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:

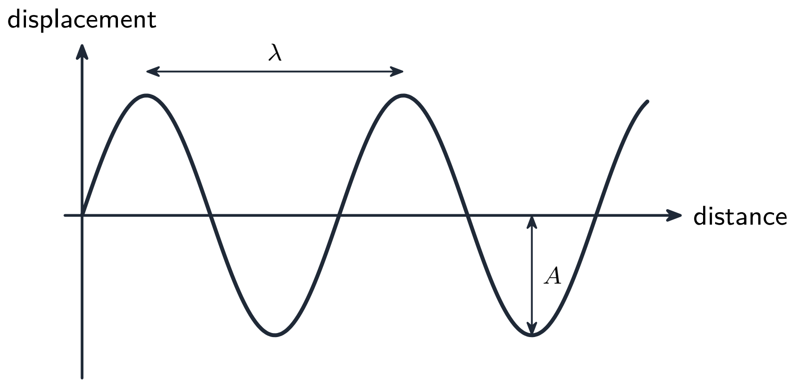
- use **displacement, amplitude, wavelength, period, frequency, phase difference**
- derive and use the **wave equation** $v = f\lambda$
- read a **CRO** trace and use **intensity** $\propto$ amplitude^2
- read two waves off one **displacement-distance** graph and superpose them
- say what a **progressive wave** transfers, and what it does not

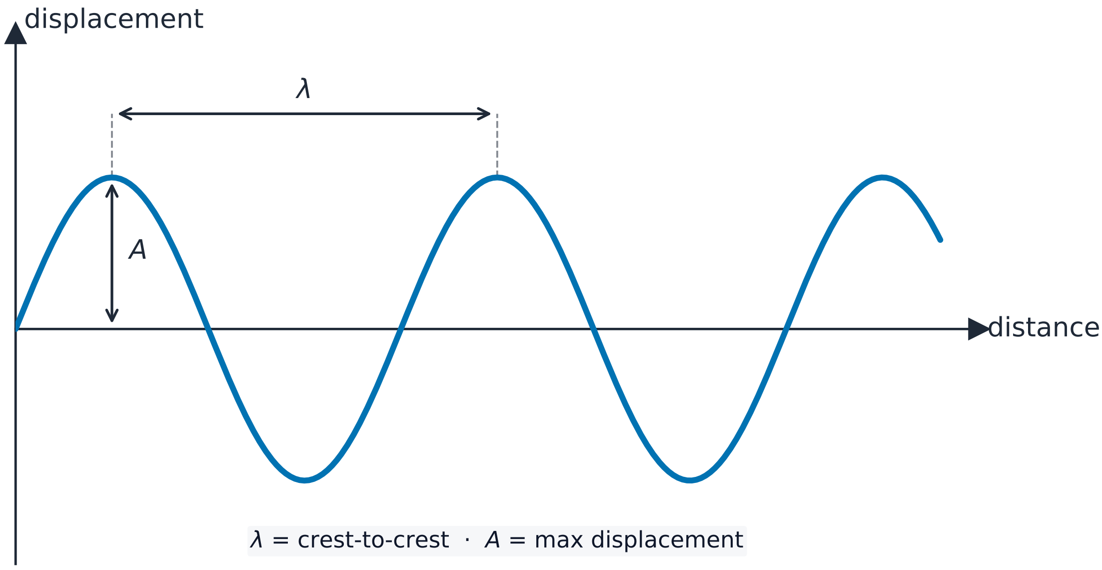
1 Worked examples

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) × time-base. Then $f = 1/T$. **Intensity** $= \dfrac{\text{power}}{\text{area}}$ 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** 5.8×10^4 m

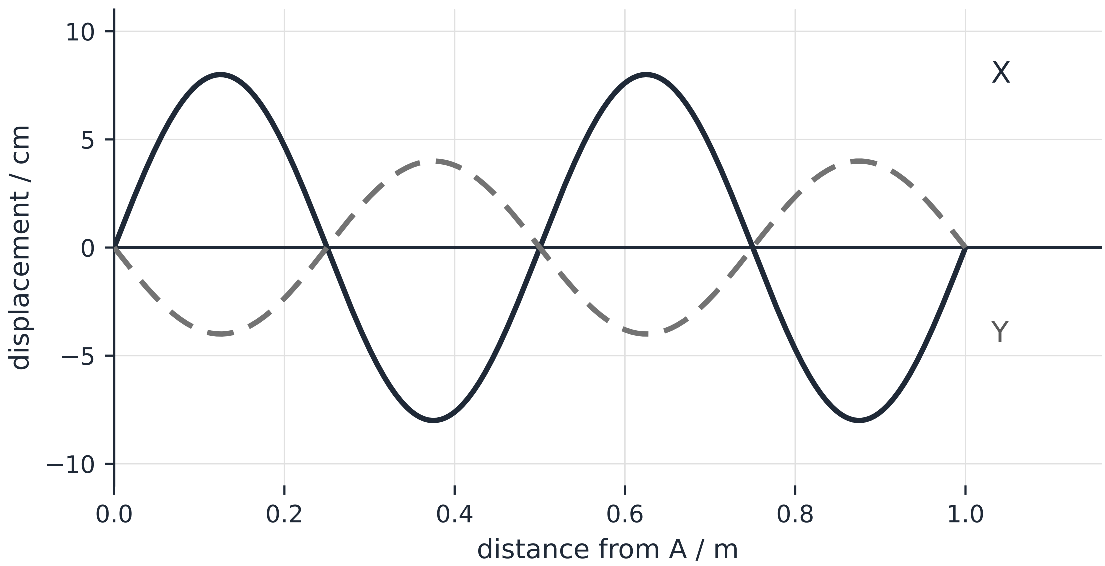
3.2 On a CRO the time-base is 5 ms per division, and one complete cycle of the trace spans 4 divisions. Calculate the **period** and the **frequency**. [3]

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.

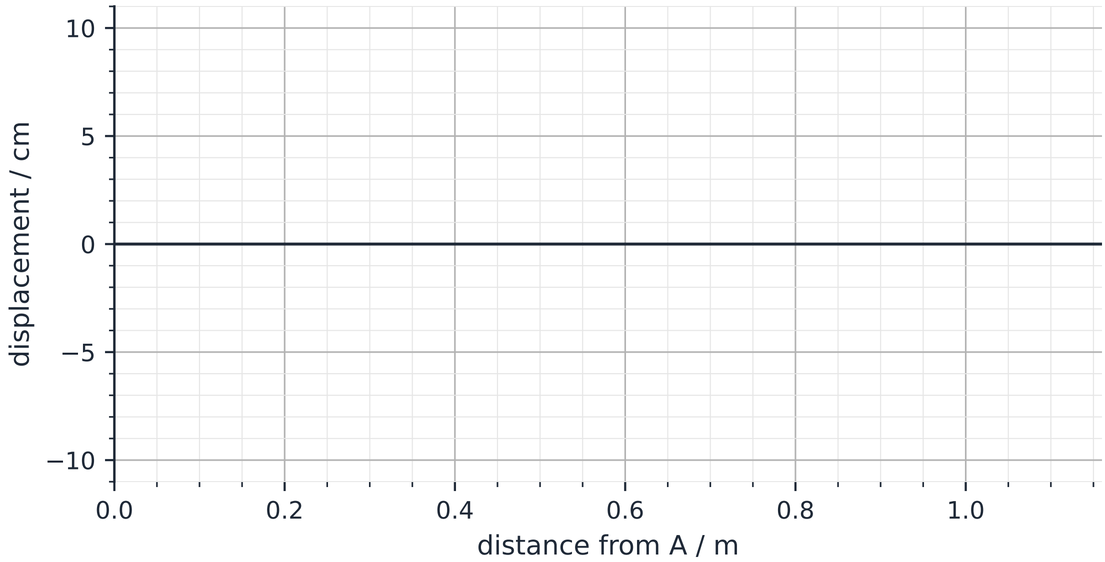


(a) **State** the amplitude and the wavelength of wave X. [2]

(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 $\dfrac{I_X}{I_Y}$. [2]

Solutions

2.1 Amplitude — the maximum displacement from the rest position; **wavelength** — the shortest distance between two points oscillating **in phase**.

2.2 $v = f\lambda = 50 \times 6.0 = 300$ m s^{-1}.

2.3 $f = 1/T$.

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

3.1 B — $\lambda = v/f = 340/170 = 2.0$ m.

3.2 $T = 4 \times 5$ ms $= 20$ ms $= 0.020$ s; $f = 1/T = 1/0.020 = 50$ Hz.

3.3 In one period T the wave moves one wavelength λ, so $v = \lambda/T$; since $f = 1/T$, $v = f\lambda$.

3.4 It becomes **four times** larger (intensity $\propto A^2$).

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 and does not travel with the ripples.

3.6 (a) Amplitude = 8.0 cm; wavelength = 0.50 m.
(b) $v = f\lambda = 12 \times 0.50 = 6.0$ m s^{-1}.
(c) **Coherent** — they have the same frequency and a **constant phase difference** (180°, i.e. π rad); coherence does not require equal amplitudes.
(d) A single wave of the same wavelength, 0.50 m, of amplitude $8.0 - 4.0 = 4.0$ cm, in phase with **X** — a crest wherever X has a crest, because X is the larger of the two.
(e) Intensity $\propto$ (amplitude)^2, so $\dfrac{I_X}{I_Y} = \left(\dfrac{8.0}{4.0}\right)^2 = 4.0$.