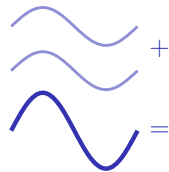


Superposition

AS Physics ■ Topic 8

A-Level Physics



Superposition

What we will cover

- 1 Principle of superposition
- 2 Stationary waves
- 3 Diffraction
- 4 Interference
- 5 The diffraction grating
- 6 Recap



1 Superposition

Principle of superposition

Where waves overlap, the displacement is the **vector sum** of each wave's displacement.

in phase

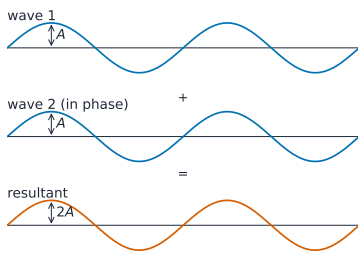
amplitude $A_1 + A_2$ (constructive)

out of phase (π)

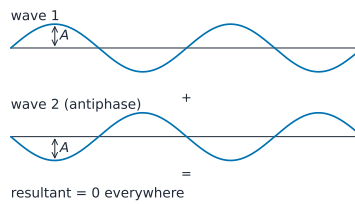
amplitude $|A_1 - A_2|$ (destructive)

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

Constructive and destructive



in phase: add



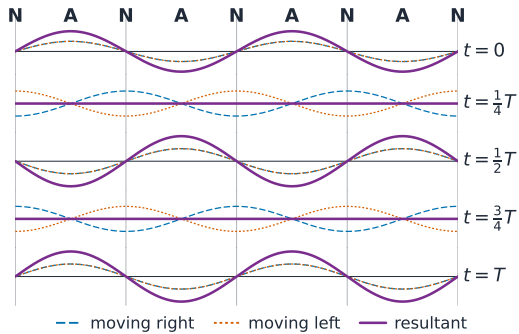
out of phase: cancel

Constructive 相长 (in phase): amplitudes add. **Destructive** 相消 (crest meets trough): they cancel.

2

Stationary waves

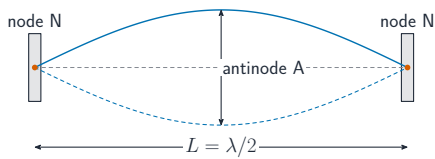
Stationary (standing) waves



Two identical waves travelling opposite ways overlap.

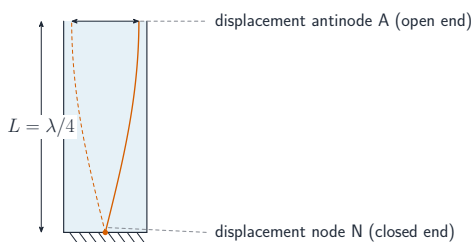
It stores energy but does **not** carry it along – the pattern stays put.

Nodes and antinodes



- **node** 波节 – always zero displacement
- **antinode** 波腹 – largest amplitude
- node to node = $\lambda/2$; node to antinode = $\lambda/4$

Resonance in pipes



Resonance tube 共鸣管, closed one end:

- closed end = node, open end = antinode
- **fundamental** 基频: $L = \lambda/4$; next $L = 3\lambda/4$
- open both ends: fundamental $L = \lambda/2$

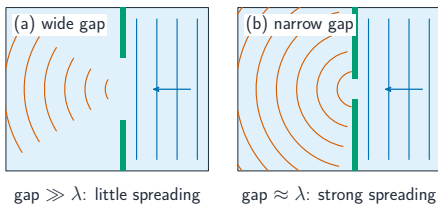
Then $v = f\lambda$ gives the wave speed.

3

Diffraction

Superposition
└─ Diffraction

Diffraction



Diffraction 衍射: a wave spreads after a gap or obstacle. Spread depends on λ vs gap width:

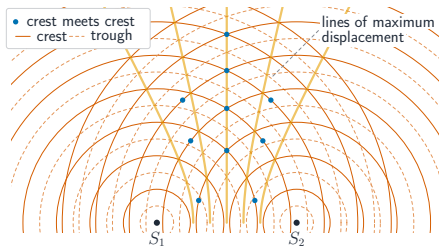
- gap $\gg \lambda$: little spread
- gap $\approx \lambda$: large spread

Why you hear round a corner but cannot see round it.

4

Interference

Interference and coherence



Interference 干涉: two **coherent** 相干 waves give a **steady** pattern. Coherent = constant phase difference (so same frequency). Two lamps are not coherent.

Path difference

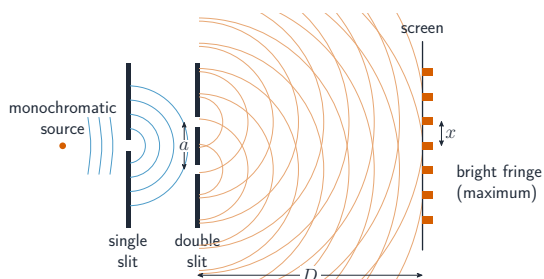
What happens at a point depends on the **path difference** 路程差 Δx :

bright: $\Delta x = n\lambda$

dark: $\Delta x = (n + \frac{1}{2})\lambda$



Young's double-slit experiment



Fringe spacing 条纹间距:

$$x = \frac{\lambda D}{a}$$

$$a = 0.50 \text{ mm}, \lambda = 600 \text{ nm}, D = 2.0 \text{ m}$$

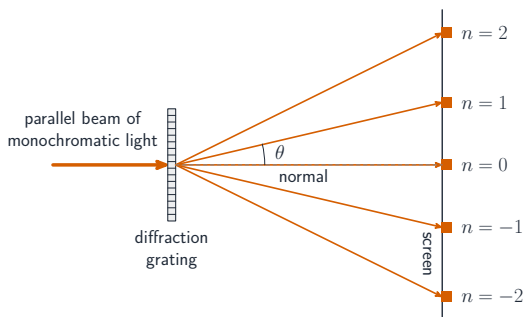
$$x = (600 \times 10^{-9})(2.0) / (0.50 \times 10^{-3}) = 2.4 \text{ mm}$$

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Diffraction grating

Superposition
└─ Diffraction grating

The diffraction grating



Many slits, spacing d – maxima where

$$d \sin \theta = n\lambda.$$

500 lines/mm, $\lambda = 600 \text{ nm}$,
 $n = 1$

$d = 2.0 \mu\text{m}$, $\sin \theta = 0.30 \Rightarrow$
 $\theta \approx 17^\circ$

Superposition
└─ Diffraction grating

Working with a grating

slit spacing

$$N \text{ lines/mm} \Rightarrow d = 10^{-3}/N \text{ m}$$

highest order

$$n_{\text{max}} = \lfloor d/\lambda \rfloor \text{ (since } \sin \theta \leq 1)$$

sharper maxima

more slits add $\Rightarrow$ narrower,
brighter lines than two slits

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Recap

Superposition
└ Recap

Topic 8 – key takeaways

1 Superposition

displacements add; in phase $4\times$ the intensity

2 Stationary waves

nodes & antinodes a $\lambda/2$ apart

3 Interference

coherent sources; $x = \lambda D/a$

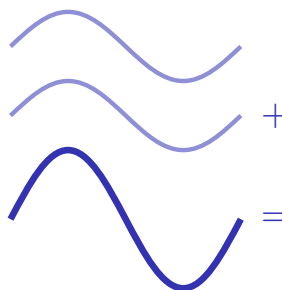
4 Grating

$d \sin \theta = n\lambda$, sharp maxima

Superposition
└ Recap

Check yourself

- 1 Distance between two next-door nodes?
- 2 What does "coherent" mean?
- 3 Path difference for a bright fringe?
- 4 Grating $d \sin \theta = n\lambda$ – which n is straight on?



Answers 1. $\lambda/2$ 2. constant phase difference 3. $\Delta x = n\lambda$ 4. $n = 0$