# Sound waves

4.6.1.4 · Waves · revision notes

How sound waves make solids vibrate, how the ear turns sound into the sensation of hearing, and why humans can only hear a limited range of frequencies. Higher tier only, and GCSE Physics only (not in Combined Science). Expect short 'describe' and 'explain' questions and wavelength calculations.

## Key facts

- Human hearing range: 20 Hz to 20 kHz
- Sound waves can travel through solids, making them vibrate
- Converting sound waves to vibrations of solids only works over a limited frequency range
- Sound cannot travel through a vacuum
- 20 kHz = 20 000 Hz
- Ear: sound wave → eardrum vibrates → vibrations passed on → sensation of sound
- This limited range is why human hearing has limits
- $v = f \lambda$ works for sound too

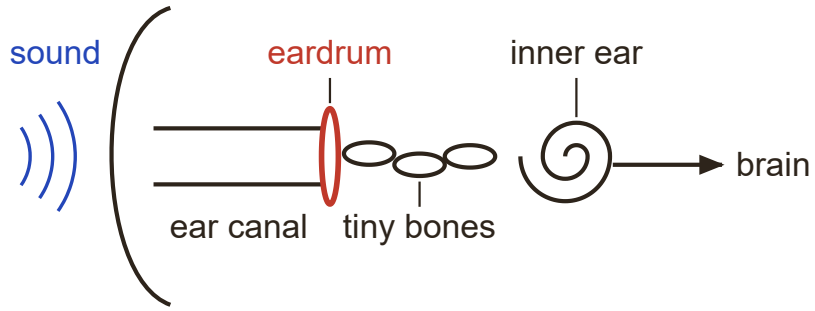
## Notes

### Sound and solids

- Sound waves are longitudinal. They need a medium (a solid, liquid or gas) and cannot travel through a vacuum.
- Sound waves can travel through solids. When a sound wave reaches a solid it makes the solid vibrate, and the vibrations travel through it. This is why you can hear music through a wall or a closed door: the wall vibrates and makes the air on the other side vibrate.
- It also works the other way round: a vibrating solid surface, such as a loudspeaker cone, pushes and pulls on the air next to it and produces sound waves.
- In a microphone, sound waves make a thin diaphragm vibrate, and these vibrations are turned into an electrical signal.

## How you hear

- Sound waves travel into the ear and make the **eardrum** vibrate.
- The vibrations are passed through tiny bones to the inner ear, where they are detected. This causes the sensation of sound.

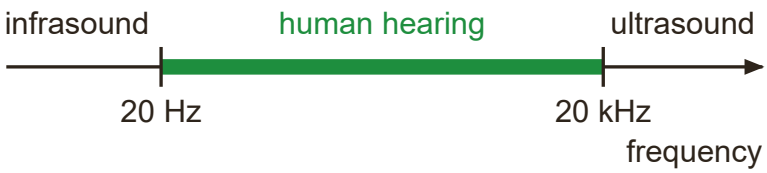



Sound makes the eardrum vibrate; the bones pass the vibrations to the inner ear.

- So hearing depends on sound waves being converted into vibrations of solid parts of the ear.

## The limits of human hearing

- The normal range of human hearing is **20 Hz to 20 kHz** (20 000 Hz).




Humans hear 20 Hz to 20 kHz. Ultrasound is above 20 kHz.

- The conversion of sound waves into vibrations of solids only works over a **limited frequency range**.
- The eardrum and the other parts of the ear can only vibrate in response to sound over a certain range of frequencies, set by their size, mass and stiffness. Outside that range they do not vibrate enough to produce the sensation of sound, and this sets the limits of human hearing.
- Sound with a frequency above 20 kHz is called **ultrasound**. It is still sound; it is just too high for humans to hear.
- The upper limit of hearing usually falls as people get older.

## How to answer each type of question

### Describe how the ear detects sound

2 to 3 marks | Grade 5

1. Start with the sound wave making the eardrum vibrate.
2. Say the vibrations are passed on through other parts of the ear.
3. Finish with the sensation of sound (the brain detects it).

**Example.** Describe how a sound wave in the air causes a person to hear a sound.

**Model answer.** The sound wave makes the eardrum vibrate (1). The vibrations are passed on through the other parts of the ear, such as tiny bones, to the inner ear (1). This causes the sensation of sound (1).

### Explain how sound passes through a solid

2 marks | Grade 6

1. Say the sound wave makes the solid vibrate.
2. Say the vibrations travel through the solid and make the air on the other side vibrate.

**Example.** A person in one room can hear music playing in the next room, even with the door closed. Explain how the sound gets through the wall.

**Model answer.** The sound waves make the wall vibrate (1). The vibrations travel through the wall and make the air on the other side vibrate, producing sound waves in the next room (1).

### Calculate the wavelength of sound at the limits of hearing

3 marks | Grade 6

1. Use 20 Hz or 20 000 Hz as the frequency, whichever limit is asked for.
2. Rearrange $v = f\lambda$ to $\lambda = v \div f$.
3. Give the answer in metres.

**Example.** The speed of sound in air is 340 m/s.
Calculate the wavelength of the highest frequency sound that a person with normal hearing can hear.

**Model answer.**

Highest frequency = 20 kHz = 20 000 Hz (1)
$\lambda = v \div f = 340 \div 20\,000$ (1)
$\lambda = 0.017$ m (1)

**Explain why humans cannot hear some frequencies** 2 marks **Grade 7**

1. Compare the frequency with the limits of hearing (20 Hz and 20 kHz).
2. Explain that the ear can only convert sound waves into vibrations over a limited frequency range.

**Example.** A dog whistle produces sound with a frequency of 30 kHz. A dog can hear it but its owner cannot.
Explain why the owner cannot hear the whistle.

**Model answer.** 30 kHz is above the upper limit of human hearing, which is 20 kHz (1). The eardrum and other parts of the human ear cannot vibrate in response to sound of this frequency, because the conversion of sound waves to vibrations only works over a limited frequency range (1).

## Don't lose marks

- Writing the range as 20 Hz to 2000 Hz, or 20 Hz to 20 000 kHz. It is 20 Hz to 20 kHz.
- Saying we cannot hear a sound because it is 'too quiet' when the question is about frequency. The ear cannot vibrate in response outside its frequency range.
- Forgetting to convert 20 kHz to 20 000 Hz in calculations.
- Saying sound can travel through a vacuum, such as space.

## More tips

### Memory tricks

- '20 to 20': human hearing runs from 20 Hz to 20 kHz.
- Sound chain: air → eardrum → tiny bones → inner ear → brain.
- Anything above 20 kHz is ultrasound: still sound, just too high for us to hear.

### Exam technique

- In 'explain' questions, link the frequency to the ear's limited frequency range; just quoting the range is not enough.
- Name the eardrum and say that it vibrates; 'the ear picks it up' will not get the mark.
- Check whether a frequency is given in Hz or kHz before comparing it with 20 kHz.

## What each grade needs

What you need to be able to do, from the first marks up to the top grade.

**Grade 4** **State the range of human hearing**
Normal human hearing is from 20 Hz to 20 kHz (20 000 Hz).

**Grade 5** **Describe how sound makes solids vibrate**
Sound waves can travel through solids: a sound wave reaching a solid makes it vibrate, and the vibrations travel through it.

**Grade 5** **Describe how the ear detects sound**
Sound waves make the eardrum vibrate; the vibrations are passed on to other parts of the ear, causing the sensation of sound.

Grade 6

### Give examples of sound–vibration conversions

E.g. the eardrum, a microphone's diaphragm, a loudspeaker cone, or a wall carrying sound into the next room.

Grade 6

### Use v = f λ for sound

E.g. the wavelength of a 20 kHz sound in air (speed 340 m/s) is 340 ÷ 20 000 = 0.017 m.

Grade 7

### Explain why hearing has a limited range

The conversion of sound waves into vibrations of the eardrum and other parts of the ear only works over a limited frequency range.

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