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SECONDARY 4 · PHYSICS · WAVE PROPERTIES AND THE ELECTROMAGNETIC SPECTRUM

Wave Properties and the Electromagnetic Spectrum

Theory and worked examples

What is a wave?

Flick one end of a long rope up and down and a hump runs along the rope to the other end. Drop a stone into a pond and ripples spread out across the water. Each is a wave: a disturbance that travels outwards from a vibrating source. The rope and the water are the medium, the material the wave passes through. Each small part of the medium only vibrates about its rest position; it passes energy on to the next part and stays where it was. So a wave transfers energy from one place to another without transferring matter.

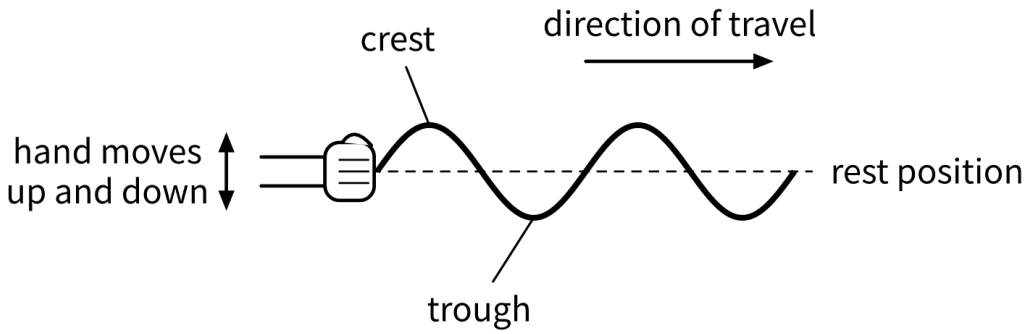
KEY IDEA

Waves transfer energy without transferring matter. The particles of the medium vibrate about their rest positions; they do not travel along with the wave.

- Rope: a hand moving up and down sends waves along the rope; a ribbon tied to the rope only moves up and down.
- Spring (slinky): pushing and pulling one end along its length sends bunched-up coils along the spring; a marked coil only moves back and forth.
- Ripple tank: a vibrating dipper makes ripples on water; a small floating cork bobs up and down but is not carried along.

WORDS TO KNOW

wave	a disturbance that transfers energy from one place to another without transferring matter
medium	the material a wave travels through, such as a rope, a spring, water or air
vibration (oscillation)	a repeated to-and-fro or up-and-down movement about a rest position
rest position	where a part of the medium sits when no wave is passing (also called the equilibrium position)



TRY THIS

A paper boat floats on a canal at Punggol Waterway. A passing boat sends waves past it. Describe how the paper boat moves, and say what this shows about waves.

Answer: It bobs up and down about the same place (it is not carried along). The waves transfer energy, not matter (water).

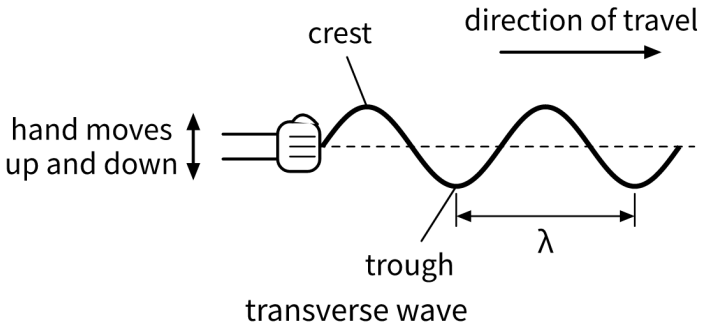
Transverse and longitudinal waves

Waves are sorted by the way the medium vibrates compared with the direction the wave travels. In a transverse wave the particles vibrate perpendicular (at 90°) to the direction of travel, like the rope moved up and down. In a longitudinal wave the particles vibrate parallel to the direction of travel, like a slinky pushed and pulled along its length. A longitudinal wave is a series of compressions, where the coils or particles are closer together, and rarefactions, where they are further apart.

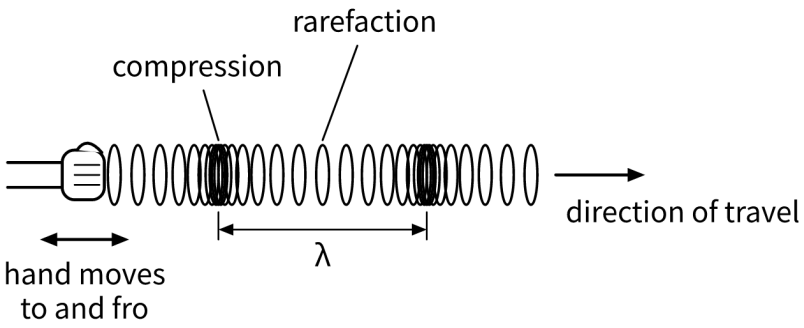
WORDS TO KNOW

transverse wave	a wave in which the particles vibrate perpendicular to the direction the wave travels
longitudinal wave	a wave in which the particles vibrate parallel to the direction the wave travels
compression	a region of a longitudinal wave where the particles (or coils) are closer together
rarefaction	a region of a longitudinal wave where the particles (or coils) are further apart

	Transverse wave	Longitudinal wave
Direction of vibration	perpendicular to the direction of travel	parallel to the direction of travel
What you see	crests (high points) and troughs (low points)	compressions and rarefactions
Model	rope or slinky moved from side to side	slinky pushed and pulled along its length
Examples	water waves, waves on a rope, all electromagnetic waves (light, radio, X-rays)	sound waves, ultrasound, a slinky pushed and pulled
Wavelength measured	crest to the next crest	centre of one compression to the centre of the next



transverse wave



longitudinal wave

WORKED EXAMPLE

Aisha holds one end of a slinky lying on a long bench. Describe how she should move her hand to send (a) a transverse wave and (b) a longitudinal wave along the slinky. For each, state the direction in which a coil vibrates.

1. What is asked: two ways of moving the hand, and the direction of vibration of a coil compared with the direction of travel.
2. Transverse: vibration perpendicular to travel. Longitudinal: vibration parallel to travel.

(a) Move her hand from side to side (across the bench), at 90° to the length of the slinky. Each coil vibrates perpendicular to the direction the wave travels. (b) Push and pull her hand backwards and forwards along the length of the slinky. Each coil vibrates parallel to the direction the wave travels, forming compressions and rarefactions.

TRY THIS

Classify each wave as transverse or longitudinal: (a) light, (b) sound, (c) ripples on a pond, (d) microwaves.

Answer: (a) transverse (b) longitudinal (c) transverse (d) transverse

Describing a wave: amplitude, wavelength, period and frequency

We use a few quantities to describe any wave. The amplitude tells us how big the vibrations are; the wavelength tells us how long one complete wave is. The period is the time for one complete vibration, and the frequency is the number of complete waves made each second. Frequency is measured in hertz (Hz): 1 Hz means one complete wave per second. Because the period is the time for one wave, the frequency and the period are linked by f = 1 / T.

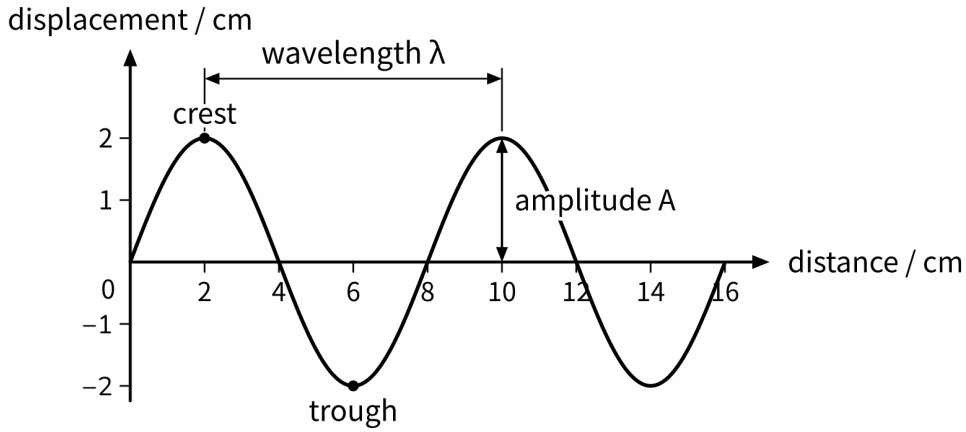
KEY IDEA

f = 1 / T, where f is the frequency in Hz and T is the period in s. A short period means a high frequency.

WORDS TO KNOW

crest and trough	the highest and lowest points of a transverse wave
displacement	the distance of a particle from its rest position, in a stated direction
in phase	two points that move in the same direction with the same displacement at the same time, such as two crests
hertz (Hz)	the unit of frequency; 1 Hz = 1 complete wave per second

Quantity	Symbol and unit	Definition (mark-scheme words)
amplitude	A, in m	the maximum displacement of a particle from its rest position
wavelength	λ, in m	the shortest distance between two points in phase, e.g. two neighbouring crests
period	T, in s	the time taken for one complete oscillation (to produce one complete wave)
frequency	f, in Hz	the number of complete waves produced per second
wave speed	v, in m/s	the distance travelled by a wave (a wavefront) per second



WORKED EXAMPLE

A marker buoy near Sentosa bobs up and down 12 times in 30 s as waves pass it. Calculate (a) the frequency of the waves and (b) the period.

1. What is asked: f and T. Frequency = number of complete waves per second.
2. (a) f = 12 ÷ 30 s = 0.40 Hz.
3. (b) T = 1 / f = 1 ÷ 0.40 = 2.5 s (check: 30 s ÷ 12 waves = 2.5 s).

(a) f = 12 ÷ 30 = 0.40 Hz (b) T = 1 / f = 1 ÷ 0.40 = 2.5 s

TRY THIS

The distance from a crest to the next trough of a water wave is 5.0 cm (measured along the water), and the crest is 2.0 cm above the trough. State the wavelength and the amplitude.

Answer: $\lambda = 2 \times 5.0 = 10$ cm; amplitude = 2.0 ÷ 2 = 1.0 cm (rest position to crest).

CHAPTER 1

Practice Questions

Part 2: Wave Properties and the Electromagnetic Spectrum



In the practice questions

23 questions, 70 marks. For each multiple-choice question, write the letter of the correct option (A, B, C or D) in the brackets. Write your other answers on the lines given. The answers are on page 322.

- Section A: Multiple-Choice Questions: 15 questions, 15 marks
- Section B: Structured Questions: 6 questions, 35 marks
- Section C: Free-Response Questions: 2 questions, 20 marks

Name: _____ Class: _____ Date: _____

SECONDARY 4 · PHYSICS · WAVE PROPERTIES AND THE ELECTROMAGNETIC SPECTRUM

Wave Properties and the Electromagnetic Spectrum

INSTRUCTIONS

- 23 questions, 70 marks in total.
- Answer all questions in the spaces provided.
- For MCQs, write the letter (A, B, C or D) in the brackets.
- Write your other answers on the lines given, in full sentences.

Section A: Multiple-Choice Questions

1 Which statement about a wave travelling across a pond is correct? ( ) [1]

(A) The water moves along with the wave to the edge of the pond.
(B) The wave transfers energy without transferring water.
(C) The wave transfers water but not energy.
(D) The water particles vibrate only along the direction of travel.

2 A leaf floats on a pond. A wave passes under it. How does the leaf move? ( ) [1]

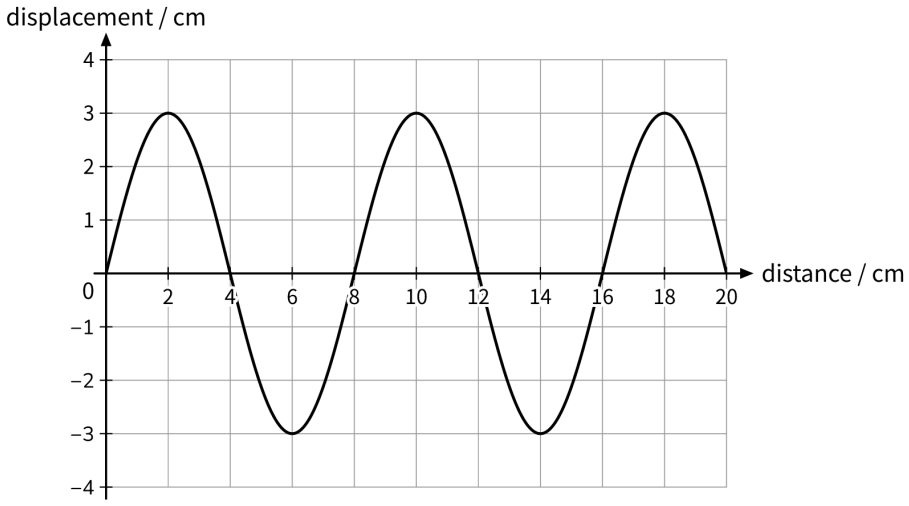
(A) It moves to the edge of the pond with the wave.
(B) It moves away from the edge of the pond.
(C) It moves up and down about the same place.
(D) It does not move at all.

3 Which row gives one example of a transverse wave and one example of a longitudinal wave? ( ) [1]

	Transverse wave	Longitudinal wave
A	light	sound
B	sound	radio waves
C	water waves	X-rays
D	sound	slinky pushed and pulled

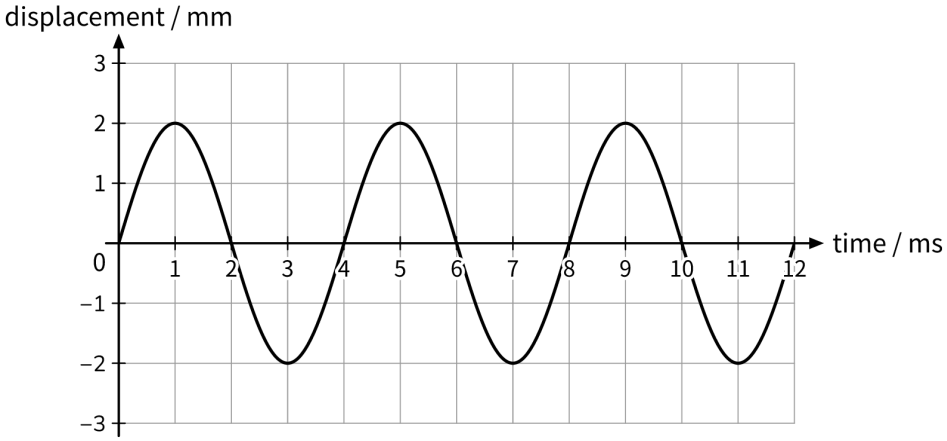
Ⓐ A Ⓑ B Ⓒ C Ⓓ D

4 The graph shows a wave at one instant. What are the amplitude and the wavelength of the wave? ( ) [1]



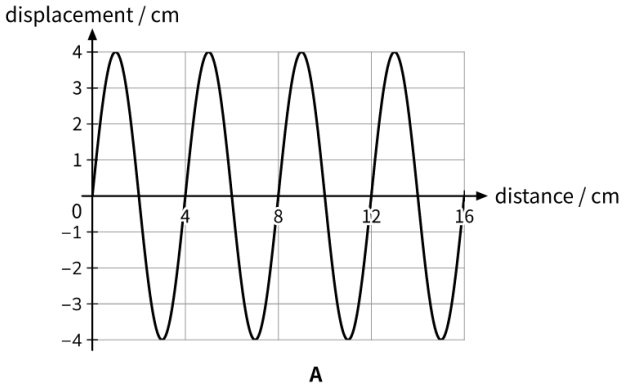
Ⓐ amplitude 6.0 cm, wavelength 8.0 cm
Ⓑ amplitude 3.0 cm, wavelength 4.0 cm
Ⓒ amplitude 6.0 cm, wavelength 4.0 cm
Ⓓ amplitude 3.0 cm, wavelength 8.0 cm

5 The graph shows how the displacement of one particle in a wave changes with time. What is the frequency of the wave? ( ) [1]

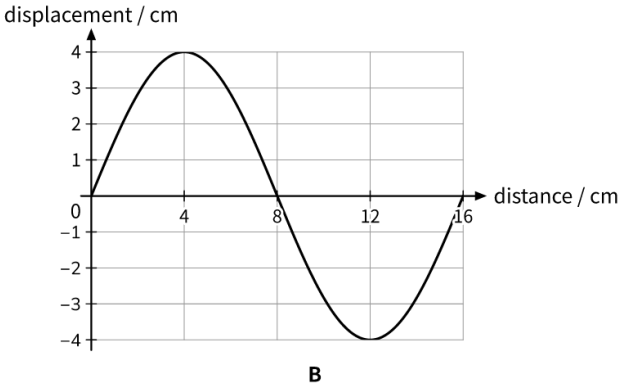


Ⓐ 0.25 Hz Ⓑ 83 Hz Ⓒ 250 Hz Ⓓ 750 Hz

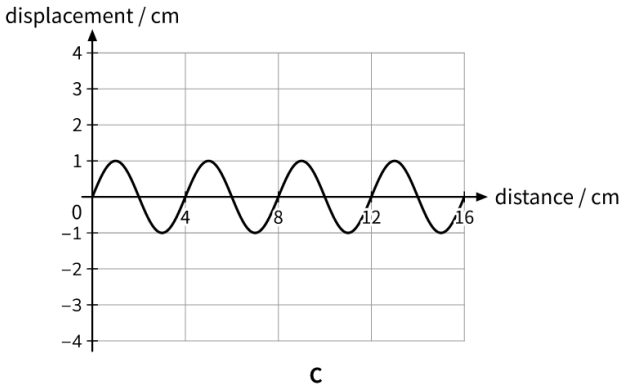
6 Wave P has an amplitude of 2.0 cm and a wavelength of 8.0 cm. Graphs A to D are drawn on the same scales. Which graph shows a wave with twice the amplitude and half the wavelength of P? ( ) [1]



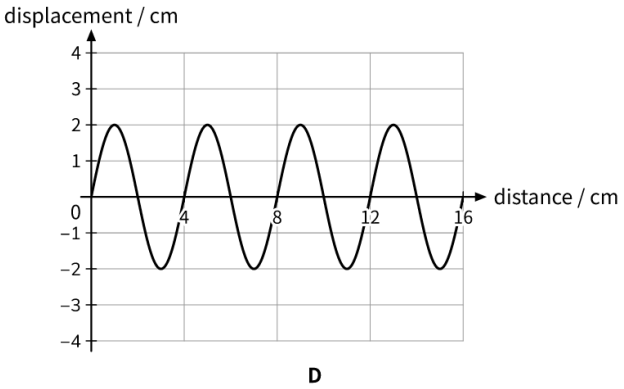
A



B



C



D

Ⓐ A Ⓑ B Ⓒ C Ⓓ D