ACCELERATEPHYSICS

JEE Main Physics Formula Sheet

Chapter wise · free · built for last-week revision

Mathematical Tools

Quantity	Formula
Resultant of two vectors	$R = \sqrt{(A^2 + B^2 + 2AB\cos\theta)}$
Direction of the resultant	$\tan\alpha = B\sin\theta / (A + B\cos\theta)$
Dot product	$A\cdot B = AB\cos\theta$
Cross product	$\lvert A \times B\rvert = AB\sin\theta$
Slope of a graph	velocity = dx/dt, acceleration = dv/dt
Area under a graph	displacement = area under the v–t graph

Units and Measurements

Quantity	Formula
Dimensions worth memorising	$[\text{Force}] = MLT^{-2}$, $[\text{Energy}] = ML^2T^{-2}$, $[\text{Power}] = ML^2T^{-3}$
Error in a sum or difference	the absolute errors add
Error in a product or quotient	the percentage errors add
Error in a power	if $Z = A^pB^\varphi$, then $\Delta Z/Z = p(\Delta A/A) + q(\Delta B/B)$
Vernier least count	1 main scale division − 1 vernier scale division
Screw gauge least count	pitch ÷ number of divisions on the circular scale

Motion in a Straight Line

Quantity	Formula
First equation	$v = u + at$
Second equation	$s = ut + \frac{1}{2}at^2$
Third equation	$v^2 = u^2 + 2as$
Distance in the nth second	$s_n = u + (a/2)(2n - 1)$
Average velocity	total displacement ÷ total time

Motion in a Plane

Quantity	Formula
Time of flight	$T = 2u\sin\theta / g$
Maximum height	$H = u^2\sin^2\theta / 2g$
Range	$R = u^2\sin 2\theta / g$, largest at $\theta = 45°$ where $R = u^2/g$
Equation of the path	a parabola, $y = x\tan\theta - gx^2 / (2u^2\cos^2\theta)$
Centripetal acceleration	$a = v^2/r = \omega^2 r$
Relative velocity	$v_{AB} = v_A - v_B$

Laws of Motion

Quantity	Formula
Newton’s second law	$F = ma = dp/dt$
Impulse	$F\Delta t = \Delta p$
Static and kinetic friction	$f_s(max) = \mu_s N$, $f_k = \mu_k N$
Body in a lift	apparent weight $N = m(g \pm a)$
Banked road, no friction	$v = \sqrt{(rg \tan\theta)}$
Level circular road	$v_{max} = \sqrt{(\mu rg)}$
Vertical circle, top of the loop	$v_{min} = \sqrt{(gr)}$

Work Energy and Power

Quantity	Formula
Work	$W = Fs\cos\theta$
Kinetic energy	$KE = \frac{1}{2}mv^2 = p^2/2m$
Work–energy theorem	$W_{net} = \Delta KE$
Potential energy of a spring	$U = \frac{1}{2}kx^2$
Power	$P = W/t = F \cdot v$
Elastic collision, equal masses	the two velocities are exchanged
Coefficient of restitution	e = relative speed of separation ÷ relative speed of approach

Rotational Motion

Quantity	Formula
Torque and angular momentum	$\tau = I\alpha$, $L = I\omega$
Moments of inertia	ring MR^2, disc $\frac{1}{2}MR^2$, solid sphere $(2/5)MR^2$, hollow sphere $(2/3)MR^2$, rod about its centre $ML^2/12$
Parallel axis theorem	$I = I_{cm} + Md^2$
Perpendicular axis theorem	$I_z = I_x + I_y$, for a flat body
Rolling body, total KE	$KE = \frac{1}{2}mv^2(1 + k^2/R^2)$
Rolling down an incline	$a = g\sin\theta / (1 + k^2/R^2)$
Conservation of angular momentum	$I_1\omega_1 = I_2\omega_2$ when no external torque acts

Centre of Mass

Quantity	Formula
Position of the centre of mass	$x_{cm} = (m_1x_1 + m_2x_2) / (m_1 + m_2)$
Velocity of the centre of mass	$v_{cm} = (m_1v_1 + m_2v_2) / (m_1 + m_2)$
With no external force	v_{cm} does not change, whatever happens inside

Gravitation

Quantity	Formula
Law of gravitation	$F = Gm_1m_2 / r^2$, $G = 6.67 \times 10^{-11}$
g at a height	$g' = g(1 - 2h/R)$ for h much smaller than R
g at a depth	$g' = g(1 - d/R)$
Orbital velocity	$v_o = \sqrt{(GM/r)}$
Escape velocity	$v_e = \sqrt{(2GM/R)} = \sqrt{2} \times v_o$, about 11.2 km/s for the earth
Time period of a satellite	$T^2 = 4\pi^2r^3 / GM$
Energy of a satellite	$E = -GMm / 2r$

Mechanical Properties of Solids

Quantity	Formula
Stress and strain	stress = F/A, strain = Δl/l
Young’s modulus	Y = FL / Al
Extension under a load	l = FL / AY
Bulk modulus	$B = -\Delta P / (\Delta V/V)$, and compressibility = 1/B
Modulus of rigidity	η = shear stress ÷ shear strain
Breaking load	breaking stress × area of cross section

Mechanical Properties of Fluids

Quantity	Formula
Pressure in a liquid	$P = P_0 + h\rho g$
Pascal’s law	pressure applied to an enclosed fluid is passed on undiminished
Buoyant force	= Vρg, the weight of the fluid displaced
Equation of continuity	$A_1v_1 = A_2v_2$
Bernoulli’s principle	$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$
Stokes’ law	$F = 6\pi\eta rv$
Terminal velocity	$v = 2r^2(\rho - \sigma)g / 9\eta$
Excess pressure	drop 2T/r, soap bubble 4T/r
Capillary rise	$h = 2T\cos\theta / r\rho g$

Thermal Properties of Matter

Quantity	Formula
Linear, areal and volume expansion	$\Delta L = L\alpha\Delta T$, $\beta = 2\alpha$, $\gamma = 3\alpha$
Heat gained or lost	$Q = mc\Delta T$
Latent heat	Q = mL; ice 80 cal/g, water 540 cal/g
Principle of calorimetry	heat lost by the hot body = heat gained by the cold body
Conduction	$Q/t = kA(T_1 - T_2) / L$
Thermal resistance	R = L / kA; rods end to end add, rods side by side add as conductances

Thermodynamics

Quantity	Formula
First law	$\Delta Q = \Delta U + \Delta W$
Isothermal process	T constant, $\Delta U = 0$, $W = nRT \ln(V_2/V_1)$
Adiabatic process	$Q = 0$, $PV^{\gamma} = \text{constant}$, $TV^{\gamma-1} = \text{constant}$, $W = (P_1V_1 - P_2V_2)/(\gamma - 1)$
Isochoric process	V constant, $W = 0$, $\Delta Q = \Delta U = nC_v\Delta T$
Isobaric process	P constant, $W = P\Delta V$, $\Delta Q = nC_p\Delta T$
Mayer's relation	$C_p - C_v = R$
Cyclic process	$\Delta U = 0$ over a full cycle, so $Q = W$
Second law	heat does not flow on its own from a colder body to a hotter one

Kinetic Theory of Gases

Quantity	Formula
Ideal gas equation	$PV = nRT$
Pressure of a gas	$P = \frac{1}{3}\rho v^2_rms$
Three speeds	$v_{rms} = \sqrt{(3RT/M)}$, $v_{mean} = \sqrt{(8RT/\pi M)}$, $v_{mp} = \sqrt{(2RT/M)}$
Average kinetic energy per molecule	$= (3/2)kT$
Degrees of freedom	monatomic 3, diatomic 5, and energy per mole $= (f/2)RT$
Specific heats	$C_v = (f/2)R$, $C_p = C_v + R$, $\gamma = 1 + 2/f$
Mean free path	$\lambda = 1 / (\sqrt{2}\, \pi d^2 n)$

Oscillations

Quantity	Formula
Displacement in SHM	$x = A \sin(\omega t + \varphi)$
Velocity and acceleration	$v = \omega\sqrt{(A^2 - x^2)}$, $a = -\omega^2 x$
Spring–mass system	$T = 2\pi\sqrt{(m/k)}$
Simple pendulum	$T = 2\pi\sqrt{(l/g)}$
Springs in combination	parallel $k = k_1 + k_2$, series $1/k = 1/k_1 + 1/k_2$
Energy in SHM	total $= \frac{1}{2}m\omega^2A^2$, kinetic at x is $\frac{1}{2}m\omega^2(A^2 - x^2)$

Waves

Quantity	Formula
Wave speed	$v = f\lambda$
Progressive wave	$y = A \sin(\omega t - kx)$, with $k = 2\pi/\lambda$
Wave on a stretched string	$v = \sqrt{(T/\mu)}$
Sound in a gas	$v = \sqrt{(\gamma P/\rho)}$, and $v \propto \sqrt{T}$
Stationary wave	node to node $= \lambda/2$
Open pipe	$f_n = nv/2L$, every harmonic present
Closed pipe	$f_n = (2n - 1)v/4L$, odd harmonics only

Quantity	Formula
Beats	$f = \lvert f_1 - f_2 \rvert$

Electric Charges and Fields

Quantity	Formula
Coulomb’s law	$F = kq_1q_2 / r^2$, with $k = 9 \times 10^9$
Electric field of a point charge	$E = kq / r^2$
Dipole moment	$p = q \times 2a$
Field of a short dipole	axial $2kp/r^3$, equatorial kp/r^3
Torque on a dipole	$\tau = pE \sin\theta$
Gauss’s law	$\varphi = q_{in} / \varepsilon_0$
Standard fields	infinite sheet $\sigma/2\varepsilon_0$, long wire $\lambda/2\pi\varepsilon_0 r$, inside a conductor zero

Electrostatic Potential and Capacitance

Quantity	Formula
Potential of a point charge	$V = kq / r$
Field from potential	$E = -dV/dr$
Potential of a dipole	$V = kp \cos\theta / r^2$
Capacitance	$C = Q/V$; parallel plate $C = \varepsilon_0 A/d$
With a dielectric	$C = K\varepsilon_0 A/d$
Combinations	series $1/C = \Sigma 1/C_i$, parallel $C = \Sigma C_i$
Energy stored	$U = \frac{1}{2}CV^2 = Q^2/2C$
Energy density	$u = \frac{1}{2}\varepsilon_0 E^2$

Current Electricity

Quantity	Formula
Current and drift velocity	$I = nAev_d$, and mobility $\mu = v_d / E$
Resistance	$R = \rho L / A$, conductivity $\sigma = 1/\rho$
Ohm’s law	$V = IR$
Resistance and temperature	$R = R_0(1 + \alpha\Delta T)$, and α is positive for a metal, negative for a semiconductor
I–V graph	a straight line through the origin for an ohmic conductor, curved for a non-ohmic one
Combinations	series $R = \Sigma R_i$, parallel $1/R = \Sigma 1/R_i$
Cell with internal resistance	$E = I(R + r)$, terminal voltage $V = E - Ir$
Kirchhoff’s laws	at a junction $\Sigma I = 0$; around a loop $\Sigma V = 0$
Wheatstone bridge	balanced when $P/Q = R/S$
Metre bridge	$R/S = l / (100 - l)$
Power	$P = VI = I^2R = V^2/R$

Moving Charges and Magnetism

Quantity	Formula
Force on a moving charge	$F = qvB \sin\theta$
Force on a current-carrying wire	$F = BIL \sin\theta$
Biot–Savart law	$dB = (\mu_0/4\pi)\, I\, dl \sin\theta / r^2$
Long straight wire	$B = \mu_0 I / 2\pi r$
Centre of a circular coil	$B = \mu_0 NI / 2r$
Inside a long solenoid	$B = \mu_0 nI$
Circular path in a magnetic field	$r = mv/qB$, $T = 2\pi m/qB$, and the period does not depend on the speed
Force between parallel wires	$F/L = \mu_0 I_1 I_2 / 2\pi d$
Torque on a current loop	$\tau = NIAB \sin\theta$
Galvanometer conversions	ammeter $S = I^g G/(I - I^g)$, voltmeter $R = V/I^g - G$

Magnetism and Matter

Quantity	Formula
Magnetic moment	$M = NIA$ for a current loop
Axial field of a short magnet	$B = (\mu_0/4\pi)(2M/d^3)$
Equatorial field	$B = (\mu_0/4\pi)(M/d^3)$
Torque and potential energy	$\tau = MB \sin\theta$, $U = -MB \cos\theta$
Work done in turning a magnet	$W = MB(\cos\theta_1 - \cos\theta_2)$
Oscillating magnet	$T = 2\pi\sqrt{(I/MB)}$
Gauss’s law in magnetism	the net magnetic flux through any closed surface is zero
Three classes	diamagnetic, paramagnetic, ferromagnetic; above its Curie temperature a ferromagnetic substance turns paramagnetic

Electromagnetic Induction

Quantity	Formula
Magnetic flux	$\varphi = BA \cos\theta$
Faraday’s law	$e = -\, d\varphi/dt$
Motional emf	$e = Bvl$
Self inductance	$e = -L\, dI/dt$, energy stored $= \frac{1}{2}LI^2$
Inductance of a solenoid	$L = \mu_0 n^2 Al$
Mutual inductance	$e = -M\, dI_1/dt$
Lenz’s law	the induced current opposes the change that caused it

Alternating Current

Quantity	Formula
Instantaneous current	$I = I_0 \sin\omega t$
Root mean square values	$I_{rms} = I_0/\sqrt{2}$, $V_{rms} = V_0/\sqrt{2}$
Average over a half cycle	$2I_0/\pi$

Quantity	Formula
Reactances	$X_L = \omega L$, $X_C = 1/\omega C$
Impedance and phase	$Z = \sqrt{(R^2 + (X_L - X_C)^2)}$, $\tan\varphi = (X_L - X_C)/R$
Resonance	$f = 1 / 2\pi\sqrt{(LC)}$; at resonance $Z = R$ and the current is largest
Average power	$P = V_{rms}\, I_{rms} \cos\varphi$, with power factor $\cos\varphi = R/Z$
Transformer	$V_s/V_p = N_s/N_p$

Electromagnetic Waves

Quantity	Formula
Speed in vacuum	$c = 1/\sqrt{(\mu_0\varepsilon_0)} = 3 \times 10^8$ m/s
Speed in a medium	$v = 1/\sqrt{(\mu\varepsilon)}$
Field ratio	$E_0 / B_0 = c$
Direction	E, B and the direction of travel are mutually perpendicular
Intensity	$I = \frac{1}{2}\varepsilon_0 E_0^2 c$
Radiation pressure	I/c when fully absorbed, 2I/c when fully reflected
Displacement current	$I_d = \varepsilon_0\, d\varphi_E/dt$
Spectrum, longest wavelength first	radio, microwave, infrared, visible, ultraviolet, X-ray, gamma; visible is about 400 to 700 nm

Ray Optics

Quantity	Formula
Mirror formula	$1/v + 1/u = 1/f$, with $f = R/2$
Magnification by a mirror	$m = -v/u$
Lens formula	$1/v - 1/u = 1/f$, and $m = v/u$
Lens maker’s formula	$1/f = (\mu - 1)(1/R_1 - 1/R_2)$
Power of a lens	$P = 1/f$ in metres; lenses in contact $P = P_1 + P_2$
Refraction	$\mu = \sin i / \sin r$, and $\mu = c/v$
Critical angle	$\sin C = 1/\mu$
Prism at minimum deviation	$\mu = \sin((A + \delta_m)/2) \div \sin(A/2)$; for a thin prism $\delta = (\mu - 1)A$
Simple microscope	$M = 1 + D/f$, with D = 25 cm
Compound microscope	$M = (v_0/u_0)(1 + D/f_e)$, tube length $L = v_0 + f_e$
Astronomical telescope	$M = f_0/f_e$ in normal adjustment, tube length $L = f_0 + f_e$

Wave Optics

Quantity	Formula
Fringe width	$\beta = \lambda D/d$
Maxima and minima	path difference $n\lambda$ for a bright fringe, $(2n - 1)\lambda/2$ for a dark one
Intensity in interference	$I = 4I_0\cos^2(\varphi/2)$
Ratio of maximum to minimum	$I_{max}/I_{min} = (\sqrt{I_1} + \sqrt{I_2})^2 \div (\sqrt{I_1} - \sqrt{I_2})^2$
Single slit diffraction	first minimum at $\sin\theta = \lambda/a$; width of the central maximum $= 2\lambda D/a$

Quantity	Formula
Brewster’s law	$\tan i_p = \mu$
Malus’s law	$I = I_0\cos^2\theta$

Dual Nature of Radiation and Matter

Quantity	Formula
Energy of a photon	$E = hf = hc/\lambda$; $hc = 1240$ eV·nm
Photoelectric equation	$hf = \varphi + KE_{max}$
Stopping potential	$KE_{max} = eV_0$
Threshold	$\varphi = hf_0 = hc/\lambda_0$
Momentum of a photon	$p = h/\lambda = E/c$
de Broglie wavelength	$\lambda = h/p = h/mv$
Electron accelerated through V	$\lambda = 12.27/\sqrt{V}$ Å

Atoms

Quantity	Formula
Bohr’s quantisation	$mvr = nh/2\pi$
Radius of the nth orbit	$r_n = 0.529\ n^2/Z$ Å
Energy of the nth level	$E_n = -13.6\ Z^2/n^2$ eV
Energy of a transition	$E = 13.6\ Z^2(1/n_1^2 - 1/n_2^2)$ eV
Rydberg formula	$1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$, $R = 1.097 \times 10^7\ m^{-1}$
Series	Lyman ultraviolet ($n_1 = 1$), Balmer visible ($n_1 = 2$), Paschen infrared ($n_1 = 3$)
Speed in the nth orbit	$v_n \propto Z/n$, and $v_1 = c/137$

Nuclei

Quantity	Formula
Nuclear radius	$R = R_0A\hat{}(1/3)$, $R_0 = 1.2$ fm
Nuclear density	about 2.3×10^{17} kg/m³, the same for every nucleus
Mass defect	$\Delta m = [Zm_p + (A - Z)m_n] - M$
Binding energy	$BE = \Delta m \times 931.5$ MeV
Mass–energy equivalence	1 u = 931.5 MeV
Peak of the binding energy curve	about 8.8 MeV per nucleon, near A = 56
Q value of a reaction	Q = (mass of reactants − mass of products) × 931.5 MeV
Energy released	about 200 MeV per fission of uranium-235; about 26 MeV when four hydrogen nuclei build one helium nucleus

Semiconductor Electronics

Quantity	Formula
Diode	conducts in forward bias, blocks in reverse bias
Rectifier output frequency	half wave = input frequency, full wave = twice the input frequency
Zener diode	works in reverse breakdown and holds the voltage steady
Other diodes	LED gives out light, photodiode works in reverse bias, solar cell makes an emf with no bias
Logic gates	AND = A·B, OR = A + B, NOT = $\bar{A}$; NAND and NOR are the universal gates
De Morgan	the complement of a sum is the product of the complements, and the other way round