Cambridge IGCSE · Physics 0625 · Notes

General properties of waves

Read online at **pastopic.com/cambridge/physics-0625/notes/general-properties-of-waves**

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Read first: **Motion**

What you need to know

This topic is about what all waves have in common: what they carry, how their parts are named, the wave equation, and the four things that can happen to them in a ripple tank. The parts marked **Extended only** are tested on Papers 2 and 4 only. By the end of it you should be able to:

1. **Know that waves transfer energy without transferring matter.**
2. **Describe wave motion** using vibrations sent along a rope or a spring, and using water waves in a ripple tank.
3. **Describe the features of a wave**: wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed.
4. **Recall and use the wave equation** $v = f\lambda$.
5. **Know what a transverse wave is**: the vibration is at right angles to the direction the wave travels (propagates). Light and all electromagnetic waves, water waves and seismic **S-waves** (secondary) can be modelled as transverse.
6. **Know what a longitudinal wave is**: the vibration is parallel to the direction the wave travels. Sound and seismic **P-waves** (primary) can be modelled as longitudinal.
7. **Describe how waves can be reflected** at a flat surface, **refracted** because their speed changes, and **diffracted** through a narrow gap.
8. **Describe how a ripple tank shows** reflection at a flat barrier, refraction when the depth (and so the speed) changes, diffraction through a gap, and diffraction at an edge.
9. **Extended only:** describe how the **wavelength and the gap size** affect diffraction through a gap.
10. **Extended only:** describe how the **wavelength** affects diffraction at an edge.

Understand it

What a wave is

Flick one end of a long rope up and down once. A hump runs along the rope to the far end, but the rope itself does not travel: each bit of rope just moves up and down and comes back to where it started. What travelled along the rope was **energy**. That is what every wave does:

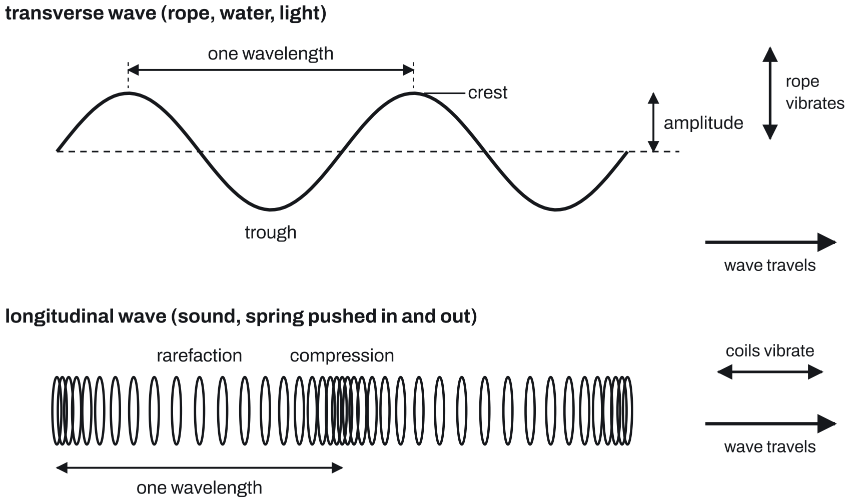
A wave transfers **energy** from one place to another **without transferring matter**.

A cork floating on a pond shows the same thing. As ripples pass, the cork bobs **up and down** in the same place; it is not carried along with the waves.

A **ripple tank** is a shallow glass-bottomed tray of water with a lamp above it. A vibrating bar (or a small dipper) touching the water makes the waves, and the lamp throws a picture of them onto a screen below, so you can see the pattern of crests from above and watch what happens when they meet barriers and changes of depth.

Transverse and longitudinal waves

There are two ways the particles can vibrate compared with the direction the wave travels.



- **Transverse**: the vibration is **at right angles** (perpendicular) to the direction of travel. Moving a rope up and down sends a transverse wave along it. Examples: **light and every other electromagnetic wave** (radio waves, microwaves, X-rays ...), **water waves**, waves on a rope, and **seismic S-waves**.
- **Longitudinal**: the vibration is **parallel** to the direction of travel (backwards and forwards along it). Pushing and pulling the end of a stretched spring (a slinky) sends a longitudinal wave along it: the coils bunch up in **compressions** and spread out in **rarefactions**. Examples: **sound** (including ultrasound) and **seismic P-waves**.

Earthquakes send out both kinds: the **P-waves** (primary, longitudinal) and the **S-waves** (secondary, transverse). A memory aid: **P** for **p**ush–pull (longitudinal), **S** for **s**ide to side (transverse).

Electromagnetic waves are the only ones here that can travel through a **vacuum**. Sound, water waves and seismic waves need a material to travel through.

Naming the parts of a wave

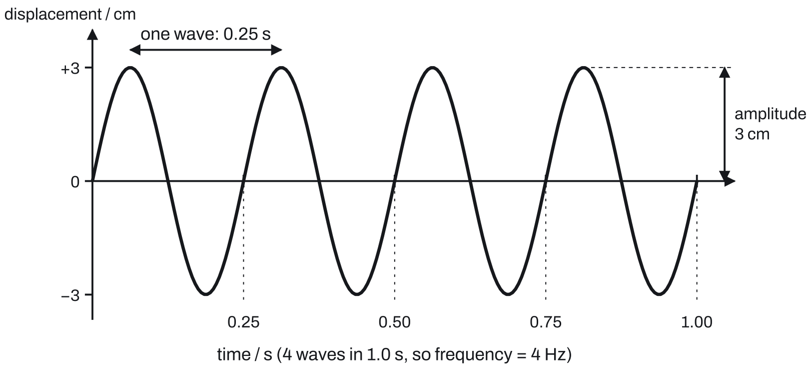
Word	What it means	Unit
Crest (peak)	a highest point of a transverse wave	
Trough	a lowest point	
Amplitude	the **greatest distance** a particle moves from its undisturbed (rest) position: from the middle line to a crest, **not** from crest to trough	m (or cm)
Wavelength, λ	the distance from one point on a wave to the **same point on the next wave**: crest to next crest, trough to next trough, or compression to next compression	m (or cm)
Frequency, f	the **number of waves** passing a point (or made by the source) **each second**	hertz, Hz (1 Hz = one wave per second)
Wave speed, v	the distance a crest (or any wavefront) moves **each second**	m/s
Wavefront	a line joining points on the wave that are all doing the same thing, such as a line along the top of a crest. In a ripple tank seen from above, each bright line is a wavefront	

On a ripple-tank picture, **wavefronts are drawn one wavelength apart**, so the gap between neighbouring lines is the wavelength. The direction of travel is always at **right angles to the wavefronts**. Straight (plane) wavefronts come from a straight vibrating bar; circular wavefronts spread out from a point, such as a dipper or a stone dropped into a pond.

Amplitude and wavelength are both **lengths**, so both are measured in metres. Frequency is not a length.

Frequency from a graph

A **displacement–time graph** shows how one point on the wave moves as time passes. The time for one complete wave (crest to crest along the time axis) tells you the frequency.



Here one wave takes 0.25 s, so 4 waves happen in 1 second: the frequency is 4 Hz. In general, frequency $= \frac{1}{\text{time for one wave}}$, or count the waves and divide by the time taken.

Be careful which graph you have. On a **displacement–distance** graph (like the rope in the first diagram), crest to crest is the **wavelength**. On a **displacement–time** graph, crest to crest is the **time for one wave**. The amplitude is read the same way on both: from zero to a peak.

The wave equation

In one second, f waves leave the source, and each is λ long. So the front of the wave has moved $f \times \lambda$ in that second, which is the wave speed:

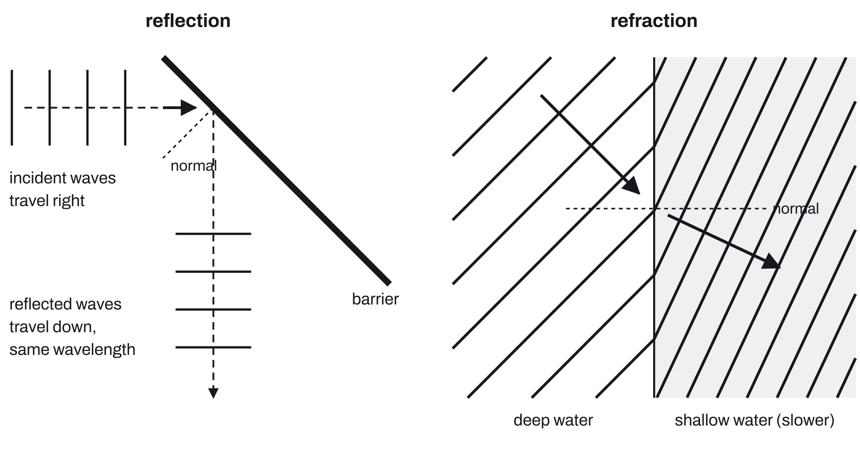
$$v = f\lambda \qquad \text{so} \qquad f = \frac{v}{\lambda} \qquad \text{and} \qquad \lambda = \frac{v}{f}$$

Use metres, seconds and hertz together (m/s, or cm and cm/s, as long as they match).

Two facts make most multiple-choice questions easy:

- **The frequency is fixed by the source.** Nothing the wave meets later (a new depth, a barrier, a gap) changes it.
- **The speed is fixed by the material** (the medium) the wave travels through. So for waves in the same medium, λ is inversely proportional to f: **double the frequency and the wavelength halves**.

Reflection and refraction



Reflection. Put a flat (plane) barrier in a ripple tank and the waves bounce off it. The **angle of incidence equals the angle of reflection**, measured from the **normal** (the line at right angles to the barrier). Only the **direction** changes: the reflected waves have the **same speed, frequency and wavelength** as before, so the reflected wavefronts are the same distance apart. Waves hitting a barrier at 45° come off at 90° to their old direction.

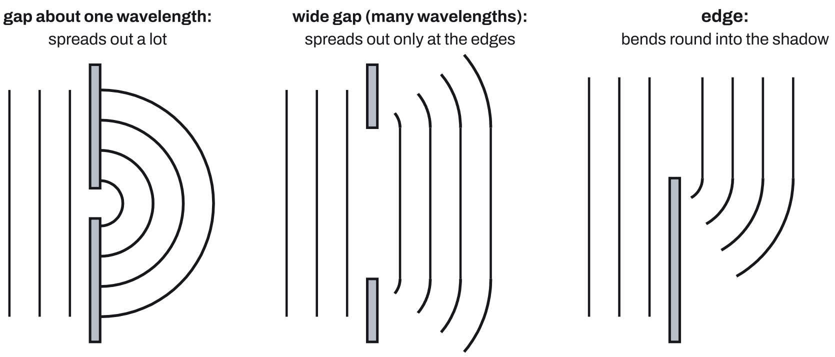
Refraction. Put a glass plate under part of the water to make it shallow. **Water waves travel more slowly in shallow water.** The frequency stays the same (the source sets it), so by $\lambda = \frac{v}{f}$ the **wavelength gets shorter**: the wavefronts bunch closer together. If the waves reach the boundary **at an angle**, one end of each wavefront reaches the shallow water first and slows down while the rest is still going fast, so the wavefront swings round and the **direction of travel changes**. That change of direction is **refraction**, and it happens **because the speed changes**.

- Deep → shallow: slower, shorter wavelength, direction bends **towards** the normal.
- Shallow → deep: faster, longer wavelength, direction bends **away from** the normal.
- Frequency: **never changes**.
- Waves that meet the boundary head on (wavefronts parallel to it) change speed and wavelength but do not change direction.

Refraction needs two regions (two media) in which the wave has **different speeds**. The same thing happens to light going into glass and to sound going between warm and cold air.

Diffraction

When waves pass through a gap, or past the edge of a barrier, they **spread out** into the region behind it. This is **diffraction**. The speed, frequency and **wavelength do not change**: the diffracted wavefronts are the same distance apart as the ones arriving.



The wavelength (spacing of the wavefronts) does not change.

Extended only: what decides how much the waves spread?

- **Through a gap**, it depends on the gap size **compared with the wavelength**. When the gap is about the **same size as the wavelength** (or smaller), the waves spread out a lot, into semicircles. When the gap is **much wider** than the wavelength, the waves go straight through and curve only at the edges. So diffraction increases with a **narrower gap** or a **longer wavelength**.
- **At an edge**, **longer wavelengths bend round more** than shorter ones.
- The **amplitude** has no effect on diffraction.

Extended only: this is why you can **hear** someone round the side of an open door but not **see** them. Sound in air has wavelengths from a few centimetres to several metres; a note of 340 Hz has $\lambda = \frac{340}{340} = 1.0$ m, about the width of a doorway, so it diffracts a lot. Light has a wavelength of about 5×10^{-7} m, far smaller than a doorway, so its diffraction there is too small to notice. For the same reason, **low (long-wavelength) sounds bend round corners better than high (short-wavelength) sounds**.

Key facts and formulas

The 0625 papers have no formula sheet, so learn every equation.

Formula	Status
$v = f\lambda$ (speed in m/s, frequency in Hz, wavelength in m)	Learn it
$f = \frac{\text{number of waves}}{\text{time taken}}$, or $f = \frac{1}{\text{time for one wave}}$	Learn it
Speed $= \frac{\text{distance}}{\text{time}}$ (for how long a wave takes to travel somewhere)	Learn it
Transverse: vibration at right angles to the direction of travel (light and all EM waves, water waves, S-waves)	Learn it
Longitudinal: vibration parallel to the direction of travel (sound, P-waves)	Learn it
Reflection: angle of incidence $=$ angle of reflection; speed, frequency and wavelength unchanged	Learn it
Refraction: speed and wavelength change, frequency does not; water waves are slower in shallow water	Learn it
Diffraction: wavelength unchanged; **Extended only:** most spreading when the gap is about one wavelength	Learn it

How to do it

We have tagged 148 questions for this topic across Papers 1–4, 2021–2025; 26 are repeats on other papers, leaving 122 different questions. 29 of the 122 mix two or more types (most structured questions do), so the counts add up to more than 122.

Question type	Questions
Features of a wave: amplitude, wavelength, wavefront, frequency	40
Wave speed, frequency and wavelength calculations	36
Diffraction: naming it, drawing it, gap size and wavelength	35
Transverse and longitudinal waves (including seismic waves)	32
Reflection and refraction in a ripple tank	25

Some structured questions go on to light, the electromagnetic spectrum, sound or redshift in their later parts; those parts belong to other topics' notes.

1. Features of a wave (40 questions)

1. **Decide what the diagram shows.** A side view of a wave or a graph with **distance** along the axis: crest to next crest is the **wavelength**. A graph with **time** along the axis: crest to next crest is the time for one wave. A ripple tank seen from above: each line is a **wavefront**, and the gap between neighbouring lines is the wavelength.
2. **Amplitude** is from the **middle (undisturbed) line to a crest**, or to a trough. Never crest to trough: if a diagram marks the crest-to-trough height as 6 cm, the amplitude is 3 cm.
3. **Wavelength** is one **complete** wave: crest to the **next** crest (or trough to the next trough). Crest to trough is only half a wavelength; the distance between two points where the wave crosses the middle line is also only half, unless they are two crossings apart.
4. **Give units**: amplitude and wavelength in m or cm; frequency in Hz.

Variations you will meet:

- **Which labelled arrow is the amplitude, which the wavelength?** Check each arrow against steps 2 and 3. A common wrong pair is "amplitude = crest to trough".
- **Several waves across a marked length**: count the complete waves, then divide. If 5 complete waves span 30 cm, $\lambda = \dfrac{30}{5} = 6$ cm.
- **"State what is meant by frequency"**: the number of waves passing a point per second (or made per second). "Speed" is the distance travelled per second.
- **Comparing two graphs drawn to the same scale**: largest amplitude = tallest; highest frequency = most waves in the same time (crests closest together on a time graph); longest wavelength = crests furthest apart on a distance graph.
- **Which quantities are measured in metres?** Amplitude and wavelength. Frequency is in Hz; speed in m/s.
- **A wave whose height shrinks as it goes, with evenly spaced crests**: the amplitude decreases but the wavelength stays the same.
- **A more accurate way to measure wavelength**: measure across **many** wavelengths (say ten crests apart) and divide by the number of wavelengths. Time **many** waves passing a point to get the frequency the same way.
- **Label a drawing**: mark the amplitude from the middle line to a crest, and one wavelength from a crest to the next crest; on a ripple-tank drawing, the wavelength is the gap between two neighbouring wavefronts.

2. Wave speed, frequency and wavelength calculations (36 questions)

1. **Find the frequency** if it isn't given: $f = \dfrac{\text{number of waves}}{\text{time}}$. Twenty waves in 5.0 s gives $f = 4.0$ Hz. From a graph, $f = \dfrac{1}{\text{time for one wave}}$: one wave every 0.02 s is 50 Hz.
2. **Find the wavelength** if it isn't given (from a diagram, see type 1).
3. **Write the equation** $v = f\lambda$, rearrange if needed, substitute and give the unit.
4. **Check the units match**: km/s with km, or convert to m/s and m. cm/s with cm.

For example, 9 crests pass a buoy in 12 s and the crests are 0.40 m apart. Count each crest that passes as one wave: $f = \dfrac{9}{12} = 0.75$ Hz, so $v = 0.75 \times 0.40 = 0.30$ m/s.

Variations you will meet:

- **Standard form**: a radio wave of frequency 1.5×10^8 Hz travels at 3.0×10^8 m/s, so $\lambda = \dfrac{3.0 \times 10^8}{1.5 \times 10^8} = 2.0$ m. Type powers of ten into the calculator with the $\times 10^x$ key.
- **Waves per minute**: divide by 60 to get waves per second first.
- **Time to travel a distance**: $t = \dfrac{\text{distance}}{\text{speed}}$. A sound pulse travelling 900 m through water at 1500 m/s takes $\dfrac{900}{1500} = 0.6$ s. Use the wave speed, not the frequency.
- **Speed from distance and time**: circular ripples that reach the edge of a pond in a known time: $v = \dfrac{\text{distance}}{\text{time}}$. Count the waves between the centre and the edge to get the wavelength (distance ÷ number of waves).
- **Ratios, no numbers**: the speed stays the same and the frequency doubles, so the wavelength halves (1.2 m becomes 0.6 m). A wave with three times the frequency and twice the speed has $\lambda = \dfrac{2v}{3f}$.
- **From a table**: in data for waves in deep and shallow water, the frequency is the same in both and the faster wave has the longer wavelength. Work out $f = \dfrac{v}{\lambda}$ for each row before judging a statement about frequency.
- **"Show that"**: write the equation in words or symbols, the substitution, and the answer to one more significant figure than the value given. Numbers alone, with no equation, can get no credit.
- **Which equation gives the speed?** $v = f\lambda$, frequency **times** wavelength (not divided, and not amplitude).

3. Diffraction (35 questions)

1. **Name it**: waves **spreading out** after passing through a **gap** or round an **edge** is **diffraction** (not refraction, which needs a change of speed).
2. **Draw it** (usually 3 wavefronts beyond the gap):
   - the **same spacing** as the wavefronts arriving, because the wavelength does not change;
   - a gap about **one wavelength** wide (or smaller): **semicircles centred on the gap**;
   - **Extended only:** a **wide** gap: **straight** across the middle, the width of the gap, curving only at the ends;
   - at an **edge**: straight, with the end nearest the barrier curving round behind it.
3. **Extended only: explain how much it spreads**: compare the gap with the wavelength. Similar size → a lot; gap much bigger than λ → very little.

Variations you will meet:

- **Diffraction does not change** the speed, frequency or wavelength. A multiple-choice option saying the diffracted waves are closer together or further apart is wrong. A gap narrower than the wavelength still gives semicircular waves with the **original** spacing.

- **Extended only: what increases the spreading?** A **narrower** gap, or a **longer** wavelength. For the same speed, a longer wavelength means a **lower frequency**, so reducing the frequency increases diffraction. Increasing the amplitude does nothing.
- **Extended only: what makes the waves less curved?** A **shorter wavelength** or a **wider gap**. Making the water shallower slows the waves, which shortens the wavelength (same frequency), so it **reduces** diffraction.
- **Extended only: which wave diffracts most through a given gap?** Work out $\lambda = \frac{v}{f}$ for each option and choose the one with the **longest** wavelength.
- **Extended only: hearing but not seeing round a door, or sound from a doorway**: sound's wavelength is similar to the width of the doorway, so it diffracts a lot; light's wavelength is far smaller, so it hardly diffracts. A high-frequency (short-wavelength) sound spreads less through the doorway, so it is harder to hear round the side.
- **Extended only: blue and red light through the same slit**: blue has the shorter wavelength, so it spreads less, and its wavefronts are drawn closer together.
- **Extended only: at an edge**, the longer wavelength bends round more. So as you walk towards a corner, you hear the low notes before the high ones.
- **A harbour entrance**: straight sea waves spread out in circles inside the harbour. That is diffraction.
- **Extended only:** a wider harbour entrance gives less spreading, because the gap is now much bigger than the wavelength.
- **Extended only: a telescope or any opening you look through**: a larger opening and a shorter wavelength give the least diffraction, so the sharpest image.

4. Transverse and longitudinal waves (32 questions)

1. **Transverse**: vibration **at right angles** to the direction of travel. Light (all electromagnetic waves), water waves, waves on a rope, **S-waves**.
2. **Longitudinal**: vibration **parallel** to the direction of travel. Sound, ultrasound, **P-waves**, a slinky pushed in and out.
3. **In a description, use both halves**: "the **particles** (or the medium) **vibrate at right angles to the direction the wave travels**". "The wave is at right angles to the wave" gets nothing.

Variations you will meet:

- **A floating object** on transverse water waves moves **up and down**; it is not carried along.
- **"State two ways transverse waves differ from longitudinal waves"**: the direction of vibration (at right angles / parallel); longitudinal waves have compressions and rarefactions while transverse waves have crests and troughs; examples of each.
- **What waves transfer**: energy, **not** matter.
- **Seismic tables**: S = transverse, P = longitudinal. A diagram showing compressions and rarefactions in the ground is a P-wave, because the ground is pushed and pulled along the direction of travel.
- **Through a vacuum**: only electromagnetic waves (which are transverse) travel through a vacuum. Sound (longitudinal) cannot.

- **Diagrams of four examples**: waves on a rope and water are transverse; sound in air and a spring pushed along its length are longitudinal. A spring shaken **sideways** carries a transverse wave.
- **Ripples from a drop** on water of the same depth everywhere are transverse and spread at the **same speed in all directions**, so the wavefronts are circles.

5. Reflection and refraction in a ripple tank (25 questions)

1. **Name the effect.**
   - Waves bounce back off a barrier: **reflection**.
   - Waves change direction because they go into water of a different **depth**: **refraction**.
   - Waves spread out through a gap or round an edge: **diffraction** (type 3).
2. **Say what changes.**
   - Reflection: only the **direction**. Speed, frequency, wavelength stay the same.
   - Refraction: **speed** and **wavelength** change (and usually the direction). **Frequency stays the same.**
3. **Explain refraction**: "the waves change speed as the depth changes, so they change direction". Deep → shallow: slower, closer wavefronts.
4. **Draw it.**
   - Reflected wavefronts: the **same spacing**, and the angle of incidence equals the angle of reflection. A barrier at 45° to the wavefronts turns them through 90°.
   - Refracted wavefronts (deep → shallow): **closer together**, joined to the incoming wavefronts at the boundary, and turned so the direction of travel bends **towards the normal** (the wavefronts make a smaller angle with the boundary).

Variations you will meet:

- **Which region is deepest?** Waves travel faster there, so the wavefronts are **furthest apart** (from a dropped stone, the circles are stretched out in the deep direction).
- **"What is needed for refraction?"** Two regions in which the wave travels at **different speeds**. Not a shiny surface, not a gap, and not a change of frequency.
- **Reflected wave statements**: after reflection the direction changes but the wavelength does not. After refraction head on, the wavelength changes but the direction does not.
- **A block sunk in the tank**: the water above the block is shallower, so the waves slow down, their wavelength decreases, and they change direction if they meet its edge at an angle.
- **Which waves can reflect, refract and diffract? All** waves can do all three, transverse and longitudinal alike.
- **Diagrams to match**: waves bouncing off a barrier (reflection); spreading through a gap (diffraction); bending at a depth change (refraction). A prism splitting white light into colours is **dispersion** (see the light note), not one of these.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A student fixes one end of a long rope and moves the other end up and down. 15 complete waves pass a marker in 6.0 s. The distance between neighbouring crests is 0.80 m.

(a) Calculate the frequency of the waves. **[2]**

(b) Calculate the speed of the waves. **[3]**

(c) Describe how the rope moves as the waves pass, and name this type of wave. **[2]**

(d) State what the waves transfer along the rope. **[1]**

(a) $f = \dfrac{\text{number of waves}}{\text{time}}$ **C1** $= \dfrac{15}{6.0} = 2.5$ Hz **A1**.

(b) $v = f\lambda$ **C1**; $v = 2.5 \times 0.80$ **C1** $= 2.0$ m/s **A1**. (The wavelength is the crest-to-crest distance, 0.80 m.)

(c) Each part of the rope vibrates up and down, at right angles to the direction the wave travels **B1**. Transverse **B1**.

(d) Energy (not the rope itself) **B1**.

Example 2

A point on the water surface in a ripple tank moves up and down. A graph of its displacement against time shows that each complete oscillation takes 0.20 s and the greatest displacement from the rest position is 1.5 cm.

(a) State the amplitude of the waves. **[1]**

(b) Calculate the frequency of the waves. **[2]**

(c) The waves travel at 30 cm/s in the deep water. Calculate their wavelength. **[3]**

(d) The waves pass at an angle into shallow water, where they travel at 20 cm/s. Name this effect, calculate the new wavelength and state one quantity that does not change. **[4]**

(a) 1.5 cm **B1** (from the rest position to a peak, not peak to trough).

(b) $f = \dfrac{1}{\text{time for one wave}}$ **C1** $= \dfrac{1}{0.20} = 5.0$ Hz **A1**.

(c) $\lambda = \dfrac{v}{f}$ **C1** $= \dfrac{30}{5.0}$ **C1** $= 6.0$ cm **A1**.

(d) Refraction **B1**. The frequency stays 5.0 Hz, so $\lambda = \dfrac{20}{5.0}$ **C1** $= 4.0$ cm **A1**. The frequency does not change **B1**.

Example 3

Extended only. A teacher uses a ripple tank. Straight waves of wavelength 1.2 cm approach a barrier with a gap 1.0 cm wide.

(a) Describe the wavefronts after they pass through the gap. **[2]**

(b) The gap is widened to 8.0 cm. Describe how the pattern changes and explain why. **[2]**

(c) A radio plays music in a room. A person stands in the corridor outside, beside an open doorway 0.80 m wide. The speed of sound in air is 340 m/s. Calculate the wavelength of a 680 Hz note, and explain why a 3400 Hz note is harder to hear in the corridor. **[4]**

(a) Semicircles centred on the gap **B1**, the same distance apart as before, 1.2 cm (the wavelength is unchanged) **B1**.

(b) The waves spread out much less: mostly straight, curving only at the edges **B1**, because the gap is now much bigger than the wavelength **B1**.

(c) $\lambda = \dfrac{v}{f} = \dfrac{340}{680}$ **C1** $= 0.50$ m **A1**. This is similar to the width of the doorway, so the 680 Hz sound diffracts (spreads out) a lot into the corridor **B1**. The 3400 Hz note has $\lambda = \dfrac{340}{3400} = 0.10$ m, much smaller than the doorway, so it diffracts much less and little of it reaches the side of the doorway **B1**.

Example 4

An earthquake sends P-waves and S-waves through the ground. The P-waves travel at 6.0 km/s and have a frequency of 1.5 Hz.

(a) State which of the two kinds of wave is longitudinal and describe the direction of vibration in it. **[2]**

(b) Calculate the wavelength of the P-waves. **[3]**

(c) A monitoring station is 540 km from the earthquake. The S-waves travel at 3.6 km/s. Calculate how much later the S-waves arrive than the P-waves. **[3]**

(a) The P-waves **B1**. The ground vibrates parallel to the direction the wave travels **B1**.

(b) $\lambda = \dfrac{v}{f}$ **C1** $= \dfrac{6.0}{1.5}$ **C1** $= 4.0$ km $(4000$ m$)$ **A1**.

(c) Time $= \frac{\text{distance}}{\text{speed}}$ **C1**: P-waves $\frac{540}{6.0} = 90$ s, S-waves $\frac{540}{3.6} = 150$ s **C1**. The S-waves arrive $150 - 90 = 60$ s later **A1**.

Common mistakes

- **Amplitude measured crest to trough.** It is from the middle (rest) line to a crest. Examiners see "amplitude = crest to trough" and "wavelength = crest to trough" every year.
- **Mixing up the graphs.** On a displacement–time graph, crest to crest is the time for one wave, not the wavelength. Candidates who then call it a wavelength, or forget to turn it into a frequency, lose the marks.
- $v = f \div \lambda$**.** A very large number of candidates divide instead of multiply. The equation is $v = f \times \lambda$; check it with units: Hz × m = m/s.
- **Numbers with no equation.** In "show that" questions, marks go for the equation written in words or symbols. Just dividing the given numbers earns nothing.
- **Vague vibration descriptions.** "The wave is at right angles to the wave" gets no credit. Say the **particles vibrate** at right angles (or parallel) to the **direction the wave travels**.
- **Thinking ultrasound is transverse.** Ultrasound is sound, so it is longitudinal. Light is transverse.
- **Confusing refraction and diffraction.** Refraction is a change of direction caused by a change of **speed** (depth). Diffraction is spreading through a **gap** or round an **edge**.
- **Changing the wavelength on a diffraction drawing.** Diffracted wavefronts must keep the same spacing. Draw them with a ruler and compasses, centred on the middle of the gap; wavefronts that are straight with slightly bent ends are wrong for a narrow gap.
- **Wrong spacing after reflection.** Reflected wavefronts keep the same wavelength, and their direction obeys angle of incidence $=$ angle of reflection. Thick, wobbly lines lose marks.
- **Extended only: thinking the amplitude affects diffraction**, or that shallower water increases it. Only the gap size and the wavelength matter; shallower water shortens the wavelength, so there is **less** diffraction.
- **Forgetting that frequency never changes** when a wave refracts. The wavelength changes instead.
- **Units and powers of ten.** Give the unit (Hz, m, m/s), and be careful typing numbers like 5.8×10^{-7} into a calculator.

How to get the marks

- **Calculations**: write the equation ($v = f\lambda$ or its rearranged form), then the numbers, then the answer with its unit. The equation and the substitution each earn a mark (**C1**) even if the final answer is wrong.
- **"Show that"**: state the equation in words or symbols, show the substitution, and give the answer to one more significant figure than the value printed.
- **"State the name of the effect"**: one word: reflection, refraction or diffraction. Don't give two.
- **"Explain why the waves change direction"**: the waves **change speed** (slow down in shallow water). Mentioning only the depth is not enough.

- **"Describe"** a transverse or longitudinal wave: say what vibrates and compare its direction with the **direction of travel** (or propagation).
- **Drawing wavefronts**: use a ruler (and compasses for circles), keep the **same wavelength** unless the speed changes, join refracted wavefronts to the incoming ones at the boundary, and draw at least as many as asked (usually three).
- **"Indicate one wavelength"**: an arrow or bracket from one crest (or wavefront) to the **next**, clearly ending on both.
- **Extended only: "Explain" diffraction differences**: compare the **gap size with the wavelength** ("the gap is similar in size to the wavelength, so the waves spread out more"). Saying just "the gap is small" is not enough.
- **Multiple choice**: check both columns of each row (type of wave **and** direction of vibration; amplitude **and** wavelength). Most wrong options get one half right.

Quick check

1. State what is meant by the amplitude and the wavelength of a wave. Which of these are transverse: sound, light, seismic S-waves, seismic P-waves?
2. A wave machine makes 1800 waves per minute. The wavelength is 0.20 m. Calculate the frequency and the speed of the waves.
3. Water waves of frequency 4.0 Hz travel at 12 cm/s in deep water, then at 8.0 cm/s in shallow water. Calculate the wavelength in each, and state what happens to the frequency.
4. **Extended only.** Straight water waves of wavelength 1.0 cm pass through a gap 4.0 cm wide. State two separate changes that would make the waves spread out more.
5. The frequency of a sound is tripled. Its speed does not change. Its wavelength was 0.90 m. Find the new wavelength.

Answers

1. Amplitude: the greatest distance of a particle from its rest (undisturbed) position. Wavelength: the distance from one crest to the next crest (the same point on neighbouring waves). Transverse: light and S-waves. (Sound and P-waves are longitudinal.)
2. $f = \frac{1800}{60} = 30$ Hz. $v = f\lambda = 30 \times 0.20 = 6.0$ m/s.
3. Deep: $\lambda = \frac{12}{4.0} = 3.0$ cm. Shallow: $\lambda = \frac{8.0}{4.0} = 2.0$ cm. The frequency stays 4.0 Hz.
4. Make the gap narrower (closer to the wavelength); make the wavelength longer (lower the frequency of the vibrating bar). Changing the amplitude would not help.
5. $\lambda = \frac{v}{f}$, so tripling f divides λ by 3: $\frac{0.90}{3} = 0.30$ m.

Past questions to try

- **0625/31/O/N/24 Q7**: naming reflection, diffraction and refraction, transverse waves, and a wavelength calculation (Core).
- **0625/33/M/J/23 Q5**: measuring wavelength and frequency in a ripple tank, then the wave speed (Core).
- **0625/43/O/N/22 Q6**: drawing reflected and diffracted wave crests, then the wave speed (Extended).
- **0625/41/M/J/24 Q5**: transverse against longitudinal, seismic waves and a time calculation (Extended).