

Learn these by heart before the exam.

Motion, forces and energy

$v = \frac{s}{t}$ average speed = total distance $\div$ total time

$a = \frac{\Delta v}{\Delta t}$ unit m/s^2 ; negative value = deceleration

Graphs: distance-time gradient = speed; speed-time gradient = acceleration; area under speed-time = distance.

$\rho = \frac{m}{V}$ kg/m^3 or g/cm^3 ; an object floats when its density < density of the liquid

$W = mg$ $g = 9.8 \text{ N/kg}$ 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 $^\circ\text{C}$; unit $\text{J/(kg } ^\circ\text{C)}$

Specific heat capacity: the energy needed to raise the temperature of 1 kg of a substance by 1 $^\circ\text{C}$

$p_1 V_1 = p_2 V_2$ 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 $^\circ$; 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 $\div$ 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 $3.0 \times 10^8 \text{ m/s}$ 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: ${}_Z^AX$ – 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 (${}_2^4\text{He}$), 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.