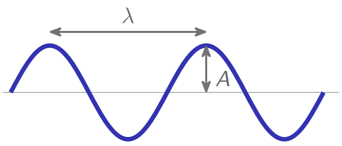
Waves

AS Physics ▪ Topic 7

A-Level Physics



What we will cover

1 Progressive waves

2 Transverse & longitudinal

3 Doppler effect

4 Electromagnetic spectrum

5 Polarisation

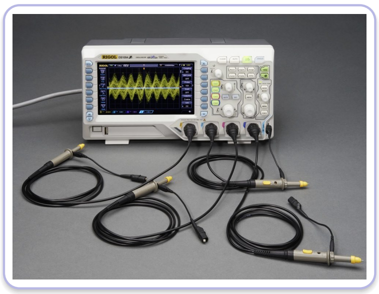
6 Recap

1 Progressive waves

What a wave is

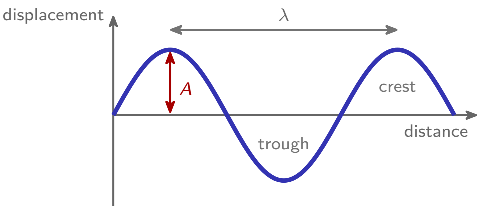
A **progressive wave** 行波 carries energy without moving matter overall.

- particles **oscillate** 振动 about rest positions
- only the disturbance **propagates** 传播



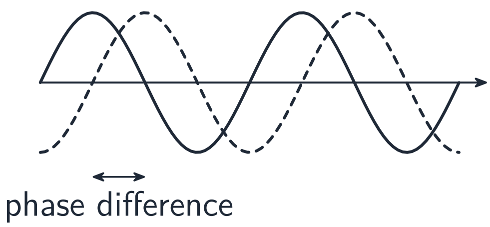
Oscilloscope

Key terms



A see-through plastic protractor placed between two crossed polarising filters. Light only reaches your eye because the stressed plastic rotates its plane of polarisation – the colours map where the plastic is squeezed most. With…

Phase, drawn



Two points are in phase when they move together, and antiphase when one is exactly half a cycle behind.

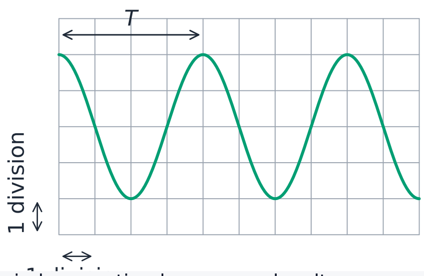
The wave equation

In one period the wave moves one wavelength:

$$\boxed{v = \frac{\text{distance}}{\text{time}} = \frac{\lambda}{T}} \xrightarrow{f = 1/T} \boxed{v = f\lambda}$$

> $v = f\lambda$ holds for every progressive wave.

Reading a CRO trace



period $= n \times$ timebase · peak voltage $= n \times$ Y-gain

- **time-base** 时基: seconds per division across → read T
- **y-gain** 垂直增益: volts per division up → read amplitude

$5\,\mathrm{ms/div}$, one cycle $= 4$ div

$T = 20\,\mathrm{ms} \Rightarrow f = 50\,\mathrm{Hz}$

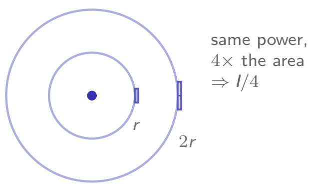
Intensity

Power through unit area:

$$I = \frac{P}{A}, \qquad I \propto (\text{amplitude})^2.$$

A **point source** 点源 spreads over a sphere $4\pi r^2$:

$$I = \frac{P}{4\pi r^2}, \qquad I \propto \frac{1}{r^2}.$$



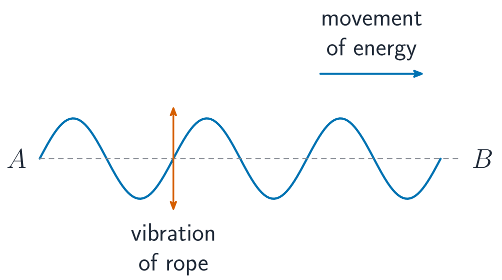
$60\,\mathrm{W}$ lamp, $r = 2.0\,\mathrm{m}$

$$I = \frac{60}{4\pi(2.0)^2} \approx 1.2\,\mathrm{W\,m^{-2}}$$

> Double the distance ⇒ quarter the intensity.

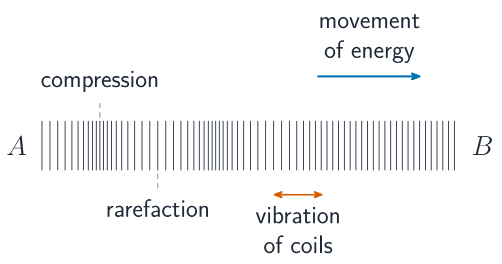
2 Wave types

Transverse waves



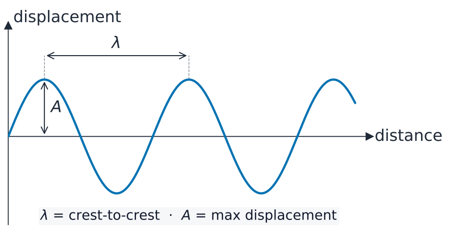
Particles **oscillate** 振动 perpendicular to the **energy** 能量 flow. Examples: a wave on a rope, all EM waves, S-waves.

Longitudinal waves

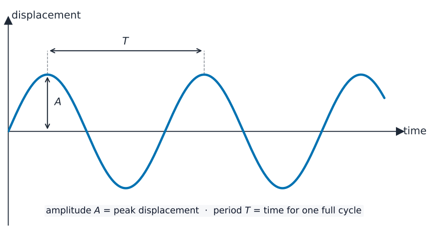


Particles oscillate parallel to the energy flow. Made of **compressions** 压缩 and **rarefactions** 稀疏. Examples: sound, P-waves.

Two graphs of a wave



distance → read λ

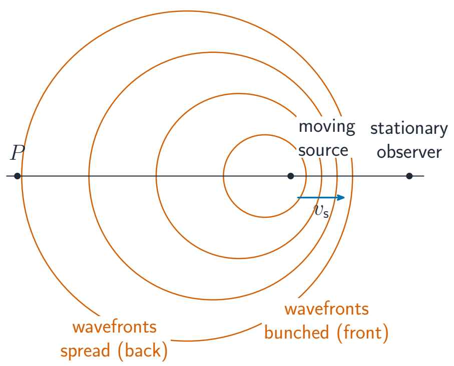


time → read T

> Distance graph → wavelength λ. Time graph → period T.

3 Doppler effect

Doppler effect



A moving **source** 波源 changes the heard frequency:

$$f_o = \frac{v\,f_s}{v \pm v_s}.$$

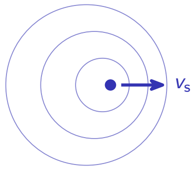
- towards → minus, f_o higher
- away → plus, f_o lower

Worked example – a car horn

$f_s = 800\,\text{Hz}$, $v_s = 30\,\text{m}\,\text{s}^{-1}$ towards you, $v = 340\,\text{m}\,\text{s}^{-1}$

$$f_o = \frac{340 \times 800}{340 - 30} = \frac{272\,000}{310} \approx 877\,\text{Hz}.$$

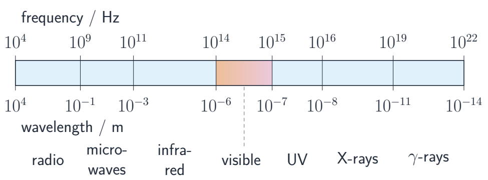
Higher than $800\,\text{Hz}$ – as expected for approach.



bunched ahead

4 EM spectrum

The electromagnetic spectrum



All EM waves are transverse and travel in a vacuum at

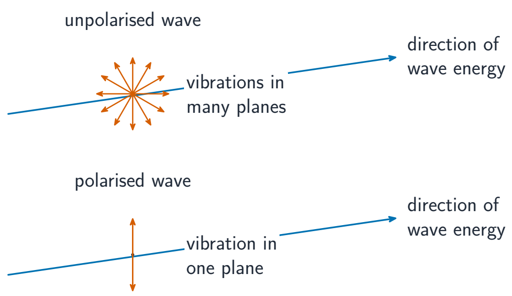
$$c = 3.00 \times 10^8\,\text{m}\,\text{s}^{-1}.$$

Use $c = f\lambda$. Visible light: 400–700 nm.

radio → **microwave** 微波 → **infrared** 红外线 → visible → **ultraviolet** 紫外线 → X-ray → γ-ray

5 Polarisation

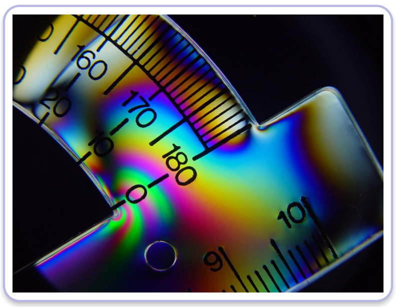
Polarisation



Polarisation 偏振: oscillation confined to one plane.

> Only transverse waves polarise. Sound (longitudinal) cannot – a useful test.

Polarisation put to work



Stressed plastic between crossed polarisers: the colour fringes map where the material is loaded.

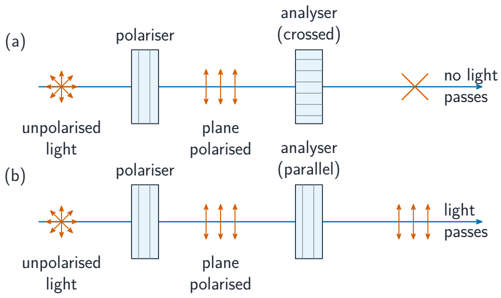
Malus's law

Through a filter at angle θ to the polarisation:

$$I = I_0 \cos^2\theta.$$

$I_0 = 12\,\mathrm{W\,m^{-2}}$, $\theta = 30°$

$I = 12\cos^2 30° = 12 \times 0.75 = 9.0\,\mathrm{W\,m^{-2}}$



6 Recap

Topic 7 – key takeaways

1 Wave equation

$v = f\lambda$; intensity $\propto$ amplitude^2, $\propto 1/r^2$

2 Two types

transverse $\perp$, longitudinal $\parallel$ to energy

3 Doppler

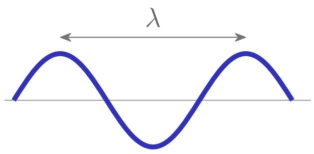
moving source shifts the heard frequency

4 Polarisation

one plane; only transverse; $I = I_0\cos^2\theta$

Check yourself

1. A wave has $f = 50\,\mathrm{Hz}$, $\lambda = 6.0\,\mathrm{m}$ – find v.
2. Can a sound wave be polarised?
3. Source moves away – does the pitch rise or fall?
4. Light through a filter at $90°$ – how much passes?



Answers **1.** $v = f\lambda = 300\,\mathrm{m\,s^{-1}}$ **2.** no (longitudinal) **3.** falls **4.** none ($\cos^2 90° = 0$)