Past-paper walk-through

Progressive waves ▪ 7.1

eXercise

Questions in this set

- 9702/12 N25 Q25 ▪ 1 mark
- 9702/12 N25 Q26 ▪ 1 mark
- 9702/14 N25 Q24 ▪ 1 mark
- 9702/11 J25 Q26 ▪ 1 mark
- 9702/13 J25 Q24 ▪ 1 mark
- 9702/13 J25 Q26 ▪ 1 mark
- 9702/14 J25 Q20 ▪ 1 mark
- 9702/21 J25 Q5 ▪ 6 marks
- 9702/22 J25 Q3 ▪ 8 marks
- 9702/12 M25 Q25 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 25

9702/12 N25 ▪ Q25 ▪ 1 mark

What is the phase difference between points P and Q on the progressive wave shown in the diagram? **[1]**

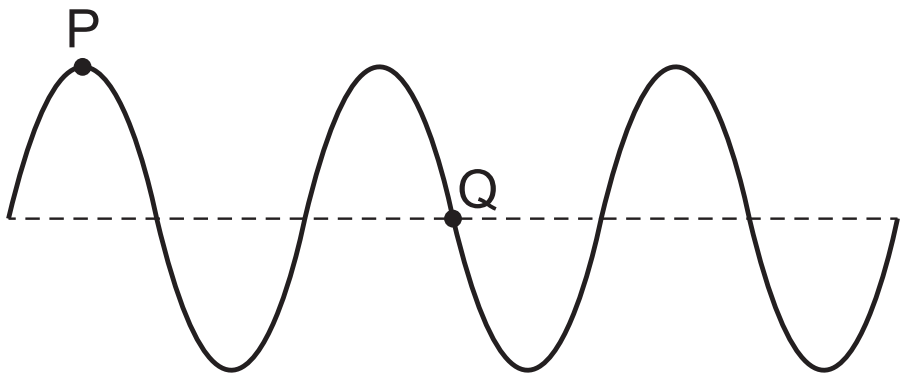
A $180°$

B $450°$

C $540°$

D $720°$

Question 25



Solution 25

A $180°$

B $450°$ ✓

C $540°$

D $720°$

Why

- Count the wavelengths between P and Q: they are $1\frac{1}{4}$ wavelengths apart.
- Each whole wavelength is $360°$, so $1.25 \times 360 = 450°$.
- A phase difference above $360°$ is perfectly normal for points more than one wavelength apart.

Question 26

9702/12 N25 ▪ Q26 ▪ 1 mark

The graph shows the variation of displacement with distance for two progressive waves X and Y of the same type in the same medium.

The intensity of wave X is I.

What is the intensity of wave Y? **[1]**

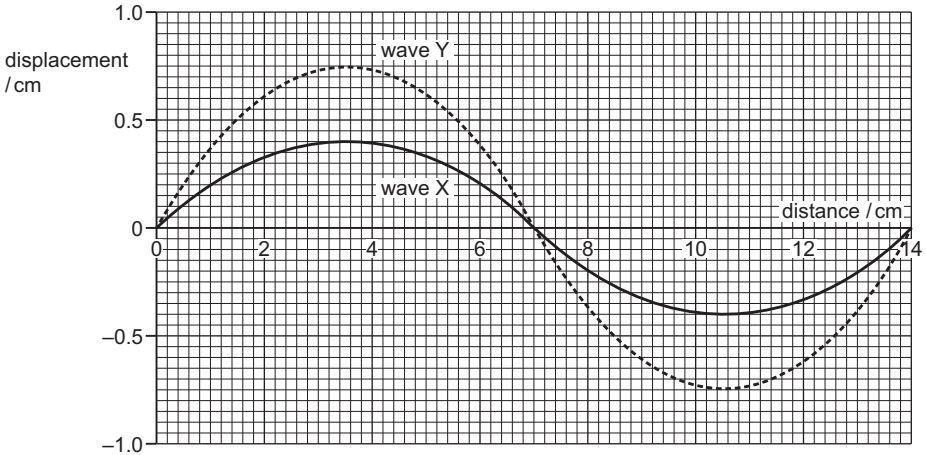
A $0.28I$

B $0.53I$

C $1.9I$

D $3.5I$

Question 26


displacement / cm
1.0
0.5
0
–0.5
–1.0
wave Y
wave X
distance / cm
0
2
4
6
8
10
12
14

Solution 26

A $0.28I$

B $0.53I$

C $1.9I$

D $3.5I$ ✓

Why

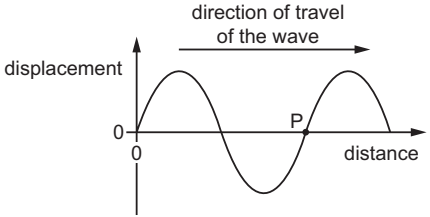
- Read the amplitudes off the graph: X is 0.40 cm and Y is 0.75 cm.
- Intensity is proportional to the *square* of the amplitude.
- $(0.75/0.40)^2 = 1.875^2 = 3.5$, so wave Y has intensity $3.5I$; C is the ratio without squaring.

Question 24

9702/14 N25 ▪ Q24 ▪ 1 mark

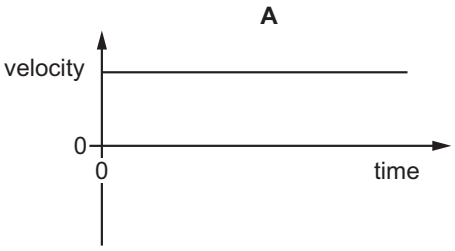
24 A transverse progressive wave travels along a string.

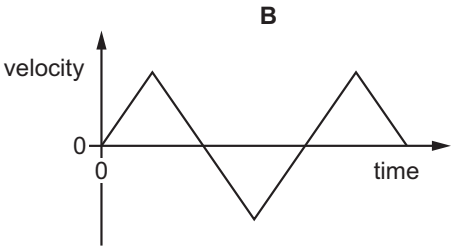
The graph shows the variation with distance of the displacement of the string at time $t = 0$.



Which graph represents the variation with time of the velocity of point P on the string?

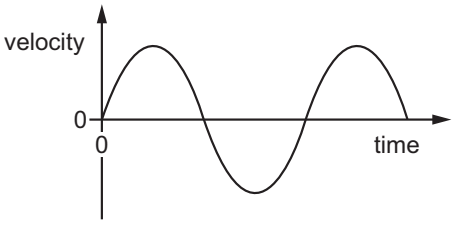
Question 24



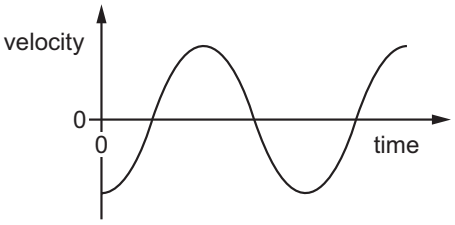


Question 24

C



D



Solution 24

Answer: **D**

Why

- The wave moves to the right, so P next takes on the displacement of the string just to its left – which is below the axis.
- P is therefore moving downwards at $t = 0$, and since it sits at zero displacement it is at maximum speed.
- So the velocity starts at its largest *negative* value; C has the right shape but starts at zero.

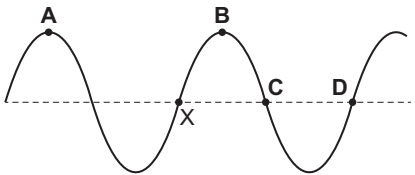
Question 26

9702/11 J25 ▪ Q26 ▪ 1 mark

26 The diagram shows a progressive transverse wave on a stretched string at one instant in time.

One point on the string is labelled X.

Which point on the string is 270° out of phase with X?



Solution 26

Answer: **A**

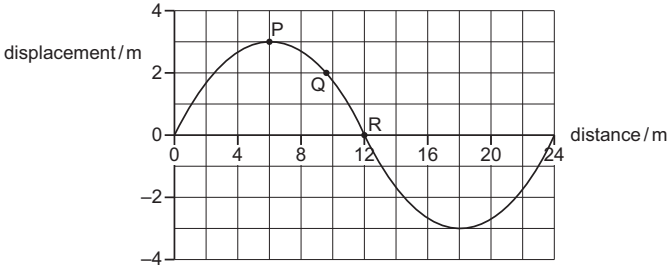
Why

- A phase difference of 270° is three quarters of a wavelength along the string.
- One wavelength is the distance between successive crests, so measure $\frac{3}{4}$ of that from X.
- For comparison, a whole wavelength apart is in phase and half a wavelength apart is antiphase.

Question 24

9702/13 J25 ▪ Q24 ▪ 1 mark

24 The graph shows the variation with distance along the wave of the displacement of water particles at a particular instant in time for a transverse water wave.



P, Q and R show the positions of three water particles in the wave.

Question 24

P, Q and R show the positions of three water particles in the wave.

Which particle has the greatest speed at the instant shown?

A all have the same speed

B particle P

C particle Q

D particle R

Solution 24

Answer: **D**

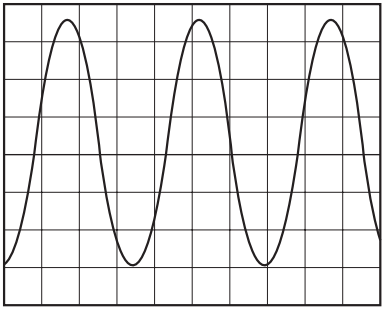
Why

- In a transverse wave a particle moves fastest as it passes through zero displacement.
- At a crest or a trough it is momentarily at rest before reversing.
- So the fastest particle is the one sitting on the axis, not the one at the largest displacement.

Question 26

9702/13 J25 ▪ Q26 ▪ 1 mark

26 A wave is displayed on an oscilloscope.



Question 26

The oscilloscope settings are:

time–base: $300\,\mu\text{s}\,\text{div}^{-1}$

y-gain: $40\,\mu\text{V}\,\text{div}^{-1}$.

What is the frequency of the wave?

A 130 Hz **B** 950 Hz **C** 1100 Hz **D** 7100 Hz

Solution 26

Answer: **B**

Why

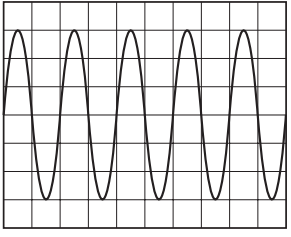
- Measure one whole cycle crest to crest: it spans 3.5 divisions.
- With the time-base at 300 μs per division, $T = 3.5 \times 300 = 1050$ μs.
- $f = 1/(1.05 \times 10^{-3}) = 950$ Hz; the y-gain plays no part in a frequency.

Question 20

9702/14 J25 ▪ Q20 ▪ 1 mark

20 A microphone is connected to a cathode-ray oscilloscope (CRO). The diagram shows the waveform on the display of the CRO when the microphone detects a sound.

The *y*-gain is set to 1 V div^{-1}. The time-base is set to 2.0 ms div^{-1}.



Which row gives the amplitude and frequency of the waveform?

Question 20

Which row gives the amplitude and frequency of the waveform?

	amplitude / V	frequency / Hz
A	3	125
B	3	250
C	6	125
D	6	250

Solution 20

Answer: **B**

Why

- Amplitude is measured from the centre line to a peak: 3 divisions at 1 V per division is 3 V.
- One complete cycle spans 2 divisions, so $T = 2 \times 2.0 = 4.0$ ms.
- $f = 1/(4.0 \times 10^{-3}) = 250$ Hz; C and D take the peak-to-peak height as the amplitude.

Question 5

9702/21 J25 ▪ Q5 ▪ 6 marks

(a) Use the definitions of speed v, frequency f and wavelength λ to derive the wave equation

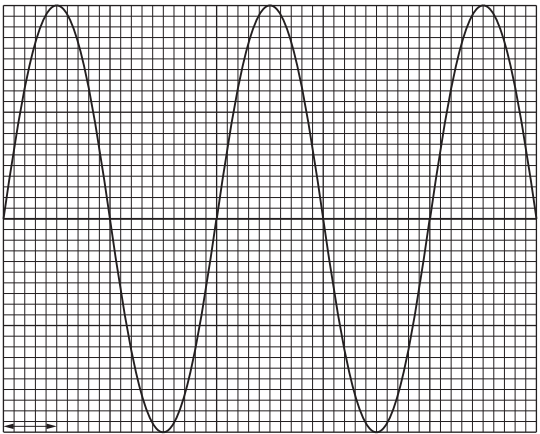
$$v = f\lambda.$$

[2]

(b)(i) Calculate the frequency of the sound waves detected by the microphone. **[2]**

(b)(ii) Determine the speed of the sound in air. **[2]**

Question 5



Solution 5

(a) Worked steps

Start from the definitions, not from the formula you are asked to reach.

- **Wavelength** λ is the distance between adjacent points in phase — one whole wave occupies that distance.
- **Frequency** f is the number of waves passing a point each second.
- So in one second, f waves pass, each λ long: the distance travelled per second is $f\lambda$.
- Speed is distance per unit time, so $v = f\lambda$.

Mark scheme

Solution 5

- wavelength:
- ▪ wavelength = distance between successive / adjacent in phase points / wavefronts / crests / troughs
- ▪ λ = d / (number of) oscillations frequency:
- ▪ frequency = (number of) oscillations / cycles crests / troughs / wavefronts (passing a point) per unit time
- ▪ f = (number of) oscillations / t
- One correct point from either list **B1**
- One correct point from both lists and speed = distance / time and one of:
- ▪ wavelength $\times$ frequency (= distance per unit time) = speed
- ▪ [(number of) oscillations / t] $\times$ [d / (number of) oscillations] = fλ

Solution 5

- ▪ v (= d / t) = λ / (1/f) = fλ or v (= d / t) = λ / T = fλ B1

Solution 5

(b)(i) Worked steps

Read the **period** off the trace first: the time for one complete cycle.

- $T = 4$ ms $= 4 \times 10^{-3}$ s
- $f = \dfrac{1}{T} = \dfrac{1}{4 \times 10^{-3}}$
- $f = 250$ Hz

Solution 5

Mark scheme

- $T = 4 \times 10{-}3$ f $= 1 / T = 1 / 0.004$ **C1**
- f $= 250$ Hz **A1**

Solution 5

(b)(ii) Worked steps

The detected frequency is higher than the emitted one, so the source is approaching: use the Doppler equation with $(v - v_s)$ on the bottom.

- $f_o = \dfrac{f_s v}{v - v_s}$, with $f_o = 250$ Hz, $f_s = 236$ Hz, $v_s = 20$ m s^{-1}.
- $250(v - 20) = 236v$
- $14v = 5000$, so $v = 357$ m s$^{-1} \approx 360$ m s^{-1} (2 s.f.)

Solution 5

Mark scheme

- $f_o = f_s \, v \, / \, (v - v_s)$
- $250 = 236 \times v \, / \, (v - 20) \; v = (250 \times 20) \, / \, (250 - 236)$ **C1**
- $= 360 \text{ m s}{-1}$ **A1**

Question 3

9702/22 J25 ▪ Q3 ▪ 8 marks

Two progressive water waves X and Y travel along a straight line from point A to point B. The variation of displacement of the waves with distance from A at an instant in time is shown in Fig. 3.1.

(a) State the amplitude of wave X. **[1]**

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

(b)(ii) State and explain whether X and Y are coherent. **[1]**

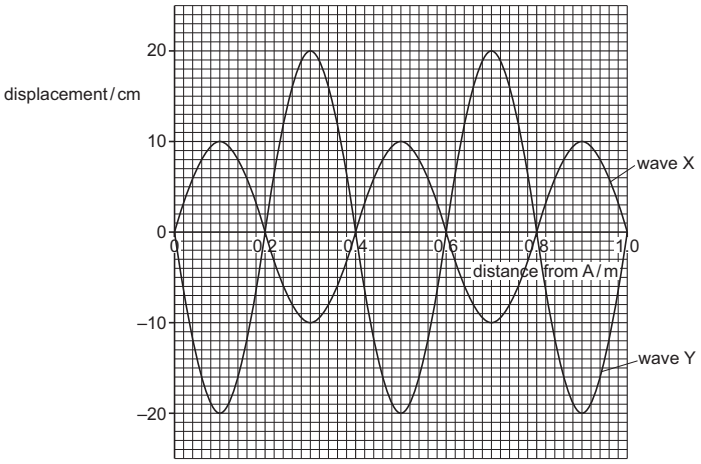
(c) Wave X and wave Y superpose to form a resultant wave.

On Fig. 3.2, sketch the variation of displacement of the resultant wave with distance from A at the instant of time shown in Fig. 3.1. **[2]**

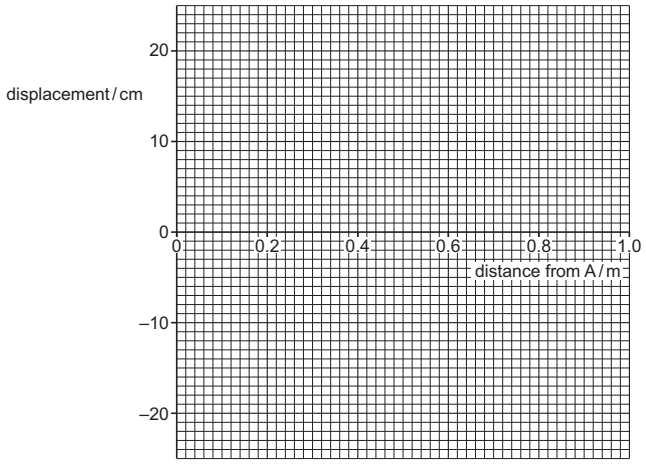
(d) The intensity of wave X is I_X. The intensity of wave Y is I_Y.

Use Fig. 3.1 to determine the ratio $\frac{I_X}{I_Y}$. **[2]**

Question 3


displacement / cm
20
10
0
–10
–20
0
0.2
0.4
0.6
0.8
1.0
distance from A / m
wave X
wave Y

Question 3



Solution 3

(a)

Mark scheme

- 10.0 cm **A1**

Solution 3

(b)(i)

Worked steps

- $v = f\lambda$
- $v = 16 \times 0.40$
- $v = 6.4$ m s^{-1}

Mark scheme

- v = fλ
- = 16 × 0.40 **C1**
- = 6.4 m s–1 **A1**

Solution 3

(b)(ii)

Mark scheme

- (X and Y have a) constant phase difference (of 180°) so (they are) coherent **B1**

Solution 3

(c) Worked steps

Superposition is addition of displacements, point by point — so do it at the places where the answer is easy to see.

- The two waves are **antiphase**: where X is at $+10$ cm, Y is at -20 cm.
- They partly cancel: the resultant amplitude is $20.0 - 10.0 = 10.0$ cm.
- The larger wave, Y, decides the sign, so the resultant follows Y's shape.
- Draw a single wave of amplitude 10.0 cm and wavelength 0.40 m, in phase with Y (i.e. inverted relative to X).

Solution 3

Mark scheme

- A single wave of amplitude 10.0 cm **B1**
- A single negative sine wave of wavelength 0.40 m **B1**

Solution 3

(d) Worked steps

- Intensity is proportional to amplitude squared: $I \propto A^2$.
- $\frac{I_X}{I_Y} = \frac{A_X^2}{A_Y^2} = \frac{10.0^2}{20.0^2}$
- ratio $= 0.25$

Doubling the amplitude quadruples the intensity, which is why the ratio is a quarter and not a half. **Mark scheme**

- I $\propto$ **A2**
- X

Solution 3

- Y
- I
- I
- $= 102 \ / \ 202$ **C1**
- ratio $= 0.25$ **A1**

Question 25

9702/12 M25 ▪ Q25 ▪ 1 mark

25 A progressive wave of frequency 300 Hz is travelling with a speed of 600 m s^{-1}.

What is the phase difference between two points on the wave that are a distance of 0.50 m apart?

A 45° **B** 90° **C** 180° **D** 360°

Solution 25

Answer: **B**

Why

- First the wavelength: $\lambda = v/f = 600/300 = 2.0$ m.
- The two points are 0.50 m apart, which is a quarter of a wavelength.
- A whole wavelength is $360°$, so a quarter is $90°$.