Coulomb force between two point charges $F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{|r|^3}r \; = \; = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{|r|^2}r$

- **The electric field intensity at any point is the force experienced by unit positive charge, given by** $\mathbf{E} = \frac{\mathbf{F}}{\mathbf{q_0}}$

Electric force on a charge 'q' at the position of electric field intensity E **produced by some source charges is** $\mathbf{F = qE}$

Electric Potential

If $(W_p)_{ext}$ is the work required in moving a point charge q from infinity to a point P, the electric potential of the point P is

$$V_p = \frac{(W_p)_{ext}}{q} \quad {}_{acc=0}$$

Potential Difference between two points A and B is

$V_A \quad V_B$

Formulae of E **and potential V**

(i) Point charge $E = \frac{Kq}{|r|^2} r = \frac{Kq}{r^3} r$, $V = \frac{Kq}{r}$

(ii) Infinitely long line charge $\frac{\lambda}{2\pi\varepsilon_0 r} r = \frac{2K\lambda r}{r}$

V = not defined, $v_B \quad v_A = \; 2K\lambda \; \ln (r_B / r_A)$

(iii) Infinite nonconducting thin sheet $\frac{\sigma}{2\varepsilon_0} n$,

V = not defined, $v_B - v_A = -\frac{\sigma}{2\varepsilon_0}(r_B - r_A)$

(iv) Uniformly charged ring

$E_{axis} = \frac{KQx}{(R^2 + x^2)^{3/2}}$, $\quad E_{centre} = 0$

$V_{axis} = \frac{KQ}{\sqrt{R^2 + x^2}}$, $\quad V_{centre} = \frac{KQ}{R}$

x is the distance from centre along axis.

(v) Infinitely large charged conducting sheet $\frac{\sigma}{\varepsilon_0} n$

V = not defined, $v_B - v_A = -\frac{\sigma}{\varepsilon_0}(r_B - r_A)$

(vi) Uniformly charged hollow conducting/ nonconducting /solid conducting sphere

(a) for $E = \frac{kQ}{|r|^2} r$, r R, $V = \frac{KQ}{r}$

(b) $E = 0$ for r < R, $V = \frac{KQ}{R}$

(vii) Uniformly charged solid nonconducting sphere (insulating material)

(a) $E = \frac{kQ}{|r|^2} r$ for r   R , V = $\frac{KQ}{r}$

(b) $E = \frac{KQr}{R^3} = \frac{\rho r}{3\varepsilon_0}$ for r   R, $V = \frac{\rho}{6\varepsilon_0}(3R^2 \;\; r^2)$

(viii) thin uniformly charged disc (surface charge density is σ)

$$E_{axis} = \frac{\sigma}{2\varepsilon_0}\; 1 - \frac{x}{\sqrt{R^2 + x^2}} \qquad\qquad V_{axis} = \frac{\sigma}{2\varepsilon_0}\; \sqrt{R^2 + x^2} - x$$

Work done by external agent in taking a charge q from A to B is

$(W_{ext})_{AB} = q\,(V_B \;\; V_A)$ or $(W_{el})_{AB} = q\,(V_A \;\; V_B)$.

The electrostatic potential energy of a point charge

U = qV

U = PE of the system =

$$\frac{U_1 + U_2 + ...}{2} = (U_{12} + U_{13} + ... + U_{1n}) + (U_{23} + U_{24} + ... + U_{2n}) + (U_{34} + U_{35} + ... + U_{3n}) ....$$

Energy Density = $\frac{1}{2}\varepsilon E^2$

Self Energy of a uniformly charged shell = $U_{self} = \frac{KQ^2}{2R}$

Self Energy of a uniformly charged solid non-conducting sphere = $U_{self} = \frac{3KQ^2}{5R}$

Electric Field Intensity Due to Dipole

(i) on the axis $E = \frac{2KP}{r^3}$

(ii) on the equatorial position : $E = \frac{KP}{r^3}$

(iii) Total electric field at general point O (r,θ) is

$$E_{res} = \frac{KP}{r^3}\sqrt{1 + 3\cos^2\theta}$$

Potential Energy of an Electric Dipole in External Electric Field :

$U = - \vec{p}.\vec{E}$

Electric Dipole in Uniform Electric Field :

torque $\vec{\tau} = \vec{p} \;\; \vec{E}$; $\vec{F} = 0$

Electric Dipole in Nonuniform Electric Field:

torque $\vec{\tau} = \vec{p} \;\; \vec{E}$; U = $- p \;\; E$, Net force |F| = $\left| p \frac{E}{r} \right|$

Electric Potential Due to Dipole at General Point (r, θ) :

$$V = \frac{P \;\; \theta}{4\pi\varepsilon_0 r^2} = \frac{\;\;.\;\;}{4\pi\varepsilon_0 r^3}$$

The electric flux over the whole area is given by

$$\phi = \;_S E.\overrightarrow{dS} \; = \;_S E_n dS$$

Flux using Gauss's law, Flux through a closed surface

$$\phi = \circ\; E \;\; \overrightarrow{dS} = \frac{q_{in}}{\varepsilon_0}\,.$$

Electric field intensity near the conducting surface

$$= \frac{\sigma}{\varepsilon_0}\; n$$

Electric pressure : Electric pressure at the surface of a conductor is given by formula

$$P = \frac{\sigma^2}{2\varepsilon_0}$$ where σ is the local surface charge density.

Potential difference between points A and B

$$V \quad V = \;{}_{A}^{B}\; E.dr$$

$$E = -\; i\frac{}{x}V + j\frac{}{x}V + k\frac{}{z}V \;\; = \;\; -\; i\frac{}{x} + j\frac{}{x} + k\frac{}{z}\;\; V$$

$$= \quad V = \;\; \text{grad } V$$