ELECTRIC CHARGES AND FIELDS

Forces between multiple charges:

Super position principle: Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to the other charges. This is termed as the principle of super position.

Let $q_1, q_2, q_3 \ldots..$ be the charges located at different positions in space. The total force on q_1 due to the other charges is,

$$\vec{F_1} = \vec{F_{12}} + \vec{F_{13}} + \vec{F_{14}} + \ldots\ldots$$

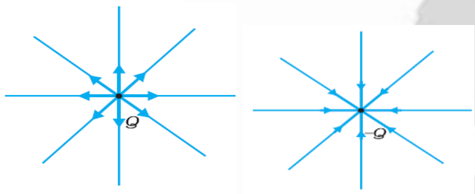
$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_3}{r_{13}^2}\hat{r}_{13} + \cdots + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_n}{r_{1n}^2}\hat{r}_{1n}$$

$$= \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{n}\frac{qi}{(r_{1i})^2}\hat{r}_{1i}$$

Electric Field:

- The region around a charged body in which another charged body experiences an electric force.
- **The electric field due to a charge Q at a point in space is the force experienced by a unit positive charge at that point.**
- The electric field produced by the charge Q at a point r is given as

$$\boldsymbol{E(r) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}}$$



- The force exerted by a charge Q on a charge q, as $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\hat{r}$
- $\boldsymbol{F = qE}$
- **SI unit of electric Field is N/C**
- The electric field E due to Q is independent of other charges.
- For a positive charge, the electric field will be directed radially outwards from the charge. On the other hand, for a negative charge, the electric field vector, points radially inwards.
- The magnitude of electric field E will depend only on the distance r of the charge q from the charge Q

Electric Field due to a system of charges:

Consider a system of charges $q_1, q_2, \ldots q_n$ with position vectors $r_1, r_2, \ldots r_n$, relative to some origin O

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1p}^2}\widehat{r_{1p}}$$

Where $\widehat{r_{1p}}$ is a unit vector in the direction from q_1 to p

Similarly

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2p}^2}\hat{r}_{2p}$$

By the super position principle,

$$E = E_1 + E_2 + \cdots + E_n$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1p}^2}\hat{r}_{ip} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2p}^2}\hat{r}_{2p} + \cdots + \frac{1}{4\pi\varepsilon_0}\frac{q_n}{r_{np}^2}\hat{r}_{np}$$

$$\boldsymbol{E(r) = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{qi}{(r_{ip})^2}\hat{r}_{ip}}$$

Physical significance of electric field:

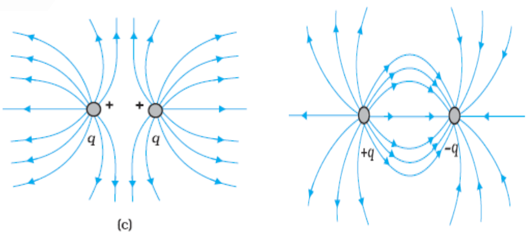
- By knowing electric field at any point, we can determine the force on a charge at that point.
- The force at any point, where a charge $q_0$is placed is

$$F = q_0 E$$

Electrostatic force=charge ×electric field

- Electric field plays an intermediary role in forces between two charges.

Electric field lines



- It is a vector quantity

- **Electric field line is a curve drawn in such a way that the tangent to it at each point is in the direction of the field at that point.**

Properties of electric field lines:-

1) Field lines start from positive charges and end at negative charges. If there is a single charge, they may start or end at infinity.

2) Two field lines can never cross each other. (If they did, at the point of inter section two tangents can be drawn, which is not possible)

3) Electrostatic field lines do not form any closed loops.

Home Assignment (P2-1-03)

1. Is electric field intensity a scalar or vector quantity? Give SI unit.
2. Does an electric charge experience a force due to the electric field produced by it?
3. An electron and a proton are kept in the same electric field. Will they experience same force and have same acceleration?
4. Why direction of an electric field is taken outward (away) for a positive charge and inward (towards) for a negative charge?
5. Do the electric lines of force really exist? What is about the field they represent?

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