

Learn these by heart before the exam.

Thermodynamics

$PV = nRT = Nk_BT$ T must be in kelvin, always

$K_{\text{avg}} = \frac{3}{2}k_BT$, $v_{\text{rms}} = \sqrt{\frac{3k_BT}{m}}$ temperature IS average molecular kinetic energy

$\Delta U = Q + W$ AP sign convention: W is work done ON the gas, so compression is positive

$W = -P\Delta V$ work is the AREA under a PV curve; no area means no work

$Q = mc\Delta T$, $Q = mL$

Second law: entropy of an isolated system never decreases. Heat flows hot to cold on its own.

Isothermal $\Delta U = 0$; adiabatic $Q = 0$; isochoric $W = 0$; isobaric P constant.

Electric Force, Field, and Potential

$F_E = \frac{kq_1q_2}{r^2}$, $k = 9.0 \times 10^9 \text{ N m}^2/\text{C}^2$

$\vec{E} = \frac{\vec{F}_E}{q}$, $E = \frac{kQ}{r^2}$ field points AWAY from positive, TOWARD negative

$U_E = \frac{kq_1q_2}{r}$, $V = \frac{kQ}{r}$, $V = \frac{U_E}{q}$

$E = -\frac{\Delta V}{\Delta r}$, $\Delta U_E = q\Delta V$

Field is a VECTOR, potential is a SCALAR. Two equal charges can give zero field where potential is not zero.

Inside a conductor in equilibrium $E = 0$ and the whole conductor is one equipotential.

Electric Circuits

$I = \frac{\Delta q}{\Delta t}$, $V = IR$, $P = IV = I^2R = \frac{V^2}{R}$

$R = \frac{\rho L}{A}$

$R_s = \sum R_i$, $\frac{1}{R_p} = \sum \frac{1}{R_i}$

$C = \frac{Q}{V}$, $C = \frac{\kappa\epsilon_0 A}{d}$, $U_C = \frac{1}{2}QV = \frac{1}{2}CV^2$

$C_p = \sum C_i$, $\frac{1}{C_s} = \sum \frac{1}{C_i}$ capacitors combine the OPPOSITE way to resistors

Kirchhoff: charge is conserved at a junction

($\sum I_{\text{in}} = \sum I_{\text{out}}$); energy is conserved round a loop ($\sum \Delta V = 0$).

Series shares current; parallel shares voltage.

Magnetism and Electromagnetism

$F_B = qvB \sin \theta$, $F_B = BIL \sin \theta$ use the right hand; reverse it for a negative charge

$B = \frac{\mu_0 I}{2\pi r}$

$\Phi_B = BA \cos \theta$, $\varepsilon = -\frac{\Delta \Phi_B}{\Delta t}$

Lenz: the induced current opposes the CHANGE in flux. The minus sign is the whole physics.

A magnetic force does NO work: it is always perpendicular to v , so it turns but never speeds up.

Geometric Optics

$n = \frac{c}{v}$, $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$\sin \theta_c = \frac{n_2}{n_1}$ only when going from denser to less dense, $n_1 > n_2$

$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$, $M = -\frac{s_i}{s_o} = \frac{h_i}{h_o}$

Sign rules: $f > 0$ converging, $f < 0$ diverging; $s_i > 0$ real image (other side), $s_i < 0$ virtual.

Waves, Sound, and Physical Optics

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

$d \sin \theta = m\lambda$ $m = 0, 1, 2, \dots$; destructive at $(m + \frac{1}{2})\lambda$ /

Standing wave on a string fixed both ends: $\lambda_n = \frac{2L}{n}$. Open-closed pipe: only odd harmonics.

Diffraction and interference need waves. A single slit spreads more when the slit is NARROWER.

Modern Physics

$E = hf = \frac{hc}{\lambda}$, $h = 6.63 \times 10^{-34} \text{ J s}$

$K_{\text{max}} = hf - \phi$ below the threshold frequency NO electron is emitted, however bright the light

$\lambda = \frac{h}{p}$

$E = mc^2$, $\Delta E = \Delta mc^2$ mass defect is the binding energy of the nucleus

Nuclear reactions conserve charge (subscripts) and nucleon number (superscripts). Check both sides balance.

Exam technique

Free-response: name the principle, state the equation, then substitute. Method earns marks even when the

number is wrong.

Circuits: redraw with the combined resistances step by step, then work back to find each branch.

Justify with physics, not with algebra: 'the field is zero because the contributions are equal and opposite' beats a bare calculation.