Relative permittivity:-

↳ The permittivity of any medium with respect to permittivity of the free space (or vaccum) is called relative permittivity of that medium. It is denoted by ϵ_r and is given by:

$$\epsilon_r = \frac{\text{permittivity of medium}}{\text{permittivity of free space}}$$

$$\therefore \epsilon_r = \frac{\epsilon}{\epsilon_0}$$

The relative permittivity of the medium is also known as the dielectric Constant of the medium. It is denoted by K.

$$K = \epsilon_r = \frac{\epsilon}{\epsilon_0}$$

Thus, For S.I. system and in the medium other than air

$$F = \frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1 q_2}{r^2}$$

OR,
$$\boxed{F = \frac{1}{4\pi\epsilon_0 K}\frac{q_1 q_2}{r^2}}$$

permittivity:-

↳ The ability of a medium to pass the electric charge through that medium is called permittivity of that medium.

Electric field:-

↳ The space around the electric charge where the electric force of attraction or repulsion exists is called electric field.

Test Charge:-

↳ The positive charge having unit magnitude is taken as test charge in electrostatics. It is denoted by q_0.

i.e. $\boxed{q_0 = \pm 1\ C}$

Electric field intensity:-

↳ Electric field intensity at a point in an electric field is defined as the force experienced by a unit positive charge placed at that point.

If 'F' is the force experienced by the unit positive test charge q_0 at a point in an electric field, the electric field intensity is given by,

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

It is a vector quantity and It's SI unit is N/C.

Electric field intensity due to a test (point) charge:-

↳ Let us consider a charge +q at point 'O' in space and also consider a point 'p' at distance 'r' from 'O'. so that OP = r. If a test

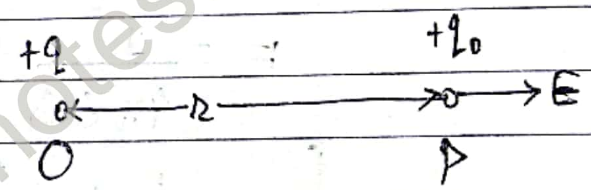

fig:- Electric field intensity due to a point (test) charge.

charge $+q_0$ is placed at 'p', the force experienced by the test charge $+q_0$ is given by;

$$F = \frac{1}{4\pi\epsilon_0}\frac{q q_0}{r^2} \quad \text{------ (i)} \quad [\text{For vaccum}]$$

Now, by definition, the magnitude of the electric field intensity 'E' at a point at distance 'r' from the charge +q is,

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

For other medium,

$$\Rightarrow \boxed{E = \frac{q}{4\pi\epsilon r^2}} \quad \text{------ (ii)} \quad \left[\because K = \frac{\epsilon}{\epsilon_0}\right]$$

Electric flux(ϕ)

↳ The number of electric lines of force passing through a given Surface when held perpendicular to the direction of line of force is called electric flux.

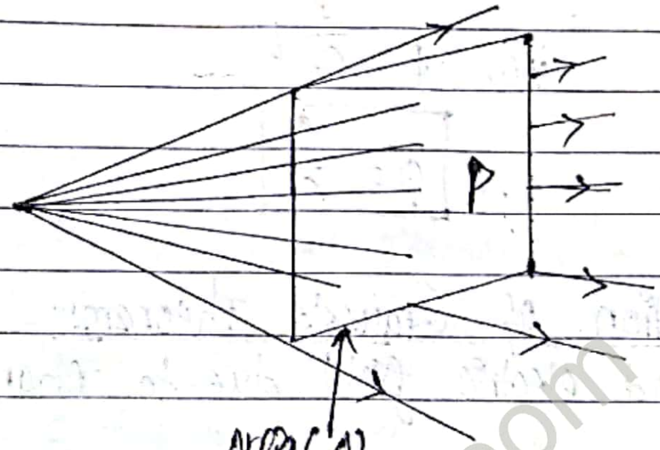

fig: flux through the Surface area 'A'.

Mathematically, Electric flux is defined as the product of electric field intensity and surface area when the field lines are parallel to the surface area vector.

i.e, Electric $flux(\phi) = EA$

Where E = electric field intensity
A = Surface area

But,
In case of surface area vector perpendicular to the field lines, $\theta = 90°$, then,

$$\phi = EA\cos\theta = EA\cos 90° = 0$$

There is no flux through the Surface parallel to the field.

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Gauss's Theorem:-

↳ It state that, "the total electric ~~flux~~ flux passing through a closed surface inclosing a charge is equal to $\frac{1}{\epsilon_0}$ times the magnitude of net charge inclosed by closed surface.

i.e., $\phi = \frac{1}{\epsilon_0} q$

$$\therefore \boxed{\phi = \frac{q}{\epsilon_0}}$$

Application of Gauss's Theorem:-

1) To find electric field due to charged sphere.

(i) At point outside the sphere:-

↳ Let us consider a point 'p' which is at distance 'r' from the centre of sphere of radius 'R' at which the electric field intensity is to be determined. For this, draw a gaussian surface to point 'p'. inclosing the charge '+q'. Which is also the sphere of radius 'r'.

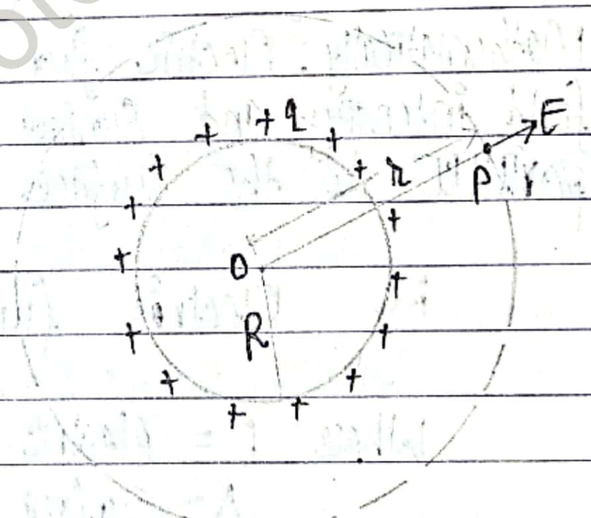

fig:- point lying outside the sphere

Then, the surface area of the Gaussian surface is;

$$A = 4\pi r^2 \quad \text{------ (i)}$$

If 'E' is the electric field intensity at point 'p' when total electric flux(ϕ) passing through a gaussian surface is given by:

$$\phi = EA$$

$$\Rightarrow \phi = E \cdot 4\pi r^2 \quad \text{---- (ii)} \quad [\because \text{using eq}^n \text{(i)}]$$

Also, From Gauss's Theorem:

$$\phi = \frac{q}{\epsilon_0} \quad \text{-----(iii)}$$

From eqⁿ (ii) & (iii)

$$E.4\pi r^2 = \frac{q}{\epsilon_0}$$

$$\therefore \boxed{E = \frac{q}{4\pi\epsilon_0 r^2}} \quad \text{-----(iv)}$$

Thus, this is required expression for electric field intensity due to charge sphere when point lies outside the sphere.

(ii) At point on the Surface of Sphere:-

In this case gaussian surface has radius equal to the charged sphere i.e. $(r=R)$.

So, the area of Gaussian Surface be,

$$A = 4\pi R^2 \quad \text{----(i)}$$

If 'E' is the electric field intensity at point 'p', then the total electric flux passing through the Gaussian Surface is given by;

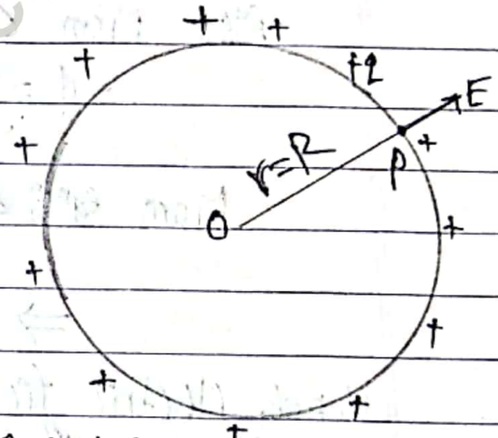

fig:- point lying on Surface of sphere

$$\phi = EA$$

$$\Rightarrow \phi = E\,4\pi R^2 \quad \text{----(ii)} \quad [\because \text{Using (i)}]$$

Also, From Gauss's Theorem,

$$\phi = \frac{q}{\epsilon_0} \quad \text{----(iii)}$$

From eqⁿ (ii) & (iii)

$$E\,4\pi R^2 = \frac{q}{\epsilon_0}$$

$$\Rightarrow \boxed{E = \frac{q}{4\pi\epsilon_0 R^2}} \quad \text{----(iv)}$$

This is the required expression for electric field intensity due to charge sphere when point lies on the surface of sphere.

(iii) When point lies inside the sphere.

↳ In this case Gaussian Surface doesnot inclose any charge (i.e. $q=0$). If E is the electric field intensity at point 'P'. When the total electric flux passing through the Gaussian Surface is given by:

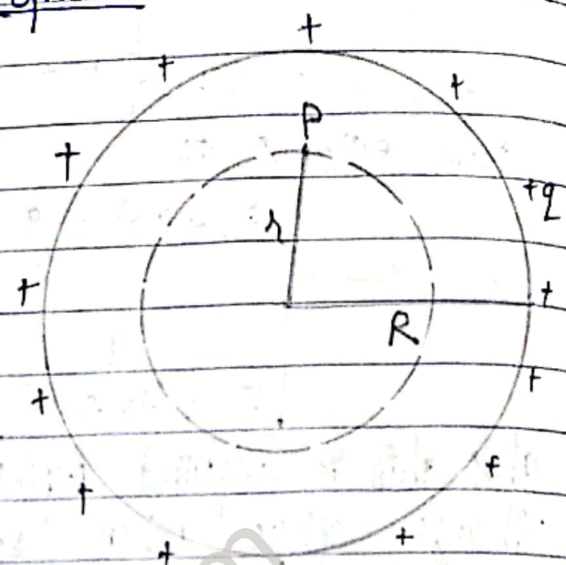

fig:- point lying inside the sphere.

$$\phi = EA$$

$$\Rightarrow \phi = E\,4\pi r^2 \text{ ----(i)}$$

Also, From Gauss's theorem,

$$\phi = \frac{q}{\epsilon_0} \text{ ----(ii)}$$

From eqn (i) & eqn (ii), $E\,4\pi r^2 = \frac{q}{\epsilon_0}$

$$\Rightarrow \boxed{E=0} \text{ ---- (iii)} \quad [\text{Since } q=0]$$

Hence, electric field intensity due to charge sphere when point lies inside the hollow sphere must be zero.

Surface Charge density:-

↳ The amount of electric charge per unit area of a charged surface of the conductor is called surface charge density. It is denoted by 'σ'.

i.e, Surface Charge density = $\frac{\text{Electric charge}}{\text{Surface area}}$

$$\therefore \boxed{\sigma = \frac{q}{A}}$$

[2] Electric field due to a Charged plane Conductor:-

Let us Consider a charge plane Conductor with uniform Surface charge density 'σ'. Let 'p' be the point Outside the charge plane Conductor about which electric field intensity is to be determined.
For this draw a Gaussian Surface of Surface area 'A' as shown in figure.

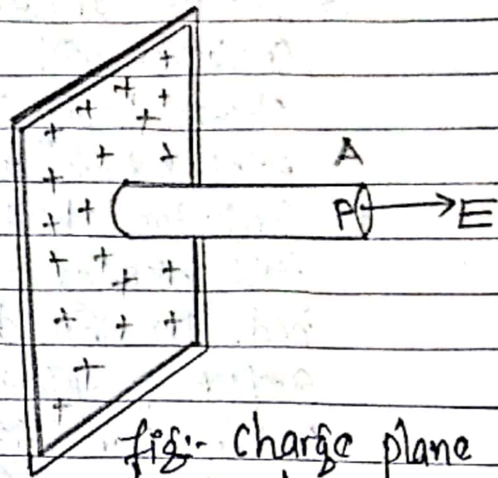

fig:- Charge plane Conductor.

If 'E' be the electric field intensity then flux be;

$$\phi = EA \text{ ---- (i)}$$

Also, the net charge 'q' enclosed by the Gaussian's Surface is,

$$q = \sigma A \text{ ---- (ii)} \quad [\because \sigma = \frac{q}{A}]$$

From Gauss's Theorem;

$$\phi = \frac{q}{\epsilon_0} \text{ ---- (iii)}$$

Using eq^n (ii) in eq^n (iii);

$$\phi = \frac{\sigma A}{\epsilon_0} \text{ ---- (iv)}$$

Comparing eq^n (i) and eq^n (iv);

$$EA = \frac{\sigma A}{\epsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\sigma}{\epsilon_0}} \text{ ---- (v)}$$

Extra//

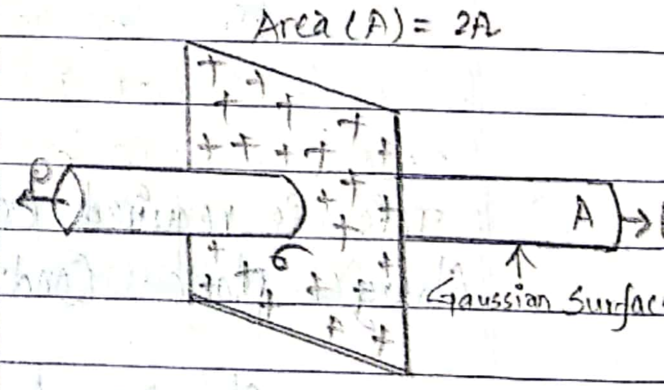

fig:- Electric field intensity due to the infinite sheet of Charge

eq^n (v) is required expression for electric field intensity due to a Charge plane Conductor.

[9] Field Outside a charged plane Conductor:-

↳ Let us consider a charged plane conductor with uniform surface charge density 'σ'. Let 'p' be any point outside a charge plane conductor about which electric field intensity is to be determined. For this, draw Gaussian surface of surface area 'A' as shown in figure.

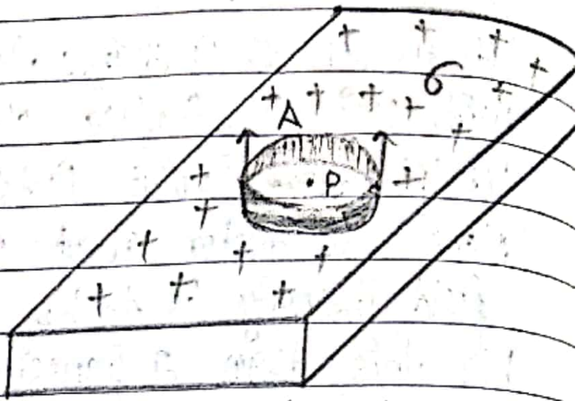

fig:- Field of a charged plane Conduct

If 'E' be the electric field intensity, the flux be,

$$\phi = EA \quad \text{---- (i)}$$

The net charge 'q' enclosed by the Gaussian surface is

$$q = \sigma A \quad \text{---- (ii)}$$

From Gauss's Theorem;

$$\phi = \frac{q}{\epsilon_0} \quad \text{---- (iii)}$$

From eqn (i), (ii) & (iii)

$$EA = \frac{\sigma A}{\epsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\sigma}{\epsilon_0}} \quad \text{---- (iv)}$$

This is required expression for electric field intensity outside a charge plane conductor.

Linear Charge density (λ):-

↳ Charge per unit length of the conductor is called linear charge density.

i.e., $\boxed{\lambda = \frac{q}{l}}$

[4] Electric field intensity due to linear charge density:-

↳ Let us consider infinite long straight conductor of uniform linear charge density 'λ'. Let 'P' be any point about which electric field intensity is to be determined. For this draw a Gaussian surface of length 'l' & radius 'r' as shown in figure.

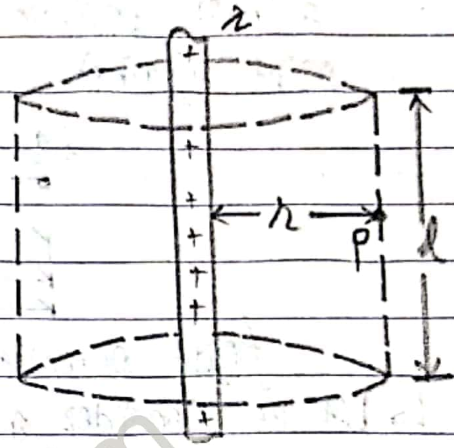

Fig: Infinite Long Conductor.

If 'E' be the electric field intensity, then flux be;

$$\phi = EA$$
$$= E\,2\pi r l \quad \text{---(i)}$$

Also, net charge 'q' enclosed by the Gaussian surface;

$$q = \lambda l \quad \text{---(ii)} \qquad \left[\because \lambda = \frac{q}{l}\right]$$

From Gauss's Theorem:

$$\phi = \frac{q}{\epsilon_0} = \frac{\lambda l}{\epsilon_0} \quad \text{---(iii)} \qquad [\because \text{Using eq}^n \text{(ii)}]$$

From eq^n (i) & (iii);

$$E\,2\pi r l = \frac{\lambda l}{\epsilon_0}$$

$$\Rightarrow \boxed{E = \frac{\lambda}{2\pi\epsilon_0 r}} \quad \text{---(iv)}$$

This is required expression for electric field intensity due to linear charge density.