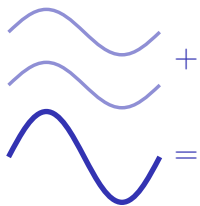
Superposition

AS Physics ▪ Topic 8

A-Level Physics



What we will cover

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

Principle of superposition

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

in phase

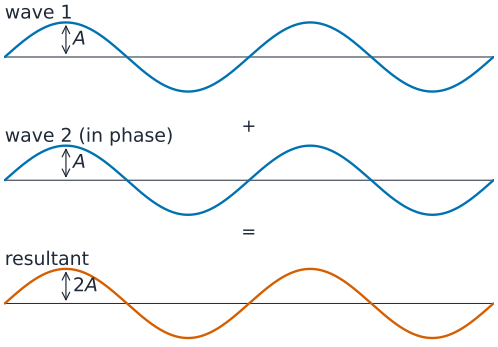
amplitude $A_1 + A_2$ (constructive)

out of phase (π)

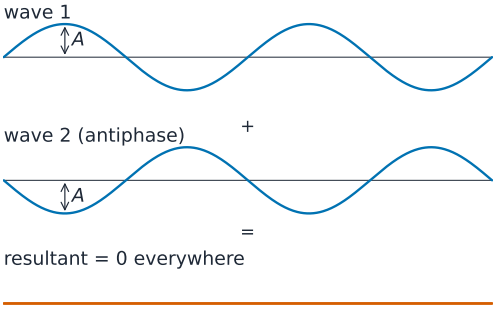
amplitude $|A_1 - A_2|$ (destructive)

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

Constructive and destructive

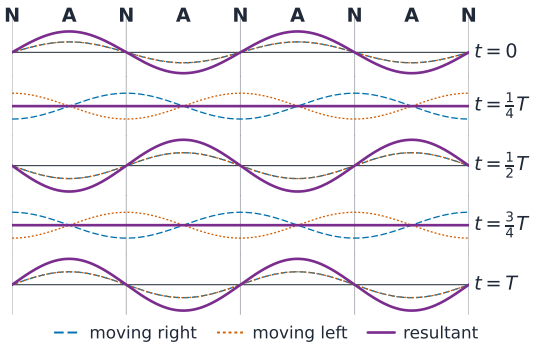


in phase: add



out of phase: cancel

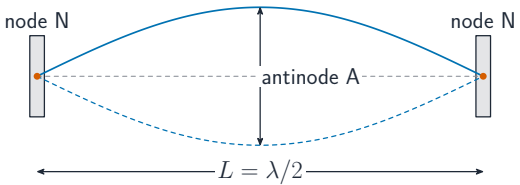
Stationary (standing) waves



Two identical waves travelling opposite ways overlap.

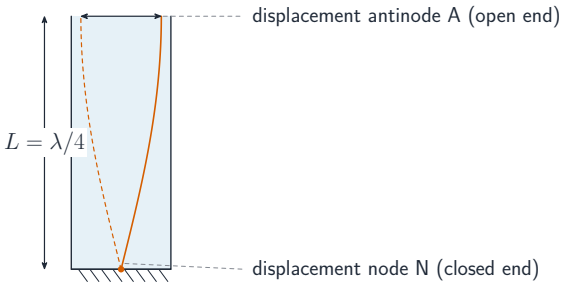
> It stores energy but does not carry it along – the pattern stays put.

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

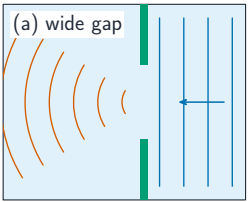


Resonance tube 共鸣管, closed one end:

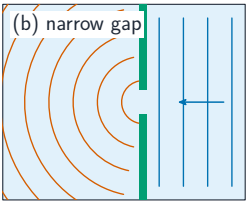
- closed end = node, open end = antinode
- **fundamental** 基频: $L = \lambda/4$; next $L = 3\lambda/4$
- open both ends: fundamental $L = \lambda/2$

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

Diffraction



gap $\gg \lambda$: little spreading



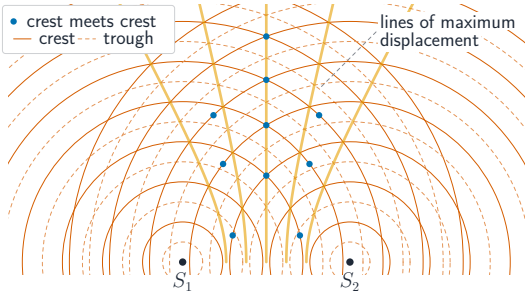
gap $\approx \lambda$: strong spreading

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.

Interference and coherence



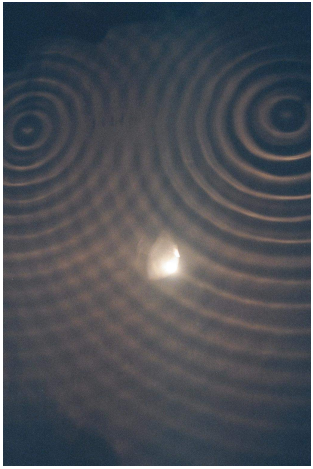
Interference 干涉: two **coherent** 相干 waves give a steady pattern. Coherent = constant phase difference (so same frequency). Two lamps are not coherent.

Path difference

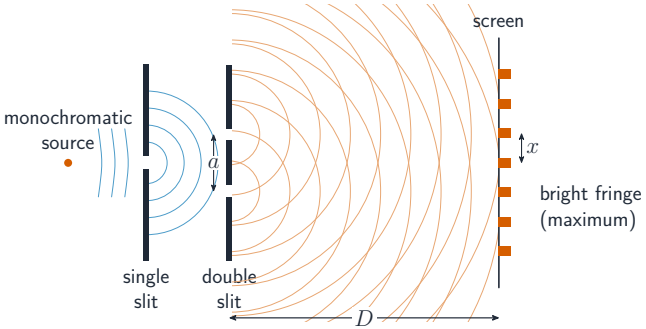
What happens at a point depends on the **path difference** 路程差 Δx:

bright: $\Delta x = n\lambda$

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



Young's double-slit experiment



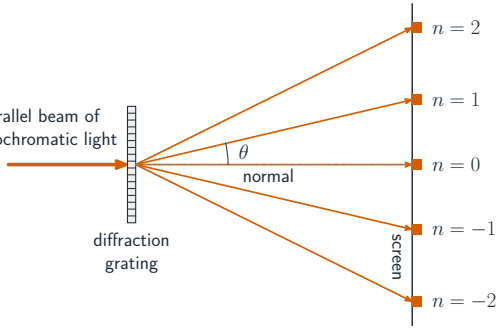
Fringe spacing 条纹间距:

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

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

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

The diffraction grating



Many slits, spacing d – maxima where

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

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

$d = 2.0\,\mu\mathrm{m}$, $\sin\theta = 0.30 \Rightarrow \theta \approx 17°$

Working with a grating

slit spacing

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

highest order

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

sharper maxima

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

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

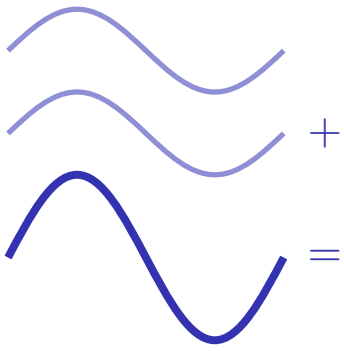
coherent sources; $x = \lambda D/a$

4 Grating

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

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.** $n = 0$