Exercise walk-through

Progressive waves ▪ 7.1

eXercise

You must be able to

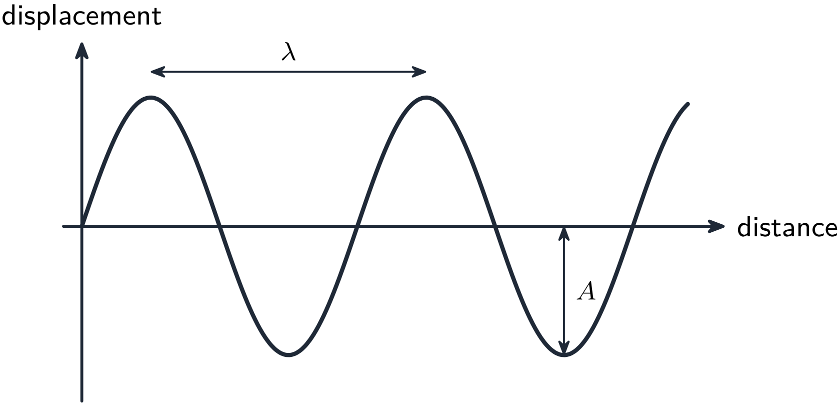
- use **displacement, amplitude, wavelength, period, frequency, phase difference**
- derive and use the **wave equation** $v = f\lambda$
- read a **CRO** trace and use **intensity** $\propto$ amplitude^2
- read two waves off one **displacement-distance** graph and superpose them
- say what a **progressive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

Method — Wave terms

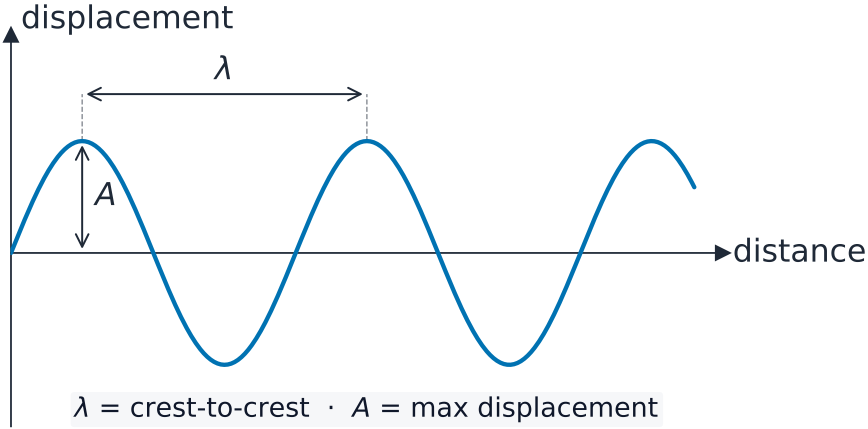
A progressive wave carries **energy** without moving matter overall:

- **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**.

Method — Wave terms



Method — Wave terms



A snapshot of a progressive wave

Method — 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.

Method — Wave equation

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

Method — 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.

Practice 2.1 ▪ 2 marks

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

Solution 2.1

Method: Wave terms

Worked steps

Amplitude — the maximum displacement from the rest position; **wavelength** — the shortest distance between two points oscillating **in phase** B1 B1.

Practice 2.2 ▪ 2 marks

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

Solution 2.2

Method: Wave terms

Worked steps

$v = f\lambda = 50 \times 6.0 = 300$ m s^{-1} **M1** **A1**.

Practice 2.3 ▪ 1 mark

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

Solution 2.3

Method: Wave terms

Worked steps

$f = 1/T$ **B1**.

Practice 2.4 ▪ 1 mark

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

Solution 2.4

Method: Wave terms

Worked steps

π radians (or $180°$) — exactly out of phase **B1**.

Exam-style 3.1 ▪ 1 mark

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

A 0.50 m

B 2.0 m

C 2.0 cm

D 5.8×10^4 m

Solution 3.1

Method: Wave terms

A 0.50 m

B 2.0 m ✓

C 2.0 cm

D 5.8×10^4 m

Worked steps

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

Exam-style 3.2 ▪ 3 marks

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**.

Solution 3.2

Method: CRO and intensity

Worked steps

$T = 4 \times 5$ ms $= 20$ ms $= 0.020$ s **M1** **A1**; $f = 1/T = 1/0.020 = 50$ Hz **A1**.

Exam-style 3.3 ▪ 2 marks

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.

Solution 3.3

Worked steps

In one period T the wave moves one wavelength λ, so $v = \lambda/T$ **M1**; since $f = 1/T$, $v = f\lambda$ **A1**.

Exam-style 3.4 ▪ 1 mark

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

Solution 3.4

Worked steps

It becomes **four times** larger (intensity $\propto A^2$) B1.

Exam-style 3.5 ▪ 2 marks

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.

Solution 3.5

Method: What a wave is, and what it carries

Worked steps

They transfer **energy** (the cork gains and loses energy as it bobs) B1; they do **not** transfer matter — the cork oscillates about the same place and does not travel with the ripples B1.

Exam-style 3.6 ▪ 2 marks

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.

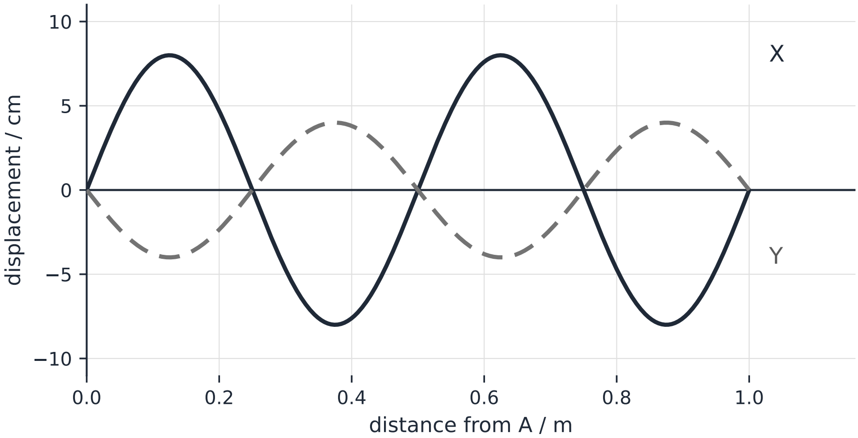
(b) **Determine** the speed of wave X.

(c) **State and explain** whether X and Y are **coherent**.

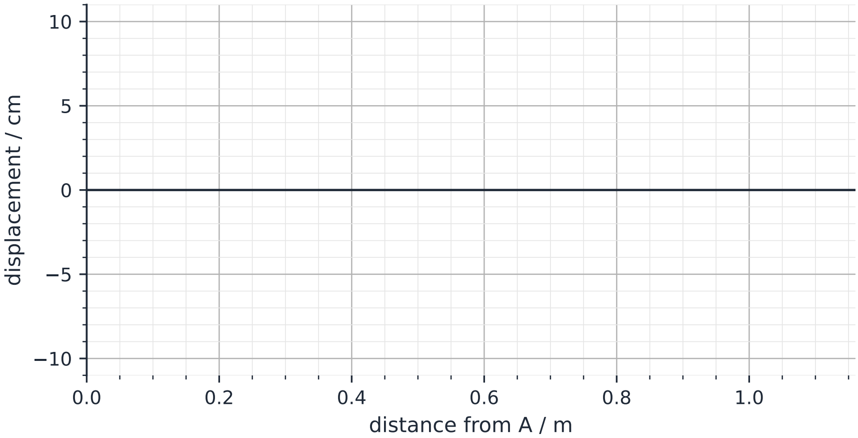
(d) The two waves superpose. On the grid below, **sketch** the displacement of the resultant wave against distance from A, at the same instant.

(e) The intensity of wave X is I_X and that of wave Y is I_Y. **Determine** the ratio $\dfrac{I_\mathsf{X}}{I_\mathsf{Y}}$.

Exam-style 3.6 ▪ 2 marks



Exam-style 3.6 ▪ 2 marks



Solution 3.6

Method: Wave terms

Worked steps

(a) Amplitude $= 8.0$ cm **B1**; wavelength $= 0.50$ m **B1**.
(b) $v = f\lambda = 12 \times 0.50$ **M1** $= 6.0$ m s^{-1} **A1**.
(c) **Coherent** **B1** — they have the same frequency and a **constant phase difference** ($180°$, i.e. π rad); coherence does not require equal amplitudes **B1**.
(d) A single wave of the same wavelength, 0.50 m **B1**, of amplitude $8.0 - 4.0 = 4.0$ cm **B1**, in phase with **X** — a crest wherever X has a crest, because X is the larger of the two **B1**.
(e) Intensity $\propto$ (amplitude)^2 **M1**, so $\dfrac{I_X}{I_Y} = \left(\dfrac{8.0}{4.0}\right)^2 = 4.0$ **A1**.