

Wavelength, frequency and how waves behave

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: A wave carries energy without carrying matter. Transverse waves vibrate at right angles to their direction of travel and longitudinal waves vibrate parallel to it. Wave speed equals frequency times wavelength, $v = f \lambda$, and waves can reflect, refract and diffract.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS4-1, GCSE P6

What is a wave?

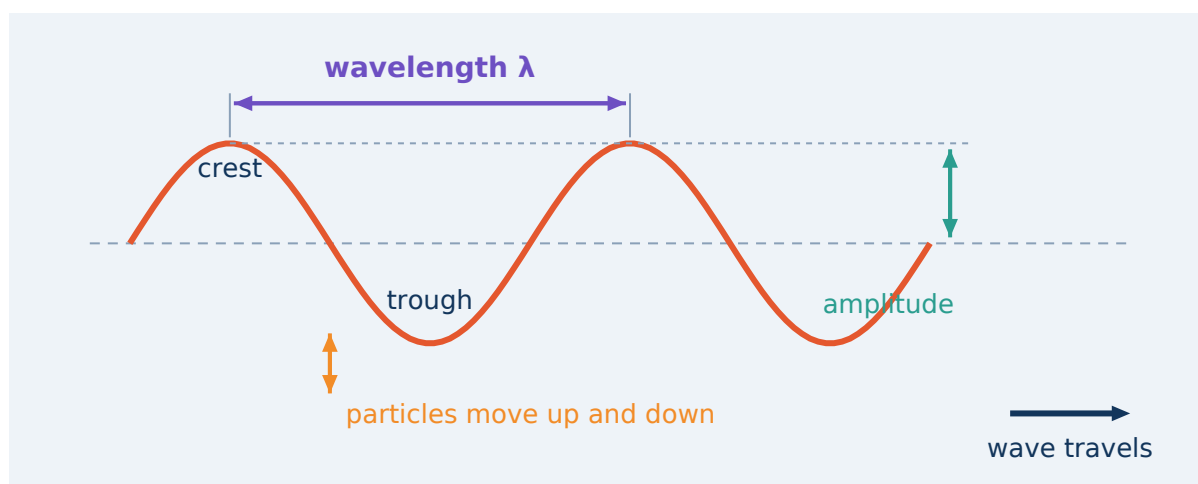
A wave is a disturbance that carries energy from one place to another without carrying the material along. When Aarav flicks one end of a long skipping rope in Pune, a bump runs along the rope, but the rope itself ends up where it started. Only the energy has travelled.

Definition

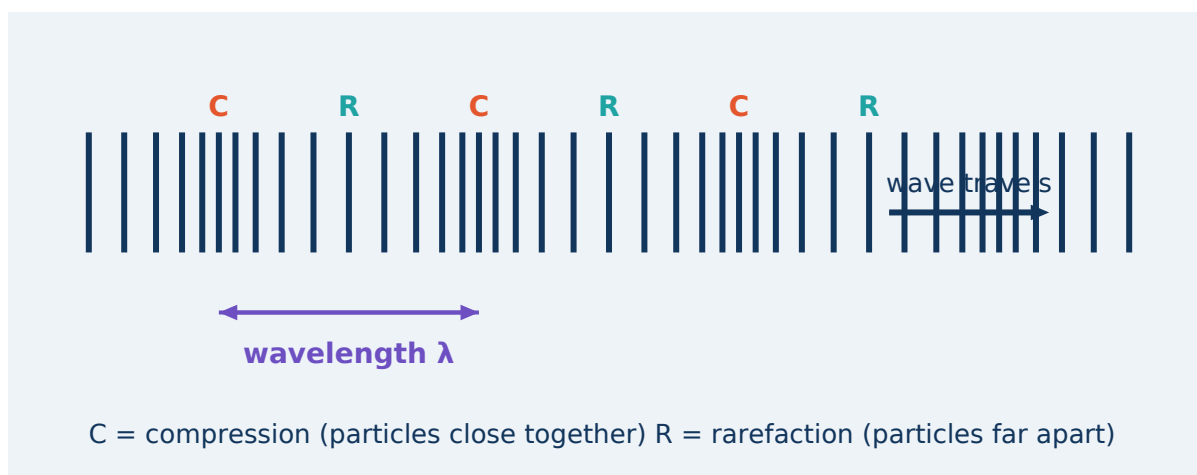
A **wave** transfers energy from place to place without transferring matter. The source vibrates, and the vibration passes on through the medium.

What is the difference between transverse and longitudinal waves?

In a **transverse wave** the vibration is at right angles to the direction of travel. Ripples on water, waves on a rope and light are transverse. In a **longitudinal wave** the vibration is parallel to the direction of travel and the medium is alternately squashed and stretched. A push-pull on a slinky spring makes a longitudinal wave.



In a transverse wave, particles vibrate at right angles to the direction of travel.



In a longitudinal wave the vibrations are parallel to the direction of travel.

How do you describe a wave?

Quantity	Meaning	Unit
Amplitude	Maximum displacement from the rest position	m
Wavelength λ	Distance from one point to the next identical point (crest to crest)	m
Frequency f	Number of waves passing a point each second	hertz (Hz)
Period T	Time for one complete wave, $T = 1 / f$	s
Wave speed v	Distance travelled by a crest each second	m/s

Formula

$$v = f \times \lambda$$

v = wave speed in m/s · f = frequency in Hz · λ = wavelength in m. Also $T = 1 / f$, with T in s.

Worked example 1

In a ripple tank a dipper vibrates at 8.0 Hz and the wavelength measured on the screen is 2.5 cm.

$$v = f \lambda = 8.0 \times 2.5 = 20 \text{ cm/s} = 0.20 \text{ m/s.}$$

Answer: **0.20 m/s.**

Worked example 2

Emma on a pier in Brighton counts 15 crests passing a post in 60 s. She estimates the wavelength as 8.0 m.

$$f = 15 / 60 = 0.25 \text{ Hz}$$

$$T = 1 / 0.25 = 4.0 \text{ s}$$

$$v = f \lambda = 0.25 \times 8.0 = 2.0 \text{ m/s}$$

Answer: **frequency 0.25 Hz, period 4.0 s, speed 2.0 m/s.**

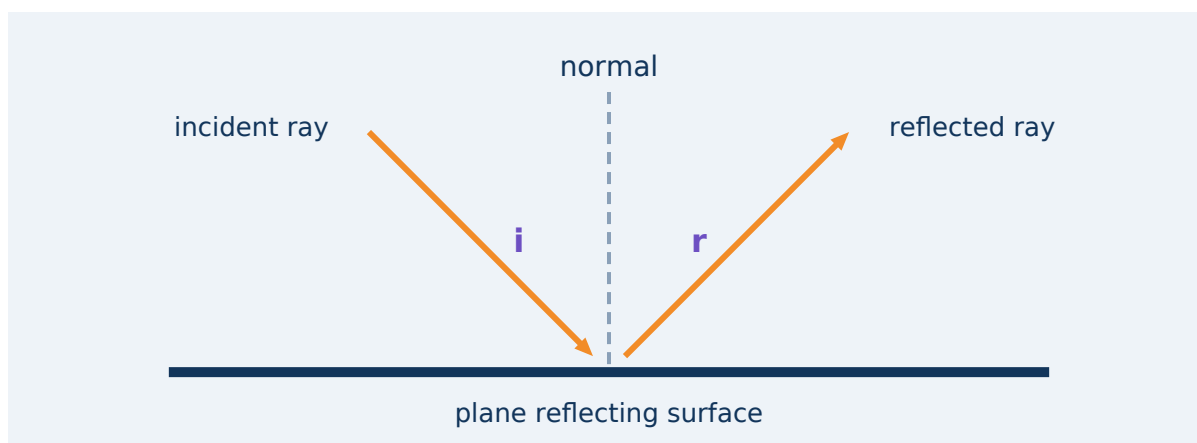
The speed of a wave depends on the medium. If the frequency is set by the source, a change of speed must change the wavelength.

How do waves reflect?

When a wave hits a barrier, it bounces off. A straight line drawn at right angles to the surface at the point of impact is the **normal**.

Key law (reflection)

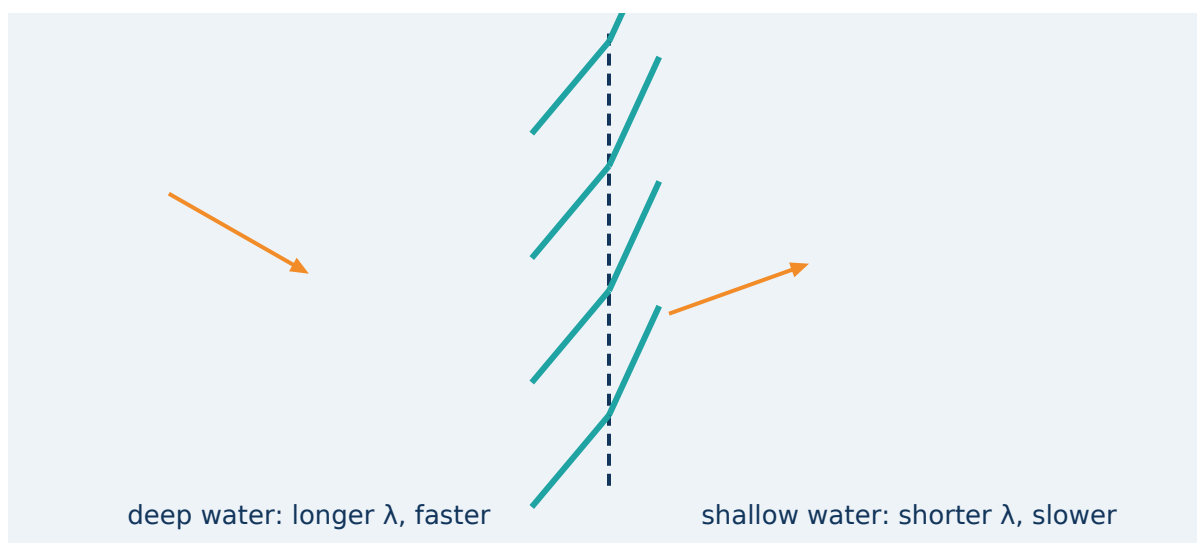
The angle of incidence equals the angle of reflection: $i = r$. Both angles are measured from the normal, not from the surface.



Law of reflection: angle of incidence i equals angle of reflection r , both measured from the normal.

What are refraction and diffraction?

Refraction is the change of direction of a wave when its speed changes at a boundary. In a ripple tank, waves entering shallower water slow down. The frequency stays the same, so the wavelength gets shorter, and the wavefronts bend towards the normal.



Entering shallow water the waves slow down, their wavelength shortens and they bend.

Diffraction is the spreading out of waves as they pass through a gap or round an edge. It is

greatest when the gap is about the same size as the wavelength, or smaller. A wide gap lets most of the wave through with little spreading.

Common mistake

Many students think that a wave with a higher frequency travels faster. In a given medium, the speed is fixed by the medium. Raising the frequency makes the wavelength shorter, not the speed larger.

Lina's tip

Remember what changes at a boundary: speed and wavelength change, frequency never does. The source sets the frequency, so the frequency is the same on both sides.

Key points to remember

- $v = f \lambda$ (m/s = Hz $\times$ m) and $T = 1 / f$
- Transverse: vibration at right angles to travel; longitudinal: parallel to travel
- Reflection: angle of incidence = angle of reflection, measured from the normal
- Refraction: speed and wavelength change at a boundary, frequency stays the same
- Diffraction is greatest when the gap is about one wavelength

Wavelength, frequency and how waves behave: frequently asked questions

What is the wave equation?

The wave equation is $v = f \lambda$, where v is the wave speed in m/s, f is the frequency in Hz and λ is the wavelength in metres. It applies to every wave.

What is the difference between frequency and period?

Frequency is the number of waves passing a point per second, in hertz. The period is the time for one complete wave, in seconds, and $T = 1 / f$.

Does a wave move the material it travels through?

No. The particles of the medium vibrate about fixed positions, and only energy is transferred along the wave. A cork on water bobs up and down but does not travel with the ripples.

Why do waves change direction when they enter shallow water?

The speed decreases in shallow water, so the part of a wavefront that enters first slows first. The frequency remains the same, so the wavelength gets shorter and the wavefronts bend towards the normal.

When does diffraction happen most?

Diffraction is most noticeable when the width of the gap or obstacle is about the same as the wavelength, or smaller. A much wider gap produces very little spreading.