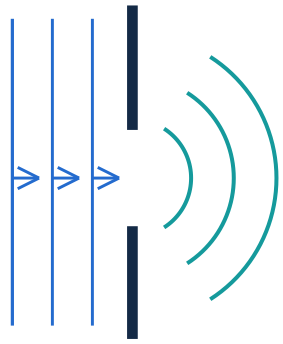
LESSON 2.1.3

Diffraction, Interference and Stationary Waves

Waves spread at gaps, combine by superposition and can form fixed patterns of nodes and antinodes.

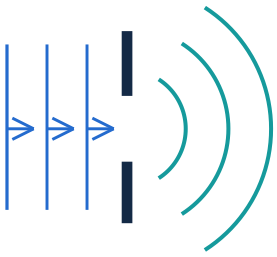
GAP ABOUT ONE WAVELENGTH



strong spreading

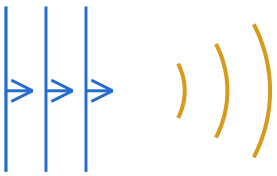
DIFFRACTION: THE SIZE COMPARISON

GAP SIZE IS ABOUT λ



maximum visible spreading

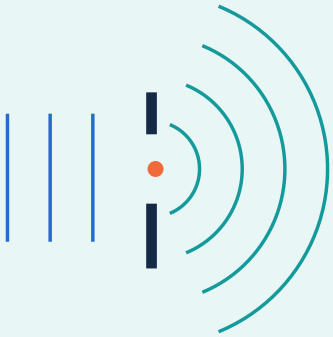
GAP SIZE IS MUCH GREATER THAN λ



little spreading

WHY THE WAVE CURVES

HUYGENS' CONSTRUCTION



Every point on a wavefront acts as a source of secondary wavelets. The next wavefront is their common envelope.

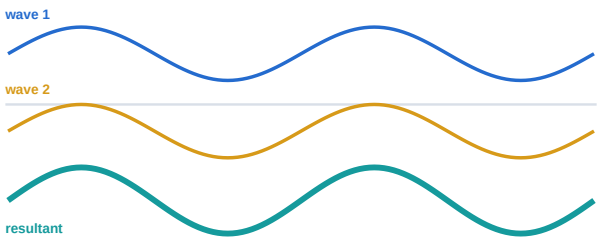
EXAM LINK

Diffraction is evidence of wave behaviour. A longer wavelength produces more spreading for the same opening.

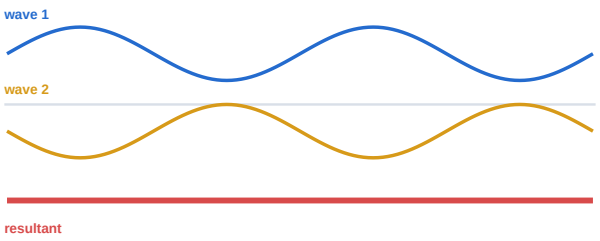
1 Superposition, interference and phase

When waves overlap, their instantaneous displacements add. A stable pattern needs coherent sources with constant phase difference.

WHAT SUPERPOSITION PRODUCES



reinforcement



cancellation

PATH DIFFERENCE CONTROLS PHASE DIFFERENCE

PATH TO PHASE

$$\Delta\varphi = 2\pi\Delta x/\lambda$$

$\Delta\phi$ in radians

CONSTRUCTIVE

$$\Delta x = m\lambda$$

0, λ, 2λ, ...

DESTRUCTIVE

$$\Delta x = (m + 1/2)\lambda$$

$\lambda/2$, $3\lambda/2$, ...

WORKED PHASE EXAMPLE

Two coherent waves have path difference 0.75λ.

$$\Delta\varphi = 2\pi(0.75\lambda)/\lambda = 1.5\pi \text{ rad} = 270°$$

This is neither fully constructive nor fully destructive; the resultant amplitude lies between the two extremes.

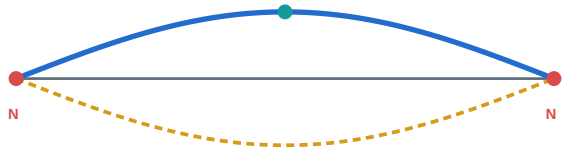
COHERENCE CHECK

Same frequency is not enough by itself. Coherent sources must maintain a constant phase difference.

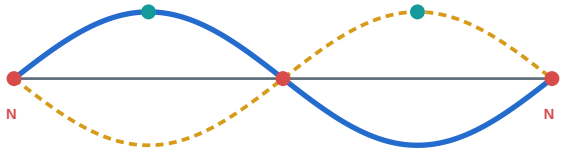
2 Stationary waves and vibrating strings

Two waves with the same frequency and amplitude travel in opposite directions. Their superposition creates fixed nodes and antinodes.

FIXED-END STRING PATTERNS



fundamental: L = λ/2



second harmonic: L = λ

READ THE PATTERN

1 NODE

Zero displacement; adjacent nodes are λ/2 apart.

2 ANTINODE

Maximum amplitude; node to adjacent antinode is λ/4.

3 ENERGY

No net energy transfer along an ideal stationary wave.

STRING EQUATIONS

WAVE SPEED ON A STRING

$$v = \sqrt{(T/\mu)}$$

T = tension; μ = mass per unit length

FIXED-END MODES

$$f_n = n/(2L)\ \sqrt{(T/\mu)}$$

n = 1, 2, 3, ...

CORE PRACTICAL 5: WHAT CHANGES THE FREQUENCY?

LENGTH L

longer string: lower f

TENSION T

greater tension: higher f

MASS / LENGTH μ

larger μ: lower f

PRACTICAL QUALITY

Change one variable at a time, identify resonance consistently, repeat frequencies and use a suitable graph to test the predicted proportionality.