Topic 6: Waves

AQA GCSE Physics 8463 · spec 4.6 · sheets 6.1–6.5

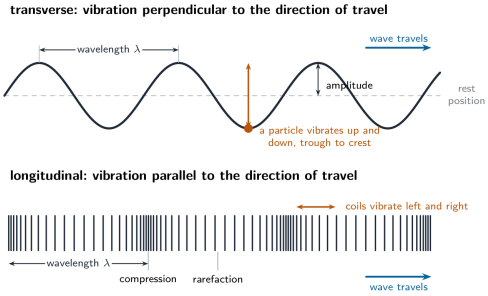
Waves: sound, light and the electromagnetic spectrum

- describe **transverse** and **longitudinal** waves, and use the wave equation;
- measure the speed of waves in water and in a solid;
- describe the electromagnetic spectrum, its uses and its dangers, and investigate infrared radiation;
- (physics only) explain reflection, sound, ultrasound and seismic waves, lenses, colour and black body radiation.

Transverse and longitudinal waves

- In a **transverse** wave, the oscillations are at right angles to the direction the wave travels. Examples: ripples on water, waves on a string, and all electromagnetic waves.
- In a **longitudinal** wave, the oscillations are in the same direction as the wave travels. Sound waves in air are **longitudinal**. They have **compressions**, where the particles are close together, and **rarefactions**, where they are spread out.

Figure: Transverse and longitudinal waves



- A **transverse** wave on a rope and a **longitudinal** wave on a slinky, with **compressions** and rarefactions.
- Match each part of the diagram to the text.

Properties of waves and the wave equation

- The **amplitude** is the maximum displacement of a point on the wave from its undisturbed position.
- The **wavelength** is the distance from a point on one wave to the equivalent point on the next wave, such as crest to crest.
- The **frequency** is the number of waves passing a point each second, in hertz (Hz).

$$T = \frac{1}{f} \qquad v = f\lambda$$

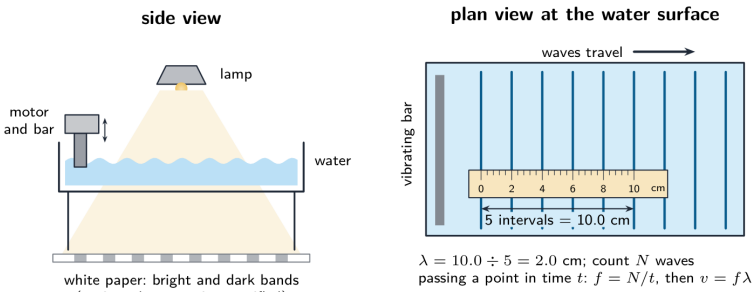
Properties of waves and the wave equation (2)

- The **period** is the time for one complete wave to pass a point.
- Three complete waves fit in 1.20 m, so $\lambda = \frac{1.20}{3} = 0.40$ m.
- The **amplitude**, from the rest position to a crest, is 3.0 cm. The height from crest to trough, 6.0 cm, is twice the amplitude.

Properties of waves and the wave equation (3)

- $f = \frac{5}{2.0} = 2.5$ Hz, so $v = 2.5 \times 0.40 = 1.0$ m/s.
- Waves on water: set up a ripple tank with a motor-driven bar, and a lamp above that makes a pattern of the waves on paper below. Measure the length of several waves together and divide by the number of waves to find the wavelength. Count the waves passing a point in 10 s to find the **frequency**, then use $v = f\lambda$.
- Waves on a string: stretch a string over a pulley with a hanging mass, and make it vibrate with a vibration generator. Change the frequency until you see a clear wave that does not move along the string. Each loop is half a wavelength. Read the frequency from the signal generator and use $v = f\lambda$.

Figure: Properties of waves and the wave equation

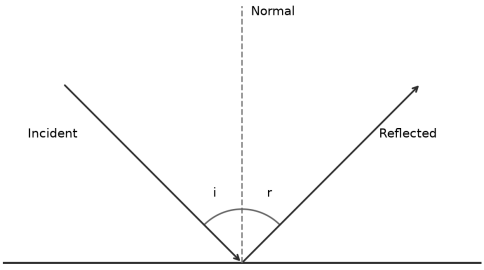


- Required practical 8: a ripple tank, and the wave pattern measured with a ruler across 5 wavelengths.
- Match each part of the diagram to the text.

Reflection (physics only)

- **Specular reflection** happens at a smooth surface, such as a mirror: all the light is reflected in one direction.
- **Diffuse reflection** happens at a rough surface, such as paper: the light is scattered in many directions.

Figure: Reflection (physics only)



Mirror: i = r; measure both angles from the normal

- Reflection ray diagram with the normal, angle of incidence and angle of reflection.
- Match each part of the diagram to the text.

Sound and detection (physics only, HT)

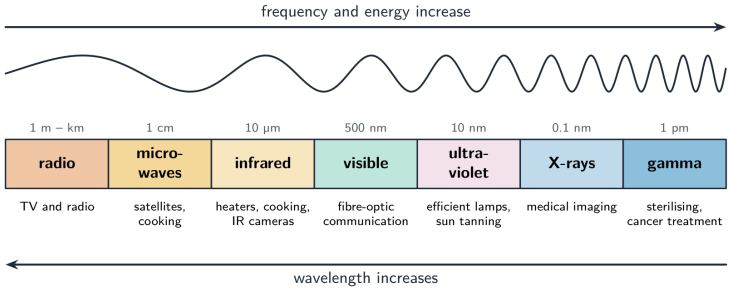
- Sound waves can travel through solids, liquids and gases.
- When sound reaches your ear, it makes the eardrum vibrate.
- The vibrations pass through small bones to the inner ear, which sends signals to the brain.
- This works only for a limited range of frequencies: humans can hear from about 20 Hz to 20 kHz.

Electromagnetic waves

- Electromagnetic (EM) waves are **transverse** waves that transfer energy from a source to an absorber.
- They form a continuous spectrum, and they all travel at the same speed in a vacuum or in air: 3×10^8 m/s.
- In order of decreasing wavelength and increasing **frequency**:
- Our eyes detect only visible light, a very small part of the spectrum.

radio $\rightarrow$ microwaves $\rightarrow$ infrared $\rightarrow$ visible light $\rightarrow$ ultraviolet $\rightarrow$ X-rays $\rightarrow$ gamma rays

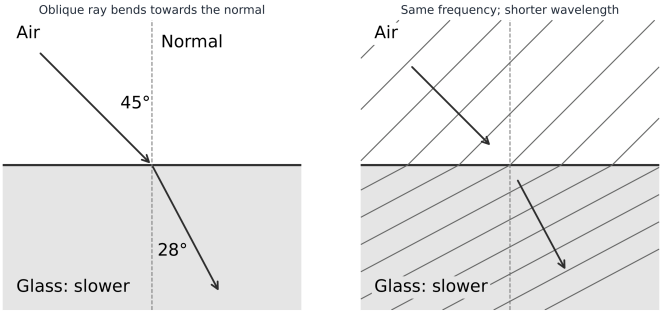
Figure: Electromagnetic waves



all travel at the same speed in a vacuum; ultraviolet, X-rays and gamma are ionising

- The electromagnetic spectrum: **frequency** increases and wavelength decreases from radio waves to gamma rays.
- Read the axes and units first.

Figure: Electromagnetic waves (2)



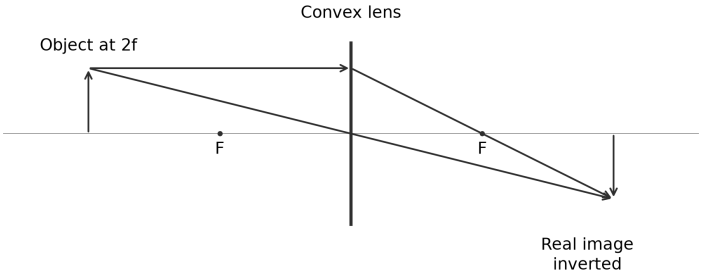
- Refraction as a ray bending towards the normal, and as wavefronts bunching in the slower medium.
- Match each part of the diagram to the text.

Lenses (physics only)

- A **convex** lens makes parallel rays of light converge (come together) at the principal focus. The distance from the lens to the principal focus is the focal length. A **convex** lens can form a real or a virtual image.
- A **concave** lens makes parallel rays spread out, as if they came from a principal focus behind the lens. A **concave** lens always forms a virtual, upright, smaller image.

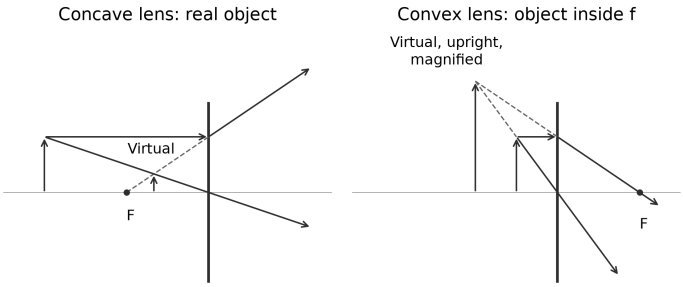
$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

Figure: Lenses (physics only)



- A **convex** lens ray diagram forming a real inverted image.
- Match each part of the diagram to the text.

Figure: Lenses (physics only) (2)



- Virtual images: **concave** lens with a real object, and **convex** lens with an object inside its focal length.
- Match each part of the diagram to the text.

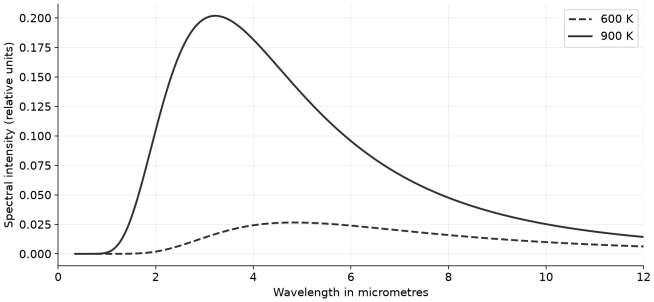
Visible light and colour (physics only)

- An opaque object reflects some wavelengths and absorbs the rest. A red apple looks red because it reflects red light and absorbs the other colours. A white object reflects all wavelengths equally; a black object absorbs them all.
- Colour filters absorb some wavelengths and transmit others. A red filter transmits only red light.
- Transparent and translucent objects transmit light.

Black body radiation (physics only)

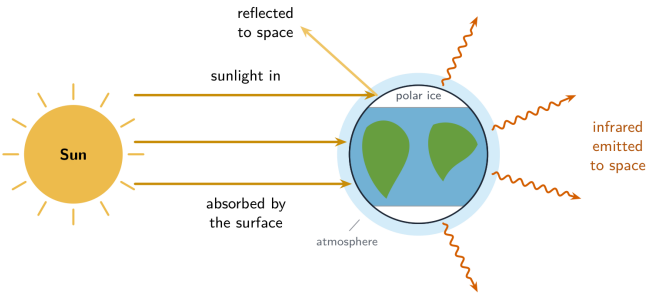
- All bodies, whatever their temperature, emit and absorb infrared radiation.
- The hotter a body is, the more infrared radiation it emits in a given time.
- A perfect black body absorbs all the radiation that hits it; it does not reflect or transmit any.
- Because a good absorber is also a good emitter, a perfect black body is the best possible emitter.

Figure: Black body radiation (physics only)



- A hotter body emits more radiation at every wavelength, and its peak is at a shorter wavelength.
- Match each part of the diagram to the text.

Figure: Black body radiation (physics only) (2)



- The Earth's radiation balance: absorbed, reflected and emitted radiation.
- Match each part of the diagram to the text.

Sources for this lesson

- AQA, *GCSE Physics (8463) specification*, section 4.6 Waves, and the *Required practical handbook* (practicals 8, 9 and 10).
- H. Hertz, *Electric Waves* (London, 1893), English translation of his papers of 1887 to 1890; Marconi Society, account of the first transatlantic radio signal, 12 December 1901.
- AQA, *GCSE Physics* Paper 2 Higher, June 2023 to June 2025 (wave graph, ripple tank and lens questions, adapted).

Common errors

- Saying the material travels with the wave; waves transfer energy, and particles only oscillate.
- Measuring **amplitude** from crest to trough; it is from the rest position to a crest.
- Forgetting to convert kHz to Hz or MHz to Hz.

Common errors (2)

- Saying refraction changes the **frequency**; the speed and wavelength change.
- Measuring angles from the surface instead of from the normal.
- Saying higher-frequency EM waves travel faster; all travel at the same speed in a vacuum.

Common errors (3)

- Giving magnification a unit.
- Saying a red filter turns light red; it absorbs the other colours.

Key terms

- **Transverse wave**: oscillations at right angles to the direction of travel.
- **Longitudinal wave**: oscillations along the direction of travel.
- **Wavelength**: the distance from one point on a wave to the same point on the next.

Key terms (2)

- **Frequency**: the number of waves passing a point each second.
- **Electromagnetic spectrum**: the family of **transverse** waves from radio to gamma rays.
- **Refraction**: the change of direction of a wave as its speed changes at a boundary.
- **Perfect black body**: an object that absorbs all the radiation that hits it.

Check yourself

- 1.
- Give one example each of a **transverse** and a **longitudinal** wave. 2.
- A wave has a **frequency** of 25 Hz and a wavelength of 0.12 m.
- Calculate its speed and its period. 3.