ELECTRIC CHARGE AND FIELDS
CHAPTER-1

1. ELECTROSTATICS-
   It deals with the study of forces , fields and potentials arising from static charges.
2. ELECTRIC CHARGE –
   Electric charge is the property associated with matter due to which it produce and experience electric and magnetic effect .
   There is two types of charges –
   1. Positive charge –
      Lack of electron in a matter is called positive charge .
   2. Negative charge –
      Excess of electron in a matter is called negative charge .

   # like charges repels and unlike charges attracts each other . (Fundamental law of electrostatics)
   # SI unit of charge =coulomb (C)
3. TYPES OF MATTER -
   According to flow of charges , there is three types of matters .
   1. Conductor –
      The substances through which electric charges can flow easily are called conductor . like iron , aluminium , copper , silver etc.
   2. Insulator –
      The substance through which electric charges can not flows , called insulators . like – plastic , wood etc.
   3. Semiconductor –
      The substances which are behave as insulator at low temperature and behave as a conductor at high temperature . called semiconductor . like germanium , silicon etc.

   #when some charges is given to surface of a conductor then due to property of conduction that charges distributed uniformly at the surface of that conductor . But if we give some charges to insulators then due to its property the charges does not distributed to its surface . it remain at the same point where we give that charges .
4. TYPES OF CHARGING -
   1. BY RUBBING METHOD –
      When we rub two substances then due to friction heat is produced . then one of substance absorb that heat and emit electron , and second one absorb that electron . The one which emit electron due to lack of electron it become positive charged substance and second one due to excess of electron become negative charged substance .

   Following table represents negative and positive charge body when it is rubbed -

Positive charge	Negative charge
Glass rod	Silk cloth
Flannel or cat skin	Ebonite rod
Woollen cloth	Amber rod
Woollen coat	Plastic seat

   2. BY CONTACT METHOD –
      When two identical shape and size conductor touches each other . where one of conductor is charged and second one is neutral . then by touching charge will transfer form charged conductor to neutral conductor . and by this both will have same charge .
   3. BY INDUCTION METHOD –
      When charged body brings nearer to a conductor . then due to attraction of unlike charges , unlike charges accumulated at closer surface of conductor and due to repulsion like charges accumulated at rear surface . this temporary electrification of a conductor is called electrostatic induction .
4. BASIC PROPERTIES OF ELECTRIC CHARGES –
   1. ADDITIVITY OF ELECTRIC CHARGES –

According to this property if a system contain n charges Q_1, Q_2 ,Q_3 ,Q_4 ,Q_5 ……..then total charges of system is

$$Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 \ldots\ldots$$

Charge has magnitude but no direction .

Proper sign have to be used while adding the charges in a system

2. CHARGES ARE CONSERVED –

According to this property no new charges either created or destroyed . Total magnitude of charges in initial and final condition is equal .

3.QUANTISATION OF CHARGES –

It is established that all free charges are integral multiple of a basic unit of charge denoted by e , thus charge Q on a body always given by

$$Q = ne \qquad n = \text{integer number}$$
$$e = 1.6 \times 10^{-19}\ C$$

This fact is called quantisation of charges.

5. COULOMB'S LAW –

According to coulomb , if two charges q_1 and q_2 are kept at r distance . then forces between these two charges is –

1. Directly proportional to product of two charges . it means

$$F \propto q_1 \times q_2$$

2. reciprocal to square of distance between these charges . it means

$$F \propto \frac{1}{r^2}$$

By combining above –

$$F \propto \frac{q1 \times q2}{r^2} \qquad \text{where k= Coulomb constant .}$$

$$F = \frac{k \times q1 \times q2}{r^2} \qquad k = 9 \times 10^9 \frac{Nm^2}{C^2}$$

Case (1) when both charges situated in vacuum , then $k = \frac{1}{4\pi\varepsilon_o}$, ε_o = permittivity of free space

$$= 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

Case (2) when both charges situated in medium ,then $k = \frac{1}{4\pi\varepsilon}$, ε = permittivity of medium .

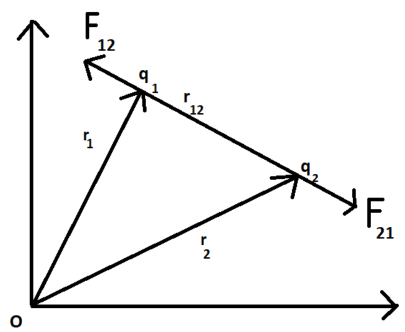
Relation between ε_o and ε $\quad \boldsymbol{\varepsilon = \varepsilon_o \times \varepsilon_r}$, $\quad \varepsilon_r$ = relative permittivity

Some values of ε_r

1. vacuum =1
2. air = 1.00054
3. water = 80
4. metal = infinite

6. VECTOR NOTION OF COULOMB LAW –

Let two charges q_1 and q_2 are located at $\mathbf{r_1}$ and $\mathbf{r_2}$ position vector with reference to point O. then joining vector along direction from $\mathbf{r_1}$ to $\mathbf{r_2}$ is



$$\mathbf{r_{12}} = \mathbf{r_1} - \mathbf{r_2} = -\mathbf{r_{21}}$$

$$\mathbf{F_{12}} = \frac{kq_1q_2}{r^2}\widehat{\boldsymbol{r_{12}}} \quad , \quad \widehat{\boldsymbol{r_{12}}} = \text{unit vector along } \mathbf{r_{12}} \text{ vector}$$

$$\mathbf{F_{21}} = \frac{kq_1q_2}{r^2}\widehat{\boldsymbol{r_{21}}} \quad , \quad \widehat{\boldsymbol{r_{21}}} = \text{unit vector along } \mathbf{r_{21}} \text{ vector}$$

Now according to vector , $\widehat{r_{12}} = -\widehat{r_{21}}$

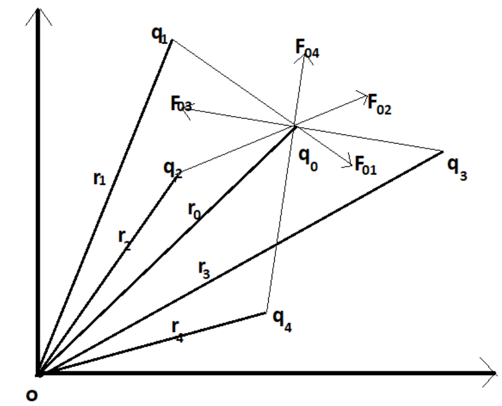
It means $\mathbf{F_{12} = - F_{21}}$

Above equation represents that coulomb rule follow newton third law of motion .

\# when sign of force is positive , then it represents repulsion . when sign of force is negative , then it represents attraction .

7. FORCES BETWEEN MULTIPLE CHARGES –

Consider a system of n charges , where q_1 ,q_2 ,q_3 ,q_4 ,q_5 ………q_n charges located at $\mathbf{r_1}$, $\mathbf{r_2}$,$\mathbf{r_3}$,$\mathbf{r_4}$,$\mathbf{r_5}$……$\mathbf{r_n}$ position vector . let us consider that an another charge q_o is located at $\mathbf{r_o}$. then total force on q_o charge is equal to vector addition of all forces , exerted by all individual charges .This is termed as principle of superposition .



1)force due to q_1 charge on q_o charge = $\mathbf{F_{01}} = \frac{kq_0q_1}{r_{01}^2}\widehat{\boldsymbol{r_{01}}}$

2)force due to q_2 charge on q_o charge = $\mathbf{F_{02}} = \frac{kq_0q_2}{r_{02}^2}\widehat{\boldsymbol{r_{02}}}$

3) force due to q_3 charge on q_o charge = $\mathbf{F_{03}} = \frac{kq_0q_3}{r_{03}^2}\widehat{\boldsymbol{r_{03}}}$

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n) force due to q_n charge on q_o charge = $\mathbf{F_{0n}} = \frac{kq_0q_n}{r_{on}^2}\widehat{\boldsymbol{r_{0n}}}$

then total force exerted on the charge q_0 is

$\mathbf{F_0 = F_{01} + F_{02} + F_{03} + F_{04} + F_{05}} .... \mathbf{F_{0n}}$

$\mathbf{F_o} = \frac{kq_1q_2}{r_{01}^2}\widehat{\boldsymbol{r_{01}}} + \frac{kq_1q_2}{r_{02}^2}\widehat{\boldsymbol{r_{02}}} + \frac{kq_1q_2}{r_{03}^2}\widehat{\boldsymbol{r_{03}}}$ ………… $\frac{kq_1q_2}{r_{on}^2}\widehat{\boldsymbol{r_{0n}}}$

$$\mathbf{F_o} = \sum_{i=1}^{n} \frac{kq_0q_i}{r_{oi}^2}\hat{\boldsymbol{r}}_{oi}$$

The vector sum is obtained as usual by the parallelogram law of addition of vector .

 # according to above derivation , it is clear that force between two charges does not affected by the presence of any other charges.

8. ELECTRIC FIELD –

A region around the charged particle where any other charged particle experience electric force is called electric field .It is a vector quantity and denoted by E .

$$\mathbf{E} = \frac{\boldsymbol{F}}{q} \qquad , \text{unit} = N / C$$

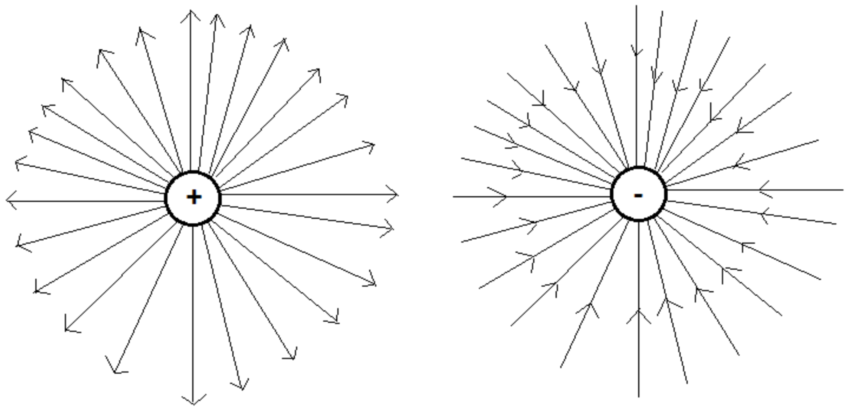
Dimension = [$M^1 L^1 T^{-3} A^{-1}$]

According to formula , if a test charge q_0 is located at r distance from q_1 charge then ratio of force applied on that test charge and magnitude of rest charge is called electric field intensity .

$$E = \frac{\frac{kq_0q_1}{r^2}}{q_0} = \frac{kq_1}{r^2}$$

It means electric field depends on two factors (1) magnitude of charge (2) distance of point from the charge .

For the positive charge , direction of electric field is radially outward and for negative charge , direction of electric field is radially inward .

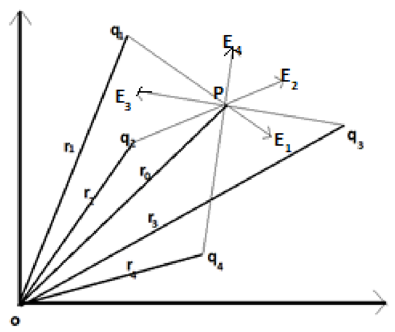


Vector notification of electric field $\mathbf{E} = \frac{\boldsymbol{F}}{q} = \frac{kq}{r^2}\hat{\boldsymbol{r}}$

A charge having unit magnitude and no electric field around it , is called test charge .

9.ELECTRIC FIELD DUE TO SYSTEM OF CHARGES –

Consider a system of n charges , where q_1 ,q_2 ,q_3 ,q_4 ,q_5 ………q_n charges located at $\mathbf{r_1}$, $\mathbf{r_2}$,$\mathbf{r_3}$,$\mathbf{r_4}$,$\mathbf{r_5}$……$\mathbf{r_n}$ position vector . let us consider that a point located at $\mathbf{r_0}$ position vector . then total electric field on p point is equal to vector addition of all electric field , produced due to all individual charges .This is termed as principle of superposition of electr



Electric field due to q_1 charge is $\mathbf{E_1} = \frac{kq_1}{r_1^2}\hat{\boldsymbol{r}}_{\mathbf{1}}$

Electric field due to q_2 charge is $\mathbf{E_2} = \frac{kq_2}{r_2^2}\hat{\boldsymbol{r}}_{\mathbf{2}}$

Electric field due to q_3 charge is $\mathbf{E_3} = \frac{kq_3}{r_3^2}\hat{\boldsymbol{r}}_{\mathbf{3}}$

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Electric field due to q_n charge is $\mathbf{E_n} = \frac{kq_n}{r_n^2}\hat{\boldsymbol{r}}_{\boldsymbol{n}}$

Then total electric field is equal to vector sum of all electric field =

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

$$\mathbf{E} = \frac{kq_1}{r_1^2}\hat{\boldsymbol{r}}_{\mathbf{1}} + \frac{kq_2}{r_2^2}\hat{\boldsymbol{r}}_{\mathbf{2}} + \frac{kq_3}{r_3^2}\hat{\boldsymbol{r}}_{\mathbf{3}} \ldots\ldots\ldots. \frac{kq_n}{r_n^2}\hat{\boldsymbol{r}}_{\boldsymbol{n}}$$

$$\mathbf{E} = \sum_{i=1}^{n} \frac{kq_i}{r_i^2}\hat{\boldsymbol{r}}_{\boldsymbol{i}}$$

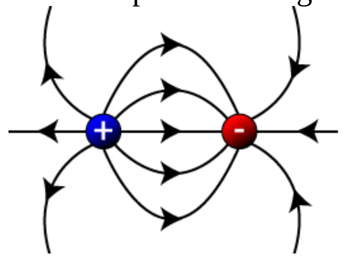
E is a vector quantity that varies from one point to another point in space and is determined from the positions of the source charges .

10. ELECTRIC FIELD LINES –

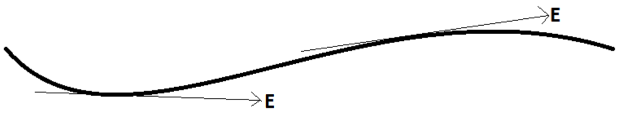
electric field is represented by some imaginary and continues lines . These lines is called electric field lines .

Properties of electric field lines is as below –

1. These lines are imaginary and continues lines without any break .
2. Electric field lines are start from the positive charge and end at negative charge .

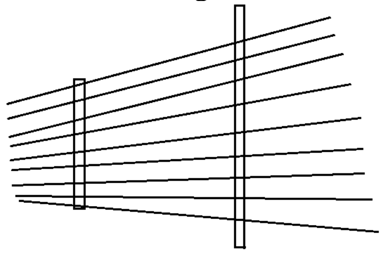


3. If we draw a tangent at any point of electric field line it represent the direction of electric field



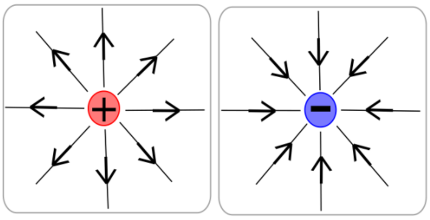
at that point .

4. The point where density of electric field lines is higher than at that point magnitude of electric

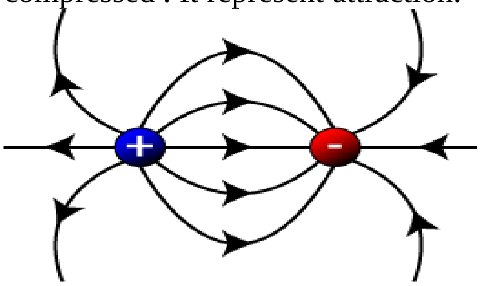


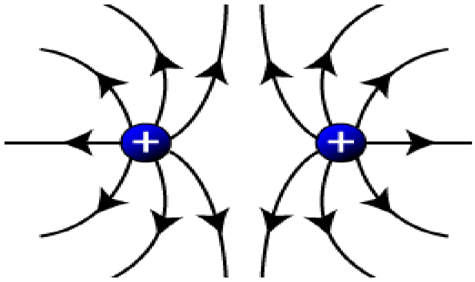
field is more and vice versa .

5. For a point charge electric field lines is radially move outside or inside acc. to nature of charge . .



6. If we represent the field lines between the unlike charge then it have a nature to being compressed . It represent attraction.



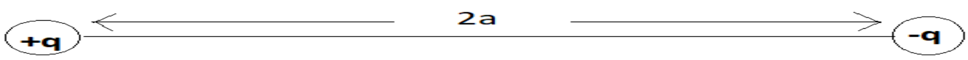


7. If we represent the field lines between the like charges then It have a nature to being expansion . It represent repulsion .
8. Two electric field lines cannot intersect each other . Because at intersecting point there is two direction of electric field that can't be possible . Means at a point acc. to law of superposition only when direction of electric field can be possible .
9. Electric field lines does not form close loop .

11. ELECTRIC DIPOLE –

An electric dipole is a pair of equal and opposite charges +q and –q separated by a distance 2a .

The midpoint of location of –q and q is called the centre of the dipole. The total charge of electric dipole is zero .



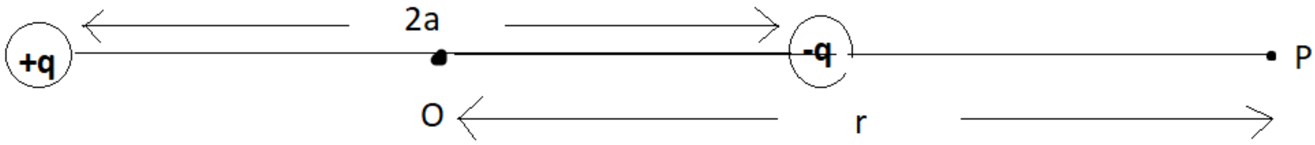
(A) ELECTRIC DIPOLE MOMENT –

Product of electric charge and distance between two charges is called electric dipole moment . it is denoted by P . it is a vector quantity . and the direction of electric dipole is from -q to +q .

$$P = q \times 2a$$

(B) ELECTRIC FIELD AT AXIS DUE TO ELECTRIC DIPOLE –

Consider , two charges +q and -q is located at 2a distance . and a point P is located at r distance from centre of dipole and axis of dipole . then



Electric field on P point due to +q charge is $E_1 = \frac{kq}{(r+a)^2}$ (towards O to P)

Electric field on P point due to -q charge is $E_2 = \frac{kq}{(r-a)^2}$ (towards P to O)

Then total electric field is = $E = E_2 - E_1$

$$E = \frac{kq}{(r-a)^2} - \frac{kq}{(r+a)^2}$$

$$E = kq\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$

$$E = kq\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2(r+a)^2}\right]$$

$$E = kq\left[\frac{r^2+a^2+2ar-r^2-a^2+2ar}{(r^2-a^2)^2}\right]$$

$$E = kq\left[\frac{4ar}{(r^2-a^2)^2}\right]$$

If r >>>>> a then

$$E = kq\left[\frac{4ar}{r^4}\right]$$

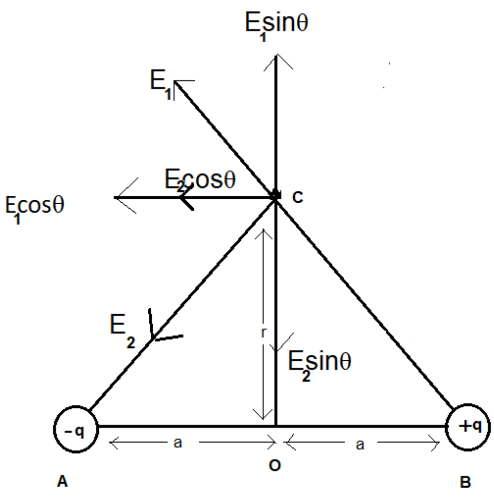
$$E = \frac{kq\,.\,4a}{r^3}$$

$$E = \frac{2kP}{r^3} \qquad [\text{ where } P = 2aq\ ]$$

In vector significance –

$$\mathbf{E} = \frac{2k\boldsymbol{P}}{r^3}$$

(C) ELECTRIC FIELD AT EQUATORIAL DUE TO ELECTRIC DIPOLE –



Consider two charges +q and -q is situated at 2a distance , and a point C is located at r distance from centre point of dipole on distance equatorial axis

Electric field on Point C due to +q charge $E_1 = \frac{kq}{a^2+r^2}$ (in direction of BC)

Electric field on Point C due to -q charge $E_2 = \frac{kq}{a^2+r^2}$ (in direction of CA)

Now these electric fields are not linear . so for solving this ,we have to use vector method . if we find component then we have four component $E_1\sin\theta$, $E_2\sin\theta$,$E_1\cos\theta$,$E_2\cos\theta$. Now $E_1 = E_2$. so according to diagram component of sinθ cancel out each other and component of cosθ add each other .

So resultant electric field component= $E = 2E_1\cos\theta$

$$E = 2 \text{ x } \frac{kq}{a^2+r^2} \text{ x } \cos\theta$$

$$E = 2 \text{ x } \frac{kq}{a^2+r^2} \text{ x } \frac{a}{\sqrt{a^2+r^2}}$$

$$E = 2 \text{ x } \frac{kqa}{(a^2+r^2)^{\frac{3}{2}}}$$

$$E = \frac{kp}{(a^2+r^2)^{\frac{3}{2}}} \qquad [2qa = P]$$

If a<<<< r

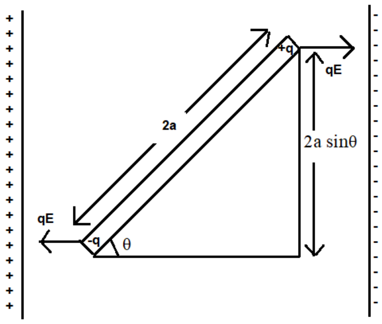
$$E = \frac{kp}{r^3} \qquad \text{(in the direction of BA)}$$

In vector significance –

$$\mathbf{E} = -\frac{k\boldsymbol{p}}{r^3}$$

Where – ve sign represent that direction of electric field and dipole moment is opposite to each other .

(D) DIPOLE IN A UNIFORM ELECTIC FIELD –



electric dipole in uniform electric field at an angle

Consider a dipole of dipole moment P is situated in uniform electric field E . Then dipole experience two forces +qE and -qE in opposite direction due to uniform electric field . it means total forces exerted on the dipole due to uniform electric field is zero.

But due to uniform electric field , dipole rotate , it means an torque is applied on the dipole . so

Torque $\quad \bar{C}$ = force x perpendicular distance

$\bar{C}$ = F x 2a sinθ

$\bar{C}$ = qE x 2a sinθ

$\bar{C}$ = P E sinθ

$\vec{C} = \vec{P} \times \vec{E}$

This torque will tend to align the dipole with the field E and when P is aligned with E . the torque become zero .

12. AREA VECTOR –

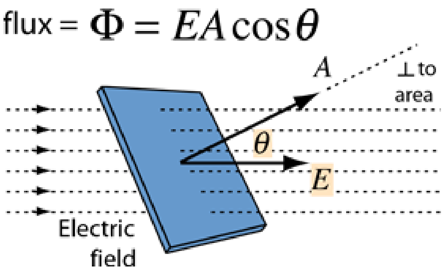
The direction of a planar area vector is specified by the normal to the plane . but every plane have two normal . in every closed surface we have to consider outward direction always .

13. ELECTRIC FLUX –

The total no. of electric lines of forces passing normally through the area, is called electric flux . if electric field lines does not pass normally to surface then we can use vector and find the component . then Electric flux through any surface **A** , open or closed , is equal to the surface integral of the electric field **E** taken over the surface **A** .

$$d\Phi = \vec{\boldsymbol{E}}.\overrightarrow{d\boldsymbol{A}}$$

dΦ = E. dA cosθ [θ =it is angle between surface area vector and E]



Unit = weber (Wb)

Dimension =

if for a closed surface magnitude of outward flux is Φ_2 and magnitude of inward flux is Φ_1. then total flux associated with that closed surface is equal = outward flux – inward flux

$$\Phi = \Phi_2 - \Phi_1$$

14.GAUSS THEOREM –

Gauss theorem states that the total flux through a closed surface is $1/\varepsilon_o$ times the net charge enclosed by the closed surface .

$$\Phi = \int \vec{E}.\vec{dA} = \frac{q}{\varepsilon_o}$$

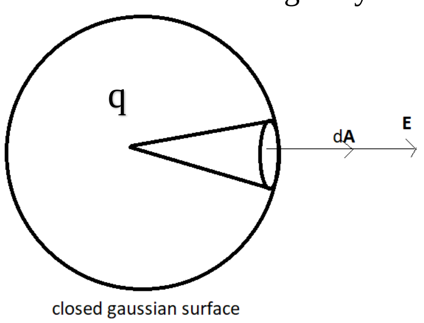
15. PROOF OF GAUSS THEOREM –

For sake of simplicity , we consider a positive charge q . suppose the surface A is a sphere of radius r centred on q charge . then surface A is a Gaussian surface .

Then electric field at any point on gaussian surface –

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

Flux through any area element situated on the surface is



$$\Phi = \int \vec{E}.\vec{dA}$$

$$\Phi = \int E.dA\, cos0$$

$$\Phi = \int E.dA$$

$$\Phi = E\,.\,4\pi r^2$$

$$\Phi = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} \times 4\pi r^2$$

$$\Phi = \frac{q}{\varepsilon_o}$$

This proves gauss theorem .

15. IMPORTANT FACTS ABOUT GAUSSIAN SURFACE –

1. Any hypothetical closed surface enclosing a charge is called the gaussian surface of that charge .

2. Gauss theorem is valid for a closed surface of any shape and for any general charge distribution .

3. for convenience , gaussian surface shape should be consider , where magnitude of electric field is same at every individual surface of any closed surface .

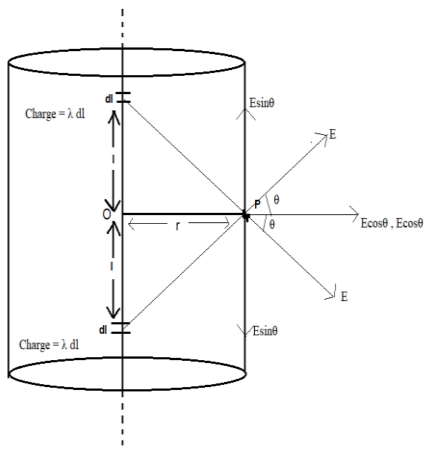
4. the term q on the right of gauss law, includes the sum of all charges enclosed by the surface . the charges may be located anywhere inside the surface .

16. FIELD DUE TO AN INIFITELY LONG STRAIGHT UNIFORMLY CHARGED WIRE –

Consider an infinity long straight wire having linear charge density λ . if we want to find magnitude of electric field on point P located at distance r , then first we have to consider a gaussian surface . according to symmetry , electric field around wire is uniform in cylindrical shape . so gaussian surface should be cylindrical shaped . so first of all we consider cylinder of r radius .

(1) direction of electric field on point –

According to diagram, first we consider a cylinder of r radius . then we draw direction of electric field originate from two small length dl situated on equal distance from point O, which is located in front of point P . then because of same charge and equidistance both electric field have same magnitude and different direction . so for finding resultant electric field we have to find component of electric field .



By finding component and according to diagram , component of sinθ cancel out each other , but component of cosθ add together and resultant direction of electric field become in the radially perpendicular direction of wire .

It means electric field due to a long straight wire is always radially perpendicular to its length.

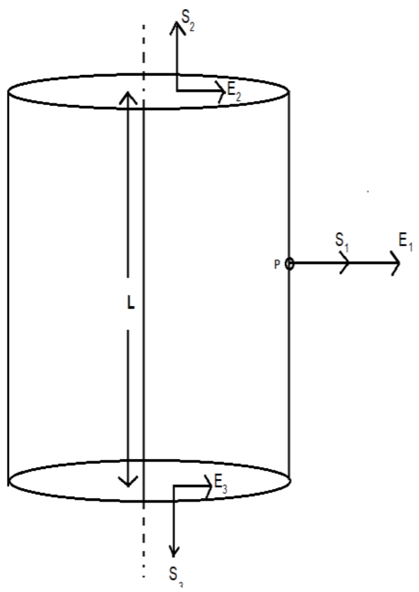
(2) Magnitude of electric field –

for finding magnitude we consider a gaussian surface having three surface .

first = curved surface of cylinder

second = upper circular disc of cylinder

third = lower circular disc of cylinder



so , according to gauss law –

total flux = $\oint \vec{E}.\overrightarrow{dS} = \frac{q}{\varepsilon_o}$

$$\int \overrightarrow{E_1}.\overrightarrow{dS_1} + \int \overrightarrow{E_2}.\overrightarrow{dS_2} + \int \overrightarrow{E_3}.\overrightarrow{dS_3} = \frac{q}{\varepsilon_o}$$

$$\int E_1 dS_1 cos0 + \int E_2 dS_2 cos90 + \int E_3 dS_3 cos90 = \frac{q}{\varepsilon_o}$$

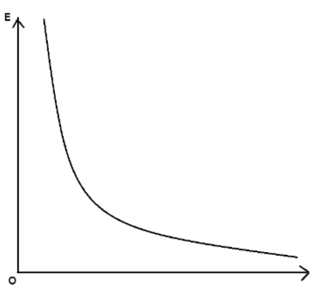
$$\int E_1 dS_1 = \frac{q}{\varepsilon_o}$$

$$E_1 \int dS_1 = \frac{q}{\varepsilon_o}$$

$$E_1 \times 2\pi r L = \frac{\lambda L}{\varepsilon_o}$$

$$E_1 = \frac{\lambda}{2\pi r \varepsilon_o} = \frac{2\lambda}{4\pi \varepsilon_o r} = \frac{2k\lambda}{r}$$

Vector significance = $\mathbf{E} = \frac{2k\lambda}{r}\hat{n}$

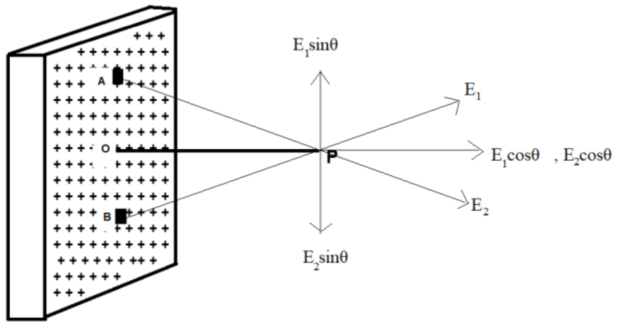


graph between electric field and perpendicular distance between

Where $\hat{n}$ is the radial unit vector in the plane normal to the wire parallel through the point .**E** is directed outward if λ is positive and inward if λ is negative .

17.FIELD DUE TO A UNIFORMLY CHARGED INFINITE PLANE SHEET –

According to diagram , an infinite sheet having σ surface charge density . and a point P is located in front of this sheet . and we have to find direction and magnitude of electric field on point P .



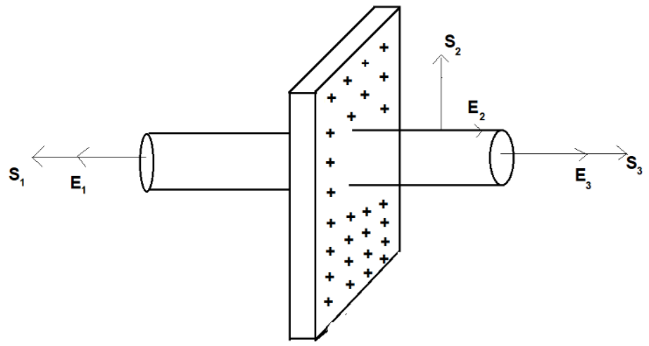
(1) Direction of electric field on point P –

According to diagram , a point O located in front of point P . and we consider two small surface dS situated at equal distance from point P . then these small surface behave like charge equal to σdS . then electric field on point P due to these charges is equal to E_1 and E_2 respectively . then if we want to find resultant then we should make component of these electric field .Due to having same charge and equidistance from point P ,E_1 is equal to E_2 . then we got two types of component (cosθ and sinθ) then by this diagram we know that component of sinθ will cancel out each other and component of cosθ will add together . it means electric field from an infinite plane sheet is perpendicular outward.

(2)Magnitude of electric field –

For finding magnitude we consider a gaussian surface having three surface .

first = Right circular surface of cylinder



second = curved surface of cylinder

third = left circular surface of cylinder

So according to gauss law –

Total flux = $\frac{\sum q}{\varepsilon_o}$

Total flux = $\oint \vec{E}.\vec{dS} = \frac{\sum q}{\varepsilon_o}$

$$\int \overrightarrow{E_1}.\overrightarrow{dS_1} + \int \overrightarrow{E_2}.\overrightarrow{dS_2} + \int \overrightarrow{E_3}.\overrightarrow{dS_3} = \frac{\sum q}{\varepsilon_o}$$

$$\int E_1 dS_1 cos0 + \int E_2 dS_2 cos90 + \int E_3 dS_3 cos0 = \frac{\sum q}{\varepsilon_o}$$

$$E_1 \int dS_1 + E_3 \int dS_3 = \frac{\sum q}{\varepsilon_o}$$

Now $E_1 = E_2 = E$ and $\int dS_1 = \int dS_3 = S$ and $\sum q = 2\sigma S$ then

$$2ES = \frac{2\sigma S}{\varepsilon_o}$$

$$E = \frac{\sigma}{\varepsilon_o}$$

Vector significance = $\mathbf{E} = \frac{\sigma}{\varepsilon_o}\hat{n}$

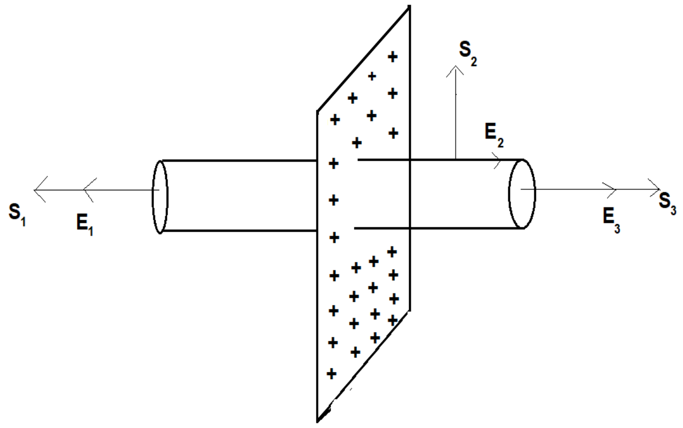
It means electric field on any point situated in front of a sheet does not depend on the distance . and direction of electric field is normal to plane sheet of charge .

18.FIELD DUE TO INFINITE LARGE SHEET OF CHARGE –

An infinite sheet of charge having σ surface charge density . and a point P is located in front of this sheet . and we have to find direction and magnitude of electric field on point P .As per above derivation we know that direction of electric field due to a plane sheet of charge is perpendicularly outward . So we have to find magnitude of electric field at point P .

For finding magnitude we consider a gaussian surface having three surface .

first = Right circular surface of cylinder



second = curved surface of cylinder

third = left circular surface of cylinder

So according to gauss law –

Total flux = $\frac{\sum q}{\varepsilon_o}$

Total flux = $\oint \vec{E}.\overrightarrow{dS} = \frac{\sum q}{\varepsilon_o}$

$\int \overrightarrow{E_1}.\overrightarrow{dS_1} + \int \overrightarrow{E_2}.\overrightarrow{dS_2} + \int \overrightarrow{E_3}.\overrightarrow{dS_3} = \frac{\sum q}{\varepsilon_o}$

$\int E_1 dS_1 cos0 + \int E_2 dS_2 cos90 + \int E_3 dS_3 cos0 = \frac{\sum q}{\varepsilon_o}$

$E_1 \int dS_1 + E_3 \int dS_3 = \frac{\sum q}{\varepsilon_o}$

Now $E_1 = E_2 = E$ and $\int dS_1 = \int dS_3 = S$ and $\sum q = \sigma S$ then

$2ES = \frac{\sigma S}{\varepsilon_o}$

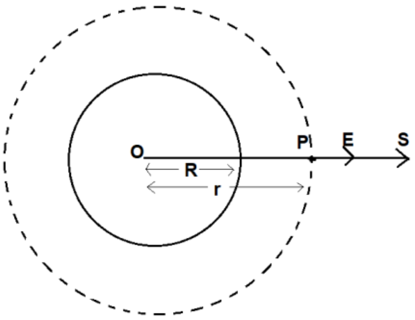
$E = \frac{\sigma}{2\varepsilon_o}$

Vector significance = $\mathbf{E} = \frac{\sigma}{2\varepsilon_o}\hat{n}$

It means electric field on any point situated in front of a sheet does not depend on the distance . and direction of electric field is normal to plane sheet .

19.FIELD DUE TO A UNIFORMLY CHARGED THIN SPHERICAL SHELL -

Let a uniformly charged thin spherical shell of radius R . and total charge at that thin spherical shell is equal to Q . this charge is consider concentrated on centre of spherical shell . we have to find magnitude of electric field on point P situated at different points (outside , on the shell , inside the shell) .
(1) when point P is located at outside of shell –
If P point is located at r distance from the centre of spherical shell. Then first we consider gaussian surface of r radius . then acc to diagram direction of area vector and electric field is similar on point P .



So according to gauss law –

Total flux = $\frac{\sum q}{\varepsilon_o}$

Total flux = $\oint \vec{E}.\overrightarrow{dS} = \frac{\sum q}{\varepsilon_o}$

$\int E\ dS\ cos0 = \frac{\sum q}{\varepsilon_o}$

$E \int dS = \frac{Q}{\varepsilon_o}$

$E \times 4\pi r^2 = \frac{Q}{\varepsilon_o}$

$E_{outside} = \frac{Q}{4\pi r^2 \varepsilon_o} = \frac{1}{4\pi\varepsilon_o} \times \frac{Q}{r^2} = \frac{kQ}{r^2}$

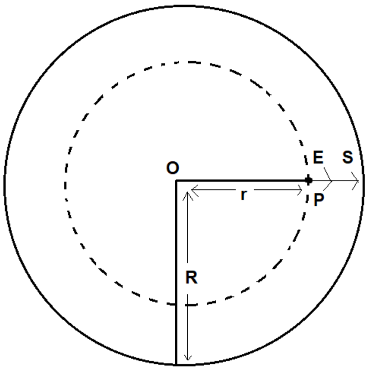
In vector formation

$\mathbf{E}_{\mathbf{outside}} = \frac{kQ}{r^2}\hat{n}$

(2) When Point P is located on spherical shell –

When point is located on spherical shell , so its distance from centre become R . then put r =R in the eq. of electric field outside of spherical shell . it means electric field at spherical shell

$$\mathbf{E}_{\text{on shell}} = \frac{kQ}{R^2}\hat{n}$$



(3) When Point P is located inside the spherical shell –

When point P is located inside the spherical shell , it means r is less than R Then first of all we assume spherical gaussian surface on which P is lie. Then acc to diagram direction of area vector and electric field is similar on point P . So according to gauss law –

$$\text{Total flux} = \frac{\Sigma q}{\varepsilon_o}$$

$$\text{Total flux} = \oint \vec{E}.\overrightarrow{dS} = \frac{\Sigma q}{\varepsilon_o}$$

$$\int E\ dS\ cos0 = \frac{\Sigma q}{\varepsilon_o}$$

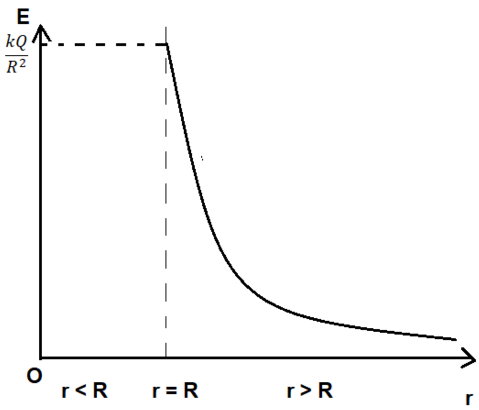
$$E \int dS = \frac{0}{\varepsilon_o}$$

[total charge enclosed by gaussian surface is equal to zero]

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

$$E = 0$$

Graph between electric field and distance from point P



q. if a positive charge is located outside of any gaussian surface then find net flex through a closed surface due to that charge .