

How waves carry energy without matter

Grade 7 science (Year 8 · Class 7) · Lesson

Quick answer: A wave is a repeating disturbance that carries energy from place to place without moving matter along with it. Waves are described by their amplitude, wavelength and frequency, and their speed equals frequency multiplied by wavelength. Transverse waves vibrate at right angles to their travel; longitudinal waves vibrate back and forth along it.

Level: Grade 7 science (Year 8 · Class 7) · **Curriculum:** MS-PS4-1

What is a wave?

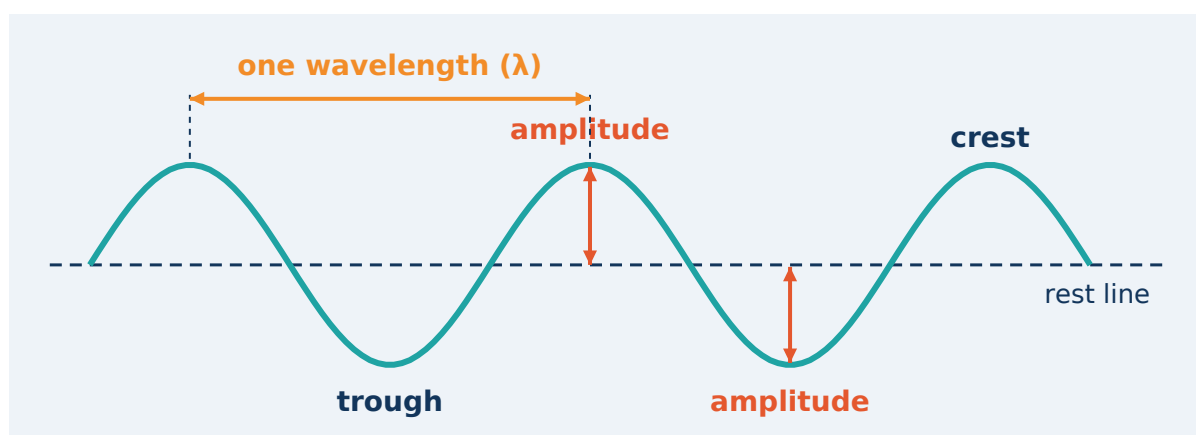
Toss a pebble into a pond and rings spread outwards. A floating leaf only bobs up and down; it does not sail away with the ring. That is the big idea of this chapter: a wave moves *energy* from place to place, not the material itself.

Definition

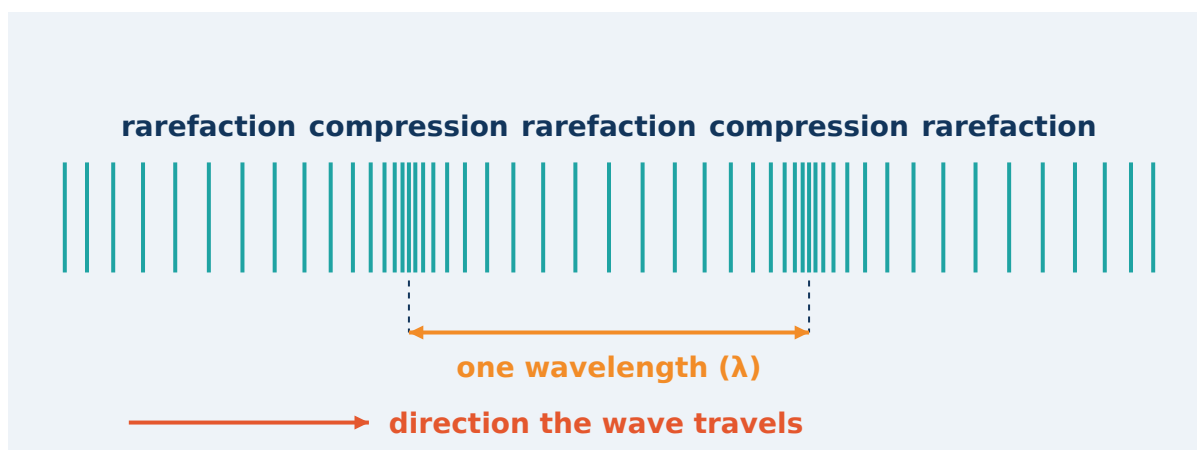
A **wave** is a repeating disturbance that carries energy through a material (a medium) or through space. The particles of the medium vibrate around fixed positions and pass the energy on to their neighbours.

How do transverse and longitudinal waves differ?

The two main kinds of wave differ in the direction of the vibration compared with the direction the wave travels. Shake the end of a rope up and down and the wave runs along the rope while the rope itself moves up and down. Push and pull the end of a spring and bunches of coils travel along it.



A transverse wave: the vibration is at right angles to the direction of travel.



A longitudinal wave: coils bunch up in compressions and spread out in rarefactions.

Feature	Transverse wave	Longitudinal wave
Vibration	At right angles to the travel direction	Back and forth along the travel direction
Pattern	Crests and troughs	Compressions and rarefactions
Examples	Ripples on water, a shaken rope, light	Sound in air, a pushed spring

What are amplitude, wavelength and frequency?

Three measurements describe every regular wave. The **amplitude** is the largest displacement from the rest position, measured from the rest line to a crest (or to a trough). The **wavelength**, written λ , is the length of one complete wave, for example crest to the next crest. The **frequency** is the number of complete waves passing a point each second.

Formula

$$f = N \div t \text{ and } T = 1 \div f$$

f is the frequency in hertz (Hz), N the number of complete waves, t the time in seconds (s), and T the period in seconds: the time for one complete wave.

Worked example

A buoy off Kovalam beach in Kerala bobs up and down 30 times in 60 s. Find its frequency and period.

$$f = N \div t = 30 \div 60 = 0.50 \text{ Hz. } T = 1 \div f = 1 \div 0.50 = 2.0 \text{ s. } \mathbf{f = 0.50 \text{ Hz, } T = 2.0 \text{ s}}$$

How do you calculate the speed of a wave?

In one period the wave moves forward by exactly one wavelength. So the speed is the wavelength divided by the period, and because $1 \div T$ is the frequency, this gives a simple rule.

Key law

$$\text{wave speed} = \text{frequency} \times \text{wavelength, or } v = f \times \lambda$$

v is in metres per second (m/s), f in hertz (Hz) and λ in metres (m).

Worked example

Ripples in a school water tank have $f = 4.0$ Hz and $\lambda = 0.15$ m. Find their speed.

$$v = f \times \lambda = 4.0 \times 0.15 = 0.60. \quad \mathbf{v = 0.60 \text{ m/s}}$$

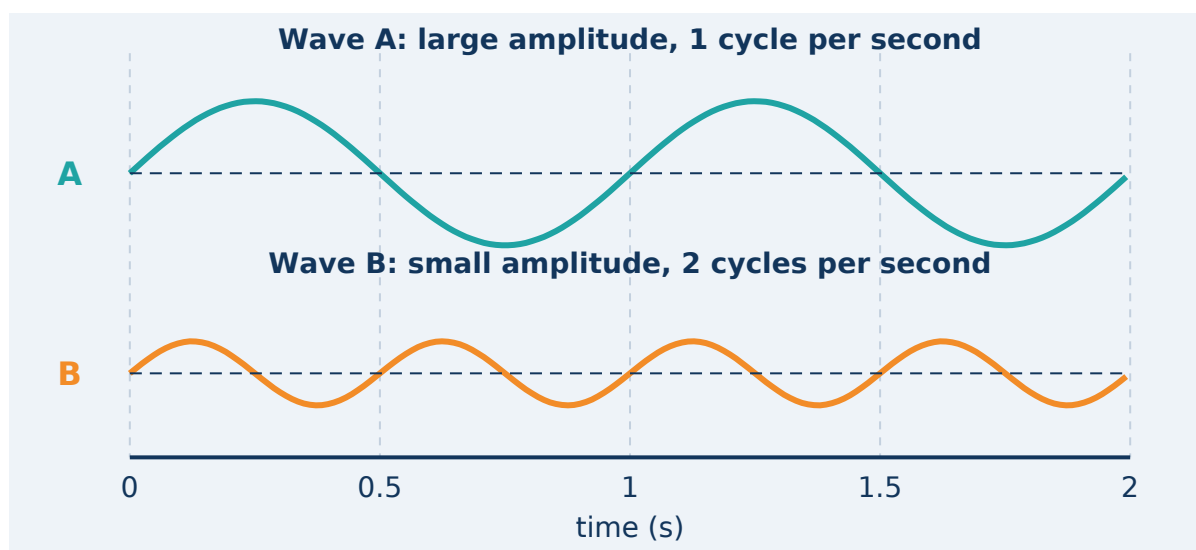
Worked example

A note of frequency 500 Hz travels through air at 340 m/s. Find its wavelength.

$$\text{Rearrange: } \lambda = v \div f = 340 \div 500 = 0.68. \quad \mathbf{\lambda = 0.68 \text{ m}}$$

How do waves carry energy?

The bigger the amplitude, the more energy each wave carries. A big ocean swell can knock a swimmer over, while a ripple barely tickles. Frequency matters too: if the amplitude stays the same, more waves per second deliver more energy each second. Loudness of sound is linked to amplitude, and pitch is linked to frequency.



Wave A has the larger amplitude and the lower frequency; wave B has the smaller amplitude and the higher frequency.

Common mistake

Do not say that water travels along with an ocean wave. The water moves in small loops and ends up almost where it started. Also do not measure wavelength from crest to trough: that is only half a wavelength.

Lina's tip

To remember the units, say it out loud: hertz means waves per second. If you are given a period, flip it with $1 \div T$ to get the frequency, then use $v = f \times \lambda$.

Key points to remember

- A wave transfers energy, not matter, from one place to another.
- Transverse waves vibrate at 90° to the travel direction; longitudinal waves vibrate along it.
- Frequency $f = N \div t$ in hertz (Hz); period $T = 1 \div f$ in seconds.
- Wave speed $v = f \times \lambda$, with v in m/s, f in Hz and λ in m.
- A larger amplitude means a wave carries more energy.

How waves carry energy without matter: frequently asked questions

What is a wave in simple words?

A wave is a regular disturbance that passes energy along. The medium, such as water or a rope, only vibrates in place while the energy moves on.

What is the difference between amplitude and wavelength?

Amplitude is how far the medium moves from its rest position, which is a height. Wavelength is the length of one complete wave, which is a distance along the direction of travel.

What is the unit of frequency?

Frequency is measured in hertz (Hz). One hertz means one complete wave passes a point every second, and 1 kHz is 1000 Hz.

Is sound a transverse or a longitudinal wave?

Sound in air is a longitudinal wave. Air particles are pushed together into compressions and spread apart in rarefactions along the direction the sound travels.

How are wave speed, frequency and wavelength related?

Wave speed equals frequency multiplied by wavelength, $v = f \times \lambda$. For a fixed speed, a higher frequency therefore means a shorter wavelength.