Electric Charges and Fields

Coulomb's Law

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$$

$q = \pm ne$

Gauss's Theorem

$$\Phi_E = \oint \vec{E}\cdot d\vec{S} = \frac{Q}{\varepsilon_0}$$

Charge density

Linear	Surface	Volume
$\lambda = \frac{q}{l}$	$\sigma = \frac{q}{A}$	$\rho = \frac{q}{V}$

- E·f due to infinite sheet of charge: $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$
- E·f due to infinite long charged wire: $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

- Electric Field: $\vec{E} = \frac{\vec{F}}{q_0}$

Due to Point Charge: $E = \frac{kq}{r^2}$, $k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2/C^2$

Electric Dipole moment: $\vec{P} = q\,2\vec{a}$

Electric Field due to dipole

on axial line	on equatorial line
$E = \frac{2P}{4\pi\varepsilon_0 r^3}$	$E = \frac{P}{4\pi\varepsilon_0 r^3}$

Torque: $\vec{\tau} = \vec{P}\times\vec{E}$ or $\tau = PE\sin\theta$

Due to charged Conducting Sphere

$E = \frac{kq}{r^2}$, $r > R$; $E = \frac{kq}{R^2}$, $r = R$; $E = 0$, $r < R$

Electric Potential & Capacitance

Electric Potential $V = \frac{q}{4\pi\varepsilon_0 r}$

Potential due to dipole: Axial → $V = \frac{P}{4\pi\varepsilon_0 r^2}$; Equatorial → $V = 0$; At any point → $V = \frac{P\cos\theta}{4\pi\varepsilon_0 r^2}$

Electric Potential Energy [for two charges]: $U = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$

U_i due to dipole in external field: $U = pE(\cos\theta_i - \cos\theta)$ or $U = -\vec{P}\cdot\vec{E}$; θ_i initial

Relation between $\vec{E}$ & $\vec{V}$: $E = -\frac{dV}{dr}$ or $V = -\int \vec{E}\cdot d\vec{r}$

Capacitance: $C = \frac{Q}{V}$

Series combination: $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$

Parallel Combination: $C_p = C_1 + C_2$

Capacitance of Parallel Plate Capacitor

Air filled	Partially filled with dielectric
$C = \varepsilon_0\frac{A}{d}$	$C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{k}\right)}$

Completely filled	Filled with metal
$C = k\varepsilon_0\frac{A}{d}$	$C = \frac{\varepsilon_0 A}{(d-t)}$

Spherical Capacitor: $C = 4\pi\varepsilon_0\frac{ab}{b-a}$

Capacitance of Isolated Sphere: $C = 4\pi\varepsilon_0 r$

Energy stored in a Capacitor: $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$

Common Potential: $V = \frac{q_1+q_2}{C_1+C_2} = \frac{C_1V_1 + C_2V_2}{C_1+C_2}$

Energy density: $u = \frac{U}{V} = \frac{1}{2}\varepsilon_0 E^2$

Energy loss: $= \frac{1}{2}\frac{C_1C_2(V_1-V_2)^2}{(C_1+C_2)}$

Force between plates of Capacitor: $F = \frac{Q^2}{2A\varepsilon_0}$

Potential due to Uniformly Charged Non Conducting Sphere

	outside $r > R$	on the shell $r = R$	inside $r < R$
$V = \frac{q}{4\pi\varepsilon_0 r}$	$V = \frac{q}{4\pi\varepsilon_0 R}$	$V = \frac{q}{4\pi\varepsilon_0 R}$	$V = \frac{q}{4\pi\varepsilon_0}\frac{(3R^2 - r^2)}{2R^3}$

Current Electricity

Electric Current: $i = \frac{q}{t}$

Current density: $J = \frac{I}{A}$

Drift Velocity: $v_d = \frac{eET}{m} = \frac{eVt}{ml}$

Relation b/w i & v_d: $i = Ane v_d$

Mobility: $\mu = \frac{|v_d|}{E}$

Resistivity: $\rho = \frac{m}{ne^2\tau}$

Relation b/w J & σ: $J = \sigma E$

EMF of a Cell: $E = \frac{W}{q}$; $\pm Ir$

Terminal Potential diff: $V = \frac{W}{q}$

Ohm's Law: $V = iR$, $R = \rho\frac{L}{A}$

Conductivity: $\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$

$E = V + Ir$

$r = R\left[\frac{E-V}{V}\right]$

Principle of Wheat stone: $\frac{P}{Q} = \frac{R}{S}$

Principle of potentiometer: $k = \frac{V}{L} = \frac{iR}{L}$

Principle of Meter bridge: $\frac{R}{S} = \frac{L_1\ (\text{length of wire})}{100 - L_1}$

Combination of Identical cells

Series (n cell)	$i = \frac{nE}{R+nr}$
Parallel (n cell)	$i = \frac{mE}{mR+r}$
Mixed	$i = \frac{mnE}{mR+nr}$

Temp. coefficient: $\alpha = \frac{R - R_0}{R_0(T - T_0)}$

Joule's Law: $H = i^2Rt$ Joule ; $H = \frac{i^2Rt}{4.18}$ Calories

Power: $P = Vi = i^2R = \frac{V^2}{R}$

Electric Energy: $W = Vq = Vit = i^2Rt = \frac{V^2t}{R}$

Moving Charges and Magnetism

Magnetic Force: $\vec{F}_m = q(\vec{v}\times\vec{B})$

Pitch $(P) = \frac{2\pi mv\cos\theta}{qB}$

Motion of charge in Uniform Transverse Magnetic Field

- $F_m = qvB = \frac{mv^2}{r}$
- Time period: $T = \frac{2\pi R}{v} = \frac{2\pi m}{qB}$
- Radius of Circular path: $r = \frac{mv}{qB} = \frac{P}{qB} = \frac{\sqrt{2mK}}{qB} = \frac{\sqrt{2mqV}}{qB}$

Biot Savart's Law: $dB = \frac{\mu_0}{4\pi}\frac{i\,dl\sin\theta}{r^2}$

- MF at Centre of a Circular Coil: $B = \frac{\mu_0 i}{2a}$
- MF at a point on the axis of current carrying coil: $B = \frac{\mu_0}{4\pi}\frac{2\pi Nia^2}{(a^2+x^2)^{3/2}}$

Force b/w two Current Carrying parallel straight Conductor: $F = \frac{\mu_0}{4\pi}\frac{2i_1i_2l}{r}$

- Magnetic force on a Current Carrying Conductor: $\vec{F} = i(\vec{l}\times\vec{B})$

- Ampere's Circuital Law: $\oint \vec{B}\cdot d\vec{l} = \mu_0 i$

Magnetic field due to an infinitely long straight wire of radius 'a' carrying current i at a point -

$B = \frac{\mu_0 i}{2\pi a^2}$, $r < a$; $B = \frac{\mu_0 i}{2\pi a}$, $r = a$; $B = \frac{\mu_0 i}{2\pi r}$, $r > a$

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