Waves Notes

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Waves are a way that energy can be transferred from one object to another or from place to place. Waves transfer energy without transferring matter. For example, think of a rope that you are moving up and down, we can make waves move through the rope but the rope doesn't fly forwards or backwards. So the energy moved through the rope as a wave without moving the rope itself.

Before we look at the different types of waves, we need to know some definitions that we will see used quite a lot.

Wavelength: the distance from one point on a wave to the same point on the next wave.

Frequency: the number of waves that pass a point each second. This means that if 80 waves passed a point in one second then that wave would have a frequency of 80 Hertz, which would be written as 80 Hz.

Amplitude: the maximum displacement of a point on a wave away from its undisturbed position.

Oscillation: the term used to describe the vibration of the wave.

Time period: the time that it takes one wave to pass a certain point. As it is time, it is measured in seconds.

Displacement: how far a point on the wave has moved from its undisturbed (rest) position, from top to bottom.

What do all waves have in common?

All waves, regardless of the type of wave, have the following properties in common.

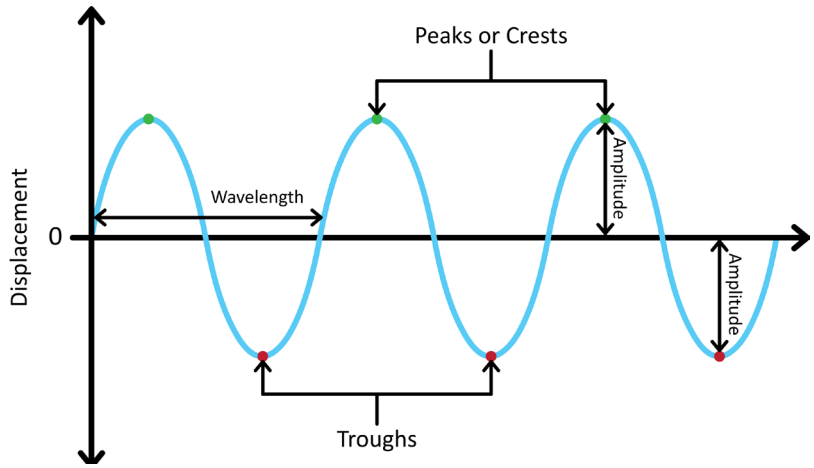
All waves have a wavelength, a frequency and an amplitude. All waves can be **reflected** and **refracted** and all waves follow the wave equation. We will cover the wave equation later in this note booklet.

Waves fall into **two categories**, they can be either transverse or longitudinal. Let's look at transverse first 😊

Transverse Waves

Transverse waves: are waves that travel perpendicular to the direction of energy transfer. This means that they travel at a 90 degree angle to the direction of wave movement. Some transverse waves, like all electromagnetic waves, for example light, can travel through a vacuum. Other transverse waves, known as mechanical waves like water waves and seismic S-waves, must have a medium to travel through

The figure below shows a labelled transverse wave. We could be asked to draw or label a diagram of a transverse wave in the physics paper 2 GCSE exam. Please do be able to draw and correctly label this diagram.



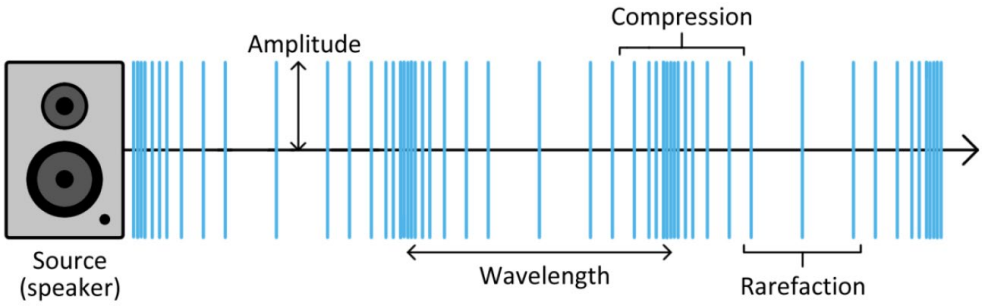
We could be asked to provide **an example** of a transverse wave so here's a few:

1. All electromagnetic waves such as microwaves, light waves and gamma rays.
2. Water waves – the ripples on the surface of water.
3. Seismic S-waves.

Longitudinal Waves

Longitudinal waves: are waves that travel parallel to the direction of energy transfer. Longitudinal waves need a medium to move through. This means they need something with particles to move through. They **cannot** travel through a vacuum. An example of longitudinal waves are sound waves.

The figure below shows a labelled longitudinal wave. We will not be asked to draw this wave, we may be asked to label a pre drawn diagram.



As you can see they look quite different compared to transverse waves. Longitudinal waves also have compressions and rarefactions. But what are these?

A compression: the part of a longitudinal wave where the pressure is higher. This is because the particles of the medium that the wave is moving through are close together in these compressions.

A rarefaction: the part of a longitudinal wave where the pressure is lower. This is because the particles of the medium that the wave is moving through are spread much further apart.

The Wave Equation

The wave equation is a great equation that brings together the **wave speed**, **frequency** and **wavelength** of a wave.

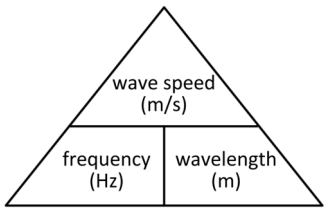
Wave speed is the speed of the wave in meters per second, the frequency is the number of waves that pass a point per second in Hertz and the wavelength is the distance between two of the same point on a wave, measured in meters.

If a question were to give us the wavelength in **cm** then we would need to convert to **m** before doing the calculation.

The wave equation is:

Wave speed (m/s) = frequency (Hz) × wavelength (m)

$$V = f \times \lambda$$



V = wave speed in m/s	**f** = frequency in Hertz (Hz)	**λ** = lambda the symbol for wavelength (m)

Let's look at a couple of examples.

Example 1: A bat emits a sound wave with a frequency of 34 kHz and a wavelength of 0.01 metres.
Calculate the speed of this sound wave.

Wave speed (m/s) = frequency (Hz) × wavelength (m)

Wave speed (m/s) = 34 000 × 0.01 (m)

Wave speed = 340 m/s

Example 2: A sound wave with a frequency of 18000 Hz travels at a speed of 340 m/s.
Calculate the wavelength of this sound wave.

wavelength (m)= Wave speed (m/s) ÷ frequency (Hz)

wavelength = 340 m/s ÷ 18000 Hz

wavelength = 0.0189 m

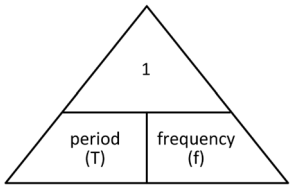
The Time Period of a Wave

The time period of a wave: the time that it takes one wave to pass a certain point. As it is time it is measured in seconds. It's a very quick calculation and the equation is very straightforward.

The time period equation is:

Time period = 1 ÷ frequency

T = 1 ÷ Hz

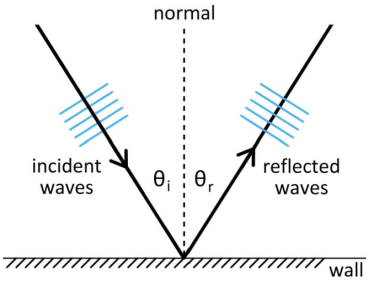


T = time period (s)	f = frequency in Hertz (Hz)

Reflection and Absorption

As mentioned on the first page all waves can be reflected. An echo is when sound waves are reflected from a surface.

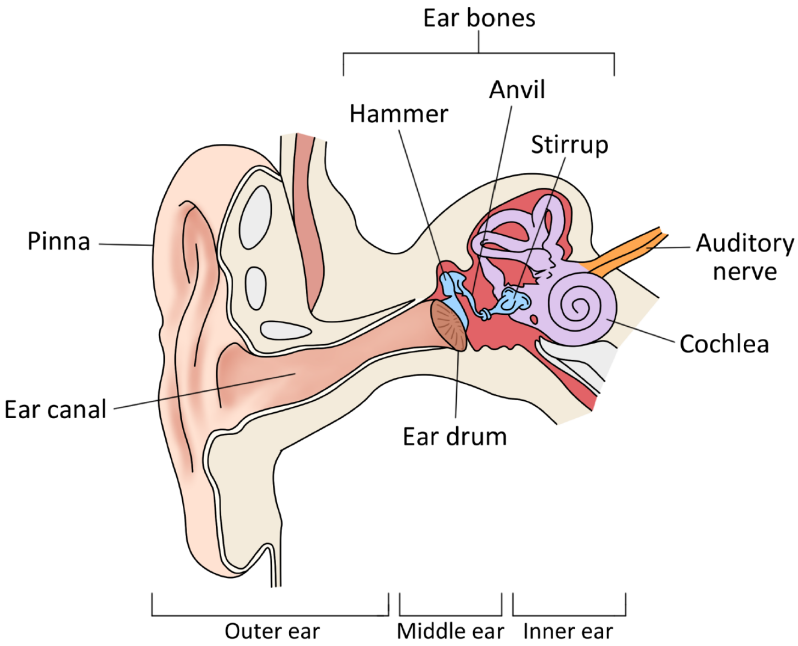
Waves can also be absorbed by a material. We can see this in a lot of places. An empty room is a lot more echoey than a room with furniture and curtains. In this case, some of the waves are absorbed by the materials in the room.
In general, some of the wave is absorbed by a material and some is reflected. Both generally happen.



Note: after the wave has been reflected it has the same speed, frequency and wavelength as it did before the reflection, it is only the direction of the wave that has changed.

The Ear

The ears are the organ through which we hear. The ears convert longitudinal waves into electrical impulses which pass on to the brain. The figure below shows a labelled section through the ear.



Structure	Function
Pinna	is the part of the outer ear that we can see.
Ear canal	is the passage that connects the outer ear to the middle ear.
Eardrum	is a thin flap of skin that is stretched tight like a drum. Sound waves cause the eardrum to vibrate. This vibration is passed on to the hammer.
Hammer, anvil and stirrup	are the three bones of the middle ear. The vibration from the ear drum is passed from the hammer to the anvil to the stirrup. These also **amplify** (make bigger) the vibrations.
Cochlea	is the part of the ear that converts the vibrations into electrical impulses.
Auditory nerve	is the nerve that carries nerve impulses from the cochlea to the brain.

Human Hearing

Humans can hear sounds between 20 Hz and 20000 Hz.

Why is our hearing limited to this range? When sound waves enter the ear, they cause the eardrum and the tiny bones in the middle ear to vibrate.

- Frequencies below 20 Hz do not vibrate fast enough to move the eardrum.
- Frequencies above 20,000 Hz are too fast for the solid bones to keep up with.

Seismic Waves

Seismic waves: waves of energy that travel through the layers of the Earth. They are produced by earthquakes, volcanic eruptions, or other large-scale sources.

When an earthquake happens it sends out vibrations through the earth's crust and downwards, into the mantle.

Seismic waves from earthquakes are detected all around the world. They are even detected on the opposite side of the planet from where they happen. As they move through the planet the waves change direction, they **refract** due to the different densities of the layers of the earth. It was actually by studying these waves that we have any idea what the mantle and core of the planet are like because, of course, no one can go down there for a look around.

Seismometers are used to detect seismic waves.

There are two types of seismic waves, these are **primary waves** and **secondary waves**. We normally call them **P** and **S** waves to make things more straight forward.

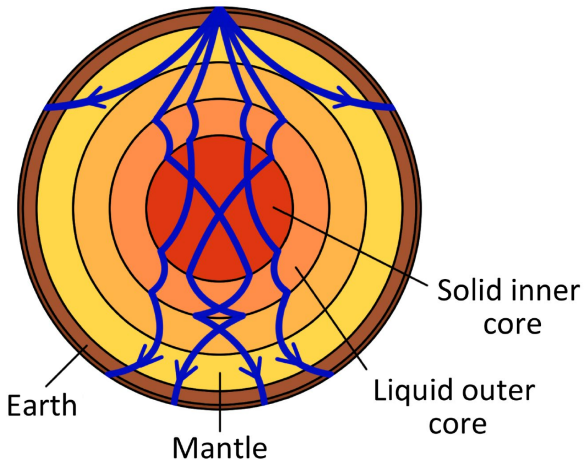
In most questions involving seismic waves, we are asked to compare P and S waves. For ease, we could study P and S waves using a table.

	P Waves	**S Waves**
What type of wave is it?	Longitudinal wave	Transverse wave
What does it travel through?	Solids and liquids	Solids only
How fast does it move?	Fast	Slow

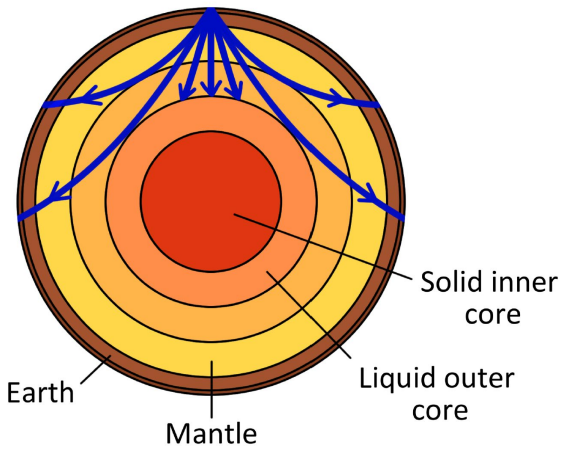
How can we remember which wave is which? Letter association works well here 😊 Transverse has the letter **s** in it 😊 So, **S** waves are transverse. Then **P** waves are just the other one.

How do P and S waves look?

P Waves



S Waves



We can see from the diagrams above that the S waves do not pass through the outer core. This was how we determined that the earth must have a liquid core around its inner core.