B.Sc. Physics Part-II

Paper-IV

(Electrostatics, magnetism)

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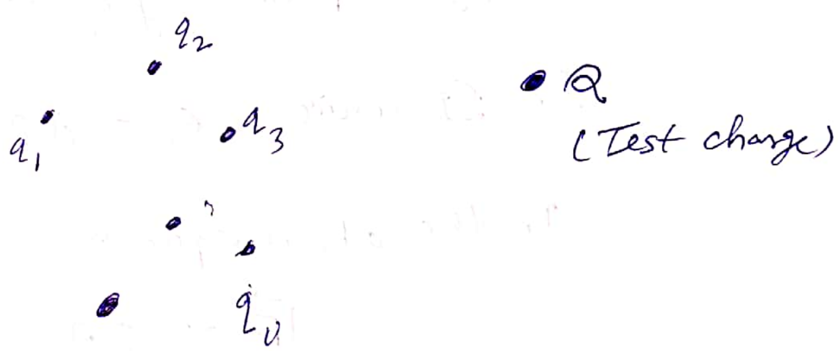
The Electric Field:

Electrostatics — Study of electromagnetic phenomena when charges are stationary

$q_1, q_2, q_3 \cdots q_i$ are electric charges.
We call them Source charges.



Q → Test charge

Source charges

→ What will be the force on test charge Q due to the source charges?

This can be calculated using 'principle of superposition'→ which says that force between two charges is completely unaffected by presence of other charges.

Now Force on Q due to source charges $q_1, q_2 \cdots q_n$ will be.

$$\vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} + \cdots \vec{F_n}$$

$\vec{F}_i \rightarrow$ Force on Q due to source charge q_i

Coulomb's law: Force on a test charge Q due to a point charge q (at rest) at a distance r away is given by

$$\boxed{\vec{F} = \frac{1}{4\pi\epsilon_0}\frac{qQ}{\chi^2}\hat{\chi}}$$

This is Coulomb's law and is based on experiments.

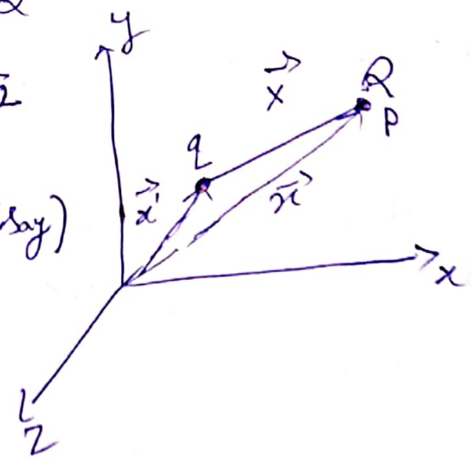
$\epsilon_0 \rightarrow$ permittivity of free space

In SI units, $\epsilon_0 = 8.85\times10^{-12}\ \frac{C^2}{Nm^2}$.

In the above equation

$|\vec{F}| \propto qQ$

$|\vec{F}| \propto \frac{1}{\chi^2}$



$\boxed{\vec{\chi} = \vec{x} - \vec{x}'} = \vec{r}$ (say)

$\vec{\chi} \rightarrow$ separation vector from $\vec{x}'$ to $\vec{x}$

and $\chi = |\vec{\chi}| = |\vec{x} - \vec{x}'| = r$ (let)

$\hat{\chi} \rightarrow$ unit vector.

Electric Field:

We consider many point charges $q_1, q_2, \ldots q_n$ at distance $r_1, r_2, r_3 \ldots r_n$ from charge Q.
According to the superposition principle, the total force on Q is given by.

$$\vec{F} = \vec{F_1} + \vec{F_2} + \ldots \vec{F_n}$$

$$= \frac{1}{4\pi\epsilon_0}\left(\frac{q_1 Q}{r_1^2}\hat{r}_1 + \frac{q_2 Q}{r_2^2}\hat{r}_2 + \ldots + \frac{q_n Q}{r_n^2}\hat{r}_n\right)$$

$$= \frac{Q}{4\pi\epsilon_0}\left[\frac{q_1\hat{r}_1}{r_1^2} + \frac{q_2\hat{r}_2}{r_2^2} + \ldots + \frac{q_n\hat{r}_n}{r_n^2}\right]$$

or $\vec{F} = Q\vec{E}$

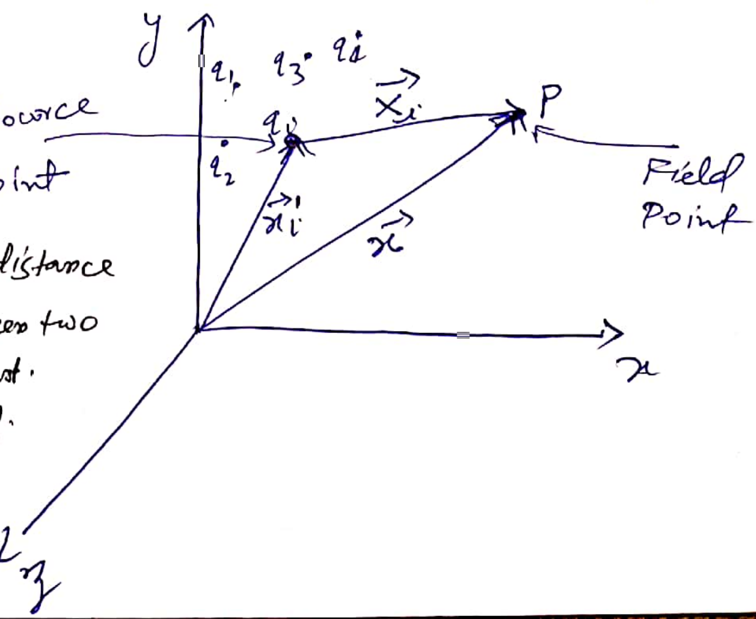
where $$\vec{E}(\vec{r}) = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1\hat{r}_1}{r_1^2} + \frac{q_2\hat{r}_2}{r_2^2} + \ldots + \frac{q_n\hat{r}_n}{r_n^2}\right]$$

or $$\boxed{E(\vec{r}) = \frac{1}{4\pi\epsilon_0}\sum_{i=1}^{n}\frac{q_i\hat{r}_i}{r_i^2}}$$

E is called electric field ~~of the~~ of the source charges

$\vec{X}_i = \vec{x} - \vec{x}_i' = \vec{r}_i$ (let)

$|\vec{X}_i| = |\vec{x} - \vec{x}_i'| = X_i = r_i$



H.W. Find electric field a distance z above the midpoint between two equal charges, q, a distance d apart. Check what happens when $z \gg d$. (see Fig)