Chapter 1 and 2

ELECTROSTATICS and CAPACITOR

Electrostatics : study of electric charges at rest.

Experiment : A glass rod rubbed with silk shows the property to attract small object such as bits of paper- why-They posses electric charges.

- What is the Process - Electricfication - The process of a cquiring electirc charges by friction (rubbing)
- Can all the bodies charged by friction - No- only insulators.
  If the material is conductor(Eg:- Cu), any charge produced on it by friction can easily get discharged to earth.
- The electrostatic experiment should be performed in dry air or climate -why? If the air is moist it is slightly conducting the electric charges get discharged to earth.
- Can electric charges be created during rubbing - No- only transfer of charges from one body to other takes place - The body which looses electrons becomes +ve charged and that which gains electrons became -ve charged.
- In the above experiment which is +ve and which is -ve? Glassrod is +ve while silk is -ve
- Is there any there transfer of mass -yes, Electron has finite mass.

What are the properties of electric charge

1) Quantization Property

   Total Charge of a body $Q = \pm ne$

   n - an integer, $e = 1.6 \times 10^{-19}$ C, charge of electron

- Find no. of electrons in charge IC

  $$\text{No of electrons } n = \frac{IC}{1.6 \times 10^{-19} C}$$

  $$= 6.25 \times 10^{18}$$

2) Conservative Property - Total charge remains constant

- What is coulombus inverse sqaure law in electrostatics

  Electrostatic force (F) between two electric charges q_1 and q_2 seperated by a distance r in a medium

  $$F \alpha \frac{q_1 q_2}{r^2}$$

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

  Where ε = absolute permituvityof the medium.

If the medium is air or free space

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

where $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$, Permitivity of air

What is the relation between ε and ε_0

Relative permitivity of a medium $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$, it is dielectric constant. For air ε_r=1.

- Electric force between two charges in a medium of relative permitivity ε_r is $F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}$
- What is the new force between two charges, when magnitude of the charges doubled and distance between them halved.

$$F = \frac{1}{4\pi\varepsilon_0 \varepsilon r}\frac{q_1 q_2}{r^2}$$

$$F^1 = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{2q_1 2q_2}{\left(\frac{r}{2}\right)^2}$$

$$\therefore \frac{F^1}{F} = 16$$, Hence F^1=16F

- Comparison of Electric force between two electric charges in a medium to air.

$$Fmedium = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2} \qquad Fair = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$\frac{Fmedium}{Fair} = \frac{1}{\varepsilon_r} \qquad \therefore Fmedium = \frac{Fair}{\varepsilon_r}$$

ε_r always greater than one. $\therefore$ F medium < Fair

- Two point charges q_1 and q_2 such that $q_1 + q_2 = 0$ what is the nature of force between them?
  If $q_1 + q_2 = 0$ $q_1 = -q_2$ Attractive nature since charges are of opposite signs
- Unit of electric charge - coulmb (C)
  IC = 6.25×10^{18} electronic charge.

What is Electric Field

- The vector representation of Electric field.
- Space around an electric charge where electric force of attaction or repulsion is felt.
- What is the intensity of electric field? It is the electric force per unit charge.
  $E=\frac{F}{q}$
- Force experienced by unit charge
  $\therefore$ Electric force = Electric field Intensity x charge
  F=qE

unit of electric field - $^{N}\!/_{C}$

Other unit is $^{V}\!/_{m}$,

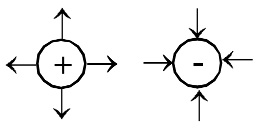
(Since $E = \frac{-dv}{dR}$, electric field is -ve of the potential gradient)

What is the EF due to a point charge (q) - It is the force experienced by the chargeIC at A

Let E(r)- Electric field at A due q.

$F = \frac{1}{4\pi\varepsilon o} \frac{q.1C}{r^2}$ $\quad E(r) = \frac{1}{4\pi\varepsilon o} \frac{q}{r^2}$ $\quad$ q ....A• →
r

Note : If the charge is +ve EF points outward and it is inward if it is -ve



- Write Dimensional formula of intensity of electric field .

$E = {}^{F}\!/_{q}$ $\qquad E = \frac{m\,a}{It}$ $\quad [E] = \frac{M^1L^1T^{-2}}{A^1T^1}$

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

Q1. How can represent electric field around a charge
By Farady EF is represented by Electric line of force

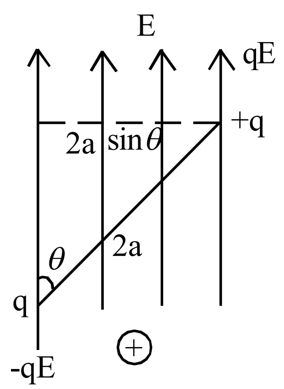
Q2. Two field lines never in set Why?
At the point of intersection EF has two directions. At a point EF has only one direction.

Q3. How to represent an uniform EF- Electric lines of force are equally spaced parallel lines.

- For isolated +ve charge E1. Field lines starting from the +ve charge and ending to infinity.

Q4. What is elctric dipole- A system which consists of two equal and opposite charges seperated by a distance.
strength of the dipole is dipole moment $+q \overset{2a}{\ldots\ldots\ldots\ldots\ldots} -q$
Itis the product of the magnitude of any one of the charge and distance between the charges.
P=2aq
Its unit is C - m

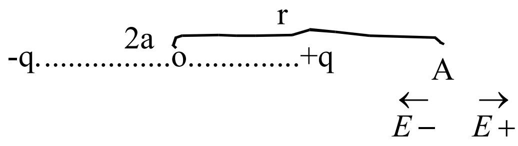
- What happens when a dipole is placed in an uniform Electric field.
E - uniform Electric field
Net force acting on the dipole
F=-qE+qE = O
Torque acting as the dipole
τ =|F|x lever arm of forces
$= qE.2a\sin\theta$
$= PE\sin\theta$
$\vec{\tau} = \vec{P} \times \vec{E}$



- When a dipole placed in non uniform Electric field it experiences both Force and Torque
- What is dipole field- Electric field around a dipole

i) Expression for electric field at the axial point

A - axial point - (Point on the axis). O - mid point of the dipole



EF at A due to the change +q

$$E+=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}along \text{ OA}$$

EF at A due to the change -q

$$E-=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}along \text{ AO}$$

Net field at A, E = E+E$_-$ (Opposite direction)

$$E=\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{(r-a)^2}-\frac{1}{(r+a)^2}\right)$$

$$E=\frac{q}{4\pi\varepsilon_0}\frac{4ra}{(r^2-a^2)^2}$$

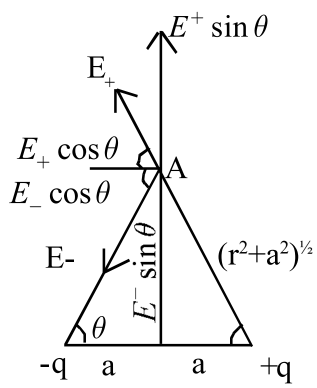
$$=\frac{q}{4\pi\varepsilon_0}\frac{4ra}{(r^2-a^2)^2}$$ using P=q. 2a

Since r>>a, $(r^2-a^2)^2 \sim r^4$

$$= E=\frac{1}{4\pi\varepsilon_0}\frac{2P}{r^3}alongOA$$

ii) Expression of Electric field at the Equatorial point

A - Equatorial point



$$E+=\frac{1}{4\pi\varepsilon 0}\frac{q}{r^2+a^2}$$

$$E-=\frac{1}{4\pi\varepsilon 0}\frac{q}{r^2+a^2}$$

Net EF at A, E = E$_+$ $\cos\theta$ +E$_-$ $\cos\theta$

E = (E$_+$+E$_-$) $\cos\theta$

$$E=2\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\frac{a}{(r^2+a^2)}{}^{1/2}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{P}{(r^2+a^2)^{3/2}}$$ using P=q.2a

since r>>a

$(r^2+a^2)^{3/2} \sim r^3$

$$E=\frac{1}{4\pi\varepsilon_0}\frac{p}{r^3},$$ acting parallel to the axis of the dipole.

- Compare Electric field at the axial point to that at the equatorial point of a dipole

$$\frac{E_{axial\ point}}{E_{equitorial\ point}} = \frac{\frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}{\frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}}$$

$$= 2$$

$\therefore$ E axial point = 2 E equitorial point for same distance.

What is Electric flux?

$\varphi_E = \int_S E.ds$ Surface integral of Electric field.

$|\phi_E| =$ ES cos θ where θ is the angle between, E and normal to the surface (s)

When $\theta = O$ $\phi_E = ES$, Maximum

When $\theta = 90$ $\phi_E = O$, Minimum

Electric flux (φ_E) = Electric field x Total area (if field is normal to the surface)

Its unit is $\frac{N - m^2}{C}$ or v - m

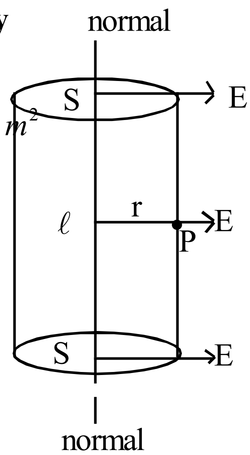
Write Gauss's Theorm:

Total electric flux over a closed surface is directly proportianal to the total charge enclosed by the surface.

$\phi_E \alpha q$

$\phi_E = \frac{q}{\varepsilon_o}$, Where ε_o is a constant called permittivity of free space.

Improtance - Help us to calculate the elctric field due to a charged body



(i) Electric field due to a straight wire of uniform charge density

ℓ $\rightarrow$ Length of the straight wire of uniform charge density $\lambda c / m^2$

P $\rightarrow$ Field point at distance r from the wire

E $\rightarrow$ Electric field at P due to the wire

Here Gaussian surface is a cylinder of length ℓ and radius r with wire as axis

(Gaussian Surface - Surface we choose to calculate the electric flux)

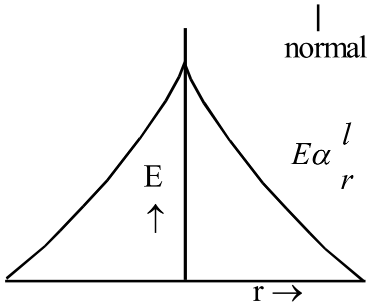
Total Electric flux over the Gaussian Surface = EF over cylindrical surface + EF over two end faces.

ϕ_E = E 2 π rl + ES cos 90 + E S cos 90

ϕ_E = E 2 π rl.

Total charge enclosed by the Gussian surface q= $\lambda\ \ell$

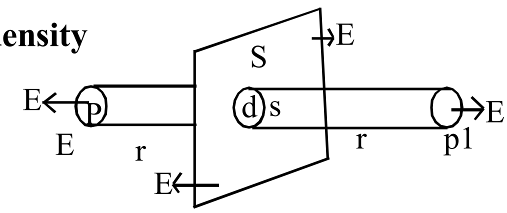
By Gauss's theorem $E 2\pi r\ell = \frac{\lambda l}{\varepsilon_o}$



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

It is not uniform since it depends on the distance (r)

(ii) EF due to a plane sheet of uniform charge density



S Plane sheet of uniform charge density, $\sigma c/m^2$

Pand P[1] be the field points at equidistant r from S

E be the electric fields field at P and P[1] due to S

Here Gaussian surface is cylinder of area cross section ds and length 2r

Electric flux over the Gaussian surface = EF over the cylinderical surface + EF over the two end faces.

$\therefore$ Total electric flux over the Gaussian surface ϕ_E = 0+Eds + Eds = 2Eds

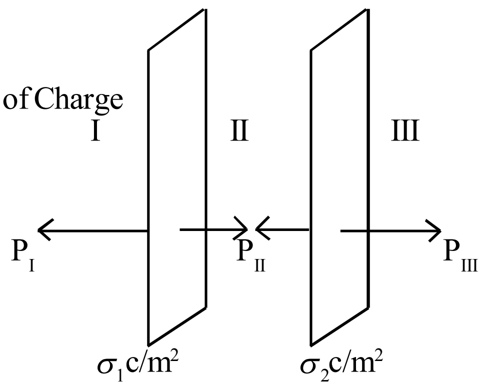
Total charge enclosed by the Gaussian Surface $q = \sigma ds$

By Gauss's Theorem $2\text{Eds} = \frac{\sigma \text{ds}}{\varepsilon_0}$

$E = \frac{\sigma}{2\varepsilon_0}$ It is uniform since it is independent distance

σ >O, Electric field is outward from the sheet, σ <O, Electric field is towards the sheet.

Case : Electric field due to two Parallel Plane Sheets of Charge



Electric Field at P_I $E_1 = \left(\frac{\sigma 1}{2\varepsilon_o} + \frac{\sigma 2}{2\varepsilon_o}\right)$

Electric Field at P_{II} $E_2 = \left(\frac{\sigma 1}{2\varepsilon_o} - \frac{\sigma 2}{2\varepsilon_o}\right)$

Electric Field at P_{III} $E_3 = \frac{{}^{-}\sigma 1}{2\varepsilon_o} + \frac{{}^{-}\sigma 2}{2\varepsilon_o}$

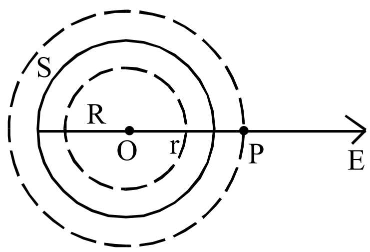
(Since Electrc field is measured from left to right)

If $\sigma_1 = {}^{+}\sigma$, $\sigma_2 = {}^{-}\sigma$ two sheets of equal and opposite charge densities

E_I = O $E_2 = \frac{\sigma}{\varepsilon_0}$, Uniform and E_{3III} = O

(iii) Electric field due to a spherical shell of uniform charge density

1) Conducting shell of radius R



S- Spherical conducting shell of uniform charge σ c/m^2

P- Field point at a distance r form O

E - Electric field at P

Here Gaussiann Surface is a sphere of radius r

Case I : If r>R, Field point outside the shell

Electric flux over the Gaussian surface $\phi E = E 4\pi r^2$

Total charge $q = 4\pi R^2 \sigma$

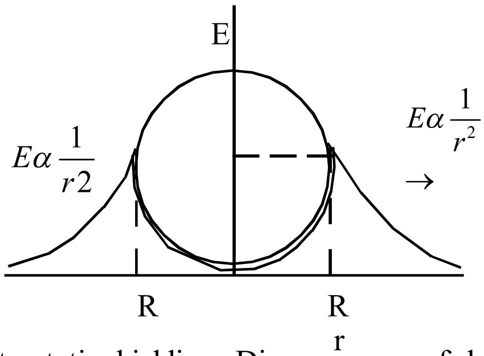
By Gauss's theorm E 4 π r^2= $\dfrac{4\pi R^2 \sigma}{\varepsilon_0}$

$$E = \frac{R^2 \sigma}{r^2 \varepsilon_0}$$

Case II : if r=R, field point on the shell $E = \dfrac{\sigma}{\varepsilon_0}$, *uniform* Magnitude.

Case III : if r<R, field point inside the shell, E= O, no charge is enclosed by the inner Gaussian surface

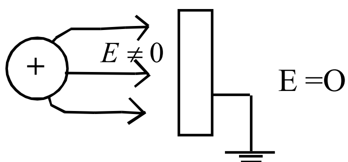
Graphical represention EF due to a shell



- What is electrostatic shielding - Disappearence of electric field in side a cavity in a conductor

Importance

- During th under accompanied with lighiting the safest place is inside a car
- Farady's cage - protect certain instruments from external EF
- Can electro static shielding provided with earthed metal sheet- Yes, how - see the figure



Case - non conductiing shell of uniform charge q

a) if r > R, E 4 π r^2 = $\dfrac{q}{\varepsilon_0}$

E = $\dfrac{1}{4\pi\varepsilon}\dfrac{q}{r^2}$ Charge assumed to be concentrated at the centre

b) r = R, $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{R^2}$ Charge enclosed by the innner gaussian surface

c) If r<R, Volume charge density, $\dfrac{q^1}{\frac{4}{3}\pi r^3} = \dfrac{q}{\frac{4}{3}\pi R^3}$ where q^1 - charge enclosed by the inner Gaussian surface.

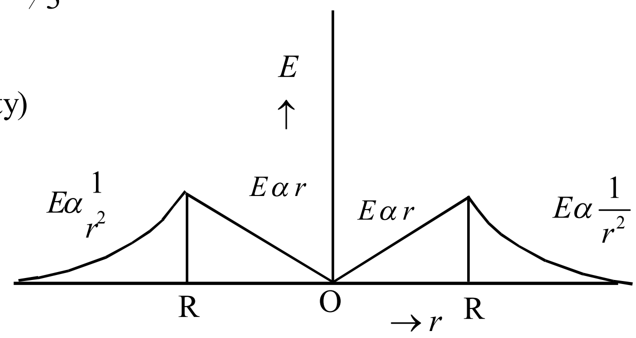
(Charge - Volume - Volume charge density)

$$q^1 = q\left(\frac{r}{R}\right)^3$$

$$E.\ 4\pi r^2 = \frac{q^1}{\varepsilon_0} = \frac{q}{\varepsilon_0}\left(\frac{r}{R}\right)^3$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^3}\times r$$

$E \alpha\ r$



Variation of E1. Field due to a non conducting shell of uniform charge

d) At the centre of the shell r = 0, E = 0

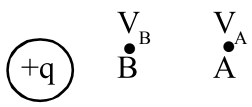
Calculate the E Flux from IC charge

Since $\phi E = {q}/{\varepsilon_o}$

$$\phi_E = \frac{1C}{8.83\times10^{-12}} \quad \frac{10\times10^{11}}{8.85} = 1.13x10^{11}\frac{Nm^2}{C}$$

- What is electrostatic potential - Scaler representationof EField
- Electrostatic P.d between two points in an EF is the work done in bringing unit +ve charge from one point to other.

$V_B - V_A = W_{AB}$ Since $V_B > V_A$



Electrostatic potential at B

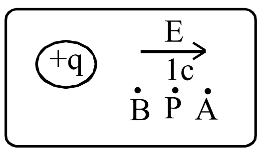
Let V_A = O (Point A is at infinity)

$V_B = W_{\alpha B}$

Electric potential at B is the workdone in bringing unit +ve charge from infinity to B

In general, Electric potential at a point is the workdone in bringing unit +ve charge from infinityto the point, $V = \dfrac{w}{q}$

ST Pot difference is the line integral of EF



Force of repulsion experienced by the charge 1c at P, F = 1c.E

Workdone in moving the charge form P through a small distance dℓ against the force.

dw = $Fd\ell = {}^{-}Ed\ell$

$\therefore$ Total workdone in moving charge from A to B $W_{AB} = \int_A^B -Ed\ell$

> Note : $W = \text{F}d\ell\cos\theta$
> When $\theta = 0$
> $W = Fd\ell$

$$V_B - V_A = -\int_A^B E d\ell$$

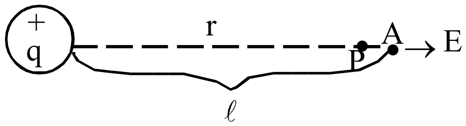
Expression for Electric potential at B, $V_B = -\int_{\alpha}^{B} E d\ell$

ie, Electric Potential is the the -ve line integral of electric field.

Derive expression for Electric Potential due to a point charge

$$EFatA, E = \frac{1}{4\pi\varepsilon_o}\frac{q}{\ell^2}$$

Electric potential P, $V = -\int_{\alpha}^{r} E d\ell$



$$= -\int_{\alpha}^{r} \frac{1}{4\pi\varepsilon_o}\frac{q}{\ell^2} d\ell$$

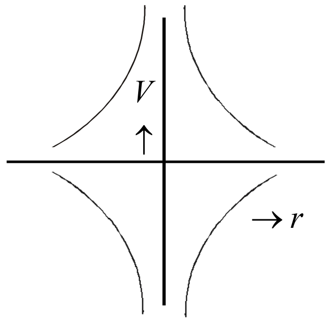
$$V = \frac{-q}{4\pi\varepsilon_o}\int_{\alpha}^{r} \ell^{-2} d\ell$$

Note : $\int \ell^{-2} d\ell = \frac{\ell^{-2+1}}{-2+1}$

$= -1/\ell$

$$\frac{-q}{4\pi\varepsilon_o}\left(\frac{-1}{\ell}\right)_{\alpha}^{r}$$

$$V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$$



If q is placed in medium of relative permitivity ε_r, $V = \frac{1}{4\pi\varepsilon_o\varepsilon_r}\frac{q}{r}$

- Can a sphere of radius 1 cm hold charge IC ,

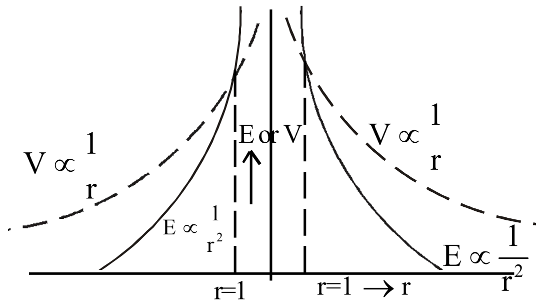
  No. Its potential become very large.

  $V = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r}$ $\qquad V = \frac{9x10^9 IC}{1X10^{-2}} = 9\times10^{11} = 9 x10^{11}$ Volt

- Electric field is the -ve of Potential gradient, $E = \frac{-dv}{d\ell}$
- If the electric field intensity at a given point is zero, will electric potential necessarly be zero at that point - No. Since $E = \frac{-dv}{d\ell}$ if E= O, $\frac{-dv}{d\ell} = 0$

  $\therefore V$ is constant

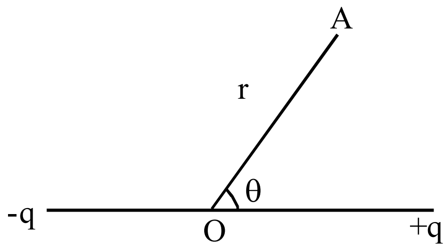
- Draw variation of EF and EP with respect to a distance from a point charge



Slope of EF> Slope of EP

- What is the electric potential at a point A of due to a dipole

$$V=\frac{1}{4\pi\varepsilon}\frac{P\cos\theta}{r^2}$$ Where P dipole moment



At the axial point

$$\theta=0\,,\ V=\frac{1}{4\pi\varepsilon_o}\frac{P}{r^2}$$

At the equatorial point $\theta=90$, V=O

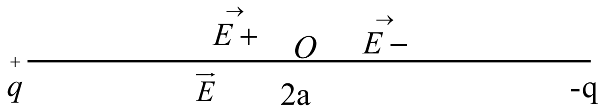
- What in the EF and EP at the mid point of a dipole

At the centre O, resultant EF = E++E-

$$E=E_{+}+E_{-}$$

$$=\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}+\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$$

$$=2\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}\right)$$



Note: V- due to +ve charge is +ve that of -ve charge is -ve.

At the mid point O, $V=V_{+}+V_{-}$

$$\frac{1}{4\pi\varepsilon}\frac{q}{a}+\frac{1}{4\pi\varepsilon_o}\frac{-q}{a}$$

$$=O$$

- **Capacitor :** System of two conductors seperated by a dielectric medium.

  Which is used to store Electric charge and hence energy

  Capacitance : Ability to store electric charge

  When a Charge Q is given to a conduct its potential increases to V.

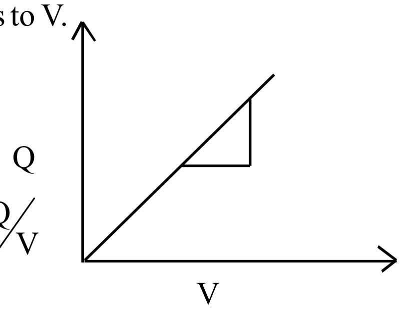
  ie, $V\propto Q$

  V=CQ- Where C - Capacitance

- Its unit is Farad (f)

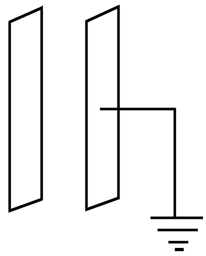
  $$\text{If}=\frac{IV}{IC}$$

  Slope of graph $C=Q/V$



- When charge given to a conductor is doubled what is it potential - It is doubled, since $V\alpha Q$
- Is a single conductor posses capacitance. Yes - Seceond conductor is at infinity

- Principle of capacetor - An erthed conductor is placed near a charged conductor the capacitance of the charged conductor increases
(use of earthed conductor - It reduces the potential)



- Capacitance of an isolated spherical conductor of radius R

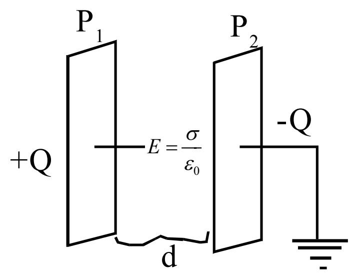
$$C = \frac{Q}{V}$$

$$C = 4\pi\varepsilon R \quad \text{But } V = \frac{1}{4\pi\varepsilon}\frac{Q}{R}$$

$C \propto R$ (Whre 'R' is the radius)

- What happens when the second plate of a parallel plate capacitor is earthed. Potential difference reduces

Explain Capacitance of a Paralled plate capacitor



A - surface area of each plate
d - Distance between the plates
+Q - charge given to a plate P_1
By induction plate P_2 acqires the charge - Q

$\therefore$ Surface charge density on each plate $\sigma = \frac{Q}{A}$

$$Q = \sigma A$$

The EF between two plates $E = \frac{\sigma}{\varepsilon_0}$

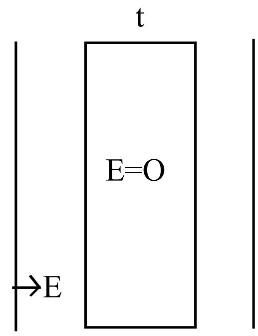
PD between the plates V=Ed

$$V = \frac{\sigma}{\varepsilon_0}d$$

$$C = \frac{Q}{V} = \frac{\sigma A}{\sigma/\varepsilon_0 \, d} = \frac{\varepsilon_0 A}{d}$$

If the plates are seperated by a medium of di-electric constant εr, $C = \frac{\varepsilon_o \varepsilon_r A}{d}$

Case (i) : What is the capacitance of a parallel plate capacitor - When a conducting slab of thickness t is placed b/w the plates



Reduced p.d b/w the plates $V^1 = E(d-t) = \sigma/\varepsilon_0\,(d-t)$

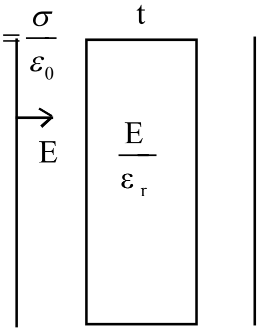
$$C^1 = Q/V = \frac{\sigma A}{\sigma/\varepsilon_0\,(d-t)}$$

$$\frac{\varepsilon_0 A}{d\left(1-t/d\right)} = \frac{C}{1-t/d}$$

If t =d, C $\Rightarrow$ inifinity

(ii) When an insulating slab of thickness t is placed b/w the plate

Reduced pd b/w the plates $V^{11} = E(d-t) + \frac{E}{\varepsilon_r} t$ Where $E = \frac{\sigma}{\varepsilon_0}$



$$V = \frac{\sigma}{\varepsilon_0}\left[d - t + t/\varepsilon_r\right]$$

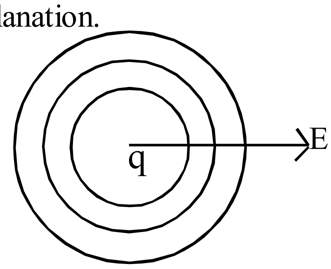
$$C^{1} = \frac{Q}{V^{11}} = \frac{\sigma A}{\sigma/\varepsilon_0\left(d - t + t/\varepsilon_r\right)}$$

$$= \frac{\varepsilon_r \varepsilon_0}{\varepsilon_r d - \varepsilon_r t + t} = \frac{\varepsilon_0 \varepsilon_r A}{d\left[\varepsilon_r\left(1-\frac{t}{d}\right) + t/d\right]} \qquad \therefore C^{11} \frac{\varepsilon_r c}{\varepsilon_r\left(1 - t/d\right) + t/d}$$

When t=d, $C^{11} = \varepsilon_r C$ its capictance increases, Faradys Explanation.

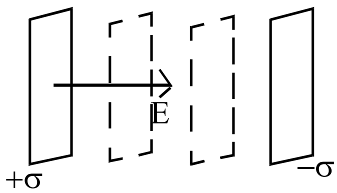
- What is equi potential surfaces

  The surface over which electric potential has constant value.



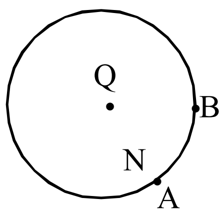
Eg:- i. For a point charge equipotential surfaces are the surface of spheres with charge q as the centre

ii. The planes $\perp$ r to the uniform EF b/w two charged parallel plates



- In the fig what is the workdone in moving a charge q from A to B

$V_A - V_B = \frac{W}{q}$



Since $V_A = V_B \quad \therefore W = O$

Work done in moving a charge in an EF

- w=qv, this work is stored as PE,

  $U = qv$

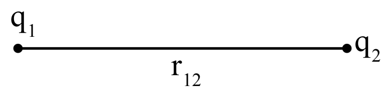
- What is the expression for velocity of charge q moving in an EF of potential V

  By conservation of energy $qV = \frac{1}{2} mv^2$

$$v = \sqrt{\frac{2qV}{m}}$$

- Expression for Potential energy of a system of a system two charges

$$V = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$



- Unit of the electriostatic PE electron volt (eV)

Ie V = 1.6 x 10^{-19}J

- Time period of oscillation of a dipole in uniform EF

since torque $\tau = PE\ \mathrm{Sin}\,\theta$, Where θ angular displacement

$\tau = PE\,\theta$ when θ is small

Since $\tau = PE\sin\theta$

$\tau \alpha \sin\theta$

τ variable

Angular acceleration, $\alpha = \frac{d^2\theta}{dt^2}$

But $\tau = I\alpha$ Where I - Moment of Inertia

$$d^2\theta/dt^2 \ \frac{-PE}{I}\theta$$ (-ve sign show Torque decreases θ)

$$d^2\theta/dt^2 + \frac{PE}{I}\theta = O$$, Equation for SHM, $\frac{d^2x}{dt^2} + w^2x = 0$

Frequency of oscillation $w = \sqrt{\frac{PE}{I}}$

$$\therefore \upsilon = \frac{w}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{PE}{I}}$$

Time period $T = \frac{2\pi}{W} = 2\pi\sqrt{\frac{I}{PE}}$

- PE of a dipole in an E1 field.

$$w = \int_{\theta_1}^{\theta_2} \tau\, d\theta$$

$$= \int_{\theta 1}^{\theta 2} PE\ Sin\theta\ d\theta$$

$$= -PE\left(Cos\theta\right)_{\theta_1}^{\theta_2}$$

$$= -PE\left(Cos\theta_2 - Cos\theta_1\right)$$

When $\theta_1 = 90,\ \theta_2 = \theta$

U = -P.E

Polar and non Polar dielectries(Insulators)

Polar Dielectric

i) In each atom the two centres of charges donot co incide (Atomic dipole)

ii) It has Permanent dipole moment

iii) In an external elctric field it experience torque

Eg : H_2O, NH_3

+ve centre of charge produced by protons and -ve centre of charge produced by electrons.

Non Polar dielectric

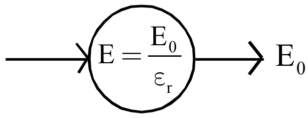
i) In each atom the two centres of charges coincides

ii) It has zero dipole moment

iii) In an external electrifield it expereince induced dipole moment

Eg : H_2, N_2 O_2

- What happens a non polar dielectric is placed in an EF
  Induced dipole moment takes place. In an external EF, in each non polar dielectric atom +ve centre of charge and -ve centre of charge are seperated a small distance.
- What is electric polarisation - Induced dipole moment in non polardielectric in an EF
- What is the EF inside a dielectric



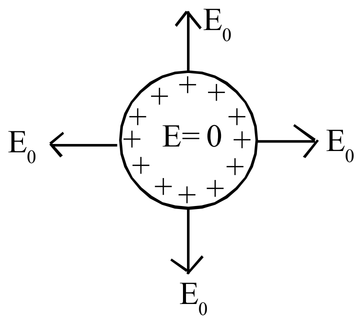
In an external field $E = \frac{E_o}{\varepsilon_r}$

E_0 - External Electrifield

- **Behaviour of a conductor in an EF**

(Electrostastics of Conductor)

1. Inside the conductor the electric field is zero
2. Electric charges can be seen only on the surface
3. Out side the conductor EF is normal to the surface of the conductor
4. Surface of the conductor is an equipotential.

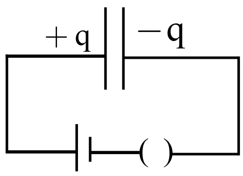


- **Calculate dielectric constant of a conductor**
  Since $\varepsilon_r = \frac{E_o}{E}$
  For a conductor E=O, $\varepsilon_r = \frac{E_o}{O} \Rightarrow$ inf inity
- What is the capacitance of a parallel plate capacitor of n plates
  Capacitance of a parallel plates capacitor - having n- plates $C = (n-1)\frac{\varepsilon_0 A}{d}$
- Dielectric constant or Relative Permiability (ε_r) of a medium is the factor by which the capacetance of capacitor increases. Since $C'' = \varepsilon_r C$

Expression for energy stored in a capacitor - During charging the capacitor, at a perticuler stage

$\pm q$ - be the charge, corresponding potential difference is V

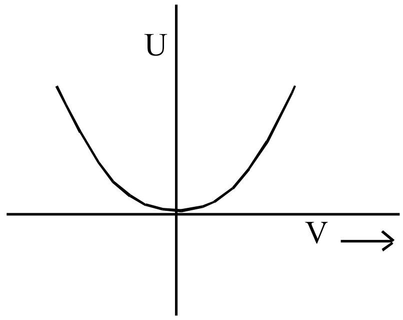
Hence work required to give additional charge dq



$dw = V\,dq$ but $V = \frac{q}{C}$ $= \frac{q}{C}dq$

$\therefore$ Total work done to charge the capacitor from O to Q (max)

$$w = \int_0^Q dw = \frac{1}{C}\int_0^Q q\,dq = \left[\frac{q^2}{2C}\right] = \frac{Q^2}{2C}$$

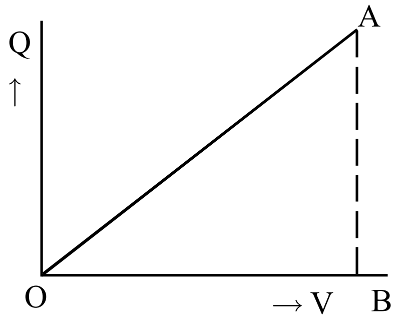


This work is stored as PE, $U = \dfrac{Q^2}{2C}$

Put $Q = CV$

$$U = \frac{1}{2}CV^2$$

OR



Note : since , work done =

Area under the $\Delta OAB = \frac{1}{2} VQ$

Put Q = CV, W=½ CV².

Hence Energy stored $U = \frac{1}{2}CV^2$

Energy density of the parallel plate capacitor

It is the energy stored/ unit volume, $\dfrac{U}{Ad}$

$$= \frac{1}{2}\frac{CV^2}{Ad} = \frac{1}{2}\frac{\varepsilon_0 A}{dAd}V^2 \qquad \text{using } C = \frac{\varepsilon_0 A}{d}$$

$$= \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2$$

$$= \frac{1}{2}\varepsilon_0 E^2 \ (J/m^3) \quad (\text{since Pd} = \text{E.F x distance } V = Ed)$$

Hence the energy stored in a capacitor is in the form of electric field.

Explain combinations of capacitors

1) Series Combination

Reduces the effective capacitance

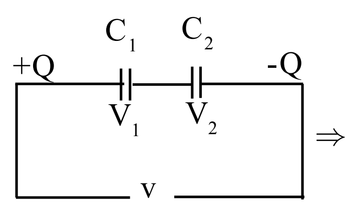


Fig (1)

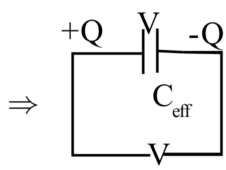


Fig (2)

(Note : Charge will be same)

From Fig.(1) $V = V_1 + V_2$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} \text{..............(1)}$$

From fig (2) $V = \dfrac{Q}{Ceff}$......(2)

From eqs(1) and (2) $\Rightarrow \dfrac{1}{Ceff} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$ $\quad \therefore\ Ceff = \dfrac{C_1C_2}{C_1 + C_2}$

1) Parallel Combination

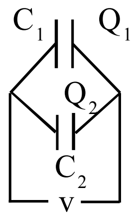
Increases the effective capacitance

From Fig.(1) : $Q = Q_1 + Q_2$

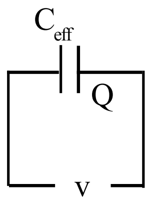
$= (C_1 + C_2)V$ ....(1)

From Fig.(2) : $C_{eff}\ V$ ....(2)

From eqs (1) and (2) $C_{eff} = C_1 + C_2$



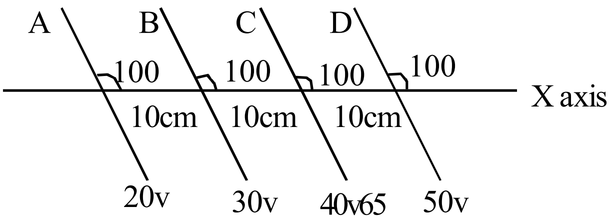
Fig(1)



Fig(2)

Note : Potential will be same

- A, B, C and D are equally spaced equipotential surfaces inclined of at angle of 100^0 with X-axis



a) Predict the direction of $\vec{E}$ interms of angle w.r to +ve x-axis.

b) Find the magnitude of the Electric field.

a) Direction of $\vec{E}$ along 190^0 w.r to x-axis

b) $|E| = \frac{dv}{dr} = \frac{10}{10\ Cos10}\ v/m$

- Find the effective capacitance in b/w A and B

$C_1 = C_2 = C_3 = 3\mu F$ $\qquad$ $C_{eff} = 3\mu F$