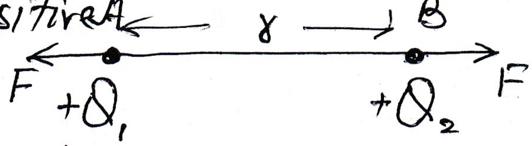
1. Coulomb's Law :

According to Coulomb's Law of electrostatic interaction.

A and B are two positive point charges $Q_1 c$ & $Q_2 c$ separated by a distance 'r'. The force of interaction is repulsive interaction F



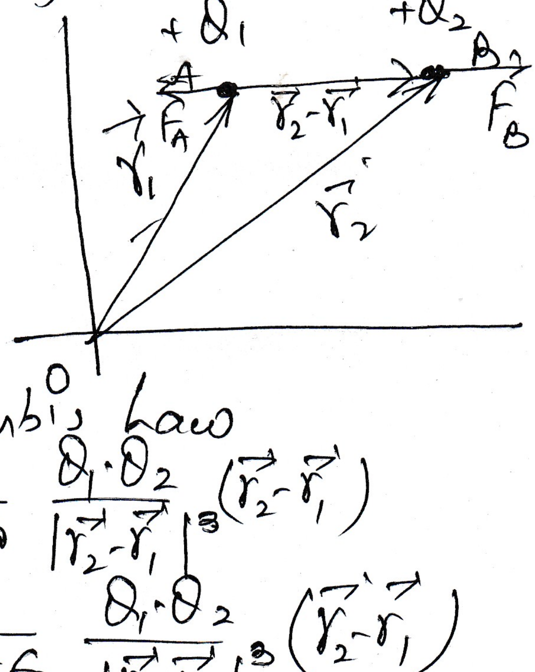
$$F \propto (Q_1 \cdot Q_2)$$

$$F \propto \frac{1}{r^2}$$

or $$F \propto \frac{Q_1 Q_2}{r^2} \quad \text{or} \quad F = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r^2}$$

where $\epsilon_0 = 8.85 \times 10^{-12}\ C^2/N\text{-}m^2$
= space Electric Constant
or Permittivity of Vacuum.

Vector Form :



In Vector Triangle OAB

$$\vec{OA} + \vec{AB} = \vec{OB}$$

$$\vec{AB} = \vec{OB} - \vec{OA}$$

$$\vec{AB} = \vec{r}_2 - \vec{r}_1$$

According to Coulomb's Law

$$\vec{F}_B = \frac{1}{4\pi\epsilon_0}\frac{Q_1 \cdot Q_2}{|\vec{r}_2 - \vec{r}_1|^3}(\vec{r}_2 - \vec{r}_1)$$

$$\vec{F}_A = -\frac{1}{4\pi\epsilon_0}\frac{Q_1 \cdot Q_2}{|\vec{r}_2 - \vec{r}_1|^3}(\vec{r}_2 - \vec{r}_1)$$

If $\vec{r} = \vec{r}_2 - \vec{r}_1$

$$\vec{F}_B = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{|\vec{r}|^3}\vec{r}, \quad \vec{F}_A = -\frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{|\vec{r}|^3}\vec{r}.$$

2. Electric Field Intensity and Potential of Electric field.

Electric Field: The property of space due to which a charged particle experience a force where (a) The force is proportional to amount of Charge $F \propto q$ (b) The force is function of Position, is called electric field.

(i) Electric Field Intensity is defined as force experienced by unit positive charge

$$E = \frac{\vec{F}}{q} \; N/C \qquad [E] = \frac{[MLT^{-2}]}{[IT]}$$

and

$$E = f(x, y, z) \qquad = [MLT^{-3}I^{-1}]$$

(ii) Electric Field Potential: of the field at any point is defined as negative value of work done in bringing unit positive charge (Test charge) from Reference Position to present Position. is called Electric Field Potential.

$$dV = -\frac{dW}{q} = -\frac{\vec{F}\cdot d\vec{r}}{q} = -\left(\frac{\vec{F}}{q}\right)\cdot d\vec{r}$$

$$dV_p = -\vec{E}\cdot d\vec{r}$$

$$V_p = -\int_{\text{Reference Position}}^{\text{Present Position}} \vec{E}\cdot d\vec{r} \quad J/C \text{ or Volt}$$

$$[V_p] = \frac{[W]}{[q]} = \frac{[ML^2T^{-2}]}{[IT]}$$

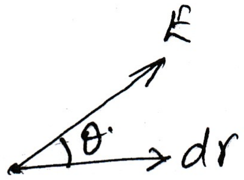
$$= [ML^2T^{-3}I^{-1}]$$

2.(c) <u>Potential Gradient</u>: If $V = f(x, y, z)$ or $V = f(r)$

Rate of change of Potential with change in position is called Potential gradient.

$$\text{Pot. Gradient} = \frac{dV}{dr} = \frac{-dW}{dr} = -\frac{E\,dr}{dr}$$

$$\boxed{E = -\frac{dV}{dr}}$$



$$dW = \vec{F}\cdot\vec{dr}$$
$$= \vec{E}q\cdot\vec{dr} = \vec{E}q\,dr\cos\theta$$

or $\frac{dW}{q} = -E\cos\theta\,dr$ or $\frac{-dW}{q} = -E\cos\theta\,dr$

$E\cos\theta\,dr = -dV$ or $E\cos\theta = -\frac{dV}{dr}$

$\boxed{E_r = -\frac{dV}{dr}}$ when $E_r = E\cos\theta$ is component of field along $\vec{dr}$.

Rectangular Coordinate System:

If $V = f(x, y, z)$ then

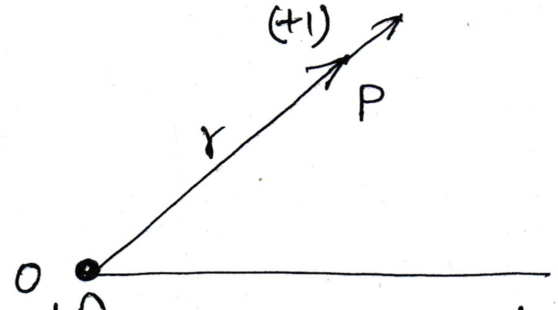
$$E_x = -\frac{dV}{dx},\quad E_y = -\frac{dV}{dy},\quad E_z = -\frac{dV}{dz}.$$

$$\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$$

$$|E| = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad \& \quad \cos\alpha = \frac{E_x}{E}\quad \cos\beta = \frac{E_y}{E}$$

$$\cos\gamma = \frac{E_z}{E}$$

3. E & V due to Point charge:



O is a point positive charge Q whose electrostatic field in its surrounding keeping Test charge at P force of interaction According to Coulomb's Law

$$F = \frac{1}{4\pi\epsilon_0}\frac{Q\times 1}{r^2}$$

According to definition of ~~point~~ Electric Field Intensity

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^3}\vec{r} \; N/C$$ in radially Outward directn

According to Definition of Potential V.

$$dV = -\vec{E}.\vec{dr} = -|\vec{E}||\vec{dr}|\cos 0^\circ = -\frac{Q}{4\pi\epsilon_0}\frac{dr}{r^2}$$

Integrating $\int_0^{V_P} dV = -\frac{Q}{4\pi\epsilon_0}\int_{r=\infty}^{r=r}\frac{dr}{r^2}$ or $V_P = -\frac{Q}{4\pi\epsilon_0}\left[-\frac{1}{r}\right]_\infty^r$

$$V_P = \frac{1}{4\pi\epsilon_0}\frac{Q}{r} \; J/C \text{ or Volt.}$$

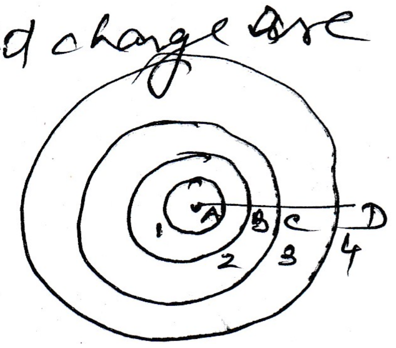
(a) Field due to Positive Point charge is radial, Non-Uniform, repulsive in nature where Tangential component is zero

(b)

1- V-r graph in Radial line.

2. E-r ,, in Radial line.

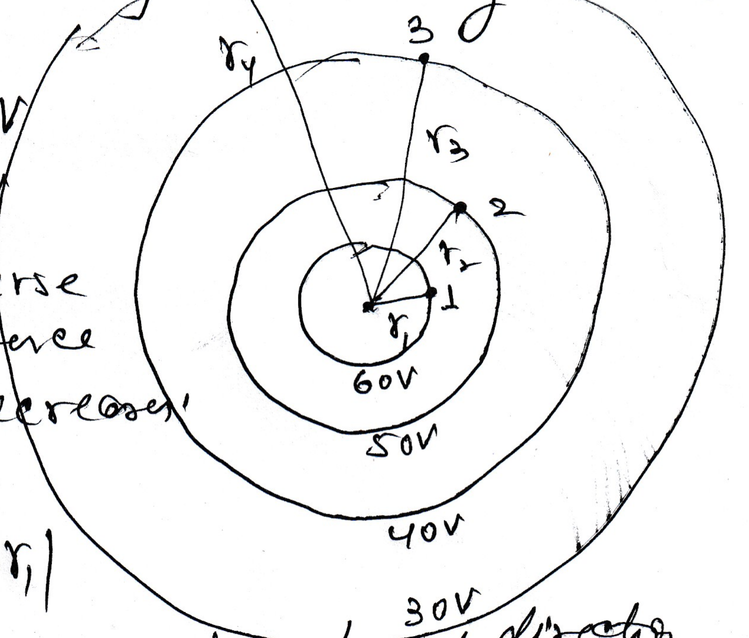
(c) Equipotential lines near the point charge are concentric Surface/circle



$V_1 = 60V$ $V_2 = 50V$ $V_3 = 40V$

If $V_3 - V_2 = V_2 - V_1 = V =$ Constnt

The equipotential lines having equal Potential gap are concentric circles of increasing spacing as the field intensity decreases.



$V_4 - V_3 = V_3 - V_2 = V_2 - V_1 = \Delta V$

$W_{4-3} = W_{3-2} = W_{2-1} = W$

The field obeys inverse Square Law therefore Field strength decreases therefore

$|r_4 - r_3| > |r_3 - r_2| > |r_2 - r_1|$

The spacing increases in outward direction

(d) The equipotential lines provides ideal condition for negative charge to move under Uniform Circular Motion.

$$\frac{mv^2}{r} = Eq,$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$$