

Learn these by heart before the exam.

Motion, forces and energy

$v = \frac{s}{t}$ average speed = total distance ÷ total time
 $a = \frac{\Delta v}{\Delta t}$ unit m/s²; negative value = deceleration
Graphs: distance-time gradient = speed; speed-time gradient = acceleration; area under speed-time = distance.
 $\rho = \frac{m}{V}$ kg/m³ or g/cm³; an object floats when its density < density of the liquid
 $W = mg$ $g = 9.8$ N/kg on Earth (gravitational field strength)
 $F = ma$ resultant force; unit newton (N)
Terminal velocity: constant top speed when air resistance has grown to balance weight, so resultant force = 0
 $k = \frac{F}{x}$ Hooke's law: extension $\propto$ force up to the limit of proportionality
moment = $F \times d$ d = perpendicular distance from the pivot; unit N m
Principle of moments: in equilibrium, total clockwise moment = total anticlockwise moment about any point
Centre of gravity: the point where all the weight of an object appears to act
 $p = mv$ unit kg m/s; conserved in collisions when no external force acts
 $F \Delta t = \Delta(mv)$ impulse = change of momentum; crumple zones increase Δt to cut the force
 $E_k = \frac{1}{2}mv^2$
 $\Delta E_p = mg \Delta h$
 $W = Fd$ work done = energy transferred; unit joule (J)
 $P = \frac{W}{t} = \frac{E}{t}$ unit watt (W); 1 W = 1 J/s
efficiency = $\frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$
 $p = \frac{F}{A}$ unit pascal (Pa); small area $\Rightarrow$ large pressure
 $\Delta p = \rho g \Delta h$ pressure difference in a liquid of density ρ at depth change Δh
Scalar vs vector: scalar has size only (speed, distance, energy, time); vector has size and direction (velocity, force, weight, acceleration, momentum)

Thermal physics

$c = \frac{\Delta E}{m \Delta \theta}$ energy per kg per °C; unit J/(kg °C)
Specific heat capacity: the energy needed to raise the temperature of 1 kg of a substance by 1 °C
 $p_1 V_1 = p_2 V_2$ fixed mass of gas at constant temperature
Internal energy: the total kinetic and potential

energy of all the particles in an object; heating raises it
Evaporation vs boiling: evaporation happens at any temperature, only at the surface, and cools the liquid; boiling happens at one fixed temperature, throughout the liquid
Conduction: energy passed on by particle vibrations (and free electrons in metals); how solids transfer heat
Convection: hot fluid expands, becomes less dense and rises, setting up a circulating current; liquids and gases only
Radiation: energy carried by infrared waves; needs no particles, so it works through a vacuum
Dull black surfaces are the best absorbers AND best emitters of infrared; shiny white/silver are the worst.
Brownian motion: smoke particles jiggle randomly because fast, invisible air molecules hit them (evidence for moving molecules).
Gas pressure comes from molecules colliding with the walls; hotter gas means faster molecules, so more frequent and harder collisions.

Waves, light and sound

$v = f \lambda$ speed (m/s) = frequency (Hz) $\times$ wavelength (m)
Transverse vs longitudinal: transverse vibrates at right angles to travel (light, water waves); longitudinal vibrates along the direction of travel (sound), with compressions and rarefactions
 $n = \frac{\sin i}{\sin r}$ light bends TOWARDS the normal entering a denser medium
 $n = \frac{1}{\sin c}$
Critical angle: the angle of incidence that gives an angle of refraction of 90°; beyond it, total internal reflection
Total internal reflection: all light reflects back inside the denser medium when the angle of incidence exceeds the critical angle; used in optical fibres
 $M = \frac{h_i}{h_o}$ linear magnification = image height ÷ object height
Law of reflection: angle of incidence = angle of reflection; the image in a plane mirror is virtual, upright, same size, and as far behind the mirror as the object is in front.
EM spectrum, long to short wavelength: radio, microwave, infrared, visible, ultraviolet, X-rays, gamma. All travel at 3.0×10^8 m/s in a vacuum.
Visible light by wavelength: red is longest, violet shortest (dispersion order red, orange, yellow, green, blue, indigo, violet).

Range of human hearing: about 20 Hz to 20 000 Hz; above this is ultrasound
Sound needs a medium (no sound in a vacuum); speed of sound in air is about 330 to 350 m/s. Echo method: $v = \frac{2d}{t}$ (the sound travels there and back).

Electricity and magnetism

$Q = It$ charge (C) = current (A) $\times$ time (s)
 $V = \frac{W}{Q}$ p.d. = energy transferred per unit charge; 1 V = 1 J/C
E.m.f.: the electrical work done by a source (cell, generator) per unit of charge driven round the circuit; unit volt
 $R = \frac{V}{I}$ unit ohm (Ω)
 $P = VI = I^2 R$
 $E = VIt$
 $R_s = R_1 + R_2$ series: same current everywhere; p.d.s add up
 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ parallel: same p.d. across each branch; currents add; combined resistance is LESS than the smallest branch
Resistance of a wire: $R \propto \frac{L}{A}$ – doubling length doubles R ; doubling cross-sectional area halves R .
I-V graphs: fixed resistor = straight line through the origin; filament lamp = curve flattening (hotter filament, more resistance); diode conducts one way only.
 $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ step-up has more secondary turns; for an ideal (100% efficient) transformer $V_p I_p = V_s I_s$
Power is transmitted at high voltage so the current is small: less energy wasted as heat in the cables ($P_{\text{loss}} = I^2 R$).
Electromagnetic induction: an e.m.f. is induced when a conductor cuts magnetic field lines, or the field through a circuit changes; faster cutting, more turns or a stronger magnet give a bigger e.m.f.
Motor effect: a current-carrying wire in a magnetic field feels a force (Fleming's left-hand rule: First finger Field, seCond finger Current, thuMb Motion).
Fuse and earth wire: the fuse melts if the current is too large (pick a rating just above normal current); the earth wire gives fault current a safe path so the case cannot become live
Switches and fuses go in the LIVE wire; double-insulated appliances need no earth wire.

Nuclear physics

Nuclide notation: A_ZX – A = nucleon (mass) number, Z = proton number; decay equations must balance both
Isotope: atoms of the same element with the same proton number but different nucleon numbers (different numbers of neutrons)

Half-life: the time taken for half the nuclei of that isotope in any sample to decay (activity halves each half-life)
Alpha α : helium nucleus (${}^4_2\text{He}$), charge +2, stopped by paper or a few cm of air; most ionising.
Beta β : fast electron from the nucleus (a neutron becomes a proton), charge –1, stopped by a few mm of aluminium.
Gamma γ : electromagnetic wave, no charge or mass, reduced by thick lead or concrete; least ionising, most penetrating.
Alpha and beta deflect opposite ways in electric and magnetic fields; gamma is not deflected.
Background radiation: always-present radiation from radon gas, rocks and buildings, cosmic rays, food, and medical sources; subtract it from measured count rates
Fission vs fusion: fission: a heavy nucleus (e.g. U-235) splits after absorbing a neutron, releasing energy and more neutrons (chain reaction); fusion: light nuclei join at extreme temperature and pressure, powering stars

Space physics

$v = \frac{2\pi r}{T}$ orbital speed; r = orbit radius, T = orbital period
Red-shift: light from distant galaxies is stretched to longer wavelengths, showing the galaxies are moving away; the further away, the faster (evidence for the expanding Universe)
 $H_0 = \frac{v}{d}$ Hubble's law; the age of the Universe is about $\frac{1}{H_0}$ ($d = \frac{v}{H_0}$)
Evidence for the Big Bang: red-shift of galaxies (everything moving apart) and the cosmic microwave background radiation (CMBR), the leftover radiation now stretched into microwaves
Life cycle of a star: nebula, protostar, main-sequence star; a Sun-like star then becomes red giant, planetary nebula, white dwarf; a massive star becomes red supergiant, supernova, then a neutron star or black hole
Light-year: the DISTANCE light travels in one year (about 9.5×10^{15} m)
The Sun: a medium main-sequence star (one of billions in the Milky Way) powered by fusion of hydrogen into helium; planets orbit in ellipses, faster when closer.