Edexcel GCSE Physics

Your notes

Sound

Contents

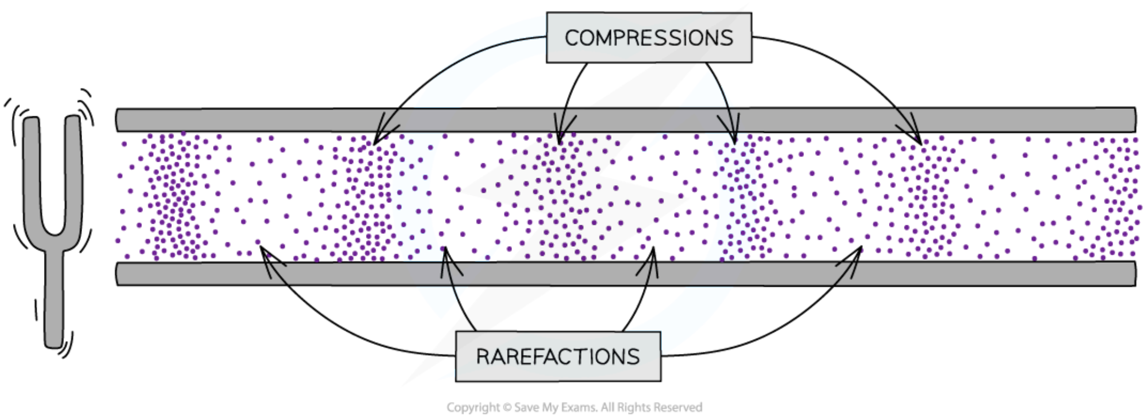
Your notes

Sound Waves

Sound in Solids

Higher Tier Only

- Sound waves are **vibrations** of molecules
- When a sound wave travelling through a gas or a liquid comes into contact with a **solid**, some of the **energy** it is transferring is **reflected** from the surface of the solid, and some is **transmitted** through or **absorbed** by the solid
  - A reflected sound wave is called an echo
- Sound is an example of a longitudinal wave, hence it consists of:
  - **Compressions** - regions of higher density
  - **Rarefactions** - regions of lower density



Sound is a longitudinal wave consisting of compressions and rarefactions – these are areas where the pressure of the air varies with the wave

- These compressions and rarefactions cause changes in pressure, which vary in time with the wave
  - Therefore, sound is a type of **pressure wave**
- When the waves hit a solid, the variations in pressure cause the surface of the solid to **vibrate** in sync with the sound wave

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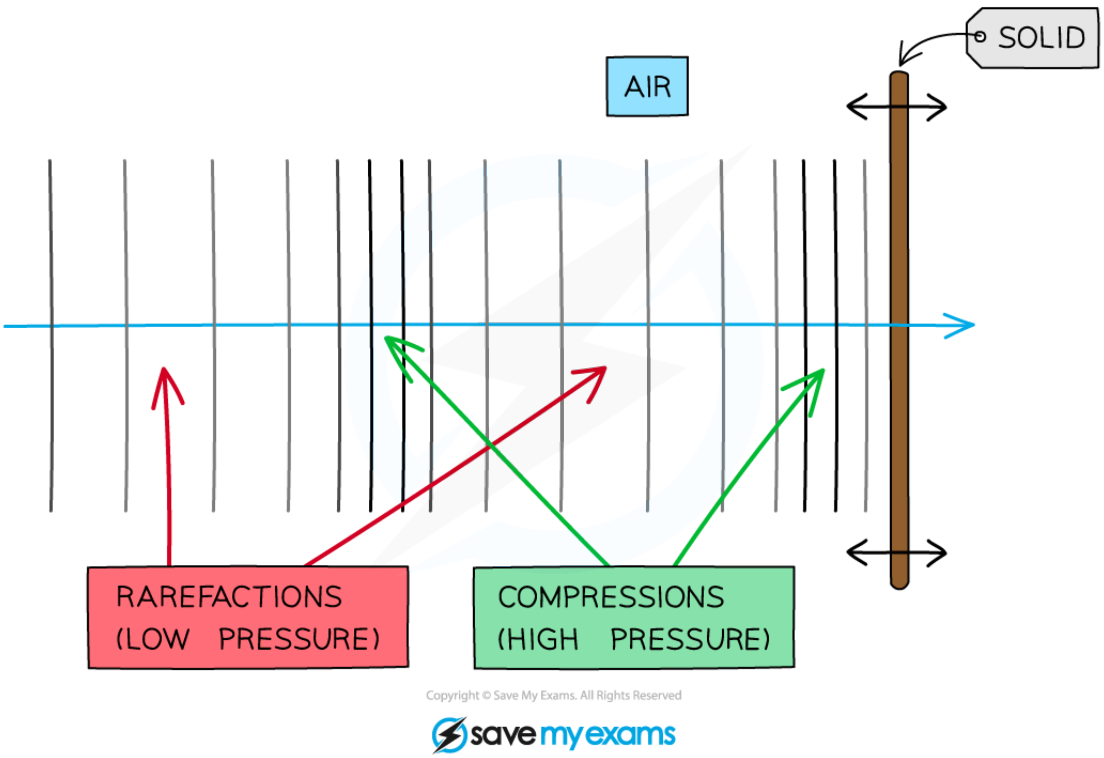


When sound waves hit a solid, the fluctuating pressure causes the solid to vibrate

Frequency Response

Higher Tier Only

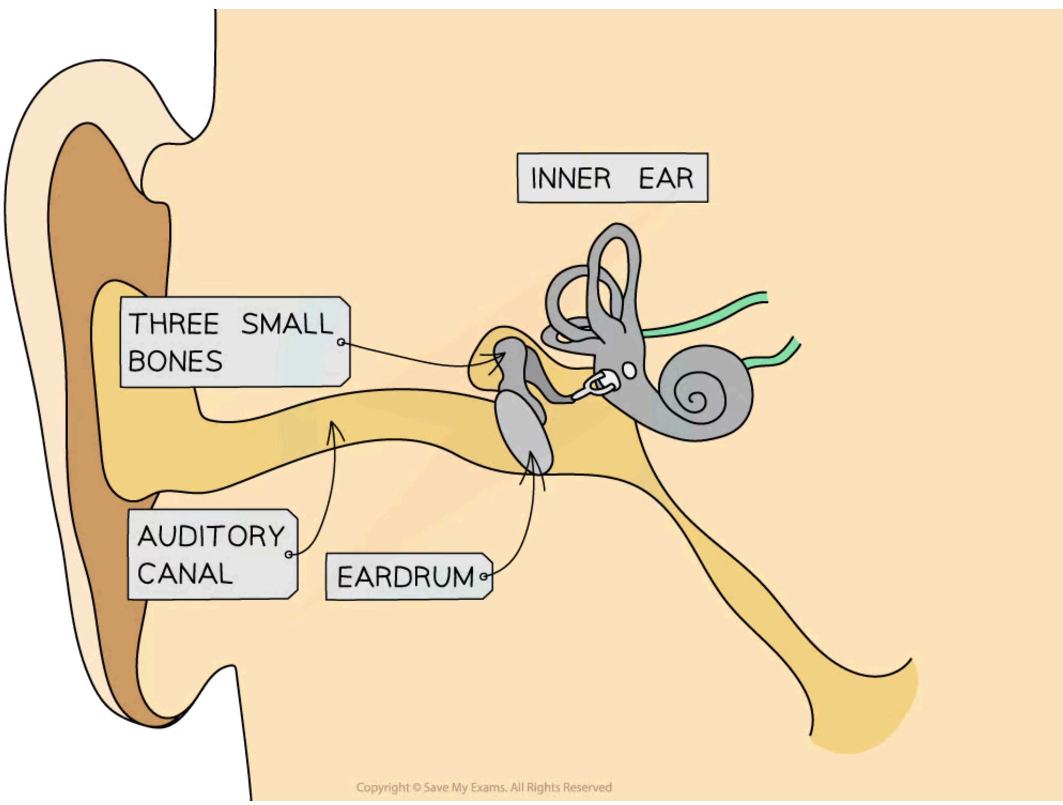
- Different solids have a tendency to **vibrate** at **different frequencies**
- This is called the object's **natural frequency**
- As a result, sound waves with a frequency that is **close** to a particular solid's **natural frequency** will cause **larger vibrations** than for sound waves with frequencies much larger or smaller than the solid's natural frequency
- This means some frequencies of sound are **transferred** much more **efficiently** to the solid than others

The Human Ear

Higher Tier Only

Your notes

- Sound waves can be heard by human beings because sound waves are **transferred efficiently** from the **air** to the **solid components** of the ear
- The transmission of sound to the human ear only works over a **limited range** of frequencies
  - This **limits** the range of sound frequencies a human can hear
- The range of frequencies a human can hear is **20 Hz to 20 000 Hz**
- In the case of the human ear, the sound waves are transferred by two main solid components:
- The **eardrum** which is made of tissue and skin
  - Three **small bones**



The human ear is made up of several components which turn sound waves into signals which the brain can interpret

- The sound wave travels down the **auditory canal** towards the eardrum
  - The **pressure** variations created by the sound wave exert a **varying force** on the eardrum causing it to **vibrate**

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- The vibration pattern of the sound waves creates the **same pattern of vibration** in the eardrum
- The eardrum vibration is transferred to the three small bones
- The vibration of these small bones **amplifies** the vibrations and then transfers the vibrations to the **liquid** in the **cochlea** located in the **inner ear**
  - Tiny **hairs** inside the cochlea **detect** the vibrations and create **electrical impulses** which travel along **neurones** in the **auditory nerve** to the **brain** giving the sensation of sound

Ultrasound & Infrasound

Your notes

Ultrasound

Higher Tier Only

- Ultrasound is defined as:

  Sound waves with a frequency above the human hearing range of 20 000 Hz

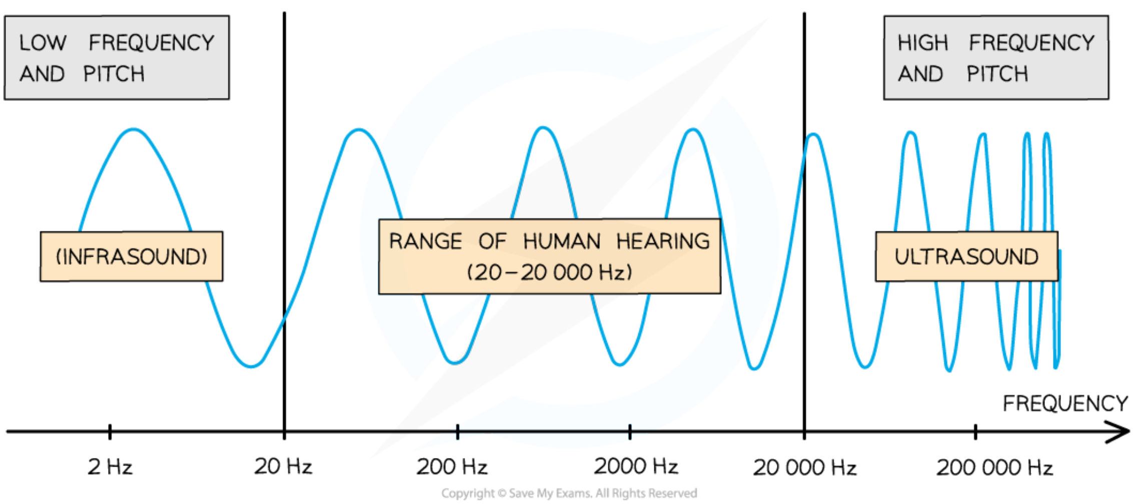
Infrasound

Higher Tier Only

- Infrasound is defined as:

  Sound waves with a frequency below the human hearing range of 20 Hz

- The spectrum of sound waves, including infrasound and ultrasound, is shown in the image below:



The human ear can detect sounds between around 20 and 20 000 Hz in frequency with a peak sensitivity at around 4000 Hz

Uses of Ultrasound & Infrasound

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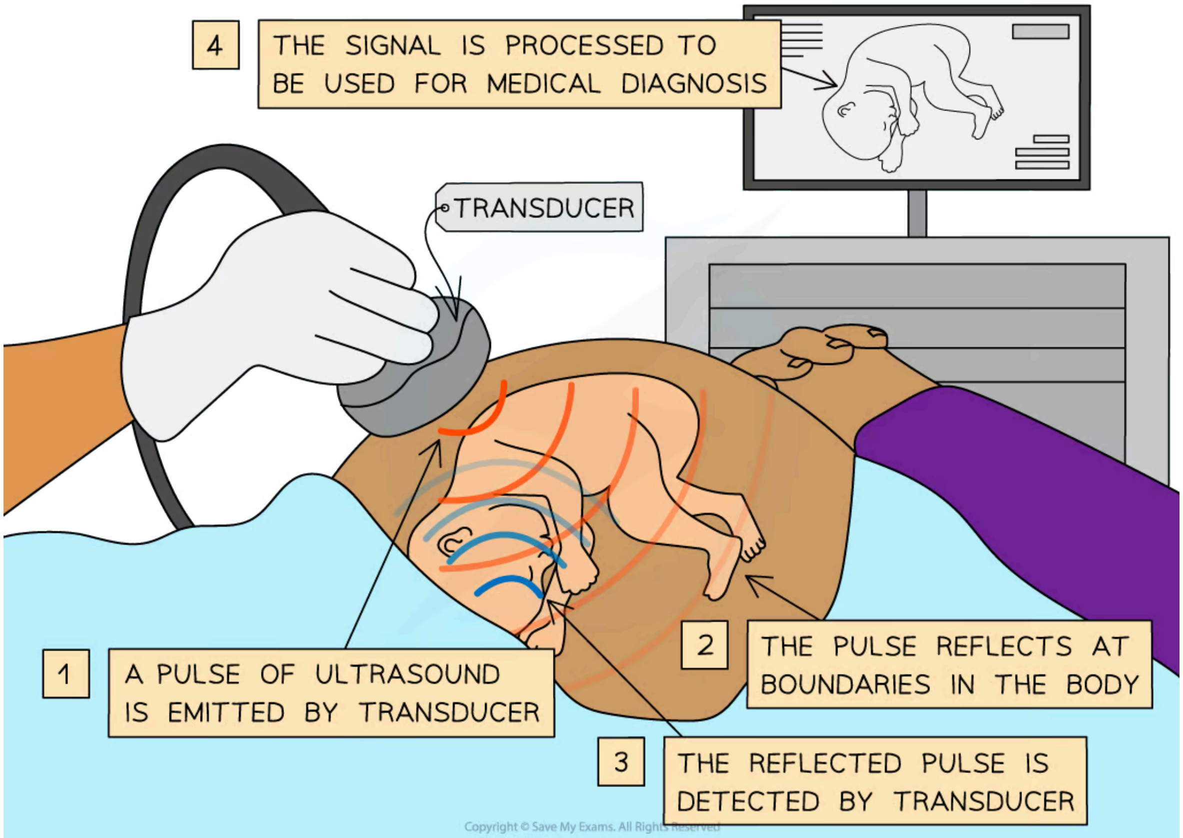
- Ultrasound and infrasound have multiple applications, including:
  - Sonar
  - Foetal scanning
  - Exploration of the Earth's core

Sonar

- **Sonar** uses **ultrasound** to detect objects underwater
- The sound wave is **reflected** off the ocean bottom
- The **time** it takes for the sound wave to return is used to calculate the **depth** of the water
- The **distance** the wave travels is **twice the depth** of the ocean
  - This is the distance to the ocean floor plus the distance for the wave to return

Foetal Scanning

- In medicine, ultrasound can be used to construct images of a **foetus** in the womb
  - An ultrasound detector is made up of a **transducer** that produces and detects a beam of ultrasound waves into the body
  - The ultrasound waves are reflected back to the transducer by different **boundaries** between tissues in the path of the beam
  - For example, the boundary between fluid and soft tissue or tissue and bone
- When these **echoes** hit the transducer, they generate **electrical signals** that are sent to the ultrasound scanner
- Using the speed of sound and the time of each echo's return, the detector calculates the distance from the transducer to the tissue boundary
- By taking a series of ultrasound measurements, sweeping across an area, the time measurements may be used to build up an **image**
- Unlike many other medical imaging techniques, ultrasound is **non-invasive** and is believed to be **harmless**



Ultrasound can be used to construct an image of a foetus in the womb

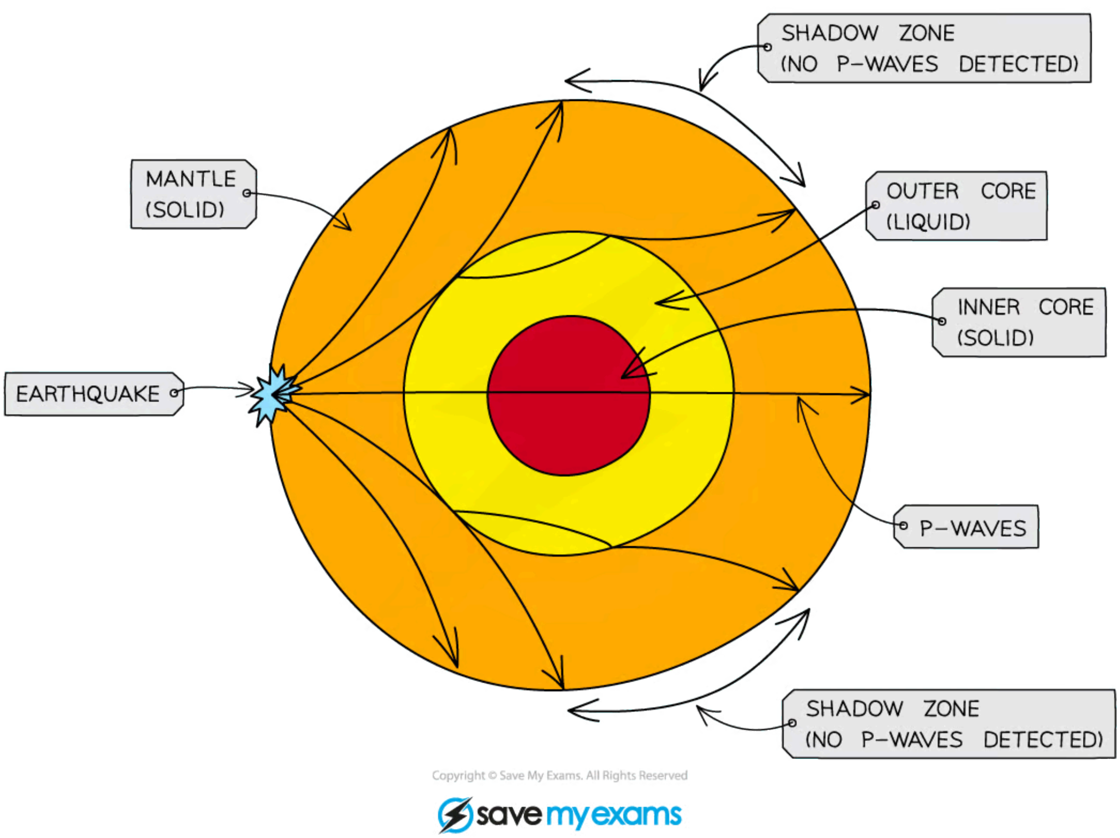
Exploration of the Earth's Core

- Earthquakes produce two types of waves:
  - **P-waves** (primary waves, named so because they travel faster and so these waves are felt first in an earthquake)
  - **S-waves** (secondary waves, named so because these travel slower and so these waves are felt second in an earthquake)
- These waves pass through the Earth's centre and can be detected at various points around the Earth using **seismometers**
- By carefully timing the arrival of the waves at each point, the **location** of the earthquake, along with its **magnitude**, can be pinpointed

P-Waves

Your notes

- P-waves are **longitudinal** waves, the direction of the oscillation is **parallel** to the direction of energy transfer
- P-waves are **faster** than S-waves
  - Therefore, P-waves are felt first during an earthquake
  - P-waves produce a forward and backward motion
- P-waves can pass through **solids** and **liquids**
  - Longitudinal waves can travel through gases, but P-waves do not
- P-waves are very low frequency sound waves known as **infrasound**
  - Infrasound is any sound **below** the frequency of human hearing (<20 Hz)
- P-waves refract as they pass through the different layers of the Earth
- This refraction affects the regions in which waves can be detected, yielding important information about the nature and size of the Earth's various layers



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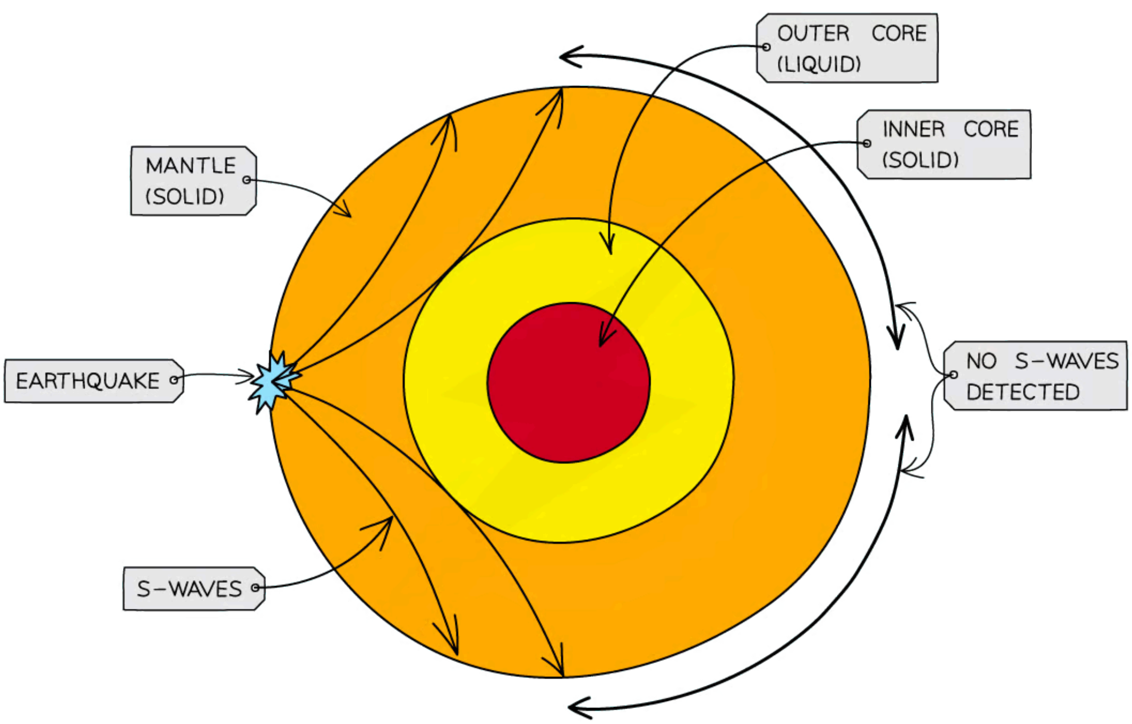
Low frequency sound waves (P-waves) produced by earthquakes, pass through the centre of the Earth, revealing useful information about its structure

S-Waves

- S-waves are **transverse** waves, the direction of the oscillation is **perpendicular** to the direction of energy transfer
- S-waves are **slower** than P-waves
  - Therefore, S-waves are felt after P-waves during an earthquake
  - S-waves produce a side-to-side motion
- Unlike P-waves, S-waves are unable to travel through liquids
  - Longitudinal waves can travel through solids, liquids and gases, but **S-waves** only travel through **solids**
- This means that they are unable to travel through the Earth's molten (liquid) outer core – providing important evidence about its state and size



Transverse S-Waves are unable to pass through the Earth's liquid outer core

Your notes

Discoveries from Seismic Waves

- The interior of the Earth is not directly observable as it is not physically possible to drill that far
  - The furthest humans have managed to drill down is 12.2 km - whereas the radius of the Earth is over 6000 km!
- Seismic waves provide vital evidence that has led to a greater understanding of the structure of the Earth
- The two main discoveries are:

1. On the opposite side of the Earth to an earthquake, only P-waves are detected, not S-waves, this suggests:
   - The **mantle** is **solid** – this is because both types of wave can pass through it
   - The **outer core** of the Earth is **liquid** – hence no S-waves can penetrate it
2. Refractions between layers cause two shadow zones, where no P-waves are detected, this suggests:
   - The **inner core** is **solid** – this is due to the size and positions of these shadow zones which indicate large refraction taking place

Your notes

Transmission of Sound

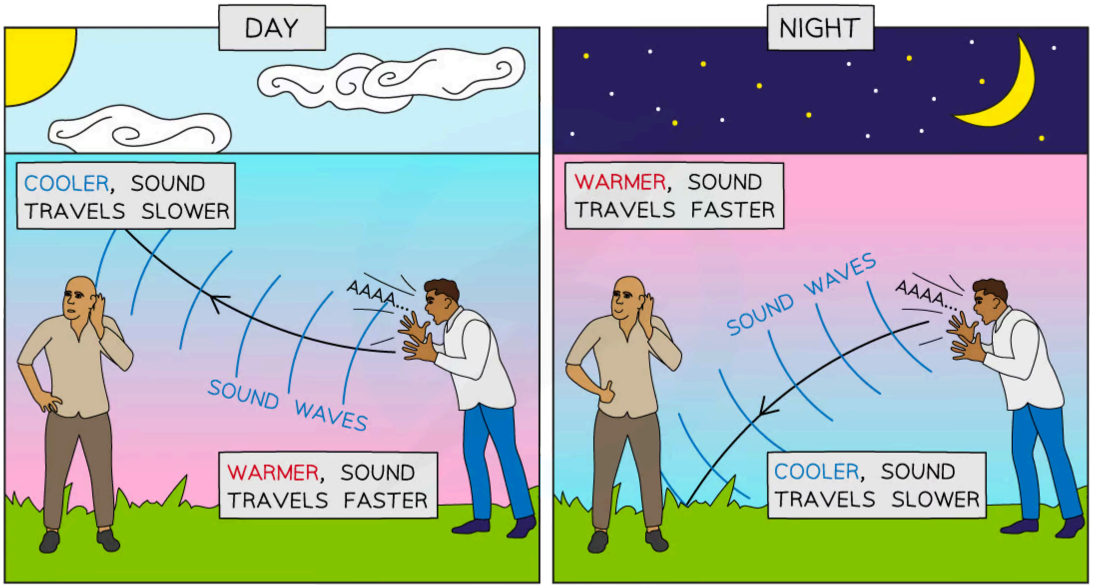
Transmission of Sound

- Sound waves are longitudinal waves
  - They transfer energy by the molecules vibrating and knocking into neighbouring molecules
- The **more molecules** that are present the **faster** the wave can transfer energy, therefore:
  - Sound waves travel **fastest** in solids
  - Sound waves travel **slowest** in gases
- When sound waves move from one medium to another, there will be changes to its:
  - Wave speed
  - Wavelength
- The relationship between the wave speed, wavelength and frequency can be determined using the wave equation
- This change in velocity can also result in a change of direction of the sound wave
  - This phenomenon is also known as **refraction**

Worked Example

A child shouts across an empty field to a friend during the day, and then again during the night. They find that their friend can hear them more clearly at night because the sound travels further at night. Explain why sound travels further at night than during the day.

Answer:



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Step 1: Identify the difference in conditions between the day and the night

- During the day, it is warmer near the ground and cooler in the atmosphere
- At night, it is cooler near the ground and warmer in the atmosphere

Step 2: Consider the effect of sound waves travelling between the two air temperatures

- Sound waves can travel faster in hot air and slower in cold air
- This change in temperature will cause the sound waves to refract

Step 3: Explain the motion of the waves during the day and the night

- During the day, the sound wave will travel faster in the warm air and refract towards the sky as the wave slows down
- At night, the sound wave will travel slower in the cool air and refract towards the ground as the wave speeds up

Step 4: Relate the explanation back to the question

- Sound travels further at night because its speed increases as it moves from a denser medium (cold air) to a less dense medium (warm air)