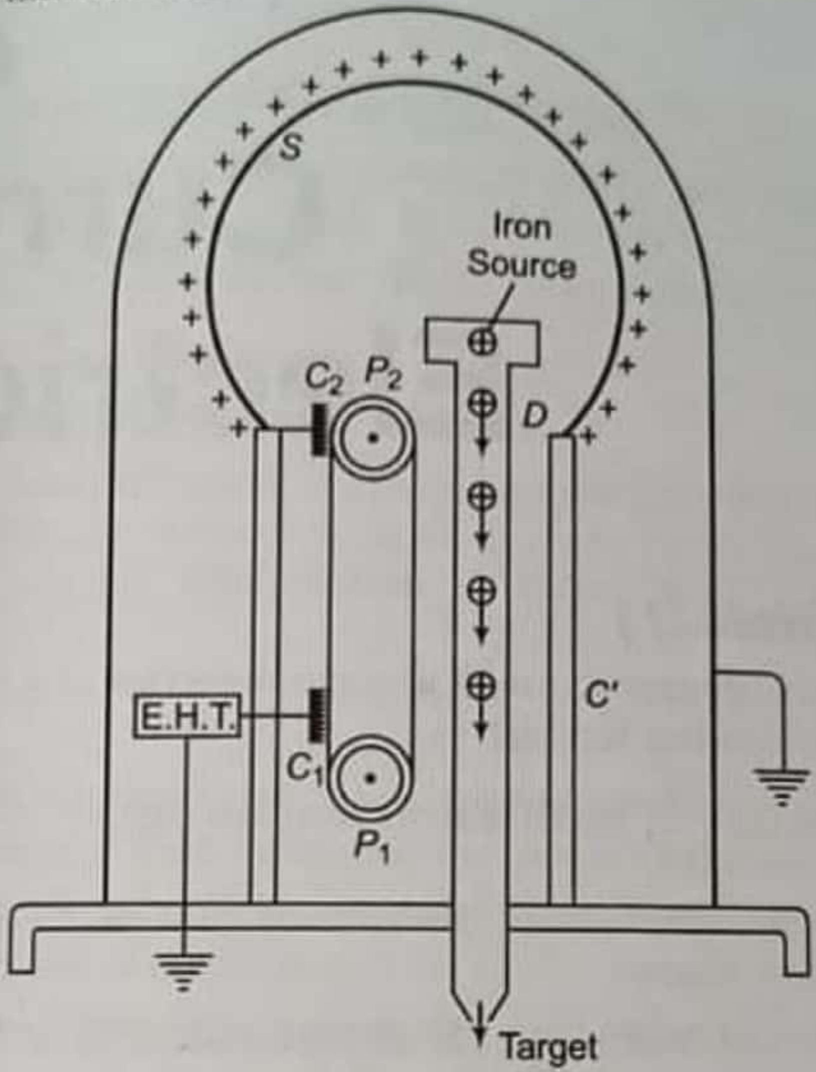
Van-de-Graaff Generator

It is a device used to build up very high potential difference of the order of few million volt.



Its working is based on two points

(i) The action of sharp points (corona discharge)

(ii) Total charge given to a spherical shell resides on its outer surface.

Lightning Conductor

When a charged cloud passes by a tall building, the charge on the cloud passes to the earth through the building. This causes a big damage to the building. Thus to protect the tall building from lightning, the lightning conductors, (which are pointed metal roads) passes over the charge on the clouds to earth, thus protecting the building.

Conservation of Charge

Charge can neither be created nor be destroyed, but can be transferred from one object to another object.

Recently a new particle has been discovered called 'Quark'. It contains charge $\pm\frac{e}{3}, \pm\frac{2e}{3}$.

The protons and neutrons are combination of other entities called quarks, which have charges $\frac{1}{3}$e. However, isolated quarks have not been observed, so, quantum of charge is still e.

Coulomb's Law of Electrostatics

Electrostatic force of interaction acting between two stationary point charges is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

where q_1, q_2 are magnitude of point charges, r is the distance between them and ε_0 is permittivity of free space.

Here, $$\frac{1}{4\pi\varepsilon_0} = \left(10^{-7}\frac{\text{N}-\text{s}^2}{\text{C}^2}\right)c^2$$

Substituting value of $c = 2.99792458 \times 10^8$ m/s,

we get $$\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ N-m}^2/\text{C}^2$$

In examples and problems we will often use the approximate value,

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$$

The value of ε_0 is 8.85×10^{-12} $\text{C}^2/\text{N-m}^2$.

If there is another medium between the point charges except air or vacuum, then ε_0 is replaced by $\varepsilon_0 K$ or $\varepsilon_0\varepsilon_r$ or ε.

where K or ε_r is called dielectric constant or relative permittivity of the medium.

$$K = \varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

where, ε = permittivity of the medium.

For air or vacuum, $K = 1$

For water, $K = 81$

For metals, $K = \infty$

Coulomb's Law in Vector Form

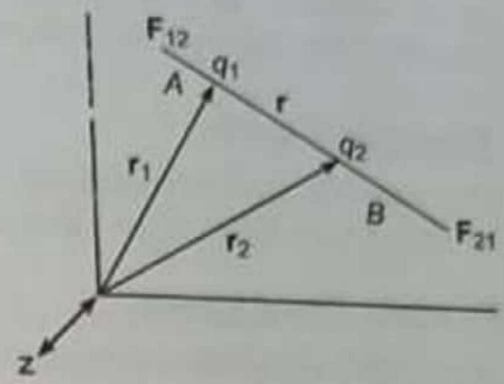
Let q_1 and q_2 both are positive.

Force on q_2 due to q_1,

$$\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}_{AB}$$

$$\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^3} \mathbf{r}_{AB}$$

$$\mathbf{F}_{21} = \frac{q_1 q_2}{4\pi\varepsilon_0} \cdot \frac{\mathbf{r}_2 - \mathbf{r}_1}{|\mathbf{r}_2 - \mathbf{r}_1|^3}$$



The above equations give the Coulomb's law in vector form.

Force on q_1 due to q_2 = – Force on q_2 due to q_1

$$\therefore \quad \mathbf{F}_{12} = -\mathbf{F}_{21}$$

$$\therefore \quad \mathbf{F}_{12} = \frac{q_1 q_2}{4\pi\varepsilon_0} \cdot \frac{\mathbf{r}_1 - \mathbf{r}_2}{|\mathbf{r}_1 - \mathbf{r}_2|^3}$$

The forces due to two point charges are parallel to the line joining the point charges; such forces are called **central forces** and so electrostatic forces are **conservative forces.**

Forces between Multiple Charges

Consider a system of n point charges $q_1, q_2, q_3 \ldots q_n$ are distributed in space. Let the charges be $q_2, q_3 \ldots q_n$, exert forces $F_{12}, F_{13}, \ldots F_{1n}$ on charge q_1. The total force on charge q_1 is given by

$$F_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}^2}\hat{\mathbf{r}}_{21} + \frac{q_1 q_2}{r_{13}^2}\hat{\mathbf{r}}_{31} + \ldots + \frac{q_1 q_2}{r_n^2}\hat{\mathbf{r}}_{n1}\right)$$

Contiuous Charge Distribution

The region in which charges are closely spaced is said to have continuous distribution of charge.

Linear Charge Density (λ)

It is defined as the charge per unit length of linear charge distribution. Its unit is coulomb/metre.

Surface Charge Density (σ)

It is defined as the charge per unit surface area of surface charge distribution. Its unit is coulomb/metre^2.

Volume Charge Density (ρ)

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

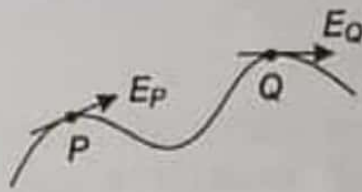
Electric Field

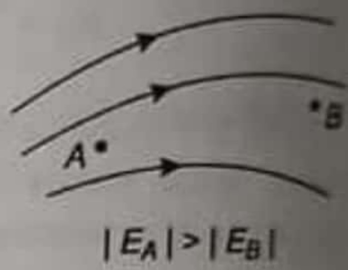
The space in the surrounding of any charge in which its influence can be experienced by other charges is called electric field.

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."





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

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