8.1 Stationary waves

Name: ____________ Class: ________ Date: __________ **Total: 18 marks**

KEY WORDS wave 波 • stationary wave 驻波 • node 波节 • antinode 波腹 • wavelength 波长

Objective

Build the skills to answer exam questions on **stationary waves 驻波** — superposition, nodes and antinodes, and the **reflection** experiments that form them.

You must be able to:

- use the **principle of superposition** (constructive/destructive)
- explain how a **stationary wave** forms — including by **reflection** off a surface
- identify **nodes** and **antinodes** and find **wavelength** from node spacing
- use $v = f\lambda$ (and $c = f\lambda$ for microwaves) and name the spectrum region

1 Worked examples

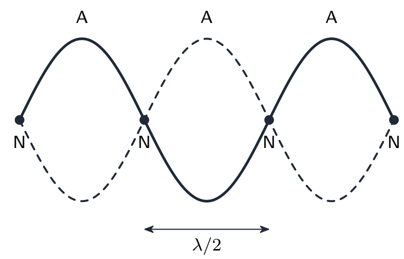
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Superposition

Where waves overlap, the displacement is the **sum** of the separate displacements. In phase → **constructive** (amplitude $A_1 + A_2$); exactly out of phase → **destructive** ($|A_1 - A_2|$). Since $I \propto A^2$, two equal waves in phase give **four times** the intensity.

Stationary waves

Two identical waves travelling in **opposite directions** overlap to make a **stationary wave**:

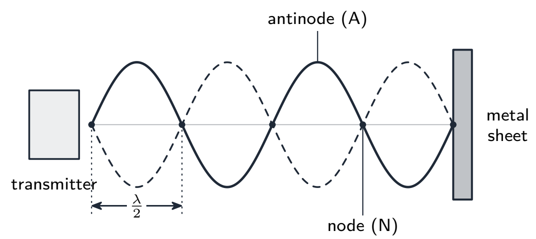


- **node (N):** always zero displacement; **antinode (A):** maximum amplitude.
- node-to-node $= \lambda/2$; node to next antinode $= \lambda/4$.

A stationary wave does **not** transfer energy along its length, and the nodes stay fixed. Find λ from node spacing, then $v = f\lambda$.

Stationary waves by reflection

In the exam, the second wave is very often the **reflection** of the first. A common set-up: a **microwave** transmitter faces a **metal sheet**. The waves travel to the sheet, **reflect**, and the reflected waves travel back and **superpose** with the incoming waves — forming a stationary wave, with a **node at the sheet**:



To explain the formation (a frequent "explain" question), say: the incident wave **reflects** off the sheet; the reflected wave travels back in the **opposite direction**; the two waves have the same frequency and **superpose**; at **nodes** they are always out of phase and cancel, at **antinodes** they reinforce.

Worked example. A detector is moved between transmitter and sheet; adjacent points of minimum signal (nodes) are 25 mm apart. Then $\lambda/2 = 25$ mm, so $\lambda = 50$ mm $= 0.050$ m. As these are microwaves (an EM wave), $f = \dfrac{c}{\lambda} = \dfrac{3.0 \times 10^8}{0.050} = 6.0 \times 10^9$ Hz — in the **microwave** region of the spectrum.

2 Practice

Now apply the methods above.

2.1 State the **principle of superposition**. [1]

2.2 State the distance between **two adjacent nodes**. [1]

2.3 Two waves each of amplitude A meet **in phase**. State the resultant **amplitude** and the **intensity** compared with one wave. [2]

2.4 State **one** difference between a stationary wave and a progressive wave. [1]

2.5 In a microwave stationary wave, adjacent nodes are 16 mm apart. State the **wavelength**. [1]

3 Exam-style questions

3.1 The distance between a node and the **next antinode** is: [1]

- **A** λ
- **B** $\lambda/2$
- **C** $\lambda/4$
- **D** 2λ

3.2 A stationary wave on a string has adjacent nodes 0.30 m apart. The frequency is 250 Hz. Find (a) the wavelength, (b) the wave speed. [3]

3.3 A microwave transmitter faces a metal sheet. The reflected microwaves superpose with the incoming microwaves to form a stationary wave.

(a) Explain how the stationary wave is formed, referring to **nodes** and **antinodes**. [3]

(b) A detector finds that adjacent nodes are 25 mm apart. Calculate the **frequency** of the microwaves, and name the region of the electromagnetic spectrum they belong to. ($c = 3.0 \times 10^8$ m s^{-1}.) [3]

3.4 State **two** differences between a **node** and an **antinode**. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- when waves overlap, the resultant displacement is the **(vector) sum** of the individual displacements

2.2

- neighbouring nodes are $\lambda/2$ apart

2.3

- amplitude $= 2A$
- intensity $= 4\times$ that of one wave ($I \propto A^2$)

2.4

- any one: a stationary wave does **not transfer energy** along its length; its amplitude **varies** (zero at nodes); the nodes are fixed

2.5

- node-to-node is $\lambda/2$, so $\lambda = 2 \times 16$ mm $=$ **32** mm

3.1 C

- a node to the nearest antinode is $\lambda/4$

3.2

(a) node spacing $= \lambda/2 = 0.30$ m

- $\lambda = \mathbf{0.60}$ m

(b) $v = f\lambda$

$$v = (250\text{ Hz})(0.60\text{ m}) = \mathbf{150}\text{ m s}^{-1}$$

3.3

(a) incident microwaves **reflect** off the sheet and travel back the **opposite way**

- incident and reflected waves have the same frequency and **superpose**
- always out of phase $\rightarrow$ **nodes**; always in phase $\rightarrow$ **antinodes**

(b) node spacing $= \lambda/2 = 25$ mm

- $\lambda = 50$ mm $= 0.050$ m

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8\text{ m s}^{-1}}{0.050\text{ m}} = \mathbf{6.0 \times 10^9}\text{ Hz}$$

- region: **microwaves**

3.4

- any two: a node has **zero** displacement, an antinode has **maximum** amplitude; a node never moves; points either side of a node are in **antiphase**