IB DP PHYSICS · THEME C WAVE BEHAVIOUR · C.2 · ~6 MIN READ

C.2 Wave model

Transverse and longitudinal travelling waves, wavelength, frequency, period and wave speed, displacement–distance and displacement–time graphs, sound waves, the electromagnetic spectrum, and mechanical versus electromagnetic waves.

Transverse & longitudinal | Wavelength, frequency & speed | Wave graphs | Sound | Electromagnetic spectrum | Mechanical vs EM waves

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No tag = **SL and HL** HL ONLY HL students only DATA BOOKLET given in the exam

M1 A1 how marks are awarded highlight = comes up again and again Test yourself at the end

IN 30 SECONDS

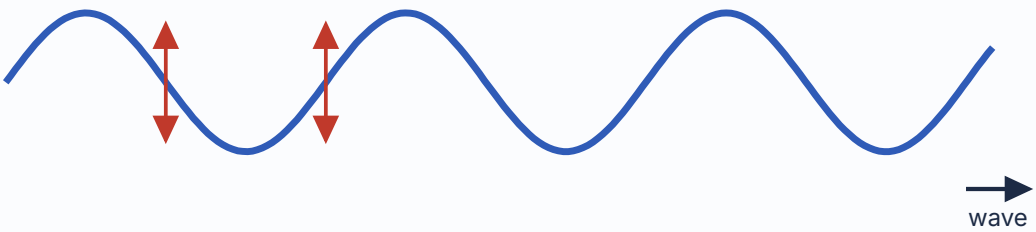
- A **travelling wave** transfers energy without transferring matter. Each particle of the medium just oscillates about its equilibrium position.
- **Transverse:** oscillation perpendicular to the energy transfer (light, waves on a string). **Longitudinal:** oscillation parallel to it, in compressions and rarefactions (sound).
- **$v = f\lambda = \lambda/T$** links speed, frequency and wavelength for every wave.
- **Mechanical waves** need a medium; **electromagnetic waves** do not and all travel at $c = 3.00 \times 10^8$ m s^{-1} in a vacuum.
- **C.2 is the same at SL and HL.**

BY THE END YOU CAN

- Describe transverse and longitudinal waves and give examples of each.
- Define and use wavelength, frequency, period, amplitude and wave speed.
- Read λ, T and A from displacement–distance and displacement–time graphs.
- Describe sound waves and the electromagnetic spectrum.
- Compare mechanical and electromagnetic waves.

1 Two kinds of wave

transverse: oscillation ⊥ to energy transfer



longitudinal: oscillation ∥ to energy transfer



Same energy transfer, different direction of oscillation.

	Transverse	Longitudinal
oscillation	perpendicular to energy transfer	parallel to energy transfer
features	crests and troughs	compressions and rarefactions
examples	EM waves, waves on strings, water ripples (roughly)	sound, P-waves in earthquakes, pressure waves in a spring

- **Polarisation** only happens with transverse waves, so it is evidence that light is transverse.

2 Describing a wave

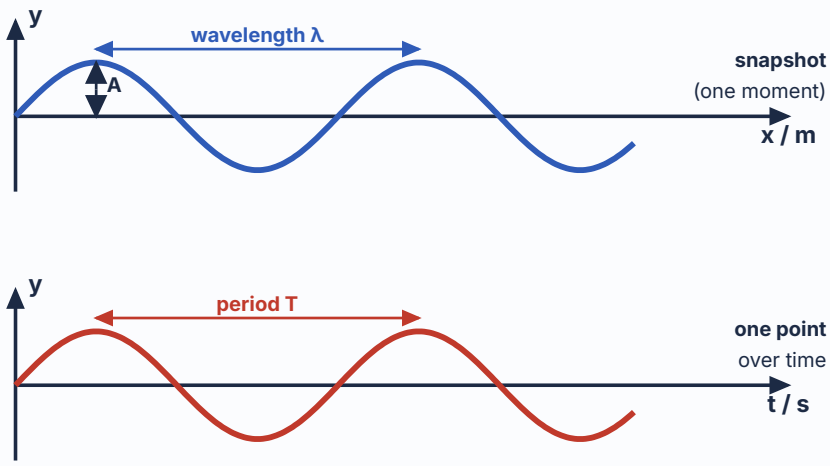
Wavelength λ — the distance between two adjacent points in phase (crest to crest, compression to compression).

Frequency f — number of oscillations per second, in Hz. Period T = 1/f is the time for one oscillation.

Amplitude A — the maximum displacement from equilibrium. Wave energy (intensity) is proportional to A^2.

$$v = f\lambda = \frac{\lambda}{T}$$ DATA BOOKLET

wave speed



Same shape, different axes: read λ from a distance graph, T from a time graph.

Top: a snapshot of the whole wave. Bottom: one particle followed over time.

WORKED EXAMPLE

Middle C on a piano has f = 256 Hz. Find its wavelength in air (v = 340 m s^{-1}).

1. λ = v/f = 340/256 M1
2. **= 1.33 m** A1

WORKED EXAMPLE

A displacement–distance graph shows λ = 0.80 m and a displacement–time graph of one point shows T = 0.020 s. Find the wave speed.

1. f = 1/T = 50 Hz M1
2. **v = fλ = 50 × 0.80 = 40 m s^{-1}** A1

COMMON MISTAKE

Reading the wavelength from a displacement–time graph. A time graph gives the **period**; only a distance graph gives the wavelength.

EXAM TIP

Changing the frequency of a source does not change the wave speed in the same medium; the wavelength changes instead. Changing the medium changes the speed (and λ), but the frequency stays the same.

3 Sound waves

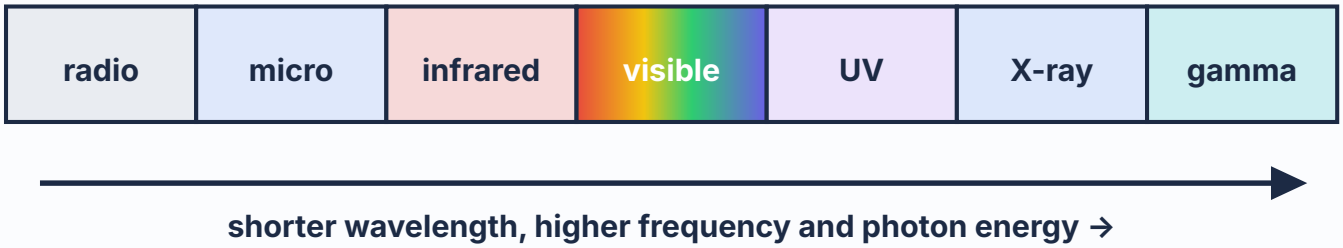
- **Sound is longitudinal** and mechanical: it needs a medium. It is fastest in solids, slower in liquids and slowest in gases (about 340 m s^{-1} in air at room temperature).
- **Human hearing:** about 20 Hz to 20 kHz. Ultrasound (above 20 kHz) is used in medical imaging and sonar.
- **Pitch** depends on frequency; **loudness** depends on amplitude (intensity).

WORKED EXAMPLE

A ship's sonar pulse returns from the sea bed after 0.80 s. Sound travels at 1500 m s^{-1} in sea water. How deep is the water?

1. total distance = 1500 × 0.80 = 1200 m M1
2. **there and back, so depth = 600 m** A1

4 Electromagnetic waves



All travel at c = 3.00 × 10^{8} m s^{-1} in a vacuum. Visible: about 400–700 nm.

One family of waves, ordered by wavelength.

- **EM waves** are oscillating electric and magnetic fields, perpendicular to each other and to the direction of travel. They travel at c in a vacuum and need no medium.
- **Uses and hazards:** radio (communication), microwaves (cooking, phones), infrared (heating, remote controls), visible (sight), UV (sterilising; skin damage), X-rays (imaging; ionising), gamma (cancer treatment; ionising).

WORKED EXAMPLE

Find the frequency of green light of wavelength 500 nm, and the wavelength of a 98 MHz radio station.

1. $f = c/\lambda = 3.00 \times 10^8 / 500 \times 10^{-9} =$ **6.0×10^{14} Hz** A1
2. **$\lambda = c/f = 3.00 \times 10^8 / 98 \times 10^6 = 3.1$ m** A1

5 Mechanical versus electromagnetic

	Mechanical	Electromagnetic
medium	needed (particles oscillate)	not needed (fields oscillate)
speed	depends on the medium, much less than c	c in a vacuum, less in materials
type	transverse or longitudinal	always transverse
examples	sound, water waves, seismic waves	light, radio, X-rays

LINKING QUESTION

Every wave equation in C.3–C.5 starts from $v = f\lambda$. The particles of the medium move in SHM (C.1), and the energy carried connects to intensity and the inverse-square law in B.1.

IDEA FOR YOUR IA / EXPLORATION

Measure the speed of sound in air with two microphones and a data logger (time of flight), or with a resonance tube, and compare with how it changes with temperature.

Test yourself — cover the answers first

QUICK CHECK

1. What does a wave transfer?
2. Give one example of a longitudinal wave.
3. Which graph gives the period: displacement–distance or displacement–time?
4. The frequency of a sound doubles in the same air. What happens to its speed and wavelength?
5. Why can sound not travel through space?
6. Which EM waves have the highest frequency?

EXAM-STYLE

7. A water wave travels 12 m in 4.0 s. Its crests are 1.5 m apart. Find its speed and frequency.
8. Light (λ = 600 nm in air) enters glass where its speed is 2.0×10^8 m s^{-1}. Find its frequency and its wavelength in the glass.

Show answers

1. energy (not matter)
2. sound
3. displacement–time
4. speed unchanged; wavelength halves
5. it needs a medium; space is (almost) a vacuum
6. gamma rays
7. $v = 12/4.0 =$ **$3.0\ m\ s^{-1}$**
   $f = v/\lambda = 3.0/1.5 =$ **2.0 Hz**
8. $f = c/\lambda = 3.0 \times 10^{8}/600 \times 10^{-9} =$ **5.0×10^{14} Hz** (unchanged)
   $\lambda_{glass} = v/f = 2.0 \times 10^{8}/5.0 \times 10^{14}$
   = **400 nm**

Stuck on a question?

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