Past-paper walk-through

Stationary waves ▪ 8.1

eXercise

Questions in this set

- 9702/11 N25 Q29 ▪ 1 mark
- 9702/12 N25 Q30 ▪ 1 mark
- 9702/14 N25 Q29 ▪ 1 mark
- 9702/24 N25 Q4 ▪ 9 marks
- 9702/11 J25 Q29 ▪ 1 mark
- 9702/11 J25 Q31 ▪ 1 mark
- 9702/12 J25 Q24 ▪ 1 mark
- 9702/12 J25 Q30 ▪ 1 mark
- 9702/14 J25 Q25 ▪ 1 mark
- 9702/22 M25 Q4 ▪ 8 marks

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 29

9702/11 N25 ▪ Q29 ▪ 1 mark

The diagram shows a stationary wave on a stretched spring at an instant in time.

Two particles on the spring, P and Q, are shown.

Which statement about the vibrations of P and Q is correct? **[1]**

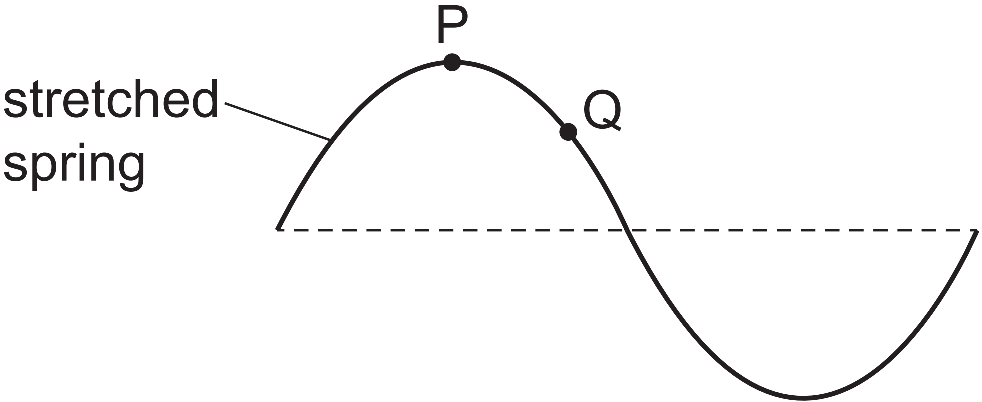
A They have different frequencies.

B They have the same amplitudes.

C They have different periods.

D They are always in phase.

Question 29



Solution 29

A They have different frequencies.

B They have the same amplitudes.

C They have different periods.

D They are always in phase. ✓

Why

- Every particle of a stationary wave oscillates with the same frequency, so A and C are wrong.
- The amplitude varies with position between the nodes and antinodes, so B need not hold.
- Within one loop – between the same pair of nodes – all the particles move together, so P and Q stay in phase.

Question 30

9702/12 N25 ▪ Q30 ▪ 1 mark

Two progressive sound waves move in opposite directions and superpose to form a stationary wave.

Which statement describes an antinode of this stationary wave? **[1]**

A a position where the phase difference between the two waves is always 0°

B a position where the phase difference between the two waves is always 180°

C a position where the stationary wave has maximum amplitude

D a position where the stationary wave has minimum amplitude

Solution 30

- **A** a position where the phase difference between the two waves is always 0°
- **B** a position where the phase difference between the two waves is always 180°
- **C** a position where the stationary wave has maximum amplitude ✓
- **D** a position where the stationary wave has minimum amplitude

Why

- An antinode is where the two waves always reinforce, giving the largest oscillation.
- So it is defined by the stationary wave having maximum amplitude there.
- A node is the opposite – a point of permanent zero amplitude.

Question 29

9702/14 N25 ▪ Q29 ▪ 1 mark

A wire is fixed at both ends and is vibrated by a source of frequency f. A stationary wave is formed on the wire with a total of two antinodes.

The frequency of the source is increased to $3f$ and a new stationary wave is formed.

What is the total number of antinodes on the new wave? **[1]**

A 4

B 5

C 6

D 9

Solution 29

- **A** 4
- **B** 5
- **C** 6 ✓
- **D** 9

Why

- On a wire fixed at both ends the number of antinodes is the harmonic number.
- Two antinodes means f is the second harmonic.
- Tripling the frequency gives the sixth harmonic, so six antinodes.

Question 4

9702/24 N25 ▪ Q4 ▪ 9 marks

(a) State the principle of superposition. **[2]**

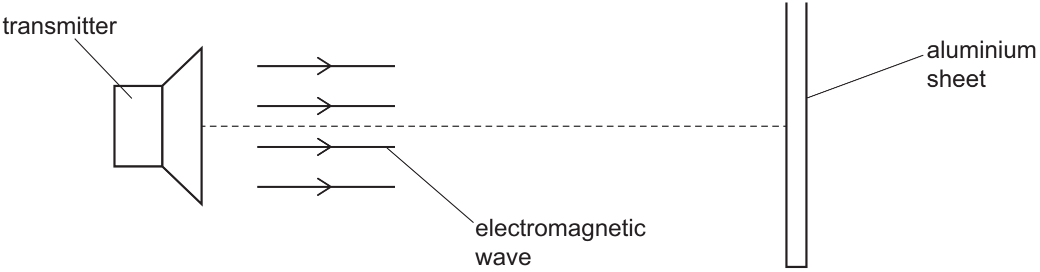
(b)(i) Explain how the stationary wave, including its nodes and antinodes, is formed. **[3]**

(b)(ii) Calculate the frequency of the electromagnetic wave. **[2]**

(b)(iii) State the principal region of the electromagnetic spectrum to which the wave belongs. **[1]**

(b)(iv) Determine the distance between a node and an adjacent antinode. **[1]**

Question 4



Solution 4

(a)

Mark scheme

- when two (or more) waves meet **M1**
- (resultant) displacement equals the sum of the displacements of the (two separate) waves **A1**

Solution 4

(b)(i)

Mark scheme

- the incident and reflected waves superpose **B1**
- (the waves superpose so that the resultant) amplitude is maximum at an antinode **B1**
- (the waves superpose so that the resultant) amplitude is minimum / zero at a node **B1**

Solution 4

(b)(ii) Worked steps

- $c = f\lambda$, so $f = \dfrac{c}{\lambda}$.
- $f = \dfrac{3.00 \times 10^8}{0.026}$
- $f = 1.2 \times 10^{10}$ Hz

Solution 4

Mark scheme

- $c = f\lambda$ **C1**
- $f = (3.00 \times 108) / 0.026$
- $= 1.2 \times 1010$ Hz **A1**

Solution 4

(b)(iii)

Mark scheme

- microwave **B1**

Solution 4

(b)(iv) Worked steps

The standard result: adjacent nodes are half a wavelength apart, so a node and its neighbouring antinode are **a quarter** of a wavelength apart.

- distance $= \dfrac{\lambda}{4} = \dfrac{0.026}{4}$
- distance $= 6.5 \times 10^{-3}$ m

Solution 4

Mark scheme

- distance $= 0.026 \;/\; 4$
- $= 6.5 \times 10–3$ m **A1**

Question 29

9702/11 J25 ▪ Q29 ▪ 1 mark

One wave has an amplitude of $2A$. A second wave has an amplitude of $\frac{A}{2}$. The waves are otherwise identical.

The two waves travel in opposite directions and overlap.

What is the ratio $\frac{\text{maximum amplitude of combined wave}}{\text{minimum amplitude of combined wave}}$? **[1]**

A $\frac{3}{2}$

B $\frac{5}{3}$

C $\frac{5}{2}$

D 4

Solution 29

A $\frac{3}{2}$

B $\frac{5}{3}$ ✓

C $\frac{5}{2}$

D 4

Why

- Where the waves reinforce the amplitudes add: $2A + A/2 = 2.5A$.
- Where they cancel the amplitudes subtract: $2A - A/2 = 1.5A$.
- The ratio is $2.5A/1.5A = 5/3$.

Question 31

9702/11 J25 ▪ Q31 ▪ 1 mark

A hollow tube is closed at one end and open at the other.

A stationary sound wave of the lowest possible frequency, 820 Hz, is produced in the tube.

The speed of sound in air is 330 m s^{-1}.

What is the length of the tube? **[1]**

A 10 cm

B 20 cm

C 40 cm

D 160 cm

Solution 31

- **A** 10 cm ✓
- **B** 20 cm
- **C** 40 cm
- **D** 160 cm

Why

- A tube closed at one end holds a quarter of a wavelength at its lowest frequency.
- $\lambda = v/f = 330/820 = 0.402$ m.
- $L = \lambda/4 = 0.101$ m, about 10 cm; B would be the open-open case.

Question 24

9702/12 J25 ▪ Q24 ▪ 1 mark

A teacher removes the turntable from a microwave oven and places a bar of chocolate in the oven. She then switches the oven on for a short time.

A stationary wave is formed in the oven.

When the chocolate is removed, the teacher observes that there are two small sections of melted chocolate 6.0 cm apart with unmelted chocolate in between.

Each section of melted chocolate is located at an antinode.

Assume that the speed of the microwaves is 3.0×10^8 m s^{-1}.

What is the frequency of the microwaves emitted by the oven? **[1]**

A 25 MHz

B 50 MHz

C 2.5 GHz

Question 24

D 5.0 GHz

Solution 24

A 25 MHz

B 50 MHz

C 2.5 GHz ✓

D 5.0 GHz

Why

- Adjacent antinodes are half a wavelength apart, so $\lambda = 2 \times 6.0 = 12$ cm.
- $f = c/\lambda = 3.0 \times 10^8/0.12$.
- $= 2.5 \times 10^9$ Hz $= 2.5$ GHz; D takes the 6.0 cm as a whole wavelength.

Question 30

9702/12 J25 ▪ Q30 ▪ 1 mark

Two waves meet.

What is **not** a necessary condition for the waves to produce a stationary wave? **[1]**

A They must be of the same type.

B They must have the same period.

C They must have the same wavelength.

D They must travel in the same direction.

Solution 30

A They must be of the same type.

B They must have the same period.

C They must have the same wavelength.

D They must travel in the same direction. ✓

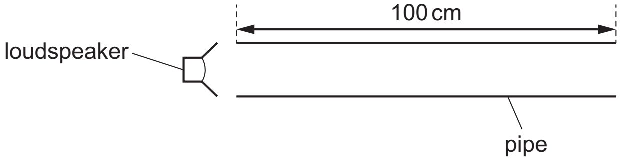
Why

- A stationary wave forms only when the two waves travel in *opposite* directions.
- So "the same direction" is not merely unnecessary – it is the opposite of the requirement.
- Same type, same wavelength and same period are all genuine conditions.

Question 25

9702/14 J25 ▪ Q25 ▪ 1 mark

25 A pipe of length 100 cm is open at both ends. A loudspeaker situated at one end of the pipe can emit sound of different wavelengths.



Which wavelength can produce a stationary wave in the pipe?

A 50 cm **B** 75 cm **C** 150 cm **D** 300 cm

Solution 25

Answer: **A**

Why

- A pipe open at both ends fits a whole number of half-wavelengths: $L = n\lambda/2$.
- So $\lambda = 2L/n = 200/n$ cm, giving 200, 100, 66.7, 50 cm, and so on.
- 50 cm is the $n = 4$ case; none of the other options divides 200 cm exactly.

Question 4

9702/22 M25 ▪ Q4 ▪ 8 marks

4 A device containing a microwave emitter and receiver is placed in front of a large metal sheet in a vacuum as shown in Fig. 4.1. X P Q Y microwave emitter and receiver metal sheet Fig. 4.1 (not to scale)

The line XY is perpendicular to the metal sheet. The device emits microwaves of frequency 6.3 GHz.

(a) When the device is at position P, a stationary wave is formed between the device and the sheet.

Explain how the stationary wave, including the nodes and the antinodes, is formed [4]

(b) (i) Calculate the wavelength of the microwaves.

wavelength = m [2] , ,

(ii) At point P the receiver detects a maximum amplitude of the stationary wave.

Question 4

The device is moved slowly from point P along the line XY and the receiver detects a series of minimum and maximum amplitudes. The first time a minimum amplitude is detected by the receiver is when the device is at point Q.
Determine the distance between P and Q.
distance = m [1]
(iii) The intensity of the microwaves emitted by the device is increased. The frequency of the microwaves is unchanged. The device is moved slowly along the line XY from point Q until the next maximum amplitude is detected at point R.
State and explain whether the distance QR is greater than, less than or the same as distance PQ [1]

, ,

(a) (a) When the device is at position P, a stationary wave is formed between the device and the

Question 4

sheet. Explain how the stationary wave, including the nodes and the antinodes, is formed.

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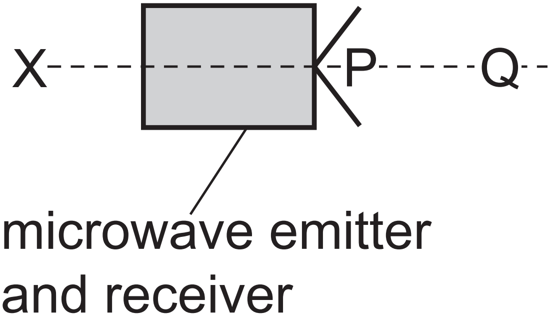
[4] **[4]**

Question 4



Question 4

9702/22 M25 ▪ Q4 ▪ 8 marks

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Question 4

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(b)(i) Calculate the wavelength of the microwaves. **[2]**
(b)(ii) At point P the receiver detects a maximum amplitude of the stationary wave. The device is moved slowly along the line XY and detects a series of minima and

Question 4

maxima. The first minimum is detected at point Q. Determine the distance between P and Q. **[1]**

(b)(iii) (iii) The intensity of the microwaves emitted by the device is increased. The frequency of the microwaves is unchanged. The device is moved slowly along the line XY from point Q until the next maximum amplitude is detected at point R. State and explain whether the distance QR is greater than, less than or the same as distance PQ.

....

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....

[1] **[1]**

Solution 4

(a)

Mark scheme

- (micro)wave (from the transmitter) reflects (at metal/sheet)
- The incident and reflected waves superpose
- (resultant) amplitude is maximum at an antinode
- (resultant) amplitude is minimum/zero at a node

Solution 4

(b)(i) Worked steps

- $c = f\lambda$, so $\lambda = \dfrac{c}{f}$, and 6.3 GHz $= 6.3 \times 10^9$ Hz.
- $\lambda = \dfrac{3.0 \times 10^8}{6.3 \times 10^9}$
- $\lambda = 0.048$ m

Solution 4

Mark scheme

- $\lambda = \mathrm{c} / \mathrm{f}$
- $= 3 \times 108 / 6.3 \times 109$
- $= 0.048\,\mathrm{m}$

Solution 4

(b)(ii) Worked steps

P is at an antinode and Q is the next node, and adjacent nodes and antinodes are a **quarter of a wavelength** apart.

- $PQ = \dfrac{\lambda}{4} = \dfrac{0.048}{4}$
- $PQ = 0.012$ m

Solution 4

Mark scheme

- distance PQ $= \frac{1}{4}\lambda$
- $= 0.048 / 4$
- $= 0.012\,\mathrm{m}$
- 9702/22
- February/March 2025

Solution 4

(b)(iii) Mark scheme

- (Distance QR is the) same (as PQ) and one of:
- ▪
- Distance (between maxima / minima) does not depend on intensity
- ▪
- distance depends only on wavelength
- ▪
- wavelength is unchanged / constant