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SECONDARY 4 · PHYSICS · GENERAL WAVE PROPERTIES AND THE ELECTROMAGNETIC SPECTRUM

General Wave Properties and the Electromagnetic Spectrum

Theory and worked examples

Recap from Sec 3: prefixes and standard form

This chapter uses very large and very small numbers: the speed of light, radio frequencies in millions of cycles per second, and wavelengths smaller than a millimetre. You met these prefixes in Sec 3 measurement. Always convert to the base unit (metres, seconds, hertz) before using a formula, unless a question tells you otherwise.

Prefix	Symbol	Multiplying factor
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}

TRY THIS

Convert (a) 2.5 MHz to Hz and (b) 450 nm to m.

Answer: (a) 2.5 MHz = 2.5×10^{6} Hz. (b) 450 nm = 450×10^{-9} m = 4.5×10^{-7} m.

What is a wave?

Flick one end of a long rope tied to a railing at a void deck, and a hump runs along the rope to the other end. Each small part of the rope only moves up and down about its rest position; it does not travel along with the hump. A wave is a disturbance that starts at a vibrating source and travels outward, carrying energy from one place to another. The material the wave travels

through, such as the rope, a spring or water, is called the medium. Crucially, a wave transfers energy without transferring matter: the rope itself does not move from one end to the other.

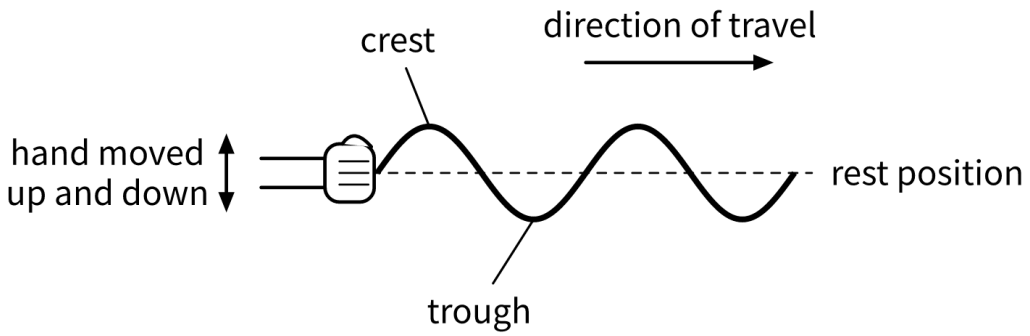
KEY IDEA

A wave transfers energy, not matter. Each part of the medium only oscillates about its own rest position.

- Rope: one end is moved up and down steadily; a ribbon tied to the rope only moves up and down, it is not carried along.
- Spring (slinky): one end is pushed and pulled along its length; a marked coil only moves back and forth.
- Ripple tank: a vibrating dipper makes ripples spread across the water surface; a floating cork bobs up and down but stays roughly in the same place.

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
oscillation (vibration)	a repeated to-and-fro movement about a rest position



TRY THIS

A fallen leaf floats on the water in a monsoon drain. Ripples from falling rain pass under the leaf. Describe how the leaf moves, and say what this shows about waves.

Answer: The leaf bobs up and down (or moves in a small circle) about roughly the same place; it is not carried along with the ripples. This shows that the wave transfers energy, not matter (the water).

Transverse and longitudinal waves

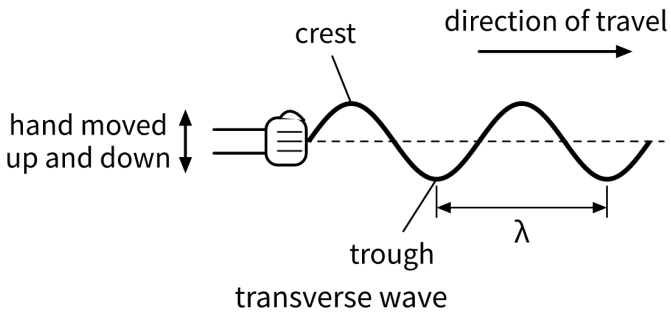
Waves are sorted into two kinds by comparing the direction in which the medium vibrates with the direction the wave travels. In a transverse wave, the particles of the medium vibrate perpendicular (at 90°) to the direction of travel, as in the rope example. In a longitudinal wave, the particles vibrate parallel to the direction of travel: pushing and pulling one end of a spring along its length sends regions of bunched-up coils, called compressions, and

regions of stretched-out coils, called rarefactions, travelling along the spring.

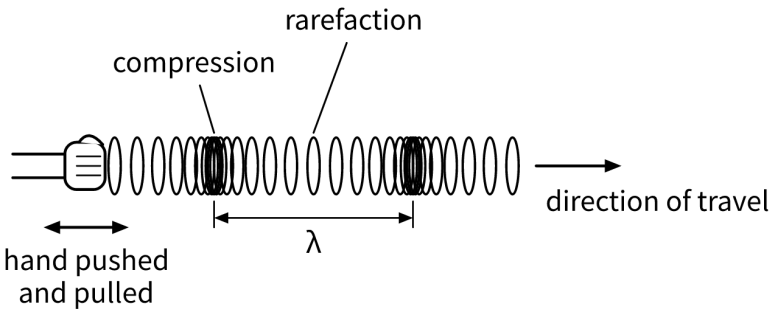
WORDS TO KNOW

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

	Transverse wave	Longitudinal wave
Direction of vibration	perpendicular to the direction of travel	parallel to the direction of travel
What is seen	crests and troughs	compressions and rarefactions
Everyday examples	water waves, waves on a rope, all electromagnetic waves	sound waves, a spring pushed and pulled along its length



transverse wave



longitudinal wave

WORKED EXAMPLE

Jun Wei stretches a long spring across the school hall floor. Describe how he should move his hand to send (a) a transverse wave and (b) a longitudinal wave along the spring. For each, state the direction in which a coil vibrates compared with the direction of travel.

1. What is asked: two different hand movements, and how the vibration direction compares with the direction of travel in each case.
2. Transverse: vibration at 90° to the direction of travel. Longitudinal: vibration along (parallel to) the direction of travel.

(a) He should move his hand from side to side (or up and down), at 90° to the length of the spring. Each coil vibrates perpendicular to the direction the wave travels: this is a transverse wave. (b) He should push and pull his hand backwards and forwards along the length of the spring. Each coil vibrates parallel to the direction the wave travels, forming compressions and rarefactions: this is a longitudinal wave.

TRY THIS

Classify each wave as transverse or longitudinal: (a) a water wave in a swimming pool, (b) sound from a loudspeaker, (c) light from a torch.

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

Describing a wave: amplitude, wavelength, period, frequency

A repeating wave can be described by four quantities. The amplitude is the maximum displacement of a particle from its rest position. The wavelength is the distance between two successive, identical points on the wave, such as one crest to the next crest. The period is the time taken for one complete wave (one full cycle) to pass a point, or for a particle to complete one full oscillation. The frequency is the number of complete waves produced (or passing a point) per second. A wavefront is an imaginary line joining all the points on a wave that are at the same stage of their cycle, that is, in phase: for a water wave spreading out from a point source, the wavefronts are circles.

KEY IDEA

Amplitude can be read from either graph; wavelength only from a displacement-distance graph; period only from a displacement-time graph.

- A greater amplitude means a wave carries more energy; it does not change the wavelength, period or frequency.
- Points one whole wavelength apart (or a whole number of wavelengths apart) are in phase.
- Points half a wavelength (half a cycle) apart move in exactly opposite directions at every instant.

WORDS TO KNOW

amplitude	the maximum displacement of a particle from its rest position
wavelength (λ)	the distance between two successive, identical points on a wave, e.g. crest to crest
period (T)	the time taken for one complete wave to pass a point, or for one complete oscillation
frequency (f)	the number of complete waves produced, or passing a fixed point, per second; unit hertz (Hz)
wavefront	an imaginary line joining all the points on a wave that are in phase (at the same stage of their cycle)
phase	two points are in phase if they move identically at every instant; two points half a cycle apart move exactly oppositely

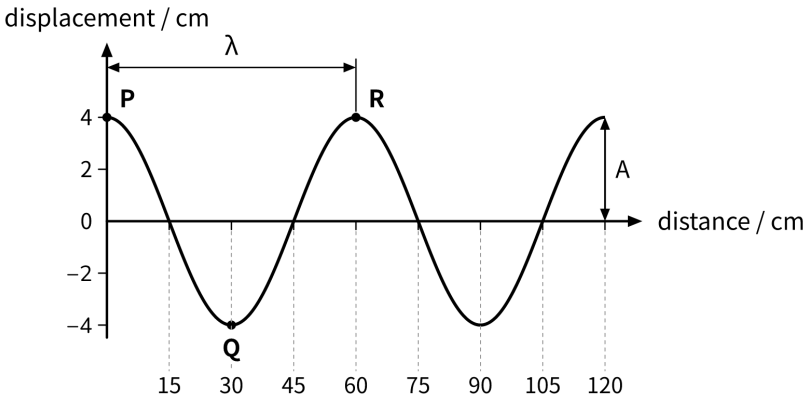
TRY THIS

Points A and B on a wave are 2.5 wavelengths apart. Are they in phase, or half a cycle apart?

Answer: Half a cycle apart: 2.5 wavelengths is 2 whole cycles (in phase) plus half a cycle, so A and B move in exactly opposite directions.

Reading a displacement-distance graph

A displacement-distance graph is a snapshot of an entire wave at one instant: it plots the displacement of every particle of the medium against its distance along the wave. From this graph, both the amplitude (the height of a crest above the rest line) and the wavelength (the distance from one crest to the next, or between any two successive points in phase) can be read directly.



CHAPTER 1

Practice Questions

Part 2: General Wave Properties and the Electromagnetic Spectrum



In the practice questions

24 questions, 75 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 445.

- Section A: Multiple-Choice Questions: 15 questions, 15 marks
- Section B: Structured Questions: 7 questions, 40 marks
- Section C: Free-Response Questions: 2 questions, 20 marks

Name: _____ Class: _____ Date: _____

SECONDARY 4 · PHYSICS · GENERAL WAVE PROPERTIES AND THE ELECTROMAGNETIC SPECTRUM

General Wave Properties and the Electromagnetic Spectrum

INSTRUCTIONS

- 24 questions, 75 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 in the spaces. Show working and units.

Section A: Multiple-Choice Questions

1 Which statement correctly describes how a wave transfers energy from one place to another? ( ) [1]

(A) It transfers matter as well as energy from one place to another.
(B) It transfers matter without transferring any energy.
(C) It transfers energy without transferring the matter (medium) itself.
(D) It can only transfer energy through a solid medium.

2 A wave has frequency 5 Hz and wavelength 12 cm. Calculate its speed. ( ) [1]

(A) 6 cm/s (B) 30 cm/s (C) 120 cm/s (D) 60 cm/s

3 The table shows four statements about the direction a particle vibrates, compared with the direction of travel, for the wave named. Which row is correct? ( ) [1]

	Wave	Direction of vibration
A	Light	parallel to the direction of travel
B	A water wave in a ripple tank	perpendicular to the direction of travel
C	Sound	perpendicular to the direction of travel
D	A spring pushed and pulled along its length	perpendicular to the direction of travel

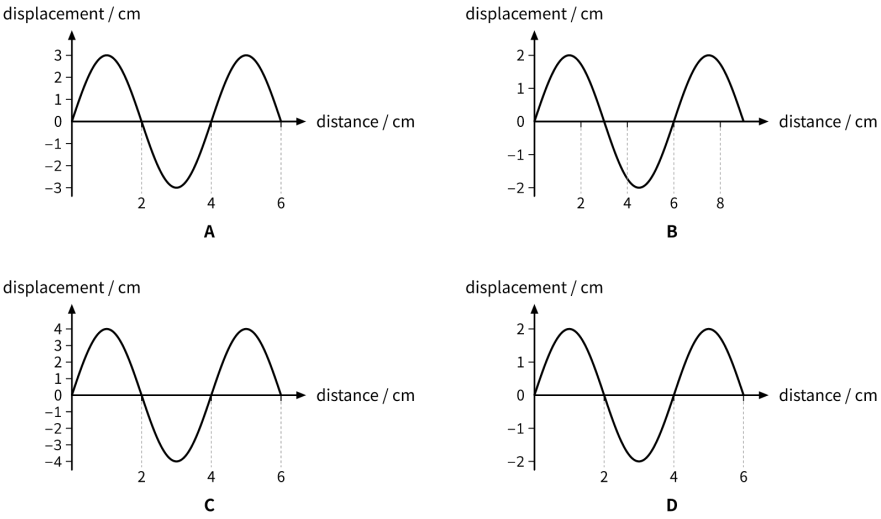
4 A ripple tank dipper vibrates steadily as waves cross from a deep region into a shallower region.

1 The speed of the waves decreases.
2 The frequency of the waves decreases.
3 The wavelength of the waves decreases.

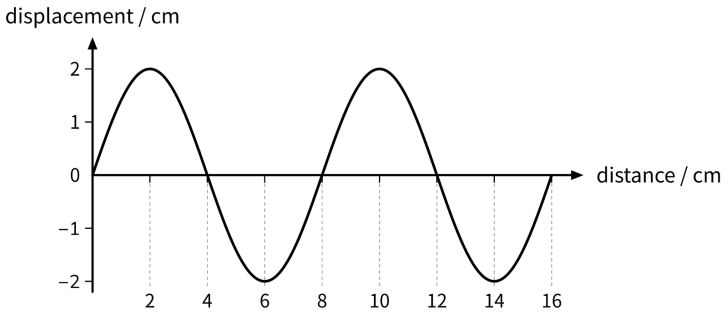
Which statements are correct? ( ) [1]

Ⓐ 1 and 2 only Ⓑ 1 and 3 only Ⓒ 2 and 3 only Ⓓ 1, 2 and 3

5 Each graph below shows the displacement of a wave plotted against distance, at one instant. Which graph shows a wave with amplitude 2 cm and wavelength 4 cm? ( ) [1]

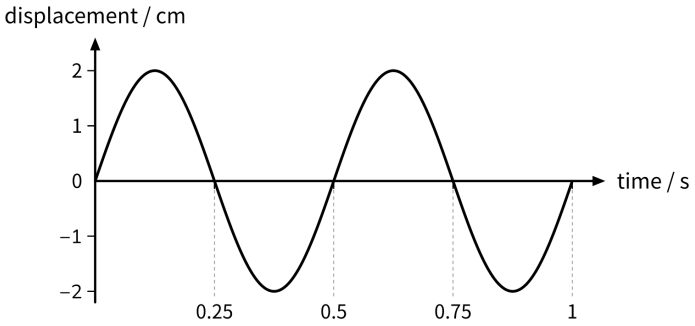


6 The graph shows a wave's displacement plotted against distance, at one instant. If this wave travels at 40 cm/s, calculate its frequency. ( ) [1]



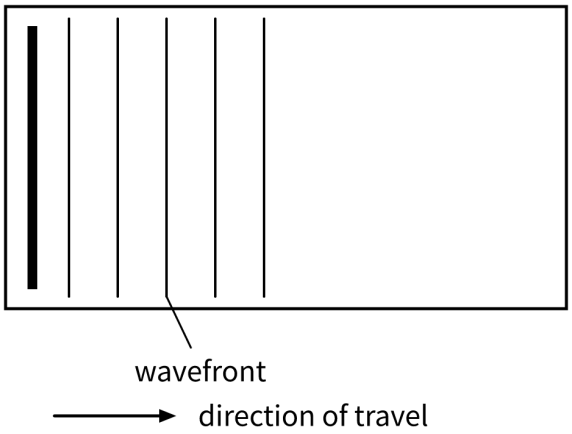
Ⓐ 1 Hz Ⓑ 2 Hz Ⓒ 10 Hz Ⓓ 5 Hz

7 The graph shows how the displacement of one point on a wave changes with time. If this wave travels at 2.0 m/s, calculate its wavelength. ( ) [1]



Ⓐ 0.25 m Ⓑ 1.0 m Ⓒ 2.0 m Ⓓ 0.5 m

8 The diagram shows 5 wavefronts in a ripple tank, spanning a total distance of 16 cm. The dipper vibrates 20 times every 2 seconds. Calculate the speed of the water waves. ( ) [1]



Ⓐ 40 cm/s Ⓑ 10 cm/s Ⓒ 20 cm/s Ⓓ 80 cm/s