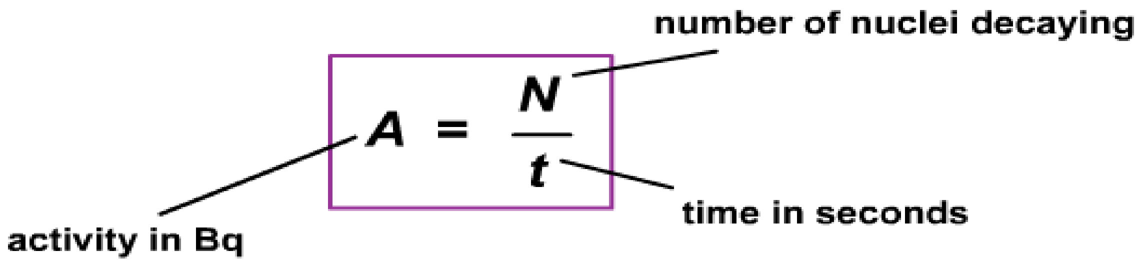
But we can see a pattern

The average **Activity** of a source is:

“The number of nuclei that decay per second”

Activity is measured in Becquerels (Bq)

One Becquerel is one decay per second



Ex: A sample in the lab has 15000 nuclei decaying in a time of 1 minute. What is the activity of the source?

A=N/t

*Remember 1 min = 60 s

A= 15000/60

A= 250 Bq

Nuclear Power Plants

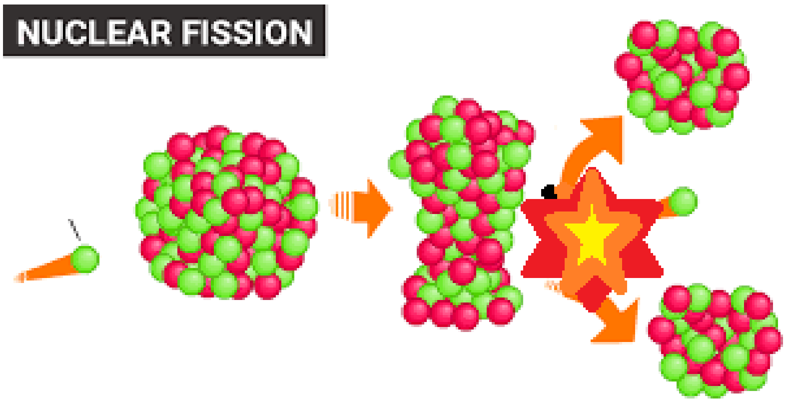
Nuclear Fission

Within a Nuclear reactor, there is a process occurring called **Fission.**

In this process a **large nucleus** is **bombarded** with **neutrons** causing it to **split**

It creates two **smaller nuclei** and more **neutrons**.

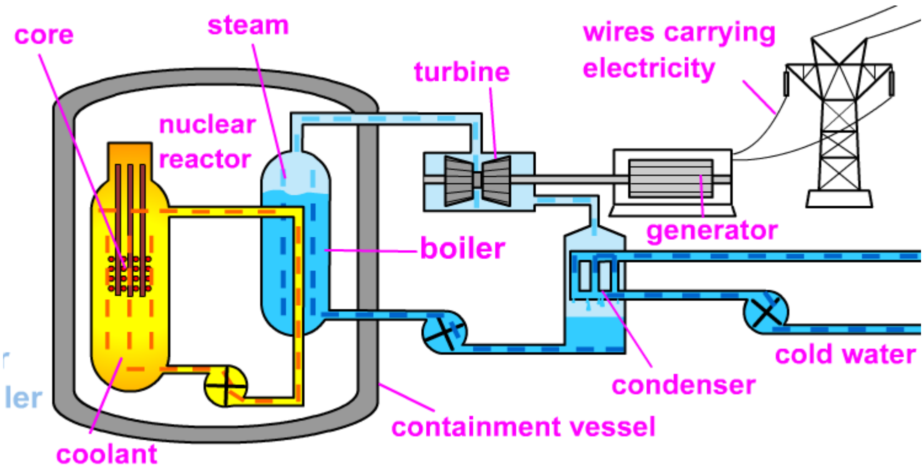
This process also releases **Energy**



When the fission reaction occurs in the reactor, heat is given off.

This heat is used to boil water to make steam that is then used to turn turbines

The turbines are connected to generators that produce electricity.



Control Rods: Absorb Neutrons to control the reaction

Containment Vessel: Houses the nuclear reactor

Fuel rods: Contain the nuclear fuel

Coolant: Is used to take heat away from the reactor

Moderator: Slows down Neutrons to control the reaction rate.

Absorption of Radiation:

In terms of the three radiations, we rank them in terms of "penetrating power"

This is a measure of how well the radiation can travel through a material like our tissue.

Each radiation has a different amount of energy and as such the amount of energy dictates the penetrating power.

When using radioactive sources we can protect ourselves by:

- Wearing lead lined clothing
- Using tongs
- Not pointing the source at our bodies
- Do not touch the source with our skin
- Limit the time of exposure
- Keep sources at a safe distance
- Store sources in lead lined boxes

Penetrative Power

Our radiations can be sorted into the following order:

- Alpha
- Beta
- Gamma
- Alpha is the least penetrative and Gamma is the most penetrative.

Absorbers

Alpha is absorbed by paper

Beta is absorbed by aluminium

Gamma is absorbed by lead