Physics Formulas Handbook

Complete Formula Reference · Class 9, 10, 11 & 12 · JEE · NEET · Board Examinations

How to read the formulas: Fractions are written with "/"; powers use superscript notation such as v^2; √ means square root; Δ means change in a quantity. Formula symbols retain the meanings used in the reference handbook.

1. Units, Dimensions & Measurement

Topic	Formula
Density	$\rho = m / V$
Relative error (a)	$\Delta a / a$
Relative error for $f = x^p y^q / z^r$	$\Delta f / f = p(\Delta x / x) + q(\Delta y / y) + r(\Delta z / z)$
Mean value	$\bar{a} = (a_1 + a_2 + \ldots + a_n) / n$
Dimensions of force	$[\text{Force}] = M\, L\, T^{-2}$
Dimensions of energy	$[\text{Energy}] = M\, L^2\, T^{-2}$
Dimensions of power	$[\text{Power}] = M\, L^2\, T^{-3}$

2. Kinematics

Topic	Formula
Uniform acceleration (1-D)	$v = u + at$
Displacement	$s = ut + (1/2)at^2$
Velocity without time	$v^2 = u^2 + 2as$
Distance in nth second	$s_n = u + (a/2)(2n - 1)$
Time of flight (projectile)	$T = 2u \sin\theta / g$
Maximum height (projectile)	$H = u^2 \sin^2\theta / (2g)$
Range (projectile)	$R = u^2 \sin 2\theta / g$
Projectile trajectory	$y = x \tan\theta - gx^2 / (2u^2 \cos^2\theta)$
Relative velocity	$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$
Resultant of two vectors	$R = \sqrt{(A^2 + B^2 + 2AB\cos\theta)}$
Dot product	$\vec{A} \cdot \vec{B} = AB\cos\theta$
Cross product magnitude	$\lvert\vec{A} \times \vec{B}\rvert = AB\sin\theta$

3. Laws of Motion & Friction

Topic	Formula
Newton's second law	$\vec{F} = m\,\vec{a} = d\,\vec{p} / dt$
Momentum	$\vec{p} = m\,\vec{v}$
Impulse	$\vec{J} = \vec{F}\,\Delta t = \Delta\vec{p}$
Static friction	$f_s \leq \mu_s N$
Kinetic friction	$f_k = \mu_k N$
Angle of repose	$\tan\theta = \mu_s$
Acceleration on incline	$a = g(\sin\theta - \mu\cos\theta)$

4. Work, Energy & Power

Topic	Formula
Work	$W = \vec{F} \cdot \vec{s} = Fs\cos\theta$
Kinetic energy	$K = 1/2\ mv^2 = p^2 / (2m)$
Potential energy	$U = mgh$
Spring potential energy	$U = 1/2\ kx^2$
Work-energy theorem	$W_{net} = \Delta K$
Power	$P = W / t = \vec{F} \cdot \vec{v}$

5. Circular Motion

Topic	Formula
Angular velocity	$\omega = d\theta / dt$
Tangential speed	$v = r\omega$
Centripetal acceleration	$a_c = v^2 / r = \omega^2 r$
Centripetal force	$F_c = mv^2 / r$
Banking angle (ideal)	$\tan\theta = v^2 / (rg)$
Maximum speed on banked road with friction	$v_{max} = \sqrt{[rg(\mu + \tan\theta) / (1 - \mu\tan\theta)]}$

6. Centre of Mass & Collisions

Topic	Formula
Centre of mass	$x_{cm} = (\Sigma\, m_i x_i) / (\Sigma\, m_i)$
Momentum conservation (1-D)	$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
Coefficient of restitution	$e = (v_2 - v_1) / (u_1 - u_2)$
Equal masses, 1-D elastic collision	$v_1 = u_2;\ v_2 = u_1$
1-D elastic collision: final velocity of mass 1	$v_1 = [(m_1 - m_2)u_1 + 2m_2u_2] / (m_1 + m_2)$

7. Rotational Motion

Topic	Formula
Torque	$\vec{\tau} = \vec{r} \times \vec{F}$; magnitude $\tau = rF \sin\theta$
Moment of inertia	$I = \Sigma m_i r_i^2$
Angular momentum	$L = I\omega$; $\tau = dL / dt$
Rotational kinetic energy	$K = 1/2\ I\omega^2$
Parallel-axis theorem	$I = I_cm + Md^2$
Rolling speed	$v_cm = r\omega$
Rolling kinetic energy	$K = 1/2\ mv^2\ [1 + I / (mr^2)]$
Ring (about centre)	$I = MR^2$
Disc (about centre)	$I = 1/2\ MR^2$
Solid sphere (about centre)	$I = 2/5\ MR^2$
Spherical shell (about centre)	$I = 2/3\ MR^2$
Rod (about centre)	$I = 1/12\ ML^2$

8. Gravitation

Topic	Formula
Newton's law of gravitation	$F = Gm_1m_2 / r^2$
Gravitational field / acceleration	$g = GM / r^2$
Gravity at height h (approx. near surface)	$g_h = g[1 - 2h / R]$
Gravity at depth d (uniform-density model)	$g_d = g[1 - d / R]$
Gravitational potential	$V = -GM / r$
Orbital velocity	$v_o = \sqrt{(GM / r)}$
Escape velocity	$v_e = \sqrt{(2GM / R)} = \sqrt{(2gR)}$
Kepler's third law	$T^2 \propto r^3$

9. Elasticity (Solids)

Topic	Formula
Stress	Stress = F / A
Strain	Strain = ΔL / L
Young's modulus	Y = FL / (A ΔL)
Bulk modulus	B = -ΔP / (ΔV / V)
Shear modulus	η = (F / A) / θ
Elastic potential energy per volume	u = 1/2 × stress × strain

10. Mechanical Properties of Fluids

Topic	Formula
Pressure at depth	$P = P_0 + \rho g h$
Pascal's principle	Pressure is transmitted equally through an enclosed fluid
Buoyant force	$F_B = \rho_{fluid} V_{displaced} g$
Continuity equation	$A_1 v_1 = A_2 v_2$
Bernoulli's equation	$P + 1/2 \rho v^2 + \rho g h = constant$
Surface tension	$T = F / L$
Excess pressure inside a liquid drop	$\Delta P = 2T / r$
Excess pressure inside a soap bubble	$\Delta P = 4T / r$
Capillary rise	$h = 2T \cos \theta / (\rho g r)$
Stokes' drag force	$F = 6\pi\eta r v$
Terminal speed of a sphere	$v_t = 2r^2(\rho - \sigma)g / (9\eta)$

11. Thermal Properties & Calorimetry

Topic	Formula
Linear expansion	$\Delta L = L\alpha\Delta T$
Expansion coefficients (isotropic solid)	$\beta = 2\alpha$; $\gamma = 3\alpha$
Heat	$Q = mc\Delta T$
Latent heat	$Q = mL$
Heat conduction rate	$Q / t = kA\Delta T / L$
Stefan–Boltzmann law	$E = \sigma T^4$
Wien's displacement law	$\lambda_{max} T = b$

12. Thermodynamics

Topic	Formula
First law (handbook convention)	$\Delta Q = \Delta U + \Delta W$
Work by a gas	$W = \int P \, dV$
Isobaric work	$W = P\Delta V$
Isothermal work (ideal gas)	$W = nRT \ln(V_2 / V_1)$
Adiabatic relation	$PV^\gamma = constant$
Adiabatic work	$W = (P_1V_1 - P_2V_2) / (\gamma - 1)$
Mayer's relation	$C_P - C_V = R$
Heat capacity ratio	$\gamma = C_P / C_V$
Heat-engine efficiency	$\eta = 1 - Q_2 / Q_1$
Carnot efficiency	$\eta = 1 - T_2 / T_1$

13. Kinetic Theory of Gases

Topic	Formula
Ideal gas	$PV = nRT = Nk_B T$
Gas pressure	$P = (1/3)\rho v_{rms}^2$
RMS speed	$v_{rms} = \sqrt{(3RT / M)} = \sqrt{(3k_B T / m)}$
Average speed	$v_{avg} = \sqrt{(8RT / (\pi M))}$
Most probable speed	$v_{mp} = \sqrt{(2RT / M)}$
Average kinetic energy per molecule	$KE = 3/2\ k_B T$
Equipartition energy per degree of freedom	$1/2\ k_B T$

14. Oscillations (SHM)

Topic	Formula
Displacement	$x = A \sin(\omega t + \varphi)$
Restoring acceleration	$a = -\omega^2 x$
Speed	$v = \omega\sqrt{(A^2 - x^2)}$
Time period	$T = 2\pi / \omega$
Total energy	$E = 1/2\ m\omega^2 A^2$
Spring-mass period	$T = 2\pi\sqrt{(m / k)}$
Simple pendulum period	$T = 2\pi\sqrt{(L / g)}$

15. Waves & Sound

Topic	Formula
Wave speed	$v = f\lambda = \omega / k$
Wave equation	$y = A \sin(\omega t - kx)$
Wave speed on a string	$v = \sqrt{(T / \mu)}$
Sound speed in a gas	$v = \sqrt{(\gamma P / \rho)}$
String harmonics	$f_n = nv / (2L)$
Open pipe harmonics	$f_n = nv / (2L)$
Closed pipe harmonics	$f_n = (2n - 1)v / (4L)$
Beat frequency	$f_{beat} = \lvert f_1 - f_2 \rvert$
Doppler effect (common 1-D form)	$f' = f\ (v \pm v_o) / (v \mp v_s)$

16. Electrostatics

Topic	Formula
Coulomb's law	$F = (1 / 4\pi\varepsilon_0) \times \lvert q_1 q_2 \rvert / r^2$
Electric field	$E = F / q = kq / r^2$
Electric potential of point charge	$V = kq / r$
Potential-field relation	$E = -dV / dr$
Electric dipole moment	$p = q(2a)$
Dipole field (axial, far away)	$E = 2kp / r^3$
Dipole field (equatorial, far away)	$E = kp / r^3$ (magnitude)
Torque on dipole	$\tau = pE \sin\theta$
Gauss's law	$\oint \vec{E} \cdot d\vec{A} = q_{in} / \varepsilon_0$
Potential energy of two charges	$U = kq_1 q_2 / r$

17. Capacitance

Topic	Formula
Capacitance	$C = Q / V$
Parallel-plate capacitor	$C = \varepsilon_0 A / d$
With dielectric	$C = K\varepsilon_0 A / d$
Capacitors in series	$1 / C_{eq} = \Sigma(1 / C_i)$
Capacitors in parallel	$C_{eq} = \Sigma C_i$
Stored energy	$U = 1/2\ CV^2 = Q^2 / (2C)$
Energy density	$u = 1/2\ \varepsilon_0 E^2$

18. Current Electricity

Topic	Formula
Current	$I = Q / t = nAev_d$
Ohm's law	$V = IR$
Resistance of a wire	$R = \rho L / A$
Drift speed	$v_d = eE\tau / m$
Resistors in series	$R_{eq} = \Sigma R_i$
Resistors in parallel	$1 / R_{eq} = \Sigma(1 / R_i)$
Power	$P = VI = I^2R = V^2 / R$
Cell with internal resistance	$\varepsilon = I(R + r)$
Wheatstone bridge (balanced)	$P / Q = R / S$
Kirchhoff's junction rule	$\Sigma I = 0$
Kirchhoff's loop rule	$\Sigma\varepsilon = \Sigma IR$

19. Moving Charges & Magnetism

Topic	Formula
Lorentz force (magnetic part)	$\vec{F} = q(\vec{v} \times \vec{B})$
Force on current-carrying wire	$\vec{F} = I(\vec{L} \times \vec{B})$
Biot–Savart law	$dB = (\mu_0 / 4\pi) \times (I\, dl \sin\theta / r^2)$
Magnetic field of a straight wire	$B = \mu_0 I / (2\pi r)$
Field at centre of circular loop	$B = \mu_0 I / (2R)$
Field inside a solenoid	$B = \mu_0 n I$
Ampère's law	$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$
Cyclotron radius	$r = mv / (qB)$
Cyclotron frequency	$f = qB / (2\pi m)$

20. Magnetism & Matter

Topic	Formula
Magnetic dipole moment	$M = NIA$
Torque on magnetic dipole	$\tau = MB \sin\theta$
Magnetic potential energy	$U = -MB \cos\theta$
Magnetic field relation	$B = \mu_0(H + M)$
Permeability and susceptibility	$\mu = \mu_0(1 + \chi)$

21. Electromagnetic Induction

Topic	Formula
Magnetic flux	$\Phi = BA \cos\theta$
Faraday's law	$\varepsilon = -d\Phi / dt$
Motional EMF	$\varepsilon = Bvl$
Self-induction EMF	$\varepsilon = -L\, dI / dt$
Inductance of a solenoid	$L = \mu_0 n^2 Al$
Mutual induction EMF	$\varepsilon_2 = -M\, dI_1 / dt$
Energy stored in an inductor	$U = 1/2\ LI^2$

22. Alternating Current

Topic	Formula
RMS current	$I_{rms} = I_0 / \sqrt{2}$
RMS voltage	$V_{rms} = V_0 / \sqrt{2}$
Inductive reactance	$X_L = \omega L$
Capacitive reactance	$X_C = 1 / (\omega C)$
Impedance	$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$
Phase angle	$\tan \varphi = (X_L - X_C) / R$
Average power	$P = V_{rms} I_{rms} \cos \varphi$
Resonant angular frequency	$\omega_0 = 1 / \sqrt{(LC)}$
Quality factor (series RLC)	$Q = (1 / R)\sqrt{(L / C)}$
Ideal transformer	$V_s / V_p = N_s / N_p = I_p / I_s$

23. Electromagnetic Waves

Topic	Formula
Wave speed	$c = 1 / \sqrt{(\mu_0 \varepsilon_0)} = E_0 / B_0$
Energy density	$u = 1/2\ \varepsilon_0 E^2 + B^2 / (2\mu_0)$
Intensity	$I = 1/2\ \varepsilon_0 c E_0^2$
Spectrum order	γ-rays < X-rays < UV < visible < IR < microwaves < radio waves

24. Ray Optics

Topic	Formula
Mirror equation	$1 / v + 1 / u = 1 / f$
Thin-lens equation (handbook convention)	$1 / v - 1 / u = 1 / f$
Magnification (mirror)	$m = h' / h = -v / u$
Refractive index	$n = c / v = \sin i / \sin r$
Critical angle (to air)	$\sin \theta_c = 1 / n$
Lens maker's equation	$1 / f = (n - 1)(1 / R_1 - 1 / R_2)$
Lens power (f in metres)	$P = 1 / f$ (dioptres)
Lenses in contact	$P = P_1 + P_2$
Prism deviation (small-angle approximation)	$\delta = (n - 1)A$
Prism refractive index at minimum deviation	$n = \sin[(A + \delta_m) / 2] / \sin(A / 2)$

25. Wave Optics

Topic	Formula
Young's double-slit fringe width	$\beta = \lambda D / d$
Path difference for maxima	$\Delta = n\lambda$
Path difference for minima	$\Delta = (2n - 1)\lambda / 2$
Interference intensity	$I = I_1 + I_2 + 2\sqrt{(I_1 I_2)} \cos \varphi$
Single-slit diffraction minima	$a \sin \theta = n\lambda$
Resolving power (proportionality)	Resolving power $\propto 1 / \lambda$
Brewster's law	$\tan \theta_p = n$

26. Dual Nature of Matter

Topic	Formula
Photon energy	$E = h\nu = hc / \lambda$
Photoelectric equation	$h\nu = \varphi_0 + K_{max}$
Stopping potential	$eV_0 = K_{max}$
Threshold frequency	$\nu_0 = \varphi_0 / h$
de Broglie wavelength	$\lambda = h / p = h / (mv)$
Electron wavelength (accelerated through V)	$\lambda \approx 12.27 / \sqrt{V}$ Å

27. Atoms & Nuclei

Topic	Formula
Bohr radius scaling	$r_n \propto n^2$
Hydrogen energy levels	$E_n = -13.6 / n^2$ eV
Rydberg formula	$1 / \lambda = R(1 / n_1^2 - 1 / n_2^2)$
Nuclear radius	$R = R_0 A^{(1/3)}$
Mass-energy equivalence	$E = mc^2$; 1 u $\approx$ 931.5 MeV/c^2
Radioactive decay	$N = N_0 e^{(-\lambda t)}$
Half-life	$t_{1/2} = 0.693 / \lambda$
Mean life	$\tau = 1 / \lambda$
Activity	$A = \lambda N$

28. Semiconductor Electronics

Topic	Formula
Mass-action law	$n_e n_h = n_i^2$
Diode current	$I = I_0 [e^(eV / k_B T) - 1]$
Transistor current	$I_E = I_B + I_C$
Current gain alpha	$\alpha = I_C / I_E$
Current gain beta	$\beta = I_C / I_B = \alpha / (1 - \alpha)$
Voltage gain	$A_V = \beta(R_{out} / R_{in})$
Logic operations	AND: A · B; OR: A + B; NAND: NOT(A · B); NOR: NOT(A + B)

Important Constants

Topic	Formula
Gravitational acceleration	$g \approx 9.8\ m/s^2$
Speed of light	$c \approx 3 \times 10^8\ m/s$
Gravitational constant	$G \approx 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$
Elementary charge	$e \approx 1.6 \times 10^{-19}\ C$
Planck constant	$h \approx 6.63 \times 10^{-34}\ J \cdot s$