IGCSE PHYSICS 0625 · CHAPTER 7 NOTES · ~10 MIN READ

Waves & sound

What a wave really is, the wave equation v = fλ, reflection, refraction and diffraction, and everything about sound — loudness, pitch, echoes and ultrasound.

Wave terms | Transverse & longitudinal waves | v = fλ | Reflection, refraction, diffraction | Sound | Speed of sound | Echoes & ultrasound

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- A wave carries **energy** from place to place without carrying matter.
- **Wave speed v = f × λ**. Frequency is in hertz (Hz), wavelength in metres.
- **Transverse** waves vibrate at right angles to the direction of travel (light, water). **Longitudinal** waves vibrate along it (sound).
- Sound needs a medium, is audible from **20 Hz to 20 kHz** and travels at about **340 m/s** in air.
- Waves can **reflect**, **refract** (change speed) and **diffract** (spread out).

BY THE END YOU CAN

- Define wavelength, frequency, amplitude, crest, trough and wavefront.
- Use v = fλ and tell transverse from longitudinal waves.
- Explain reflection, refraction and diffraction using a ripple tank.
- Relate pitch to frequency and loudness to amplitude.
- Describe how to measure the speed of sound and use echoes. EXT

1 Wave basics

What is a wave?

- A wave is a vibration that carries energy. A cork on water bobs up and down but does not travel along with the wave: **the energy moves, the water does not**.

Wavefront — a line joining points on a wave that are in the same state of vibration, such as the crests.

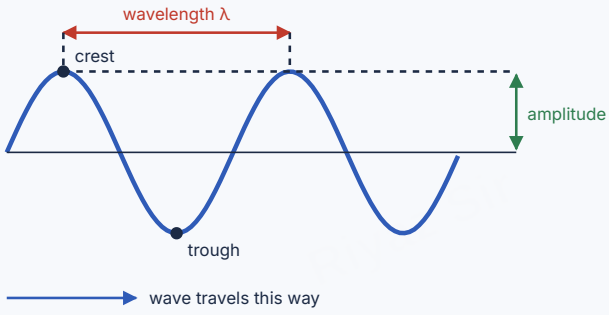
Wavelength (λ) — the distance between two matching points on neighbouring waves, such as crest to crest. Measured in metres.

Frequency (f) — the number of complete waves passing a point each second. Measured in hertz (Hz).

Amplitude — the maximum displacement from the rest position. A bigger amplitude means more energy.

Wave speed (v) — the distance a crest travels each second.

- The time for one complete wave is the **period**: T = 1 ÷ f.



A wave on a rope or water. Wavelength is crest to crest. Amplitude is measured from the middle line, not from trough to crest.

The wave equation

$$v = f \lambda$$

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

WORKED EXAMPLE

A water wave has frequency 5.0 Hz and wavelength 0.40 m. Find its speed.

1. $v = f\lambda = 5.0 \times 0.40$
2. **= 2.0 m/s**

WORKED EXAMPLE

A radio station broadcasts at 100 MHz. Radio waves travel at 3.0×10^8 m/s. Find the wavelength.

1. Convert: 100 MHz = $100 \times 10^6 = 1.0 \times 10^8$ Hz
2. $\lambda = v \div f = 3.0 \times 10^8 \div 1.0 \times 10^8$
3. **= 3.0 m**

COMMON MISTAKE

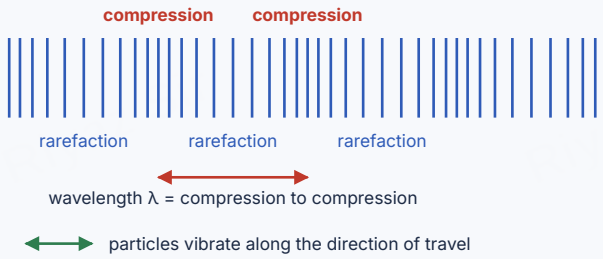
Forgetting to convert kHz and MHz into Hz before using the equation.

EXAM TIP

When the wave goes into a new material its frequency **never changes**. Only the speed and wavelength change.

Riyaz Sir

Transverse and longitudinal waves



In a longitudinal wave the particles vibrate backwards and forwards along the direction the wave travels.

	Transverse	Longitudinal
vibration	at right angles to the direction of travel	parallel to the direction of travel
pattern	crests and troughs	compressions and rarefactions EXT
examples	light and all electromagnetic waves, water waves, S-waves from earthquakes	sound, P-waves from earthquakes
medium needed?	electromagnetic waves do not need one	always needs a medium

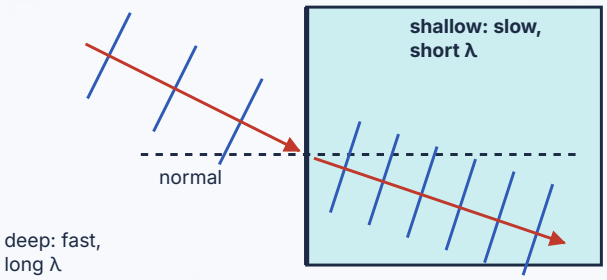
PICTURE IT

Shake a rope up and down and a transverse pulse runs along it. Push and pull a slinky spring along its length and a longitudinal pulse runs along it.

2 Reflection, refraction and diffraction

Waves meeting boundaries

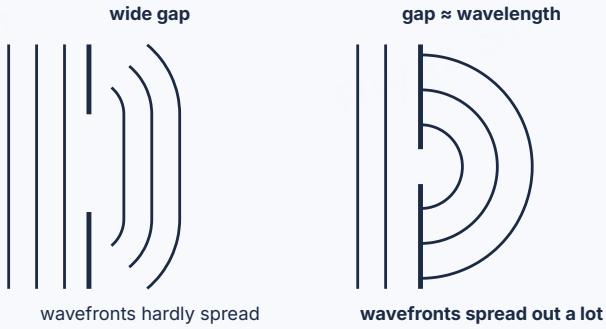
- A **ripple tank** makes water waves visible. A lamp above shines through the water onto a screen, so the wavefronts appear as bright and dark lines.
- **Reflection:** waves bounce off a barrier. The angle of incidence equals the angle of reflection. The speed, wavelength and frequency stay the same.
- **Refraction:** waves change speed when they pass from one material to another (for water, from deep to shallow). The wavelength changes, the frequency does not, and the waves change direction if they hit the boundary at an angle.



frequency stays the same; speed and wavelength change

Waves slow down in shallow water, so the wavelength gets shorter and the waves bend towards the normal. The frequency stays the same.

- **Diffraction:** waves spread out when they pass through a gap or go round the edge of an obstacle.



A narrow gap spreads the waves out most. A wide gap lets them go through, with only a little spreading at the edges.

- EXT Diffraction is greatest when the gap is about the **same size as the wavelength**. A longer wavelength spreads out more at a gap and bends more round an edge.

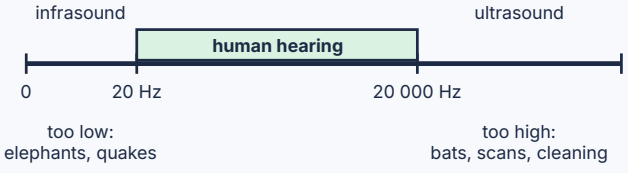
PICTURE IT

You can hear someone talking round a corner but cannot see them. Sound has a wavelength of about a metre, so it diffracts round the corner. Light has a wavelength of about 0.0005 mm, which is far too small to spread noticeably.

3 Sound

Sound waves

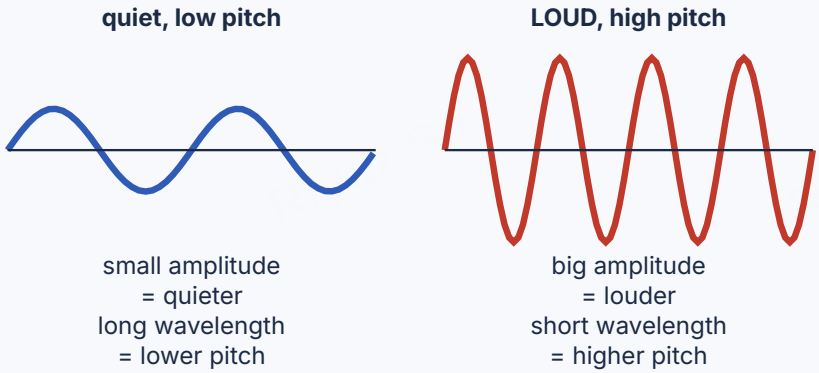
- Sound is made by **vibrating objects** such as a loudspeaker cone, a guitar string or vocal cords.
- It is a **longitudinal** wave and needs a **medium** (a solid, liquid or gas). In a vacuum there is no sound — a ringing bell in a jar fades as the air is pumped out.
- EXT Where particles are squashed together there is a **compression** (high pressure). Where they are spread out there is a **rarefaction** (low pressure).
- Audible range for humans: **20 Hz to 20 000 Hz (20 kHz)**. Above 20 kHz is **ultrasound**.



children can hear up to ~20 kHz; adults hear less as they age

Human hearing runs from 20 Hz to 20 kHz. Ultrasound is above, infrasound is below. Hearing gets worse with age.

Loudness and pitch



amplitude → loudness · frequency → pitch

An oscilloscope trace. Bigger waves are louder. More waves in the same time means a higher pitch.

- **Amplitude → loudness.** A larger amplitude gives a louder sound.
- **Frequency → pitch.** A higher frequency gives a higher pitch.

Speed of sound

- In air the speed of sound is about **330 to 350 m/s**. Use 340 m/s or the value in the question.
- EXT Sound travels fastest in solids and slowest in gases because the particles are closer together in solids and pass the vibrations on faster.

Material	Speed of sound (about)
air	340 m/s
water	1500 m/s
steel	5000 m/s

- **Measuring it:** stand a measured distance d from a large wall and clap. Time the interval t between the clap and its echo with a stopwatch, which means the sound has travelled a distance 2d. Then v = 2d ÷ t. Repeat several times and average, and use a large distance, to reduce the effect of your reaction time.

WORKED EXAMPLE

A student stands 85 m from a wall. The echo of a clap returns after 0.50 s. Find the speed of sound.

1. The sound goes to the wall and back: distance = 2 × 85 = 170 m
2. v = distance ÷ time = 170 ÷ 0.50
3. **= 340 m/s**

WORKED EXAMPLE

Thunder is heard 3.0 s after the flash of lightning. How far away is the storm? (v = 340 m/s; the light arrives almost instantly)

1. distance = speed × time = 340 × 3.0
2. **= 1020 m (about 1 km)**

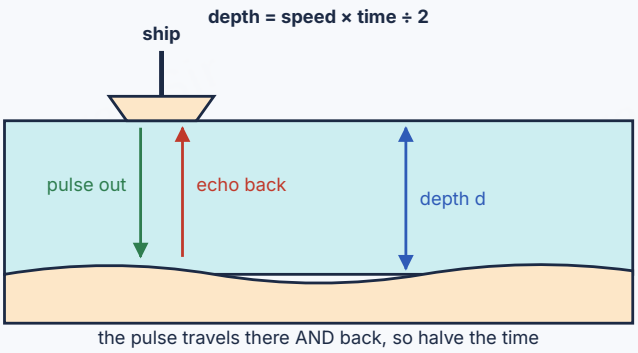
WORKED EXAMPLE

A note has frequency 256 Hz. Find its wavelength in air (v = 340 m/s).

1. λ = v ÷ f = 340 ÷ 256
2. **= 1.3 m**

Echoes and ultrasound

- An **echo** is a reflection of sound from a hard surface.



Sonar. The pulse goes down and comes back, so the depth uses only half the total time.

- EXT **Ultrasound** is used for: **sonar** (finding the depth of the sea or shoals of fish); **medical scans** (echoes from the boundaries between different tissues, for example an unborn baby, and safer than X-rays); **non-destructive testing** (echoes from cracks inside metal).

WORKED EXAMPLE

EXT **A ship sends an ultrasound pulse to the sea bed and hears the echo 0.40 s later. The speed of sound in sea water is 1500 m/s. Find the depth.**

1. One-way time = 0.40 ÷ 2 = 0.20 s
2. depth = speed × time = 1500 × 0.20
3. **= 300 m**

COMMON MISTAKE

Forgetting to halve the time for an echo.

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4 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. A wave has wavelength 2.0 m and frequency 5.0 Hz. What is its speed?
2. Is sound a transverse or a longitudinal wave?
3. What is the range of human hearing?
4. What happens to the frequency of a wave when it goes from deep to shallow water?
5. Why can sound not travel through a vacuum?
6. A sound gets louder but the pitch stays the same. What changed?

EXAM-STYLE

7. A student sees lightning and hears the thunder 4.5 s later. How far away is the lightning? (v = 340 m/s)
8. Describe how to measure the speed of sound in air. [4]
9. EXT Explain why a long-wavelength wave spreads out more through a gap than a short-wavelength wave. [2]
10. A sound wave passes from air into water. State what happens to its frequency, wavelength and speed. [3]

Show answers

1. 2.0 × 5.0 = 10 m/s
2. longitudinal
3. 20 Hz to 20 kHz
4. It stays the same.
5. There are no particles to pass the vibration on.
6. the amplitude
7. distance = 340 × 4.5 = 1530 m, about 1.5 km
8. Stand a measured distance from a large wall
   Make a loud sound and use a stopwatch to time the echo
   speed = 2 × distance ÷ time
   Repeat and average the results
9. Diffraction is greatest when the gap is about the same size as the wavelength
   a longer wavelength is closer to the gap size, so it spreads more
10. frequency stays the same
    speed increases
    wavelength increases (since v = fλ and f is constant)

Stuck on a question?

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