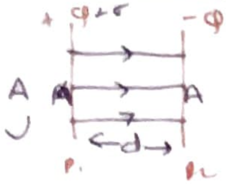
* Capacitance *



* Capacitor

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

$\therefore E = \frac{V}{d}$

$Q \propto V$

$\therefore \boxed{Q = CV}$ $\boxed{C = \frac{Q\uparrow}{V\uparrow}}$

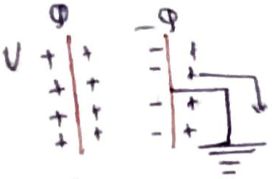
unit → C/V or F $\boxed{1F = \frac{1C}{1V}}$

cgs → stat F

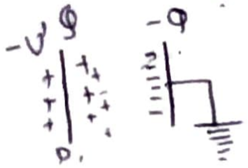
$\boxed{1F = 9\times10^{11} \text{ stat-F}}$

* Principle of Capacitor or Condensor

- Capacity of the conductor is increased by keeping another earth connected conductor near it.



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

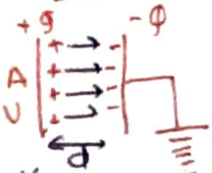


$\rightarrow C_1\uparrow = \frac{Q}{(V - V')\downarrow}$

$\therefore \boxed{C_1 > C}$

* Types of capacitors

① Parllel Plate Capacitor



$E = \frac{\sigma}{\varepsilon_0 K} = \frac{Q}{A\varepsilon_0}$

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

$\frac{V}{d} = \frac{Q}{A\varepsilon_0 K}$

$\frac{Q}{V} = \frac{\varepsilon_0 AK}{d}$ $\therefore \boxed{C = \frac{\varepsilon_0 AK}{d}}$

For air K=1

$\boxed{C_a = \frac{A\varepsilon_0}{d}}$

$\boxed{K = \frac{C_m}{C_a}}$

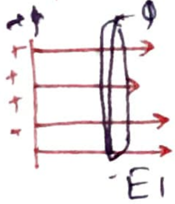
$\boxed{K = \frac{\varepsilon}{\varepsilon_0} = \frac{F_a}{F_m} = \frac{E_a}{E_m} = \frac{V_a}{V_m} = \frac{U_a}{U_m} = \frac{C_m}{C_a}}$

* Force betn two plates of Capacitor.

$F = -QE_1$

$= -Q \times \frac{\sigma}{2\varepsilon_0}$

$= -Q \cdot \frac{Q}{A2\varepsilon_0}$



$\boxed{F = \frac{-Q^2}{2\varepsilon_0 A}}$ $\boxed{F = \frac{\sigma^2 \cdot A}{2\varepsilon_0}}$

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

$\therefore \boxed{F = \frac{CV^2}{2d}}$

* Capacitance of isolated spherical Conductor:

$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

$\frac{Q}{V} = 4\pi\varepsilon_0 R$

$\therefore \boxed{C = 4\pi\varepsilon_0 R}$ $\boxed{C = \frac{R}{K}}$

$K = 9\times10^9$

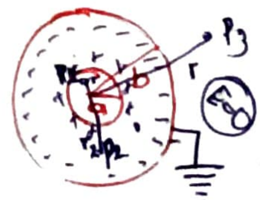
$C \propto R$

$\therefore \frac{C_1}{C_2} = \frac{R_1}{R_2}$

unit of $\varepsilon_0 \Rightarrow$ Farad/meter

$\rightarrow \boxed{C_{earth} = 711\mu F}$

* Spherical Capacitor



At Pt. P_1 $E = 0$.

At P_3 $E = 0$

At $P_2 \Rightarrow E \neq 0$.

$\rightarrow E = \frac{KQ}{R^2}$ $\rightarrow E = -\frac{dv}{dr}$

$\therefore dv = -Edr$

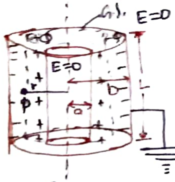
$\int dv = -\int_b^a Edr$

$V = -\int_b^a \frac{Kq}{r^2} dr$ $\therefore V = KQ\left(\frac{1}{a} - \frac{1}{b}\right)$

$V = \frac{K\varphi(b-a)}{ab}$ $\frac{\varphi}{V} = \frac{ab}{K(b-a)}$.

$$\boxed{C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)}$$

* Cylindrical Capacitor.



$E = \frac{1}{2\pi\varepsilon_0}\cdot\frac{\lambda}{r}$

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\frac{\varphi}{rl}}$$

$\frac{2K\lambda}{r}$

$V = \int_b^a -E.dr = \int_a^b E dr$

$= \frac{1}{2\pi\varepsilon_0}\int \frac{\varphi}{rl} dr = \frac{\varphi}{2\pi\varepsilon_0 l}\int_a^b \frac{1}{r} dr$

$= \frac{\varphi}{2\pi\varepsilon_0 l}[\log r]_a^b$

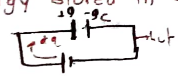
$$\boxed{V = \frac{\varphi}{2\pi\varepsilon_0 l}\log\left[\frac{b}{a}\right]}$$

$\frac{\varphi}{V} = \frac{2\pi\varepsilon_0 l}{\ln(b/a)}$ $C = \frac{2\pi\varepsilon_0 l}{\ln(b/a)}$.

$$\boxed{C = \frac{2\pi\varepsilon_0 l}{2.303\log_{10}\left(\frac{b}{a}\right)}}$$

** $C \alpha l$

* Energy stored in Capacitor.



$\varphi = 0$
$V = 0$
$C \neq 0$

$\boxed{W_T = \varphi V}$ by battery.

$dv \to q$
$dv = \frac{q}{C}$.

$dw = dq.dv$

$dw = \frac{q}{C}dq$.

$w = \frac{1}{C}\int_0^{\varphi} q\,dv$ ∴

∴ $w = \frac{\varphi^2}{2C}$.

∴ $\varphi = CV$.

∴ $w = \frac{1}{2}CV^2$.

$U = \frac{1}{2}\varphi V$.

∴ $w = U$
stored in capacitor

**

$$\boxed{U = \frac{1}{2}CV^2 = \frac{\varphi^2}{2C} = \frac{1}{2}\varphi V}$$

~~① Battery conn.~~ d

① If separation b/w two plate capacitor is increases then

Battery disconn. → φ const	Battery remain conn. V const
① C→ $C = \frac{A\varepsilon_0}{d\uparrow}$ $\boxed{C\alpha\frac{1}{d\uparrow}}$ C decrease	① C→ $C = \frac{A\varepsilon_0}{d}$ $\boxed{C\alpha\frac{1}{d}}$. C decrease.
② φ→ φ = const.	② $\varphi = CV$ $\boxed{\varphi\alpha C\alpha\frac{1}{d}}$ φ→decrease.
③ V→ $V\alpha\frac{1}{C}\alpha d$ ∴ V increase	③ V = const.
④ E.F.→ $E = \frac{V\uparrow}{d\uparrow} = \frac{\varphi}{A\varepsilon_0}$ $E\alpha\frac{V}{d}$ ∴ E = const.	④ ∴ $E\alpha\frac{1}{d}$ E = decreases
⑤ Energy stored $U = \frac{\varphi^2}{2C}$ ∴ U = increases	⑤ $U = \frac{1}{2}CV^2$ ∴ U = decreases

• If Dielectric slab of dieletric const. K is introduced betn two plates of capacitor.

Battery Disconn.	Battery remain same
① Capacitance C↑	① C↑
② φ - charge → const.	② φ → $\frac{\varphi^2}{2C}$ $\varphi = CV$. ∴ φ = increases
③ V→ $\varphi = CV$. $V\alpha\frac{1}{C}$. ∴ V - decreases	③ V = const.
④ E.F. = $\frac{V}{d} = \frac{\varphi}{A\varepsilon_0}$. E = decreases	④ $E = \frac{V}{d} = \frac{\varphi}{A\varepsilon_0}$. const. E = ~~increases~~ const.
⑤ U→ $\frac{\varphi^2}{2C}$. ∴ U = decreases	⑥ $U = \frac{1}{2}CV^2$ U = increases.

Q. A metal surface of area $1m^2$ is charged with 8.85μC in air then mechanical force acting on it is

→ $F = \frac{\varphi^2}{2\varepsilon_0 ds} = \frac{8.85\times8.85\times10^{-12}}{2\times8.85\times10^{-12}\times1}$

= 4.425 N.

Q. A charge of 6μC is uniformly distributed on surface of a rect. metallic plate of length 2m & breadth 1.5m placed in air. then outward pull on the plate is.

→ $F = \frac{\varphi^2}{2\varepsilon_0 ds}$

$= \frac{36\times10^{-12}}{2\times8.85\times10^{-12}\times(3)2} = \frac{\cancel{6}3}{9\cdot1} = \underline{0.339}$

Q. The energy density at a point in a medium of $\underline{K=8}$ is 26.55×10^{-6} J/m³. The electric field intensity is

→ $26.55\times10^{-6} = \frac{1}{2}\frac{8.85\times10^{-12}}{8}\times E^2$

$\frac{6\times10^{+6}}{8}$

$\frac{3}{4}\times10^{+18} = E^2$

∴ $E = \frac{\sqrt{3}}{2}\times10^{9}$.

Q. A circular metal plate of radius 1.5cm charged with 100μC situated in air then mechanical force acting on 1 side of plate is

→ $F = \frac{100\times10^{-12}}{8.8\times10^{-12}\times2\times1.5\times1.5\times10^{-4}\times\pi}$

$= \frac{10^6}{8.8\times4.5\times\pi} = \frac{10^6}{36}\approx\frac{3\times10^6}{4}$

$$\boxed{F = \frac{1}{4\pi\varepsilon_0}\frac{\varphi^2}{r^2}}$$

$= \frac{9\times10^9\times100\times10^{-12}}{15\times15\times10^{-4}}$

$= 4\times10^3$

$= 4000N$

Q. A cond. of capacity 4μF is charged to pot. of 300Volt. If an additional charge of -3×10^{-4}C is deposited on it then resultant pot. is

→ $\varphi = CV$.
$= 4\times10^{-6}\times300 = 1200\times10^{-6}$.

$V' = 1200\times10^{-6} - 3\times10^{-4}$.

$= \frac{9\times10^{-4}}{4\times10^{-6}} = 2.25\times10^2 = 225V$

Q. A spherical capacitor has an inner sphere of radii 9cm and outer sphere of 10cm radius. The capacitance of capacitor is.

→ $C = \frac{2\pi\varepsilon_0 l}{2}$. $C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$

$= 4\times\frac{22}{7}\times8.85\times10^{-12}\times\ldots$

$= \ldots$

$= \underline{10^{-8}}$

Q. What capacitance is required to store an energy of 100kwh at a pot. diff. of 10^4 volt.

$\rightarrow$ $E = \frac{1}{2}cv^2$. $\therefore c = \frac{2E}{v^2}$.

$\frac{2\times100\times10^3\times3600}{10^8} = \underline{7.2}$ F

Q. Find energy stored in the E.F. produced by a metal sphere of radii R containing charg Q.

$\rightarrow$ $E = \frac{Q^2}{2C}$ $\quad c = \frac{Q^2}{8\pi\epsilon_0 R}$

Q. A metal sphere of 4cm radius is suspendended within hollow sphere of radii 6cm. The inner sphere charged to pot. of 3esu & outer sphere is earth then charge on inner sphere is.

$\rightarrow$ $V = \frac{1}{4\pi\epsilon_0}Q\left(\frac{b-a}{ab}\right)$.

$Q = \frac{3}{3\times10^5\times9\times10^9}\cdot\left(\frac{24\times10^{-4}}{2\times10^{-2}}\right)$

$Q = 36\times10^{-11}$

$c = 4\pi\epsilon_0\frac{ab}{b-a} = \frac{24}{2} = 12esu.$

$Q = cV = \underline{36esu}$

Q. A capacitor having capacity of 50uF is charged to pot. of 200volt. If area of each plate of capacitor is 10cm² & dist. betn plate is 0.1mm then energy density betn plate is

$\rightarrow$ $Q = CV = 50\times10^{-6}\times200 = 10^{-2}$

$u = \frac{U}{v} = \frac{\frac{1}{2}cv^2}{A.d} = \frac{\frac{1}{2}\times50\times10^{-6}\times200\times200}{10\times10^{-4}\times0.1\times10^{-3}}$

$= 10^7 J/m^3$

what dist. apart should 2 plate of area (0.2m×0.1m) of a pp air capacitor be placed in order to have the same capacitance as spherical cond. of rad. 0.5m

$\rightarrow$ $\frac{\epsilon_0 A}{d} = 4\pi\epsilon_0 R$

$d = \frac{0.2\times0.1}{4\pi\times0.5}$

$= \frac{7}{1100} = 10^{-2}$

$= \underline{3mm}$

Q. If charge on capacitor is increased by 2coulomb, the energy stored in it increased by 21% then original charge on capacitor is

$\rightarrow$ $E = \frac{Q^2}{2c}$ $\quad E\propto Q^2$

$E - 0.21E = (x-2)^2$.

$1.79E = (x-2)^2$ $\quad x=$

$E\propto Q^2$

Q. $E' = 1.21E = \frac{121}{100}E$ $\quad Q' = (Q+2)$

$\frac{E'}{E} = \left(\frac{Q'}{Q}\right)^2$.

$\frac{11}{10} = \frac{Q+2}{Q}$. $\therefore 11Q = 10Q+20$

$\boxed{Q = 20}$

* Combination of charged drops

n identical small drop

000
000 } B.D.

q	Q'
C	C'
r	R
σ	σ'
V	V'
U	U'

① charge (Q)

$Q' = nq.$

② Radius (R).

$V_{B.D.} = n V_{S.D.}$

$\frac{4}{3}\pi R^3 = n\times\frac{4}{3}\pi r^3$

$\therefore R = n^{1/3} r$

③ Capacitance

$C'\propto R$

$\therefore C = n^{1/3}C$

④ Surface charge density.

$\sigma' = \frac{Q}{4\pi R^2}$.

$\sigma' = n^{1/3}\sigma$

⑤ Potential (V').

$Q = C'V'$

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

$= \frac{nq}{n^{1/3}C}$

$V' = n^{2/3}V$

⑥ U'

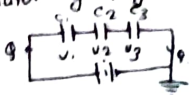
$U' = \frac{1}{2}C'V'^2$

$\cancel{U' = n^{4/5}}$

$U' = n^{5/3}.U$

* Grouping of capacitor.

① Series capacitor grouping



Q → same

V → diff.

$V = V_1 + V_2 + V_3$

$\frac{1}{C} = \frac{1}{C_2} + \frac{1}{C_1} + \frac{1}{C_3}$

① $C_s < C_1/C_2/C_3$

② series combn → capacitance ↓es

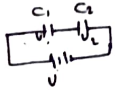
③ $V = \frac{Q}{C}$ → same $\quad \therefore \uparrow V \propto \frac{1}{C\downarrow}$

④ $\frac{V_1}{V_2} = \frac{C_2}{C_1}$

⑤ For n identical capacitor

$C_s = \frac{C}{n}$

⑥



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

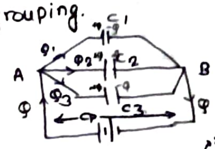
$V_1 = V\left[\frac{C_2}{C_1+C_2}\right]$

$V_2 = V\left[\frac{C_1}{C_1+C_2}\right]$

② Parllel grouping.

Q → diff

V → same.



$Q = Q_1 + Q_2 + Q_3$ $\quad Q = CV$, same.

$C_P = C_1 + C_2 + C_3$

$C_P > C_1/C_2/C_3$

① Parllel combn = capacitance ↑ses.

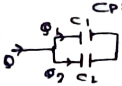
② $Q = CV$.

$\therefore \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$

③ For n identical capacitor

$C_P = nC$

④



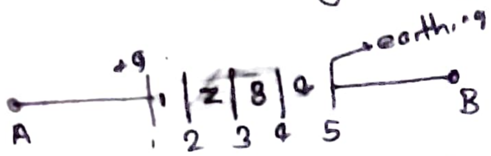
$Q_1 = Q\left[\frac{C_1}{C_1+C_2}\right]$

$Q_2 = Q\left[\frac{C_2}{C_1+C_2}\right]$.

* Group of plates

① Series

→ If n no of plates are arranged one after another b/w two pts as shown in fig then (n-1) capacitor will form & they will be in series grouping.



$$C_s = \frac{C}{n-1}$$

plates = n

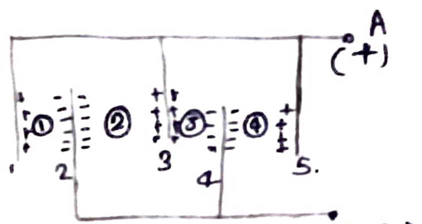
capacitor form = n-1

$$C_s = \frac{A\varepsilon_0}{(n-1)d}$$

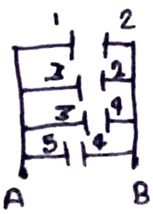
$$C_{AB} = \frac{C}{4} = \frac{A\varepsilon_0}{4d}$$

② Parllel.

→ If n no. of plates are arranged b/w two points such that even no. of plates are conn. together and odd no. of plate conn. together then (n-1) capacitor will be formed and they will be in parllel groping



⇓

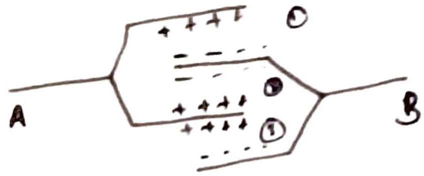


$$C_s = 4C = \frac{4A\varepsilon_0}{d}$$

$$C_s = \frac{(n-1)\varepsilon_0 A}{d}$$

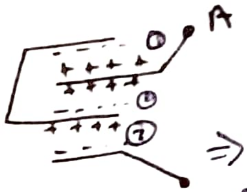
①

②



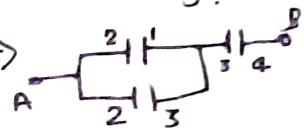
$C = 3C$

③

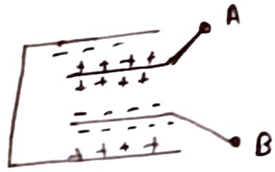


$$C_{eq} = \frac{2C}{3}$$

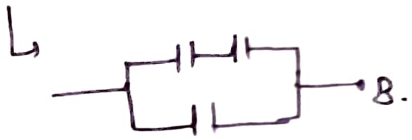
⇒



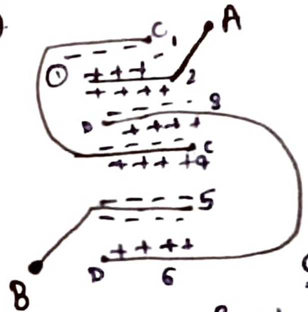
④



$$C_{eq} = \frac{3C}{2}$$

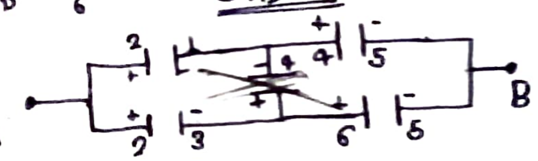


⑤

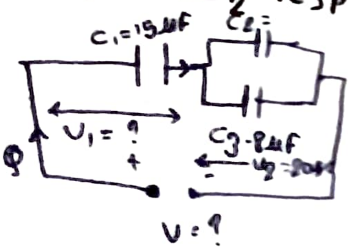


$C_{AB} = C$

$C_{AB} = C$



Q In circuit shown in fig. The total charge is 750 μC then value of V_1, V & C_2 resp. are.



→ Ceq,

~~Q = CV.~~

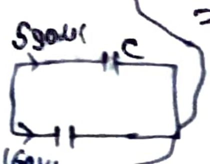
$750 = 15\mu F \times V_1$

$\therefore V_1 = \frac{750}{15} = 50V$

$V = V_1 + V_2 = 70V.$

$\therefore Q_3 = V_2 C_3$

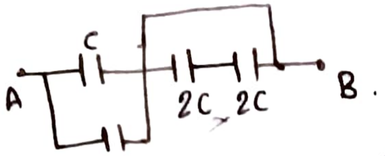
$= 160 \mu C.$



$$C = \frac{Q}{V} = \frac{590}{20} = 29.5\mu F$$

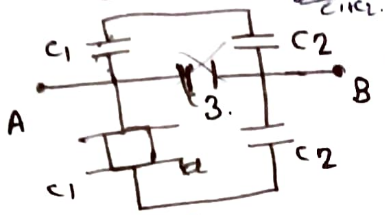
Q. The eq. capacitance betn A & B is

(1)



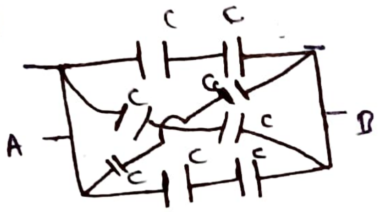
$C_{AB} = 2C$

(2)



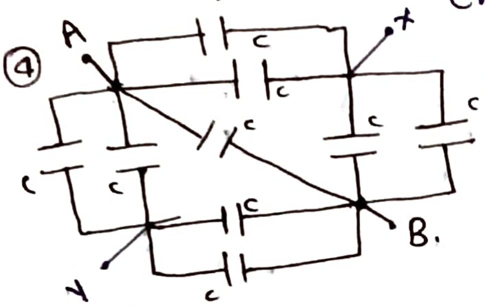
$C_{eq.} = \frac{2C_1C_2}{C_1+C_2}$

(3)



$= 2C$

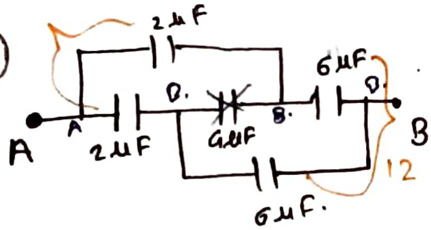
(4)



$C_{xy} \Rightarrow 2C$ b/c of WSB

$C_{AB} \Rightarrow 3C.$

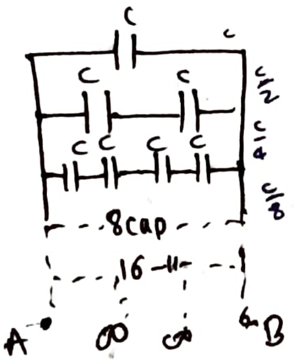
(5)



$\frac{4\times12}{16} \Rightarrow 3C$

$\underline{3\mu F}$

(6)



$n = \frac{1}{2}$ $a = 1$

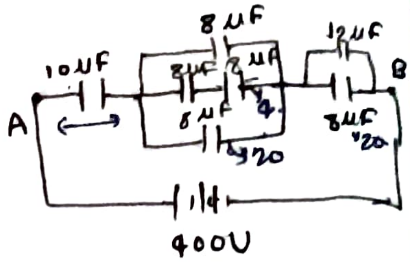
$\therefore C_{eq.} = C \times \frac{1}{1-\frac{1}{2}}$

$= 2C.$

$C\left[1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} \dots\right]$

$\therefore r = \frac{1}{2}$

Q. In circuit shown in fig. the charge on 12μF capacitor is



$C_{eq} = 5\mu F$

$Q = 5\mu F \times 400$

$= 2000\ \mu C.$

$= 2\ mC.$

$400\left(\frac{10^{-1}}{8}\right)$

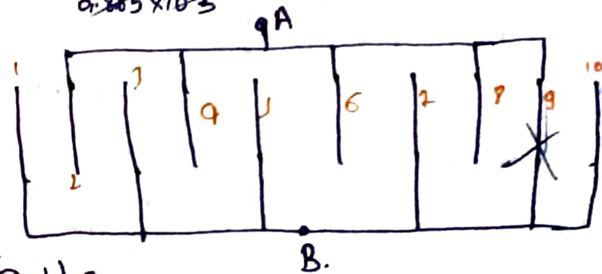
$Q_{12} = \left(\frac{12}{20}\right) \times 2 \times 10^{-3}.$

$= \frac{12}{10} \times 10^{-3}\ mC$

$= \underline{1200\ \mu C.}$

Q A gang capacitor is formed by interlocking a number of plates as shown in fig. The dist. betn plate is 0.885 cm and overlapping area of plate is $5\ cm^2$ then capacity of gang capacitor is

$\frac{\varepsilon_0 A}{d} \Rightarrow \frac{8.85\times10^{-12}\times5\times10^{-4}}{0.885\times10^{-2}} = 5\times10^{-13}.$



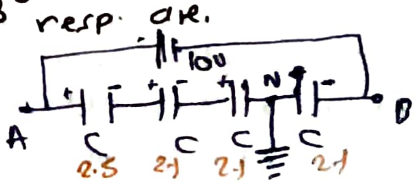
$C = (n-1)\ c.$

$= \underline{8C.}$

$\therefore\ 8\times5\times10^{-13} \Rightarrow 4\times10^{-12}$

4picoF

Q. Four identical capacitor are conn. in series with 10V battery as shown in figure then pot. at pt. A and at pt. B resp. are.



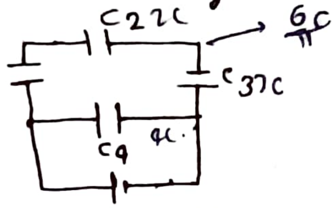
$V_A - V_N = 2.5 + 2.5 + 2.5$

$\underline{V_A = 7.5V}$

$V_N - V_B = 2.5.$

$\underline{V_B = -2.5V}$

Q. A Network of 4 capacitor of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$, $C_4 = 4C$ are conn. to battery as shown in figure then ratio of charges on C_2 & C_4 is →



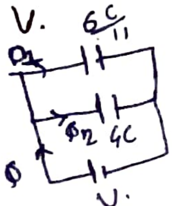
→ $\frac{1}{C} + \frac{1}{2C} + \frac{1}{3C}$

$6+3+2$

$\frac{6}{11}C + 4C$ $\frac{11}{6C}$

$\frac{50C}{11} \Rightarrow C_{eq}$

$Q = \frac{50CV}{11}$



$\frac{Q_1}{Q_2} = \frac{C_1}{C_2} = \frac{6C/11}{\cancel{4C}} = \frac{6C}{11 \times 2C}$

$= \frac{3}{22}$

$Q = CV$

$\therefore Q \propto C$

Q. In given circuit a charge of 80μC is given to upper plate of 4μF capacitor then charge on lower plate of 2μF is-

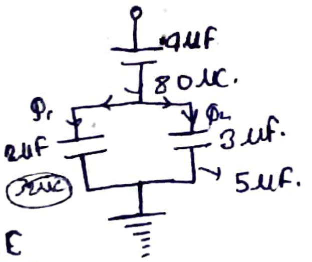
~~$\frac{80}{9}$ μF~~

→

$Q = Q_1 + Q_2$

For 5μF = 80μC

∴ For ⇒ 2μF = 32μC



$Q_1 = Q\left[\frac{C_1}{C_1 + C_2}\right]$

$= 80\left(\frac{2}{5}\right)$ $= 32\mu C$

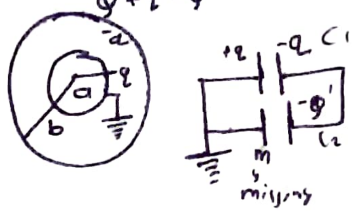
Q. Two concentric spherical metal shell of radii a & b (b>a). The outer shell has charge Q. & inner ~~charge~~ shell grounded then charge appear on inner shell is

→ ~~q=~~ ind. only inner to outer.

$V_P = K\left[\frac{Q}{b} + \frac{q}{a}\right]$ $V_P = 0$

$\therefore \frac{Q}{b} = \frac{-q}{a}$ $\therefore q = -\frac{Qa}{b}$

$Q + q = Q'$



$C_1 = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$

$C_2 = 4\pi\varepsilon_0 b.$

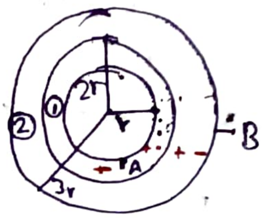
$\therefore C_{eq} = C_1 + C_2 = 4\pi\varepsilon_0\left(\frac{ab}{b-a} + b\right)$

$$\boxed{C_{eq.} = 4\pi\varepsilon_0\left(\frac{b^2}{b-a}\right)}$$

↳ inner sphere grounded.

Q. The eq. capacitance betn A & B is.

→

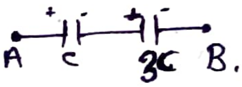


$C_1 = 4\pi\varepsilon_0\left(\frac{2r^2}{r}\right)$

$= 4\pi\varepsilon_0 2r.$

$C_2 = 4\pi\varepsilon_0\left(\frac{6r^2}{r}\right)$

$= 4\pi\varepsilon_0 6r$



$C_{eq} = \frac{3C}{4} = \frac{2}{3} \times 4\pi\varepsilon_0 2r \frac{2C}{3}$

$C_{eq} = \frac{3C}{4}.$

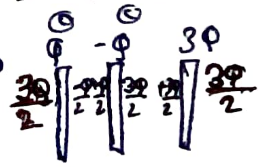
⇒

Then u पहले से induced करना Q & divide by c

Q. The charges given to the isolated plates of large surface area as shown in fig. The capacitance betn adjacent plate is C. Then pot. diff. betn plates 1 & 2 is.

$Q_T = Q_1 + Q_2 + Q_3 \ldots + Q_n$

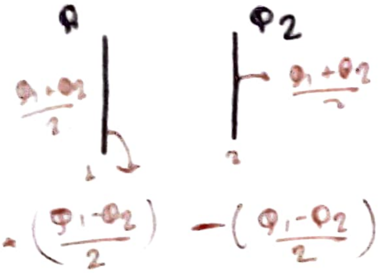
$\therefore Q_{outer} = \frac{Q_T}{2}$



$Q_{outer} = \frac{3Q}{2}$

$V_{12} = \frac{Q}{2C}$ (induced on)

$V_{23} = \frac{3Q}{2C}$



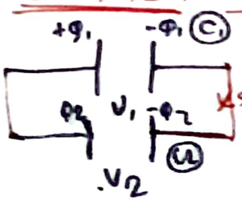
$$V = \frac{Q_1 - Q_2}{2C}$$

Q. Two metal sphere of radii a & b resp. are Joined by metal wire. then capacitance of arrangement is-

→ V same ∴ parallel.

∴ $4\pi\varepsilon_0 a + 4\pi\varepsilon_0 b \Rightarrow 4\pi\varepsilon_0 (a+b)$.

* Common potential (V_c)



+ Bf sharing

$Q_1 = C_1V_1$

$Q_2 = C_2V_2$

* After sharing → V_c → same

∴ $Q_1' = C_1V_c$

$Q_2' = C_2V_c$

Q bf sharing = $(Q)_T$ after sharing

$Q_1 + Q_2 = Q_1' + Q_2$

$$V_c = \left[\frac{Q_1+Q_2}{C_1+C_2}\right]$$

$$V_c = \frac{C_1V_1 + C_2V_2}{C_1+C_2}$$

If conn. to opp. terminal C_1 antillel to C_2

$$V_c = \frac{C_1V_1 - C_2V_2}{C+C_2} \quad (C_1 > C_2)$$

* Loss of energy (ΔU)

→ Before sharing

$U_1 = \frac{1}{2}C_1V_1^2$

$U_2 = \frac{1}{2}C_2V_2^2$

$U_T = \frac{1}{2}[C_1V_1^2 + C_2V_2^2]$

→ After sharing

$U_1' = \frac{1}{2}C_1V_c^2$

$U_2' = \frac{1}{2}C_2V_c^2$

$U_T' = \frac{1}{2}V_c^2[C_1+C_2]$

$$U_T' = \frac{1}{2}[C_1+C_2]\frac{(C_1V_1+C_2V_2)^2}{(C_1+C_2)^2}$$

$$U_T' = \frac{1}{2}\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2}.$$

$\cancel{\Delta U = U_2 - U_1 - U_T = -\frac{1}{2}(C_1V_1+C_2V_2)}$

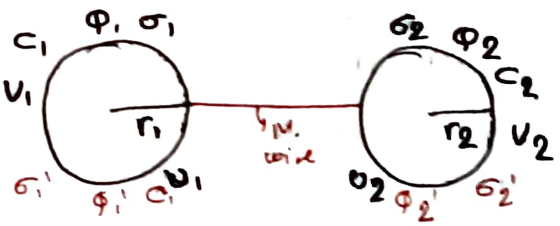
$$\Delta U = U_i - U_f = \frac{1}{2}[C_1V_1^2 + C_2V_2^2] - \frac{1}{2}\frac{[C_1V_1+C_2V_2]^2}{(C_1+C_2)}$$

$$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}[V_1 \mp V_2]^2$$

→ parllel

→ antiparllel

* Redistribution of charges



$C_1 = 4\pi\varepsilon_0 r_1$

$C_2 = 4\pi\varepsilon_0 r_2$

$C_{eq} = 4\pi\varepsilon_0[r_1+r_2]$ → parllel. so.

$$Q_1' = Q_T\left[\frac{C_1}{C_1+C_2}\right]$$

$$Q_1' = Q_1+Q_2\left[\frac{r_1}{r_1+r_2}\right]$$

$$Q_2' = Q_1+Q_2\left[\frac{r_2}{r_1+r_2}\right]$$

Q. Two condensor of capacities 4 μF & 8 μF are charged to 20V & 15V resp. then common pot. when they are conn. in parllel

→ $V_c = \left[\frac{Q_1+Q_2}{C_1+C_2}\right] = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

$= \frac{4+8}{} = \frac{80+120}{12\,\mu F}$

$= \frac{200}{12} = \frac{100}{6} = \underline{\frac{50}{3}\,V}$

Q. A 5μF capacitor is fully charged across a 12V battery and then conn. to an uncharged capacitor ($V_2 = 0$) the voltage across it is found to be 3 volt then capacity of uncharg capacitor is

→ $3 = \frac{60+C_2V_2}{C_1+C_2}$ ($C_2V_2 \to 0$)

$15 + 3C_2 = 60$

$3C_2 = 45$

$C_2 = \underline{15\,\mu F}$

Q. Two insulated metallic sphere of 3μF & 5μF capacitance are charged to 300volt & 500volt resp. when they are joined by wire then energy loss is

→ $\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}[V_1-V_2]$.

$= \frac{1}{2} \times \frac{15\,\mu F}{8\,\mu F}[\cancel{-200}\ 100]$.

$= \frac{1500\times10^{-6}}{8} = \frac{1.5}{8}\times10^{-3}$.

Q. A 10 μF capacitor & 20 μF capacitor are conn. in series across 200V supply. The charge capacitors are then disconn. from supply and reconnected with their +ve plate together & -ve plate together & no ext volt is applied then pot. diff across each capacitor is

→ Series → $V_1 = 200\left(\frac{20}{30}\right)$

$= \frac{400\times10^{-6}}{3}$

$V_2 = \frac{200}{3}\times10^{-6}$.

$V_c = \frac{C_1V_1+C_2V_2}{C_1+C_2} = \frac{10\times10^{-6}\times\frac{400}{3}\times10^{-6}+\frac{200}{3}\times20}{30}$

$= \frac{600}{90}$

$C_s = \frac{C_1C_2}{C_1+C_2} = \frac{20}{3}\,\mu F$

$Q = CV = \frac{20}{3}\times200 \Rightarrow \frac{4000\times10^{-6}}{3}$

$= \frac{4}{3}\,mF \qquad = Q_1 = Q_2 = Q$

$V_c = \frac{Q_1+Q_2}{C_1+C_2}$

$= \frac{\frac{4}{3}+\frac{4}{3}}{30} = \frac{8\times10^{-3}}{3\times30\times10^{-6}}$

$= \frac{8000}{90} = \underline{88.8\,V}$.

Q. A 20F capacitor is charged to 5V & isolated. It is then conn. in parllel with an uncharged 30F capacitor then dec. in energy of system will be

→ ~~$\Delta U = \frac{1}{2}\frac{C_1V_1+C_2V_2}{C_1+C_2}$~~ $= \frac{100}{50}$

$= 2$

$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}[V_1-V_2]$

$= \frac{1}{2}\times\frac{600}{50}\times[5]^2 = \underline{150\,J}$

Q. Two isolated met. sphere of radii r & 2r are charged such that both of these have same surface charge density σ. The sphere are conn. by thin cond. wire then the new charge density on bigger sphere is.

→ $\frac{Q_1}{4\pi r^2} = \frac{Q_2}{4\pi(4r^2)}$

$Q_1 = \frac{Q_2}{4}$

$Q_2 = 4Q_1$

$Q_2' = (Q_1+Q_2)\frac{r_2}{r_1+r_2}$

$= 5Q_1\,\frac{2r}{3r}$

$= \frac{10Q_1}{3}$

$= Q_2' = 5Q_1\frac{r}{3r} = \frac{5Q_1}{3}$

$\sigma_2' = \frac{10Q_1}{3\times4\pi(2r)^2}$

$= \frac{10\times Q_2}{12\times4\pi(2r)^2}$

$= \frac{5}{6}\sigma$

* Dielectric and Polarisation

Polar	Non-polar
→ C.O.M. of +ve charge does not coinside with −ve charg COM	→ COM of +ve charge coinside with COM of −ve charge.
→ 	→ 
→ shape-unsymm. **	→ shape-symm.
→ $\vec{p} = 2ql = 10^{-30}$ cm	→ $\vec{p} = 0$
→ eg. HCl, H_2O	→ eg. O_2, H_2, N_2, CH_4, ...

① Behaviour of Non-polar dielectric in ext. electric Field.

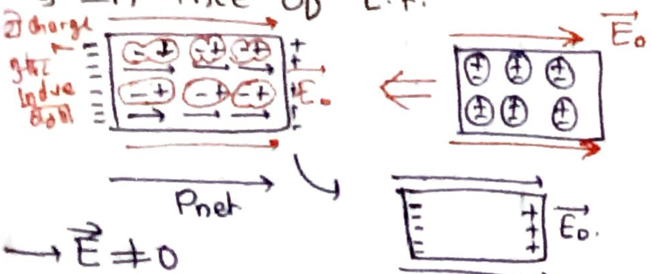
a) In absence of E.F.

$\vec{E} = 0$

$\vec{p} = 0$

$\vec{P}_{net} = 0$

b) In presence of E.F.



→ $\vec{E} \neq 0$

→ $\vec{P}_{e.m} \neq 0$ [e.m. = each mol.]

$(P_{net})_{sub} \neq 0$.

* electric Polarization.

→ The process of inducing eq. and opp. charge on two opp. faces of dielectric is called electric Polarization.

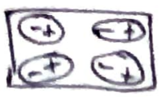
② Polar dielectric in ext. e.f.

a) In absence of $\vec{E}$

$\vec{E} = 0$.

$\vec{P}_{em} \neq 0$

$\vec{P}_{net} = 0$

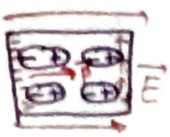


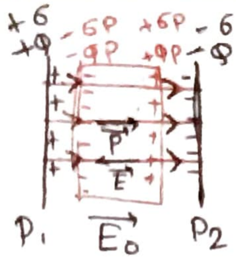
b) In presence of $\vec{E}$.

$E \neq 0$

$P_{em} \neq 0$

$(P_{net})_{sub} \neq 0$.





$E_0 = \frac{\sigma}{\varepsilon_0}$

$E_p = \frac{\sigma_p}{\varepsilon_0}$

$E_{net} = \frac{1}{\varepsilon_0}[\sigma - \sigma_p]$.

$E_{net} = \frac{1}{\varepsilon_0}[\sigma - \sigma_p]$

$\frac{\sigma}{\varepsilon_0 K} = \frac{1}{\varepsilon_0}\ \sigma - \sigma_p$.

$K = \frac{\sigma}{\sigma - \sigma_p}$ → SIC → specific inductive capacitance.

$K\sigma - K\sigma_p = \sigma$

$\sigma(K-1) = K\sigma_p$

$\sigma_p = \sigma\left[1 - \frac{1}{K}\right]$.

$\sigma_i = \sigma\left[1 - \frac{1}{K}\right]$ $\quad q_i = -q\left[1 - \frac{1}{K}\right]$

* Polarization Density $[\vec{P}]$:-

↑ $\vec{P}_{net} \propto$ Volume ↑ **

$\vec{P}_{net} = \vec{P} \cdot V$

$\vec{P} = \frac{P_{net}}{V}$. $[TAL^{-2}]$ $\quad P_{net} = q_p \cdot d$

$V = A \cdot d$

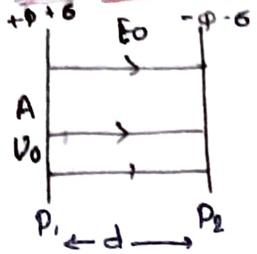
$\frac{\vec{P}_{net}}{V} = \frac{q_p}{A} = \vec{P} = \sigma_p$. $\quad \vec{P} = \sigma_p$

* Electric Susceptibility. (χ_e).

$\vec{P} \propto \vec{E}_R$ — reduced E.F.

$P = \chi_e \vec{E}_R \varepsilon_0$. $\quad$ ** $\chi_e = \frac{\vec{P}}{E_R \varepsilon_0}$.

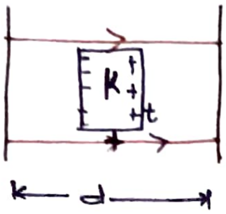
* Effect of dielectric on capacitance



→ $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

→ $V_0 = E_0 d$.

→ $C = \frac{\varepsilon_0 A}{d}$.



→ $E_m = \frac{E_0}{K}$

→ $t = E_m$

→ $(d-t) = E_0$

→ $V = (d-t)E_0 + t(E_m)$

$V = E_0\left[(d-t) + \frac{t}{K}\right]$ — New p.d. betn two plate.

$V = \frac{Q}{\varepsilon_0 A}\left[(d-t) + \frac{t}{K}\right]$.

$\therefore C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}}$

→ If entire space betn two capacitor is filled with dielectric then capacitance is

→ $t = d$.

$\therefore C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}}$

$\therefore C = \frac{\varepsilon_0 A K}{d}$

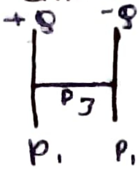
→ If several dielectric slab of dielectric const. K_1, K_2, K_3 --- with their resp. thickness t_1, t_2, t_3, t_4 --- fill completely b/w two plate of capacitor then new capacitance is.

→ $C = \frac{\varepsilon_0 A}{\frac{t_1}{K_1} + \frac{t_2}{K_2}}$ $d = t_1 + t_2 + t_3 ...$

→ If dielectric slab is replaced by cond. slab thickness t then new capacitance is

$C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{\cancel{K}}}$ ∞ $\therefore C = \frac{\varepsilon_0 A}{(d-t)}$

→ Two plate joined by another plate.



$\therefore C = \frac{Q}{V} = \frac{\infty}{}$ $V = 0$

Q. A PPC partialy filled with dielectric plate of thickness 6 mm & K = 3. The area of plate of capacitor is $2 \times 10^{-3} m^2$ & dist. b/w plate is 0.01m then capacitance of capacitor

→ d = 10mm

$C = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}} = \frac{\varepsilon_0 \times 2 \times 10^{-3}}{4 \times 10^{-3} + \frac{6}{3} \times 10^{-3}}$.

$C = \frac{\varepsilon_0 \times 2}{6} = \frac{\varepsilon_0}{3}$.

Q. The A of plate of PPC is A the dist. b/w plate is 10mm there are 2 dielectric sheet in it one of dielectric const. 10 & t = 6mm & other of K = 5 & t = 4mm find capacitance

→ Q. $C = \frac{\varepsilon_0 A}{\frac{t_1}{K_1} + \frac{t_2}{K_2}} = \frac{\varepsilon_0 A}{\frac{6}{10} + \frac{4}{5}} = \frac{10 \varepsilon_0 A}{14}$

$\therefore \frac{5 \varepsilon_0 A \times 10^3}{7}$.

Q. If dielectric plate of thickness t is introduced b/w plate of capacitor of dist. d, the capacitance become half. then original value of dielectric const of plate is,

→ $C_1 = \frac{\varepsilon_0 A}{d}$ $C_2 = \frac{C_1}{2} = \frac{\varepsilon_0 A}{(d-t) + \frac{t}{K}}$

$\therefore \frac{C_1}{C_2} = \frac{(d-t) + \frac{t}{K}}{d}$.

$2d = (d-t) + \frac{t}{K}$.

$d = \frac{t}{K} - t$.

Q. The capacitance of capacitor is 10µF without dielectric, K=2 is used to fill half dist. b/w plate then find new C.

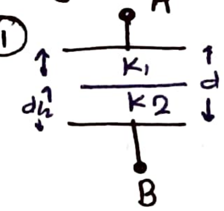
→ $C_1 = \frac{\varepsilon_0 A}{d}$

$C_2 = \frac{\varepsilon_0 A}{(d-\frac{d}{2}) + \frac{d}{4}}$

$C_2 = \frac{\varepsilon_0 A}{\frac{d}{2}+\frac{d}{4}} = \frac{4\varepsilon_0 A}{3d} = \frac{40}{3}$ µF.

Q. A capacitor is fill with two dielectric of same dimension but of dielectric const. K_1 & K_2 resp. then capacitance b/w two possible arrangement shown in fig. is.

(1)



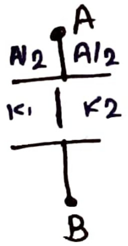
$C_1 = \frac{A\varepsilon_0}{(d-\frac{d}{2}) + \frac{d/2}{K_1}} = \frac{A\varepsilon_0}{\frac{d}{2}+\frac{d}{2K_1}}$

$C_2 = \frac{\varepsilon_0 A}{d-\frac{d}{2}+\frac{d}{2K_2}} = \frac{\varepsilon_0 A}{\frac{d}{2}+\frac{d}{2K_2}}$

dist. half or divide arrange in series.

$C_{AB} = \frac{\varepsilon_0 A 2}{d}\left[\frac{K_1K_2}{K_1+K_2}\right]$

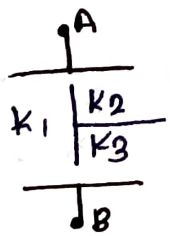
(2)



Area divide → parllel

$C_{AB} = \frac{\varepsilon_0 A}{2}[K_1+K_2]$

(3)



K_2, K_3 in series & K_1 in parllel.

$C_{AB} = \varepsilon_0 A\left[\frac{K_2K_3}{K_2+K_3} + \frac{K_1}{2}\right]$

Q. A slab of material of dielectric K has same area as the PPC has thickness 3d/4 where d is sep. of plate the ratio of capacitance C to C_0.

→ $C_0 = \frac{\varepsilon_0 A}{d}$ $\quad C = \frac{\varepsilon_0 A}{\frac{d}{4}+\frac{3d}{4K}}$

$C = \frac{\varepsilon_0 A}{\frac{d}{4}(1+\frac{3}{K})}$

$\therefore C = \frac{4\varepsilon_0 A}{d(1+\frac{3}{K})} = \frac{4C_0}{(1+\frac{3}{K})}$

$\therefore \frac{C}{C_0} = \frac{4}{(1+\frac{3}{K})} = \frac{4K}{K+3}$.

Q. A PPC is maintain at certain pot. diff. when 3mm slab is introduced b/w the plate in order to maintain same p.d. distance b/w plate is increased by 2.4 mm then dielectric const. of slab.

→ $\frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 A}{(d+2.4-3) + d}$

ASL Jelectro.

49. → take $V' = V\left[\frac{C_2C_3}{C_1C_2+C_2C_3+C_1C_3}\right]$

59. $E = \frac{\sigma}{\varepsilon_0 K}$

$\sigma = \varepsilon_0 K E$.

$= 8.8\times10^{-12}\times2.2\times3\times10^4$.

$= 6.3\times10^{-7}$ c/m².

25. ध्यान रख $\frac{\varepsilon_0 A}{2d}[K_1+K_2]$.

37 → $\frac{5}{6}C$ से जो आए उससे उल्टा bcoz यहा series parllel हो जायेगा

44. $\frac{3}{K} + d + 2.4 - 3 = d$.

$-0.6 = -\frac{3}{K}$.

$K = \frac{3}{0.6}$ $\quad K = \underline{5}$.

89. यहा Area है बे $\therefore \frac{1}{2}QV \rightarrow$ energy.