1 Electrostatics

Coulomb’s law: \( F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \)

Electric field: \( \vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \vec{r} \)

Electric dipole moment: \( \vec{p} = q \vec{d} \)

Potential of a dipole: \( V = \frac{1}{4\pi\varepsilon_0} \frac{p \cos \theta}{r^3} \)

Field of a dipole:

\[ E_r = \frac{1}{4\pi\varepsilon_0} \frac{2p \cos \theta}{r^3}, \quad E_\theta = \frac{1}{4\pi\varepsilon_0} \frac{p \sin \theta}{r^3} \]

Torque on a dipole placed in \( \vec{E} \): \( \vec{\tau} = \vec{p} \times \vec{E} \)

Potential energy of a dipole placed in \( \vec{E} \): \( V = -\vec{p} \cdot \vec{E} \)

2 Gauss’s Law and its Applications

Electric flux: \( \phi = \oint \vec{E} \cdot d\vec{S} \)

Gauss’s law: \( \oint \vec{E} \cdot d\vec{S} = q_{\text{in}} / \varepsilon_0 \)

Field of a uniformly charged ring on its axis:

\[ E_P = \frac{1}{4\pi\varepsilon_0} \frac{q_2}{(a^2 + x^2)^{3/2}} \]

Field of an infinite sheet:

\[ \vec{E} \] is the electric field at a point \( P \) due to a line charge

Electrostatic potential:

\[ V = \frac{1}{4\pi\varepsilon_0} \int \frac{Q}{r} \]

Field of a uniformly charged sphere:

\[ E = \begin{cases} \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2}, & \text{for } r < R \\ \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2}, & \text{for } r \geq R \end{cases} \]

\[ V = \begin{cases} \frac{Q}{4\pi\varepsilon_0} \left(3 - \frac{r^2}{R^2}\right), & \text{for } r < R \\ \frac{Q}{4\pi\varepsilon_0} \frac{1}{R}, & \text{for } r \geq R \end{cases} \]

Field of a uniformly charged spherical shell:

\[ E = \begin{cases} 0, & \text{for } r < R \\ \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2}, & \text{for } r \geq R \end{cases} \]

\[ V = \begin{cases} \frac{Q}{4\pi\varepsilon_0} \left(2 - \frac{r^2}{R^2}\right), & \text{for } r < R \\ \frac{Q}{4\pi\varepsilon_0} \frac{1}{R}, & \text{for } r \geq R \end{cases} \]

Field of a line charge:

\[ E = \frac{\lambda}{2\pi\varepsilon_0} \]

Field of an infinite sheet:

\[ E = \frac{\sigma}{\varepsilon_0} \]

Field in the vicinity of conducting surface:

\[ E = \frac{\sigma}{\varepsilon_0} \]

3 Capacitors

Capacitance: \( C = q/V \)

Parallel plate capacitor: \( C = \varepsilon_0 A/d \)

Spherical capacitor: \( C = \frac{4\pi\varepsilon_0 r_2}{r_2 - r_1} \)

Cylindrical capacitor: \( C = \frac{2\pi\varepsilon_0 l}{m(r_2/r_1)} \)

Capacitors in parallel: \( C_{eq} = C_1 + C_2 \)

Capacitors in series: \( \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \)

Force between plates of a parallel plate capacitor:

\[ F = \frac{Q^2}{2\varepsilon_0} \]

Energy stored in capacitor: \( U = \frac{1}{2} CV^2 = \frac{Q^2}{2C} = \frac{1}{2} QV \)

Energy density in electric field: \( U/V = \frac{1}{2}\varepsilon_0 E^2 \)

Capacitor with dielectric: \( C = \frac{\varepsilon_0 K A}{d} \)

4 Current electricity

Current density: \( j = i/A = \sigma E \)

Drift speed: \( v_d = \frac{1}{2} \frac{E}{\rho} \)

Resistance of a wire: \( R = \rho l / A \)

Temp. dependence of resistance: \( R = R_0 (1 + \alpha \Delta T) \)

Ohm’s law: \( V = i R \)

Kirchhoff’s Laws: (i) The Junction Law: The algebraic sum of all the currents directed towards a node is zero i.e., \( \Sigma_{\text{nodes}} I_i = 0 \). (ii) The Loop Law: The algebraic sum of all the potential differences along a closed loop in a circuit is zero i.e., \( \Sigma_{\text{loops}} \Delta V_i = 0 \).

Wheatstone bridge:

Balanced if \( R_1 / R_2 = R_3 / R_4 \)

Electric Power: \( P = V^2 / R = I^2 R = IV \)
Galvanometer as an Ammeter: \[ i_g G = (i - i_g)S \]
Galvanometer as a Voltmeter: \[ V_{AB} = i_g (R + G) \]
Charging of capacitors: \[ q(t) = CV \left[ 1 - e^{-\frac{t}{RC}} \right] \]
Discharging of capacitors: \[ q(t) = q_0 e^{-\frac{t}{\tau}} \]

Time constant in RC circuit: \( \tau = RC \)

Peltier effect: \( \text{emf} e = \frac{\Delta H}{\Delta Q} = \text{Peltier heat charge transferred} \)

Seebeck effect: \[ e = \frac{T_0 - T_v}{T_v} \left| T_n - T \right| \]

1. Thermo-emf: \( e = aT + \frac{b}{2} T^2 \)
2. Thermoelectric power: \( de/dt = a + bT \).
3. Neutral temp.: \( T_n = a/b \).
4. Inversion temp.: \( T_i = -2a/b \).

Thomson effect: \[ \text{emf} e = \frac{\Delta H}{\Delta Q} = \text{Thomson heat charge transferred} = \sigma \Delta T \]

Faraday’s law of electrolysis: The mass deposited is \[ m = Zit = \frac{1}{T} Eit \]
where \( i \) is current, \( t \) is time, \( Z \) is electrochemical equivalent, \( E \) is chemical equivalent, and \( F = 96485 \text{ C/g} \) is Faraday constant.

5 Magnetism

Lorentz force on a moving charge: \[ \vec{F} = q \vec{v} \times \vec{B} + q \vec{E} \]

Charged particle in a uniform magnetic field: \[ r = \frac{qv}{qB}, T = \frac{2\pi m}{qB} \]

Force on a current carrying wire: \[ \vec{F} = i \vec{l} \times \vec{B} \]

Magnetic moment of a current loop (dipole): \[ \vec{\mu} = i \vec{A} \]

Torque on a magnetic dipole placed in \( \vec{B} \): \( \vec{\tau} = \vec{\mu} \times \vec{B} \)

Energy of a magnetic dipole placed in \( \vec{B} \): \[ U = -\vec{\mu} \cdot \vec{B} \]

Hall effect: \[ V_w = \frac{Bi}{n\mu} \]

Biot-Savart law: \[ d\vec{B} = \frac{\mu_0 i}{4\pi} \frac{dl \times \vec{r}}{r^3} \]

Field due to a straight conductor: \[ B = \frac{\mu_0 i}{4\pi d} (\cos \theta_1 - \cos \theta_2) \]

Force between parallel wires: \[ \frac{dF}{dt} = \frac{\mu_0 i^2}{2\pi d} \]

Field on the axis of a ring: \[ B_P = \frac{\mu_0 i^2}{\pi(a^2 + d^2)^{3/2}} \]

Field at the centre of an arc: \[ B = \frac{\mu_0 i^2}{4\pi a} \theta \]

Ampere’s law: \[ \oint \vec{B} \cdot d\vec{l} = \mu_0 i \]

Field inside a solenoid: \( B = \mu_0 ni \), \( n = \frac{N}{l} \)

Field inside a toroid: \[ B_1 = \frac{\mu_0 N_i}{2\pi}, B_2 = \frac{\mu_0 M}{2\pi} \]

Field of a bar magnet: \[ B_h = B \cos \delta \]

Angle of dip: \[ B_h = B \cos \delta \]

Tangent galvanometer: \[ B_h \tan \theta = \frac{m_i}{2}, i = K \tan \theta \]

Moving coil galvanometer: \[ n_i AB = k \theta, i = \frac{k}{n_i AB} \theta \]

Time period of magnetometer: \[ T = 2\pi \sqrt{\frac{l}{MB_h}} \]

Permeability: \[ \vec{B} = \mu \vec{H} \]
7 Electromagnetic Induction

Magnetic flux: $\phi = \oint \mathbf{B} \cdot d\mathbf{S}$

Faraday’s law: $e = -\frac{d\phi}{dt}$

Lenz’s Law: Induced current create a $B$-field that opposes the change in magnetic flux.

Motional emf: $e = Blv$

Self inductance: $\phi = Li, \quad e = -L \frac{di}{dt}$

Self inductance of a solenoid: $L = \mu_0 n^2 (\pi r^2 l)$

Growth of current in LR circuit: $i = \frac{e}{R} \left[ 1 - e^{-\frac{t}{\tau}} \right]$

Decay of current in LR circuit: $i = i_0 e^{-\frac{t}{\tau}}$

Time constant of LR circuit: $\tau = L/R$

Energy stored in an inductor: $U = \frac{1}{2} Li^2$

Energy density of $B$ field: $u = \frac{U}{V} = \frac{B^2}{2\mu_0}$

Mutual inductance: $\phi = Mi, \quad e = -M \frac{di}{dt}$

EMF induced in a rotating coil: $e = NAB\omega \sin \omega t$

Alternating current: $i = i_0 \sin(\omega t + \phi), \quad T = \frac{2\pi}{\omega}$

Average current in AC: $\bar{i} = \frac{1}{T} \int_0^T i \, dt = 0$

RMS current: $i_{\text{rms}} = \left( \frac{1}{T} \int_0^T i^2 \, dt \right)^{1/2} = \frac{i}{\sqrt{2}}$

Energy: $E = i_{\text{rms}}^2 RT$

Capacitive reactance: $X_c = \frac{1}{\omega C}$

Inductive reactance: $X_L = \omega L$

Impedance: $Z = e_0/i_0$

RC circuit:

$Z = \sqrt{R^2 + (1/\omega C)^2}, \quad \tan \phi = \frac{1}{\omega CR}$

LR circuit:

$Z = \sqrt{R^2 + \omega^2 L^2}, \quad \tan \phi = \frac{1}{\omega L}$

LCR Circuit:

$Z = \sqrt{R^2 + (\omega_0^2 - \omega^2 L^2)^2}, \quad \tan \phi = \frac{1}{\omega_0 L}$

$\nu_{\text{resonance}} = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$

Power factor: $P = e_{\text{rms}}i_{\text{rms}} \cos \phi$

Transformer: $\frac{N_1}{N_2} = \frac{e_1}{e_2}, \quad i_1i_1 = e_2i_2$ $e_1, N_1, i_1, N_2, i_2$

Speed of the EM waves in vacuum: $c = 1/\sqrt{\mu_0 \epsilon_0}$

Visit www.concepts-of-physics.com to buy
“IIT JEE Physics: Topic-wise Complete Solutions”
and our other books. Written by IITians, Foreword
by Dr. HC Verma, Appreciated by Students.