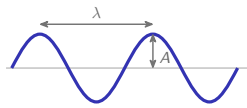


Waves

AS Physics ■ Topic 7

A-Level Physics



Waves

What we will cover

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



1

Progressive waves

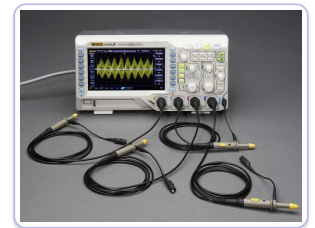
Waves

Progressive waves

What a wave is

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

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

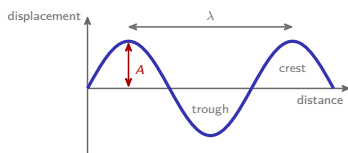


Oscilloscope

Waves

Progressive waves

Key terms

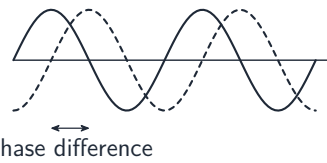


- **displacement** 位移 y – how far a particle has moved from rest *now*; a **vector** 矢量
- **amplitude** 振幅 A – the largest displacement
- **wavelength** 波长 λ – shortest distance between two points **in phase** 同相
- **period** 周期 T and **frequency** 频率 $f = 1/T$, in **hertz** 赫兹
- **speed** 速率 v – how fast a **crest** 波峰 travels
- **phase difference** 相位差 – the

Waves

Progressive waves

Phase, drawn



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

Two points one wavelength apart are **in phase** (phase difference 0 or 2π); half a wavelength apart they are exactly **out of phase** (π).

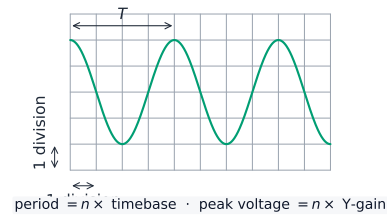
The wave equation

In one period the wave moves one wavelength:

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

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

Reading a CRO trace



- a **cathode-ray oscilloscope** 示波器 (CRO) plots voltage against time
- **time-base** 时基: seconds per division across → read T
- **y-gain** 垂直增益: volts per division up → read amplitude

5 ms/div, one cycle = 4 div

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

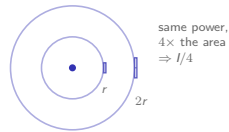
Intensity

Power through unit area:

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

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

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



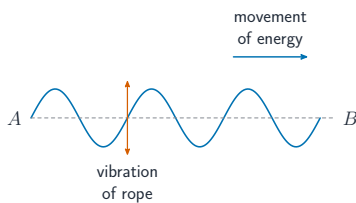
60 W lamp, $r = 2.0 \text{ m}$

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

Double the distance $\Rightarrow$ quarter the intensity.

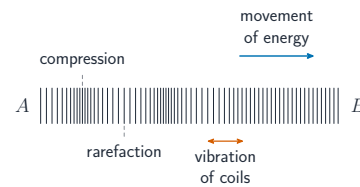
2 Wave types

Transverse waves



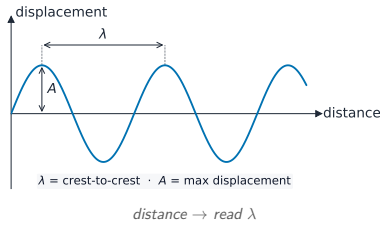
Particles **oscillate** 振动 **perpendicular** to the **energy** 能量 flow. Examples: a wave on a rope, all EM waves, S-waves.

Longitudinal waves



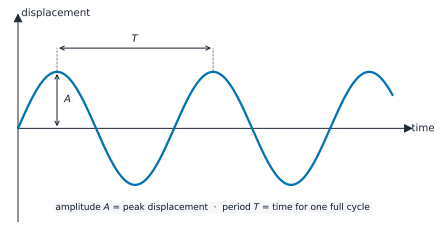
Particles oscillate **parallel** to the energy flow. Made of **compressions** 压缩 and **rarefactions** 稀疏. Examples: sound, P-waves.

Displacement against *distance*: read A and λ



A snapshot of the whole wave at one moment – a **sine curve** 正弦曲线 for both kinds. For a longitudinal wave the axis is the small back-and-forth displacement *along* the direction of travel.

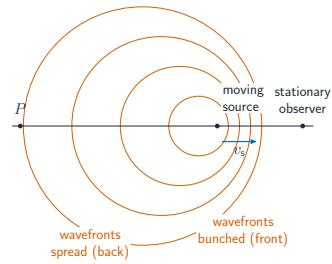
Displacement against *time*: read A and T



One particle followed through time – also a sine curve. This is the graph that gives you T , and so $f = 1/T$.

3 Doppler effect

Doppler effect



A moving **source** 波源 changes the frequency a **stationary** 静止 **observer** 观察者 hears, because the **wavefronts** 波前 ahead are squashed:

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

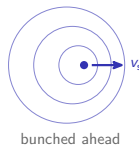
- towards $\rightarrow$ **minus**, wavefronts squashed, f_o higher
- away $\rightarrow$ **plus**, wavefronts spread out, f_o lower

Worked example – a car horn

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

$$f_o = \frac{340 \times 800}{340 - 30} = \frac{272000}{310} \approx 877 \text{ Hz.}$$

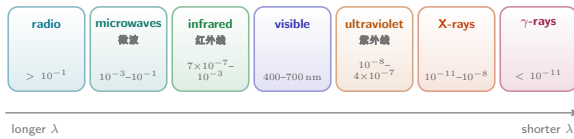
Higher than 800 Hz – as expected for approach.



4 EM spectrum

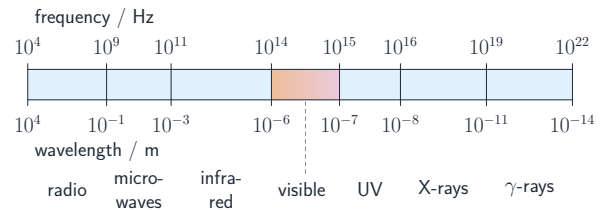
The electromagnetic spectrum

All electromagnetic waves 电磁波 are **transverse** and travel in a **vacuum** 真空 at $c = 3.00 \times 10^8 \text{ m s}^{-1}$. Use $c = f\lambda$.



The boundaries are **not sharp**. Learn the orders of magnitude, not the edges.

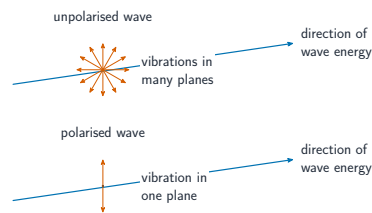
The electromagnetic spectrum, in detail



One family, one speed: only the wavelength changes across it.

5 Polarisation

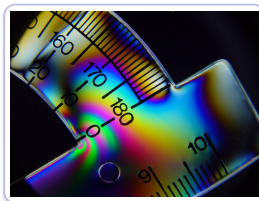
Polarisation



Polarisation 偏振: oscillation confined to **one plane**. Light that has been through a **polarising filter** 偏振片 is **plane-polarised** 平面偏振; the filter passes the part along its **transmission axis** 透光轴.

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

Polarisation put to work



Stressed plastic between crossed polarisers: the plastic rotates the plane of polarisation by an amount that depends on the stress, so the colour fringes **map where the material is loaded**.

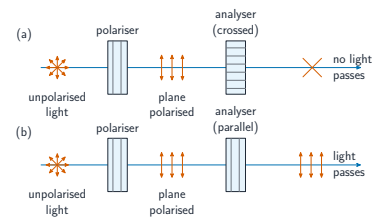
Malus's law

Through a filter at angle θ to the polarisation:

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

$$I_0 = 12 \text{ W m}^{-2}, \theta = 30^\circ$$

$$I = 12 \cos^2 30^\circ = 12 \times 0.75 = 9.0 \text{ W m}^{-2}$$



Crossed filters (a) block the light; parallel filters (b) let it pass

Exam tips

- Define terms precisely (displacement, amplitude, wavelength, period, frequency) and use $v = f\lambda$.
- Distinguish **transverse** (vibration perpendicular to travel) from **longitudinal** (parallel); only transverse waves can be **polarised**.
- For the **Doppler effect**, the observed frequency **rises** as the source approaches and falls as it recedes.
- Learn the **electromagnetic spectrum** order; all its waves travel at c in a vacuum.

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Recap

Topic 7 – key takeaways

1 Wave equation

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

2 Two types

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

3 Doppler

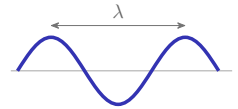
moving source shifts the heard frequency

4 Polarisation

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

Check yourself

- 1 A wave has $f = 50 \text{ Hz}$, $\lambda = 6.0 \text{ m}$ – 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. $v = f\lambda = 300 \text{ m s}^{-1}$ 2. no (longitudinal) 3. falls
4. none ($\cos^2 90^\circ = 0$)