Lecture 4

Electrostatic Fields and Coulomb Law

1. For further Assessment of lecture taken through Zoom, Watch the YouTube video available on following link:

   https://www.youtube.com/watch?v=VuptdDvjwYI

2. Read out chapter 2.1 of book of following lecture

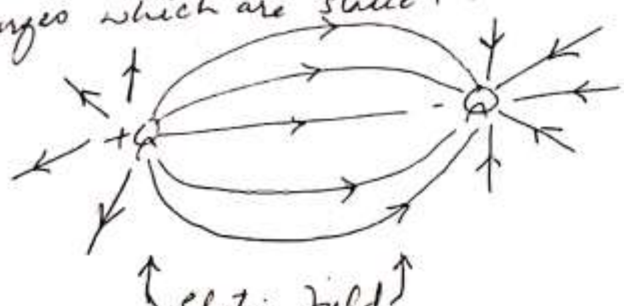
3. As well the Notes of class Lecture is available below:

Electrostatic Fields (1B)

or

The Static Electrical Field

"Electrostatic is a science relatede to the electric charges which are static. i.e. are at rest"



Electric field

{ Due to static electric charge } Called Static
{ does not vary with time } Electric field
{ and Called time Invariant }

Fundamental Law's governing electrostatic fields, are

1) Coulomb's law:- Any charge distribution.

2) Gauss's law: charge distribution is symmetrical.

Note:- Concept of electric field Intensity will be introduced and applied to case involving point, line, surface and volume charge.

"we assume that electric field is in a vaccum or free space".

Coulomb's Law and Field Intensity.

(2)

Coulomb's law states that the force F b/w two point charges Q_1 and Q_2 is

$$F \propto \frac{Q_1 Q_2}{R^2}$$

Q_1 ←— R —→ Q_2

or $F = K \frac{Q_1 Q_2}{R^2}$ — ① K = Called proportionality constant

In SI units: charges Q_1 and Q_2 are in coulomb (C), distance R is in meters (m), Force F is in Newton (N). $K = \frac{1}{4\pi\varepsilon_0} \simeq 9 \times 10^9$ m/F

where, ε_0 → Permittivity of Free Space (in Farads/meters)

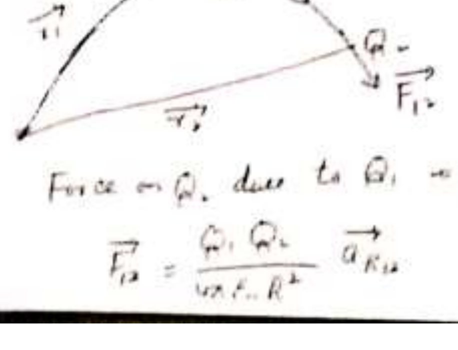
$$\varepsilon_0 = 8.854 \times 10^{-12} F/m$$

$$\varepsilon_0 \simeq \frac{10^{-9}}{36\pi} F/m$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}$$

Note: Force F b/w two charges Q_1 & Q_2 is along the line joining them.

⇒ Coulomb vector force on point charges Q_1 and Q_2



$\vec{r_1}$ and $\vec{r_2}$ are position vector

Force on Q_2 due to Q_1 is given as

$$\vec{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2} \vec{a_{R_{12}}}$$

$$\vec{R_{12}} = \vec{r_2} - \vec{r_1}$$

$$|\vec{R}| = R, \quad \vec{a_{R_{12}}} = \frac{\vec{R_{12}}}{R}$$

or $\vec{F}_{12} = \frac{Q_1 Q_2}{4\pi \varepsilon_0 R^3} \vec{R}_{12}$

or $\vec{F}_{12} = \frac{Q_1 Q_2}{4\pi \varepsilon_0} \frac{(\vec{r_2} - \vec{r_1})}{|\vec{r_2} - \vec{r_1}|^3}$ ✓

Similarly,

$\vec{F}_{21} = \frac{Q_1 Q_2}{4\pi \varepsilon_0 R^2} \vec{a}_{R_{21}}$; Since $\vec{a}_{R_{21}} = -\vec{a}_{R_{12}}$

So, $\vec{F}_{12} = -\vec{F}_{21}$

Note:-

1) Like charges (charge of same sign) repel each other while unlike charges attract.

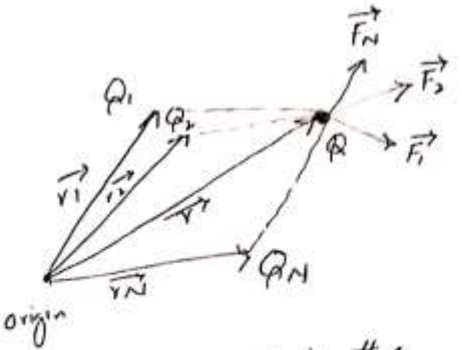
For like charges, $Q_1 Q_2 > 0$
For unlike charges, $Q_1 Q_2 < 0$
} Q_1 & Q_2 must be static (at rest).

2) The distance R b/w the charge Q_1 and Q_2 must be large compared with the dimensions of Q_1 and Q_2 [called point charges].

Special charges:

(d)

et there are N charges $Q_1, Q_2, \ldots, Q_N$ with osition vector $\vec{r_1}, \vec{r_2}, \ldots, \vec{r_N}$ espectively.



Force $\vec{F}$ on charge Q located at point $\vec{r}$ is the vector sum of force exerted on Q by each of the charges $Q_1, Q_2, \ldots, Q_N$.

Hence,

$$\vec{F} = \frac{Q Q_1 (\vec{r} - \vec{r_1})}{4\pi\varepsilon_0 |\vec{r} - \vec{r_1}|^3} + \frac{Q Q_2 (\vec{r} - \vec{r_2})}{4\pi\varepsilon_0 |\vec{r} - \vec{r_2}|^3} + \cdots + \frac{Q Q_N (\vec{r} - \vec{r_N})}{4\pi\varepsilon_0 |\vec{r} - \vec{r_N}|^3}$$

$$\vec{F} = \frac{Q}{4\pi\varepsilon_0} \sum_{K=1}^{N} \frac{Q_K (\vec{r} - \vec{r_K})}{|\vec{r} - \vec{r_K}|^3}$$