44 DERIVATIONS

Derivations you must know

Class 12 Physics. Where each one starts, the step that matters, and where it must end.

DERIVE	START FROM	KEY STEP	END WITH
Chapter 1 · Electric Charges and Fields			
Field on the axial line of a dipole	Coulomb's law for each charge at distance $r \mp a$	Subtract the two fields; simplify $1/(r-a)^2 - 1/(r+a)^2 = 4ar/(r^2-a^2)^2$	**$E = 2kpr/(r^2-a^2)^2 \approx 2kp/r^3$**
Field on the equatorial line of a dipole	Equal fields from $\pm q$ at distance $\sqrt{(r^2+a^2)}$	Vertical parts cancel; horizontal parts add: $2E\cos\theta$ with $\cos\theta = a/\sqrt{(r^2+a^2)}$	**$E = kp/(r^2+a^2)^{3/2} \approx kp/r^3$, opposite to p**
Torque on a dipole in a uniform field	Forces $+qE$ and $-qE$ on the two ends	Net force zero; the couple has arm $2a\sin\theta$	**$\tau = pE\sin\theta$, $\tau = p \times E$**
Field of an infinite line charge	Gauss's law, cylindrical surface of radius r, length l	Flux only through the curved face: $E\cdot 2\pi rl = \lambda l/\varepsilon_0$	**$E = \lambda/(2\pi\varepsilon_0 r)$**
Field of an infinite plane sheet	Gauss's law, cylinder through the sheet	Flux through both flat ends: $2EA = \sigma A/\varepsilon_0$	**$E = \sigma/(2\varepsilon_0)$**
Field of a thin spherical shell	Gauss's law, sphere of radius r	$r > R$: $E\cdot 4\pi r^2 = Q/\varepsilon_0$; $r < R$: no charge enclosed	**$E = kQ/r^2$ outside, 0 inside**
Chapter 2 · Electrostatic Potential and Capacitance			
Potential of a point charge	$V = -\int E\cdot dr$ from ∞ to r	Integrate $kq/r^2\, dr$	**$V = kq/r$**
Potential of a dipole	Add $kq/r_1 - kq/r_2$	For $r \gg a$, $r_1 - r_2 \approx 2a\cos\theta$ and $r_1 r_2 \approx r^2$	**$V = kp\cos\theta/r^2$**
Capacitance of a parallel-plate capacitor	$E = \sigma/\varepsilon_0$ between the plates	$V = Ed = Qd/(\varepsilon_0 A)$; $C = Q/V$	**$C = \varepsilon_0 A/d$**
Capacitor with a dielectric slab	Field in the gap E_0, in the slab E_0/K	$V = E_0(d - t) + (E_0/K)t$	**$C = \varepsilon_0 A/(d - t + t/K)$**
Series and parallel combinations	Series: same Q; parallel: same V	Add the voltages or the charges	**$1/C = \Sigma 1/C_i$; $C = \Sigma C_i$**
Energy stored in a capacitor	Work to move dq against $V = q/C$	$W = \int_0^Q (q/C)\, dq$	**$U = Q^2/2C = \frac{1}{2}CV^2$; $u = \frac{1}{2}\varepsilon_0 E^2$**
Chapter 3 · Current Electricity			
Drift velocity and current	Acceleration eE/m for mean time τ	$v_d = eE\tau/m$; charge crossing area A per second	**$I = neAv_d$**
Ohm's law and resistivity from drift	$I = neA(eE\tau/m)$ with $E = V/l$	Rearrange to $V = I\cdot[m/(ne^2\tau)]\cdot l/A$	**$\rho = m/(ne^2\tau)$**
Cells in series and in parallel	Kirchhoff's loop rule	Series: add emfs and r; parallel: equal terminal voltage	**$E_{eq} = (E_1 r_2 + E_2 r_1)/(r_1 + r_2)$ for parallel**

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Balance condition of a Wheatstone bridge	Kirchhoff's rules with $I_g = 0$	Same current through P and Q, and through R and S	**$P/Q = R/S$**
Chapter 4 · Moving Charges and Magnetism			
Field on the axis of a circular loop	Biot–Savart law for each element dl	Perpendicular parts cancel; axial parts add with $\sin\varphi = R/\sqrt{(R^2+x^2)}$	**$B = \mu_0 I R^2/[2(R^2+x^2)^{3/2}]$**
Field of a long straight wire	Ampère's law, circle of radius r	$B \cdot 2\pi r = \mu_0 I$	**$B = \mu_0 I/(2\pi r)$**
Field inside a long solenoid	Ampère's law, rectangular loop	Only the side inside contributes: $Bl = \mu_0(nl)I$	**$B = \mu_0 nI$**
Force between two parallel wires	Field of wire 1 at wire 2 = $\mu_0 I_1/(2\pi d)$	$F = I_2 l B_1$	**$F/l = \mu_0 I_1 I_2/(2\pi d)$; same direction attract**
Torque on a current loop	Forces on the four sides of a rectangle in B	Two sides form a couple with arm $b \sin\theta$	**$\tau = NIAB \sin\theta = m \times B$**
Galvanometer as ammeter and voltmeter	G carries only I_g at full scale	Shunt in parallel takes $I - I_g$; series R drops the rest of V	**$S = I_g G/(I - I_g)$; $R = V/I_g - G$**
Chapter 6 · Electromagnetic Induction			
Motional emf	Flux through the circuit $\Phi = Blx$	$\varepsilon = -d\Phi/dt$ with $dx/dt = v$ (or: force on charges qvB)	**$\varepsilon = Blv$**
Self-inductance of a long solenoid	$B = \mu_0 nI$ inside	$N\Phi = (nl)(\mu_0 nI)A = LI$	**$L = \mu_0 n^2 Al$**
Mutual inductance of two coaxial solenoids	Field of the inner one $B_1 = \mu_0 n_1 I_1$	Flux linkage of the outer: $(n_2 l)B_1 A_1 = MI_1$	**$M = \mu_0 n_1 n_2 A_1 l$**
Energy stored in an inductor	Work against $\varepsilon = L\,dI/dt$	$W = \int_0^I LI\,dI$	**$U = \frac{1}{2}LI^2$**
Emf of an AC generator	$\Phi = NBA\cos\omega t$	$\varepsilon = -d\Phi/dt$	**$\varepsilon = NBA\omega \sin\omega t$**
Chapter 7 · Alternating Current			
Impedance of a series LCR circuit	Phasors: V_R with I, V_L ahead by 90°, V_C behind by 90°	$V^2 = V_R^2 + (V_L - V_C)^2$	**$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$, $\tan\varphi = (X_L - X_C)/R$**
Resonance	Z is least when $X_L = X_C$	$\omega L = 1/(\omega C)$	**$\omega_0 = 1/\sqrt{(LC)}$**
Average power	$p = vi$ with $v = V_m \sin\omega t$, $i = I_m \sin(\omega t - \varphi)$	Average of $\sin\omega t \cdot \sin(\omega t - \varphi)$ over a cycle is $\frac{1}{2}\cos\varphi$	**$P = V_{rms} I_{rms} \cos\varphi$**
Ideal transformer ratios	Same flux change per turn in both coils	$\varepsilon_s/\varepsilon_p = N_s/N_p$; no loss: $V_p I_p = V_s I_s$	**$V_s/V_p = N_s/N_p = I_p/I_s$**
Chapter 9 · Ray Optics and Optical Instruments			
Mirror formula	Similar triangles in a ray diagram of a concave mirror	Use $f = R/2$ and small angles	**$1/v + 1/u = 1/f$**
Refraction at a spherical surface	Snell's law at the surface, small angles	$n_1 i = n_2 r$ with $i = \alpha + \gamma$, $r = \gamma - \beta$	**$n_2/v - n_1/u = (n_2 - n_1)/R$**
Lens maker's formula	Apply the spherical-surface formula to each face	The image of face 1 is the object for face 2; add	**$1/f = (n - 1)(1/R_1 - 1/R_2)$**

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Thin lens formula	Lens maker's result with u = ∞ giving f	Combine the two surface equations for any u	**$1/v - 1/u = 1/f$**
Two thin lenses in contact	Image of lens 1 is the object for lens 2	Add the two lens equations	**$1/f = 1/f_1 + 1/f_2$, $P = P_1 + P_2$**
Prism formula	At minimum deviation $r_1 = r_2 = A/2$, $i = e$	$A + D_m = 2i$	**$n = \sin[(A + D_m)/2]/\sin(A/2)$**
Magnifying power of microscope and telescope	Ray diagrams with the final image at infinity	Angle at the eye with and without the instrument	**Microscope $m \approx (L/f_o)(D/f_e)$; telescope $m = f_o/f_e$**
Chapter 10 · Wave Optics			
Laws of reflection and refraction from Huygens	Plane wavefront meeting a surface; secondary wavelets	Equal times for the two edges: $\sin i/\sin r = v_1/v_2$	**$i = r$; $n_1 \sin i = n_2 \sin r$**
Fringe width in Young's experiment	Path difference $S_2P - S_1P = yd/D$	Bright when $yd/D = n\lambda$; subtract neighbours	**$\beta = \lambda D/d$**
Chapter 11 · Dual Nature of Radiation and Matter			
de Broglie wavelength of an accelerated electron	$K = eV = p^2/2m$	$p = \sqrt{(2meV)}$; $\lambda = h/p$	**$\lambda = h/\sqrt{(2meV)} = 1.227/\sqrt{V}$ nm**
Chapter 12 · Atoms			
Radius of the nth Bohr orbit	$mv^2/r = kZe^2/r^2$ and $mvr = nh/2\pi$	Eliminate v	**$r_n = n^2h^2\varepsilon_0/(\pi mZe^2) = 0.529\ n^2/Z$ Å**
Energy of the nth orbit	$KE = \frac{1}{2}mv^2 = kZe^2/2r$, $PE = -kZe^2/r$	$E = KE + PE = -kZe^2/2r$; put in r_n	**$E_n = -13.6\ Z^2/n^2$ eV**
Chapter 13 · Nuclei			
Nuclear density is the same for all nuclei	Mass ≈ Am, volume $(4/3)\pi R_0^3 A$	$\rho = Am / [(4/3)\pi R_0^3 A]$: A cancels	**$\rho \approx 2.3 \times 10^{17}$ kg/m³**

How to use this list

Cover the last two columns and try each derivation on paper. In the exam, draw the diagram first and state the law you start from: both earn marks even if the algebra slips. Chapters 5, 8 and 14 have no long derivations in the NCERT book; learn their results and diagrams from the Revision Sheets. Always check this list against the current year's CBSE or ISC syllabus, which can delete or add topics.