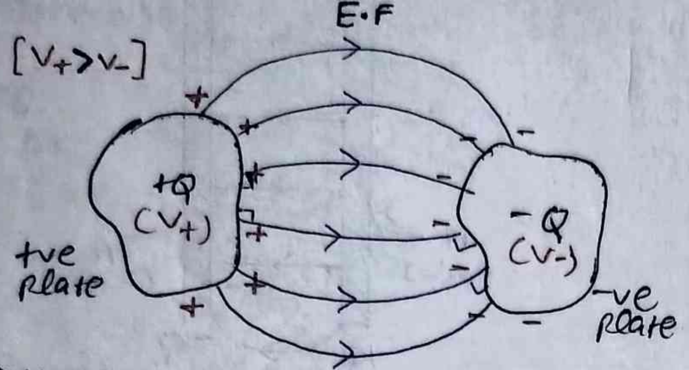
> CAPACITOR :-

Combination of two conductor placed closed to each other seperated by Insulated Medium



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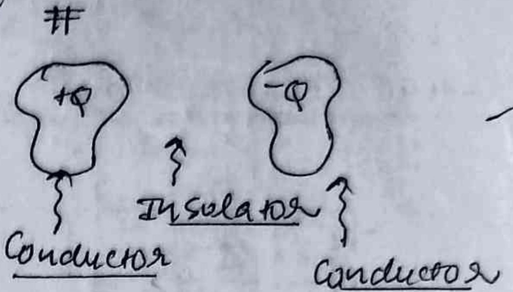


> Used for storing electric charge & electrical energy.

$V = (V_+ - V_-)$ = potential diff b/w plates

and $Q \propto V \longrightarrow [Q(\uparrow), E(\uparrow), V(\uparrow)]$ ∵

$\boxed{\therefore\ Q = CV}$

Capacitance (measure ability of conductor to store charge)

Unit :- C/V or farad.

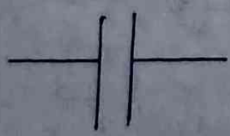
∴ $1\mu F = 10^{-6} F$

∴ $1nF = 10^{-9} F$

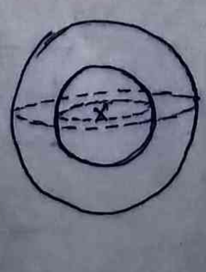
∴ $1pF = 10^{-12} F$

> TYPES OF CAPACITOR :-

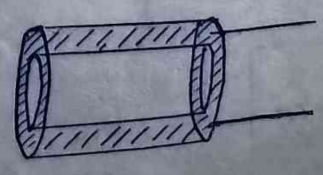
(I) Parallel plate



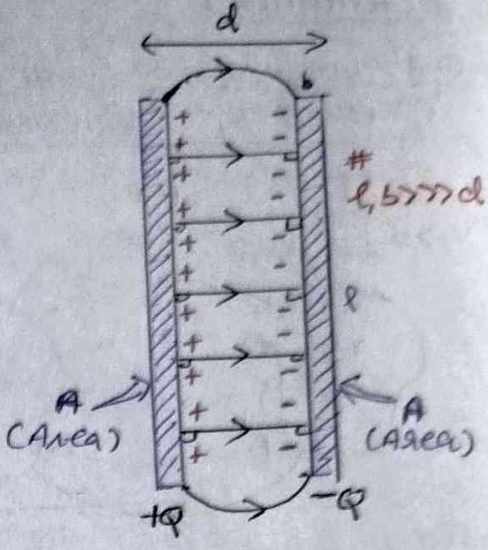
(II) Spherical



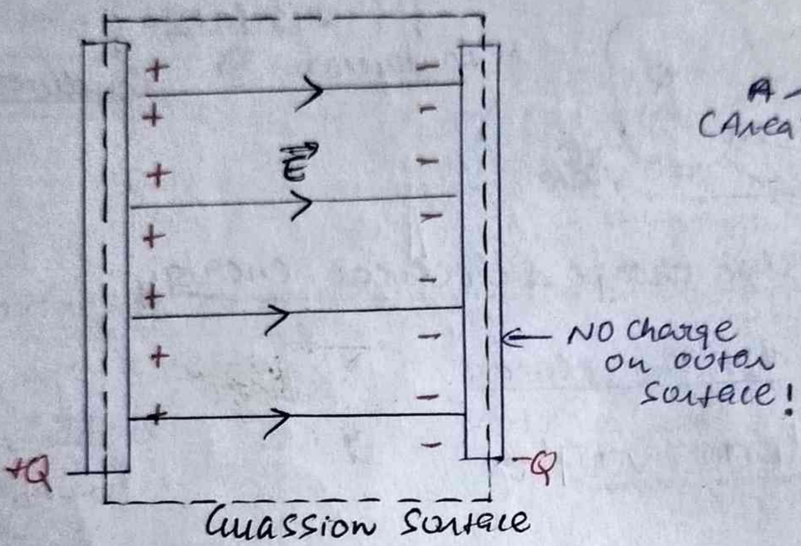
(III) Cylindrical



> PARALLEL PLATE CAPACITOR :-



∵ CHARGE REDISTRIBUTION :-



#

$\vec{E}_{in} = \vec{0}$

$\phi = \oint \vec{E}\cdot\vec{dA} = 0$

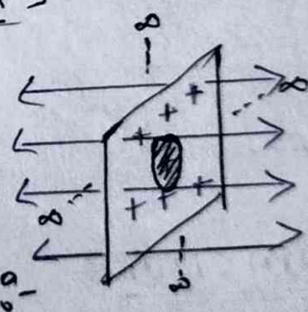
$\frac{q_{in}}{A} = 0 \Rightarrow \boxed{q_{in} = 0} \rightarrow$

> hence;

∵ $q_{inner\,R} = +Q$

∵ $q_{inner\,L} = -Q$

$\boxed{q_{in} = 0}$



$EA + EA = \frac{\sigma A}{\varepsilon_0}$

∵ $E = \frac{\sigma}{2\varepsilon_0}$

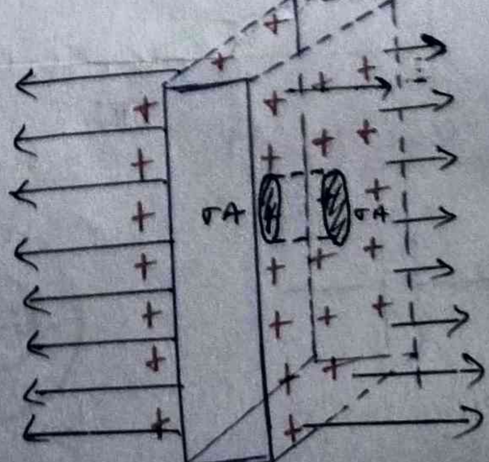
∵ for an non conducting plane; $E = \frac{\sigma}{2\varepsilon_0}$

> Filed due to ∞ conducting plane :-

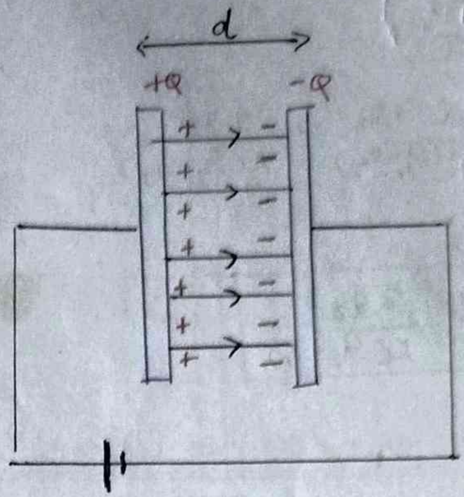
$EA + EA = \frac{\sigma A + \sigma A}{\varepsilon_0}$

$EA = \frac{\sigma A}{\varepsilon_0}$

∴ $\boxed{E = \frac{\sigma}{\varepsilon_0}}$



> CAPACITANCE OF PPC :-



(I)

$$E = \frac{\sigma}{2\varepsilon_0} = \frac{Q}{2A\varepsilon_0} \times 2 = \frac{Q}{A\varepsilon_0}$$

$\therefore$ $\boxed{E_{Net} = \frac{Q}{A\varepsilon_0}}$ — ①

(II)

$\Delta V = -\vec{E}\cdot\Delta\vec{r}$; $V = V_+ - V_-$

$V_- - V_+ = -E\Delta r \cos 0$

$V_- - V_+ = \frac{-Q}{A\varepsilon_0} \times d \times 1$

$-V = -\frac{Qd}{A\varepsilon_0} \Rightarrow \boxed{V = \frac{+Qd}{A\varepsilon_0}}$ — ②

(III)

$C = \frac{Q}{V} \Rightarrow \frac{Q \times A\varepsilon_0}{Qd} \Rightarrow \frac{A\varepsilon_0}{d} \Rightarrow \boxed{C = \frac{A\varepsilon_0}{d}}$

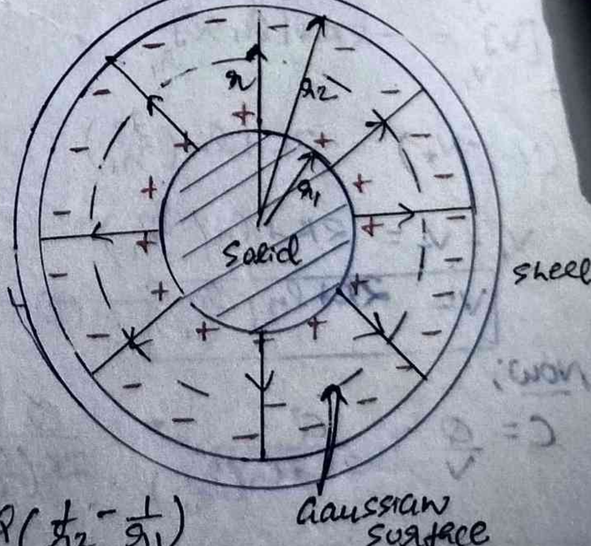
$\therefore$ Rectangular plate $\boxed{C = \frac{lb\varepsilon_0}{d}}$ — ①

$\therefore$ Circular plate $\boxed{C = \frac{\pi r^2 \varepsilon_0}{d}}$ — ②

> Spherical Capacitor :-

$\therefore$ (A conducting sphere surrounded by another conducting spherical shell)

> $\phi_{total} = \oint \vec{E}\cdot\vec{dA} = \frac{q_{in}}{\varepsilon_0}$ (Gauss's law)



$E(4\pi r^2) = \frac{+Q}{\varepsilon_0}$

$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}}$ — ①

> $dV = -\vec{E}\cdot\vec{dr}$

$= -KQ\frac{1}{r^2}dr\cos 0$

$V = -KQ\int r^{-2}dr$

$[V]_{V_i}^{V_f} = -KQ\left[\frac{-1}{r}\right]_{r_1}^{r_2}$

$V_- - V_+ = KQ\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

$\therefore$ $\boxed{V_+ - V_- = \frac{KQ(r_2 - r_1)}{r_1 r_2}}$

Now;

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

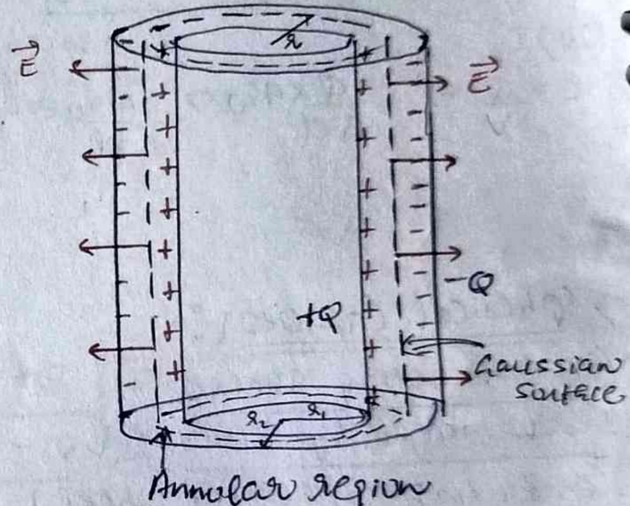
$\Rightarrow \frac{\cancel{Q}\, r_1 r_2}{KQ(r_1 - r_2)} \Rightarrow \frac{r_1 r_2}{K(r_2 - r_1)}$

Hence;

$$\boxed{\therefore C = \frac{r_1 r_2}{K(r_2 - r_1)}}$$

Capacitance does not depend upon Q, V, Potential E of conductor

> CYLINDRICAL CAPACITOR :-



$\phi_{total} = \oint \vec{E} \cdot \vec{dA} = \frac{q_{in}}{\varepsilon_0}$

$E(2\pi r l) = \frac{Q}{\varepsilon_0}$

$E = \frac{1}{2\pi\varepsilon_0} \times \frac{Q}{l r}$

$$\boxed{\therefore E = \frac{2K\lambda}{r}} \text{ --- (1)}$$

$dV = -\vec{E} \cdot \vec{dr}$

$dV = -\frac{2K\lambda}{r} dr$

$[V]_{V_+}^{V_-} = -2K\lambda [\ln r]_{r_1}^{r_2}$

$(V_- - V_+) = -2K\lambda \ln\left(\frac{r_2}{r_1}\right)$

$V_+ - V_- = 2K\lambda \ln\left(\frac{r_2}{r_1}\right)$

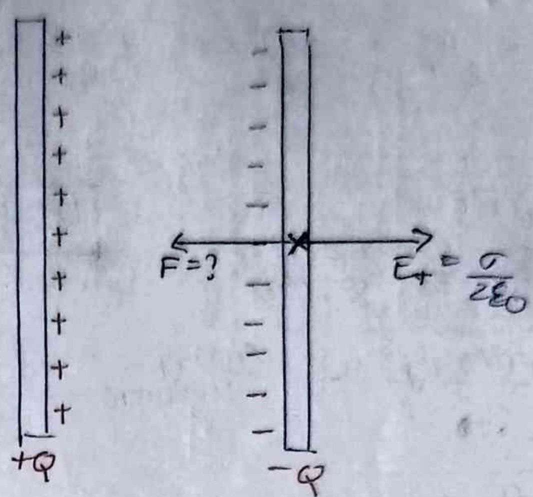
$$\boxed{V = 2K\lambda \ln\left(\frac{r_2}{r_1}\right)} \text{ --- (2)}$$

Now;

$C = \frac{Q}{V} = \frac{Q}{2K\lambda \ln\left(\frac{r_2}{r_1}\right)} = \frac{\cancel{Q}}{2K\left(\frac{\cancel{Q}}{l}\right)\ln\left(\frac{r_2}{r_1}\right)}$

$$\boxed{\therefore C = \frac{l}{2K \ln\left(\frac{r_2}{r_1}\right)}}$$

> FORCE B/W PLATE OF CAPACITOR :-



$$E_1 = \frac{\sigma}{2\varepsilon_0} = \frac{Q}{2A\varepsilon_0}$$

$$F = QE = \frac{Q \times Q}{2A\varepsilon_0}$$

$$\therefore \boxed{F = \frac{Q^2}{2A\varepsilon_0}}$$

and

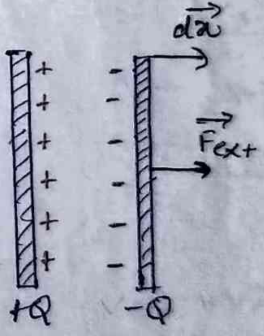
$$F = \frac{(\sigma A)^2}{2A\varepsilon_0} = \frac{\sigma^2 A}{2\varepsilon_0}$$

$$\frac{F}{A} = \frac{\sigma^2}{2\varepsilon_0} \Rightarrow \boxed{\frac{dF}{dA} = \frac{\sigma^2}{2\varepsilon_0}}$$

Force/unit area

∴ [electrostatic pressure]

> ENERGY STORED IN A CAPACITOR :-



$$dW_{ext} = F_{ext}\, dx \cos 0$$

$$dW_{ext} = F_{ext}\, dx$$

and $dW_{ext} = dU$

$$\Rightarrow dU = F_{ext}\, dx$$

$$\Rightarrow dU = \frac{Q^2}{2A\varepsilon_0} dx$$

$$\int_0^U dU = \frac{Q^2}{2A\varepsilon_0} \int_0^d dx$$

$$\therefore U = \frac{Q^2 d}{2A\varepsilon_0} = \frac{Q^2}{2} \times \frac{1}{(A\varepsilon_0/d)}$$

$$> \boxed{U = \frac{Q^2}{2C}}$$

> **Energy density in $\vec{E}$:-**

$$U = \frac{Q^2}{2C} = \frac{Q^2}{2\left(\frac{A\varepsilon_0}{d}\right)} = \frac{(\sigma A)^2}{2A\varepsilon_0} \times d = \frac{\sigma^2 A d}{2\varepsilon_0} = \frac{1}{2}\left(\frac{\sigma}{\varepsilon_0}\right)^2 \times \varepsilon_0 A d$$

$$= \frac{1}{2} E^2 \varepsilon_0 A d$$

#

$$\boxed{U = \frac{1}{2} E^2 \varepsilon_0 A d} \quad (1)$$

and

$$E_{net} = (E_+) + (E_-)$$

$$= \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

> **energy density (u)** $= \dfrac{\text{energy}}{\text{volume}} = \dfrac{\frac{1}{2}\varepsilon_0 E^2 A d}{(Ad)} = \frac{1}{2}\varepsilon_0 E^2$

hence;

$$\boxed{\therefore u = \frac{1}{2}\varepsilon_0 E^2}$$

> **PARALLEL COMB. OF CAPACITORS:-**

$Q_1 = C_1 V$ — (1)

$Q_2 = C_2 V$ — (2)

and

$Q = Q_1 + Q_2$ — (3)

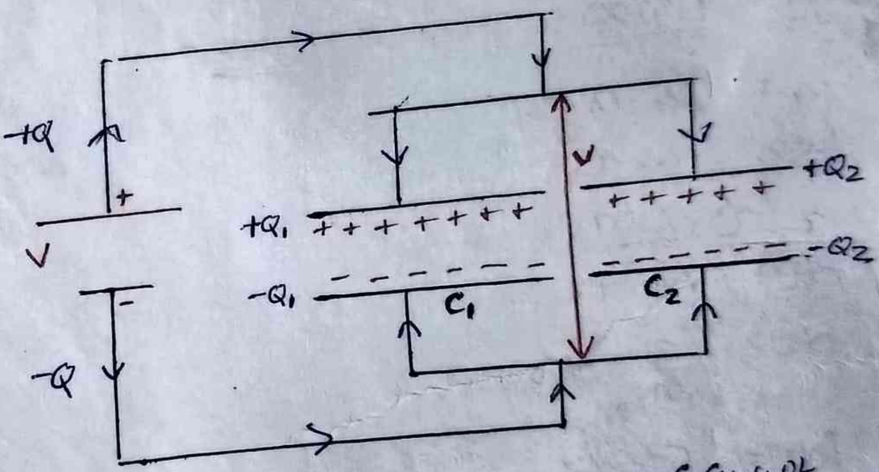
$Q = C_{eq} V$ — (4)

so;

$C_{eq} V = C_1 V + C_2 V$

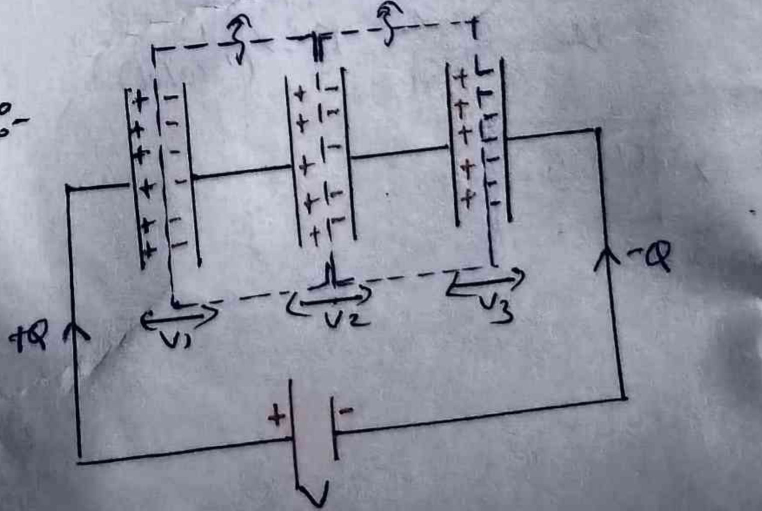
so;

$$\boxed{C_{eq} = C_1 + C_2}$$



> **SERIES COMB. OF CAPACITORS:-**

isolated conductor (cons. of charge holds)



$Q = C_1 V_1$

$Q = C_2 V_2$

$Q = C_3 V_3$

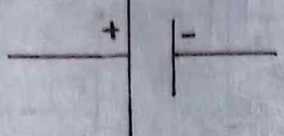
$Q = C_{eq} V$

$V = V_1 + V_2 + V_3$

$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

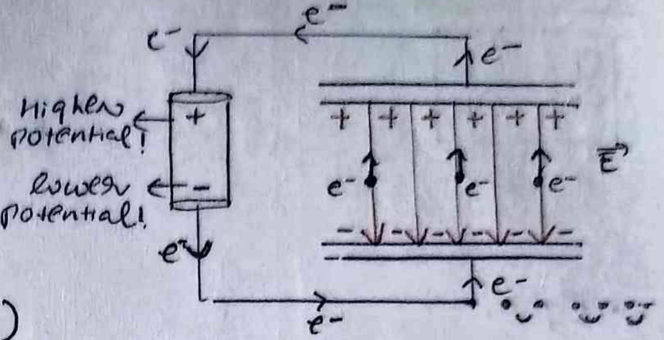
> CONCEPT OF BATTERY :-



∵ Battery

Q_{net} delieverd by Battery $= 0$

∵ $(e^-_{accept} = e^-_{donate})$



> WORK DONE BY BATTERY :-

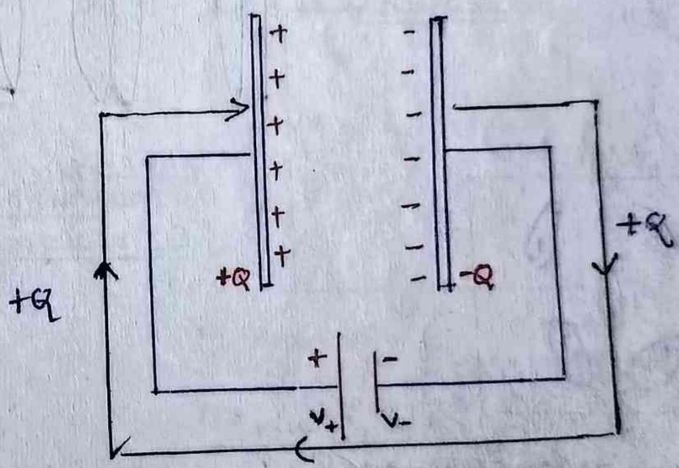
Battery shifts +ve charge from lower pot. to higher Potential
(-ve plate) (+ve plate)

$\Rightarrow W_{Batt} = Q\Delta V$

$\Rightarrow W_{Batt} = Q(V_+ - V_-)$

$\Rightarrow W_{Batt} = QV_{Batt}$

$\therefore \boxed{W_{Bat} = QV_{Bat}}$



> HEAT PROD. IN CIRCUIT :-

$W = QV = CV^2$ —— ① [energy Gained]

$\Rightarrow U = \frac{1}{2}CV^2$ —— ② [energy stored]

$\Rightarrow$ so,

$\Rightarrow H = W - U = CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$

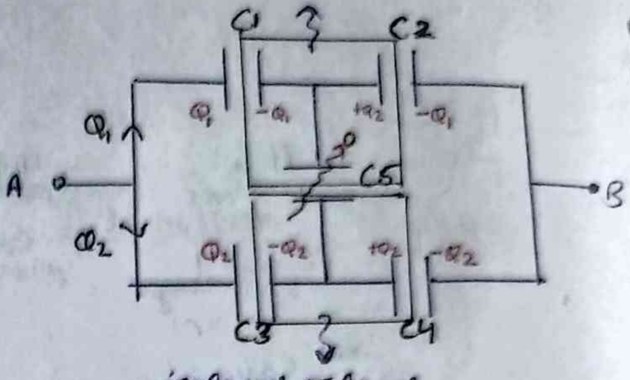
$\therefore \boxed{H = \frac{1}{2}CV^2}$

> WHEATSTONE BRIDGE :-

Wheatstone Bridge is said to be Balanced If;

$$\boxed{\frac{C_1}{C_2} = \frac{C_3}{C_4}}$$

∵ (charge on plate $C_5 = 0$)
isolated Island



isolated Island
∵ (charge on plate $C_5 = 0$)

> di-electric Material :-

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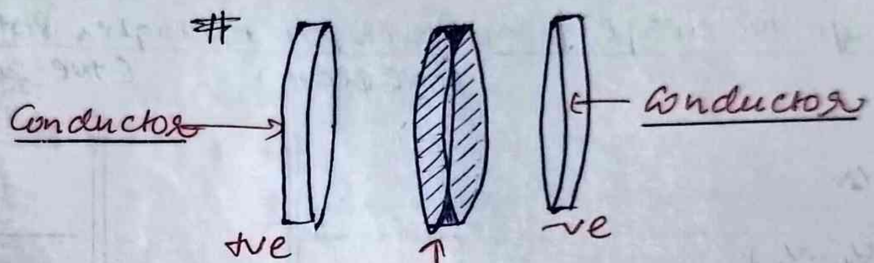
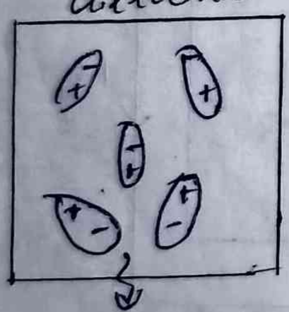


dielectric Material (Insulator)

#

dielectric



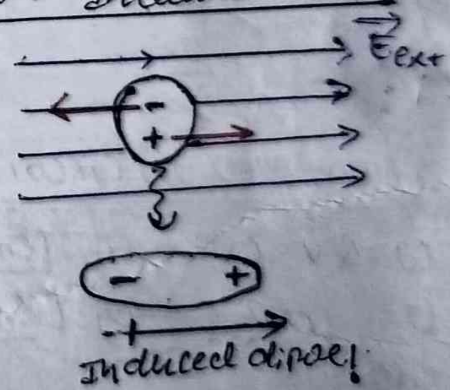
> random arrangement of dipoles

∵ $P_{Net} = 0$

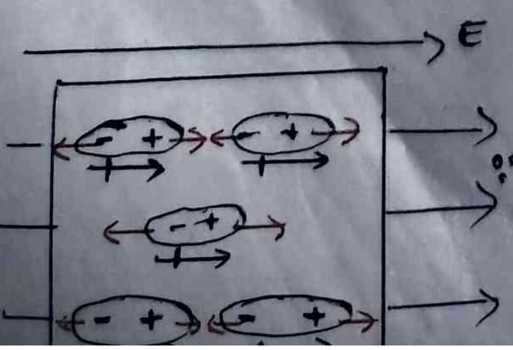
∵ P_{avg} / unit volume = 0

∵ Q / unit volume = 0

Non-polar Mol have Induced dipole

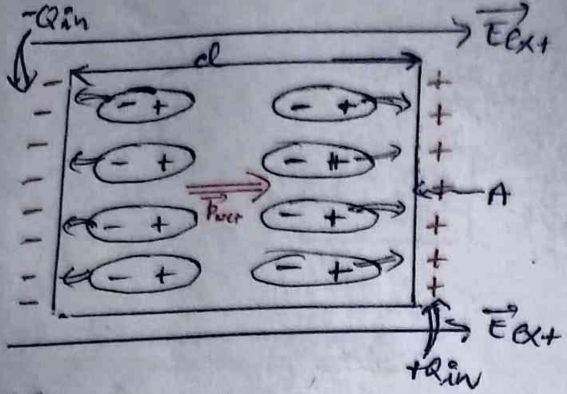


due to E_{ext} Net dipole Moment is developed



∵ $\boxed{P_{Net} \neq 0}$

There is a net charge's on surface;

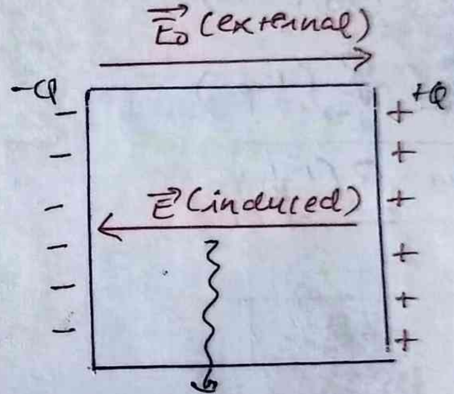


polarization (vector) :-
(dipole moment per unit volume)

$\vec{P} = \frac{\vec{p}}{V} = \frac{Q_{ind}\,d}{Ad} = \frac{Q_{in}}{A} = \sigma_{in}$

Now;
$\vec{E}_{in}$ is smaller than $\vec{E}_0$
then;

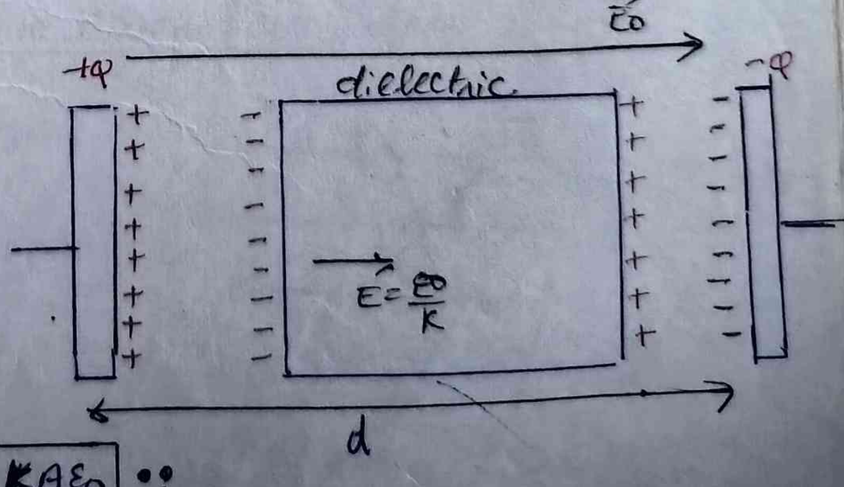
$\therefore \vec{E}_{in} = \frac{\vec{E}_0}{K}$; K is dielectric constant



However
Net $\vec{E}$ inside dielectric ≠ 0
$[\vec{E}_{ext} \neq \vec{E}_{ind}]$

> PPC with dielectric :-

$E_0 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$ — (1)



$E = \frac{E_0}{K} = \frac{Q}{AK\varepsilon_0}$ — (2)

and
$V = Ed$
$V = \frac{Q\,d}{A(K\varepsilon_0)}$ — (3)

Now!
$C = \frac{Q}{V} = \frac{QA(K\varepsilon_0)}{Qd} = \boxed{\frac{KA\varepsilon_0}{d}}$

7 Charge Induced on dielectric :-

$\because E_0 = \dfrac{Q}{A\varepsilon_0}$ —— (1)

$E = \dfrac{E_0}{K}$ —— (2)

and;

$E_0 - E_{ind} = E$

$E_{ind} = E_0 - E$

$\Rightarrow E_0 - \dfrac{E_0}{K}$

$\Rightarrow \dfrac{Q}{A\varepsilon_0}\left(1-\dfrac{1}{K}\right)$

$E_{ind} = \dfrac{Q}{A\varepsilon_0}\left(1-\dfrac{1}{K}\right)$

$\dfrac{Q_{in}}{A\varepsilon_0} = \dfrac{Q}{A\varepsilon_0}\left(1-\dfrac{1}{K}\right)$

$\therefore \boxed{Q_{in} = Q\left(1-\dfrac{1}{K}\right)}$