Wave model

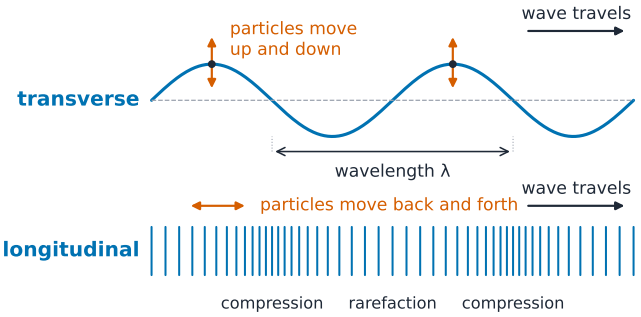
C.2 · SL and HL

How does a seismometer locate an earthquake?

A wave carries energy across hundreds of kilometres while the rock only shakes in place.

- Invented uniform-rock model: P-wave speed 6.0 km/s and S-wave speed 3.5 km/s.
- At 500 km the S-waves arrive about a minute later.
- This unit: wave types $\rightarrow$ $v = f\lambda$ $\rightarrow$ wave graphs $\rightarrow$ sound $\rightarrow$ EM waves.

Transverse and longitudinal



- Transverse oscillations are perpendicular to the travel direction.
- Longitudinal particles move parallel to it, making compressions and rarefactions.

Energy, not matter

Transverse

Waves on a string, S-waves.

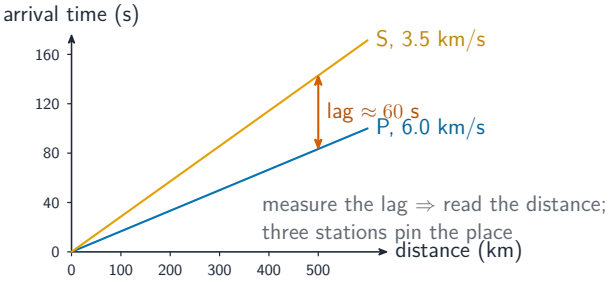
All electromagnetic waves.

Longitudinal

Sound, P-waves.

Pushes along a spring.

Locating an earthquake



The lag grows with distance

The wave equation

- 5.0 Hz and 0.40 m give 2.0 m s^{-1}.
- A 100 MHz radio wave has $\lambda = 3.0$ m.

$$v = f\lambda = \frac{\lambda}{T}$$

In one period the wave moves forward one wavelength.

A new medium

Quantity	**Into a new medium**
frequency	unchanged
speed	changes
wavelength	changes with the speed

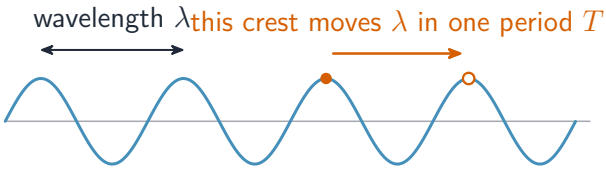
Measuring waves at a boundary

1. **Wavelength.** Measure several crest spacings in a ripple-tank snapshot; divide by their number to reduce fractional reading uncertainty.
2. **Rays.** Trace a ray-box beam into glass; draw the entry normal and measure both angles from it. Keep beams away from eyes.
3. **Explain.** Slower waves bend towards the normal; frequency stays fixed and wavelength falls.

Decision

Label the normal before reading either angle.

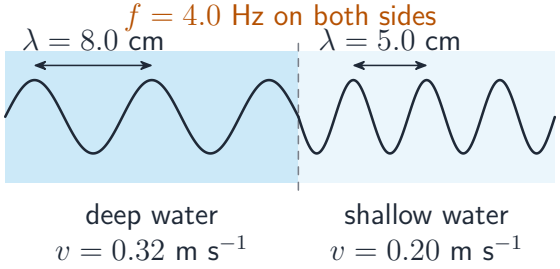
Wave speed from one period



$$v = \frac{\lambda}{T} = f\lambda$$

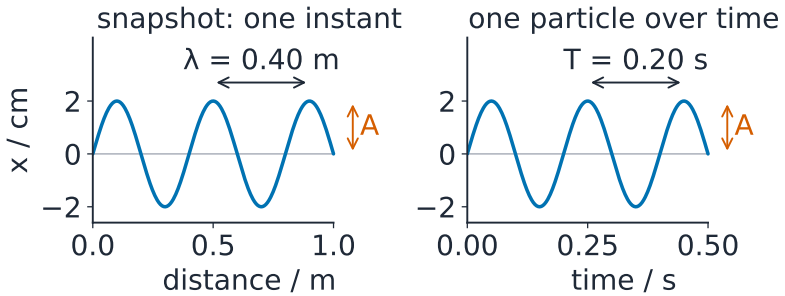
> Frequency is set by the source

Into shallow water



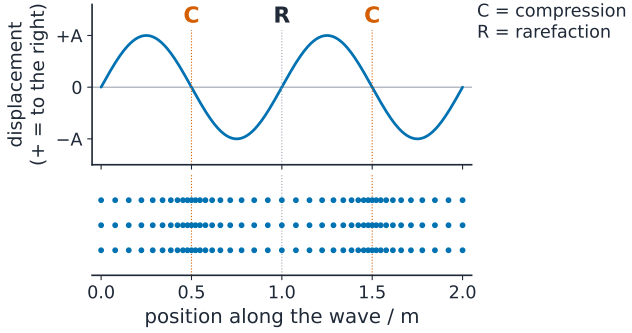
The source sets f; the **medium** sets v

Two kinds of wave graph



- Distance on the axis gives wavelength; time gives period.
- $v = \lambda / T = 0.40/0.20 = 2.0$ m s^{-1}.

Graphs of a sound wave



- Displacement to the right is drawn as positive.
- Compressions are at zero displacement where the graph slopes down.

Check: a wave graph

Your turn

A displacement–distance graph shows four complete wavelengths in 2.4 m. Wave speed is 1.2 m/s. What is the frequency?

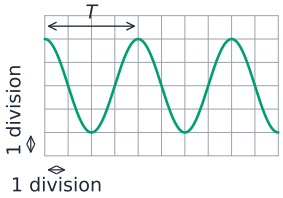
A. 0.50 Hz
B. 2.0 Hz
C. 2.9 Hz
D. 8.0 Hz

Sound waves

> Thunder 3.0 s after lightning means the storm is about 1 km away.

- Sound is longitudinal and needs a **medium**.
- Hearing range: 20 Hz to 20 kHz, 17 m to 17 mm in air.

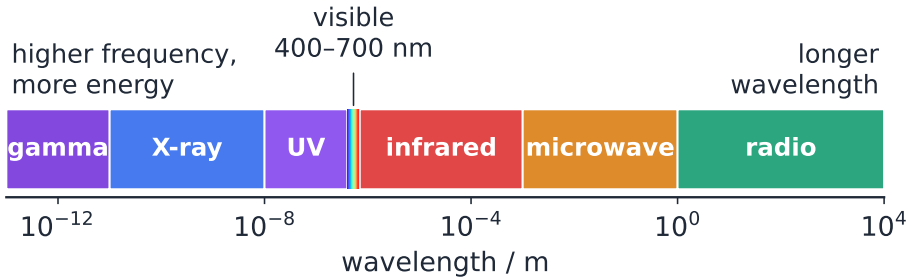
Reading an oscilloscope



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

$$f = 1/T$$

Electromagnetic waves



- Oscillating electric and magnetic fields, so always transverse.
- All travel at 3.00×10^{8} m s^{-1} in a vacuum.

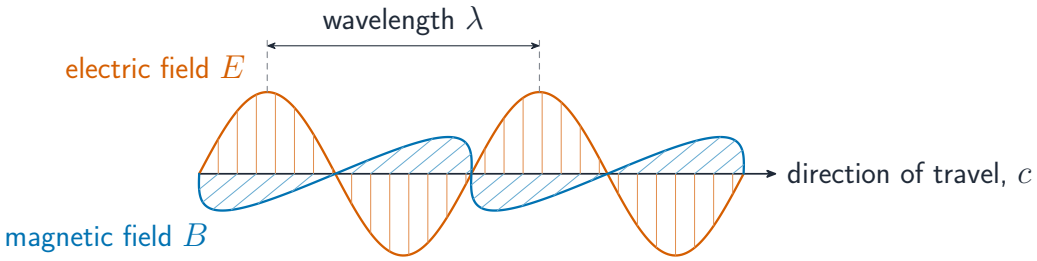
Wavelength and frequency of EM waves

- A 2.45 GHz microwave oven gives $\lambda = 0.12$ m.
- Green light of 550 nm has $f = 5.5 \times 10^{14}$ Hz.

$$c = f\lambda$$

Convert GHz and nm to SI units first.

An electromagnetic wave



Both are perpendicular to the direction of travel at c

Mechanical and electromagnetic

Mechanical

Particles oscillate; a **medium** is needed.

Transverse or longitudinal.

Electromagnetic

Fields oscillate; travel through a vacuum.

Always transverse.

Exam tips

> Read the horizontal axis of a wave graph before you use it.

- Waves transfer energy, not matter.
- Into a new **medium**, frequency stays the same.
- Compressions are at zero displacement.

Check yourself

Try these

Find the wavelength of a 512 Hz sound in air at 340 m/s and in water at 1500 m/s.

Find the wavelength of a 98 MHz radio wave.

Explain why astronauts on the Moon need radios to talk.