

7.1 Progressive waves

Name: _____ Class: _____ Date: _____

Total: 26 marks**KEY WORDS** wave 波 • frequency 频率 • wavelength 波长 • progressive wave 行波 • speed 速率

Objective

Build the skills to answer exam questions on **progressive waves** — the wave terms, the wave equation, the CRO, and intensity.

You must be able to:

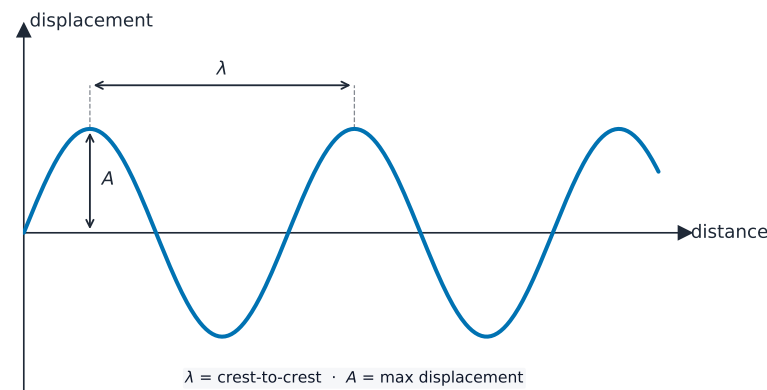
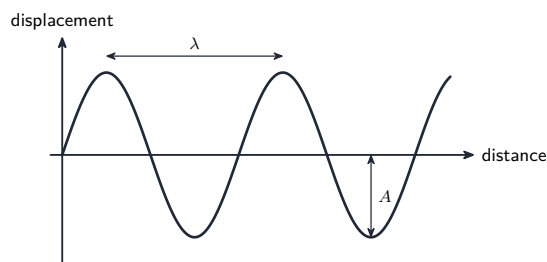
- use **displacement**, **amplitude**, **wavelength**, **period**, **frequency**, **phase difference**
- derive and use the **wave equation** $v = f\lambda$
- read a **CRO** trace and use **intensity** $\propto$ amplitude²
- read two waves off one **displacement-distance** graph and superpose them
- say what a **progressive wave** transfers, and what it does not

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Wave terms

A progressive wave carries **energy** without moving matter overall:



A snapshot of a progressive wave

- **amplitude** A — maximum displacement; **wavelength** λ — distance between points in phase; **period** T — time for one cycle; **frequency** $f = 1/T$.
- points $\frac{1}{2}\lambda$ apart are **out of phase** (π); points λ apart are **in phase**.

■ What a wave is, and what it carries

A **progressive wave** is a disturbance that travels: each particle oscillates about its own rest position and passes the disturbance on to the next. Watch it three ways:

- a **rope** flicked at one end — a hump runs along the rope while every piece of rope only moves up and down;
- a stretched **spring** pushed along its length — compressions travel while each coil moves back and forth about the same place;
- a **ripple tank** — circular ripples spread out, but a floating cork bobs and does not travel with them.

So the wave transfers **energy** (and momentum) from one place to another, but **not matter**. That cork is the sentence the mark scheme wants.

■ Wave equation

In one period T the wave moves one wavelength, so $v = \lambda/T = f\lambda$.

■ CRO and intensity

Read the **period** from the screen: (cycles' width in divisions) $\times$ time-base. Then $f = 1/T$. **Intensity** = $\frac{\text{power}}{\text{area}}$ and intensity $\propto A^2$ — so doubling the amplitude makes the intensity **four times** larger.

2 Practice

Now apply the methods above.

2.1 Define **amplitude** and **wavelength**.

[2]

2.2 A wave has frequency 50 Hz and wavelength 6.0 m. Find its **speed**.

[2]

2.3 State the relationship between **period** and **frequency**.

[1]

2.4 Two points on a wave are **half a wavelength** apart. State their **phase difference**.

[1]

3 Exam-style questions

3.1 A wave travels at 340 m s^{-1} with frequency 170 Hz. Its wavelength is:

[1]

- A 0.50 m
- B 2.0 m
- C 2.0 cm
- D $5.8 \times 10^4 \text{ m}$

3.2 On a CRO the time-base is 5 ms per division, and one complete cycle of the trace spans 4 divisions. Calculate the **period** and the **frequency**.

[3]

3.3 A wave travels forward exactly one wavelength during one complete oscillation of its source. Use this fact, with $f = 1/T$, to obtain an expression for the wave **speed**, and state what each symbol means.

[2]

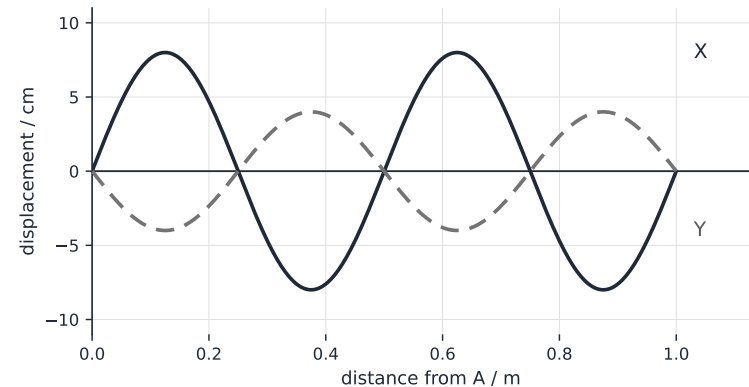
3.4 The amplitude of a wave is **doubled**. State what happens to its **intensity**.

[1]

3.5 A cork floats on the surface of a pond as ripples pass under it. **State** what the ripples transfer past the cork, and what they do **not** transfer.

[2]

3.6 Two progressive water waves, X and Y, travel along the same straight line from a point A. The graph shows the displacement of each wave against distance from A, at one instant. Both waves have a frequency of 12 Hz.



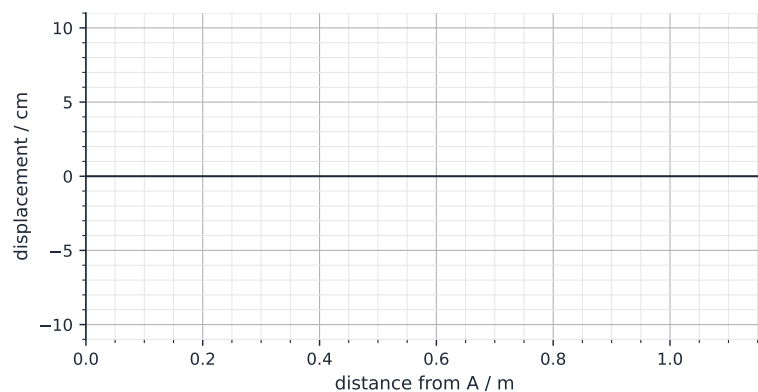
(a) **State** the amplitude and the wavelength of wave X.

[2]

- (b) **Determine** the speed of wave X. [2]

- (c) **State and explain** whether X and Y are **coherent**. [2]

- (d) The two waves superpose. On the grid below, **sketch** the displacement of the resultant wave against distance from A, at the same instant. [3]



- (e) The intensity of wave X is I_X and that of wave Y is I_Y . **Determine** the ratio $\frac{I_X}{I_Y}$. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- **amplitude**: the maximum displacement from the rest position
- **wavelength**: the shortest distance between two points oscillating **in phase**

2.2

$$v = f\lambda$$

$$v = (50 \text{ Hz})(6.0 \text{ m}) = \mathbf{300 \text{ m s}^{-1}}$$

2.3

$$f = 1/T$$

2.4

- π radians (or 180°) — exactly out of phase

3.1 B

$$\lambda = v/f$$

$$\lambda = \frac{340 \text{ m s}^{-1}}{170 \text{ Hz}} = \mathbf{2.0 \text{ m}}$$

3.2

- one period is four of the 5 ms intervals

$$T = 4 \times 5 \text{ ms} = 20 \text{ ms} = 0.020 \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{0.020 \text{ s}} = \mathbf{50 \text{ Hz}}$$

3.3

- in one period T the wave moves one wavelength λ , so $v = \lambda/T$
- $f = 1/T$, so $v = f\lambda$

3.4

- intensity $\propto A^2$, so doubling A makes intensity **four times** larger

3.5

- they transfer **energy** (the cork gains and loses energy as it bobs)
- they do **not** transfer matter — the cork oscillates about the same place

3.6

(a) amplitude = **8.0 cm**; wavelength = **0.50 m**

(b) $v = f\lambda$

$$v = (12 \text{ Hz})(0.50 \text{ m}) = \mathbf{6.0 \text{ m s}^{-1}}$$

(c) **coherent**

- same frequency and a **constant phase difference** ($180^\circ = \pi$ rad); equal amplitudes are **not** required

(d) a single wave of the same wavelength, 0.50 m

- amplitude $8.0 \text{ cm} - 4.0 \text{ cm} = \mathbf{4.0 \text{ cm}}$
- in phase with **X** (the larger wave)

(e) intensity $\propto$ (amplitude)²

$$\frac{I_X}{I_Y} = \left(\frac{8.0 \text{ cm}}{4.0 \text{ cm}} \right)^2 = \mathbf{4.0}$$