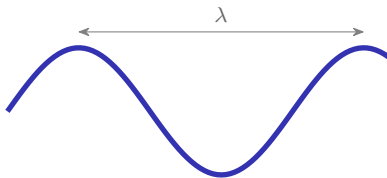


Waves, Sound, and Physical Optics

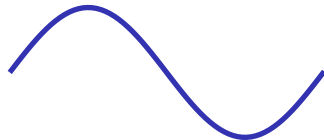
AP Physics 2 ■ Unit 14

AP Physics 2



What we will cover

- 1 Wave types and properties
- 2 Periodic waves
- 3 Polarization
- 4 The electromagnetic spectrum
- 5 The Doppler effect
- 6 Interference and standing waves
- 7 Diffraction and the double slit

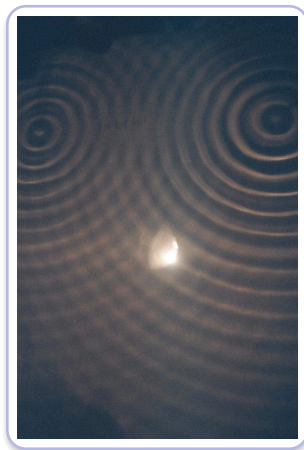




Wave types

A **wave** carries **energy**, not matter – the medium jiggles in place.

- **transverse** : medium moves **across** the travel (string, light)
- **longitudinal** : medium moves **along** it, in compressions (sound)



Waves superpose to reinforce or cancel



Periodic waves and polarization

The wave equation

$$v = f\lambda, \quad f = \frac{1}{T}$$

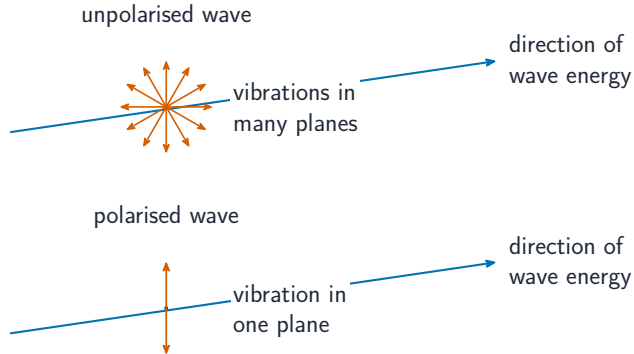
Speed is set by the **medium**: raise f and λ shrinks.

170 Hz at 340 m/s: $\lambda = 2$ m.

Polarization works only on **transverse** waves – a filter passes one plane of vibration. Sound cannot be polarized.

Reflecting off a denser medium flips a wave over (inverted).

Boundary Behavior and Polarization



Unpolarised waves vibrate in many planes; a polarised wave vibrates in one

Intensity, beats, and thin films

intensity

the average power a wave delivers **per unit area** over one period, in W/m^2

through a polarizer

$I = I_0 \cos^2 \theta$ – unpolarised light loses **half** its intensity at the first polarizer

beats

two waves of **slightly different** frequency drift in and out of step, so the sound swells loud and soft at $|f_1 - f_2|$

a thin film

light reflecting off the top and bottom of a soap bubble or oil slick interferes with **itself**

what decides the colour

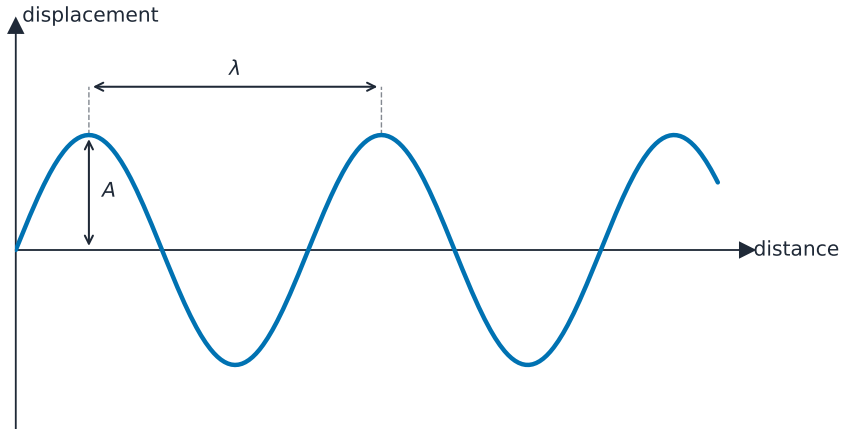
the film's **thickness** and the wavelength – which is why the colours shift as the film thins

an antireflection coating

the same physics used deliberately: a layer that makes the two reflections cancel

A reflection off a **denser** medium adds a half-wavelength shift. Counting that extra half is what turns a thin-film question from guesswork into arithmetic.

Periodic Waves



A displacement-distance graph shows the amplitude and wavelength

The quantities that describe a periodic wave

wavelength λ

the distance between two successive identical points

period T

the time for one complete oscillation

frequency f $1/T$ – oscillations per second, in hertz**amplitude A** the maximum displacement from equilibrium – it sets the **energy**, not the speed**the wave equation** $v = f\lambda$ **what sets v** the **medium**, not the source – so changing f changes λ , and never v

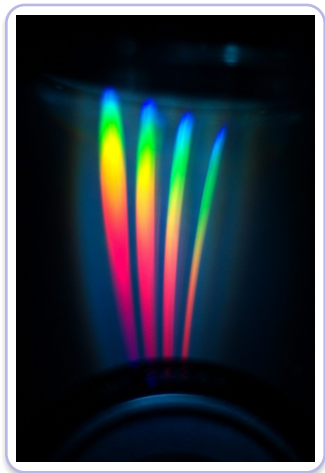
When a wave crosses into a new medium, **frequency is conserved** and wavelength changes. Getting that the wrong way round inverts every refraction answer.



The electromagnetic spectrum

An **electromagnetic wave** is oscillating E and B fields – no medium needed.

All travel at $c = 3 \times 10^8$ m/s; they differ only in frequency.



Diffraction reveals the wave nature of

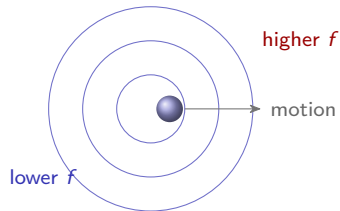


The Doppler effect

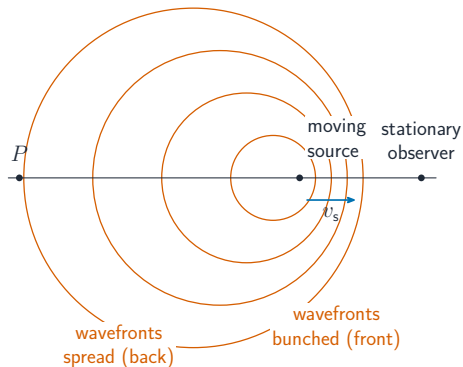
The **Doppler effect** : the observed frequency shifts when source and observer move relatively.

- approaching $\Rightarrow$ bunched up, **higher** pitch
- receding $\Rightarrow$ stretched, **lower** pitch

The **redshift** of galaxies is Doppler proof the universe expands.



A moving source squashes the wavefronts ahead of it



A moving source squashes the wavefronts ahead of it, raising the observed frequency

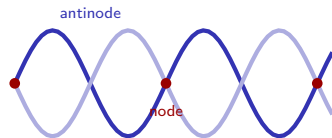


Interference and standing waves

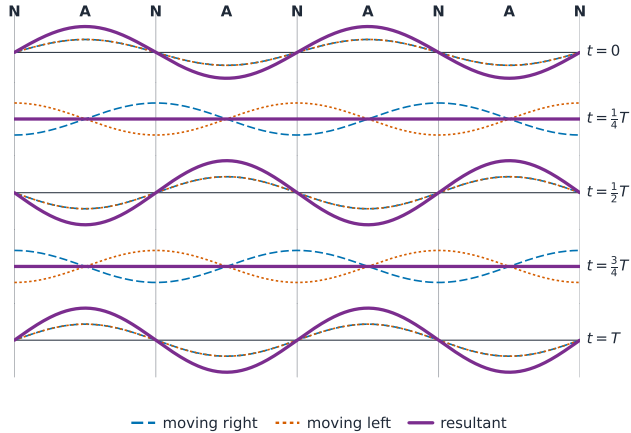
Overlapping waves add point by point
(**superposition**):

- **constructive** : crest + crest $\Rightarrow$ bigger
- **destructive** : crest + trough $\Rightarrow$ cancel

A **standing wave** has fixed **nodes** and **antinodes** – only certain wave-lengths fit (musical notes).

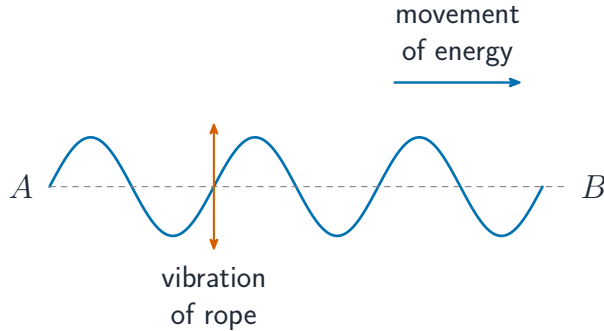


Wave Interference and Standing Waves



A standing wave forms where two waves travelling in opposite directions overlap

A transverse wave



A transverse wave: the medium moves at right angles to the wave's travel



Diffraction and the double slit

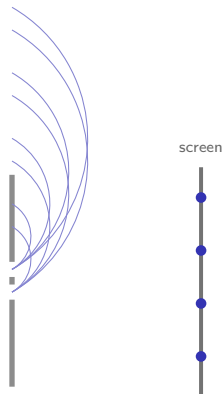
Diffraction : waves spread through gaps and around obstacles – most when the gap $\approx \lambda$.

Young's double slit – bright fringes

$$d \sin \theta = m \lambda$$

A **grating** (many slits) sharpens them into thin lines.

Thin-film interference colours soap bubbles and oil slicks.



Intensity, and the antireflection coating

intensity

the average power a wave delivers **per unit area** over one period, in W/m^2

through a polarizer

unpolarised light loses **half**; after that, $I = I_0 \cos^2 \theta$

a thin film

light reflecting off its top and bottom surfaces interferes with itself

what decides the colour

the film's thickness and the wavelength – which is why a soap bubble's colours shift as it thins

an antireflection coating

the same physics used deliberately, on camera lenses, glasses and solar cells

how it works

a layer of chosen thickness makes the two reflections **cancel**, so more light is transmitted

A reflection off a **denser** medium adds a half-wavelength shift. Counting that extra half turns a thin-film question from guesswork into arithmetic.

Describing a periodic wave, and how two waves add

the quantities

wavelength λ , period T , frequency $f = 1/T$, amplitude, and speed $v = f\lambda$

coherent sources

same frequency and a **constant** phase relationship – the condition for a stable interference pattern

constructive interference

path difference is a whole number of wavelengths; the amplitudes add

destructive interference

path difference is an odd number of half wavelengths; they cancel

beat frequency

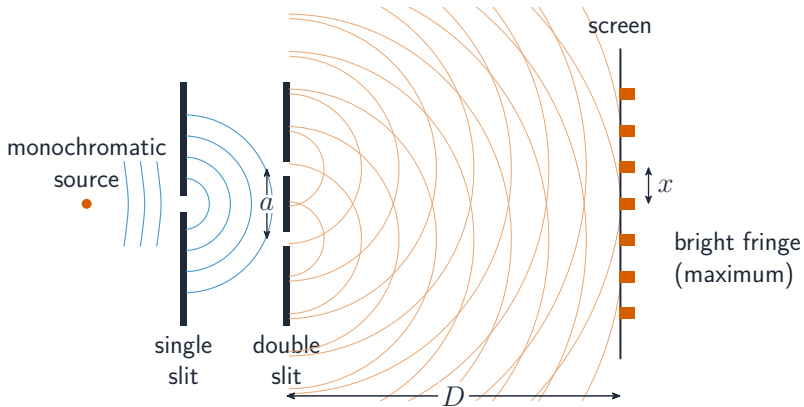
$|f_1 - f_2|$ – the slow swell when two close frequencies overlap

what sets v

the **medium**, not the source – so changing f changes λ

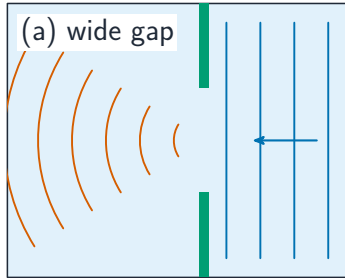
Every interference question reduces to a **path difference in wavelengths**. Work that out first and the constructive/destructive answer follows.

Double-Slit Interference and Diffraction Gratings

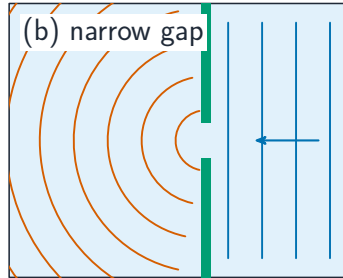


Young's double slits give an interference pattern of bright and dark fringes

Diffraction



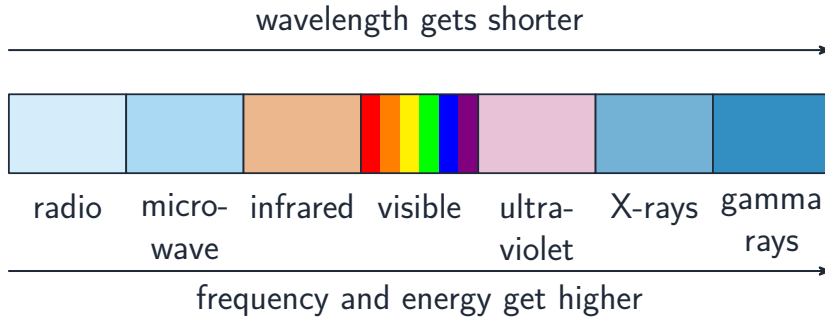
gap $\gg \lambda$: little spreading



gap $\approx \lambda$: strong spreading

Waves spread out (diffract) as they pass through a gap

Electromagnetic Waves



The electromagnetic spectrum, from radio waves to gamma rays

Exam tips

- Use $v = f\lambda$; the **source sets the frequency**, and when a wave enters a new medium the frequency stays fixed while the speed and wavelength change.
- Distinguish **transverse** (vibration perpendicular, can be polarised) from **longitudinal** (vibration along the travel, e.g. sound).
- **Constructive** interference needs a path difference of a whole number of wavelengths; **destructive** needs a half-odd number.
- On a string fixed at both ends the fundamental fits **half a wavelength** ($\lambda = 2L$).

Exam tips (continued)

- **Diffraction** is significant only when the gap is comparable to the wavelength – sound bends round doorways, light needs a very narrow slit.
- **Beats**: two waves of *slightly different* frequency throb at $f_{\text{beat}} = |f_1 - f_2|$ (e.g. two tuning forks; tuning to zero beats).
- An **antireflection coating** is a quarter-wavelength-thick layer (index between air and glass) whose two reflections cancel, cutting the reflected light.



Unit 14 – key takeaways

1

Waves

$v = f\lambda$; transverse vs longitudinal;
only transverse polarize

2

EM spectrum

all travel at c ; differ only in frequency

3

Doppler

approach raises pitch; redshift
shows expansion

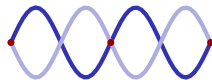
4

Interference

standing-wave nodes; $d \sin \theta = m\lambda$ for the double slit

Check yourself

- 1 Double a wave's frequency in the same medium – what happens to λ ?
- 2 Can sound be polarized?
- 3 A siren speeds toward you – higher or lower pitch?
- 4 What is a point that never moves on a standing wave called?



Answers 1. it halves 2. no 3. higher 4. a node