

Edexcel GCSE Combined Science — Physics

Topic 4

Waves

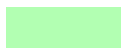
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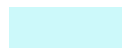
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Transverse wave

- oscillations are at right angles to the direction of energy transfer.

Define Compression / rarefaction

- regions of a longitudinal wave where particles are pushed together / spread out.

Define Wavelength

- the distance from a point on a wave to the same point on the next, e.g. crest to crest.

Define Period

- the time for one complete wave to pass a point, in seconds (s).

Define Wavefront

- a line joining all points on a wave that are in step, e.g. all the crests.

Define Refraction

- a wave changes direction crossing a boundary, because its speed changes.

Define Absorption

- a wave's energy is transferred into the material's stores, mostly thermal.

Define Echo

- a sound wave reflected back from a surface; timing one lets you measure the speed of sound.

Define Wave

- a disturbance transferring energy and information without transferring matter.

Define Longitudinal wave

- oscillations are parallel to the direction of energy transfer.

Define Amplitude

- the maximum displacement of a point on the wave from its undisturbed position.

Define Frequency

- the number of complete waves passing a point each second, in hertz (Hz).

Define Wave velocity (wave speed)

- the distance travelled by a wave each second, in m/s.

Define Reflection

- a wave bounces off a boundary, staying in the same material.

Define Transmission

- a wave passes through a material and carries on.

Define Normal

- the line at 90° to a boundary where a wave hits; all angles are measured from it.

4.1 What a wave is and what it carries (4.1, 4.2)

- Waves **transfer energy and information without transferring matter** (4.1). The medium oscillates about a fixed position and does not travel with the wave.
- Evidence that with water and sound waves it is the wave, not the water or air, that travels (4.2):
- A **floating cork bobs up and down** as ripples pass, but does not move towards the shore.
- **Sound** crosses a room but there is no wind: a candle flame before a loudspeaker flickers but is not blown out.
- Ripples from a dropped stone do not empty the pond's middle.

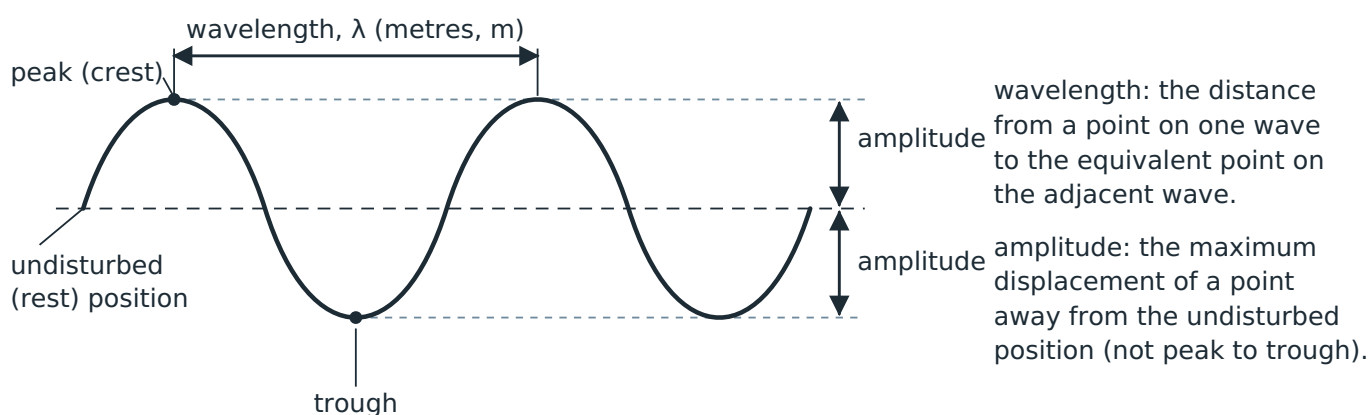
4.2 Describing waves (4.3, 4.4)

You must **define and use** frequency and wavelength (4.3), and **use** amplitude, period, wave velocity and wavefront (4.4).

- **Amplitude** — measured from the rest line to a crest, **not** crest to trough. Bigger amplitude means more energy: a louder sound, a brighter light.
- **Wavelength (λ)** — in metres, from any point to the identical point on the next wave; on a longitudinal wave, compression to compression.
- **Frequency (f)** — waves per second, in hertz (Hz). 1 kHz = 1000 Hz; 1 MHz = 1 000 000 Hz. Higher frequency, higher pitch.
- **Period (T)** — seconds for one complete wave; the reciprocal of frequency.
- **Wave velocity (v)** — in m/s; fixed in a given material, whatever the frequency.
- **Wavefront** — a line along a crest; wavefronts are one wavelength apart and travel at 90° to themselves.

The parts of a wave and the wave equations

Parts of a wave



The equations

wave speed = frequency $\times$ wavelength

$$v = f \lambda$$

wave speed, v , in metres per second, m/s

frequency, f , in hertz, Hz

wavelength, λ , in metres, m

period = $1 \div$ frequency

$$T = 1 / f$$

period, T , in seconds, s

frequency, f , in hertz, Hz

frequency = waves passing a point each second

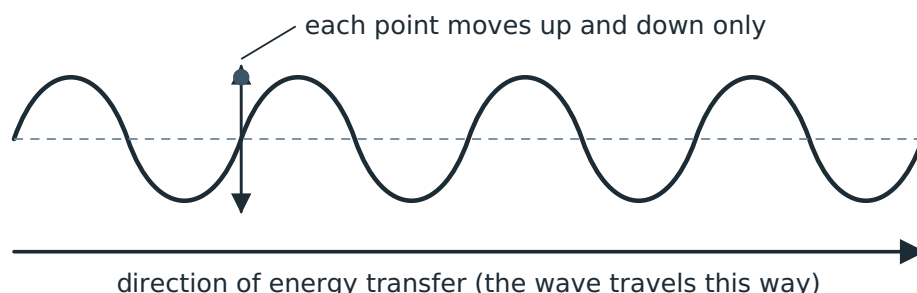
4.3 Longitudinal and transverse waves (4.5)

You must describe the difference between longitudinal and transverse waves by referring to sound, electromagnetic, seismic and water waves.

	Transverse	Longitudinal
Direction of oscillation	at 90° to the direction of energy transfer	parallel to the direction of energy transfer
Shape	crests and troughs	compressions and rarefactions
Wavelength measured	crest to crest	compression to compression
Can travel through a vacuum?	electromagnetic waves can; water and S-waves cannot	no — a medium is always needed
Examples	all electromagnetic waves (light, radio, X-rays); water waves; seismic S-waves ; a rope flicked sideways	sound in air, liquids and solids; seismic P- waves ; a slinky pushed and pulled along its length

Transverse and longitudinal waves

Transverse wave — a wave sent along a rope



The oscillations are at right angles (90°) to the direction of energy transfer.

Examples: ripples on water, all electromagnetic waves, S-waves.

Longitudinal wave — a wave sent along a slinky spring

compression — coils pushed together

rarefaction — coils spread apart



coils vibrate back and forth, parallel to the direction of energy transfer

direction of energy transfer

Examples: sound waves travelling through air, P-waves (seismic waves).

Waves transfer energy (and information) — they do not transfer matter

float bobs up and down



A float resting on water ripples, or a piece of paper in front of a loudspeaker, just oscillates about a fixed point — it is not carried along with the wave. This is evidence that it is the wave (the disturbance) that travels, and not the water or the air itself.

ANALOGY

Hold a **slinky** flat on a table. Flick your hand **side to side** and a wiggle runs down the spring while every coil only moves sideways: **transverse**. Now push and pull **along** the spring: a squash travels down it while each coil moves back and forth in the line the wave travels: **longitudinal**. Either way, the wave reaches the far end; the slinky does not.

WATCH OUT

Seismic waves are **both**. **P-waves are longitudinal** (they push and pull, and pass through liquids); **S-waves are transverse** (they shake sideways and cannot). Sound in air is always longitudinal.

4.4 The wave equations (4.6)

WATCH OUT

The commonest error in echo questions is **forgetting to double the distance**. The sound travels to the wall **and back**, so decide at the start whether the number you are given is the *one-way* distance or the *total* path, and write the " $\times 2$ " into your working before touching the calculator.

4.5 Measuring the velocity of waves (4.7, 4.17)

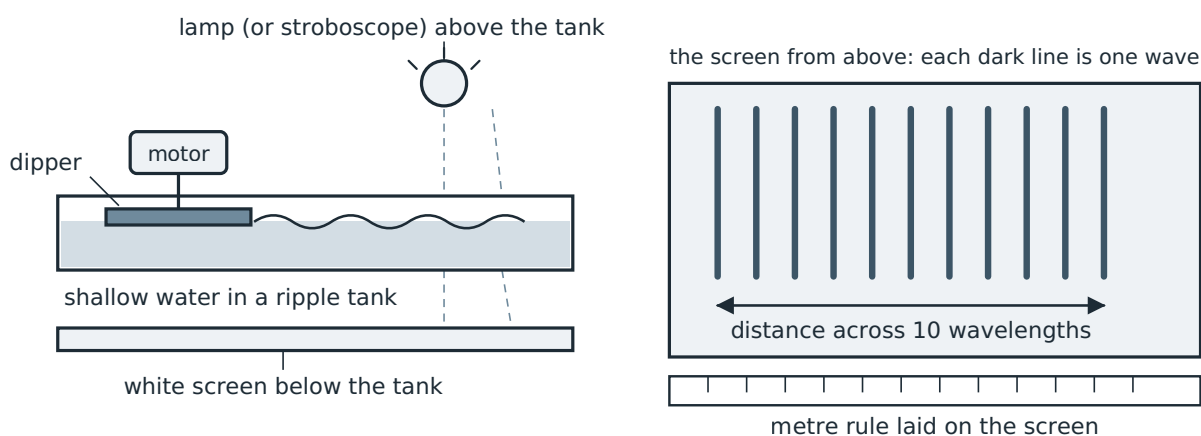
You must **describe how to measure the velocity of sound in air and ripples on water surfaces** (4.7).

Sound in air (echo method): stand a measured distance d (at least 50 m) from a large flat wall; clap and time the echo. Better: time **20** claps synchronised with their echoes and divide, or use two microphones a known distance apart on a data logger, removing reaction time. Then $v = 2d \div t$.

Ripples on water: use a ripple tank — method in full in the core practical below.

Measuring waves in a ripple tank and in a solid

Core Practical 4.17 — measuring waves in a ripple tank (a fluid)

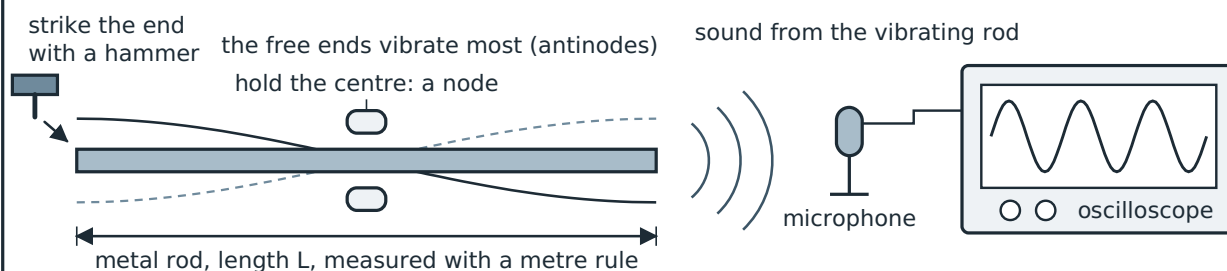


Frequency f : count the waves passing a point in 10 s and divide by 10.

Wavelength λ : measure across 10 wavelengths with the metre rule and divide by 10.

Wave speed: $v = f \lambda$. A stroboscope freezes the pattern, making it easier to measure.

Waves in a solid — a struck metal rod



Hold the rod at its centre and strike one end: the wavelength $\lambda = 2 \times$ the length of the rod.

Read the frequency f from the oscilloscope trace, or from a frequency app. Then $v = f \lambda$.

Speed in the metal is a few thousand m/s, far faster than ripples — judge which equipment suits each.

4.6 Waves at a boundary (4.10, 4.11)

HIGHER TIER

Refraction and why it happens (4.10)

You must **explain how waves will be refracted at a boundary in terms of the change of direction** HT ONLY and speed.

- All tiers: crossing a boundary at an angle to the normal, the wave's **direction changes**. Entering a material where it travels **more slowly** (air into glass) it bends **towards the normal**; where it travels **faster, away from the normal**.
- HT ONLY The cause is the **change of speed**: one side of the wavefront enters the new material and slows before the other does, so the wavefront pivots round.
- A wave meeting the boundary **along the normal** (0° incidence) still changes speed and wavelength, but not direction.
- The **frequency never changes**; the wavelength changes in proportion to the speed.

NOTE

Use of mathematics (Topic 4). Make calculations using ratios and proportional reasoning to convert units and to compute rates; apply the formulae relating velocity, frequency and wavelength.

Suggested practicals (not core practicals): model refraction with toy cars running into sand; investigate refraction in rectangular glass blocks (this becomes Core Practical 5.9 in Topic 5).

ANALOGY

Drive a **toy car** at an angle onto a patch of sand. The wheel reaching the sand first slows while the other is still on smooth floor, so the car **swings round** towards the sand — direction changed because one side slowed first. That is why light bends towards the normal entering glass. (Edexcel suggests this as a model.) It breaks down in that a wave is not rigid, so no part is "dragged".

HIGHER TIER

HT ONLY Wavelength-dependent behaviour (4.11)

HT ONLY You must **recall that different substances may absorb, transmit, refract or reflect waves in ways that vary with wavelength**. The same material treats different wavelengths differently:

- HT ONLY Glass **transmits** visible light but **absorbs** most ultraviolet — so you do not get sunburnt through a window.
- HT ONLY Glass refracts **blue** light more than **red**, so a prism splits white light into a spectrum.
- HT ONLY The atmosphere transmits visible light and radio waves but absorbs much infrared and X- radiation.
- HT ONLY A red object **absorbs** most visible wavelengths and **reflects** red.