WJEC (Eduqas) Physics GCSE

5.2: Waves at Material Interfaces

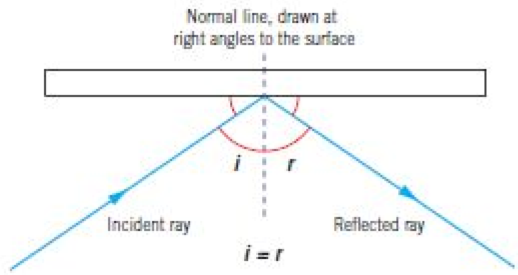
Detailed Notes

(Content in **bold** is for higher tier **only**)

Reflection

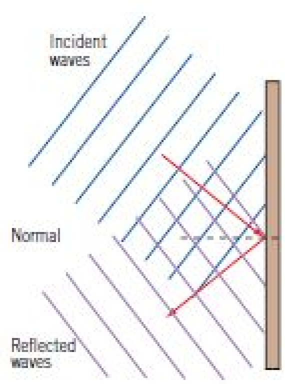
Plane Surface Reflection

Waves incident on a surface will be **reflected**. They reflect at the **same angle** that they were incident at (ie. angle of incidence (i) = angle of reflection (r)). Both of these angles are measured from the **normal**, the dotted line **perpendicular** to the reflecting surface.



Ray diagram of a reflected ray off a planar surface (revisionscience.com).

Reflection can also be shown using **planar wave fronts** (how a wave appears when viewed from above) instead of with rays.



Reflection of plane wave fronts off a planar surface (revisionscience.com).

Diffuse Reflection

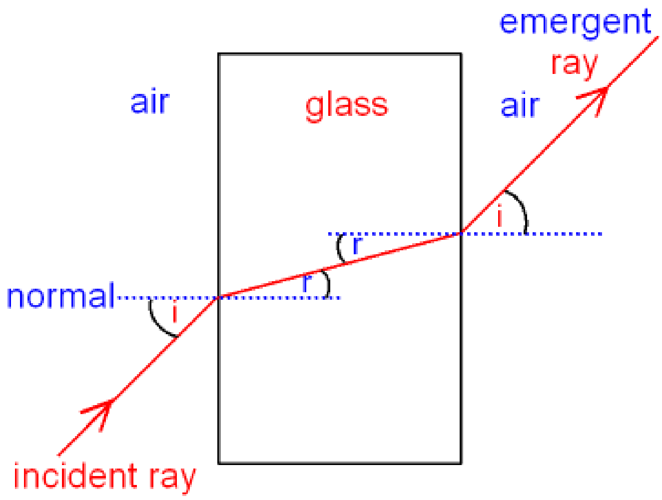
When rays are reflected off a **rough** surface, they can reflect at **various angles**. This results in a **distorted** reflected image or **no image** at all. Each individual ray obeys the laws of reflection where the angle of incidence is equal to the angle of reflection. An example of this is **rippling water** producing a distorted image of under the water.

Refraction

Waves **change speed** when they move between two different substances (media) with **different densities**. This change in speed also results in a **change in direction** of the wave, an effect known as refraction.

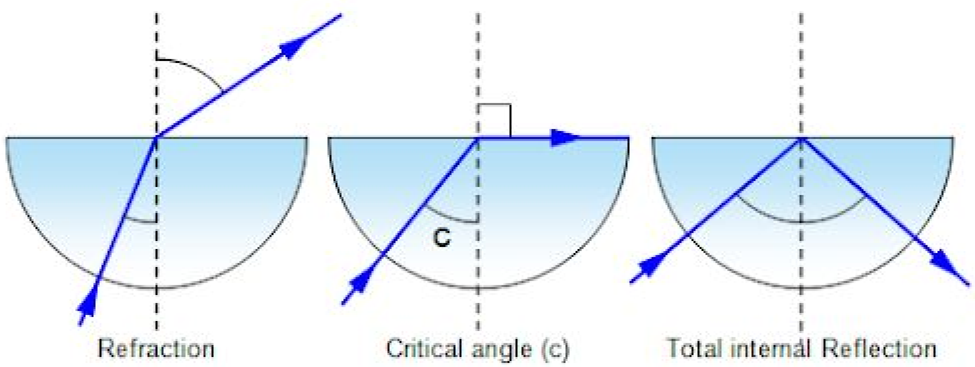
When the wave enters a **denser** medium, it will **slow down** and its **wavelength decreases** (frequency remains constant). When it slows down, the angle of refraction decreases so the wave appears to **bend in towards the normal** ($i > r$).

When the wave enters a **less dense** medium, it will **speed up** and its **wavelength increases**. It appears to **bend away from the normal** ($i < r$).



Refraction of a ray of light passing through a glass block (gcsescience.com).

If the angle of incidence is **equal to a critical angle**, the ray will be refracted along the medium **boundary**. If the angle of incidence **exceeds** the critical angle, it will not be refracted and will instead undergo **total internal reflection** and will not escape the glass block.



Refraction and total internal reflection (getrevising.co.uk).

The Human Auditory System

How the Ear Works

The outer ear collects the sound and channels it down the ear canal. As it travels through the canal, it acts as an air pressure wave. The sound waves hit the eardrum which is a

tightly stretched membrane, causing it to vibrate at the same frequency as the sound. As the incoming pressure waves reach it, compressions force the eardrum inwards and rarefaction forces the eardrum outwards.

The small bones (hammer, anvil and stirrup) connected to the drum then also vibrate at the same frequency. These small bones act as an amplifier of the sound waves and transfer the compression waves to the fluid in the cochlea.

As the fluid moves, small hairs that line the cochlea move too. Each hair is sensitive to different sound frequencies, so some move more than others for certain frequencies.

Each hair is attached to a nerve cell. When a specific frequency is received, the hair attuned to that frequency moves more, triggering an electrical impulse to the brain, which interprets this as the sound.

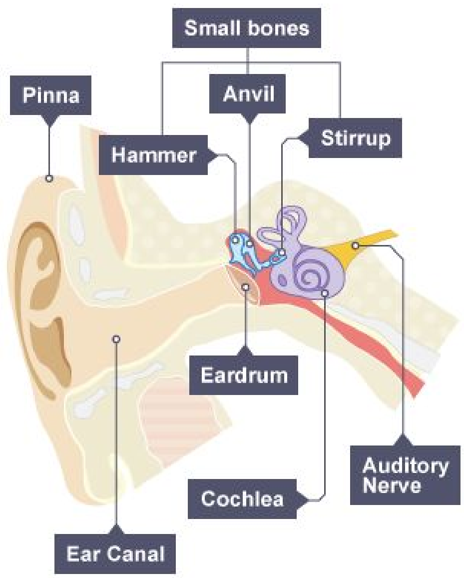


Diagram showing the structure of a human ear (bbc.co.uk)

Limitation Hearing Range

The human hearing range is 20 - 20,000Hz. The hairs in the cochlea attuned to the higher frequencies can easily die or get damaged. Commonly caused by exposure to constant loud noise over a long period of time. It can also be due to the changes in the inner ear as you grow older. As a result, humans tend to lose the upper frequencies of their hearing range as they get older.

We have evolved to hear this specific range of frequencies as it gives us the greatest survival advantage. We cannot hear ultrasound as we do not use sonar to hunt, instead, we have accurate vision.

Ultrasound

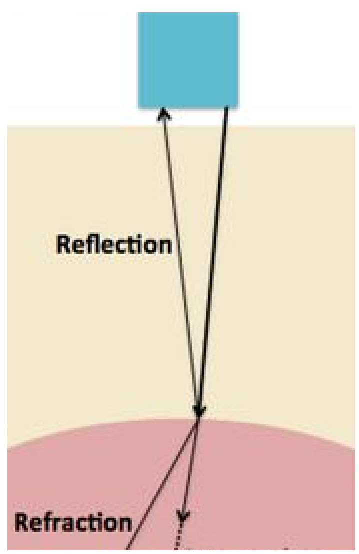
Ultrasound is a type of wave with a frequency greater than 20,000 Hz, higher than the typical range of human hearing. This means humans cannot hear it, however different animals have different hearing ranges and some are even in the range of ultrasound.

Uses of Ultrasound

When ultrasound reaches a boundary between two media, they are partially reflected back. The remainder of the waves continue and pass through. The speed of the waves is constant, so measuring the time between emission and detection can show the distance from the source at which they were reflected. A receiver next to the emitter can record the reflected waves. Therefore ultrasound is good to use for imaging under surfaces.

Medical Imaging

Ultrasound is commonly used in medicine to image inside the body. This is good as it removes the need for invasive surgery. A probe emits ultrasound waves that penetrate into the body through muscle, bone and tissues. At each boundary between these in the body, some of the waves are reflected back to outside the body to be detected. Others penetrate deeper into the body before being reflected.



Ultrasound probe with rays reflecting off a boundary (imagingkt.com).

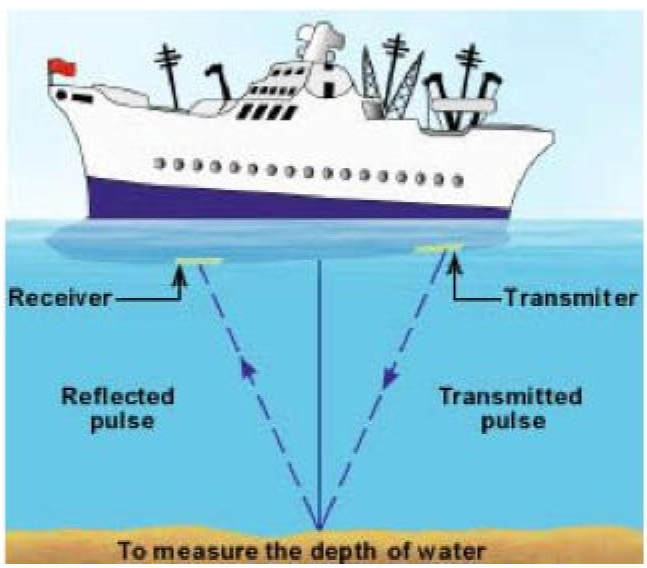
The reflected signals are picked up by the probe and processed by a computer to produce an image that is viewable on a screen.

Common uses of this technology include imaging unborn babies and diagnosing heart, kidney or bladder problems.

Ultrasound image of an unborn baby (bbc.co.uk).

Underwater Imaging

High frequency ultrasound can be used to image the seafloor or objects beneath the water. A wave is transmitted from a ship and reflected off a boundary beneath the water before being detected again at the ship. The time between the transmitted and reflected signals can be found and used to calculate the distance of the boundary from the ship (*distance = speed x time).*

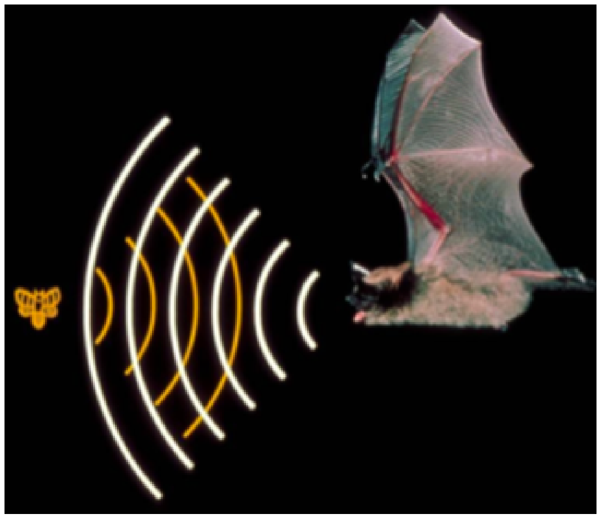


Underwater ultrasound imaging from a ship (myscienceschool.org).

Higher frequency ultrasound signals are required because water absorbs lower frequency signals making them too weak to detect once reflected.

Echolocation

Dolphins and bats are some common animals known to communicate by ultrasound out of the range of human hearing. This is sometimes called 'sonar' and it helps them to visualise their environment in the dark by listening to reflections of their signal off objects around them. It can also be used for communication with others through very distinct signals.



A bat using echolocation to detect a food source (peec.org).

Seismic Waves

Earthquakes produce seismic waves as they cause the ground to vibrate. There are three main types of seismic waves:

P-Waves

P-waves travel as longitudinal waves through solids and liquids. They travel faster than the other types of seismic waves.

S-Waves

S-waves travel as transverse waves and can only travel through solids. They are slower than p-waves.

Surface Waves

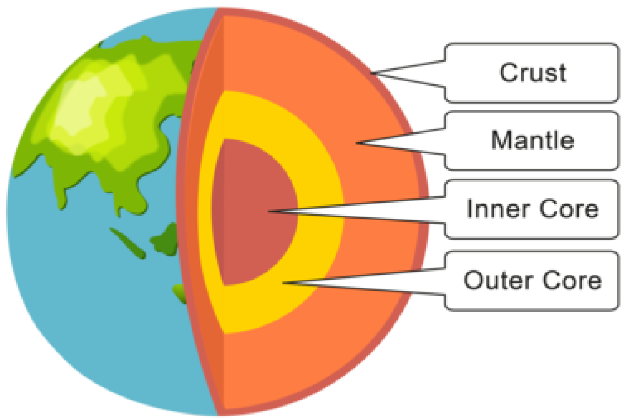
These are the slowest type of seismic wave and are also longitudinal. They only travel across Earth's surface and into the ground.
do not penetrate

Structure of Earth

The internal structure of the Earth consists of several different layers each with different properties. These have been hypothesised from analysing seismic waves and signals that have travelled through the Earth.

The surface layers are the crust and upper mantle (lithosphere) which are broken up into large fragments called tectonic plates. When these plates move, friction between them causes a release of energy and stress that produces seismic waves.

The mantle sits below the crust and is much more fluid. It still has the properties of rock but can flow, enabling the movement of the tectonic plates.



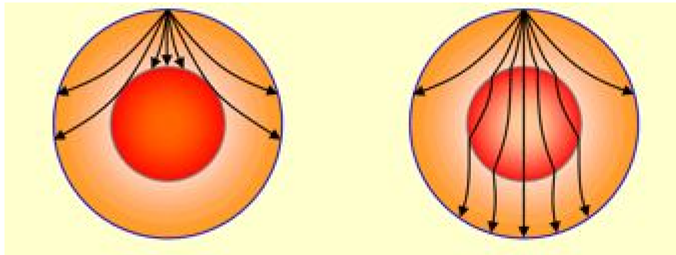
Internal Structure of the Earth (goconqr.com).

The Earth's core is made up of an inner and outer core. The outer core is more liquid, made up of molten iron and nickel. The inner core is made up of more solid iron and nickel. Earth's core is very large and its diameter is over half that of the whole Earth.

Seismic Wave Paths

P and S-waves can be used to determine Earth's internal structure. The speed of seismic waves increases with depth and they travel with curved paths within the Earth. At each layer boundary, the waves can be refracted as the density of each layer changes.

S-waves can only travel through solids, meaning they cannot pass through the molten outer core. Therefore, only p-waves can be detected on the opposite side of Earth to a quake. This helps to provide evidence for the hypothesised internal structure of the Earth.



S-Waves P-Waves

Seismic wave paths within Earth (sutori.com).

This creates an s-wave shadow zone where s-waves cannot be detected after an earthquake. Typically this zone sits between 105º angles from the quake epicentre.