Volume Charge Density (ρ)

It is defined as the charge per unit volume of volume charge distribution. Its unit is coulomb/metre^3.

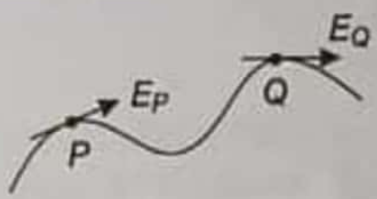
Electric Field

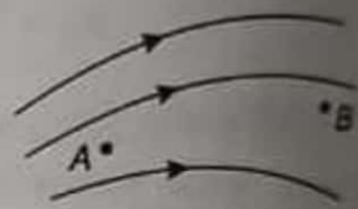
The space in the surrounding of any charge in which its influence can be experienced by other charges is called electric field.

Electric Field Lines

"An electric field line is an imaginary line or curve drawn through a region of space so that its tangent at any point is in the direction of the electric field vector at that point.

The relative closeness of the lines at some place give an idea about the intensity of electric field at that point."





$|E_A| > |E_B|$

Two lines can never intersect.

Electric field lines always begin on a positive charge and end on a negative charge and do not start or stop in mid space.

Electric Field Intensity (E)

The electrostatic force acting per unit positive charge on a point in electric field is called electric field intensity at that point.

Electric field intensity $\mathbf{E} = \lim_{q_0 \to 0} \frac{\mathbf{F}}{q_0}$

where $\mathbf{F}$ = force experienced by the test charge q_0.

Its SI unit is NC^{-1} or V/m and its dimension is $[MLT^{-3}A^{-1}]$.

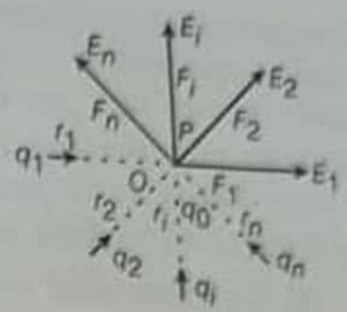
It is a vector quantity and its direction is in the direction of electrostatic force acting on positive charge.

Electric field intensity due to a point charge q at a distance r is given by

$$E = \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2}$$

Electric Field due to System of Charges

If E is electric field at point P due to the systems of charges is given by



$$E = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$$

Electric Potential (V)

Electric potential at any point is equal to the work done per unit positive charge in carrying it from infinity to that point in electric field.

Electric potential, $$V = \frac{W}{q}$$

Its SI unit is J/C or volt and its dimension is $[ML^2T^{-3}A^{-1}]$.

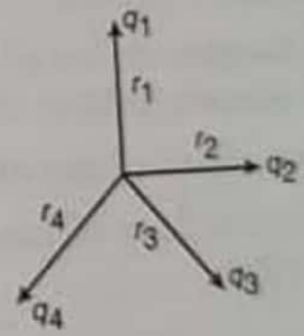
It is a scalar quantity.

Electric potential due to a point charge at a distance r is given by

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

Potential due to System of Charges

Let there be a number of point charges $q_1, q_2, q_3, \ldots, q_n$ at distances $r_1, r_2, r_3, \ldots, r_n$ respectively from the point P, where electric potential is given by



$$V = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}$$

Potential Gradient

The rate of change of potential with distance in electric field is called potential gradient.

Potential gradient $= \dfrac{dV}{dr}$

Its unit is V/m.

Relation between potential gradient and electric field intensity i given by

$$E = -\left(\frac{dV}{dr}\right)$$

Equipotential Surface

Equipotential surface is an imaginary surface joining the points of same potential in an electric field. So, we can say that the potential difference between any two points on an equipotential surface is zero. The electric lines of force at each point of an equipotential surface are normal to the surface.

(i) Equipotential surface may be planer, solid etc. But equipotential surface can never be point size.

(ii) Electric field is always perpendicular to equipotential surface.

(iii) Equipotential surface due to an isolated point charge is spherical.

(iv) Equipotential surface are planer in an uniform electric field.

(v) Equipotential suface due to a line charge is cylindrical.

Electric Lines of Force

Electric lines of force are the imaginary lines drawn in electric field at which a positive test charge will move if it is free to do so.

Electric lines of force start from positive charge and terminate on negative charge.

A tangent drawn at any point on electric field represents the direction of electric field at that point.

Two electric lines of force never intersect each other.

Electric lines of force are always perpendicular to an equipotential surface.

Electric Flux (ϕ_E)

Electric flux over an area is equal to the total number of electric field lines crossing this area.

Electric flux through a small area element dS is given by

$$\phi_E = \mathbf{E} \cdot d\mathbf{S}$$

where $\mathbf{E}$ = electric field intensity

and $d\mathbf{S}$ = area vector.

Its SI unit is N-m^{2}C^{-1}.

Gauss' Theorem

The electric flux over any closed surface is $\frac{1}{\varepsilon_0}$ times the total charge enclosed by that surface, i.e.

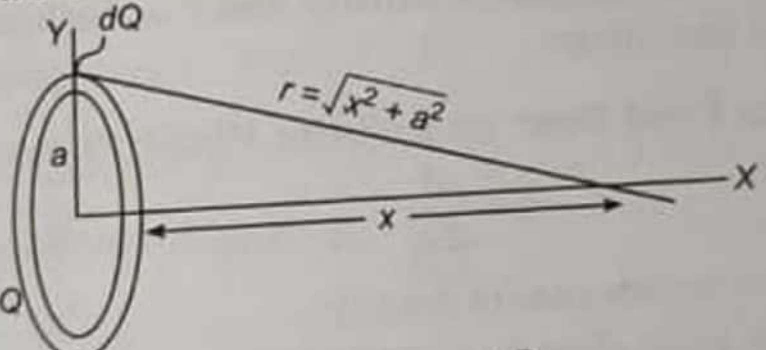
$$\phi_E = \oint_s \mathbf{E} \cdot d\mathbf{S} = \frac{1}{\varepsilon_0} \Sigma q$$

If a charge q is placed at the centre of a cube, then

total electric flux linked with the whole cube $= \frac{q}{\varepsilon_0}$

electric flux linked with one face of the cube $= \frac{q}{6\varepsilon_0}$

(i) **Electric Field at Any Point on the Axis of a Uniformly Charged Ring** A ring-shaped conductor with radius a carries a total charge Q uniformly distributed around it. Let us calculate the electric field at a point P that lies on the axis of the ring at a distance x from its centre.



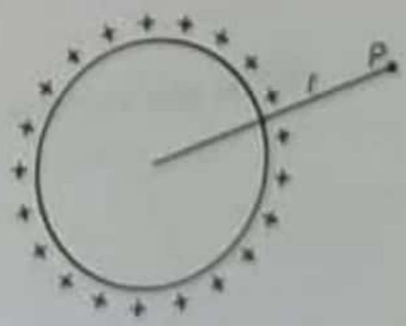
$$E_x = \frac{1}{4\pi\varepsilon_0} \cdot \frac{xQ}{(x^2 + a^2)^{3/2}}$$

The maximum value of electric field

$$E = \frac{1}{4\pi\varepsilon_0} \left(\frac{2Q}{3\sqrt{3}R^2} \right)$$

(ii) **Electric Field due to a Charged Spherical Shell**

(a) At an extreme point ($r > R$)



$$E = \frac{1}{4\pi\,\varepsilon_0} \frac{q}{r^2}$$