Electric Charges and Fields

Coulomb's Law

q_1 —— r —— q_2

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

$$q = \pm ne$$

Gauss's Theorem

$$\phi_E = \oint \vec{E}\cdot d\vec{s} = \frac{Q}{\varepsilon_0}$$

Charge density

linear $\quad$ surface $\quad$ volume

$\lambda = \frac{q}{l}$ $\quad$ $\sigma = \frac{q}{A}$ $\quad$ $\rho = \frac{q}{V}$

EF due to infinite sheet of charge $\rightarrow$ $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

• EF due to infinite long charged wire $\rightarrow$ $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

• **Electric Field**

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Due to Point Charge

$$E = \frac{Kq}{r^2} \qquad K = 9\times10^9 \, Nm^2/C^2$$

$E_r = \frac{E}{E_0}$

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

Electric Field due to dipole

on axial line $\qquad\qquad$ on equatorial line

$E = \frac{2P}{4\pi\varepsilon_0 r^3}$ $\qquad$ $E = \frac{P}{4\pi\varepsilon_0 r^3}$

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

Due to Charged Conducting Sphere

$E = \frac{Kq}{r^2}, r>R$ $\quad$ $E = \frac{Kq}{R^2}, r=R$ $\quad$ $E=0$ $\quad r<R$

Potential due to

Uniformly Charged Sphere $\qquad$ **Non Conducting Sphere**

$V = \frac{q}{4\pi\varepsilon_0 r}$ $\qquad$ Outside $r>R$ $\quad$ $V = \frac{q}{4\pi\varepsilon_0 r}$

$V = \frac{q}{4\pi\varepsilon_0 R}$ $\qquad$ On the Shell $r=R$ $\quad$ $V = \frac{q}{4\pi\varepsilon_0 R}$

$V = \frac{q}{4\pi\varepsilon_0 R}$ $\qquad$ Inside $r<R$ $\quad$ $V = \frac{q}{4\pi\varepsilon_0}\frac{(3R^2-r^2)}{2R^3}$

Electric Potential & Capacitance

Electric Potential $V = \frac{q}{4\pi\varepsilon_0 r}$ $\qquad$ Potential due to dipole $\rightarrow$ Axial $\rightarrow$ $V = \frac{P}{4\pi\varepsilon_0 r^2}$

Equatorial $\rightarrow V=0$

Electric Potential Energy [for two charge]

$$U = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

At any point $\rightarrow$ $V = \frac{P\cos\theta}{4\pi\varepsilon_0 r^2}$

Due to dipole in External Field

$U = pE(\cos\theta_1 - \cos\theta_2)$ or $U = -\vec{P}\cdot\vec{E}$ $\quad \theta_1 = $ initial

Relation between $\vec{E}$ & V

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

Capacitance $\qquad C = \frac{q}{V}$

Series Combination $\qquad$ Parallel Comb.

$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$ $\qquad$ $C_P = C_1 + C_2$

Capacitance of Parallel Plate Capacitor

Air filled $\qquad$ Partially filled with dielectric

$C = \frac{\varepsilon_0 A}{d}$ $\qquad$ $C = \frac{\varepsilon_0 A}{d - t(1 - \frac{1}{k})}$

Completely filled $\qquad$ Filled with metal

$C = K\varepsilon_0\frac{A}{d}$ $\qquad$ $C = \frac{\varepsilon_0 A}{(d-t)}$

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

$$U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$$

Energy density

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

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

Common Potential

$$V = \frac{q_1 + q_2}{C_1 + C_2} = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

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

Current Electricity

Electric Current $\qquad$ **Current density**

$i = \frac{q}{t}$ $\qquad\qquad$ $J = \frac{I}{A}$

Relation b/w i & V_d

$$i = Ane V_d$$

Principle of Wheat Stone

$$\frac{P}{Q} = \frac{R}{S}$$

Principle of Meter bridge

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

Principle of potentiometer

$$K = \frac{V}{L} = \frac{iR}{L}$$

Power $\qquad$ Electric $\qquad$ **Energy**

$$P = Vi = i^2 R = \frac{V^2}{R} \qquad W = Vq = Vit = i^2Rt = \frac{V^2 t}{R}$$

Drift Velocity

$$V_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

Mobility

$$\mu = \frac{|V_d|}{E}$$

Resistivity

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

Ohm's Law

$V = iR$

$R = \rho\frac{L}{A}$

Conductivity

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

Combination of identical cells

Series n-cell $\qquad i = \frac{nE}{R+nr}$

Parallel m-cell $\qquad i = \frac{mE}{mR+r}$

Mixed $\qquad i = \frac{mnE}{mR+nr}$

Relation b/w J & $\vec{V}$

$$J = \sigma E$$

EMF of a Cell

$$E = \frac{W}{q} \qquad \frac{+}{-}|\,-$$

$$E = V + Ir$$

Temp. coefficient

$$\alpha = \frac{R - R_0}{R_0(T - T_0)}$$

Terminal Potential diff

$$V = \frac{W}{q}$$

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

Joule's Law

$$H = i^2 Rt \quad \text{Joule}$$

$$H = \frac{i^2 Rt}{4\cdot18} \quad \text{Calories}$$

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

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$$

$\rightarrow$ MF at Centre of a Circular Coil $\qquad B = \frac{\mu_0 i}{2a}$

Force b/w two Current Carrying parallel straight Conductor

$$F = \frac{\mu_0}{4\pi}\frac{2i_1 i_2 L}{r}$$

$\rightarrow$ MF at a point on the axis of Current Carrying Coil $\qquad B = \frac{\mu_0}{4\pi}\frac{2\pi Nia^2}{(a^2+x^2)^{3/2}}$

• **Magnetic force on a Current Carrying Conductor** $\rightarrow$ $\vec{F} = i(\vec{L}\times\vec{B})$

• **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 -

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

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