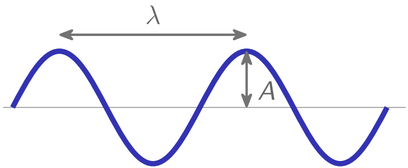
Waves

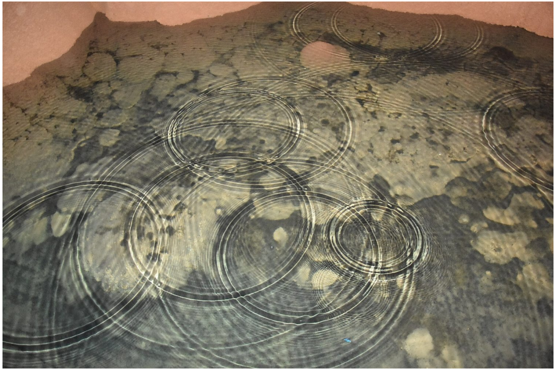
AS Physics ▪ Topic 7

A-Level Physics



What we will cover

1. Progressive waves
2. Transverse & longitudinal
3. Doppler effect
4. Electromagnetic spectrum
5. Polarisation
6. Recap



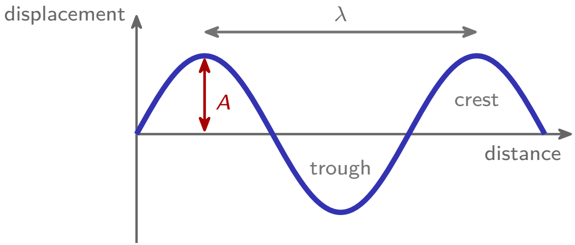
What a wave is

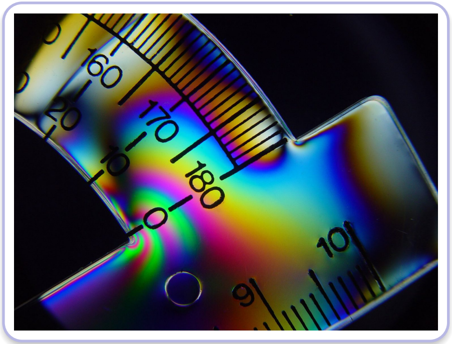
A **progressive wave** 行波 carries energy without moving matter overall.

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

oscilloscope

Key terms





photoelasticity

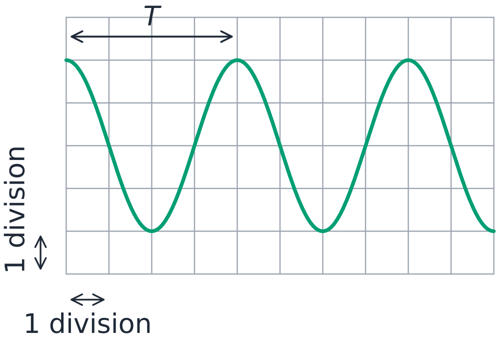
The wave equation

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



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

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

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

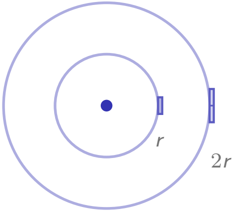
Intensity

Power through unit area:

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

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

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



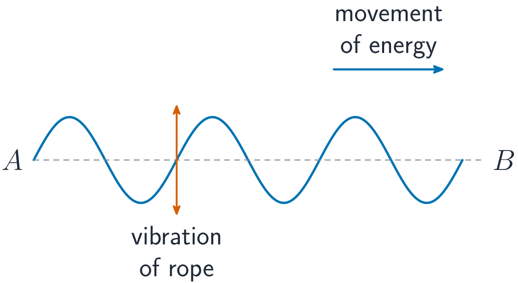
same power,
$4\times$ the area
$\Rightarrow I/4$

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

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

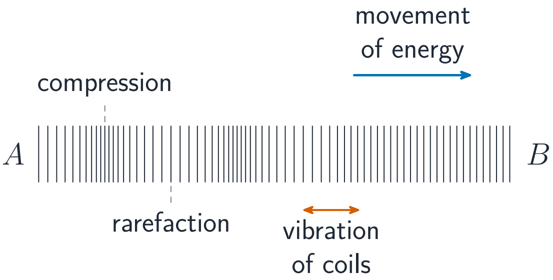
Double the distance $\Rightarrow$ quarter the intensity.

Transverse waves



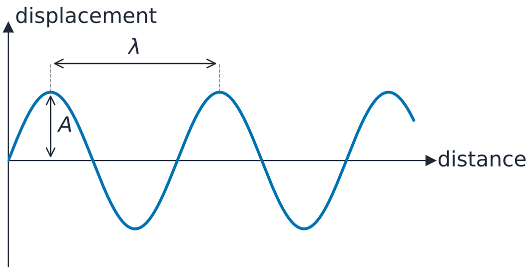
Particles oscillate perpendicular to the energy flow. Examples: a wave on a rope, all EM waves, S-waves.

Longitudinal waves

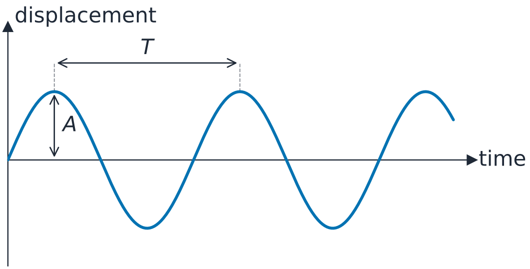


Particles oscillate parallel to the energy flow. Made of **compressions** 压缩 and **rarefactions** 稀疏. Examples: sound, P-waves.

Two graphs of a wave

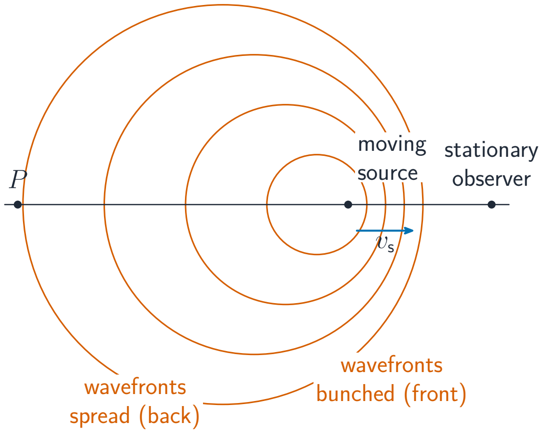


distance → *read* λ



time → *read* T

Doppler effect



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

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

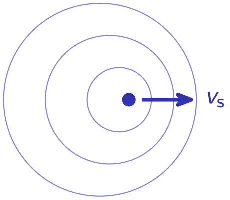
- towards → minus, f_o higher
- away → plus, f_o lower

Worked example – a car horn

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

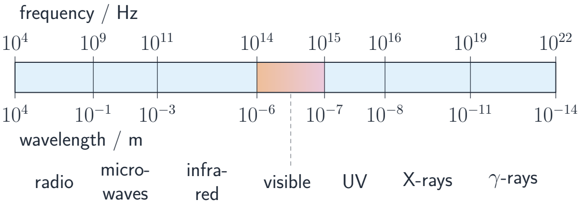
$$f_o = \frac{340 \times 800}{340 - 30} = \frac{272\,000}{310} \approx 877\,\mathrm{Hz}.$$

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



bunched ahead

The electromagnetic spectrum



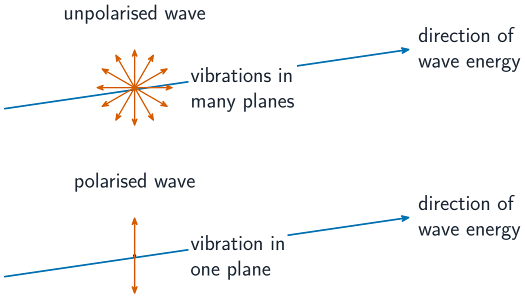
All EM waves are transverse and travel in a vacuum at

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

Use $c = f\lambda$. Visible light: 400–$700\,\mathrm{nm}$.

radio $\rightarrow$ **microwave** 微波 $\rightarrow$ **infrared** 红外线 $\rightarrow$ visible $\rightarrow$ **ultraviolet** 紫外线 $\rightarrow$ X-ray $\rightarrow$ γ-ray

Polarisation



Polarisation 偏振: oscillation confined to one plane.

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

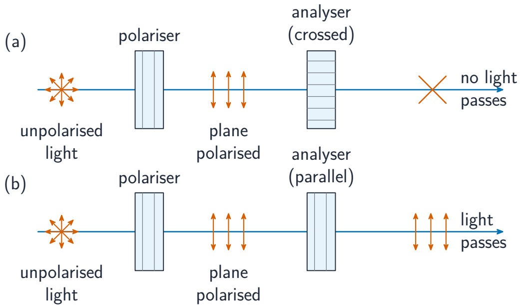
Malus's law

Through a filter at angle θ to the polarisation:

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

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

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



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

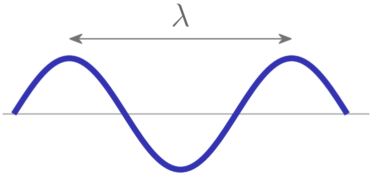
Check yourself

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 ($\cos^2 90^\circ = 0$)