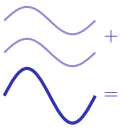
Superposition

AS Physics ▪ Topic 8

A-Level Physics



What we will cover

1 Superposition

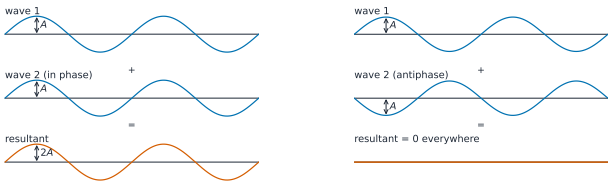
Principle of superposition

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

in phase	**out of phase (π)**
amplitude $A_1 + A_2$ (constructive)	amplitude $\lvert A_1 - A_2 \rvert$ (destructive)

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

Constructive and destructive

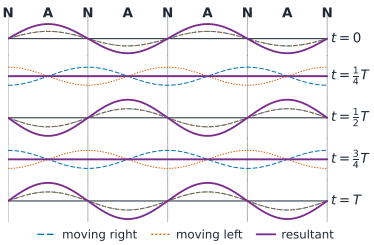


in phase: add *out of phase: cancel*

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

2 Stationary waves

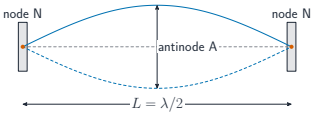
Stationary (standing) waves



Two identical waves travelling opposite ways overlap.

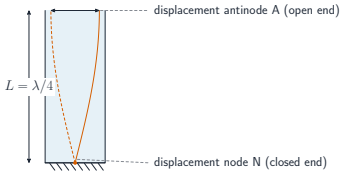
> It stores energy but does not carry it along – the pattern stays put.

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



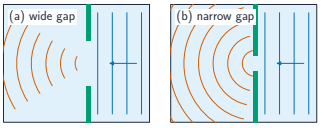
Resonance tube 共鸣管, closed one end:

- 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

Diffraction



gap $\gg \lambda$: little spreading gap $\approx \lambda$: strong spreading

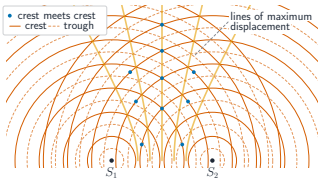
Diffraction 衍射: a wave spreads after a gap or obstacle. Spread depends on λ vs gap width:

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

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

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.

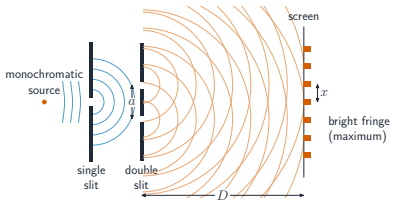
Path difference

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:

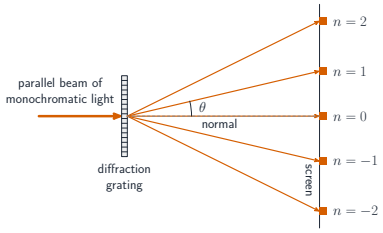
$$x = \frac{\lambda D}{a}$$

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

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

5 Diffraction grating

The diffraction grating



Many slits, spacing d – maxima where

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

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

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

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

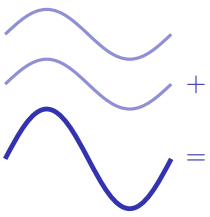
6 Recap

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

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.** $n = 0$