Coulomb's Law of Electrostatics

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

$F = 1 / 4\pi \varepsilon_o \, q_1q_2 / r^2$

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

Here, $1 / 4\pi\varepsilon_o = (10^{-7} N - s^2 / C^2)C^2$

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

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

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

$1 / 4\pi\varepsilon_o = 9 * 10^9 N\text{-}m^2/C^2$

The value of ε_o is $8.85 * 10^{-12} C^2 / N\text{-}mC^2$.

If there is another medium between the point charges except air or vacuum, then ε_o is replaced by ε_oK or $\varepsilon_o\varepsilon_r$ or ε.

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

$K = \varepsilon_r = \varepsilon / \varepsilon_o$

(i) **On Axial Line**

Electric field intensity $E = 1 / 4 \pi \varepsilon_o * 2 pr / (r^2 - a^2)^2$

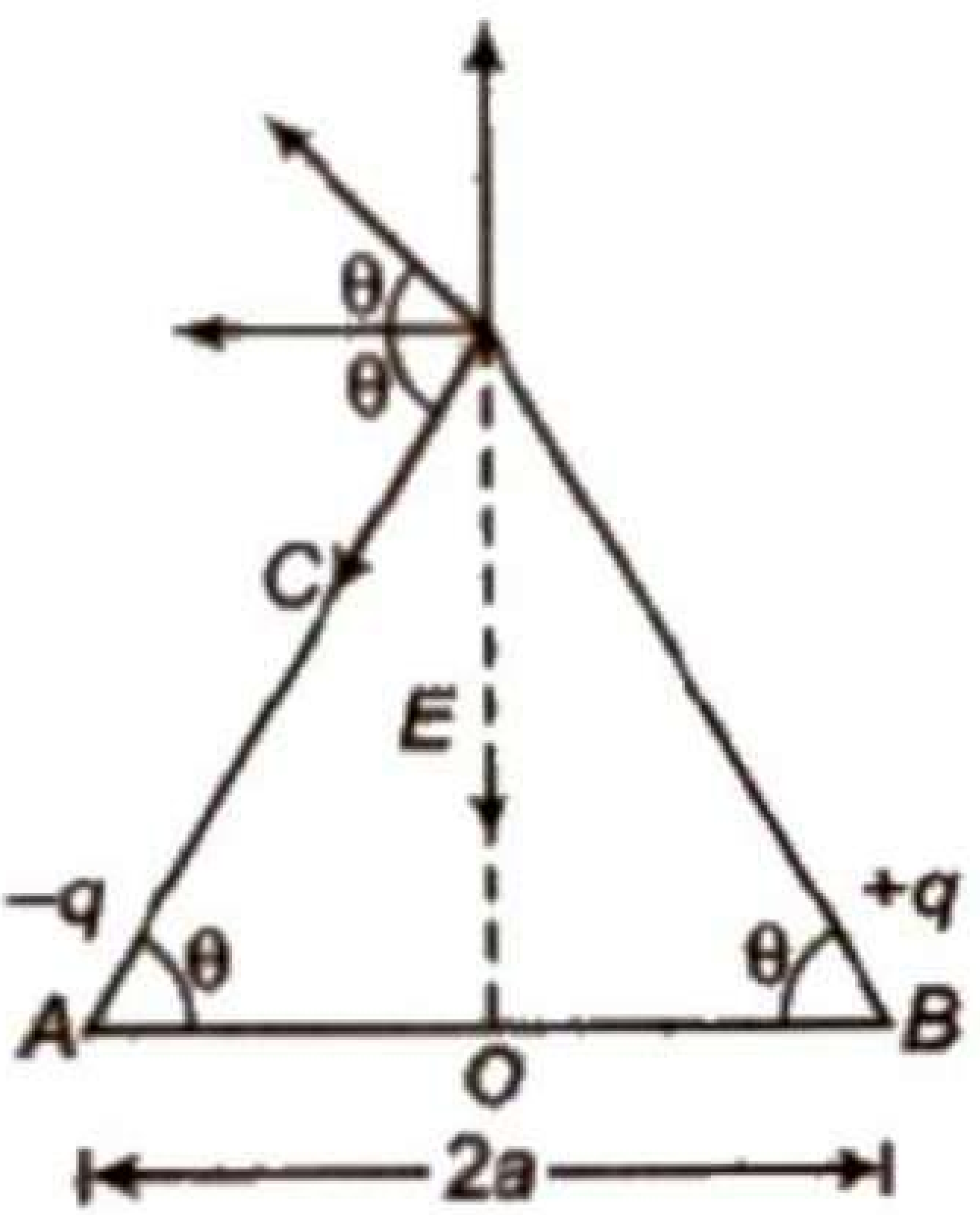
If $r >> 2a$, then $E = 1 / 4 \pi \varepsilon_o * 2 p / r^3$

Electric potential $V = 1 / 4 \pi \varepsilon_o * p / (r^2 - a^2)$

If $r >> 2a$, then $V = 1 / 4 \pi \varepsilon_o * p / r^2$

(ii) **On Equatorial Line**

Electric field intensity $E = 1 / 4 \pi \varepsilon_o * p / (r^2 + a^2)^{3/2}$



Torque

Torque acting on an electric dipole placed in uniform electric field is given by

$\tau = Ep \sin \theta$ or $\tau = p * E$

When $\theta = 90°$, then '$\tau_{max} = Ep$

When electric dipole is parallel to electric field, it is in stable equilibrium and when it is anti-parallel to electric field, it is in unstable equilibrium.

Work Done

Work done is rotating an electric dipole in a uniform electric field from angle θ_1 to θ_2 is given by

$W = Ep (\cos \theta_1 - \cos \theta_2)$

If initially it is in the direction of electric field, then work done in rotating through an angle θ, $W = Ep (1 - \cos \theta)$.

Potential Energy

Potential energy of an electric dipole in a uniform electric field is given by U = – pE cos &theta.

The process of protecting certain field from external electric field is called, electrostatic shielding.

Electrostatic shielding is achieved by enclosing that region in a closed metallic chamber.

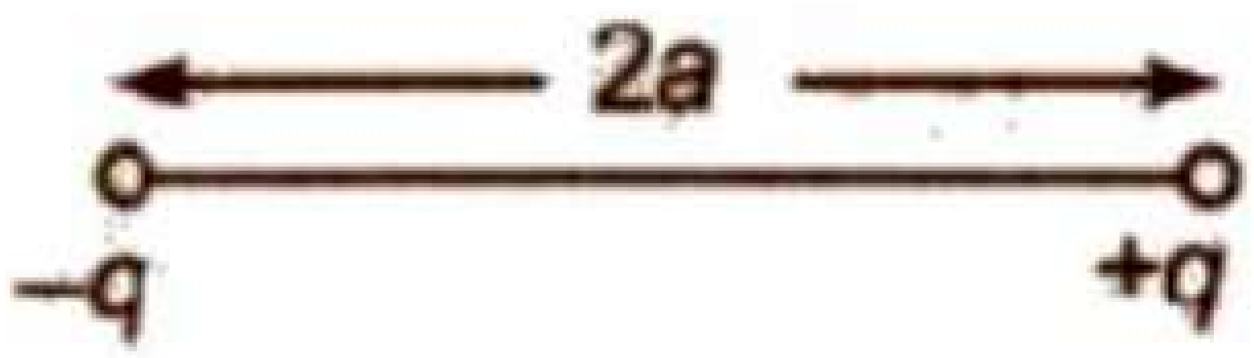
where σ = surface charge density.

If infinite plane sheet has uniform thickness, then

$E = \sigma / \varepsilon_o$

Electric Dipole

An electric dipole consists of two equal and opposite point charges separated by a very small distance. e.g., a molecule of HCL, a molecule of water etc.



Electric Dipole Moment p = q * 2 l

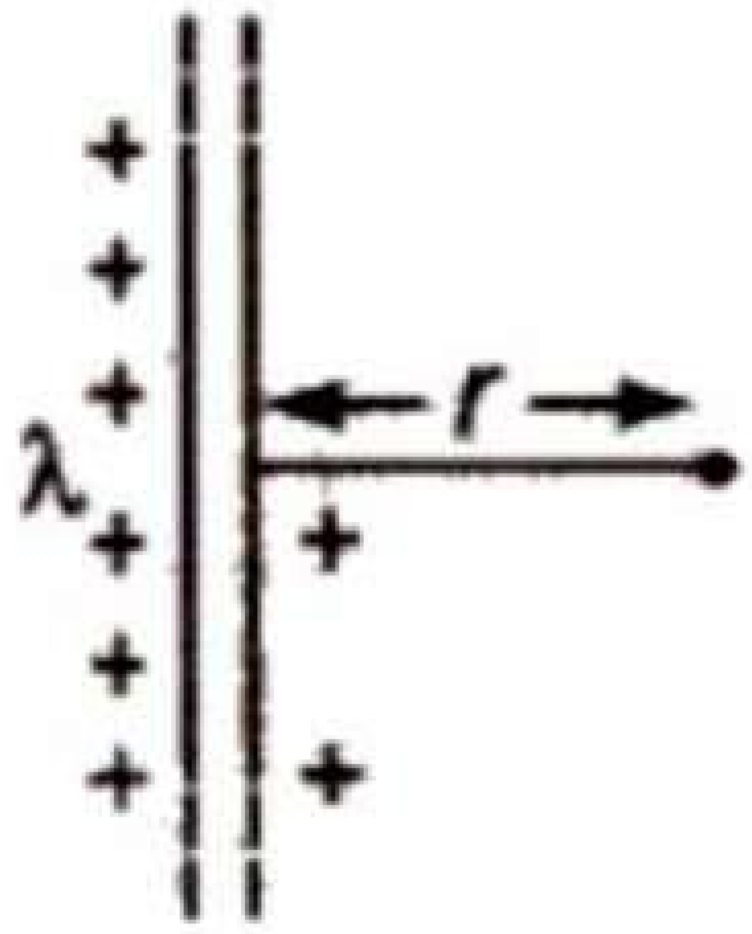
Its SI unit is 'coulomb-metre' and its dimension is [LTA).

It is a vector quantity and its direction is from negative charge towards positive charge.

Electric Field Intensity and Potential due to an Electric Dipole

(i) **On Axial Line**

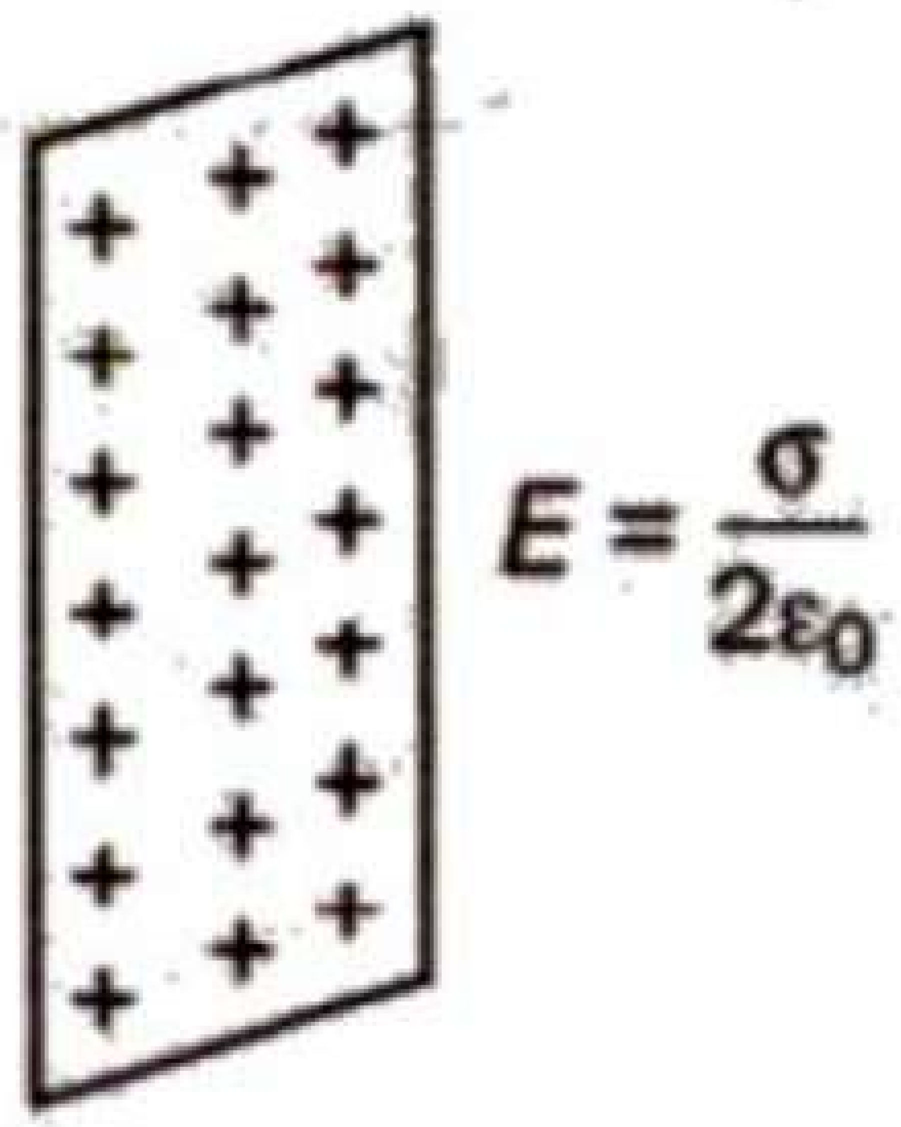
(v) **Electric Field Intensity due to an Infinite Line Charge**



$E = 1 / 2 \pi \varepsilon_o \lambda / r$

where λ is linear charge density and r is distance from the line charge.

(vi) **Electric Field Near an Infinite Plane Sheet of Charge**



$E = \sigma / 2 \varepsilon_o$

where σ = surface charge density.

If infinite plane sheet has uniform thickness,

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

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

$E = 1 / 4\pi \varepsilon_o \; q / r^2$

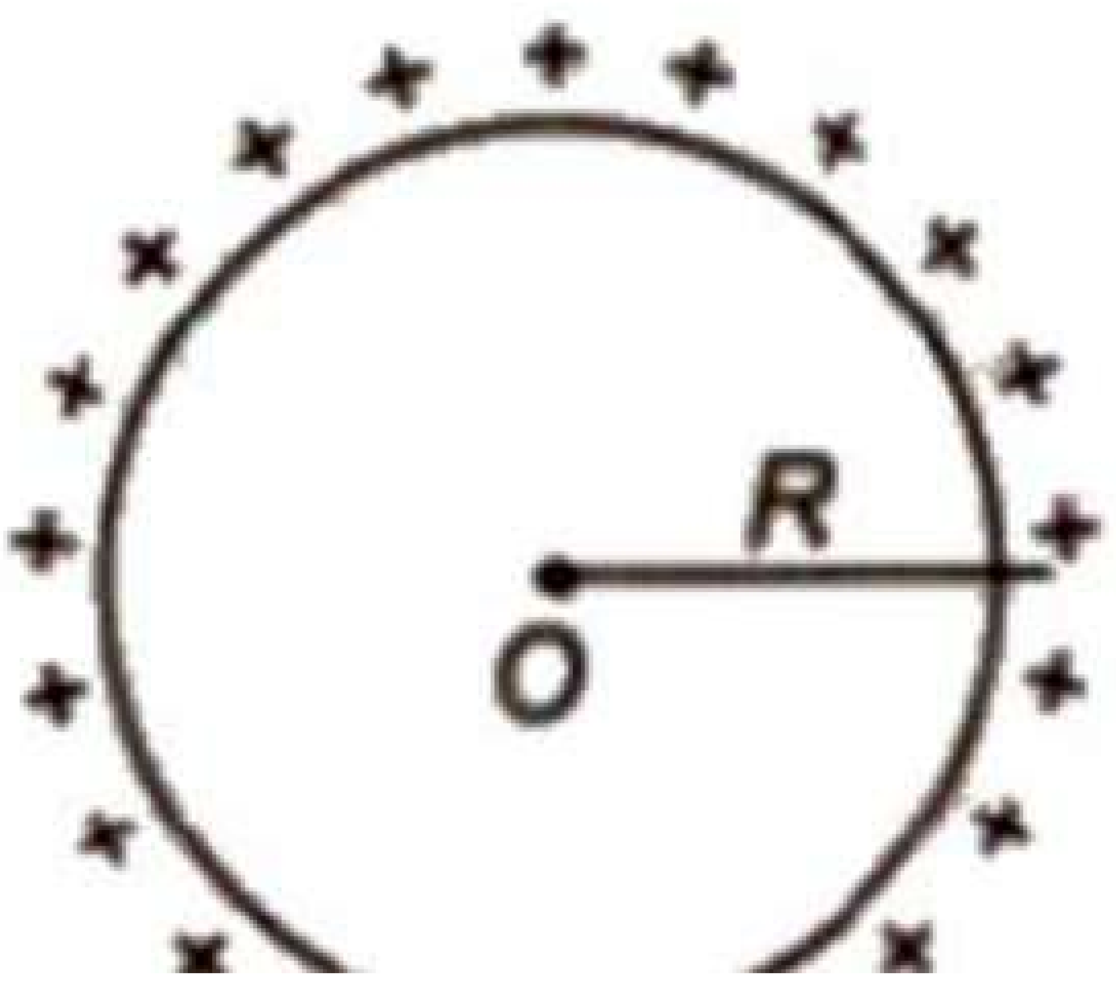
(b) At the surface of a shell (r = R)

$E = 1 / 4\pi \varepsilon_o \; q / R^2$

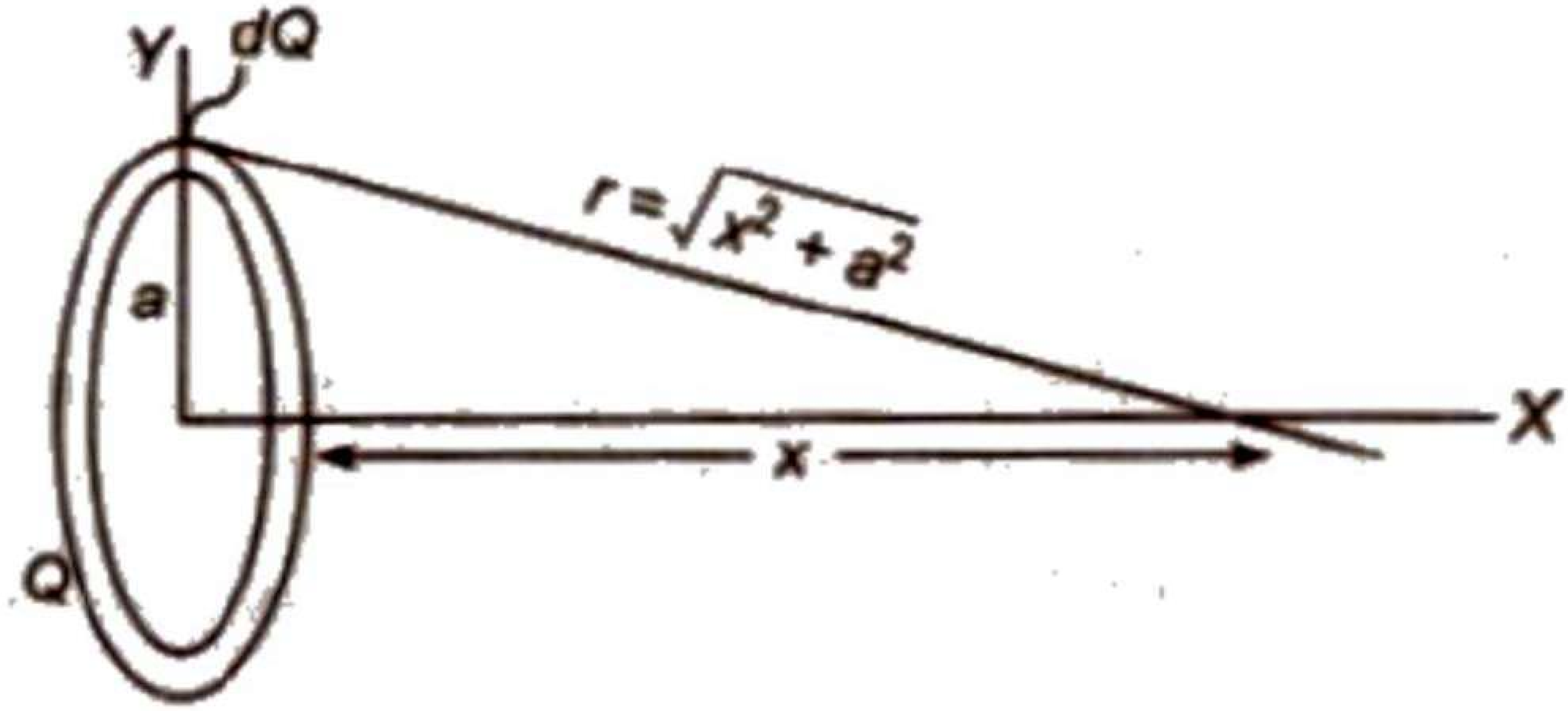
(c) At an internal point (r < R)

$E = 0$

(iii) **Electric Potential due to a Charged Conducting Spherical Shell**



(i) **Electric Field at Any Point on the Axis of a Uniformly Charged Ring** A ring-shaped conductor with radius a carries 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 distance x from its centre.



$E_x = 1 / 4\pi \varepsilon_o * xQ / (x^2 + a^2)^{3/2}$

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

$\varphi_E = E. dS$

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.

$$\lim_{q_0 \to 0} \frac{\mathbf{F}}{q_0}$$

Electric field intensity E =

Its SI unit is NC^{-1} or Vim 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

$E = 1 / 4\pi \varepsilon_o q / r^2$

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

$F_{12} = - F_{21}$

$F_{12} = q_1q_2 / 4\pi\varepsilon \,.\, r_1 - r_2 / |r_1 - r_2|^3$

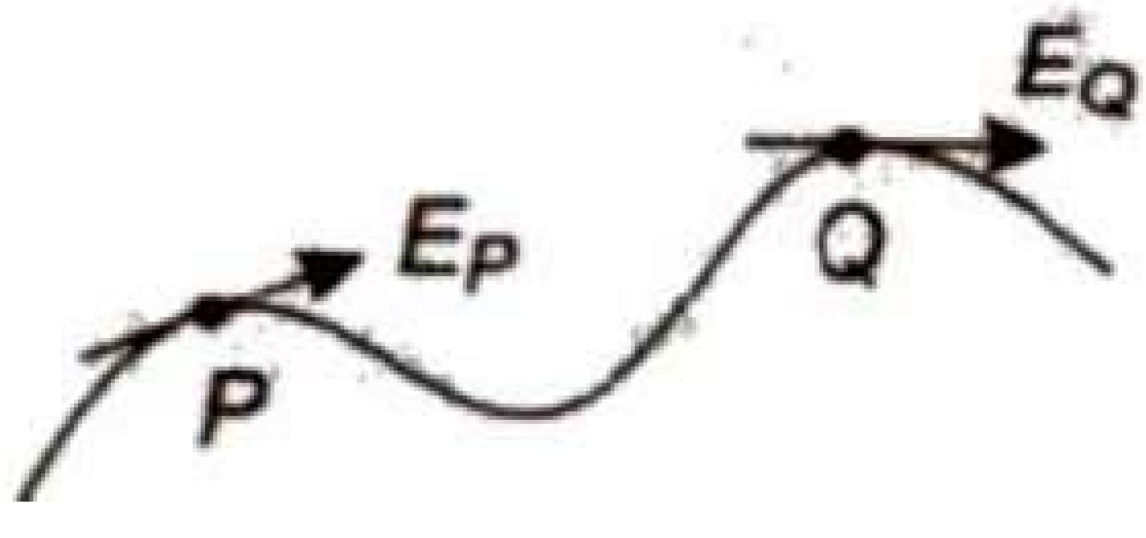
The forces due to two point charges are parallel to the line joining point charges; such forces are called central forces and electrostatic forces are conservative forces.

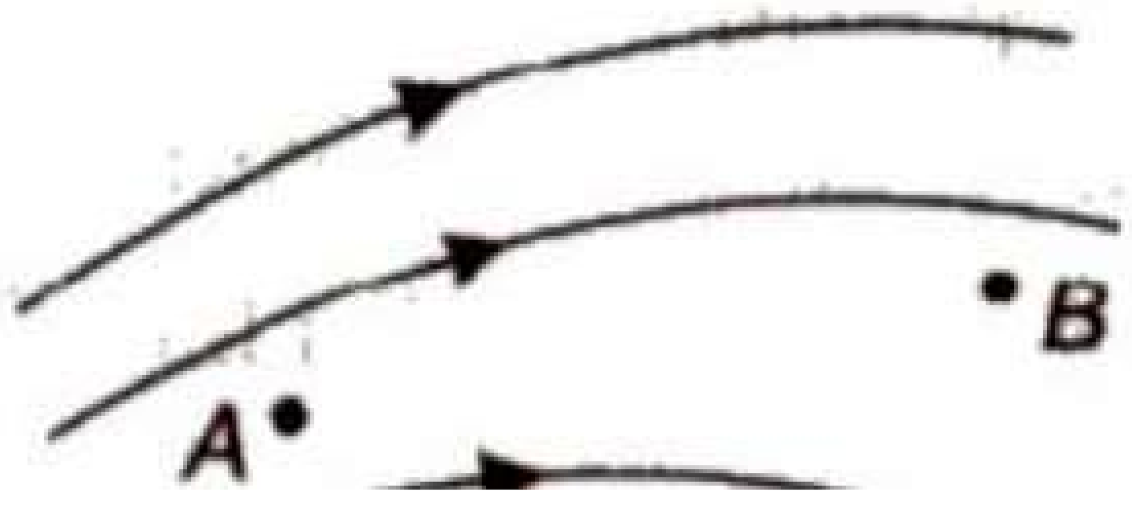
Electric Field

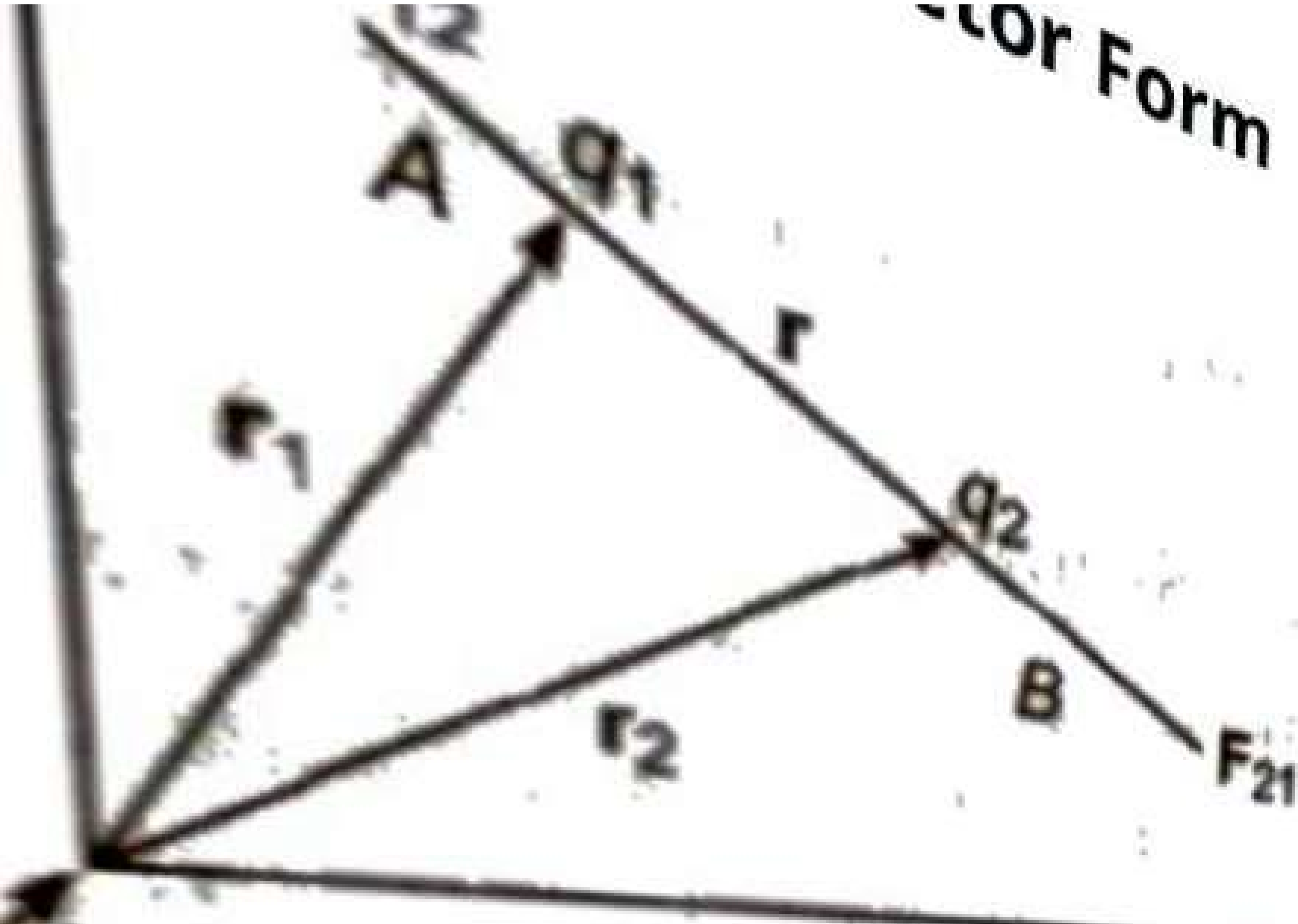
The space in the surrounding of any charge in which its influence can be experienced by other charges is called electric field.

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."






tor Form
A
q1
r
r1
q2
B
r2
F21

Charge is that property of an object by virtue of which it apply electrostatic force of interaction on other objects.

Charges are of two types

(i) Positive charge

(ii) Negative charge

Like charges repel and unlike charges attract each other.

Quantization of Charge

Charge on any object can be an integer multiple of a smallest charge (e).

$Q = \pm ne$

where, n = 1, 2, 3,....... and $e = 1.6 * 10^{-19}$ C.

Conservation of Charge

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