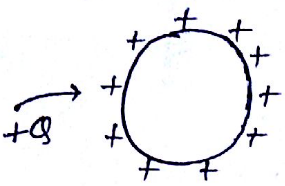
CAPACITOR

* c does not depend on Q & V.

The capacity of conductor to store charge on its shape & size.

* Dielectric strength of medium → It is max electric field after which insulation of medium get punctured. for air $= 3\times10^{6}$ V/m

solid conducting sphere :→



$V_{sphere} = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{Q}{R}$

$V_{sphere} - V_{infinite} = \Delta V = \frac{Q}{(4\pi\epsilon_0)R}$

$\boxed{Q = \underbrace{(4\pi\epsilon_0 R)}\Delta V}$ $\boxed{Q = C\Delta V}$

$\boxed{C = 4\pi\epsilon_0 R}$

* In conductor

$Q(\uparrow) = V(\uparrow)$

Means, charge $(Q) \propto$ pot. (V)

unit → MKS → C/volt, Farad (F)
cgs → stat farad
(1F $= 9\times10^{11}$ st. F)

Imp
* $C_{earth} = ?$

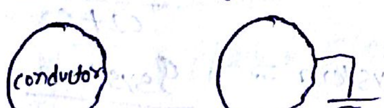
* Theoritical value → By considering It conductor of 6370 (6400) km

* $\boxed{C = 711\ \mu F}$

* Practically → earth can accept unlimited charge so its capacitance is infinite. (∞)

* capacitance of any earth conductor is infinite.

EX →



capacitance $= C$ take limited charge

capacitance $= \infty$ take unlimited charge $\left\{ b/c \quad C = \frac{Q}{V} = \frac{Q}{0} = \infty \right\}$

potential energy stored in charge conductor →

which is some external work is done during charging of conductor which is stored in form of pot. energy.

$$\boxed{U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}}$$

* P.E ⊕nt only in charge conductor but capacitance ⊕nt in charge or uncharge.

Imp * Energy spend by Battery

$\because$ Emf = V

1 charge $\rightarrow$ Work = V

q $\longrightarrow$ Work = qV

Work by battree = ΔU + Heat

$$qV = \left(\frac{1}{2}qV - 0\right) + \text{Heat}$$

$$\text{Heat} = \frac{1}{2}qV$$

NOTE $\rightarrow$ During charging half of energy spend for battery is stored in the form of P.E of conductor & remaning half wasted in form of Heat in connected wire.

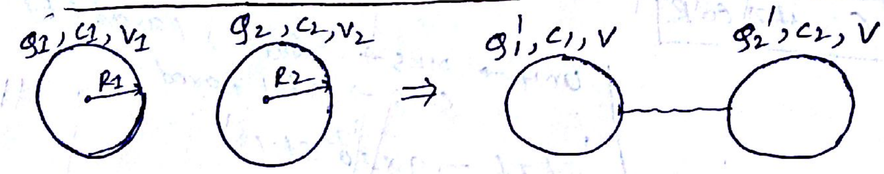
EX $\rightarrow$ For a conductor

If charge = q = PE = U

then charge = q/2 = PE = ?

c = const. , $U = \frac{q^2}{2c} \propto q^2$, $U' = \frac{U}{4}$

** # Re-distribution of charge : $\rightarrow$



* $C_{system} = c_1 + c_2 + c$ $\leftarrow$ It is capacitance of conductor wire it is negligible.

$C_{system} = c_1 + c_2$

* Total charge of cystem is re-distributed is ratio of capacitance.

$q \cancel{\propto} cV$

$q \propto c \propto R$

* V_{common} = ?

$q_1 + q_2 = q_1' + q_2'$

$c_1V_1 + c_2V_2 = c_1V + c_2V$

$$V_{common} = \frac{c_1V_1 + c_2V_2}{c_1 + c_2}$$

$$V_{common} = \frac{q_1 + q_2}{c_1 + c_2}$$

$$V_{system} = \frac{q_{system}}{C_{system}}.$$

* Energy loss (ΔV)

$$U_{Initial} = \frac{1}{2}c_1V_1^2 + \frac{1}{2}c_2V_2^2$$

$$U_{Final} = \frac{1}{2}c_1V^2 + \frac{1}{2}c_2V^2$$

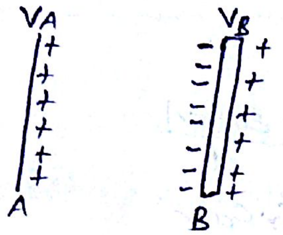
$$U_{Initial} - U_{Final}$$

$$\Delta U = U_{final} - U_{Initial}$$

$$\Delta U = \frac{c_1c_2}{2(c_1+c_2)}(V_1 - V_2)^2.$$

Concept of capacitor :→ A/R Generally, capacitor are termed by using 2 conductor having equal & opposite charge on them. The advantage of using opp. charge is to contine all the critical energy in certain volume so that it can be easly extracted when required.

Case : I



pot. of plate A

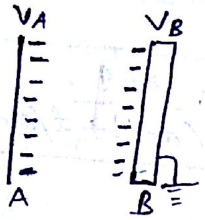
$V_A' = V_A - V_B^- + V_B^+$

$\because |V_B^-| > |V_B^+|$ (Here B^- more due to more impact of plate A)

$\Rightarrow V_A' < V_A$

$\because C = \frac{Q \leftrightarrow}{V(\downarrow)} = C(\uparrow)$

Case II



$V_A'' = V_A - V_B^-$

$V_A'' << V_A$

$\because C = \frac{Q \leftrightarrow}{V \downarrow\downarrow} = C(\uparrow\uparrow)$

A/R

*→ When a neutral or, opp. charge conductor is placed near a charge conductor then charge of Ist conductor remain uncharge While pot. change significantly so capacitance ↑

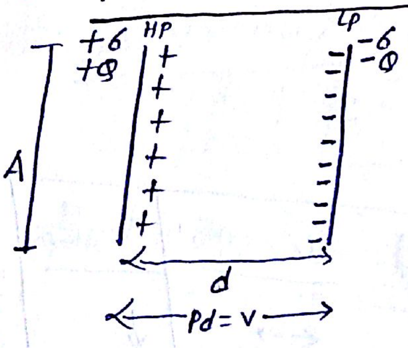
Type of capacitor →

|i|→ Parallel Plate capacitor (PPC) → $\boxed{C = \frac{A\epsilon_0}{d}}$

|ii|→ Spherical capacitor → $\boxed{C = 4\pi\epsilon_0\left(\frac{ab}{b-a}\right)}$

|iii|→ Cylindrical capacitor. → $\boxed{C = \frac{2\pi\epsilon_0 L}{\ln\frac{R_2}{R_1}}}$

|i|→ Parallel plate capacitor :→



|a|→ Electric field (E)→

$$\left[\begin{array}{l} E_{inside} = \frac{\sigma}{\epsilon_0\epsilon_r} = V/d \\ E_{outside} = 0 \end{array}\right] \text{(uniform)}$$

|b|→ Pot. energy (U) :→ $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$

|c|→ Energy density / Electrostatic pressure (u) :→ energy store in unit vol.

$u = \frac{\text{Energy}}{\text{vol.}}$ $\quad U = \frac{1}{2}\frac{\epsilon_0}{a}\left(\frac{V}{d}\right)^2 = \frac{1}{2}\epsilon_0 E^2$

$$* \; u = \left\{\frac{1}{2}\epsilon_0\left(\frac{\sigma}{\epsilon_0}\right)^2 = \frac{\sigma^2}{2\epsilon_0}\right\}$$

E^2

|d| → Attraction force b/w || plate :→

$$= \frac{\sigma^2}{2\epsilon_0}$$

$$= \left(\frac{\sigma^2}{2\epsilon_0}\right)A$$

$$\boxed{F = \left(\frac{\sigma^2}{2\epsilon_0}\right)A}$$ *

|e| → capacitance (c) :→

|Air| $\boxed{C_{air} = \frac{\epsilon_0 A}{d}}$

 $C_{med} = \frac{\epsilon_0 \epsilon_r A}{d}$

$\because C_{med} = \epsilon_r C_{air}$

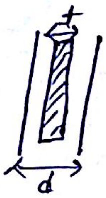
$\because \epsilon_r > 1$

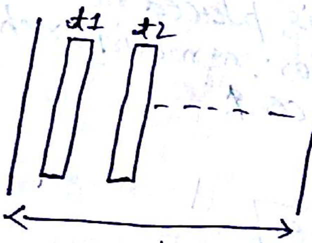
$\Rightarrow C_{med} > C_{air}$.

If $C_{air} = C_{med}$

$$\frac{\epsilon_0 A}{d_{air}} = \frac{\epsilon_0 \epsilon_r A}{d_{med}}$$

$$d_{air} = \frac{d_{med}}{\epsilon_r}$$

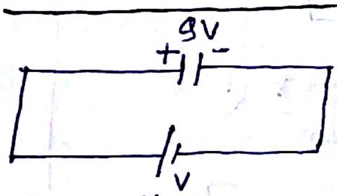
 $\boxed{C_{partial} = \frac{\epsilon_0 A}{(d-t) + t/\epsilon_r}}$



$$\boxed{C = \frac{\epsilon_0 A}{(d - t_1 - t_2 - \cdots) + \left(\frac{t_1}{\epsilon_{r1}} + \frac{t_2}{\epsilon_{r2}} \cdots\right)}}$$

* capacitance is independent of position of slab with respect to plate

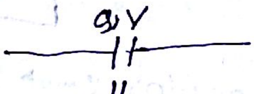
Variation in charge PPC :→



⇓

$V_c = \text{const}$

(battre connected)



⇓

$q_c = \text{const}$.

battree disconnected

case-I → Battery dis connected ($q_c = \text{const}$) :→

Variation	$C = \frac{\epsilon_0 \epsilon_r A}{d}$	$V_c = \frac{q}{V}$		$q_c = \text{const}$	$E = \frac{q}{A\epsilon_0\epsilon_r}$	U_e ↓ $\frac{q^2}{2C}$
ϵ_r (↑)	↑	↓		⟷	↓	↓
A (↑)	↑	↓		⟷	↓	↓
d (↑)	↓	↑		⟷	⟷	↑

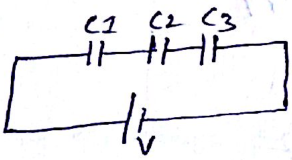
case II ⇒ Battery connected (V_c = const)

Variation	$C=\frac{\varepsilon_0\varepsilon_r A}{d}$	V_c = const	$Q\propto C$ $Q=CV$	$E=\frac{V}{d}$	$U_c=\frac{1}{2}CV^2$
$\varepsilon_r \uparrow$	↑	↔	↑	↔	↑
A ↑	↑	↔	↑	↔	↑
d ↑	↓	↔	↓	↓	↑

* If nothing is given in question then consider battree disconnected.

Grouping of capacitor :→

Series



→ Q = same

→ $\frac{1}{C_{net}} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$

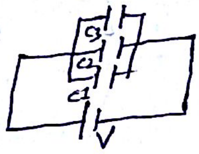
→ $\boxed{C_{net} = \frac{C_1 \times C_2}{C_1+C_2}}$

→ voltage distribution

$V \propto \frac{1}{C}$

$\boxed{V_1 : V_2 : V_3 = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}}$

parallel



→ V = same

→ $\boxed{C_{net} = C_1+C_2+C_3}$

→ charge distribution

$Q = CV$

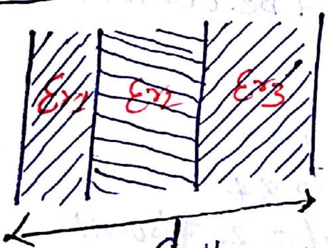
$Q \propto C$

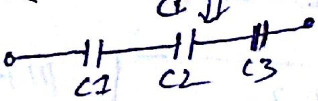
$\boxed{Q_1 : Q_2 : Q_3 = C_1 : C_2 : C_3}$

Distribution in PPC by dielectric medium :→

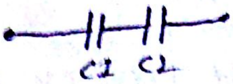
| Air PPC | $\boxed{C = \frac{\varepsilon_0 A}{d}}$

(a) → Division in distance →





[Each section is capacitor & all capacitor are in series]

EX→  

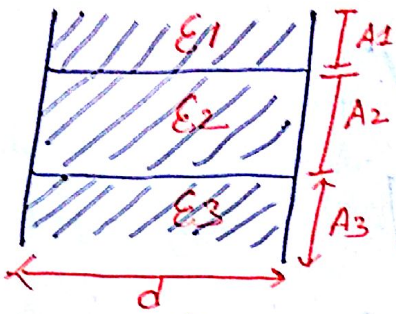
$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$C_{eq} = \frac{2\varepsilon_{r1}\varepsilon_{r2}}{\varepsilon_{r1} + \varepsilon_{r2}}$$

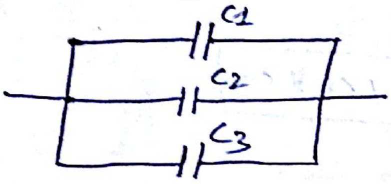
$$C_{eq} = \frac{\varepsilon_0 A}{(d - t_1 + t_2 - -) + \left(\frac{t_1}{\varepsilon_{r1}} + \frac{t_2}{\varepsilon_{r2}}\right)}$$

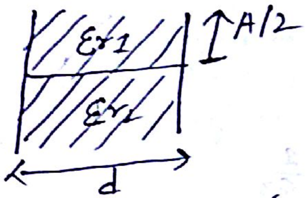
** Equivalent dielectric const $(\varepsilon_r)_{eq} = \frac{2\varepsilon_{r1}\varepsilon_{r2}}{\varepsilon_{r1} + \varepsilon_{r2}}$

(b) → Division in Area :→



[Each section is a capacitor and all capacitor are in //.]



EX→ 

$$C_{eq} = C_1 + C_2 = \left(\frac{\varepsilon_{r1} + \varepsilon_{r2}}{2}\right) C$$

$$(\varepsilon_r)_{eq} = \frac{\varepsilon_{r1} + \varepsilon_{r2}}{2}$$

*

$$\boxed{\begin{array}{l} x \,\&\, y \\ A.M \Rightarrow \frac{x+y}{2}, \quad G.M = \sqrt{xy}, \quad H.M = \frac{2xy}{x+y} \end{array}}$$

Multiple capacitor →

→* Given plate arrangement converted into equivalent ckt using point potential method.

(i) → No. of all plate is done

(ii) → For making capacitor plate should be consecutive there pot. should be diff.

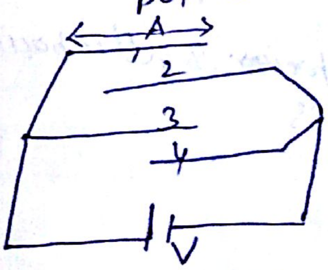
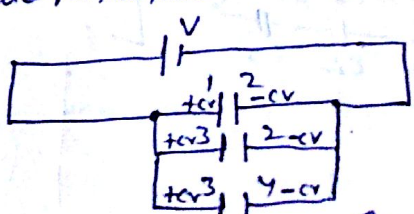
EX→ 

plate = 4

conductor = 2 < 1 & 3, 2 & 4

seprate potential = 2 = point



(i) → $C_{eq} = 3C = 3\left(\frac{\varepsilon_0 A}{d}\right)$

(ii) → charge on each plate

$q_1 = +CV$

$q_2 = -CV - CV = -2CV$

$q_3 = +CV + CV = +2CV$

$q_4 = -C$

Scanned by CamScanner

* 3e ⇒ In case of n-parallel plate, if alternate plate are connected with each other then max $(n-1)$ capacitor are there in parallel groping so, $\boxed{C_{Max} = (n-1)C}$

Spherical capacitor ⇒

Case I → If Inner sphere is charged & outer is earthed →

$$V_{small} = \frac{Kq}{r} - \frac{Kq}{R}$$

$$V_{big} = \frac{Kq}{R} - \frac{Kq}{R} = 0$$

pot. difference

$$V = Kq\left(\frac{1}{r} - \frac{1}{R}\right), \quad V = \frac{q}{4\pi\epsilon_0}\left(\frac{R-r}{Rr}\right)$$

$$\frac{q}{V} = \frac{4\pi\epsilon_0 Rr}{R-r} \qquad \boxed{C_2^{!} = \frac{4\pi\epsilon_0 Rr}{R-r}}$$

* If r = fixed $R = \uparrow$ then capacitance = ?

$$C = \frac{4\pi\epsilon_0 r}{1 - \frac{r}{R}} \qquad \text{(divided by } R)$$

$C = \downarrow$ bcoz $\frac{r}{R}\downarrow$ so, $1 - \frac{r}{R}\uparrow$ something by घटाया $(\downarrow)$

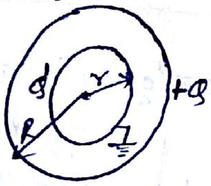
* If r = Fixed, $R\downarrow$ then capacitance → ↑

* If $R = \infty$ then capacitance ?

$$C = \frac{4\pi\epsilon_0\epsilon_r r}{1 - \frac{r}{R}} \qquad (C = 4\pi\epsilon_0\epsilon_r r)$$

Each indivisual conductor is also a capacitor considering that its other conductor is at infinite.

Case II → If outer sphere is charged & inner is earthed.



As inner sphere is earthed the some charge q' is shifted from earth to this sphere for making its pot zero.

$$V_{big} = \frac{Kq}{R} + \frac{Kq'}{R}$$

$$V_{small} = 0$$

∴ P.D

$$V = \frac{Kq}{R} + \frac{K}{R}\left(\frac{-rq}{R}\right)$$

$$V = \frac{Kq}{R}\left(1 - \frac{r}{R}\right)$$

$$V = \frac{q}{4\pi\epsilon_0\epsilon_r R}\left(\frac{R-r}{R}\right)$$

$$C_{II} = 4\pi\epsilon_0\epsilon_r R\left(\frac{R}{R-r}\right)$$

$$C_{II} = \frac{4\pi\epsilon_0\epsilon_r Rr}{R-r} + 4\pi\epsilon_0\epsilon_r R$$

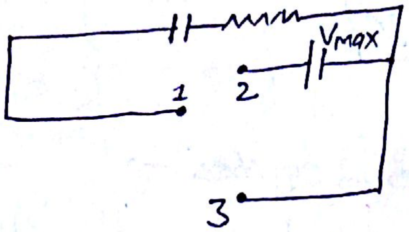
$$\boxed{C_{II} = C_I + 4\pi\epsilon_0\epsilon_r R}$$

$$\boxed{C_{II} > C_I}$$

* If nothing is given in question then we use case I

Scanned by CamScanner

Charging $ discharging of capacitor →



case I ⇒ Charging ⇒

(1−2)

$t=0$	$t=\uparrow$	$t=\infty$ (full charging)
$V_c=0$	$V_c=\uparrow$	$V_c=V_{max}$ (max)
$Q_c=0$	$Q_c=\uparrow$	$Q_c=CV_{max}$ (max)
$U_c=0$	$U_c=(\uparrow)$	$U_c=\frac{1}{2}CV_{max}^2$ (max)
$I_{ckt}=\frac{V_{max}}{R}$ (max)	$I_{ckt}\downarrow$	$I_{ckt}=0$

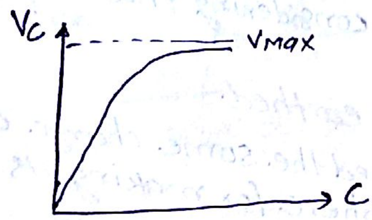
* Here, R is used to safe the capacitor from starting excess current.

By KVL

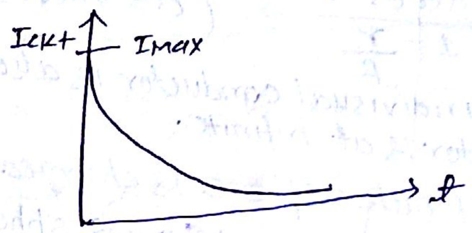
$$V_c = V_{max}(1-e^{-t/RC})$$

$$I_{ckt} = I_{max}\, e^{-t/RC}$$

Graph b/w V_c $ t



Graph b/w I_{ckt} $ t



$e=2.73$	$\log_{10}^{2}=0.301$	$\log_e^{2}=2.303\log_{10}^{2}=2.303\times0.301$
$\frac{1}{e}=0.37$	$\log_{10}^{3}=0.473$	$=0.693$
$e^{0}=1$	$\log_{10}^{5}=0.699$	$\log_x^{x}=1$, $\log_{10}^{10}=1$
$e^{\infty}=\infty$	$\log_e^{x}=2.303\log$	
$e^{-\infty}=0$		

Time cost (τ) → It is time in wich approx 63% working take place.

$$V_c = V_{max}(1-e^{-t/RC})$$

If ⇒ $t=RC$

* $\boxed{V_c = V_{max}(1-e^{-1})}$

* $\boxed{V_c = 0.63\,V_{max}}$

$\boxed{\tau = RC}$ *

* Imp +

$t=5\tau=99.3\%$

$t=\tau=63\%$

* Heat produced $= \frac{1}{2}cV^2$ [Not depend on Resistance]

* If $R\uparrow \Rightarrow$ Heat $\leftrightarrow$
timing $\uparrow$
$I_{ckt}\downarrow$

* If $R\downarrow \Rightarrow$ Heat $\leftrightarrow$
timing $\downarrow$
$I_{ckt}\uparrow$

[* Time for 99% charging $\rightarrow$ 0.921 msec.
Trick
* $1\tau = 200\,\mu sec$
$5\tau = 1000\,\mu sec$
$t = 5\tau = 99.9\%$ work done so $t =$ less than $1000\,\mu sec$.]

* time for 50% charging $\rightarrow$ $t = 200\times10^{-6}\times0.693 = t = 138.6\,\mu sec$.

case II $\Rightarrow$ Discharging :$\rightarrow$

$t = 0$
$V_c = V_{max}$
$q_c = q_{max}$
$U_c = \frac{1}{2}cV^2_{max}$
$I_{ckt} = \frac{V_{max}}{R}$

$t = \uparrow$
$V_c = \downarrow$
$q_c = \downarrow$
$U_c = \downarrow$
$I_{ckt} = \downarrow$

$t = \infty$ (Full discharge)
$V_c = 0$
$q_c = 0$
$U_c = 0$
$I_{ckt} = 0$

$\therefore V_c = V_{max}e^{-t/RC}$

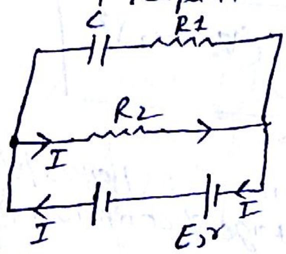
$I_{ckt} = -I_{max}e^{-t/RC}$

$\Rightarrow \tau = RC$
63% discharge
$\Rightarrow t = 5\tau$
$= 99.3\%$ discharge.

Trick
* $\tau = 1\,sec$ में 63% discharge ho jayega, so 50% discharge less than 1 sec.

RC CKt $\rightarrow$ In steady state condn capacitor are fully charge so current in capacitor branched is zero.

EX$\rightarrow$



In stable condn find charge on capacitor

$I = \frac{E}{R_2+r}$

$\therefore V_{R_2} = I\times R_2 = \frac{R_2}{R_2+r}E$

$\therefore V_{R_1} = const\times R_1 = 0\times R_1 = 0$

$V_{C_1} = V_{R_2} = \frac{R_2}{R_2+r}E$

$Q = CV_C = \frac{R_2}{R_2+r}CE$

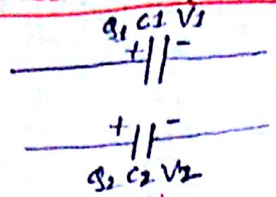
* If $R_2(\uparrow) \Rightarrow Q = ?$

$Q = \frac{R_2}{1+\frac{r}{R_2}}$

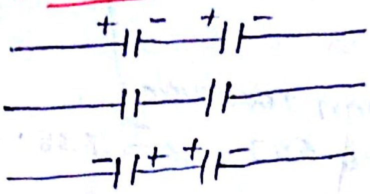
Trick
[$\frac{r}{R_2}$ ratio कम $+1 =$ कम, something upon कम ज्यादा]

NOTE$\rightarrow$[* At $(t=0)$, $I = I_{max}$ 'c' is like short ckt.
* At $(t=\infty)$, $I = 0$ 'c' is like open ckt.]

To connect two charge PPC →

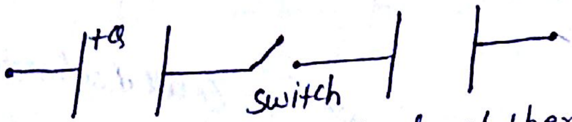


case-I → series –



!! * No close loop so no charge flow so no change in detail of capacitor.

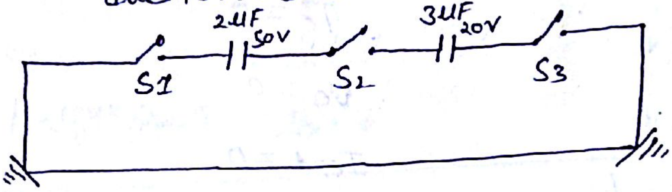
IIT ** Ex →



After switch on after long time what will charge on uncharged capacitor.

Ans → When switch is closed then no charge flow in uncharged capacitor due to no close loop.

IIT Ex →

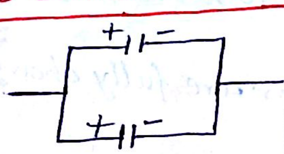


* If any one or two switch are made on then there is no close loop no charge, no current flow so, the details of charge & voltage remain same.

* When all of them are switch are made then there is change in charge current due to close loop is formed.

case II → parallel –

(a) → To connect same polarity ends →

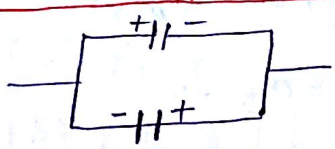


* If voltage are different then charge sharing take place to obtain same voltage.

$$\boxed{V_{common} = \frac{V_1C_1 + V_2C_2}{C_1 + C_2}}$$

$$\boxed{\Delta U = \frac{C_1C_2}{2(C_1C_2)}(V_1 - V_2)^2}$$

(b) → To connect opposite polarity plate →



* charge sharing does take place to obtain common voltage & common polarity.

$V_2 \rightarrow -V_2$

$$\boxed{V_{common} = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}}$$

$$\boxed{\Delta U = \frac{C_1C_2}{2(C_1 + C_2)}(V_1 + V_2)^2}$$

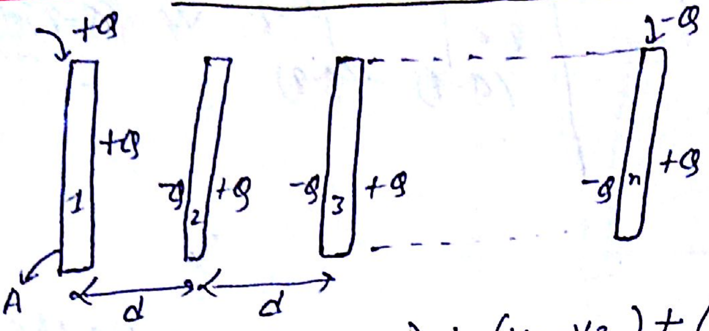
(plus)

* Nothing is said in q. then we assume same polarity.

NOTE → $C_1 = C$, If $C_2 = xC$, then $V_1 = C$, $V_2 = V/x$ b/c $q = \text{constant}$ $V \propto \frac{1}{C}$ $q = CV$

Different cases of capacitor

case-I ⇒ 'n' no. of plates are placed:–



$$V_1 - V_n = (V_1 - V_2) + (V_2 - V_3) + (V_3 - V_4) + \cdots + (V_{n-1} - V_n)$$

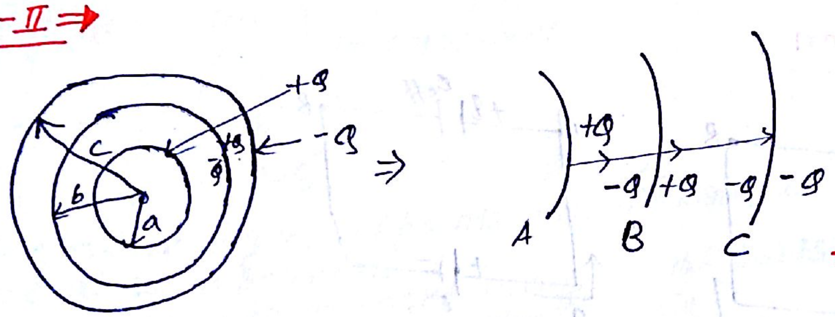
$$\Delta V = \frac{Qd}{A\epsilon_0} + \frac{Qd}{A\epsilon_0} + \cdots + \frac{Qd}{A\epsilon_0}$$

$$\Delta V = \frac{Qd(n-1)}{A\epsilon_0}$$

$$Q = \left[\frac{A\epsilon_0}{(n-1)d}\right]$$

* $\boxed{C = \frac{A\epsilon_0}{(n-1)d}}$

case-II ⇒



$$V_A = \frac{kQ}{a} - \frac{kQ}{c}$$

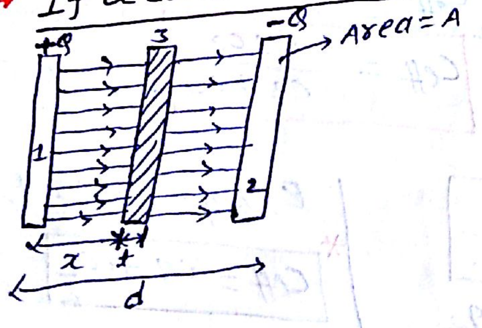
$$V_c = \frac{kQ}{c} - \frac{kQ}{c} = 0$$

$$\Delta V = V_A - V_C = kQ\left[\frac{c-a}{ac}\right]$$

$$Q = \frac{(4\pi\epsilon_0)ac}{(c-a)}\Delta V$$

* $\boxed{C = \frac{(4\pi\epsilon_0)ac}{c-a}}$

case-III ⇒ If a conducting slab with thickness 't' is introduced. →



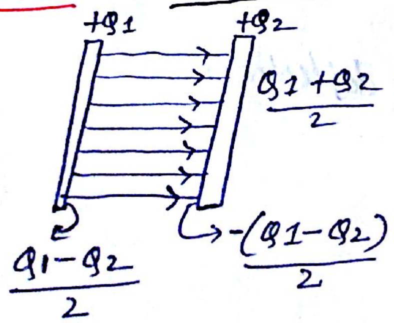
$$V_1 - V_2 = (V_1 - V_3) + (V_3 - V_2)$$

$$= \frac{Qx}{A\epsilon_0} + \frac{Q(d-t-x)}{A\epsilon_0}$$

$$\Delta V = \frac{Q(d-t)}{A\epsilon_0}$$

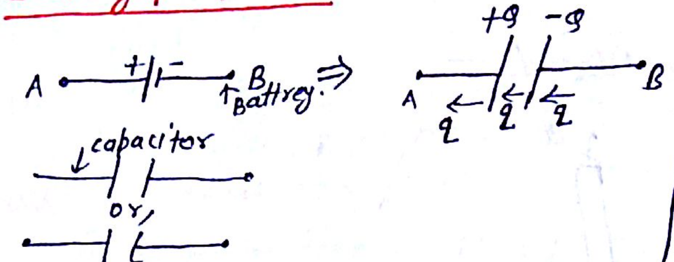
* $\boxed{C = \frac{A\epsilon_0}{d-t}}$

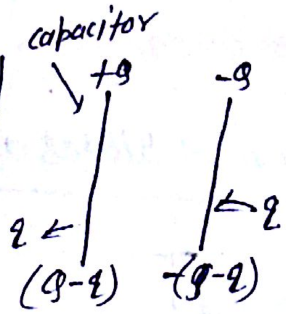
case-IV ⇒ Actual charge on capacitor →



* $\boxed{\text{charge on capacitor} = \frac{Q_1 - Q_2}{2}}$

Battery & capacitor →

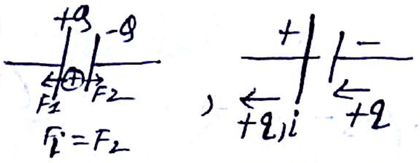




$V_i = \frac{Qd}{A\epsilon_0}$

$V_f = (Q-q)\frac{d}{A\epsilon_0}$

Battery →

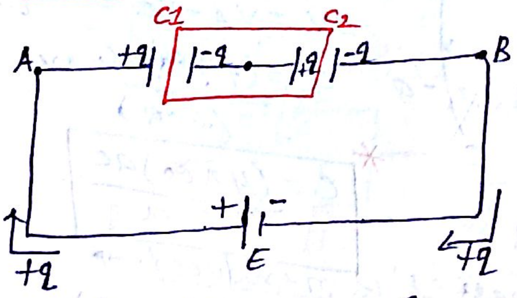


* ⊕ve charge will leave from ⊕ve terminal & must entre the ⊖ve terminal of the battery.
* Inside the battery charge is taken from lower pot. plate to higher pot. plate with the help of battery mechanism.

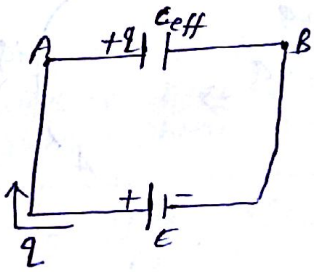
• $\boxed{\text{Work done by battery} = \text{charge flow}(q) \times \text{pot difference b/w terminal (Emf of battery)}}$

Series & Parallel combination

Series combination



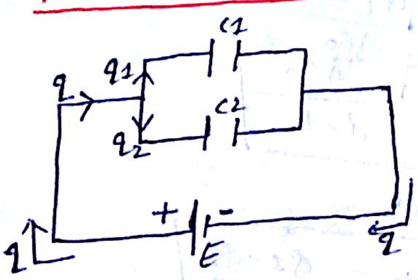
⇒



$V_A - V_B = \frac{q}{c_1} + \frac{q}{c_2} = \frac{q}{c_{eff}} = E$, $\frac{1}{c_{eff}} = \frac{1}{c_1} + \frac{1}{c_2}$

* $\boxed{C_{eff} = \frac{C_1 C_2}{C_1 + C_2}}$

Parallel combination



* $\boxed{\frac{q_1}{q_2} = \frac{C_1}{C_2}}$

$q = q_1 + q_2$

$\cancel{E} \times C_{eff} = \cancel{E} \times C_1 + \cancel{E} \times C_2$

* $\boxed{C_{eff} = C_1 + C_2}$

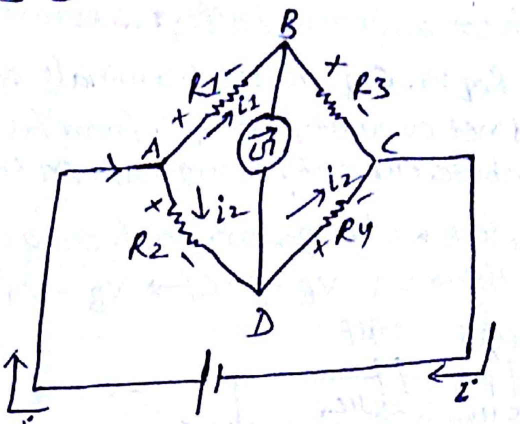
NOTE Wheatstone Bridge

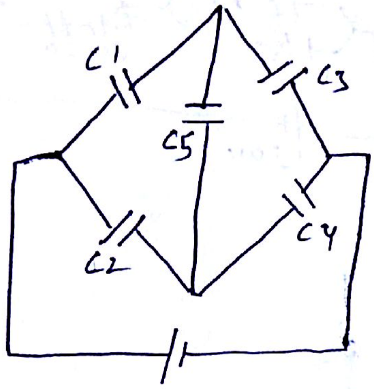
When galvanometer should null (zero) deflection

$$\left.\begin{aligned} V_A - V_B &= +i_1 R_1 \\ V_A - V_D &= +i_2 R_2 \end{aligned}\right] V_B - V_D$$

$i_1 R_1 = R_2 i_2$ — ① , $i_3 R_3 = i_2 R_4$ — ②

* $\boxed{\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}}$

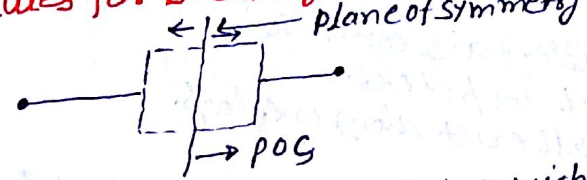




* $\boxed{\dfrac{C_1}{C_2} = \dfrac{C_3}{C_4}}$

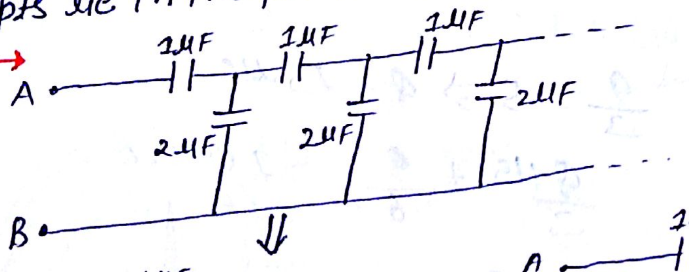
Balanced Wheat stone Bridge

Rules for Breaking or, folding of ckt.

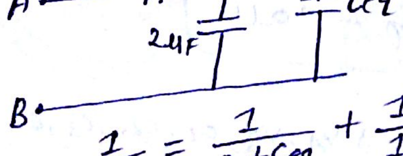


* We can join any no. of points wich are laying on plane of symmetry. They all are at same potential.
* we can break a point in ckt in any no. of points if after breacking all the pts lie in the plane of symmetry.

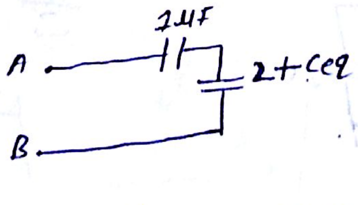
EX→



⇓



⇒



$$\frac{1}{c_{eq}} = \frac{1}{2+c_{eq}} + \frac{1}{1}$$

$$c_{eq} = \frac{1 \times (2+c_{eq})}{1+2+c_{eq}}$$

$$c_{eq}^2 = 3c_{eq} = c_{eq} + 2$$

$$c_{eq}^2 + 2c_{eq} - 2 = 0$$

$$C_{eq} = \frac{-2 \pm \sqrt{4+8}}{2}$$

$$= (-1+\sqrt{3})\,\mu F$$

General ckt solving –

Case-I ⇒ When only one battery is connected –

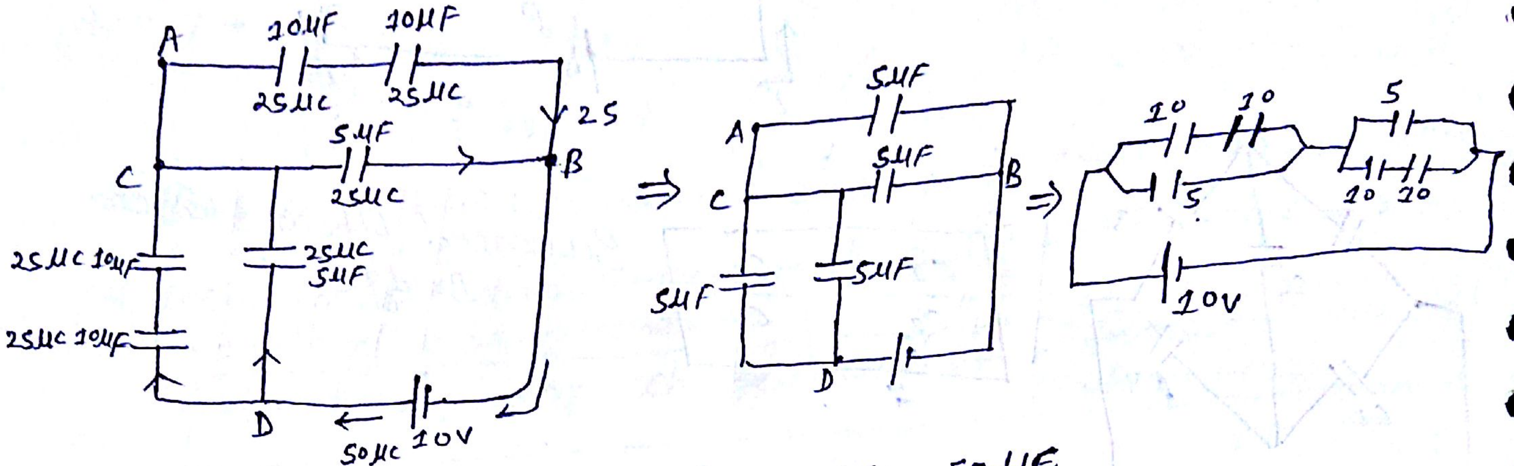
(i) → Find R_{eq} or, C_{eq} across terminals of battery.

(ii) → Find net current / Charge from battery as $i_{net} = \frac{V}{R_{eq}}$ or, $q_{total} = C_{eq} \times V$

(iii) → Distribute current / charge A/C to the ckt.

EX → Find → (a) → charge on each capacitor

(b) → $V_A - V_B = ?$ (C) → $V_B - V_D = ?$



(a) → $C_{eq} = 5\mu F$, $q_{total} = 10 \times 5 = 50\mu C$

(b) → $V_A - V_B = \frac{+25\mu C}{5\mu F} = +5V$

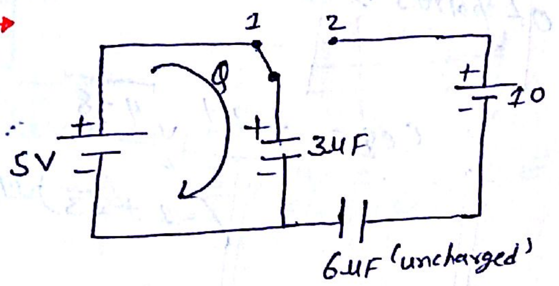
(c) → $V_B - V_D = -10V$

Case-II ⇒ When more than one battery are connected –

→ Apply loop rule (KVL) in each loop of ckt.

→ only one current / charge will exist along one loop.

EX →



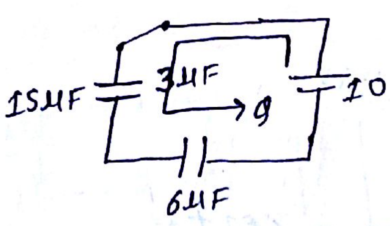
Initially switch was at position 1 Find final charge on capacitor when switch is thrown to position 2.

$\frac{q}{3} = 5 \Rightarrow q = 15\mu C$

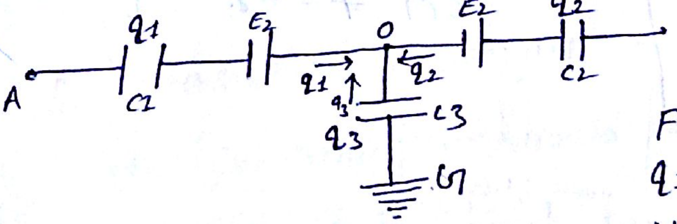
$\frac{q+15}{3} + \frac{q}{6} - 10 = 0$

$\frac{q}{2} = 5$

$\boxed{q = 10\mu F}$



Case-III ⇒ When given ckt is an open ckt.



Given ⇒ $V_A, V_B, C_1, C_2, C_3, E_1, E_2$

From KCL

$q_1 + q_2 + q_3 = 0$ — ①

$V_A - V_O = \frac{q_1}{a} - E_1$ — ②

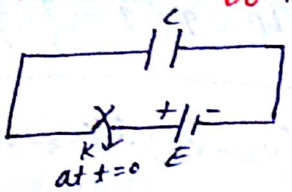
$V_A - V_O = +\frac{q_2}{C_2} + E_2$ — ③

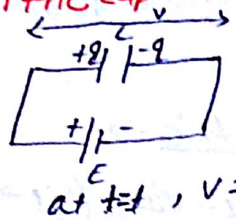
$$V_{in} - V_0 = \frac{q_3}{C_3} \quad \text{— (4)}$$

From (1) (2) (3) (4) $V = ?$

$q_1 = ?$, $q_2 = ?$, $q_3 = ?$

***
potential energy stored in the capacitor :—





at t=t , $V = \frac{q}{C}$

In next 'dt' time battery delivers dq charge to the capacitor

dW on capacitor

$$dW_{cap} = dU_{cap} = dq \cdot V$$

$$\int dU_{cap} = \int_0^Q \frac{q}{C}\, dq$$

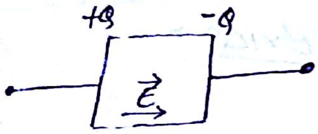
* $$\boxed{U_{cap} = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CE^2 = \frac{1}{2}QE}$$

Total Work done by battery.

* $$\boxed{W_{Batt.} = QE = 2U_{cap}}$$

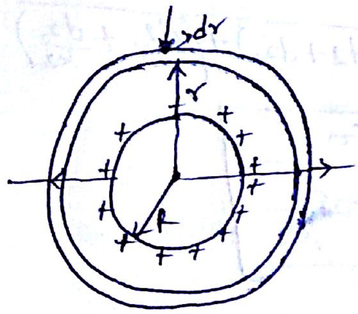
* $$\boxed{\text{Heat generated} = H = W_{Battery} - \uparrow \text{in PE of capacitor.}}$$

A/R
****
NOTE → Energy density / Electrostatic pressure (u) →



$\vec{E} = \frac{Q}{A\epsilon_0}$, $U = \frac{1}{2}\frac{Q^2}{C}$, $U = \frac{Q^2 d}{2A\epsilon_0}$

* $$\boxed{u = \frac{U}{Ad} = \frac{Q^2}{2A^2\epsilon_0 d} = \frac{1}{2}\epsilon_0 E^2}$$



$C = 4\pi\epsilon_0 R$

$$U = \frac{Q^2}{2C} = \frac{Q^2}{8\pi\epsilon_0 R}$$

* $$\boxed{U_{self} = \frac{Q^2}{2C} = \frac{Q^2}{8\pi\epsilon_0 R}}$$

For linear Isotropic dielectrics :→

$$\vec{E}_{net} = \vec{E}_{Ext} + \vec{E}_{in}$$

$$|\vec{E}_{net}| = |\vec{E}_{ext}| - |\vec{E}_{in}|$$

* $$\boxed{|\vec{E}_{net}| = \frac{|\vec{E}_{ext}|}{k}}$$

k → dielectric const.

$$\vec{E}_{in} = |\vec{E}_{ext}| - |\vec{E}_{net}|$$

* $$\boxed{|\vec{E}_{in}| = |\vec{E}_{ext}|\left(1 - \frac{1}{k}\right)}$$

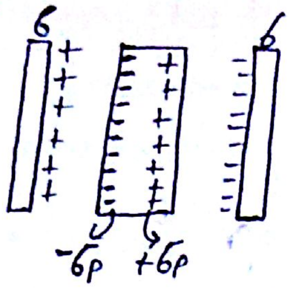
For conductor

* $\boxed{k = \infty}$

* $\boxed{1 \leq k \leq \infty}$

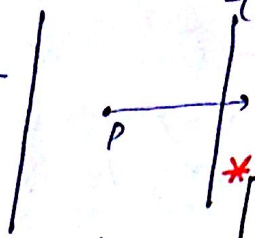
* $\boxed{k = 1}$ → For vaccum

NOTE→



$\vec{E}_{p\,initially} = \frac{\sigma}{\epsilon_0}$

$\vec{E}_{p\,initially} = \frac{\sigma}{K\epsilon_0}$



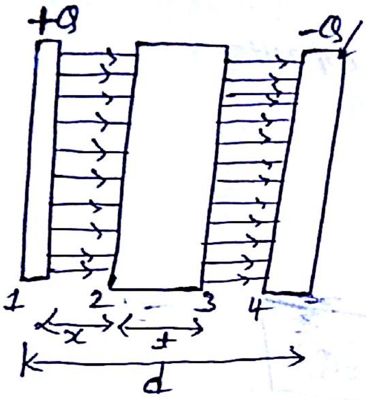
$-(\sigma-\sigma_p)$ $+(\sigma-\sigma_p)$

$\frac{\sigma-\sigma_p}{\epsilon_0} = \frac{\sigma}{K\epsilon_0}$

* $\boxed{\sigma_p = \sigma\left(1-\frac{1}{K}\right)}$

* $\boxed{q_p = q\left(1-\frac{1}{K}\right)}$

Case IV → capacitor with dielectric →



$V_1 - V_4 = (V_1 - V_2) + (V_2 - V_3) + (V_3 - V_4)$

$\Delta V = \frac{Qx}{A\epsilon_0} + \frac{Qt}{KA\epsilon_0} + \frac{Q(d-x-t)}{A\epsilon_0}$

* $\boxed{C = \frac{A\epsilon_0}{d-t+\frac{t}{K}}}$

NOTE→

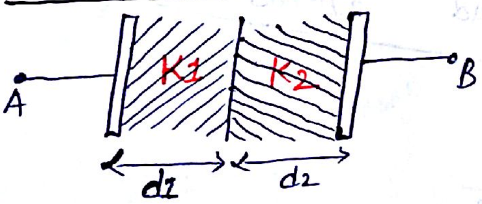
(i) → If 'n' no. of plates with $(t_1, K_1), (t_2, K_2), (t_3, K_3) ----- (t_n, K_n)$ are introduced,

* $\boxed{C = \frac{A\epsilon_0}{d-(t_1+t_2+ ---+t_n)+\left(\frac{t_1}{K_1}+\frac{t_2}{K_2}+---+\frac{t_n}{K_n}\right)}}$

(ii) → If a conducting slab with thickness 't' is introduced.

* $\boxed{C = \frac{A\epsilon_0}{d-t}}$

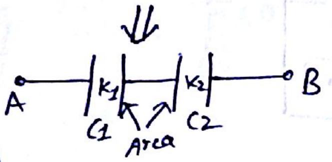
Case V → capacitor filled with different dielectrics →



$C = \frac{A\epsilon_0}{(d_1+d_2)-(d_1+d_2)+\left(\frac{d_1}{K_1}+\frac{d_2}{K_2}\right)}$

* $\boxed{C = \frac{A\epsilon_0}{\frac{d_1}{K_1}+\frac{d_2}{K_2}}}$

⇓



$C_1 = \frac{K_1 A\epsilon_0}{d_1}$

$C_2 = \frac{K_2 A\epsilon_0}{d_2}$

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

Case-VI → Dielectric const is varying →

$K = K_0\left(1+\frac{x}{L}\right)$

$dC = \frac{(L\,dx)\epsilon_0 K}{d}$

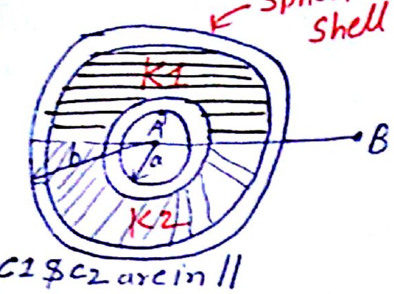
$\int dx = \int_0^L \frac{K_0\epsilon_0 L}{d}\left(1+\frac{x}{L}\right)\cdot dx$

$K = K_0\left(1+\frac{x}{d}\right)$

$dC = \frac{LAK\epsilon_0\left(1+\frac{x}{d}\right)}{dx}$

$\therefore \frac{1}{C_{eq}} = \int\frac{1}{dC} = \int_0^d \frac{dx}{\left(1+\frac{x}{d}\right)} \times \frac{1}{LAK_0\epsilon_0}$

***
EX→



$C_1 = \dfrac{2\pi\epsilon_0 ab K_1}{b-a}$

$C_2 = \dfrac{2\pi\epsilon_0 ab K_2}{b-a}$

C_1 & C_2 are in ||

$C_{eq} = C_1 + C_2$

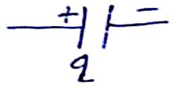
$= \dfrac{2\pi\epsilon_0 ab}{b-a}(K_1+K_2)$

case-VII → When dielectric slab is inserted in charged capacitor →

(a) → When battery is disconnected →

$\boxed{q = \text{const}}$ *

$C_i = \dfrac{A\epsilon_0}{d}$



$V' = V/K$

$C' = KC$

(i) → capacitance $(C) = KC$

(ii) → potential $= \dfrac{V}{K}$

(iii) → $E = \dfrac{V}{d} \Rightarrow K' = \dfrac{E}{K}$

(iv) → $W_{ext} = U' = \dfrac{U}{K}$

$W_{ext} = \Delta U = \ominus ve.$

(b) → When battery remains connected →

* $\boxed{V = \text{const}}$

(i) → capacitance $(C) \Rightarrow C' = KC$

(ii) → charge $(q) = q' = Kq$

(iii) → Electric field $(E) \Rightarrow$ const.

(iv) → pot energy $(U) \Rightarrow U' = KU$

(V) → $W_{ext} = ?$

$W_{ext} + W_{battery} = \Delta V$

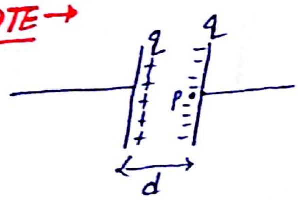
$W_{ext} = (K-1)\dfrac{CV^2}{2} - (K-1)CV^2$

$W_{ext} = (K-1)\dfrac{CV^2}{2} - (K-1)CV^2 < 0$

* $W_{ext} = -\dfrac{1}{2}CV^2(K-1)$

**
***

NOTE →



Electric field at 'P' due to +q plate

* $E_P = \dfrac{q}{2A\epsilon_0}$

Force on 2nd plate $\Rightarrow F = qE_P = \dfrac{q^2}{2A\epsilon_0}$ *

case-VIII → Force acting on dielectric slab while insertion.

(a) → When battery is disconnected – (system have only capacitor)

$F = -\dfrac{dU_{capacitor}}{dx}$

* $U_{capacitor} = \dfrac{1}{2}\dfrac{q^2}{C} = \dfrac{q^2}{2(Ax+b)}$

* $\boxed{F = -\dfrac{dU}{dx}}$

(b) → When battery Remain connected →

$dU = dU_{capacitor} + dU_{Battery}.$

* $dU_{Battery} = -dW_{Battery}.$

✓ charge Release from battery $(dq) = (dC)V$

* $dq = \dfrac{(K-1)l\epsilon_0 V}{d}(dx)$

$F = -\dfrac{dU_{system}}{dx}$

* $\boxed{F = \dfrac{(K-1)l\epsilon_0 V^2}{2d} = \text{const.}}$