Exercise walk-through

Stationary waves ▪ 8.1

eXercise

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

Method — Superposition

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

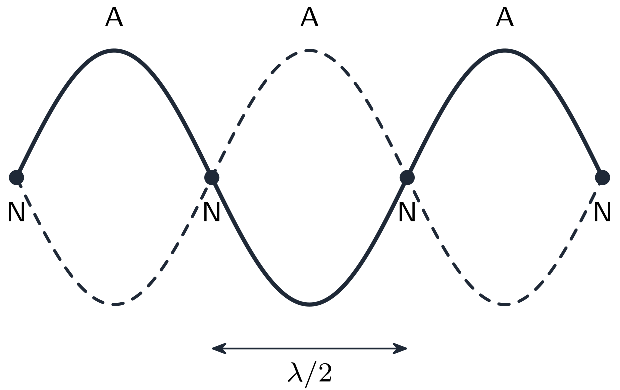
Method — Stationary waves

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 $v = f\lambda$.

Method — Stationary waves



Method — Stationary waves by reflection

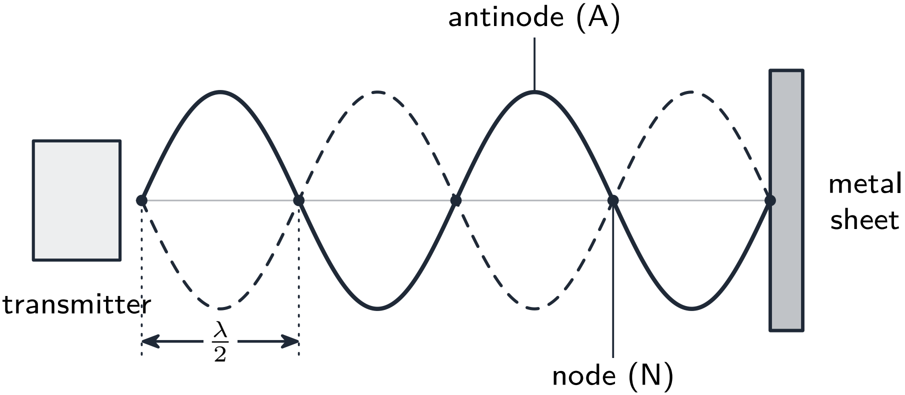
In the exam, the second wave is very often the **reflection** of the first. A common set-up: a **microwave** transmitter faces a **metal sheet**. The waves travel to the sheet, **reflect**, and the reflected waves travel back and **superpose** with the incoming waves — forming a stationary wave, with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

Method — Stationary waves by reflection



Practice 2.1 ▪ 1 mark

State the **principle of superposition**.

Solution 2.1

Worked steps

When waves overlap, the resultant displacement is the **(vector) sum** of the individual displacements **B1**.

Practice 2.2 ▪ 1 mark

State the distance between **two adjacent nodes**.

Solution 2.2

Method: Stationary waves by reflection

Worked steps

$\lambda/2$ **B1**.

Practice 2.3 ▪ 2 marks

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

Solution 2.3

Method: Superposition

Worked steps

Amplitude $= 2A$; intensity $= 4\times$ that of one wave (since $I \propto A^2$) **B1** **B1**.

Practice 2.4 ▪ 1 mark

State **one** difference between a stationary wave and a progressive wave.

Solution 2.4

Worked steps

Any one: a stationary wave does **not transfer energy** along its length; its amplitude **varies** (zero at nodes, max at antinodes) whereas a progressive wave has the same amplitude everywhere; the nodes are fixed **B1**.

Practice 2.5 ▪ 1 mark

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

Solution 2.5

Method: Stationary waves by reflection

Worked steps

$\lambda = 2 \times 16 = 32$ mm **B1**.

Exam-style 3.1 ▪ 1 mark

The distance between a node and the **next antinode** is:

A λ

B $\lambda/2$

C $\lambda/4$

D 2λ

Solution 3.1

Method: Stationary waves

A λ

B $\lambda/2$

C $\lambda/4$ ✓

D 2λ

Worked steps

C — $\lambda/4$.

Exam-style 3.2 ▪ 3 marks

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.

Solution 3.2

Method: Stationary waves by reflection

Worked steps

(a) node spacing $= \lambda/2 = 0.30$ m, so $\lambda = 0.60$ m **M1** **A1**. (b) $v = f\lambda = 250 \times 0.60 = 150$ m s^{-1} **A1**.

Exam-style 3.3 ▪ 3 marks

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**.

(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}.)

Solution 3.3

Method: Stationary waves by reflection

Worked steps

(b) $\lambda = 2 \times 25 = 50$ mm $= 0.050$ m **M1**; $f = \dfrac{c}{\lambda} = \dfrac{3.0 \times 10^8}{0.050} = 6.0 \times 10^9$ Hz **A1**; region: **microwaves** **A1**.

Exam-style 3.4 ▪ 2 marks

State **two** differences between a **node** and an **antinode**.

Solution 3.4

Method: Stationary waves

Worked steps

Any two: a node has **zero** displacement, an antinode has **maximum** amplitude; a node never moves, an antinode oscillates most; adjacent points either side of a node are in **antiphase** B1 B1.