

Electrostatics & Electromagnetism Sheet

Class 12 • JEE Main & Advanced • NEET | by Anish Kumar Sir

Electric Charge & Field

TOPIC	FORMULA	CONCEPT
Coulomb's law	$F = kq_1q_2/r^2$, $k = 1/(4\pi\epsilon_0) = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$	Central, inverse-square force; in a medium F reduces by factor K .
Quantisation	$q = ne$, $e = 1.6 \times 10^{-19} \text{ C}$	Charge always comes in whole multiples of e .
Electric field	$E = F/q_0$; point charge $E = kq/r^2$	Force per unit positive test charge; vector sum for many charges.
Ring (on axis)	$E = kQx / (R^2 + x^2)^{3/2}$	Zero at centre; maximum at $x = R/\sqrt{2}$.
Infinite line charge	$E = \lambda / (2\pi\epsilon_0 r)$	Falls as $1/r$; found with a cylindrical Gaussian surface.
Infinite sheet	$E = \sigma / (2\epsilon_0)$	Independent of distance: uniform field.
Conductor surface	$E = \sigma / \epsilon_0$	Field inside a conductor is zero; charge sits on the surface.
Charged sphere (shell)	$E = kQ/r^2$ ($r \geq R$), $E = 0$ inside	Behaves like a point charge at its centre from outside.
Solid sphere (uniform)	$E = kQr/R^3$ inside	Field grows linearly inside, peaks at surface.

Gauss's Law & Dipole

TOPIC	FORMULA	CONCEPT
Electric flux	$\Phi = \oint \mathbf{E} \cdot d\mathbf{A}$	Counts field lines crossing a surface.
Gauss's law	$\Phi = q_{\text{enc}} / \epsilon_0$	Only enclosed charge matters; outside charges give zero net flux.
Dipole moment	$p = q \times 2a$ (from $-q$ to $+q$)	Vector points from negative to positive charge.
Axial field	$E = 2kp / r^3$	Twice the equatorial value at the same distance ($r \gg a$).
Equatorial field	$E = kp / r^3$ (opposite to p)	Field on the perpendicular bisector.
Torque on dipole	$\tau = p \times E = pE \sin\theta$	Rotates dipole to align with field; net force zero in uniform E .
Dipole energy	$U = -p \cdot E$	Stable at $\theta = 0$, unstable at $\theta = 180^\circ$; work = $pE(\cos\theta_1 - \cos\theta_2)$.

Electric Potential

TOPIC	FORMULA	CONCEPT
Potential of point charge	$V = kq/r$	Scalar: just add potentials of all charges.
Field from potential	$E = -dV/dr$	Field points towards decreasing potential.
Potential energy (pair)	$U = kq_1q_2/r$	Work done to assemble the charges from infinity.

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Work by field	$W = q(V_A - V_B)$	Independent of path: electrostatic force is conservative.
Dipole potential	$V = kp \cos\theta / r^2$	Zero everywhere on the equatorial line.
Equipotential surface	$E \perp$ surface; $W = 0$ along it	Conductor surface is always equipotential.

Capacitors

TOPIC	FORMULA	CONCEPT
Capacitance	$C = Q/V$	Depends only on geometry and medium, not on Q or V.
Parallel plate	$C = \epsilon_0 A/d$; dielectric $C = K\epsilon_0 A/d$	Dielectric raises C by factor K.
Partial dielectric slab	$C = \epsilon_0 A / [d - t(1 - 1/K)]$	Metal slab: $K \rightarrow \infty$ gives $C = \epsilon_0 A/(d - t)$.
Spherical capacitor	$C = 4\pi\epsilon_0 ab/(b - a)$; isolated sphere $C = 4\pi\epsilon_0 R$	Earth's capacitance $\approx 711 \mu\text{F}$.
Series / parallel	$1/C_s = \sum 1/C_i$, $C_p = \sum C_i$	Series: same Q; parallel: same V.
Energy stored	$U = \frac{1}{2}CV^2 = Q^2/2C = \frac{1}{2}QV$	Stored in the electric field between plates.
Energy density	$u = \frac{1}{2}\epsilon_0 E^2$	Energy per unit volume of field.
Sharing charge	Common $V = (C_1V_1 + C_2V_2)/(C_1 + C_2)$	Some energy is always lost as heat when sharing.
RC circuit	$q = Q_0(1 - e^{-(t/RC)})$, $\tau = RC$	Charges to 63% in one time constant.

Current Electricity

TOPIC	FORMULA	CONCEPT
Drift velocity	$I = neAv_d$	Electrons drift slowly ($\sim \text{mm/s}$) though signals travel fast.
Ohm's law (micro)	$J = \sigma E$, $\rho = m/(ne^2\tau)$	Resistivity rises with temperature for metals.
Temperature dependence	$R_T = R_0(1 + \alpha\Delta T)$	α positive for metals, negative for semiconductors.
Cell EMF	$V = \epsilon - Ir$ (discharging); $V = \epsilon + Ir$ (charging)	Terminal voltage equals EMF only when $I = 0$.
Max power transfer	P_{max} when $R = r$; $P_{\text{max}} = \epsilon^2/4r$	Load resistance must match internal resistance.
Cells in series / parallel	$\epsilon_{\text{eq}} = \sum \epsilon$, $r_{\text{eq}} = \sum r$; parallel: $\epsilon_{\text{eq}}/r_{\text{eq}} = \sum (\epsilon_i/r_i)$, $1/r_{\text{eq}} = \sum 1/r_i$	Parallel identical cells keep ϵ but cut r .
Kirchhoff's laws	$\sum I = 0$ (junction); $\sum \Delta V = 0$ (loop)	Conservation of charge and of energy.
Wheatstone bridge	$P/Q = R/S$ (balanced)	No current through galvanometer at balance.
Meter bridge / potentiometer	$R/S = l/(100 - l)$; $\epsilon_1/\epsilon_2 = l_1/l_2$	Null methods draw no current from the cell.

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Magnetic Effects of Current

TOPIC	FORMULA	CONCEPT
Biot-Savart law	$dB = (\mu_0/4\pi) I dl \sin\theta / r^2$	Magnetic analogue of Coulomb's law for a current element.
Finite straight wire	$B = (\mu_0/4\pi d)(\sin\theta_1 + \sin\theta_2)$	Infinite wire: $\theta_1 = \theta_2 = 90^\circ$ gives $\mu_0 I/2\pi d$.
Infinite wire	$B = \mu_0 I / (2\pi r)$	Field lines are circles around the wire.
Circular loop (centre)	$B = \mu_0 I / 2R$; arc: $(\theta/2\pi) \cdot \mu_0 I/2R$	Arc field is a fraction of the full loop.
Loop on axis	$B = \mu_0 I R^2 / [2(R^2 + x^2)^{3/2}]$	Far away it behaves like a magnetic dipole.
Ampère's law	$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{enc}$	Easy for symmetric cases: wires, solenoids, toroids.
Solenoid / toroid	$B = \mu_0 nI$; toroid $B = \mu_0 NI/(2\pi r)$	Uniform field inside a long solenoid; zero outside.
Lorentz force	$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$	Magnetic force does no work; it only bends the path.
Circular motion in B	$r = mv/(qB)$, $T = 2\pi m/(qB)$	Period is independent of speed (cyclotron principle).
Force on wire	$\mathbf{F} = I(\mathbf{L} \times \mathbf{B})$; between wires $F/l = \mu_0 I_1 I_2 / (2\pi d)$	Parallel currents attract, antiparallel repel.
Torque on loop	$\tau = NIAB \sin\theta = \mathbf{m} \times \mathbf{B}$	Basis of the moving-coil galvanometer.

EMI & AC

TOPIC	FORMULA	CONCEPT
Faraday's law	$\varepsilon = -N d\Phi/dt$	EMF appears whenever flux changes.
Lenz's law	Induced current opposes the change	Direct result of energy conservation.
Motional EMF	$\varepsilon = Blv$; rotating rod $\varepsilon = \frac{1}{2}B\omega l^2$	A moving conductor in B acts like a battery.
Self inductance	$\varepsilon = -L di/dt$; solenoid $L = \mu_0 n^2 Al$	Inductor resists change in current.
Energy in inductor	$U = \frac{1}{2}LI^2$; density $B^2/2\mu_0$	Stored in the magnetic field.
Mutual inductance	$\varepsilon_2 = -M di_1/dt$	Principle of the transformer.
LR circuit	$i = i_0(1 - e^{-(tR/L)})$, $\tau = L/R$	Current grows to 63% in one time constant.
RMS values	$I_{rms} = I_0/\sqrt{2}$, $V_{rms} = V_0/\sqrt{2}$	AC meters read rms values.
Reactance	$X_L = \omega L$, $X_C = 1/(\omega C)$	Inductor blocks high f; capacitor blocks low f.
LCR impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$, $\tan\phi = (X_L - X_C)/R$	ϕ is the phase lead of voltage over current.
Resonance	$\omega_0 = 1/\sqrt{LC}$, $Q = \omega_0 L/R$	At resonance $Z = R$ and current is maximum.

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Power in AC	$P = V_{\text{rms}} I_{\text{rms}} \cos\phi$	$\cos\phi$ is the power factor; pure L or C uses no power.
Transformer	$V_s/V_p = N_s/N_p = I_p/I_s$ (ideal)	Step-up raises voltage and lowers current.

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