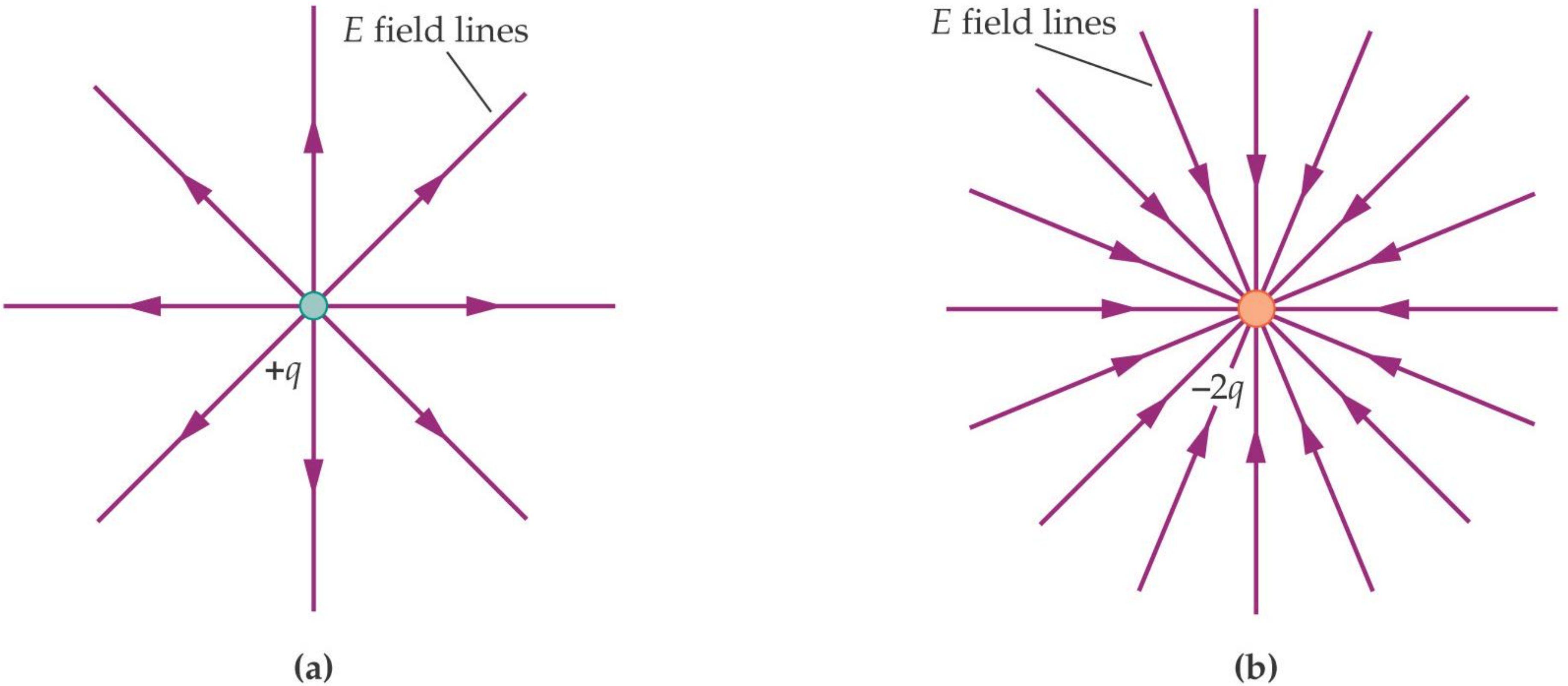
Electricity and Magnetism
Lecture -2-



The Electric Field

- The magnitude of the electric field called the electric field intinsity and defined :

  the force per unit charge

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_0}$$

SI unit: N/C

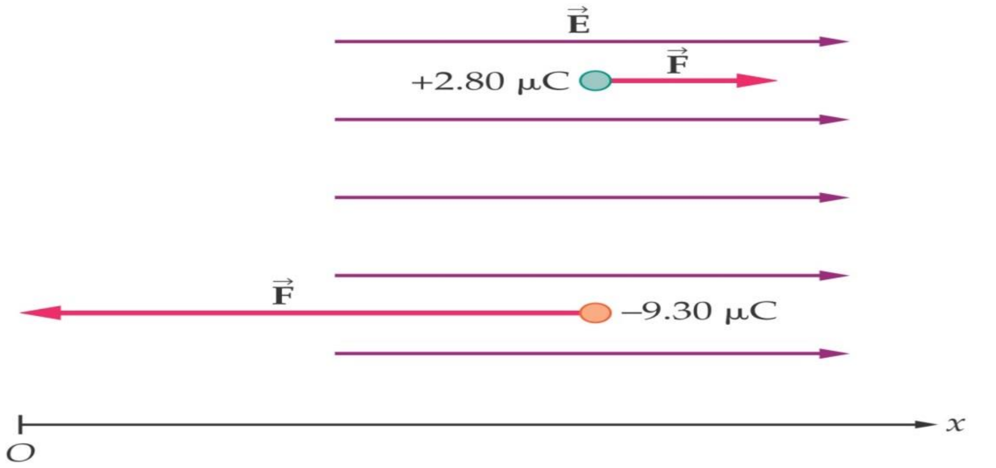
$\overrightarrow{\boldsymbol{E}} \equiv$ ***is a vector because*** $\overrightarrow{\boldsymbol{F}}$ **is avector**

$\overrightarrow{\boldsymbol{E}} \equiv$ Electric field intensity

$\overrightarrow{\boldsymbol{F}} \equiv$ The force

$q_0 \equiv$ the charge (or test charge)

- The charge q_0 can be either +ve or –ve.
- If q_0 is +ve , the force $\vec{F}$ experienced by the charge is the same direction as $\vec{E}$
- If q_0 is -ve , $\vec{F}$ & $\vec{E}$ are in opposite directions



❖ **The direction of the force depends on the sign of the charge – in the direction of the field for a positive charge, opposite to it for a negative one.**

$$\vec{E} = \frac{\vec{F}}{q_\circ} = \frac{Newton\ (N)}{Coulmb(coul)}$$

$\vec{E}$ ⟶ N/coul

$\vec{F} = q_\circ \vec{E}$ **(Force exerted on apoint charge $q_\circ$ by in electric field $\vec{E}$).**

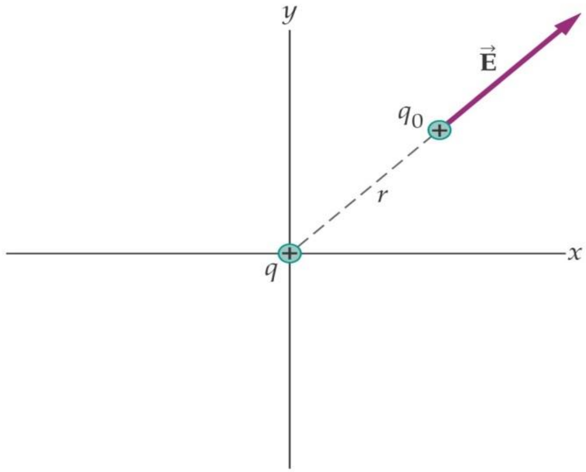
- The electric field of a point charge points radially away from a positive charge and towards a negative one.

Electric Field of a Point charge

- If we place a small test charge q_o at the field point P , at a distance r from the source point , the magnitude F_o of the force is given by coulomb's law , $$F_o = \frac{1}{4\pi\epsilon_o}\frac{q\,q_o}{r^2}$$

from eq. [$\vec{E} = \frac{\vec{F_o}}{q_\circ}$] the magnitude E of the electric field at P is

$$E = \frac{1}{4\pi\epsilon_o}\frac{q}{r^2}$$



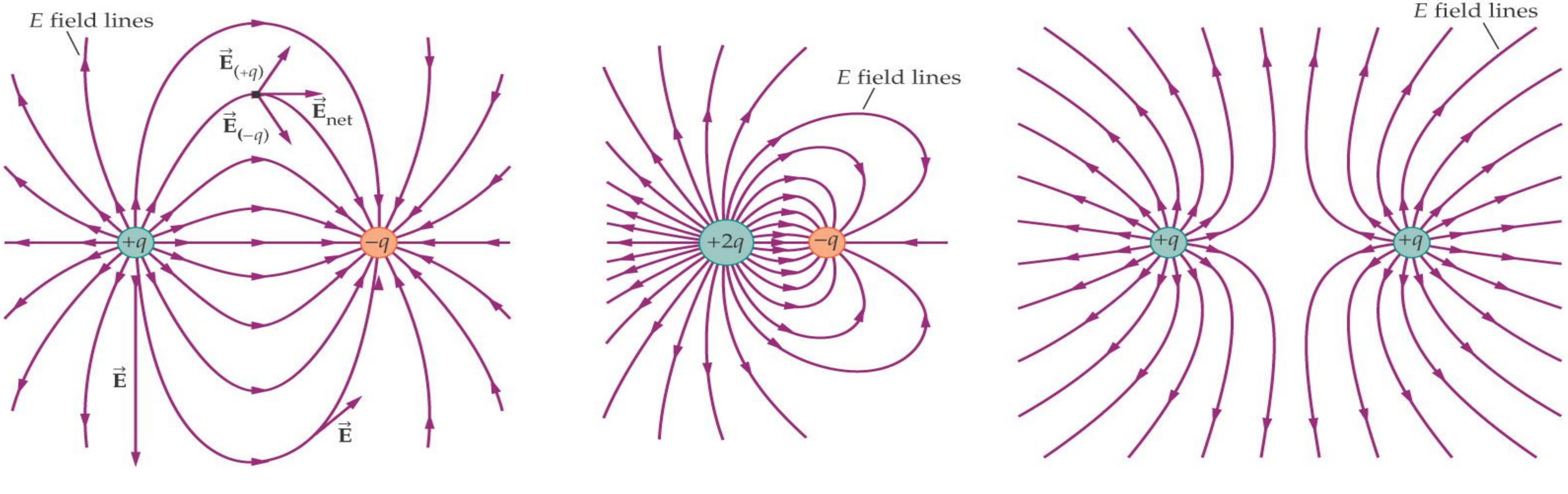
Example/

Field lines

- Electric field lines is an imaginary line drawn in such away that its direction at any point (i.e. the direction of its tangent)

Electric field lines:

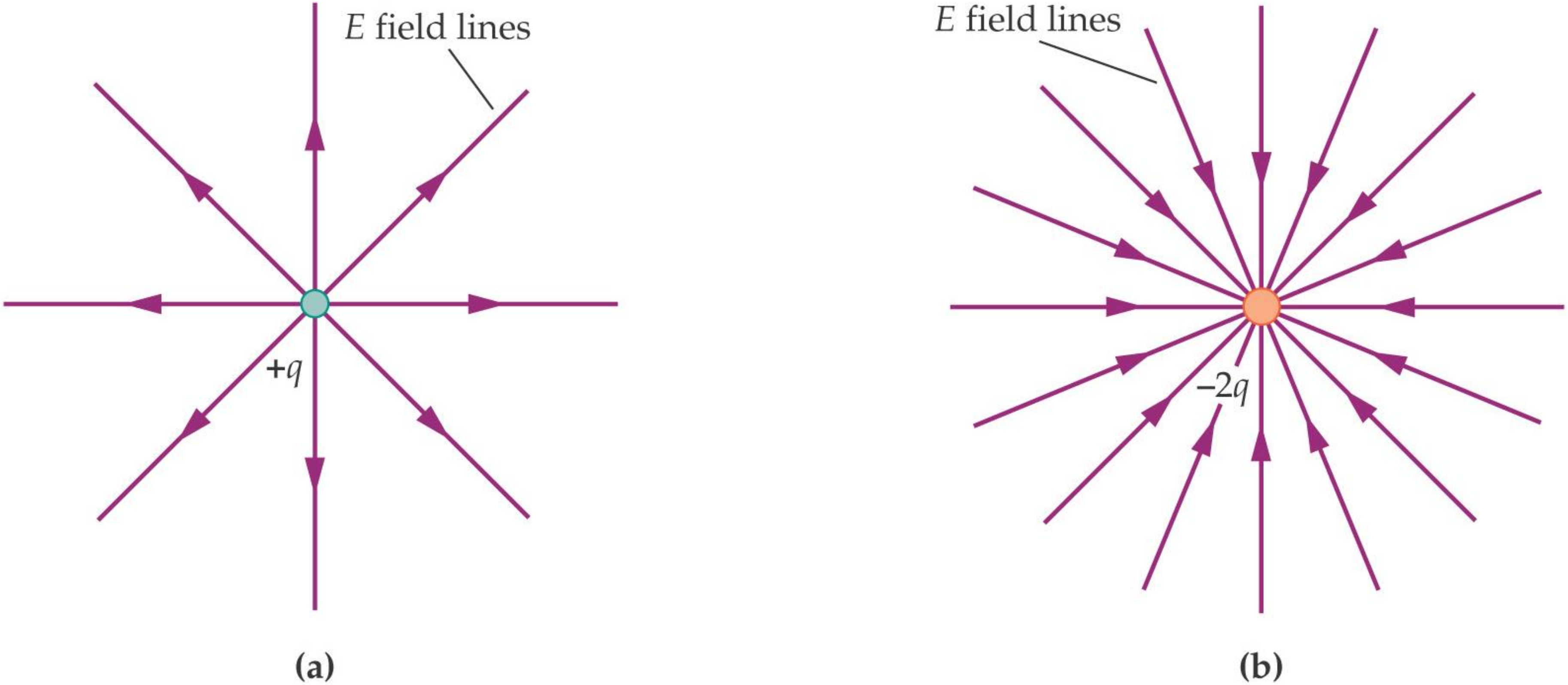
- Point in the direction of the field vector at every point
- Start at positive charges or infinity
- End at negative charges or infinity
- Are more dense where the field is stronger



(a) (b) (c)

Electric Field Lines

The charge on the right is twice the magnitude of the charge on the left (and opposite in sign), so there are twice as many field lines, and they point towards the charge rather than away from it.



Number of lines of force

$$N = E\,A$$

N= No. of lines

E= Electric intensity

A= Surface area

$$E = \frac{1}{4\pi \in_o} \frac{Q}{r^2}$$

$$N = E\,A = \frac{1}{4\pi\in_o} \frac{Q}{r^2} \cdot A$$

$$N = \left(\frac{1}{4\pi\in_o} \cdot \frac{Q}{r^2}\right) \cdot 4\pi r^2$$

$$N = \frac{1}{\in_o} Q$$

- **Does not depend on radius**
- **Lines of force never intersect**

***When the field intensity is one at all points**

$$N = \frac{1}{\in_o} Q$$

- If the field intensity changed from one point to another on a particular surface, and if this surface is not perpendicular to the field at each point of the number of lines, the points are calculated as follows:

$$N = \int E \, dA \, cos\emptyset$$

- Where the limits of integration must be chosen so as to include the entire surface .
- E cos Ø is the component of e normal to the surface.
- Example/

Calculation of the Electric – Field

In most realistic situations that involve electric field and forces, we encounter charge that is distributed over space.

The Superposition of Electric Fields

To find the field caused by a charge distribution , we imagine the distribution to be made up of many point charges q_1 , q_2 , q_3 , ……

*At any given point P, each point charge produced its own electric fields $\overrightarrow{E_1}$,$\overrightarrow{E_2}$,….

So a test charge q_0 placed at P

Experience a force $\overrightarrow{F_1} = q_0 \overrightarrow{E_1}$ from charge q_1

a force $\overrightarrow{F_2} = q_0 \overrightarrow{E_2}$ from charge q_2 and so on

*From the principle of supersession of force , the total force $\overrightarrow{F_0}$ that the charge distribution exert on q_0 is the vector sum of these individual forces:-

$$\overrightarrow{F_0} = \overrightarrow{F_1} + \overrightarrow{F_2} + \overrightarrow{F_3} = q_0 \overrightarrow{E_1} + q_0 \overrightarrow{E_2} + q_0 \overrightarrow{E_3} + \dots$$

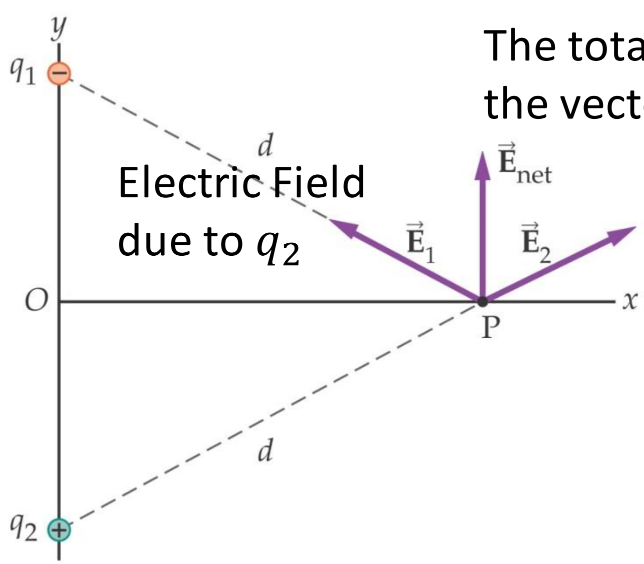
$$F = \sum_n^1 Fn$$

The combined effect of all the charges in the distribution is described by the total electric field $\vec{E}$ at point P

$$\overrightarrow{\boldsymbol{E}} = \frac{\overrightarrow{\boldsymbol{F}_{\mathbf{o}}}}{\boldsymbol{q}_{\circ}} = \overrightarrow{\boldsymbol{E}_{\mathbf{1}}} + \overrightarrow{\boldsymbol{E}_{\mathbf{2}}} + \overrightarrow{\boldsymbol{E}_{\mathbf{3}}} + \cdots$$

- The total electric field at P is vector sum of the field at P due to each point charge in the charge distribution (fig.)
- This is Principle of Superposition of electric field.

The total electric field $\overrightarrow{E}$ at point P is the vector sum of E_1 & E_2



Electric field at Pdue to q_2

$$\vec{E} = \frac{\vec{F_\circ}}{q_\circ}$$

$$F = k\frac{q_1 q_2}{r^2}$$ Coulomb´s law

$$F = k\frac{q_1 q}{{r_1}^2} + k\frac{q_2 q}{{r_2}^2}$$

$$F = q\ k\left[\frac{q_1}{{r_1}^2} + k\frac{q_2}{{r_2}^2} + ...\right]$$

$$\frac{F}{q} = k\left[\frac{q_1}{{r_1}^2} + k\frac{q_2}{{r_2}^2} + ...\right]$$

$$E = k\left[\frac{q_1}{{r_1}^2} + k\frac{q_2}{{r_2}^2} + ...\right]$$

$$E = k\sum_n \frac{q_n}{r^2}$$ For apoint charge

$$E = k\int \frac{dq}{r^2}$$

$$E = \frac{1}{4\pi \in_\circ}\int \frac{dq}{r^2}$$ For distribution charge