

AQA GCSE Combined Science: Trilogy — Physics

Topic 23

Waves

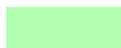
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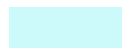
Revision notes for one topic, free to download.

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 perpendicular to the direction of energy transfer.

Define Compression

- region of a longitudinal wave where particles are pushed together.

Define Amplitude

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

Define Frequency

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

Define Wave speed

- the speed at which the energy is transferred (or the wave moves) through the medium.

Define Reflection

- a wave bouncing back at a boundary between two materials.

Define Ionising radiation

- radiation with enough energy to knock electrons off atoms, so it can cause the mutation of genes and cancer.

Define Longitudinal wave

- oscillations parallel to the direction of energy transfer.

Define Rarefaction

- region of a longitudinal wave where particles are spread apart.

Define Wavelength

- the distance from a point on one wave to the equivalent point on the adjacent wave.

Define Period

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

Define Electromagnetic waves

- transverse waves that transfer energy from a source to an absorber, forming a continuous spectrum.

Define Refraction

- a wave changing direction at a boundary because its velocity changes.

Define Radiation dose

- a measure, in sieverts, of the risk of harm from exposure to radiation.

23.1 Waves in air, fluids and solids

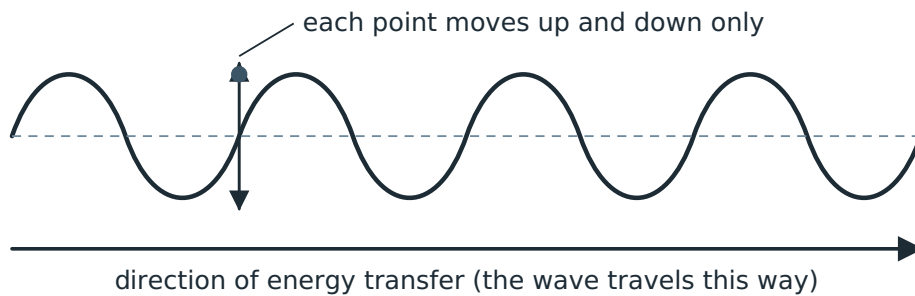
23.1.1 Transverse and longitudinal waves

Waves may be either **transverse** or **longitudinal**. Both transfer energy from a source to an absorber.

	Transverse	Longitudinal
Oscillation	Perpendicular to energy transfer	Parallel to energy transfer
Features	Peaks and troughs	Compressions and rarefactions
Examples	Ripples on a water surface, all electromagnetic waves	Sound waves in air

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

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.

Evidence that the wave travels, not the medium

- A cork on a pond bobs **up and down** as ripples pass but is not carried to the far bank.
- A loudspeaker makes air particles vibrate about fixed positions. If the air itself travelled to your ear there would be a wind, and the room would empty of air.

ANALOGY

Rope vs slinky. Flick a **rope** and a hump runs along it — your hand moves at right angles to the hump's travel: **transverse**. Push and pull a **slinky** and a squashed patch runs along it — your hand moves along the line the wave travels: **longitudinal**. Both end up where they started; only energy moves along.

WATCH OUT

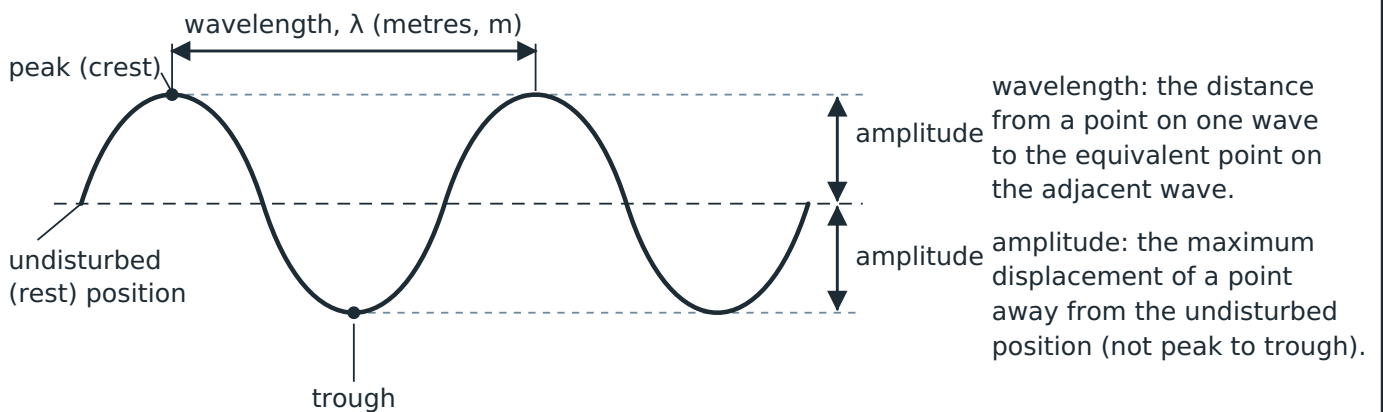
"Waves carry the water or air along with them." Waves transfer **energy**, not **matter**. Particles of the medium oscillate about a fixed undisturbed position and stay there. Answer as "the wave transfers energy from the source to an absorber; the particles only vibrate".

23.1.2 Properties of waves

- **Amplitude** is measured from the middle (undisturbed) line to a peak — **not** peak to trough.
- **Wavelength** (λ) is peak to peak, or compression to compression.
- **Wave speed** is the speed at which energy is transferred through the medium.
- You must identify amplitude and wavelength from given diagrams. On a displacement–distance graph the x-axis gives the wavelength; on a displacement–time graph one wave gives the **period**.

Amplitude, wavelength, frequency and period

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

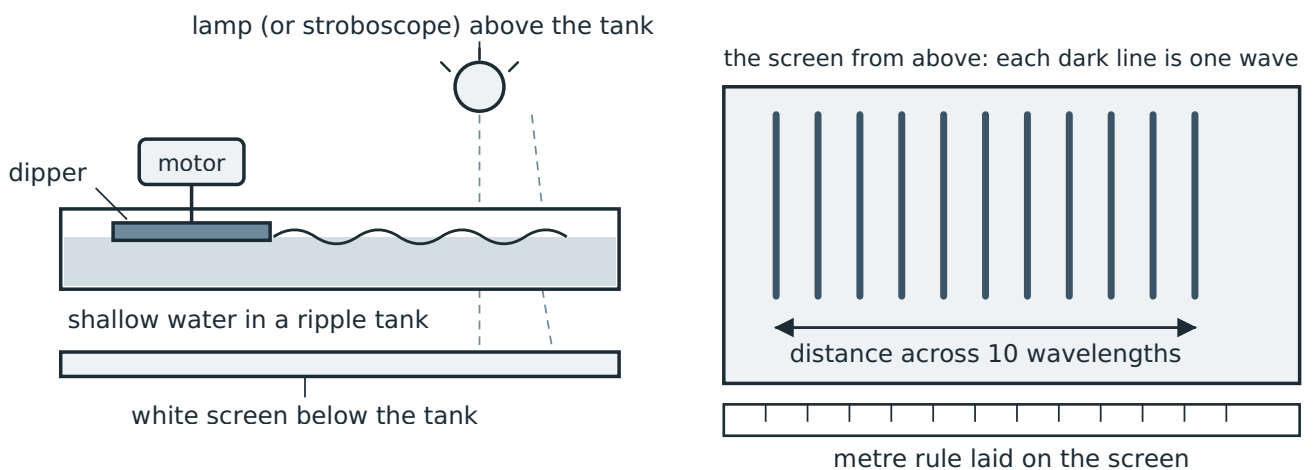
Measuring the speed of sound waves in air

1. Connect two microphones a measured distance apart (about 1 m) to an oscilloscope.
2. Make a sharp sound beyond the first microphone; measure the **time delay** between the two traces.
3. speed = distance $\div$ time delay. Repeat and mean (about 330–340 m/s).
4. Or clap a measured distance from a large wall and time 20 echoes; total distance = $2 \times \text{distance} \times 20$.

Measuring the speed of ripples on a water surface. Use a **ripple tank**, as in required practical 20.

The ripple tank

Required practical 20 — measuring waves in a ripple tank

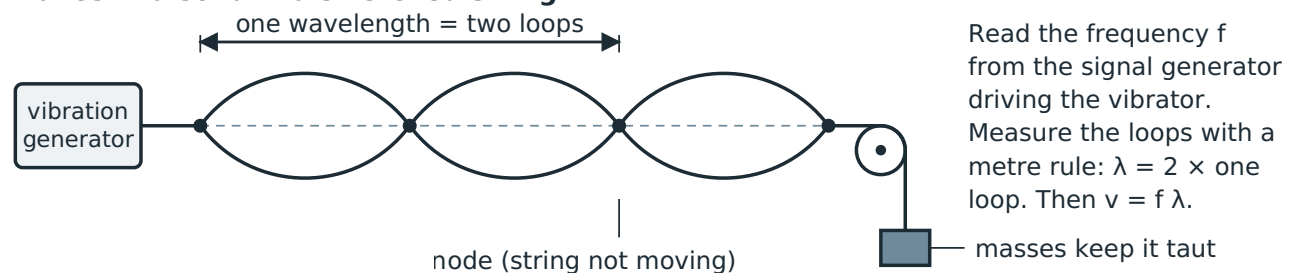


Frequency f : count the waves passing a point in 10 s and divide by 10.

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 stretched string

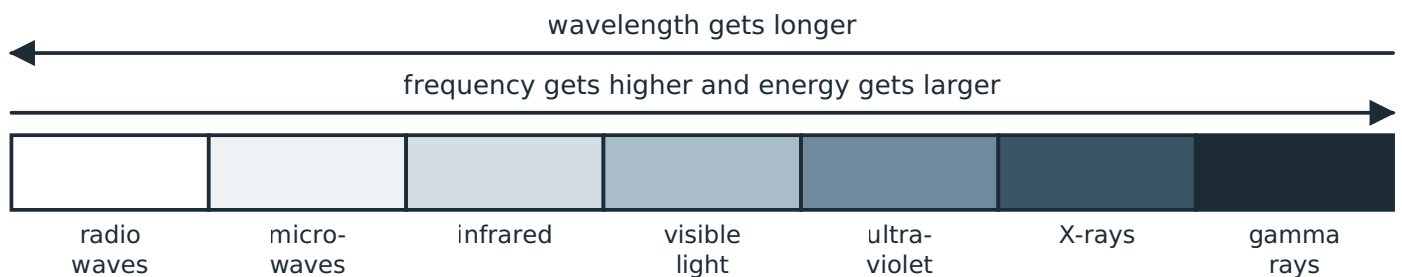


23.2 Electromagnetic waves

23.2.1 Types of electromagnetic waves

- Electromagnetic waves are **transverse** waves that transfer energy from the **source** of the waves to an **absorber**. They form a **continuous spectrum**, and all types travel at the same velocity through a vacuum (space) or air — 3×10^8 m/s.
- Grouped by **wavelength** and **frequency**, from **long to short wavelength (low to high frequency)**: radio, microwave, infrared, visible light (red to violet), ultraviolet, X-rays, gamma rays.
- Our **eyes only detect visible light**, so we detect a limited range of electromagnetic waves.
- Energy transfer examples: a microwave oven heating food; sunlight warming a pavement; an aerial absorbing radio waves to produce a current.

The electromagnetic spectrum



Group	One use	One hazard
radio waves	television and radio broadcasts	very large doses heat tissue
microwaves	satellite links, cooking food	internal heating of body tissue
infrared	electric heaters, infrared cameras	skin burns
visible light	fibre optic communications	retina damage if very bright
ultraviolet	energy efficient lamps, tanning	skin ages early; skin cancer
X-rays	medical imaging (X-ray photos)	ionising: mutation and cancer
gamma rays	sterilising food, treating cancer	ionising: mutation and cancer

All electromagnetic waves are transverse and transfer energy from a source to an absorber. They form a continuous spectrum and all travel at the same speed through a vacuum (space) or air. Visible light runs from red (longest wavelength) to violet (shortest); our eyes detect only this narrow band.

WATCH OUT

Getting the spectrum the wrong way round. Use **Rich Men In Vegas Use eXpensive Gold**. In that order **wavelength decreases, frequency increases** and the **energy carried increases** — which is why the ionising ones (UV, X-rays, gamma) are at the gamma end. What does **not** change is the **speed**: in a vacuum every part travels at the same speed, so gamma rays are not "faster" than radio waves, only higher in frequency.

ANALOGY

A car driving onto sand. A car leaves the road onto soft sand at an angle: the wheel reaching the sand first slows while the other is still on tarmac, so the car **slews round**. Drive straight on (along the normal) and both wheels slow together, so it slows but carries straight on. Refraction happens for exactly that reason — the **change of speed**.

HIGHER TIER

23.2.3 Properties of electromagnetic waves 2

HT ONLY Radio waves can be produced by oscillations in electrical circuits. An alternating current in a transmitting aerial makes electrons oscillate, and these oscillating charges emit radio waves of the **same frequency** as the current.

HT ONLY The reverse also happens: when radio waves are **absorbed** they may create an alternating current with the same frequency as the radio wave itself, so radio waves can induce oscillations in an electrical circuit.

- Changes in **atoms and the nuclei of atoms** can generate or absorb electromagnetic waves over a wide frequency range; gamma rays originate from changes in the nucleus of an atom.
- Ultraviolet waves, X-rays and gamma rays can have hazardous effects on human body tissue, depending on the **type of radiation** and the **size of the dose**.
- **Radiation dose (in sieverts)** measures the **risk of harm** from exposure of the body to radiation; 1000 millisieverts (mSv) = 1 sievert (Sv). You need **not** recall this unit, but may be asked to draw conclusions from given data about the risks of exposure.
- **Ultraviolet** can cause skin to **age prematurely** and increases the risk of **skin cancer**. **X-rays and gamma rays** are **ionising radiation** that can cause the **mutation of genes** and **cancer**.

HIGHER TIER

23.2.2 Properties of electromagnetic waves 1

HT ONLY Different substances may **absorb, transmit, refract or reflect** electromagnetic waves in ways that **vary with wavelength** — glass transmits visible light but absorbs most ultraviolet.

HT ONLY Some effects, for example **refraction**, are due to the difference in velocity of the waves in different substances. When a wave meets a boundary at an angle, one side of the wavefront changes speed **before** the other, swinging it round so the direction of travel changes. Slowing down bends the ray **towards** the normal, speeding up bends it **away**; a wave arriving **along** the normal changes speed and wavelength but not direction.

Ray diagrams for refraction. You must be able to construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media. Draw the boundary and the **normal** (dashed, at 90° to it), then the incident ray marking the **angle of incidence** from the normal, then the refracted ray bent towards or away from the normal as above. Angles are always measured **from the normal**.

HT ONLY On a **wavefront diagram**, draw wavefronts as parallel lines at right angles to the ray: in the slower medium they are **closer together** (shorter wavelength, frequency unchanged) and **tilted** relative to the first medium.

23.2.4 Uses and applications of electromagnetic waves

Part of spectrum	Use	Hazard
Radio waves	Television and radio	No significant hazard — lowest frequency and energy
Microwaves	Satellite communications; cooking food	Internal heating of body tissue
Infrared	Electrical heaters; cooking food; infrared cameras	Skin burns
Visible light	Fibre optic communications	Retinal damage if very intense
Ultraviolet	Energy efficient lamps; sun tanning	Premature skin ageing; skin cancer
X-rays	Medical imaging and treatments	Ionising: mutation of genes, cancer
Gamma rays	Medical imaging and treatments	Ionising: mutation of genes, cancer

NOTE

The specification only names hazards for **ultraviolet, X-rays and gamma rays**; the others are given for completeness and are not required.

HIGHER TIER

HT ONLY Why each type suits its application:

- **Radio** — barely absorbed by the atmosphere, so covers wide areas.
- **Microwaves** — pass **through** the atmosphere to satellites; oven wavelengths are absorbed by water in food.
- **Infrared** — strongly absorbed by surfaces, heating them; all warm objects emit it, so cameras detect heat.
- **Visible light** — weakly absorbed by glass fibres and reflects along them, so data is carried with little loss.
- **Ultraviolet** — makes fluorescent coatings glow, wasting less energy.
- **X-rays** — pass through flesh but are absorbed by bone, giving a shadow image; **gamma rays** penetrate the body and kill cancer cells.