Wave types

- **Mechanical waves**: need a medium (sound, water)
- **Electromagnetic (EM) waves**: no medium required; travel in vacuum at

$$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$$

- **Transverse**: oscillations ⊥ direction (all EM waves)
- **Longitudinal**: oscillations ∥ direction (sound)

Wave quantities

- **Amplitude** A(m): max displacement
- **Wavelength** λ(m)
- **Period** T(s)
- **Frequency** f(Hz), $f = \frac{1}{T}$
- **Wave speed**

$$v = f\lambda$$

Radio → Micro → IR → Visible → UV → X-ray → Gamma
(Visible: ~400–700 nm)

Refractive index

$$n = \frac{c}{v}$$

- n larger → light slower in that medium

Snell's Law

$$n_1 \sin\ \theta_1 = n_2 \sin\ \theta_2$$

$$n_1 v_1 = n_2 v_2$$

Angles measured **from the normal**.

Bending rules

- Into higher n(slower): **towards** normal
- Into lower n(faster): **away from** normal

Total internal reflection (TIR)

Conditions:

1. light goes **from higher** $n$to **lower** n
2. $\theta_i > \theta_c$

Critical angle:

$$\sin\ \theta_c = \frac{n_2}{n_1}(n_1 > n_2)$$

Optical fibres

- Core has higher $n$than cladding → repeated TIR → guides light
- Pros: high bandwidth, low loss, immune to EM interference

Dispersion (white light splitting)

- Refractive index depends on wavelength
- Shorter λ (blue/violet) refracts more than longer λ (red)
- Leads to spectra in prisms, rainbows

Rainbows (core idea)

- Refraction + dispersion on entry
- Internal reflection inside drop
- Refraction on exit → colours separated

Mirages (core idea)

- Temperature gradient → $n$gradient → continuous refraction
- Light curves, producing apparent “water”/shifted images

Temperature (K)

$$T(K) = T(^{\circ}C) + 273$$

Internal energy U

Total microscopic energy (particle KE + PE).

- ↑T → ↑average particle KE
- Phase change → changes particle PE (T constant)

Heating (no phase change)

$$Q = mc\Delta T$$

- **UNITS:** Q=J, m=kg, c=J kg^{-1} K^{-1}, ΔT=K or °C

Phase change (latent heat)

$$Q = mL$$

- Fusion L_f: solid↔liquid
- Vaporisation L_v: liquid↔gas
  Temperature constant during phase change.

Heat transfer mechanisms

- **Conduction**: collisions (solids best; metals good conductors)
- **Convection**: fluid motion due to density differences
- **Radiation**: EM waves (IR); no medium needed

Thermal radiation basics

- All objects emit EM radiation due to temperature
- Hotter → more emitted power, higher typical frequency (shorter λ)
- Dark/dull surfaces: better absorbers/emitters than shiny surfaces (qualitative)

Wien's displacement

$$\lambda_{\max} T \approx 2.898 \times 10^{-3} \text{ m·K}$$

Where $\lambda_{\max}$ = Metres, T = Kelvin

- Lets you estimate temperature from peak wavelength (or vice versa)

Absorption / emission (core idea)

- A good absorber is a good emitter (qualitative)
- Earth absorbs mostly visible/shortwave, emits IR/longwave

Greenhouse effect (physics framing)

- Certain gases absorb IR emitted by Earth and re-emit it → reduces net energy leaving → warms surface/lower atmosphere (qualitative, not "heat trapped" as a substance)