2. Conductors, Dielectrics & Capacitances

Electric diode :-

It is defined as ~~and~~ opposite charges and two equal charges ~~and~~ are seperated by a small distance is called as electric dipole.

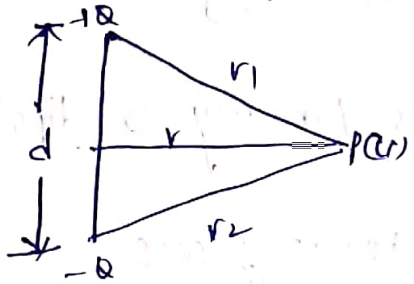
Electric dipole movement :- (m)

the product of charge and distence.

$$\boxed{m = Q \times d}$$

in vector for $\bar{m} = Q\bar{d}$ ~~Cm~~ Cmt

Expression for potential due to Electric dipole :-



from the figure let it be required to determine the potential at point "P" due to electric dipole with distence of r_1 and r_2 and r from positive charge, negative charge and centre.

WKT

The potential at any point is

$$V = \frac{Q}{4\pi\varepsilon r}\,\bar{a}_r \longrightarrow (1)$$

Now V_1 is the potential at positive charge

$$V_1 = \frac{Q}{4\pi\varepsilon r_1} \rightarrow (2).$$

V_2 is the potential at -ve charge

$$V_2 = \frac{-Q}{4\pi\varepsilon r_2} \rightarrow (3)$$

Total potential $V = V_1 + V_2$ at point "p" is

$$V = \frac{Q}{4\pi\varepsilon r_1} - \frac{Q}{4\pi\varepsilon r_2}$$

$$= \frac{Q}{4\pi\varepsilon}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \rightarrow (4)$$

If the required point is faraway to dipole movement then $r_1 = r - \frac{d}{2}\cos\theta$, $r_2 = r + \frac{d}{2}\cos\theta$

substituting these values in eqn (4)

$$V = \frac{Q}{4\pi\varepsilon}\left[\frac{1}{r - \frac{d}{2}\cos\theta} - \frac{1}{r + \frac{d}{2}\cos\theta}\right]$$

$$= \frac{Q}{4\pi\varepsilon}\left[\frac{\cancel{r} + \frac{d}{2}\cos\theta - \cancel{r} + \frac{d}{2}\cos\theta}{r^2 - (\frac{d}{2}\cos\theta)^2}\right]$$

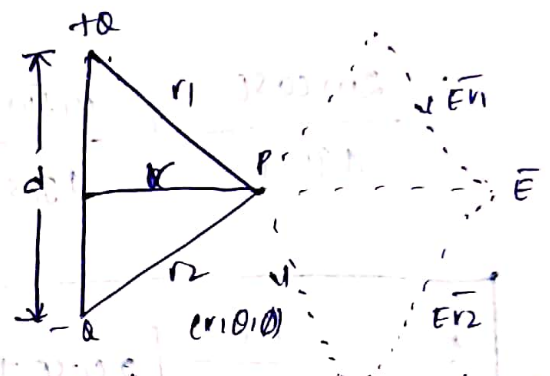
if $d/2 \cos\theta << r$

$$= \frac{Q}{4\pi\varepsilon}\left[\frac{d\cos\theta}{r^2}\right]$$

$$V = \frac{Qd\cos\theta}{4\pi\varepsilon r^2}$$

$$\boxed{V = \frac{m\cos\theta}{4\pi\varepsilon r^2}}$$

Electric field intensity due to an Electric dipole :-



from the figure let it be required to determine electric field intensity at point P due to electric dipole with a distance of r_1 from positive charge and r_2 from -ve charge and centre r. Now we are considering spherical co-ordinate system at point P as shown in figure.

WKT $\bar{E} = -\nabla V \longrightarrow (1)$

Now the potential at point P due to electric dipole is

$$V = \frac{m\cos\theta}{4\pi\varepsilon r^2}\bar{a_r} \longrightarrow (2)$$

from the spherical co-ordinate system (r,θ,ϕ) the operator ∇ is

$$\nabla = \frac{\partial}{\partial r}\bar{a_r} + \frac{1}{r}\frac{\partial}{\partial\theta}\bar{a_\theta} + \frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}\bar{a_\phi} \longrightarrow (3)$$

Substitute (2) & (3) in (1).

$$\bar{E} = -\nabla V$$

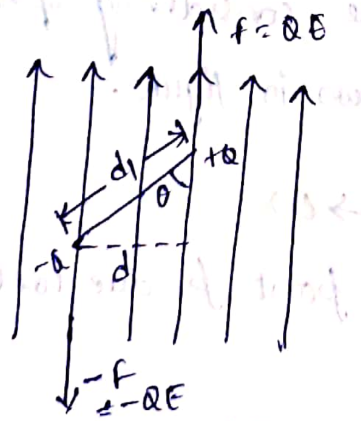
$$= -\left[\frac{\partial}{\partial r}\left[\frac{m\cos\theta}{4\pi\varepsilon r^2}\right] + \frac{1}{r}\frac{\partial}{\partial\theta}\left[\frac{m\cos\theta}{4\pi\varepsilon r^2}\right] + \frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}\left[\frac{m\cos\theta}{4\pi\varepsilon r^2}\right]\right]$$

$$= -\left[\frac{m\cos\theta}{4\pi\varepsilon}\left[\frac{-2}{r^3}\right] + \frac{m}{4\pi\varepsilon r^3}\left[-\sin\theta\right] + 0\right]$$

$$= \frac{2m\cos\theta}{4\pi\varepsilon r^3} + \frac{m\sin\theta}{4\pi\varepsilon r^3}$$

$$\boxed{\bar{E} = \frac{m}{4\pi\varepsilon r^3}\left[2\cos\theta + \sin\theta\right]\bar{a}_r}$$

* Torque on an Electric dipole in a electric field:-



uniform electric field

consider an electric dipole is placed in uniform electric field it experience a force whose magnitude is equal and opposite to each other. We know that the torque is defined as,

$$\tau = F \times d \quad = \text{force} \times \text{perpendicular distance} \longrightarrow (1)$$

WKT

$$F = \frac{Q_1 Q_2}{4\pi \varepsilon r^2} \quad [\text{columb's law}]$$

$$f = \frac{Q_1}{4\pi \varepsilon r^2} \cdot Q_2$$

$$F = \bar{E} \cdot Q \longrightarrow (2)$$

substitute (2) in (1)

$$\tau = \bar{E} \cdot Q\, d$$

from the figure

$$\sin\theta = \frac{d}{d_1}$$

$$d = d_1 \sin\theta .$$

$$\tau = \bar{E} \cdot Q \cdot d_1 \sin\theta$$

$$\tau = E m \sin\theta$$

$$\theta = 90^\circ, \sin\theta = 1$$

$$\boxed{\tau = E m}$$

$$\boxed{\bar{\tau} = \bar{E} \times \bar{m}} \quad [\text{vector form}]$$

m = electric dipole movement c-m

E = field intensity = N/m (or) V/m

* A point charge of $3\mu C$ and $-3\mu C$ are located at $(0,0,1)$ and $(0,0,-1)$ mts. respectively in free space.

i) find electric dipole movement.

ii) find electric field Intensity with a Spherical co-ordinates $(2,40,5)$

iii) find Intensity at point of $(1,2,1.5)$

Solⁿ:- $Q_1 = 3\mu C$, $Q_2 = -3\mu C$

$r_1 = (0,0,1)$ $\quad r_2 = (0,0,-1)$

$$d = \sqrt{0+0+2^2} = 2$$

i) $m = Q \times d$

$= 3 \times 10^{-6} \times 2$

$= 6 \times 10^{-6}$ c-mt

ii) $\bar{E} = \dfrac{m}{4\pi\varepsilon r^3}[2\cos\theta + \sin\theta]$

$= \dfrac{6 \times 10^{-6}}{4 \times \pi \times 8.85 \times 10^{-12} \times 8}[2\cos 40 + \sin 40]$

$= 6743.85 \quad [1.532 + 0.642]$

$E = 14661.137$

iii)

$E = \dfrac{m}{4\pi\varepsilon r^3}[2\cos\theta + \sin\theta]$

$= 67493.85 [1.998 + 0.034]$

$= 109671.243$

Q. Find the potential at point $P(10, 60^\circ, 0^\circ)$ due to dipole charge $Q_1 = 1\mu C$ at $(0.1, 0, 0)$ and $Q_2 = -1\mu C$ at $(-0.1, 0, 0)$

Sol: $Q_1 = 1\mu C = 1\times10^{-6}\,C$ $\qquad$ $r_1 = (0.1, 0, 0)$

$Q_2 = 1\mu C = -1\times10^{-6}\,C$ $\qquad$ $r_2 = (-0.1, 0^\circ, 0)$

$$d = \sqrt{(0.2)^2} = 0.2$$

i) $m = Q\times d$

$= 1\times10^{-6}\times0.2 = 2\times10^{-7}$

ii) $$\bar{E} = \frac{m}{4\pi\varepsilon r^3}[2\cos\theta + \sin\theta]$$

$$= \frac{2\times10^{-7}}{4\pi\times8.85\times10^{-12}\times(10)^3}[2\cos60^\circ + \sin0^\circ]$$

$= 1.798\,[1+0]$

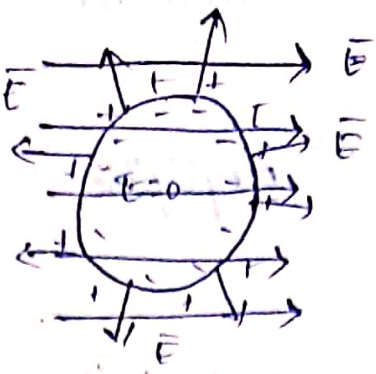
$= 1.798$

Difference b/n conductor, insulator and semiconductors

Basic for comparison	conductor	Insulator	Semiconductor
Definition	The elements which allow the flow of electric current through it by the application voltage	The elements which donot allow any flow of electric charge	The elements whose conductivity lies between insulators and conductors
Electric conductivity	Good conductor	Bad conductor	At 0K works, it works as an insulator. by adding impurity becomes good conductor
Examples	copper, Mercury	wood Rubber	Germanium, silicon
Energy band	conduction band and valance band overlap each other	both are seperated by a distance 6eV	conduction band and valence band seperated by 1eV.
charge carriers	electrons	They donot contain any charge carriers	Intrinsic charge carriers are holes and electrons
current flow	current flow due to electrons	current does not flow	current due to holes and electrons

Basic for comparison	conductor	Insulator	semiconductor
No. of charge carriers	very high	Negligible	low
Effect of Temperature	conductivity decreases	conductivity increases	conductivity increases.
Effect of doping	Resistance increases	Resistance remain unchanged	Resistance decreases
Behaviour at 0K Temperature	Behaves as super conductor	Behave like an insulator	Behave like an insulator
Bonding Types	Ionic bond	Ionic Bond and covalent Bond	covalent Bond.

* Behaviour of conductor in electric field :-



* consider an uniform electric field as shown in fig.
* while placing a conductor in uniform electric field depending on the direction of electric field it appears 2 charges on the conductor.
* A negative charge will occur on the part of the conductor through field lines enter to the conductor. A positive charge will occur on the surface of the conductor through which field lines leave the conductor.
* Inside of the conductor the electric field intensity is zero.

$$\boxed{\bar{E}=0}$$

properties :-

- The field intensity at any point on the surface of the conductor is directly proportional to $1/\varepsilon_0$ times of Electric flux density

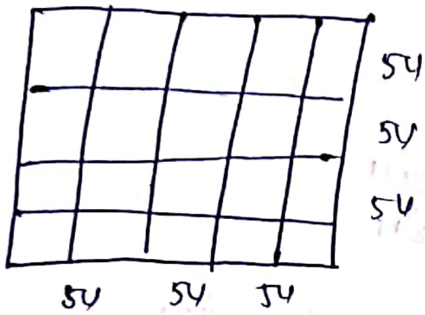
$$\bar{D}=\varepsilon\bar{E}$$

$$\boxed{\bar{E}=\frac{1}{\varepsilon}\bar{D}}$$

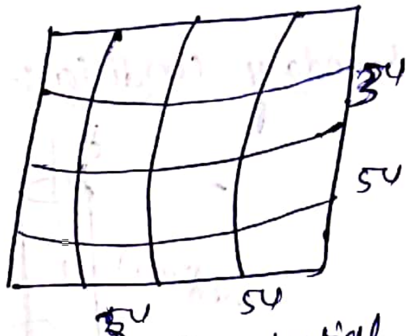
- Electricity field intensity inside of the conductor is zero.
- The conductor surface is equal to equi potential surface.

equi potential surface:-

If all the points on the surface having the same potential then the surface is called equipotential surface.



Equal potential surface



unequal potential surface.

Boundary Condition's:-

When an electric field passes from one medium to other medium it is important to study the conditions at the boundary between the 2-media. The conditions existing at the boundary of 2-media when field passes from one medium to another medium, that is called as "boundary condition's."

Depending upon the nature of the media there are 2 situation's of the boundary conditions.

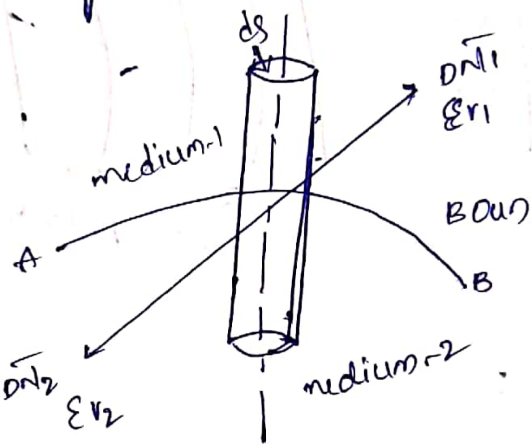
- Boundary b/n 2 dielectrics.
- Boundary b/n dielectric and conductor.

1. Boundary between two dielectrics:-

Generally the boundary between two dielectric consists of two parts.

1. first boundary condition
2. second boundary condition

1. first boundary condition:-



The electric field intensity $(\bar{E})$ and electric flux density $(\bar{D})$ is required to be decomposed into two components namely tangential to the boundary, normal component to the boundary ($\bar{E}_{tan}$, $\bar{E}_N$, $\bar{D}_{tan}$, $\bar{D}_N$)

$$\therefore \bar{E} = \bar{E}_{tan} + \bar{E}_N$$

$$\bar{D} = \bar{D}_{tan} + \bar{D}_N$$

* The first boundary condition deals with that is to find the normal components of electric flux density i.e., $\bar{D}_{N1}$, $\bar{D}_{N2}$

* from the fingure A, B in the boundary line b/n medium-1 and medium 2 with a relative permittivity of ε_{r1}, ε_{r2}.

* Now consider a small area 'ds' on the boundary arrving with a Gaussian surface.

* θ_1, θ_2 are the angles.

Acc. to Gauss law

$$\oint_S \bar{D} \cdot ds = Q = \psi \longrightarrow (1)$$

from the figure,

the electric flux leading the top and bottom surfaces ($N-1, N-2$).

$$ds D_{N1} - ds D_{N2} = Q$$

$$ds(D_{N1} - D_{N2}) = Q$$

$$D_{N1} - D_{N2} = \frac{dQ}{ds} \qquad \left[\frac{dQ}{ds} = \rho_s\right]$$

$$D_{N1} - D_{N2} = \rho_s$$

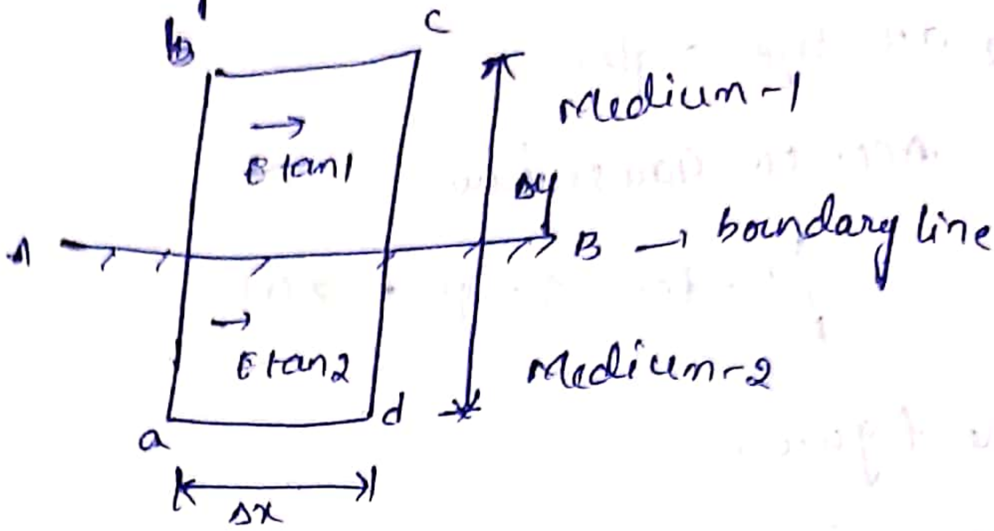
$$D_{N1} - D_{N2} = 0$$

$$\boxed{D_{N1} = D_{N2}}$$

at the boundary the surface charge density in 0.

The Normal component of electric flux density is continous across the boundary b/n two dielectrics.

ii) Second boundary condition :-



Tangetial to boundary is

$$\oint \bar{E} \cdot dl = 0$$

$$\int_a^b \bar{E} \cdot dl + \int_b^c \bar{E} \cdot dl + \int_c^d \bar{E} \cdot dl + \int_d^a \bar{E} \cdot dl = 0$$

$$0 + \Delta x \cdot \bar{E}_{tan_1} + 0 - \Delta x \bar{E}_{tan_2} = 0 \qquad [\Delta y = 0]$$

at the boundary ⊥ler lines are

$$\Delta x (\bar{E}_{tan_1} - \bar{E}_{tan_2}) = 0$$

$$\bar{E}_{tan_1} - \bar{E}_{tan_2} = 0$$

$$\boxed{\bar{E}_{tan_1} = \bar{E}_{tan_2}}$$

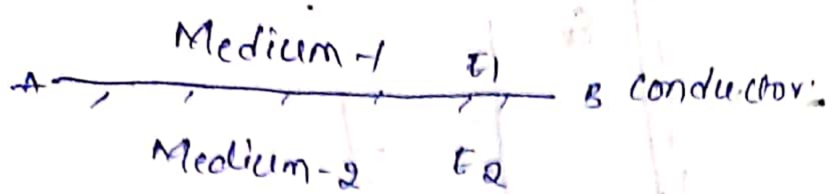
or

$$\boxed{\bar{E}_{T_1} = \bar{E}_{T_2}}$$

E_t is continuous at across boundary

Boundary between dielectric and conductor:-

Electric field in a conductor is zero.



$\bar{E} = 0$

$\bar{E}_{tan1} = \bar{E}_{tan2} = 0$

$$\boxed{\bar{E}_{T1} = \bar{E}_{T2}}$$

Capacitance and capacitor:-

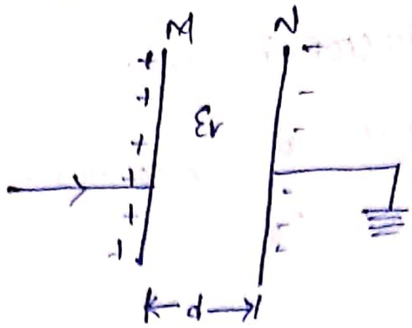
Capacitor:- A capacitor essentially consists of a conducting surfaces seperated by a small distance with dielectric medium is called a capacitor.

Generally the conducting surfaces are in the form of parallel plates, spherical, rectengular, co-axial shapes.

Capacitance:- It is the property of capacitor and it stores the energy in the form of electric field. The capacitence of the capacitor is defined as the charge per unit potential difference across its plates.

$$\therefore C = \frac{Q}{V} \text{ farads}$$

* Capacitance of a parallel plate capacitor :-



- A parallel plate capacitor consists of two plates M and N each of conducting surface area A in m^2 seperated by a distance d in meters as shown in fig.

W.K.T. The electric flux density $\bar{D} = \frac{Q}{A} \longrightarrow (1)$

W.K.T The relation b/n $\bar{D}$ and $\bar{E}$ is

$$\bar{D} = \varepsilon \bar{E}$$

$$\bar{E} = \frac{\bar{D}}{\varepsilon} \longrightarrow (2)$$

By the definition of potential difference is

$$\bar{V} = \bar{E} \cdot d \longrightarrow (3)$$

or($\bar{D}$)

substitute (1) & (2) in (3)

$$\boxed{V = \frac{\bar{D}}{\varepsilon} \cdot \frac{Q}{A}} \longrightarrow (4)$$

W.K.T.

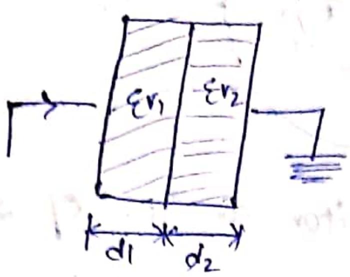
capacitance $C = \frac{Q}{V} \longrightarrow (5)$

substitute (4) in (5)

$$C = \frac{\cancel{Q}}{\frac{\bar{D}}{\varepsilon} \cdot \frac{\cancel{Q}}{A}}$$

$$\boxed{C = \frac{\varepsilon A}{D}}$$

* capacitance of a parallel plate capacitor with 2-Dielectric Media:-



→ the fig. constists of space b/n 2-parallel plates filled with a 2-Dielectric Media with a relative permitivities of ε_{r_1}, ε_{r_2}.

W.K.T $\quad \bar{D} = \frac{Q}{A} \longrightarrow (1)$

W.K.T the relation b/n $\bar{D}$ and $\bar{E}$ is

$$\bar{D} = \varepsilon \bar{E}$$

$$\bar{E} = \frac{D}{\varepsilon} \longrightarrow (2)$$

$$\bar{E}_1 = \frac{\bar{D}}{\varepsilon_0 \varepsilon_{r_1}}, \quad \bar{E}_2 = \frac{\bar{D}}{\varepsilon_0 \varepsilon_{r_2}}$$

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

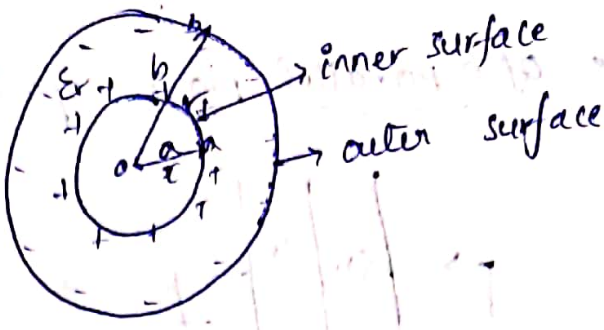
$$V = \bar{E}_1 d_1 + \bar{E}_2 d_2$$

$$V = \frac{\bar{D}}{\varepsilon_0}\left[\frac{d_1}{\varepsilon_{r_1}} + \frac{d_2}{\varepsilon_{r_2}}\right]$$

$$\frac{\cancel{Q}}{C} = \frac{\cancel{Q}}{A\varepsilon_0}\left[\frac{d_1}{\varepsilon_{r_1}} + \frac{d_2}{\varepsilon_{r_2}}\right]$$

$$\boxed{C = \frac{A\varepsilon_0}{\frac{d_1}{\varepsilon_{r_1}} + \frac{d_2}{\varepsilon_{r_2}}}}$$

* Capacitance of a Spherical plate capacitor:-



- The spherical capacitor consists of 2 concentric spheres of radius a and b mt seperated by a di-electric media ϵ_r as shown in fig.

- w.k.T potential at any point in an electric field with a distance of r mt.

i.e., $V = \dfrac{Q}{4\pi\epsilon r} \longrightarrow (1)$

- the potential of a inner surface conductor a ~~due~~ due to charge +Q i.e.,

$$V_a = \frac{Q}{4\pi\epsilon a} \longrightarrow (2)$$

- the potential of a outer surface conductor b due to charge positive charge Q is i.e.,

$$V_b = \frac{-Q}{4\pi\epsilon b} \longrightarrow (3)$$

w.k.T the total potential $V = V_a + V_b$.

$$\therefore V = \frac{Q}{4\pi\epsilon a} - \frac{Q}{4\pi\epsilon b}$$

$$V = \frac{Q}{4\pi\varepsilon}\left[\frac{1}{a} - \frac{1}{b}\right]$$

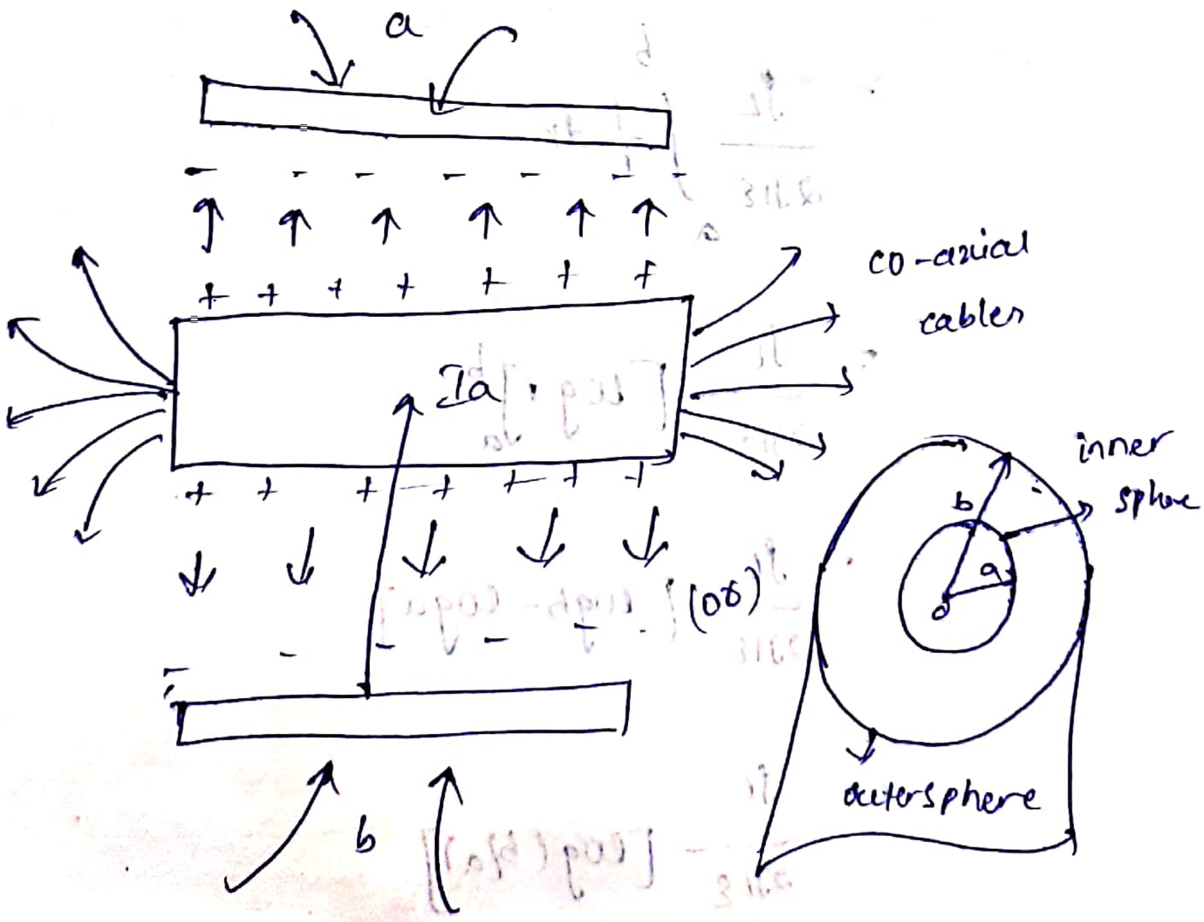
$$= \frac{Q}{4\pi\varepsilon}\left[\frac{b-a}{ab}\right]$$

$$C = Q/V$$

$$= \frac{\cancel{Q}}{\frac{\cancel{Q}}{4\pi\varepsilon}\left[\frac{b-a}{ab}\right]}$$

$$\boxed{C = 4\pi\varepsilon\left[\frac{ab}{b-a}\right]}$$

* capacitance of co-axial or cylindrical cable:-



→ w.k.T the electric field intensity due to line charge

$$\bar{E} = \frac{\rho_L}{2\pi\varepsilon r} \longrightarrow (1)$$

→ w.k.T the potential difference is

$$V = \int_{I.V}^{F.V} \bar{E} \cdot \bar{dr} \longrightarrow (2)$$

substitute (1) in (2)

$$V = \int_{I.V}^{F.V} \frac{\rho_L}{2\pi\varepsilon r} \bar{dr}$$

$$= \int_a^b \frac{\rho_L}{2\pi\varepsilon r} dr$$

$$= \frac{\rho_L}{2\pi\varepsilon} \int_a^b \frac{1}{r} dr$$

$$= \frac{\rho_L}{2\pi\varepsilon} [\log r]_a^b$$

$$= \frac{\rho_L}{2\pi\varepsilon} [\log b - \log a]$$

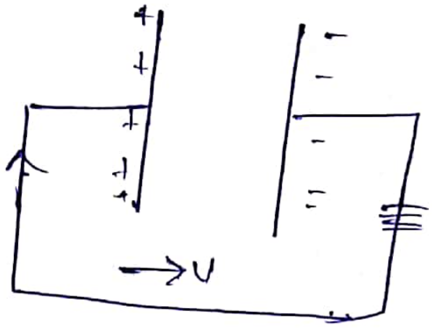
$$= \frac{\rho_L}{2\pi\varepsilon} [\log(b/a)]$$

w.k.t $C = Q/V$

$$= \frac{\cancel{Q}}{\frac{\cancel{\rho_L}}{2\pi\varepsilon}[\log(b/a)]}$$

$$\boxed{C = 2\pi\varepsilon/[\log(b/a)]} \qquad [\because Q = \rho_L]$$

* Energy stored in a capacitor:-



- consider a capacitor of capacitance being charged from a source of 'V' volts as shown in fig, so capacitor is charged and stores energy in the form of electric form.

by the defenition of capacitance

$$C = \frac{Q}{V} \rightarrow (1)$$

$$Q = CV \rightarrow (2)$$

$$V = \frac{Q}{C} \rightarrow (3)$$

$$V = \frac{dw}{dQ} \Rightarrow dw = V\,dQ$$

$$w = \int_0^Q V\,dQ$$

$$= \int_0^Q \frac{Q}{C} \cdot dQ$$

$$= \frac{1}{C}\int_0^Q Q \cdot dQ$$

$$= \frac{1}{C}\left[\frac{Q^2}{2}\right]_0^Q$$

$$= \frac{Q^2}{2C}$$

$$W = \frac{1}{C} \cdot Q \cdot \frac{Q}{2}$$

$$= \frac{V \cdot Q}{2}$$

$$W = \frac{V}{2}(CV)$$

$$\boxed{W = \frac{1}{2}CV^2}\ J$$

* Energy density in a static electric field :-

- Energy density is defined as Energy per unit volume. It is indicated by w_d.

Mathematically, $w_d = \dfrac{\text{energy}}{\text{unit volume}}$

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

$C = \frac{\varepsilon A}{d}$ [Parallel plate capacitor]

$$w_d = \frac{\frac{1}{2}CV^2}{Ad}$$

$$= \frac{\frac{1}{2}\left[\frac{\varepsilon \cancel{A}}{d}\right]V^2}{\cancel{A}\,d}$$

$$wd = \frac{1}{2} \varepsilon \frac{V^2}{d^2}$$ $V = Ed E$
$E = V/d$

$$wd = \frac{1}{2} \varepsilon (E)^2$$

$$wd = \frac{1}{2} (\varepsilon E) E$$

$$\boxed{wd = \frac{1}{2} D E}$$

* find the capacitance of a respective parallel plates 30cm x 30cm seperated by 5mm in air? what is the energy stored by the capacitor if it is charged to a potential difference 500V.

sol:-

Given that

$A = 30 \times 30 \text{ cm}^2$ $\quad V = 500V$

$= 900 \times 10^{-4} m^2$

$\varepsilon_r = 1$

$d = 5mm$

$= 5 \times 10^{-3} m$

$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon_0 \varepsilon_r A}{d} = \frac{8.85 \times 10^{-12} \times 900 \times 10^{-4}}{5 \times 10^{-3}}$$

$= 1.59 \times 10^{-10}$

$= 159$ pf [pico farads]

Energy stored $= \frac{1}{2} C V^2$

$= \frac{1}{2} \times 159 \times 10^{-12} \times 500 \times 500$

$= 1.987 \times 10^{-5}$

$= 19.87$ μJ

* calculate capacitance of a parallel plate capacitor with following details.

plate = $100 cm^2$

dielectric $\varepsilon_{r1} = 4$

$d_1 = 2mm$

dielectric $\varepsilon_{r2} = 3$

$d_2 = 3mm$

If 200V is applied across the plates what will be the voltage gradient across each dielectrics and also find the energy stored in a each dielectrics.

sol:-

$$C = \frac{\varepsilon_0 A}{\frac{d_1}{\varepsilon_{r1}} + \frac{d_2}{\varepsilon_{r2}}} = \frac{8.85 \times 10^{-12} \times 100 \times 10^{-4}}{\frac{2\times 10^{-3}}{4} + \frac{3\times 10^{-3}}{3}}$$

$$= \frac{885 \times 10^{-16}}{5\times 10^{-4} + 1\times 10^{-13}} = \frac{885 \times 10^{-16}}{10^{-3}[0.5+1]}$$

$$= 590 \times 10^{-13} = 59 pf$$

$$C_1 = \frac{\varepsilon A_1}{d_1} \qquad C_2 = \frac{\varepsilon A_2}{d_2}$$

$$= \frac{\varepsilon_0 \varepsilon_r A_1}{d_1} \qquad = \frac{\varepsilon_0 \varepsilon_r A_2}{d_2}$$

$$= \frac{8.85 \times 10^{-12} \times 100 \times 10^{-4} \times 4}{2 \times 10^{-3}} \qquad = \frac{8.85 \times 10^{-12} \times 100 \times 10^{-4} \times 3}{3\times 10^{-3}}$$

$$= 177.08 pf \qquad = 88.5 pf$$

$C = Q/V$

$C = Q/200$

$Q = 59 \times 10^{-12} \times 200$

$= 1.18 \times 10^{-8}$

$C_1 = \frac{Q_1}{V_1} \Rightarrow V_1 = \frac{Q_1}{C_1}$ $\qquad$ $C_2 = \frac{Q_2}{V_2} \Rightarrow V_2 = \frac{Q_2}{C_2}$

$= \frac{1.18 \times 10^{-18}}{177.08 \times 10^{-12}}$ $\qquad$ $V_2 = \frac{1.18 \times 10^{-18}}{88.5 \times 10^{-12}}$

$= 66.67V$ $\qquad$ $= 133.33V$

Energy stored in 1st plate $E = \frac{1}{2} C_1 V_1^2$

$= \frac{1}{2} \times 177.08 \times 10^{-12} \times (66.67)^2$

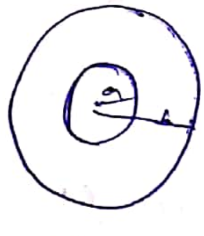
$= 3.93 \times 10^{-7}$ J

Energy stored in 2nd plate $E = \frac{1}{2} C_2 V_2^2$

$= \frac{1}{2} \times 88.5 \times 10^{-12} \times (133.33)^2$

$= 7.866 \times 10^{-7}$ J

* A spherical condenser has capacitence 54 pf. it consists of 2 concentratic spheres difference in radius by 4 cm having and air has dielectric if radial of inner and outer spheres.



sol:

$C = 54\ pF = 54 \times 10^{-12}\ F$

$b - a = 4\,cm = 4 \times 10^{-2}\ m$

$C = \frac{\cancel{2\pi l \varepsilon}}{\cancel{\log(b/a)}}$ $\quad C = 4\pi\varepsilon\left[\frac{ab}{b-a}\right]$

$54 \times 10^{-12} = 4 \times \pi \times 8.85 \times 10^{-12}\left[\frac{ab}{4 \times 10^{-2}}\right]$

$ab = 0.0194$

$(a+b)^2 = (a-b)^2 + 4ab$

$= (-4 \times 10^{-2})^2 + 4 \times 1.942 \times 10^{-2}$

$= \cancel{08.0804}$

$a+b = 0.2814$

$b+a = 0.011$

$b-a = 4 \times 10^{-2}$

$2b = 0.3214$

$b = 0.1607$

$a = 0.12$

* Current :-

The flow of electrons (or) the charge flows from one place to another place in the conductor.

(or)

Rate of flow of charge is called as Current.

It is denoted by I (or) i Amp.

Mathematically, $i = \frac{Q}{t}$

Current is a scalar quantity.

* Current density :- The current density is defined as current to unit surface area.

Mathematically. $J = \frac{I}{A}$ Amp/m^2

$$J = \frac{dI}{dA}$$

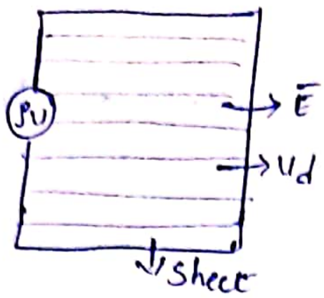
$$dI = J \cdot dA \quad [dA = ds]$$

(or)

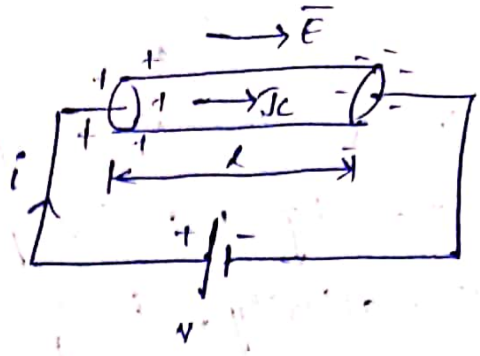
$$dI = J \cdot ds$$

$$\boxed{I = \int_s J \cdot ds}$$

* Difference b/n conduction Current density and Convection Current density:-



convection



Convenction :-

A set of charge particles giving raine to a charge density in a volume (ρv) to have a drift velocity (vd) as shown in fig.

the charge particles are assumed to maintain the irrelative positions with in the volume. as this charge configuration produces a surface (s). it is called as Convenction Current density (Jcon).

$$J_{con} \propto v_d$$

$$J_{con} = \rho v_d$$

J_{con} = conventional current density amp/m^2

ρ = Resistivity

v_d = drift velocity.

conduction current density:-

conduction current density ocured in the presence of electric field intensity associated with conductor with a fixed cross-sectional area as shown in fig. It is indicated by J_c Amp/m2.

Mathematically,

$$J_c \propto v_d$$

$$J_c = \rho v_d$$

WKT $v_d \propto E$

$$v_d = \mu \bar{E}$$

$$J_c = \mu \bar{E} \rho$$

$$\boxed{J_c = \sigma \bar{E}}$$

where σ = conductivity = $1/\rho$

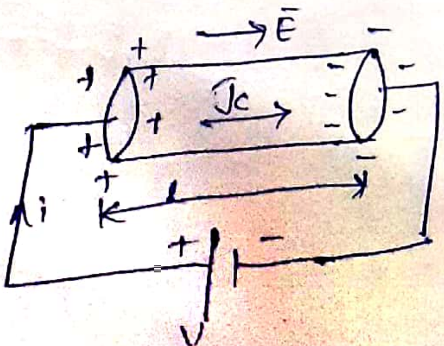
J_c = conduction current density

$\bar{E}$ = Electric field intensity

∴ The above equation is called as

"point form of ohm's law"

*point form of ohm's law:-



Statement:-

According to ohm's law " At constant temperature the voltage across the two ends of the conductor is directly proportional to the current flowing through the conductor. as shown in figure.

Mathematically, $i \propto V \Rightarrow V = iR$

w.k.t $i = V/R$

w.k.T $R \propto l/A \Rightarrow R = \rho l/A$

$$I = \frac{V}{\rho l/A}$$

$$I = \frac{VA}{\rho l}$$

$$\Rightarrow \frac{I}{A} = \frac{V}{\rho L}$$

$$\boxed{\Rightarrow J = \sigma \bar{E}}$$

This is called as point form of ohm's law

* Note

convenction (Jcon)

* convenction current occurs in insulators or dielectrics such as liquid, vaccum gas etc.

* convenction current does not involve conductors. hence, it does not satisfy the ohm's law.

conduction (J_c)

conduction current occurs in conductor where there are large no. of free electrons.

It satisfies ohm's law.

* Equation of continuity (or) Maxwell's fifth Equation:-

The differential equation relating to current density (J) and volume charge density (ρ_v) at each point in the circuit is known as Equation of continuity (or) continuity equation.

- Based on law of conservation of charge,

$$I_c = -q/t$$

$$I_c = \frac{-dq}{dt} \rightarrow (1) \quad [\text{-ve indicates flow of } e^-\text{'s}]$$

W.K.T. $J = I/s \Rightarrow J = \frac{dI}{ds}$

$$dI = J \cdot ds$$

$$I = \int_s J \cdot ds \rightarrow (2)$$

W.K.T $\rho_v = Q/V$

$$\rho_v = \frac{dQ}{dV}$$

$$dQ = \rho_v \cdot dV$$

$$Q = \int_V \rho_v \cdot dv \rightarrow (3)$$

substitute (2) & (3) in (1)

$$\int_S J \cdot ds = -\frac{d}{dt}\left(\int_V \rho_v \cdot dv\right)$$

Applying divergence theorem

$$\int_V \nabla \cdot J \, \cancel{dv} = -\frac{d}{dt}\left(\int_V \rho_v \cdot \cancel{dv}\right)$$

$$\nabla \cdot J = -\frac{d}{dt}(\rho_v)$$

$$\boxed{\nabla \cdot J + \frac{d}{dt}(\rho_v) = 0}$$