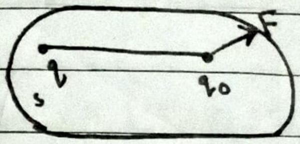
ELectrostat chapter: 2

Electric field : Electric field due to a charge is defined as the Space around the carge due to which any other charge in the field experinces a Coulomb force due to the charge.



- Source charg: Source charge is a charge which produces an electric field that we study
- Test charge: Test charge is a charge which helps to determine the electric field due to the Source charge.

If the test charge experiences a force due to a source charge then it is inside the electric field but if it doesn't experience any force then it is outside the electic field.

⇒ The strength of electric field can be calculated by studying:

(i) Electric field intensity $(\vec{E})$
(ii) Electric potential (V)

Electric field intensity $(\vec{E})$

Electric field intensity at a point is defined as the force experinced by a unit positive test charge at the point.

Mathematically:-

$$\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$$

question why test charge is always taken as positive charge

It is possible to take negative charge as a test charge. why?

why two lines of electric force never intersect

Dimension of $\vec{E}$

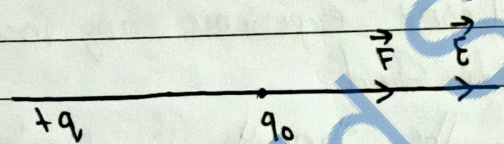
we know that,

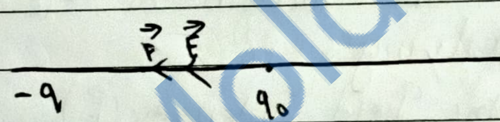
$$\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$$

$$\frac{[MLT^{-2}]}{AT}$$

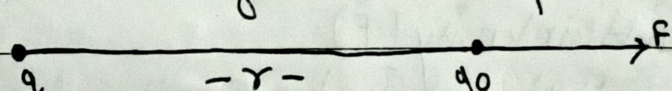
$$[MLT^{-3}A^{-1}]$$

The electric field intensity is a vector quantity and the direction of electric field intensity is direction of Coulomb force betn the charges.





Electric field intensity due to point charge.



⇒ Consider a test ~~charge~~ source charg q which produces having intensity E and test charge q_0 and distance of r from the source charge then E can be,

$$E = \lim_{q_0 \to 0} \frac{F}{q_0}$$

$$= \lim_{q_0 \to 0} \frac{Kq\cancel{q_0}}{r^2 \cancel{q_0}}$$

$$\lim_{q_0 \to 0} \frac{Kq}{r^2}$$

$$E = \frac{q}{4\pi\epsilon_0 r^2} \quad \text{--- (1)}$$

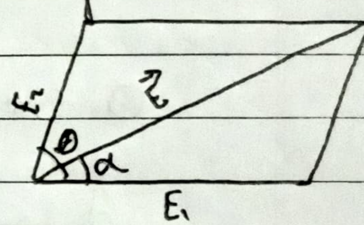
from eq^n (1) it is concluded that, the electric field intensity is inversely proportional to the ~~dis~~ square of distance between the source charge and test charge. and the point of observa

-x

Electric field intensity due to mutiple charges (super position p)

It states that "The resultant electric field intensi at a point is the vector sum of individual electric field intensity due to ~~the~~ other charges.

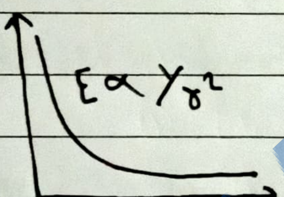
$$\vec{E} = \vec{E_1} + \vec{E_2} + \vec{E_3} + \ldots\ldots + \vec{E_n}$$



$$E = \sqrt{(E_1)^2 + (E_2)^2 + 2E_1 . E_2 \cos\theta}$$

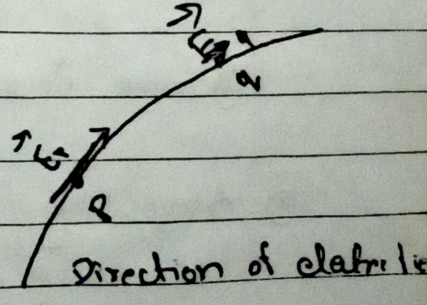
$$\tan\alpha = \frac{E_2 \sin\theta}{E_1 + E_2 \cos\theta}.$$

Ex



Electric lines of force:

Electric lines of force are the line that are drawn around the charge and the tangent drawn at the point in the electric line of force gives the direction of electric field at the point



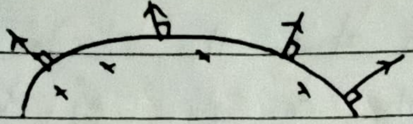
-

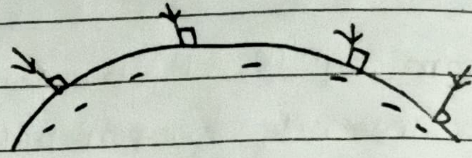
(i) It is a continous curve starting from positive charge to negative charge

(ii) Two electric lines of force never intersect each other.

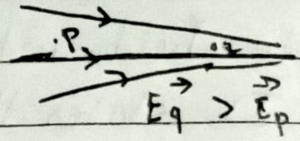
(iii) The tangent drawn at a point in the electric lines of force gives the direction of electric field at that point.

(iv) The electric lines of force are always perpendicular to the charge conductor.



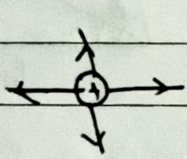


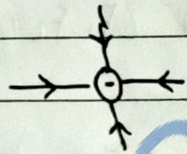
(v) The density of field lines ~~are~~ represent the strength of electric field



Electric lines of force due to distribution of charge.

(a) Single charge.



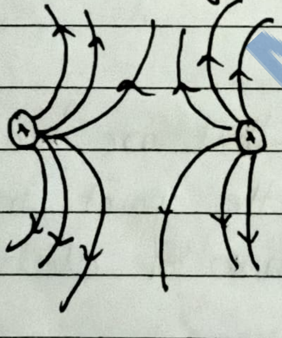


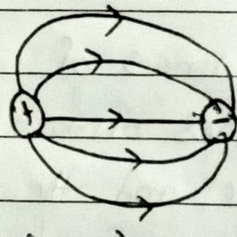
∴ electric lines of force due to single charge

(i) outward for (+)ve

(ii) Inward for (-)ve

(b) Pair of charge,

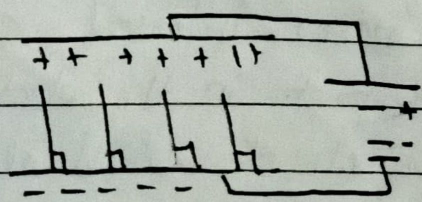




(ii) unlike charges

(i) Same charge.

(c) Oppositely charged parallel plates.



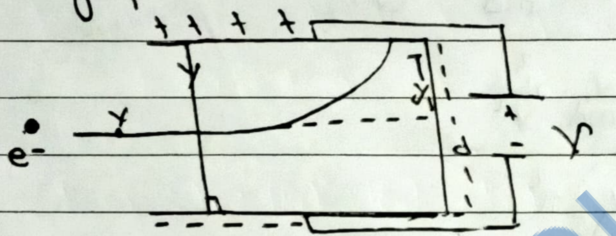
$S = ut + \frac{1}{2}at^2$

Motion of an electron in electric field.

Question: Show that the path of electron in an electric field is parbolic

proof:

let us consider a beam of electron into an electric field with the intensity of (E), with a velocity of (V), the electric field is setup between the two parallel plates at a distance of small (d) by ~~doing~~ giving poteintal difference of (V')



If the electron expirences a force (F) inside the electric field, then it is given by

$$E = \frac{F}{e} \quad \therefore F = eE \; --- (i)$$

Again,

The electric field set-up betn the parallel plate is given by.

$$E = \frac{V}{d}$$

Now, eq^n (i) becomes as $F = \frac{eV}{d} \; --- (ii)$

If the elebron is accierated by a inside the electric field then force expersinced by a electron is given by

$$F = ma \; -- (iii)$$

Equating eq^n (ii) & (iii) we get, $ma = \frac{eV}{d}$

$$\therefore a = \frac{eV}{md} \; --- (iv)$$

If a electron travel a distance x at a time t then

$V = \frac{x}{t}$ $\quad \therefore t = \frac{x}{V} \; ... (v)$

from eqⁿ: $s = ut + \frac{1}{2}at^2$

$s = \frac{1}{2}at^2$,

for vertical displacement, initial velocity of electrons in y-axis $(u_y) = 0$ for vertical displacement $(S_y) = y$

Then,

$$S_y = U_y t + \frac{1}{2} a_y t^2,$$

$$y = 0 + \frac{1}{2} \cdot \frac{eV}{md} \times \left(\frac{x}{v}\right)^2$$

$$y = \frac{1}{2} \times \frac{eV}{md} \frac{x^2}{v^2}$$

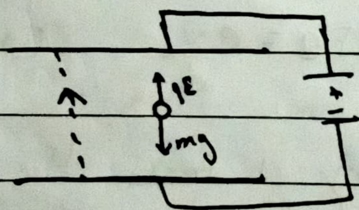
$$y = \left(\frac{1}{2} \frac{eV}{md v^2}\right) x^2$$

$$y = k x^2 \quad \text{---- (i)},$$

where $k = \frac{1}{2} \frac{eV}{md v^2}$

where eqⁿ (i) represents parabolic path of electron in electric field

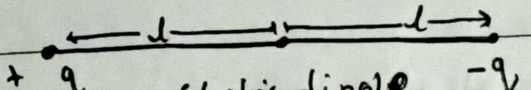
Special Case:



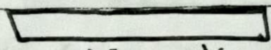
$qE = mg$ [for

Electric dipole :-

Two equal & opposite charge which are separated at the finite distance is known as electric dipole.



Electric dipole



Magnetic dipole

Electric dipole movement :

The strength of electric dipole is given by electric dipole movement. it is the product of one of the magnitud of charge & perpendicular distance between the charges, as

$$\vec{P} = |q| \times 2l$$

Electric flux:

Electric flux is defined as the total number of electric lines of force passing through a surface which is held perpendicular to the electric line of force.

If $\vec{E}$ be the electric field intensity at point p on the surface having area A then electric flux 'ϕ' is calculated as

$$\phi = \vec{E} \cdot \vec{A} \times \cos\theta \qquad [\theta = 0^\circ]$$

$$\therefore \phi = EA$$

Gauss law :-

It states that "The total electric flux passing through a closed surface is equal to the $\frac{1}{\varepsilon_0}$ times the charge inclosed by the surface.

Mathematically :- $\phi = \frac{1}{\varepsilon_0} \times q$

Gaussian surface:

It is the closed surface inclosing the charge and it can be of any shape.

Proof:

Consider a point charge +q at a point O in free space with point O draw a sphere of radius (r) let us calculate the flux passing through the area of the sphere which surrounds the charge +q. If the $\vec{E}$ be the electric field intensity at any point on the surface of the sphere, then the total electric flux through the sphere is given by

$$\phi = E \cdot A \quad \text{---} (1)$$

Again, The surface of sphere is given by $A = 4\pi r^2$

now,

$$\phi = E \times A$$

$$\text{or, } \phi = E \times 4\pi r^2 \qquad [A = 4\pi r^2]$$

$$\text{or } \phi = \frac{q}{4\pi\varepsilon_0 r^2} \times 4\pi r^2 \qquad [\theta = 1/\varepsilon_0 \text{ or, } E = q/4\pi\varepsilon_0 r^2]$$

$$\therefore \phi = \frac{q}{\varepsilon_0}$$

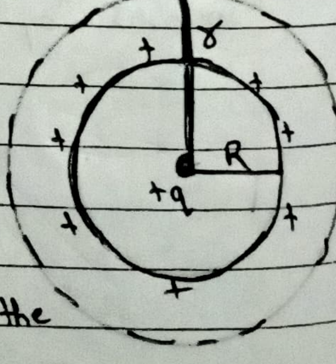
=) Application of Gauss law

Gauss law can be used to find the electric field intensity far more easily than the coulomb's law.

a) Electric field intensity due to charge sphere

let us consider a charge sphere with +q having a centre O & radius R

(I) Electric field intensity outside the charged sphere



Suppose a point P which is outside the charged sphere of radius R. let us draw a gaussian surface in the form of a sphere whose radius is r. This gaussian surface encloses a charge +q. If the electric field intensity (E) at a point p is due to the charged Sphere then the Electric flux is calculated as :-

$$\phi = EA \quad ---- (i)$$

where A is the surface area of gausian surface,

Now, The surface area of a gaussian surface is given by:

$$A = 4\pi r^2$$

Then, eq^n (i) becomes $\phi = E \times 4\pi r^2$ ... (ii)

Again, According to gausse theorem,

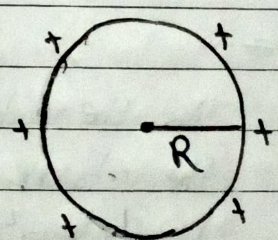
$$\phi = \frac{q}{\epsilon_0} \quad ... (iii)$$

from eq^n (ii) & (iii) we get,

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

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

(ii) Electric field intensity on the surface of a charged sphere



Suppose a point P which is on the surface of sphere with radius R. let us draw a gaussian surface in the form of Sphere whose radius is R. This gaussian surface encloses a charge +q. if the electric field intensity (E) at a point P is E, due to charged Sphere then the electric flux is calculated as:

$\phi = E \times A$ (i) [where A is the surface area.

The Surface area of Sphere is given by $4\pi r^2$

Again According to gausse theorem,

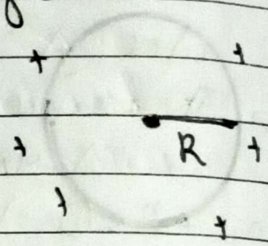
$$\phi = \frac{q}{\epsilon_0}$$

Then, eq^n (i) becomes

$$\frac{q}{\epsilon_0} = E \times 4\pi r^2, \quad \therefore E = \frac{q}{4\pi \epsilon_0 r^2},$$

(11) Electric field intensity inside a charged sphere.

Suppose a point p which is inside a charged sphere having radius R. let us draw a gaussian surface in the form of sphere whose radius is ____. This gaussian surface encloses no charge. if the electric field intensity at point p due to charged sphere is E then electric flux is calculated as:



$$\phi = EA \ldots (1)$$

wher A is surface area of gaussian surface,

A: is given by $4\pi r^2$

Also, According to the gauss law:-

$$\phi = \frac{q}{\varepsilon_0}$$

now, eq^n (1) becomes $\frac{q}{\varepsilon_0} = E \times 4\pi r^2$

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

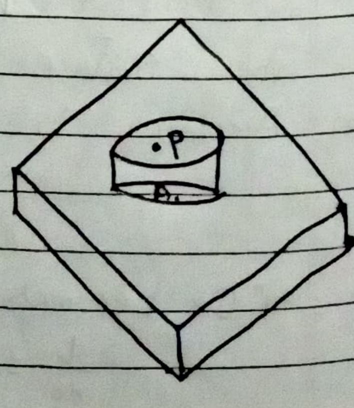
As the charge reside on the surface of charged sphere, the total charge enclosed $q = 0$.

So, $E \times 4\pi r^2 = 0$

$\therefore E = 0$.

(12) Electric field intensity due to a plane charged conductor.

Consider, a charged plane conductor, which has a surface charge density of Sigma (σ). to find the electric field intensity at a point 'p' outside the conductor, draw a cylinder of cross sectional area A.



classmate

Date
Page

as shown in the figure. If E be the electric field intensity at a point and ϕ be the electric flux due to the charged plane conductor then,

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

Again, if sigma be the surface charge density $\sigma = q/A$ where q is the total charge enclosed by cylinder surface:

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

from gauss law,

we can write, $\phi = q/\epsilon_0$ --- (iii) also, $\frac{q}{\epsilon_0} = E \times A$,

equating eq^n (ii) & (iii)

$$\frac{\sigma \cancel{A}}{\epsilon_0} = E \times \cancel{A}$$

$$\therefore E = \frac{\sigma}{\epsilon_0}$$

which is electric field intensity of a plane conductor.

Electric field Intensity due to a line charge.

let us consider a thin wire having uniform linear charge density (λ) To find the electric field intensity at point 'P', a cylindrical gaussian surface is drawn of cross-section Area 'A' if 'E' be the electric field and ϕ be the electric flux due to charged wire then,

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

if (λ) is the linear charge density $\lambda = \frac{q}{l}$ $\therefore q = \lambda l$ --- (ii)

now, from gauss law,

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

from eq^n (i), (ii) & (iii)

$$EA = \frac{\lambda l}{\epsilon_0} \quad // \quad E \cdot 2\pi r l = \frac{\lambda l}{\epsilon_0}$$

$$\therefore E = \lambda / 2\pi r \epsilon_0$$

Date
Page

Electric field Intensity due to infinite plane sheet a charge.

let us consider a charged metal sheet to find the electric field Intensity at paint 'P'. A gaussian surface is drawn with cross-section area 'A'. The electric field intensity 'E' and electric flux of the sheet can be written as.

ϕ .

Electrostatic Shielding

It is the process of isolating a certain region of Space from external field. It is based on the fact that the electric field inside a conductor is zero

Eg:- It is safer to sit inside the bus than in open grand during a lightening.

Question: A charge q is placed at the corner of a cube of side The electric flux through cube is

$\Rightarrow \frac{1}{8} \times \frac{q}{\epsilon_0}$