

Exercise walk-through

8.1

Stationary waves

A-Level Physics

Sheet 8.1 – what you need to know

You must be able to:

- state the **principle of superposition**
- explain how a **stationary wave** forms, and compare it with a progressive wave
- find λ from the positions of nodes and antinodes
- describe the microwave, string and air-column experiments

What the exam asks

“State the principle of superposition.” [2]

“Explain how a stationary wave is formed between the vibration generator and the wall.” [2]

“Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube.” [3]

Practise on exercise sheet 8.1, then try the real exam questions on past-paper sheet 8.1.

Principle of superposition

Where waves overlap, the displacement is the **vector sum** of each wave's displacement – and they then **pass through each other unchanged**.

in phase

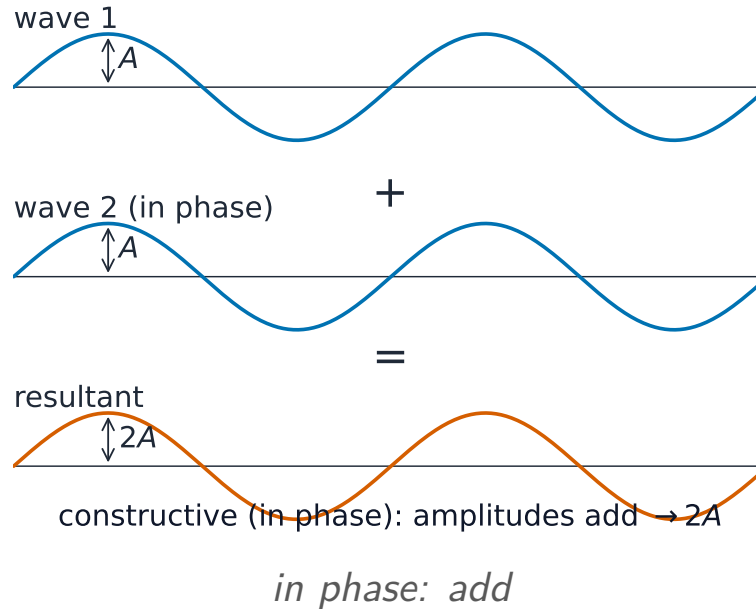
$A_1 + A_2$ – **constructive interference**

out of phase (π)

amplitude $|A_1 - A_2|$ (destructive)

Two equal waves in phase: $I \propto (2A)^2 = 4A^2$ – **four times** the intensity.

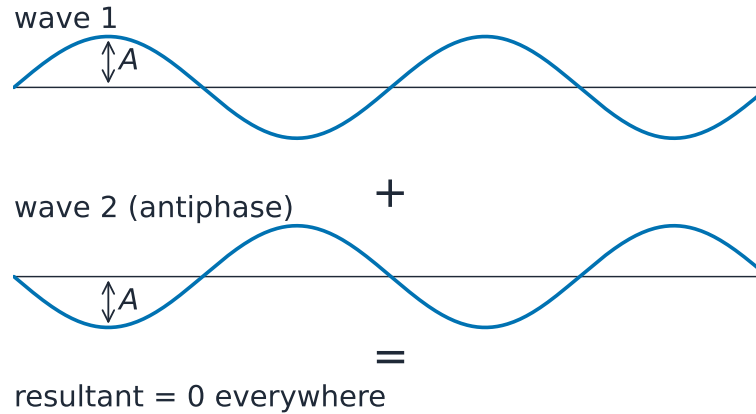
In phase: add



Crest

on crest: the two add, and the result is **constructive interference**

Out of phase: cancel



destructive (out of phase by $\lambda/2$): cancel if equal A

out of phase: cancel

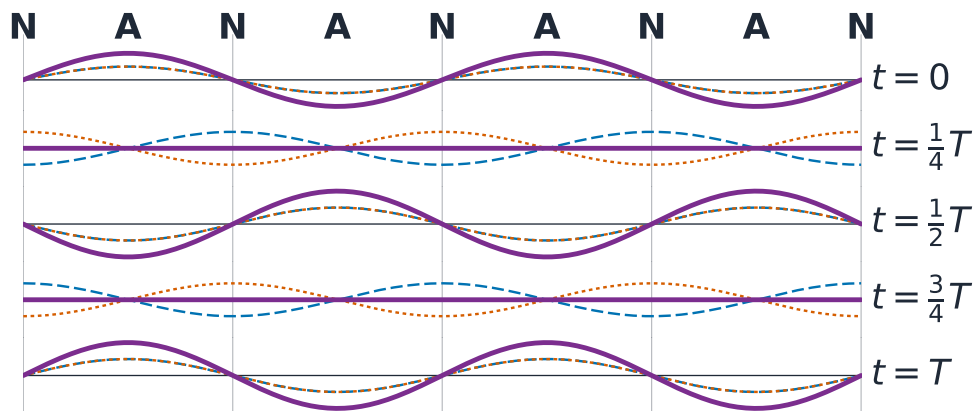
Crest on **trough**
cancel.

– exactly in **antiphase**

– gives **destructive interference**

: they

Stationary (standing) waves



-- moving right ... moving left — resultant
stationary wave: nodes and antinodes from two
opposite waves

Two identical **progressive waves** travelling **opposite ways** overlap – usually a wave and its own **reflected** copy from a fixed end.

It stores energy but does **not** carry it along – the pattern stays put.

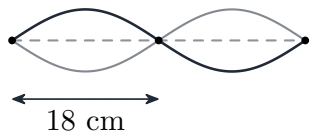
Exercises 2.1·2.2

2.1 State the principle of superposition.

[2]

superposition

2.2 On a stationary wave, neighbouring nodes are 18 cm apart. State the wavelength.[1]



Exercises 2.1·2.2

2.1 State the **principle of superposition**.

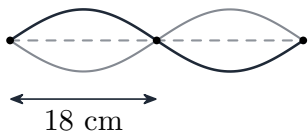
[2]

superposition

2.1

- when two or more waves meet at a point
 - the resultant displacement is the sum of the individual displacements
-

2.2 On a stationary wave, neighbouring nodes are 18 cm apart. State the wavelength.[1]

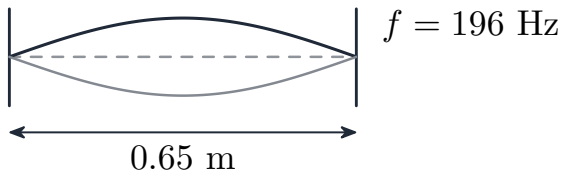


2.2

- node to node is half a wavelength, $\frac{\lambda}{2} = 18 \text{ cm}$, so $\lambda = \mathbf{36} \text{ cm}$

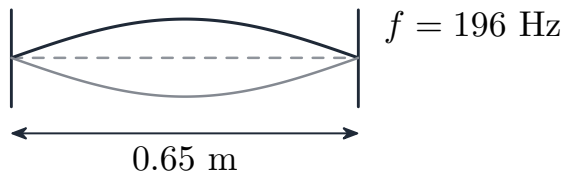
Exercise 2.3

2.3 A guitar string 0.65 m long vibrates in its fundamental mode at 196 Hz. Calculate the speed of the waves on the string. [2]



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2.3

- fundamental: one loop, so $\lambda = 2L = 1.30 \text{ m}$

$$v = f\lambda = 196 \times 1.30 = \mathbf{255} \frac{\text{m}}{\text{s}}$$

Exercise 2.4

2.4 State **two** differences between a stationary wave and a progressive wave. [2]

stationary

progressive

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stationary

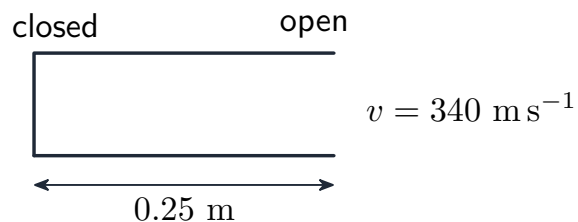
progressive

2.4

- a stationary wave does not transfer energy along its length; a progressive wave does
- the amplitude of a stationary wave varies from zero at nodes to a maximum at antinodes; in a progressive wave every point has the same amplitude (or: points between neighbouring nodes are in phase)

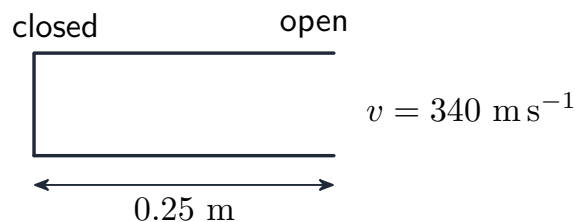
Exercise 2.5

2.5 A pipe closed at one end is 0.25 m long. The speed of sound is $340 \frac{\text{m}}{\text{s}}$. Calculate the frequency of its fundamental. [2]



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2.5

- closed pipe fundamental: $L = \frac{\lambda}{4}$, so $\lambda = 1.0 \text{ m}$

$$f = \frac{v}{\lambda} = \frac{340}{1.0} = \mathbf{340 \text{ Hz}}$$

Exercise 3.1

3.1 Neighbouring nodes of a stationary sound wave are 12 cm apart. The frequency is 1400 Hz. What is the speed of sound? [1]

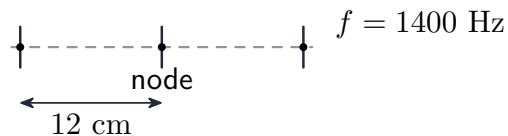
☐

A $168 \frac{\text{m}}{\text{s}}$

B $336 \frac{\text{m}}{\text{s}}$

C $672 \frac{\text{m}}{\text{s}}$

D $1.2 \times 10^4 \frac{\text{m}}{\text{s}}$



Exercise 3.1

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- ☐ **A** $168 \frac{\text{m}}{\text{s}}$
- B** $336 \frac{\text{m}}{\text{s}}$
- C** $672 \frac{\text{m}}{\text{s}}$
- D** $1.2 \times 10^4 \frac{\text{m}}{\text{s}}$



3.1 B

- node to node is half a wavelength, $\frac{\lambda}{2} = 0.12 \text{ m}$, so $\lambda = 0.24 \text{ m}$ and $v = f\lambda = 1400 \times 0.24 = 336 \frac{\text{m}}{\text{s}}$
- A** uses the node spacing as the wavelength

Exercise 3.2

3.2 Two points on a stationary wave lie in neighbouring loops. What is the phase difference between their oscillations? [1]

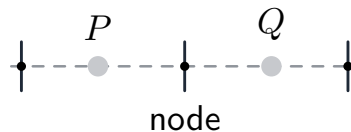
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A 0°

B 45°

C 90°

D 180°



Exercise 3.2

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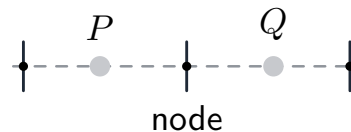
☐

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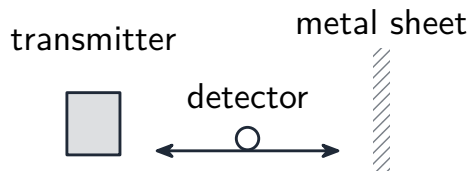
3.2 D

- points in neighbouring loops of a stationary wave oscillate in antiphase
- points within one loop are in phase (0°)

Exercise 3.3 (a)

3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

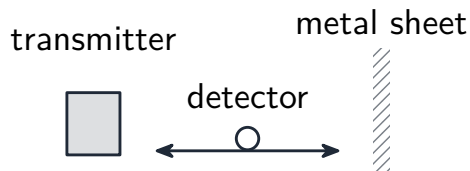
(a) **Explain** how a stationary wave forms between the transmitter and the sheet. [3]



Exercise 3.3 (a)

3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

(a) **Explain** how a stationary wave forms between the transmitter and the sheet. [3]



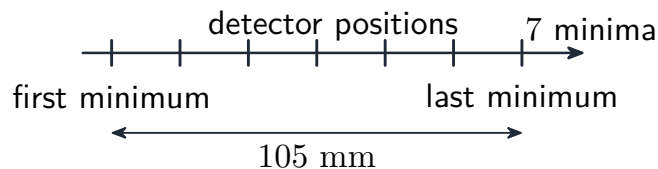
(a) the microwaves reflect from the metal sheet

- the reflected waves travel back in the opposite direction with the same frequency and speed
- the two waves superpose, forming nodes where they always cancel and antinodes where they reinforce

Exercise 3.3 (b)

3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

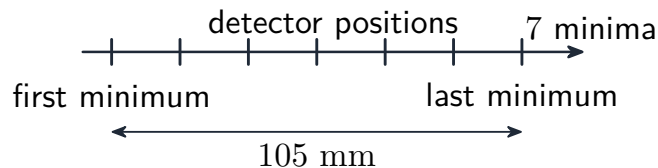
(b) The detector passes through 7 neighbouring minima over a distance of 105 mm, measured from the first minimum to the last. **Determine** the wavelength of the microwaves. [2]



Exercise 3.3 (b)

3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

(b) The detector passes through 7 neighbouring minima over a distance of 105 mm, measured from the first minimum to the last. **Determine** the wavelength of the microwaves. [2]



(b) 7 minima span 6 gaps of $\frac{\lambda}{2}$: $6 \times \frac{\lambda}{2} = s = 105 \text{ mm}$

$$\bullet \quad \lambda = \frac{2s}{6} = \frac{2 \times 105}{6} = \mathbf{35 \text{ mm}}$$

Exercise 3.3 (c)

3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

(c) Calculate the frequency of the microwaves.

[2]

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3.3 A microwave transmitter faces a flat metal sheet. A detector is moved along the line between them, and the reading rises and falls.

(c) Calculate the frequency of the microwaves.

[2]

(c) wave equation, $f = \frac{c}{\lambda}$

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{0.035} = \mathbf{8.6 \times 10^9 \text{ Hz}}$$

Exercise 3.4 (a)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(a) State the positions of the nodes on the string.

[1]

Exercise 3.4 (a)

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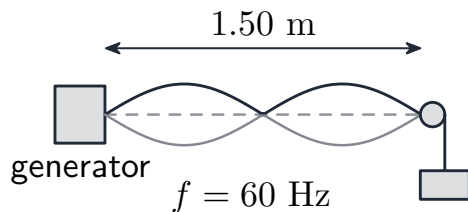
(a) at the two ends and at the middle of the string

Exercise 3.4 (b)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(b) Calculate the speed of the waves on the string.

[2]

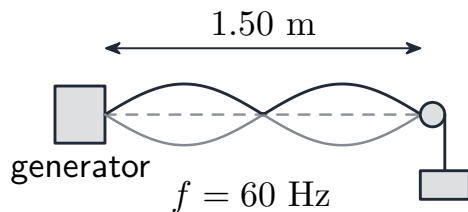


Exercise 3.4 (b)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(b) Calculate the speed of the waves on the string.

[2]



(b) two loops: $L = 2 \times \frac{\lambda}{2}$, so $\lambda = 1.50 \text{ m}$

$$v = f\lambda = 60 \times 1.50 = \mathbf{90} \frac{\text{m}}{\text{s}}$$

Exercise 3.4 (c)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(c) Calculate the frequency at which the string vibrates with three loops. [2]

Exercise 3.4 (c)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(c) Calculate the frequency at which the string vibrates with three loops. [2]

(c) three loops fill the length, $L = 3 \times \frac{\lambda}{2}$, so $\lambda = \frac{2L}{3} = \frac{2 \times 1.50}{3} = 1.00 \text{ m}$

$$f = \frac{v}{\lambda} = \frac{90}{1.00} = \mathbf{90 \text{ Hz}}$$

Exercise 3.4 (d)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(d) State the phase difference between the oscillations of a point in the first loop and a point in the second loop. [1]

Exercise 3.4 (d)

3.4 A string of length 1.50 m is stretched between a vibration generator and a pulley. At a frequency of 60 Hz it vibrates with two loops.

(d) State the phase difference between the oscillations of a point in the first loop and a point in the second loop. [1]

(d) **180°** (antiphase)