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Capacitor :- (device)

some electric device requires very High current (25-50A) to start them like Motor, Fan. -, camera flash.

* "capacitor stores Electrical Energy" & supply it at ONCE. (suddenly.)

* capacitor is a device which stores Electric charge.

* Capacitance (property.)

Ability to hold Electrical Energy.

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

→ C is independent of Q & V

→ C depends on conductor dimension & property of medium.

→ $\left(\text{Unit} = \frac{C}{V} = \text{Farad}\right) = F.$

Note :- $C = 1F$ i.e. $\frac{1C}{V}$ ⇒ If 1C is given to this conductor potential ↑ by 1 Volt

$C = 2F$ → 2C → 1V↑.

$C = 10F$ → 10C charge ⇒ potential 1V ↑.

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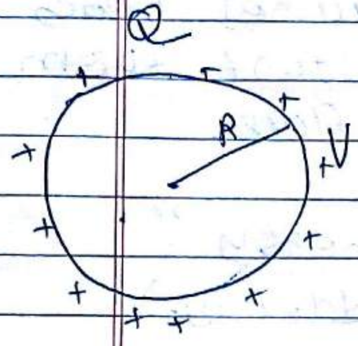
* Spherical capacitor / conductor :-



$$C = \frac{Q}{V} = \frac{Q}{\frac{KQ}{R}} = \frac{R}{K} = \frac{R}{1/4\pi\varepsilon_0}$$

$$\boxed{C = 4\pi\varepsilon_0 R}$$

→ C depends on dimension (R)

→ medium (ε_0) air.

Q) R=1m, Find capacitance

$\therefore C = 4\pi\varepsilon_0(1)$

$= \frac{1}{9\times10^{9}} = 1.1\times10^{-10}$ F

Q. $C = 1F \Rightarrow R = ?$ $\quad \frac{1}{4\pi\varepsilon_0} = R \Rightarrow 9\times10^{9}$ m.

↓

very Big.

problem → For this kind of capacitor capacitance is smaller but size is very Big.

Energy stored in a capacitor (spherical) :-

work done by external agent to bring each dq element from ∞ to this sphere $\rightarrow$ stores in form of P.E.

$t=0,\ Q=0,\ V=0$

$t=t,\ Q=q,\ V=q/C$

$t=\infty,\ Q=Q,\ V=Q/C$

$\rightarrow$ w.d. to bring dq charge from ∞ to sphere } $dW = \cancel{q\,dV}$. $dW = V\,dq$

$= \cancel{\frac{q}{C}}$ $\boxed{dW = \frac{q}{C}\,dq}$

$\rightarrow$ total work by external Force } $W_{ext} = \int dW = \frac{1}{C}\int_0^Q q\,dq = \frac{1}{C}\left(\frac{q^2}{2}\right)_0^Q$

$\therefore$ $\boxed{W_{ext} = \frac{Q^2}{2C}} = \underline{P.E = \Delta U}$

$\rightarrow$ $\boxed{\Delta U = -W_{\substack{elec.\\force}} = +W_{ext.}}$

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

$\therefore$ $U_f - U_i = \frac{Q^2}{2C}$

$\therefore$ $U - 0 = \frac{Q^2}{2C}$ (In starting No P.E)

$\therefore$ $\boxed{U = Q^2/2C}$.

- P.E. of spherical conductor } $U = \dfrac{Q^2}{2(4\pi\varepsilon_0 R)}$

$$\Rightarrow U = \frac{Q^2}{2C} = \frac{(CV)^2}{2C} \quad (\because Q = CV)$$

C & V

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

Q & V

$$\Rightarrow U = \frac{Q^2}{2C} = \frac{Q^2}{2\,Q/V} = \boxed{\frac{1}{2} Q V = U}$$

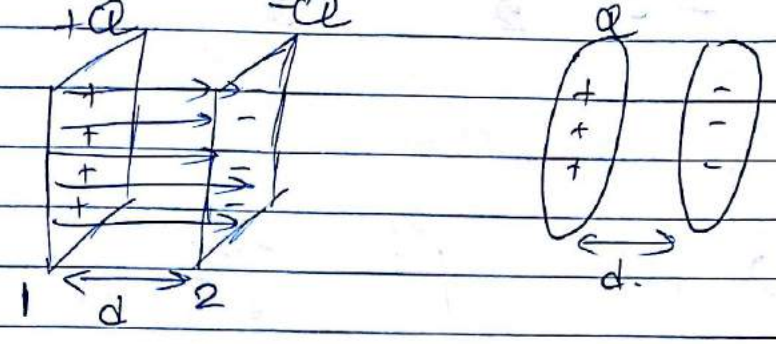
<u>Limits</u> :- i) low capacitance C↓

ii) P.E. losses for attracting nearer charges.

(i.e. Energy is not bounded.)

∴ distributed $R \to \infty$.

* Parallel plate capacitor :-



conditions

i). $d << \text{Area}$.

ii) $A_1 = A_2$.

→ plates behaves as ∞ plane.

capacitance :- $\boxed{C = \frac{Q}{\Delta V}}$ — charge on plate; ΔV → p.d. b/w plate. — (1)

Electric field due to First plate $\left\{ E_1 = \frac{\sigma}{2\epsilon_0} \rightarrow \right.$

$E_2 = \frac{\sigma}{2\epsilon_0} \rightarrow$

$\therefore E_{Net} = E_1 + E_2$

$= \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0} = E$

→ $\therefore \boxed{E = \frac{Q}{A\epsilon_0}}$

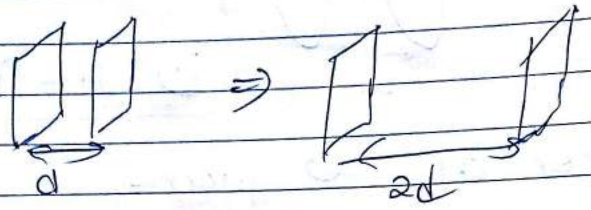
→ $\boxed{\therefore \Delta V = Ed = \frac{Q}{A\epsilon_0} \cdot d}$ — (2) $\left(\because dV = -E \cdot dl \right)$

→ put (2) → (1) :- $C = \frac{\cancel{Q}}{\frac{\cancel{Q}}{A\epsilon_0} \cdot d} = \frac{\epsilon_0 A}{d}$

$\therefore \boxed{C = \frac{\epsilon_0 A}{d}}$

* P.E } $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

Q:-



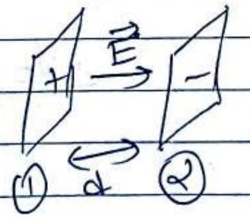
Find

$W_{ext} = \Delta U = U_f - U_i$

$= \frac{Q^2}{2C_f} - \frac{Q^2}{2C_i} = \frac{Q^2}{2\frac{\epsilon_0 A}{(2d)}} - \frac{Q^2}{2\frac{\epsilon_0 A}{d}}$

$\boxed{W_{ext}} = \frac{1}{2}\frac{Q^2}{\frac{\epsilon_0 A}{d}} = \boxed{\frac{Q^2 d}{2\epsilon_0 A}}$

* Force on one plate of capacitor due to other plate.



For one plate

$\vec{E}_{21} = \frac{\sigma}{2\epsilon_0} = \frac{Q}{2A\epsilon_0}$

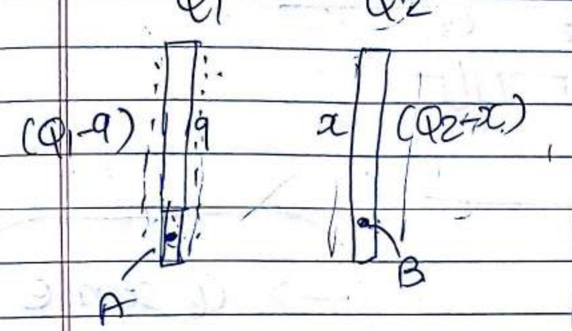
$\therefore F_{21} = Q E_{21}$

$= Q\left(\frac{Q}{2A\epsilon_0}\right) = \boxed{\frac{Q^2}{2A\epsilon_0} = F_{21}}$

→ $W_{ext} = F \times d = \boxed{\frac{Q^2}{2A\epsilon_0} d}$

(charge distribution on caps)

what if different charge on each plate



$\therefore E_A = \left(\frac{Q_1-q}{2A\epsilon_0}\right) - \left(\frac{q}{2A\epsilon_0}\right) - \frac{x}{2A\epsilon_0} - \frac{(Q_2-x)}{2A\epsilon_0}$

$\boxed{E_A = E_B = 0}$ (inside conductor)

$E = \frac{\sigma}{2\epsilon_0} = \frac{Q}{2A\epsilon_0}$

$\therefore 0 = \frac{1}{2A\epsilon_0}\left[Q_1 - q + x - x - Q_2 + x\right]$

$\boxed{0 = Q_1 - Q_2 - 2q}$ — (i)

$\therefore \boxed{q = \frac{Q_1-Q_2}{2}}$

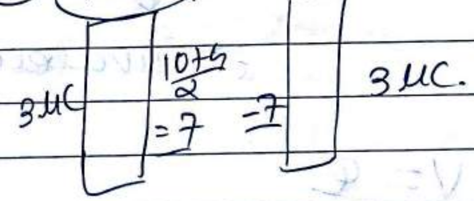
$E_B = \frac{Q_2-x}{2A\epsilon_0} - \frac{x}{2A\epsilon_0} - \frac{q}{2A\epsilon_0} - \frac{(Q_1-q)}{2A\epsilon_0}$

$\therefore \boxed{Q_2 - Q_1 - 2x = 0}$ — (ii)

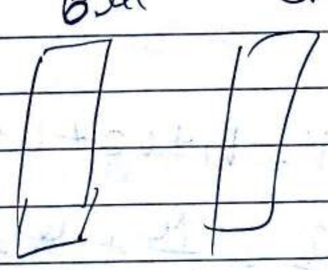
$\therefore \boxed{x = \frac{Q_2-Q_1}{2}}$

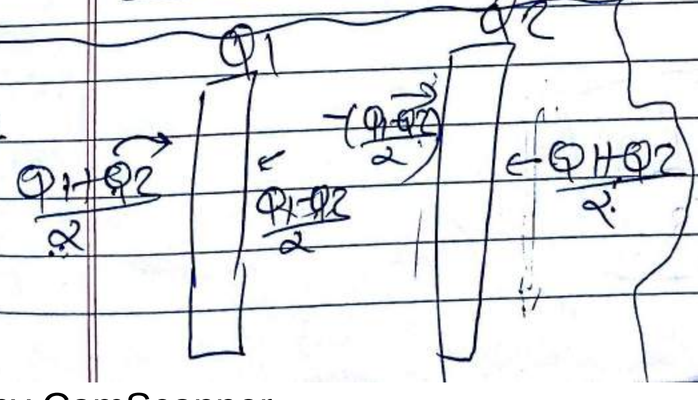
$\boxed{x = -q}$

(1) 10μC −4μC



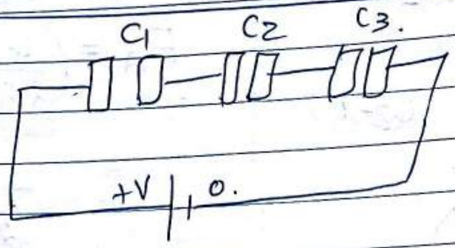
(2) 6μC 8μC

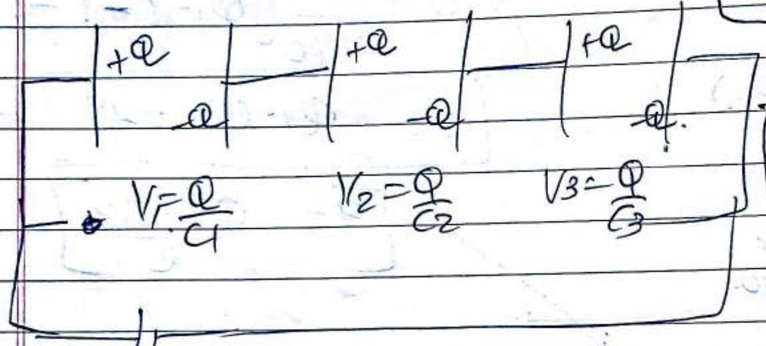




* Combination of capacitors :-

i) Series.

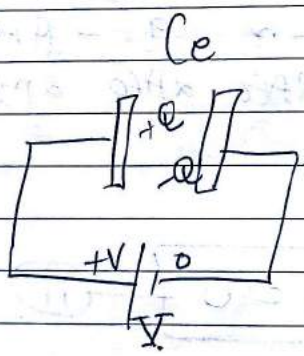




→ Q same
→ V diff.
→ $V \propto \frac{1}{C}$
→ $V = V_1 + V_2 + V_3$

⇓

Equivalent



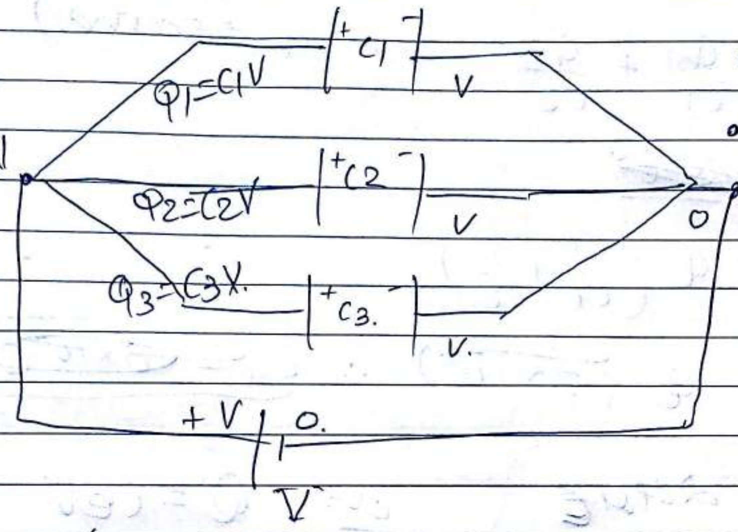
→ $V = \frac{Q}{C_e}$.

∴ $V = V_1 + V_2 + V_3$

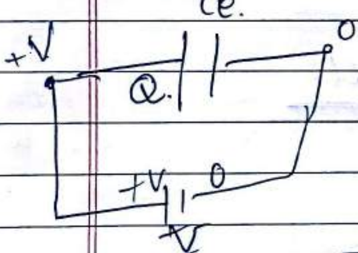
$\frac{Q}{C_e} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

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

ii) Parallel



• V same
• Q diffnt
↓
$Q = Q_1 + Q_2 + Q_3$



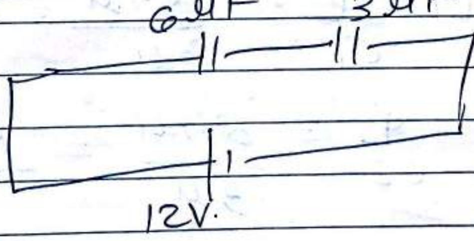
$\therefore Q = Q_1 + Q_2 + Q_3$

$C_eV = C_1V + C_2V + C_3V$

$\therefore \boxed{C_e = C_1 + C_2 + C_3}$

$\therefore \boxed{C_e = QV}$

1)



Find.
i) Ce
ii) Q on each capa
iii) ΔV on each capa
iv) Energy in 3μF capa stored.

$\rightarrow C_e = \frac{C_1C_2}{C_1+C_2} = \frac{18 \times 10^{-12}}{9 \times 10^{-6}} = 2\,\mu F$

$Q = CV$

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→ $V = V_1 + V_2$

$\therefore 12 = \frac{Q_1}{C_1} + \frac{Q_2}{C_2}$ (Q = same)

~~6×10^{-6}~~

$\therefore 12 = Q\left(\frac{1}{C_1}+\frac{1}{C_2}\right)$

$\therefore 12 = Q \frac{1}{(2\times10^{-6})}$ $\therefore$ ~~$Q = 6\times10^{-6}\,C$~~

$\boxed{Q = 24\mu C}$ or $Q = C_{e}V$
$= 2\times12$

→ ii) $C_1 = 6\mu F$

$+24\mu$ -24μ — $24\mu C$

→ iii) $Q = CV$

$\therefore C_1 = \frac{Q}{V_1} \Rightarrow V_1 = \frac{Q}{C_1} = \frac{24\mu}{6\mu} = 4\,V$

$V_2 = \frac{Q}{C_2} = \frac{24\mu}{3\mu} = 8\,V$

→ (iv) Energy in $3\mu F$ capa.

$U = \frac{1}{2}CV^2 = \frac{1}{2}(3\times10^{-6})(8)^2 = 96\mu J$

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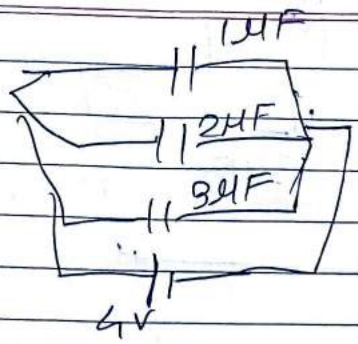
Q:-



i) Ce
ii) Q in each capa.
iii) p.d. in each capa
iv) Energy stored in 1μF.

$V = 4V \therefore V_1 = V_2 = V_3$

→ i) parallel ⇒ $C_e = C_1 + C_2 + C_3 = 6\mu F$

→ ii) V will be same, Q different

$Q = C_e V$

$\therefore Q = 6\times10^{-6}(4)$

$\boxed{Q = 24\mu C}$

$\therefore Q_1 = C_1 V = 1\mu\times4$, $\boxed{Q_1 = 4\mu C}$ | $Q_2 = C_2 V = 2\mu\times4$, $\boxed{Q_2 = 8\mu C}$ | $Q_3 = C_3 V = 3\mu\times4$, $\boxed{Q_3 = 12\mu C}$

→ iii) $V_1 = V_2 = V_3 = V = 4V$.

→ iv) $U = \frac{1}{2}CV^2 = \frac{1}{2}(1\mu)(16) = 8\mu J$.

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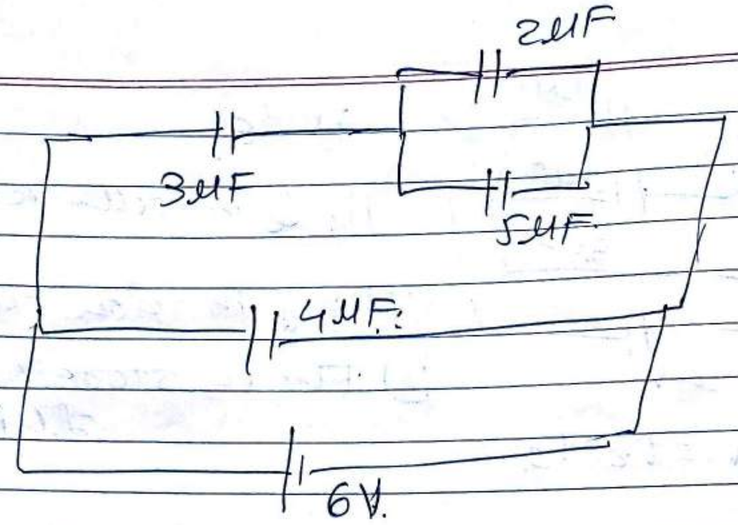
Q3|

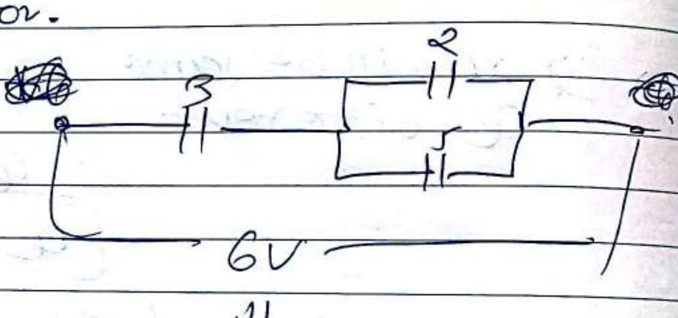


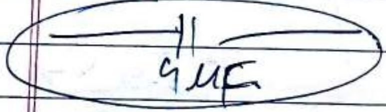
Find ratio of charge on 5μF capa. to 4μF capacitor.

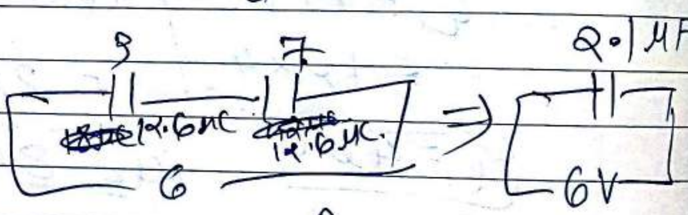
→ ∵ $Q = CV$

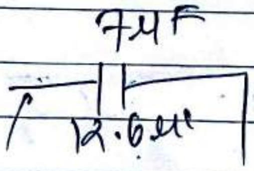
∴ $Q = 4\mu(6)$

$\boxed{Q_1 = 24\mu C}$







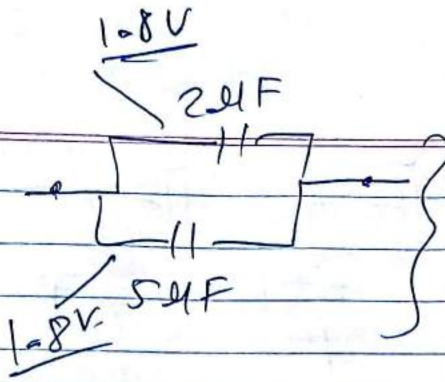


$V = \frac{Q}{C} = \frac{12.6}{7} = \boxed{1.8V}$

∴ $Q = CV$

$= 2.1 \times 6\mu$

$= 12.6 \mu C$



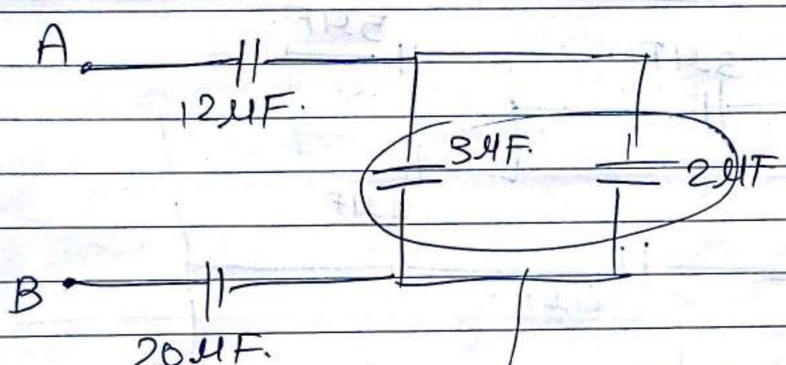
$Q = CV$

$= 5\mu \times 1.8$

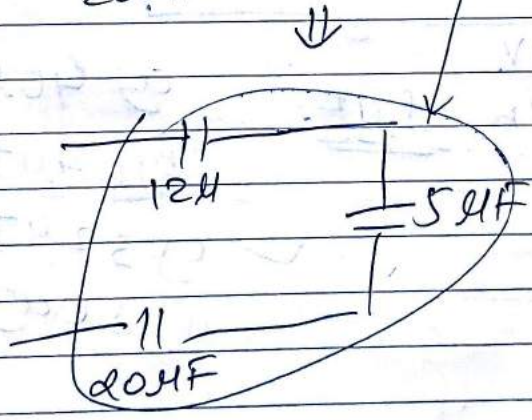
$\boxed{Q_2 = 9\mu C}$

$\therefore \frac{Q_2}{Q_1} = \frac{\overset{3}{\cancel{9}}\mu C}{\underset{8}{\cancel{24}}\mu C} = \frac{3}{8}$

Q:-



Find Ce b/w A&B.



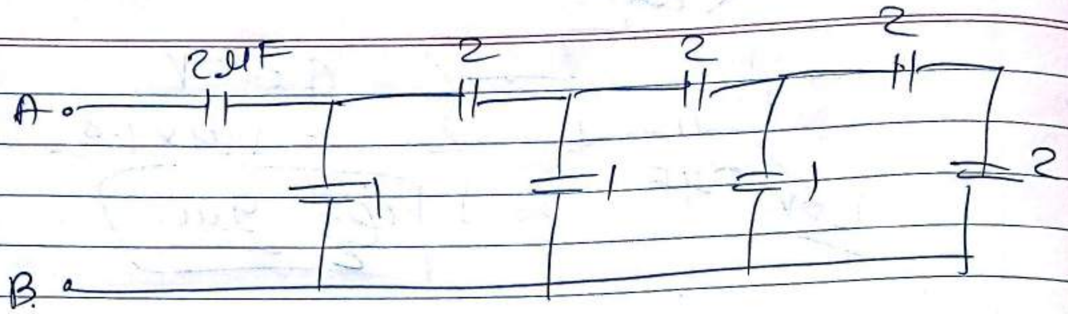
→ series

$\therefore \frac{1}{C_e} = \frac{1}{5} + \frac{1}{12} + \frac{1}{20}$

$= \frac{12 + 5 + 3}{60}$

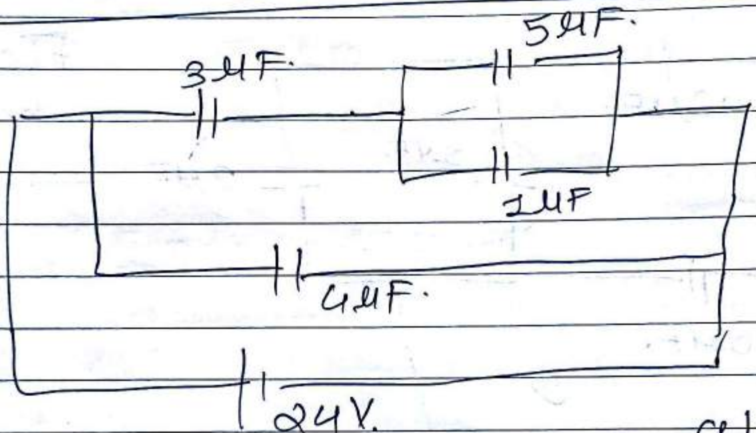
$= \frac{20}{60} = \frac{1}{3}$

$\therefore \boxed{C_e = 3\mu F}$

Q:- 

Find Eq. capacitance b/w A & B.

∴ Ans. 1μF

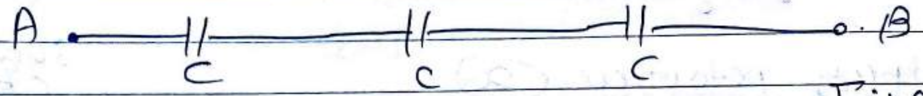
Q:- 

Energy stored in 1μF.

a) 40μJ
b) 64μJ
c) 32μJ
d) 80μJ

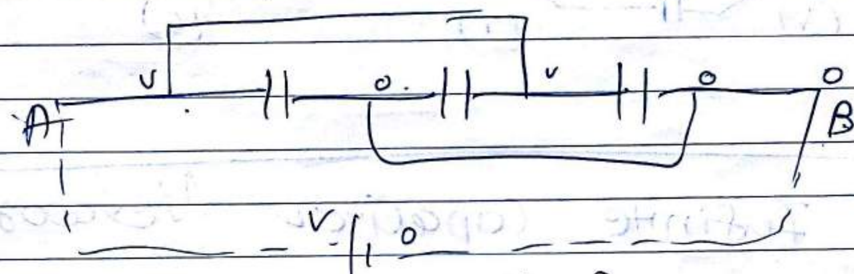
* combination of capacit continue ----

i) wired connection problem

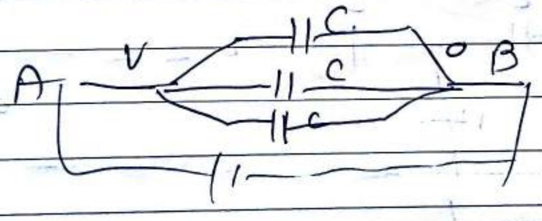
Q:- 

Find eq. capo. b/w A&B

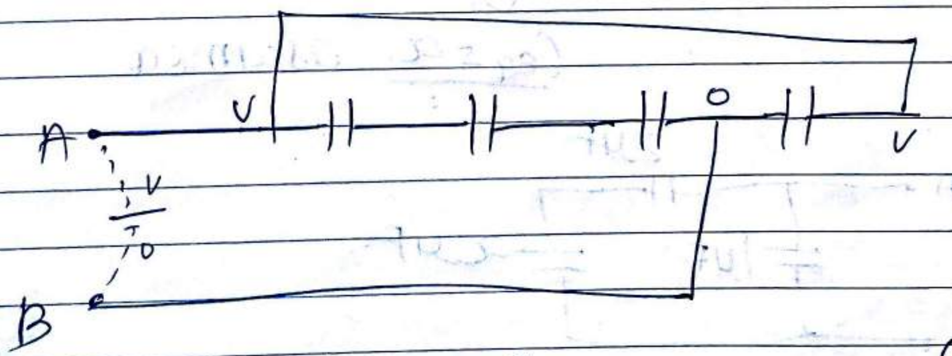
$= C/3$

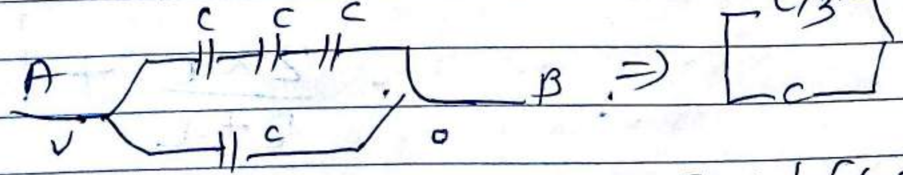
if 

(img Battrs.)



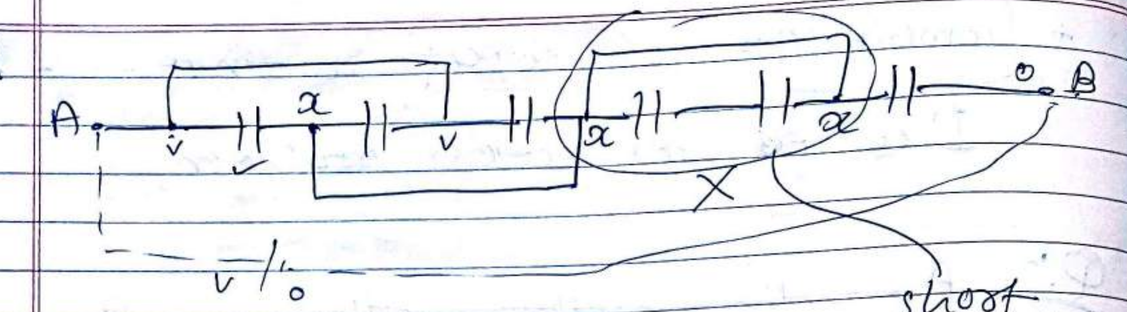
$\Rightarrow \underline{3C}$

Q:- 



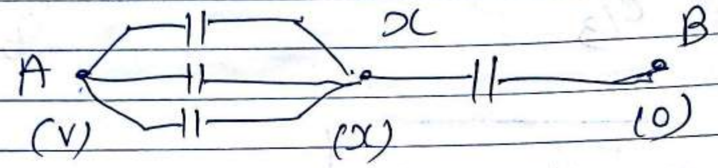
$= C + C/3 = \frac{4C}{3}$

(3).

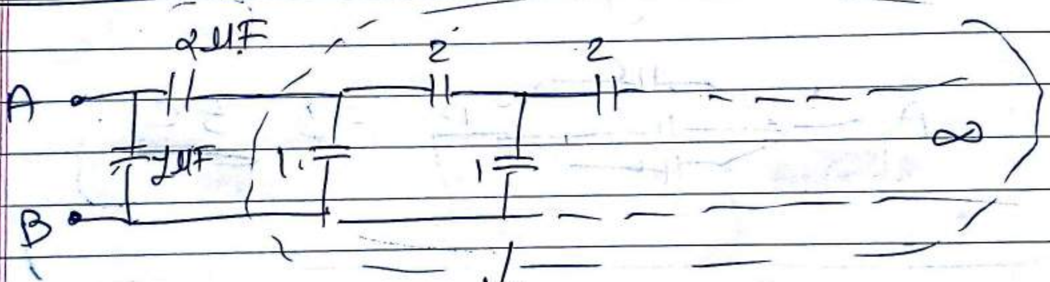


short ckted.

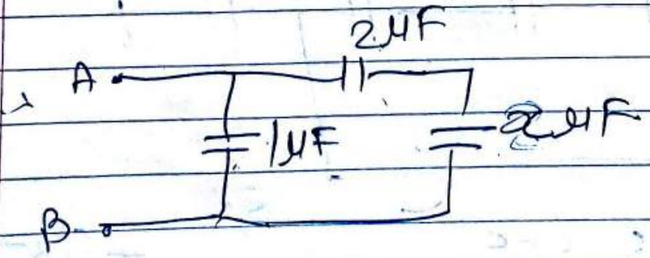
imaginary potential (x)



Type:-2 Infinite capacitor Network :-



$C_{eq} = x$. assumed



whole

$$\frac{2\times x}{2+x} + 1 = C_{eq}$$

$$\therefore \frac{2x}{2+x} + 1 = x$$

$$\therefore x = \frac{2+x+2x}{(2+x)} = \frac{2+3x}{2+x}.$$

$$\therefore 2x + x^2 = 2+3x.$$

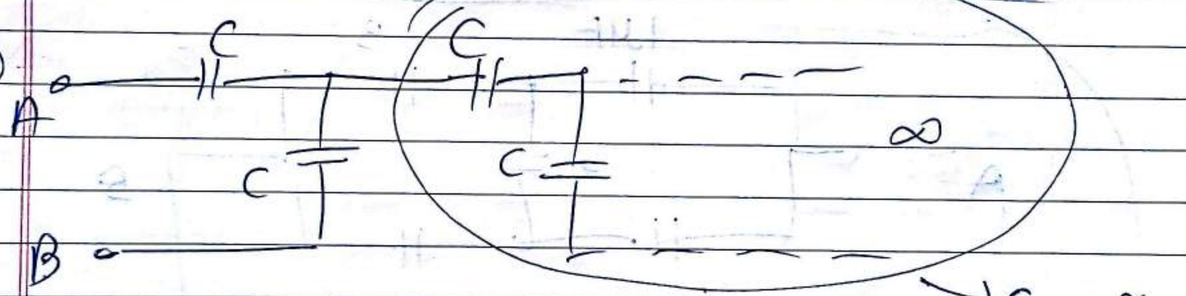
$$\therefore x^2 - x - 2 = 0 \leftarrow \therefore x^2 - 2x + x - 2 = 0.$$

$$\rightarrow x(x-2) + 1(x-2) = 0$$

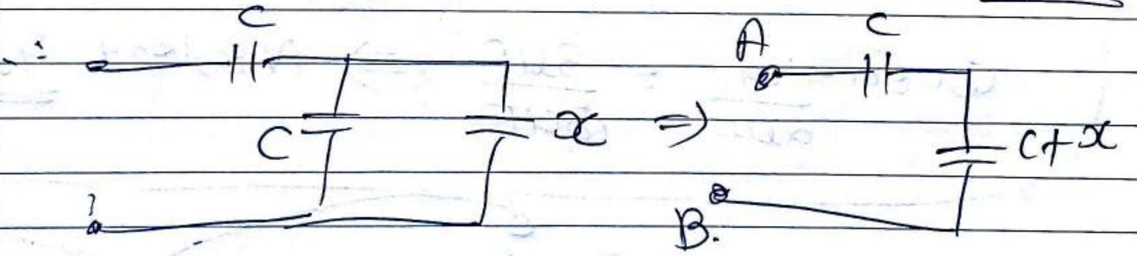
$$\therefore x = 2 \text{ or } \cancel{x = -1}$$

$$\boxed{\therefore x = 2\,\mu F}$$

(2)



$\rightarrow C_{eq} = x$



$$\frac{(c+x)c}{c+c+x} = C_{eq} \downarrow x$$

$$\therefore \frac{cx+c^2}{2c+x} = x$$

$$\therefore \cancel{c^2 + cx = 2cx + x^2}$$

$$c^2 + cx = 2cx + x^2$$

$$\therefore x^2 + 2cx - cx - c^2 = 0$$

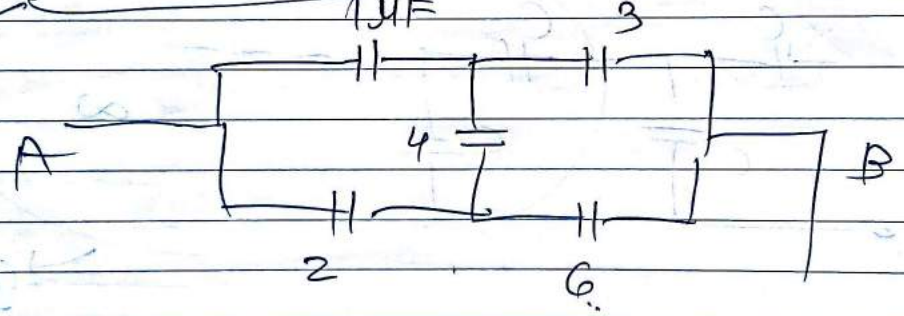
$$\therefore \boxed{x^2 + cx - c^2 = 0}$$

$$x = \frac{-c \pm \sqrt{c^2+4c^2}}{2}$$

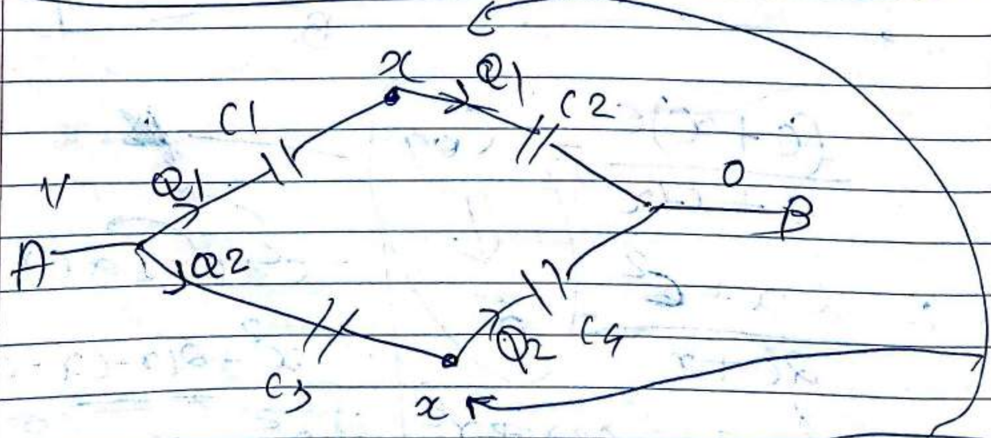
$$x = \frac{-c \pm c\sqrt{5}}{2} \rightarrow +ve$$

$$\therefore x = \frac{-c+\sqrt{5}c}{2} = \frac{c(\sqrt{5}-1)}{2}$$

Type: 3 Wheatstone Bridge :-



When $\frac{1\mu F}{2\mu F} = \frac{3\mu F}{6\mu F} \Rightarrow$ Neglect $4\mu F$



suppose at edge potential is same

$$C_1 \Rightarrow \quad (V-x) = \frac{Q_1}{C_1}$$
$$C_3 \Rightarrow \quad (V-x) = \frac{Q_2}{C_3}$$

i.e. $\frac{Q_1}{C_1} = \frac{Q_2}{C_3}$

$$\therefore \boxed{\frac{Q_1}{Q_2} = \frac{C_1}{C_3}}$$

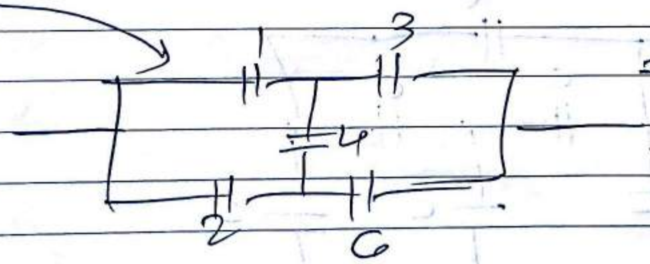
similarly

$$(x-0) = \frac{Q_1}{C_2}$$
$$(x-0) = \frac{Q_2}{C_4}$$

$$\boxed{\frac{Q_1}{Q_2} = \frac{C_2}{C_4}}$$

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

Q:-

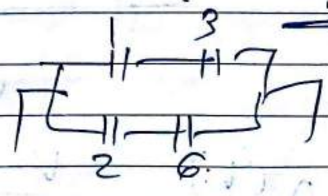


$\Rightarrow$ i.e. $\frac{C_1}{C_3} = \frac{C_2}{C_4}$

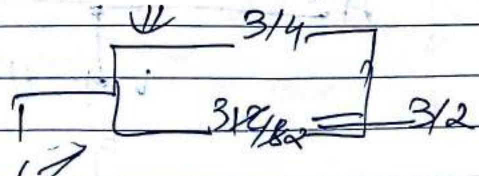
$\therefore \frac{1}{2} = \frac{1}{2}$

$\therefore$ i.e. Neglect $4\mu C$

$\therefore C_e =$

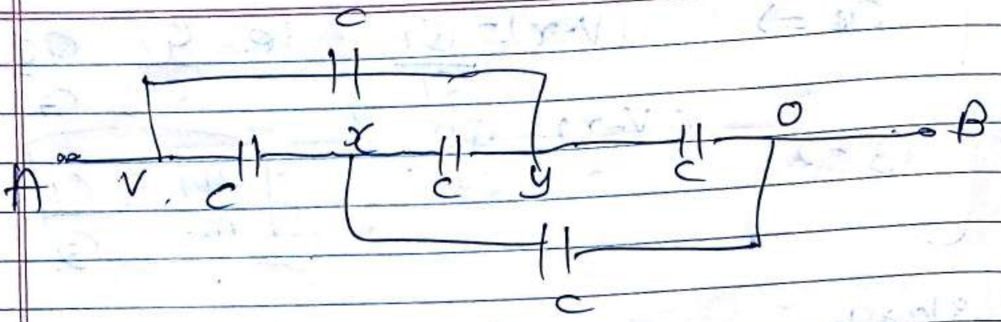


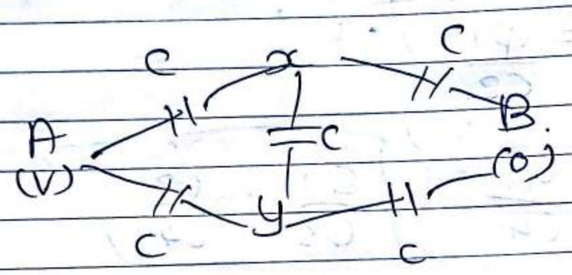
$\therefore C_e$



$$C_e = \frac{3}{4} + \frac{3}{2} = \frac{9}{4} = \boxed{2.25\,\mu F}$$

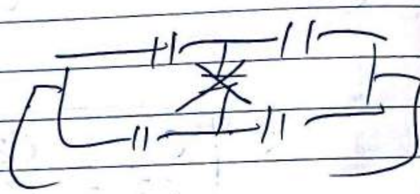
(2)





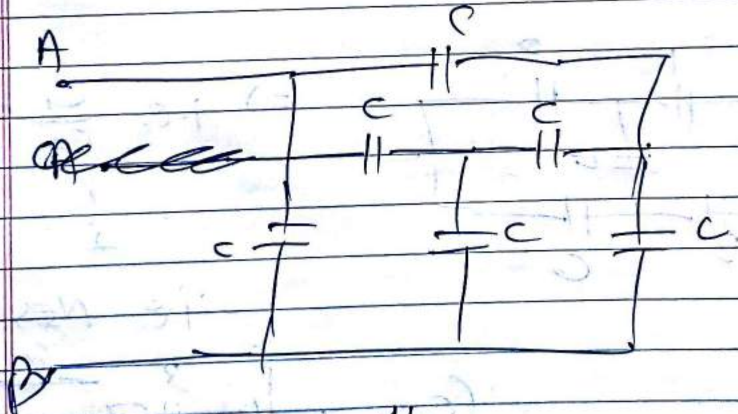
wheetstone

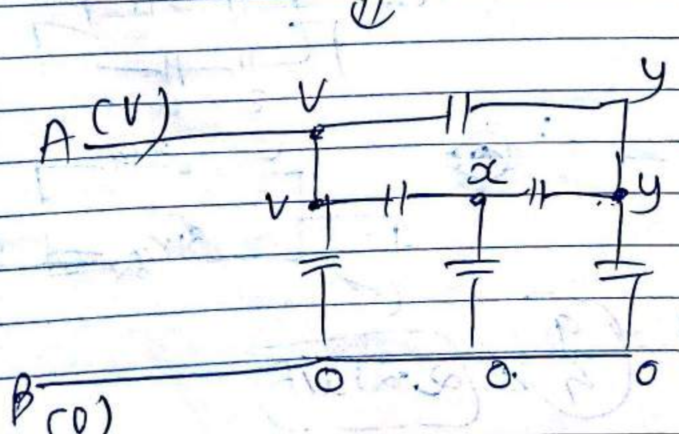
i.e



$\boxed{C_{eq} = C}$

(3.)

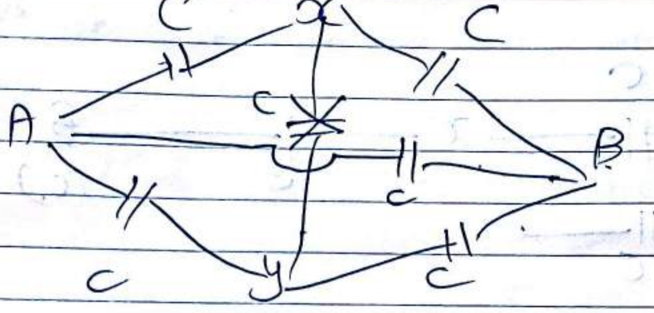




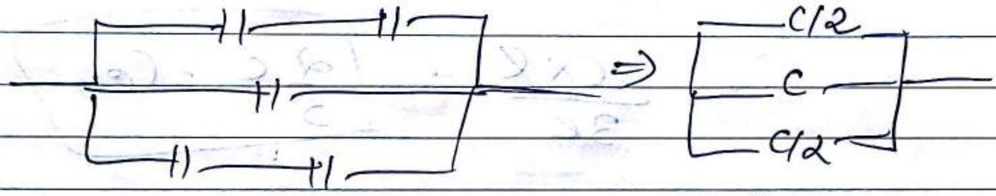
$\boxed{\text{Type } 4.}$

* Fin

∴



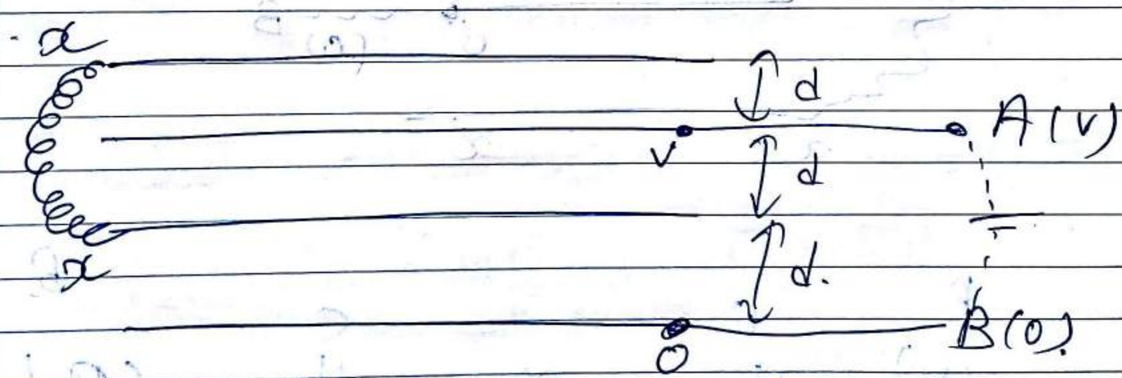
⇓



⇓

$\underline{2C}$

$\boxed{\text{Type 4.}}$ Parallel plates Problem :-

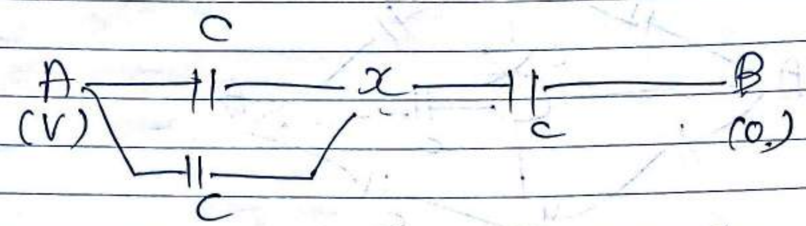


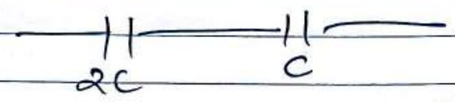
* Find Equi. capa. b/w A & B

(1) Area of All plate = A
(2) dist b/w each plate = d.

} kept in air.

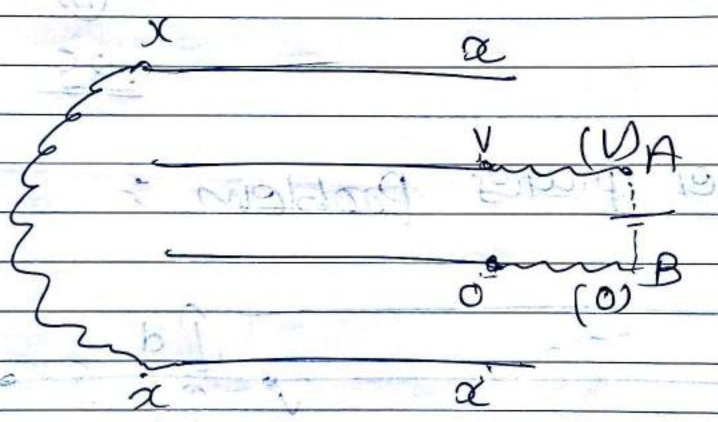
$C = \frac{\varepsilon_0 A}{d}$

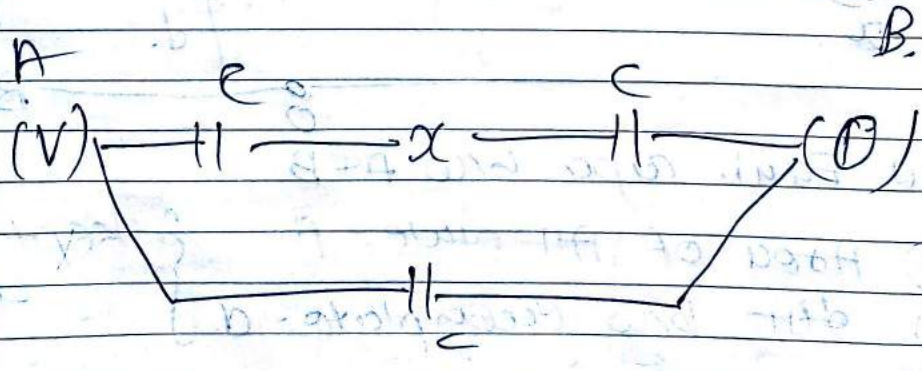




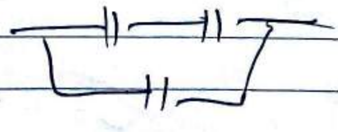
$\therefore \frac{2C \times C}{3C} = \boxed{\frac{2}{3} C = C_{eq}}$

(2)





$\Rightarrow$



* Effect of Dielectrics in Capacitors :-

Dielectric → Don't Allow current to flow
Allow development of $\vec{E}$ field.

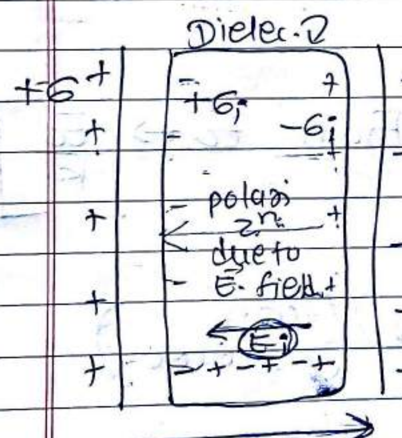
↓

Non-conductor   i.e. glass, mica.

(i.e. conductor ✗
insulator ✗
semicond. ✗)

→ Electric field polarizes Dielectric material.

→ Use. → CT.
→ plates are remain separated.



External E field due to plates.

- due to Ext $\vec{E}$. Dielec. material polarized.
- Hence, it also produces Induced Elec field (i.e charges separated.)
- E_i opposes E_0. $(E_0 > E_i)$

$$\boxed{E_{NET} = E_0 - E_i}$$

b/w plates.

- K = dielectric constant: (Every Dielectric material has this.)
  (property of material.)

↓

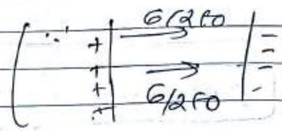
→ No. of times it decreases, $\vec{E}_{Net}$ field is called as Dielec. no.

(i.e. $E_0 = 10$ $E_i = 5$ ⇒ $E_{NET} = 10 - 5 = \underline{5}$

i.e. $E_{NET} = \dfrac{E_0}{K}$ ⇒ $5 = \dfrac{10}{K}$ ∴ $\boxed{K = 2}$)

Hence, $\vec{E}_{net}$ Reduces due to Dielectric

→ $\boxed{E_0 = \frac{\sigma}{\epsilon_0}}$ (original $\vec{E}$ field)



$\therefore$ $E_{NET} = E_0 - E_i$

$\therefore \frac{E_0}{K} = \frac{\sigma}{\epsilon_0} - \frac{\sigma_i}{\epsilon_0}$

(σ_i = induced charge density. i.e. due to induced charge in dielec. material)

$\therefore \frac{\sigma}{\cancel{\epsilon_0} K} = \frac{\sigma}{\cancel{\epsilon_0}} - \frac{\sigma_i}{\cancel{\epsilon_0}}$

$\therefore \frac{\sigma}{K} = \sigma - \sigma_i$

$\therefore \boxed{\sigma_i = \sigma\left(1 - \frac{1}{K}\right)}$

Hence; ① $\left[\vec{E} \text{ decreases From } E_0 \rightarrow \frac{E_0}{K} \right]$

P.D. initial $(V_0 = E_0 \times d)$ (w.o. Dielec.)

Final: $V = E\,d$

$= \frac{E_0}{K} d$ (with dielec.)

$\boxed{V = \frac{V_0}{K}}$

Hence: ② $\left[V \downarrow \text{ From } V_0 \rightarrow \frac{V_0}{K} \right]$

Capacitance :- $\boxed{C = \frac{Q}{\Delta V}}$

$\therefore$ $\boxed{C_0 = \frac{Q}{V_0}}$ (w.o. dielec.) $\Rightarrow$ $C = \frac{Q}{V} = \frac{Q}{\left(\frac{V_0}{k}\right)} = \frac{kQ}{V_0}$

$\therefore$ $\boxed{C = k\, C_0}$

Hence; $C \uparrow \Rightarrow$ From $C_0 \rightarrow C = kC_0$
i.e. Increased capacity of storage.

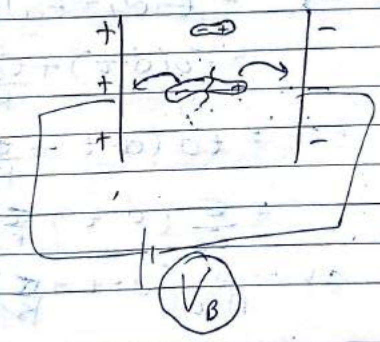
Note :- $\vec{E}$ decreases to $\frac{E_0}{k}$

V " $\frac{V_0}{k}$

C increases to kC_0

ADVANTAGE :-

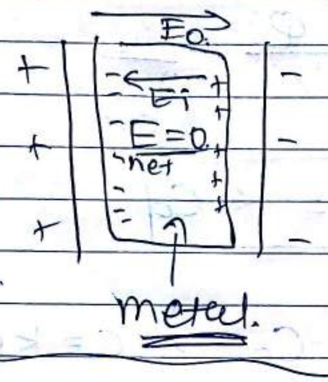
① Provides stability to plates
② Prevents plates from sticking each other.
③ $C\uparrow$.
⑤ can prevent breakdown of medium



(Use such dielectric which has high B.d. voltage.)

$(K)_{vacume} = \underline{1}.$

Q:- For Metals/conductors correct value of K ?



in metals

$E_{net} = \frac{E_0}{K}$

$\therefore 0 = \frac{E_0}{K}$

$\therefore \boxed{K = \infty}$

→ $\sigma_i = ?$

$\therefore \sigma_i = \sigma\left(1 - \frac{1}{K}\right) = \sigma\left(1 - \frac{1}{\infty}\right) = \sigma$

$\boxed{\sigma_i = \sigma}$

same.

→ In Metals $E_0 = E_i$

Capacitor with Partially filled Dielectric :-

imp

$\therefore \Delta V = E\,d$

$= E_1 d_1 + E_2 d_2$

$= E_0(d-t) + \frac{E_0}{K}t$

$= E_0\left(d - t + \frac{t}{K}\right)$

$= \frac{\sigma}{\epsilon_0}\left(d - t + \frac{t}{K}\right)$

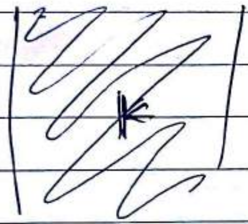
$\Delta V = \frac{Q}{A\epsilon_0}\left(d - t + \frac{t}{K}\right)$

For metal $K \to \infty$

$\therefore \Delta V = \frac{Q}{A\epsilon_0}\left(d - t + \frac{t}{K}\right)$

$\therefore C = \frac{Q}{\Delta V} = \boxed{\frac{A\epsilon_0}{\left(d - t + \frac{t}{K}\right)} = C}$ $\left(\because Q = CV \quad C = \frac{Q}{V}\right)$

$C > C_0$

(ii)  $\Rightarrow$ $C = KC_0$

$\boxed{C = K\frac{\epsilon_0 A}{d}}$

→ Fig. A shows two capacitor are in series (C_1 & C_2)

In air/vacuum $\boxed{C_1 = \frac{\epsilon_0 A}{(d-t)}}$; dielectric : $\boxed{C_2 = K\frac{\epsilon_0 A}{t}}$

→ In series :- $\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2}$

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

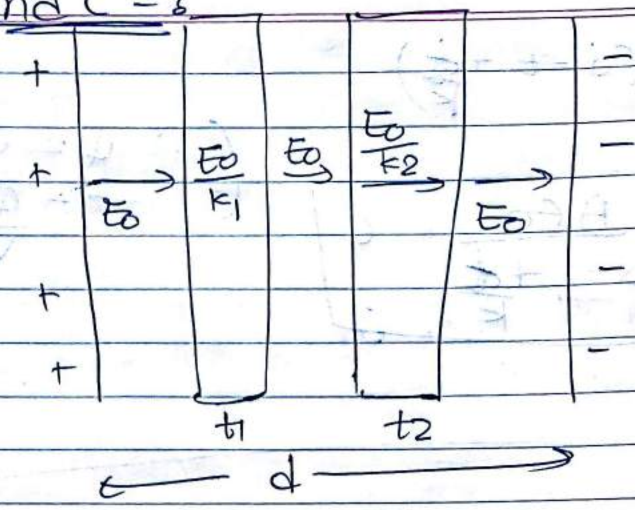
$= \frac{d-t}{\epsilon_0 A} + \frac{t/K}{\epsilon_0 A}$

$\boxed{\frac{1}{C_e} = \frac{d-t+t/K}{\epsilon_0 A}}$

$\therefore \boxed{C_e = \frac{\epsilon_0 A}{d-t+t/K}}$

Find $C = ?$

Q:-



$\Delta V = E d$

$= \underbrace{E_1 d_1}_{(air)} + \underbrace{E_2 d_2}_{(k_1)} + \underbrace{E_3 d_3}_{(k_2)}$

$= E_0(d - t_1 - t_2) + \left(\frac{E_0}{k_1} \cdot t_1\right) + \left(\frac{E_0}{k_2} \cdot t_2\right)$

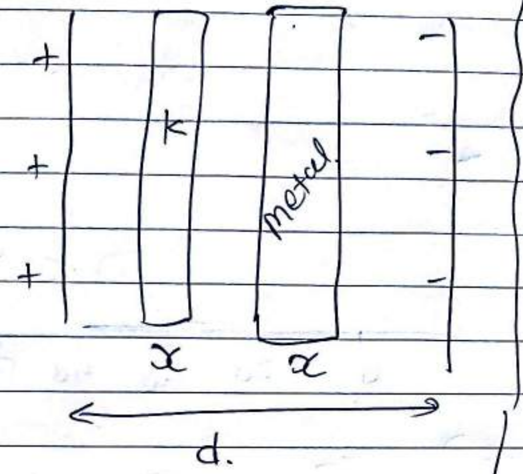
$= E_0\left(d - t_1 - t_2 + \frac{t_1}{k_1} + \frac{t_2}{k_2}\right)$

$\Delta V = \frac{Q}{A\epsilon_0}\left(\quad '' \quad \right)$

$\therefore C = \frac{A\epsilon_0}{(d - t_1 - t_2) + \left(\frac{t_1}{k_1} + \frac{t_2}{k_2}\right)}$

For n $\Rightarrow$ $\boxed{C = \frac{\epsilon_0 A}{(d - t_1 - t_2 - \cdots - t_n) + \left(\frac{t_1}{k_1} + \frac{t_2}{k_2} + \cdots + \frac{t_n}{k_n}\right)}}$

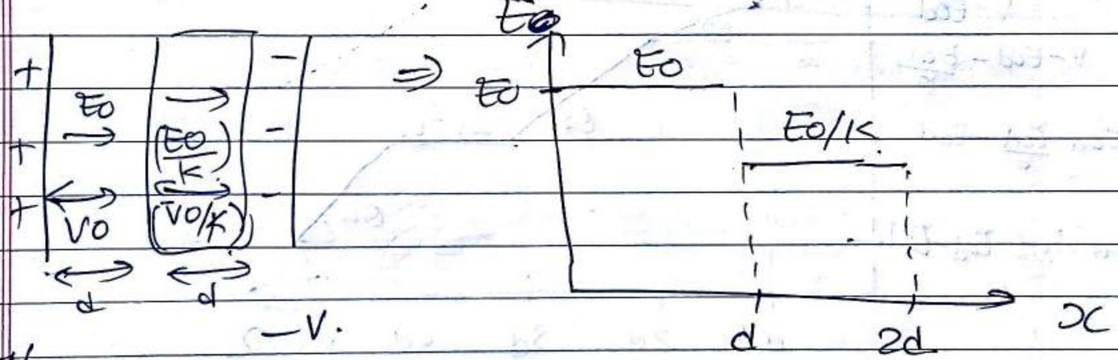
Q:- Find $c = ?$

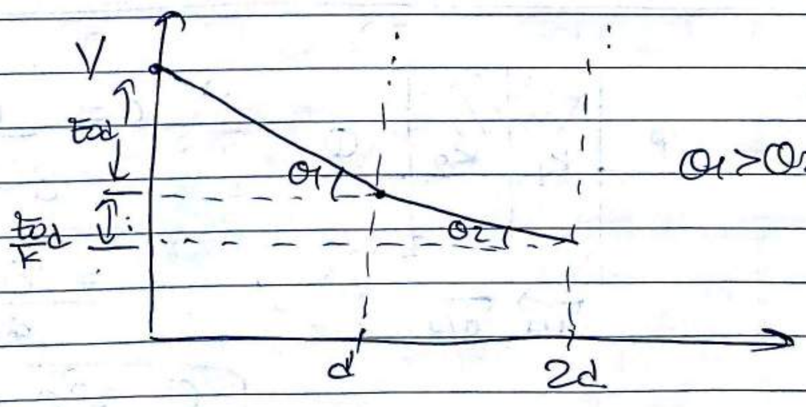


$$C = \frac{\epsilon_0 A}{(d-2x) + \left(\frac{x}{K} + \frac{x}{\infty}\right)}$$

$$= \frac{\epsilon_0 A}{d - 2x + \frac{x}{K}}$$

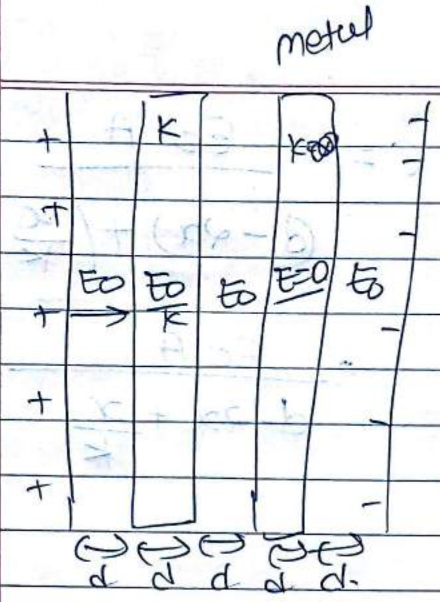
Graph $E \to x$

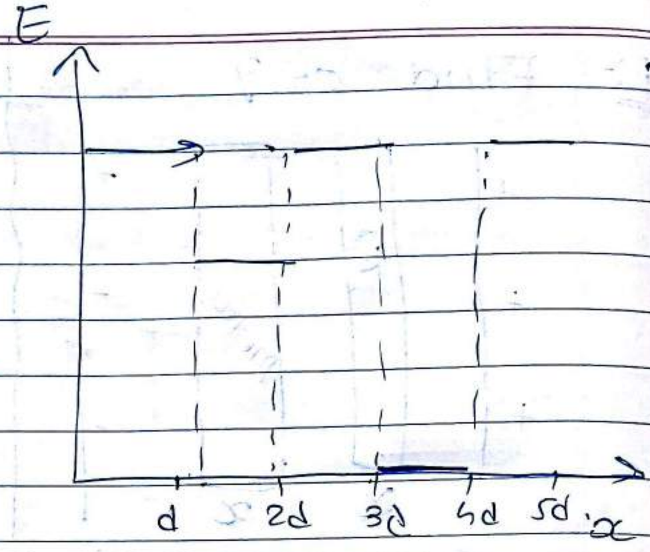




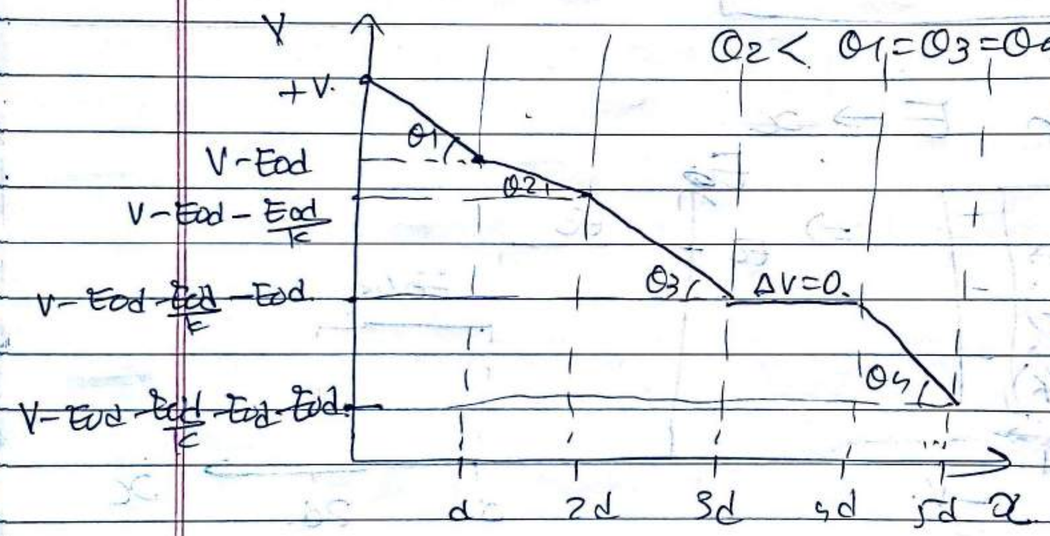
$\theta_1 > \theta_2$.

Q:-

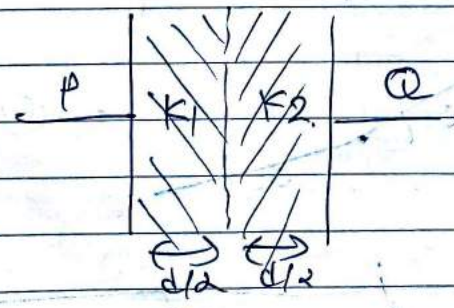




$\theta_2 < \theta_1 = \theta_3 = \theta_4$



Q:-



$$C = \frac{\varepsilon_0 A}{\cancel{d} - \cancel{\left(\frac{d}{2}\right)} - \cancel{\left(\frac{d}{2}\right)} + \left(\frac{d}{2K_1}\right) + \left(\frac{d}{2K_2}\right)}$$

$$= \frac{\varepsilon_0 A \quad 2}{\frac{d}{K_1} + \frac{d}{K_2}}$$

$$\boxed{C = \frac{2\varepsilon_0 A}{\frac{dK_2 + dK_1}{K_1 K_2}}}$$

(Both capa. are in i.e. series.)

$$C_1 = \frac{\varepsilon_0 A K_1}{(d/2)}$$
$$C_2 = \frac{\varepsilon_0 A K_2}{(d/2)}$$

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\therefore \quad = \frac{1}{\frac{\varepsilon_0 A K_1}{d/2}} + \frac{1}{\frac{\varepsilon_0 A K_2}{(d/2)}}$$

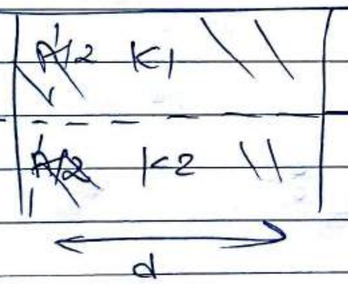
$$= \frac{d}{2\varepsilon_0 A K_1} + \frac{d}{2\varepsilon_0 A K_2}$$

$$= \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

$$\frac{1}{C_e} = \frac{d}{2\varepsilon_0 A}\left(\frac{K_2 + K_1}{K_1 K_2}\right)$$

$$\boxed{C_e = \frac{2\varepsilon_0 A}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)}$$

Q:-



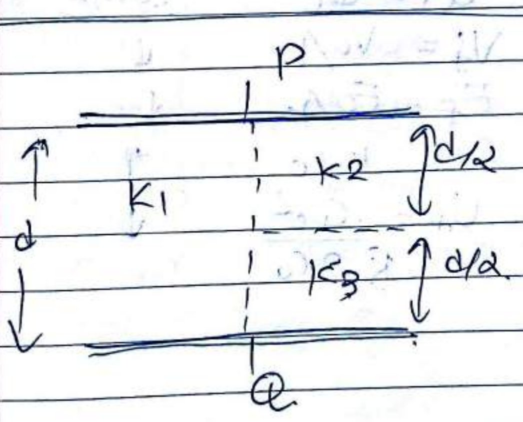
Both are in parallel.

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

$$= \frac{\varepsilon_0 A/2 \, K_1}{d} + \frac{\varepsilon_0 \frac{A}{2} K_2}{d}$$

$$C_{eq} = \frac{\varepsilon_0 A (K_1 + K_2)}{2d}$$

Q:-

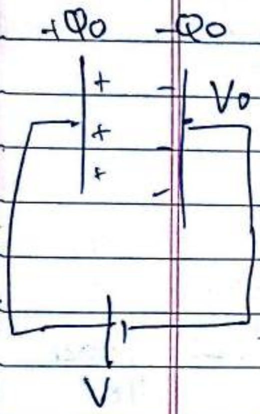


Here 3 capacitors.
C_2 & C_3 are in parallel
$\therefore C_{eq} = C_2 + C_3$ is
in series with C_1.

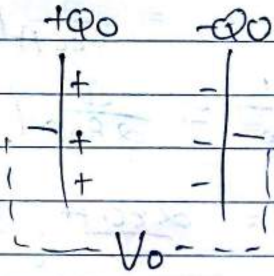
* Battery Connected/Removed & Dielectric Inserted :

Case-I :- Battery Removed & Dielectric Inserted

(connect a cell)



⇒ Removed a cell.



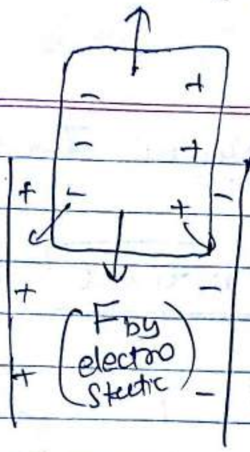
⇒ Q = constant after removed from Battery

Now;

⇒ Insert Dielectric slab :-

Before inserted	After Inserted	
→ $Q_i = Q_0$	→ $Q_f = Q_0$	const
→ $V_i = V_0$	→ $V_f = V_0/k$	↓
→ $E_i = E_0$	→ $E_f = E_0/k$	↓
→ $C_i = C_0$	→ $C_f = kC_0$	↑
→ $U_i = \frac{Q_0^2}{2C_0}$	→ $U_f = \frac{Q_0^2}{(k)2C_0}$	↓

F_{ext} (by external agent to remove/avoid acceleration of dielectric.



$\therefore$ w.d. by external agent

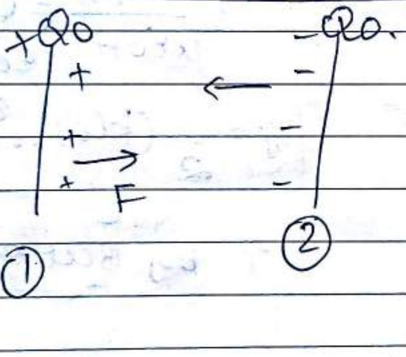
$\therefore W_{ext} = F_{ext}(-x)$

$= -ve.$

i.e. $\boxed{\text{work is obtained.}}$

$$\left(W_{ext} = \Delta U = U_f - U_i = \frac{Q_0^2}{2KC_0} - \frac{Q_0^2}{2C_0} = \boxed{\frac{Q_0^2}{2C_0}\left(\frac{1}{K} - 1\right) = W_{ext}} \right)$$

$\boxed{\text{Force on Plates}}$:-



• Force on ② due to ①

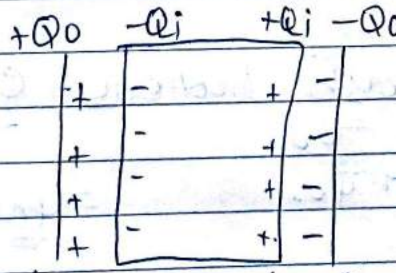
$\therefore F_{21} = qE_{21}$

$= Q_0\left(\frac{\sigma}{2\varepsilon_0}\right)$

$= Q_0\left(\frac{Q_0}{2A\varepsilon_0}\right) = \boxed{\frac{Q_0^2}{2A\varepsilon_0} = F_{21}}$

Initial i.e. $\boxed{F_i = \frac{Q_0^2}{2\varepsilon_0 A}}$

After.

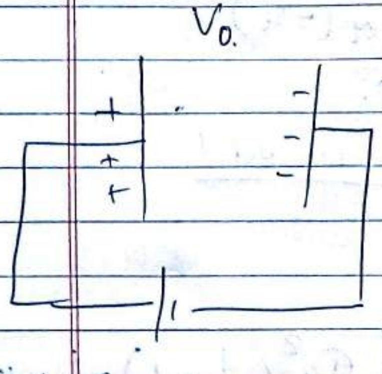


$\therefore \vec{E}$ on 2 due to 1, 3 & 4.

$$\vec{E}_2 = \underset{\rightarrow}{\frac{Q_0}{2\varepsilon_0 A}} - \underset{\leftarrow}{\frac{\cancel{Q_i}}{2\varepsilon_0 A}} + \underset{\rightarrow}{\frac{\cancel{Q_i}}{2\varepsilon_0 A}}$$

$$\vec{E}_2 = \frac{Q_0}{2\varepsilon_0 A} \Rightarrow \boxed{F_f = \frac{Q_0^2}{2\varepsilon_0 A}} = \text{Remain same.}$$

case :(II) Battery connected & Dielec. Inserted

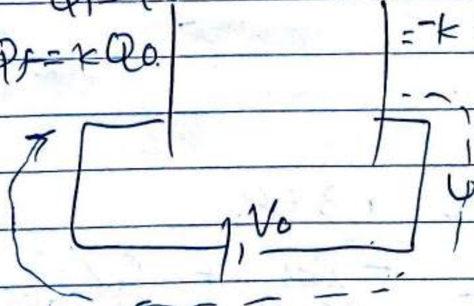


Here; $\boxed{V = \text{constant}}$

Before k	After k
$C_i = C_0$	$C_f = kC_0 \uparrow$
$V_i = V_0$	$V_f = V_0 \Rightarrow \boxed{\text{const}}$
$Q_i = Q_0$	$Q_f = CV = C_0 k V_0 = kQ_0 \uparrow$
$E_i = E_0 = \frac{Q_0}{\epsilon_0 A}$	$E_f = \frac{kQ_0}{k\epsilon_0 A} = \frac{Q_0}{\epsilon_0 A}$ same
$U_i = \frac{1}{2} C_0 V_0^2$	$U_f = \frac{1}{2}(kC_0)V_0^2 \uparrow$ (↑ by Battery)

(Wext = Fext(−x) = −ve obtained by Battery)

charge supplied through battery $= Q_0 k - Q_0 = Q_0(k-1)$



w.d. by Battery $= qV = Q_0(k-1)V_0$

$\boxed{W_{Batt} = Q_0 V_0 (k-1)}$

$= C_0 V_0^2 (k-1)$

classmate
Date ______
Page ______

$\left\{ \Delta U = U_f - U_i = \frac{1}{2} C_0 V_0^2 (K-1) \right\} \rightarrow$ given to capacitor

other Half gone to past ext. Agent $\Big\}$ $\boxed{W_{ext} = -\frac{1}{2} C_0 V_0^2 (K-1)}$

Q:- Batt. conn. Inserted dielec., in this condn. w.d. by Batter is 2 J. what is chge in P.E. of dielec.?
$\Rightarrow$ Half = 1 J

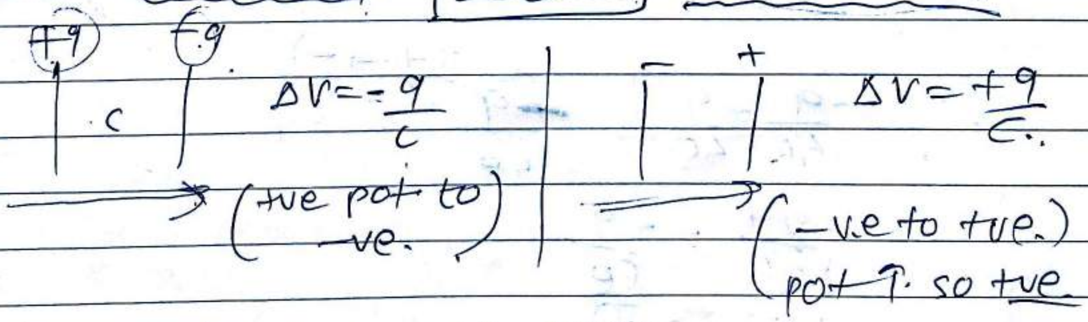
other Half $\rightarrow$ 1 J to $\uparrow$ Energy of capacitor

---

All q. are solvable.

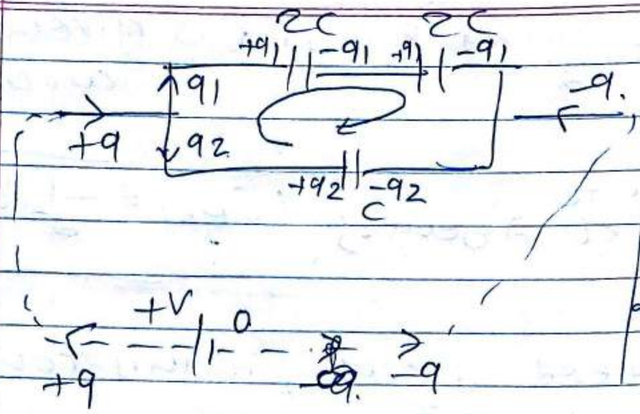
Q.1 **CHARGE Distribution Method :-**

① connect img... cell.
②. Take +q charge from +ve ter of cell. −q from −ve ter of cell to ckt.
③ Distribute charge on each capa.
④ For closed loop $\boxed{\Sigma \Delta V = 0}$ (K. 2nd law)



⑤ Find charge on all capa.
⑥ choose 1 path from +ve to −ve terminus of cell
⑦ Ecalculate $\Sigma \Delta V$ along one path
Eqvate this $\boxed{\Sigma \Delta V = \frac{q}{C_e}}$

Q.1



$\boxed{q_1+q_2=q}$ — (1)

→ Closed loop : $\Sigma \Delta V = 0$

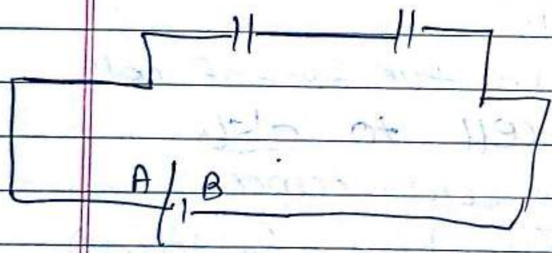
$\therefore -\frac{q_1}{2C} - \frac{q_1}{2C} + \frac{q_2}{C} = 0$

$-\frac{q_1}{C} + \frac{q_2}{C} = 0$

$\therefore \boxed{q_1=q_2}$ — (2)

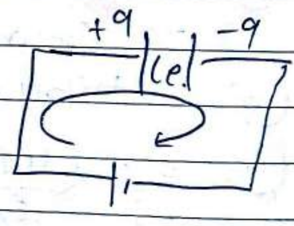
i.e. $q_1 = q_2 = \boxed{\frac{q}{2}}$ → on each capa.

→ 1 path :-



$\therefore \frac{-q/2}{2C} - \frac{q/2}{2C} = \pm \frac{q}{C_e}$

i.e.

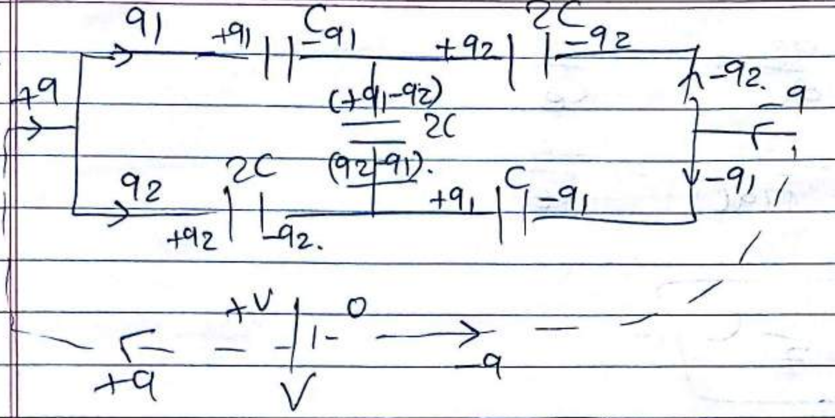


$\therefore -\frac{q}{4C} - \frac{q}{4C} = \cancel{+}\frac{q}{C_e}$ $(+ \to -)$

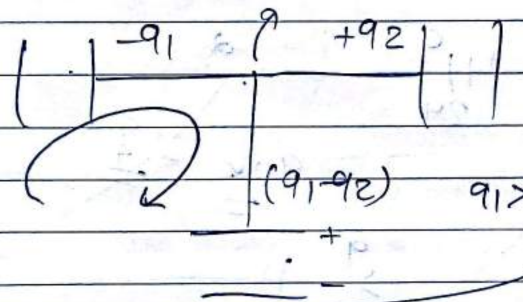
$\therefore \frac{\cancel{2}q}{\cancel{4}C} = \frac{q}{C_e}$

$\therefore \boxed{C_e = 2C}$

Q.2.



Net charge = 0.



$q_1 > q_2$ assumed.

→ Closed loop :- $\Sigma \Delta V = 0$.

i.e. $\boxed{q_1 + q_2 = q}$ — (i)

$$-\frac{q_1}{C} - \frac{(q_1 - q_2)}{2C} + \frac{q_2}{2C} = 0$$

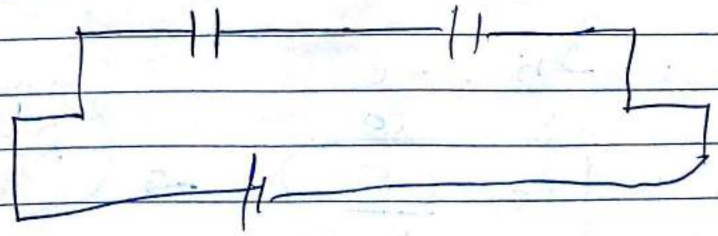
assumed $q_1 > q_2$.

$\boxed{q_2 = \frac{3}{2} q_1}$ — (ii)

$\therefore \boxed{q_1 = \frac{2}{5} q}$ — (A)

$\therefore q_2 = \frac{\cancel{2}}{5} \times \frac{3}{\cancel{2}} q = \boxed{\frac{3}{5} q = q_2}$ — (B)

→ 1 path :-



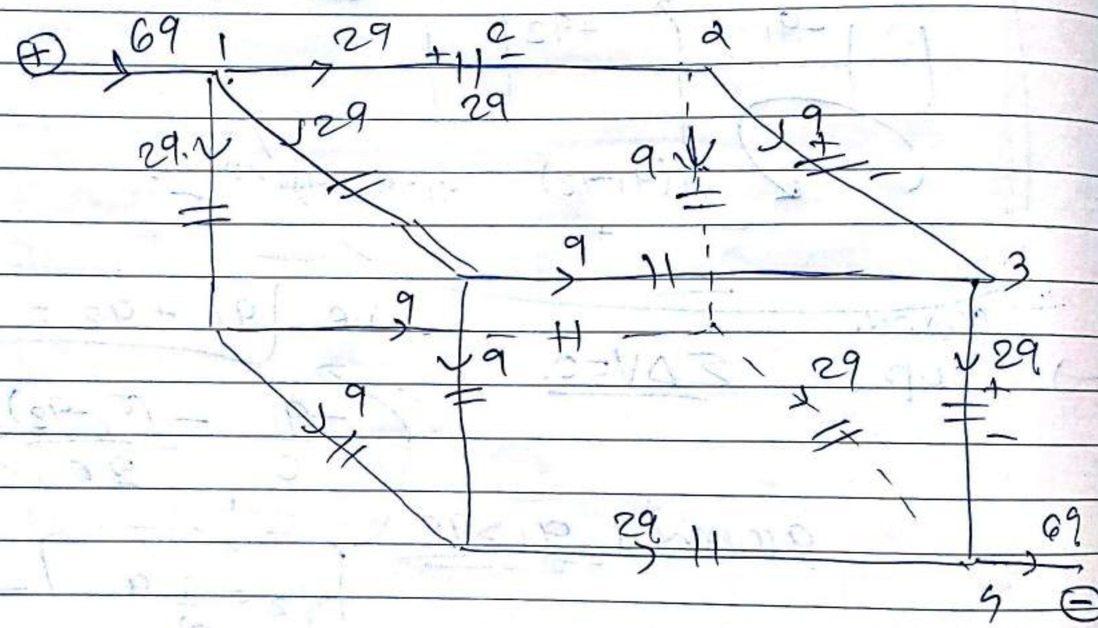
$$\therefore -\frac{q_1}{C} - \frac{q_2}{2C} = -\frac{q}{C_e}$$

$$\therefore -\frac{2q}{5C} - \frac{3q}{5(2C)} = -\frac{q}{C_e}$$

$$\therefore \boxed{C_e = \frac{10}{7} C}$$

all are C

Q:-



→ 1234 path :-

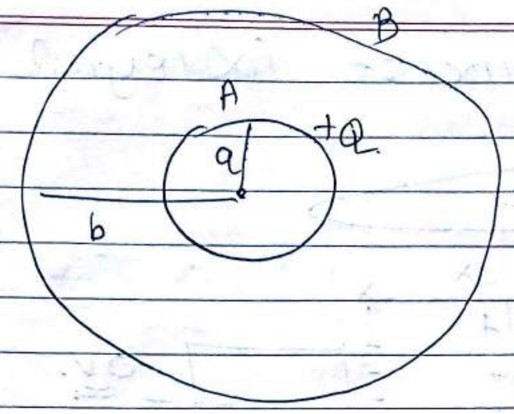
$$\therefore -\frac{2q}{C} - \frac{q}{C} - \frac{2q}{C} = -\frac{6q}{C_e}$$

$$\therefore \frac{-2-1-2}{C} = \frac{-6}{C_e}$$

$$\therefore \frac{+5}{C} = \frac{+6}{C_e}$$

$$\therefore \boxed{C_e = \frac{6C}{5}} \Rightarrow R_{eq} \Rightarrow \frac{5}{6} R$$

Q:-



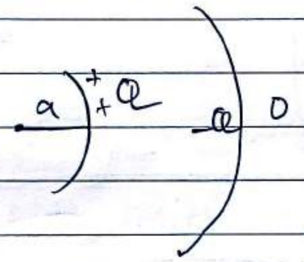
$V_B = 0$.

$\therefore \frac{kQ}{b} + \frac{kq}{b} = 0$

$\therefore \boxed{Q = -q}$

$\boxed{q_B = -Q}$

i.e.



Here; $V_B = 0$

$E_{inside\ a} = 0$

$E_{inside\ b} = 0$

i.e. $\vec{E}$ is only b/w 2 spheres i.e. Bounded.

$$\therefore C = \frac{Q}{V_A - V_B} = \frac{Q}{V_A}$$

$$C = \frac{Q}{\frac{kQ}{a} + \frac{k(-Q)}{b}} = \frac{\cancel{Q}}{k\cancel{Q}\left(\frac{1}{a} - \frac{1}{b}\right)}$$

$$C = \frac{1}{\frac{1}{4\pi\epsilon_0}\left(\frac{b-a}{ab}\right)}$$

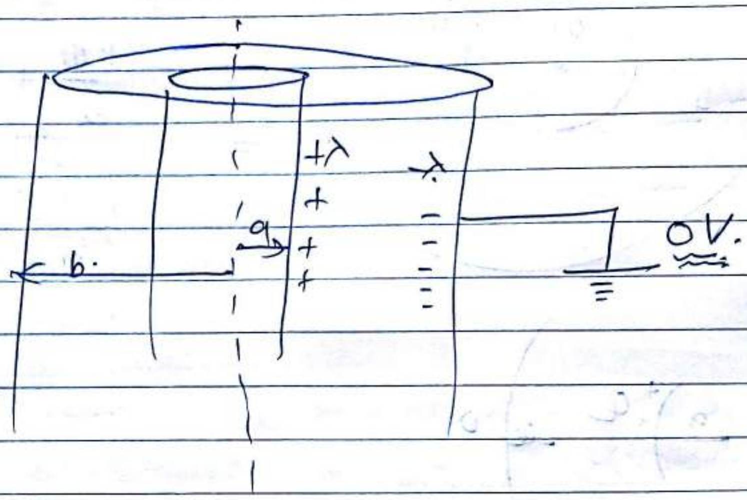
$$\boxed{C = \frac{4\pi\epsilon_0 (ab)}{(b-a)}}$$

classmate

Date

Page

* Cylindrical capa :- (∞ length)



$$\therefore C = \frac{Q}{\Delta V} = \frac{\lambda l}{\Delta V}$$

$$\boxed{\frac{C}{l} = \frac{\lambda}{\Delta V} = \text{capa. per unit length}}$$

$$|\Delta V| = \int E \cdot dr = \int_a^b \frac{\lambda}{2\pi\epsilon_0 r} \, dr = \frac{\lambda}{2\pi\epsilon_0} \int_a^b \frac{1}{r} \, dr$$

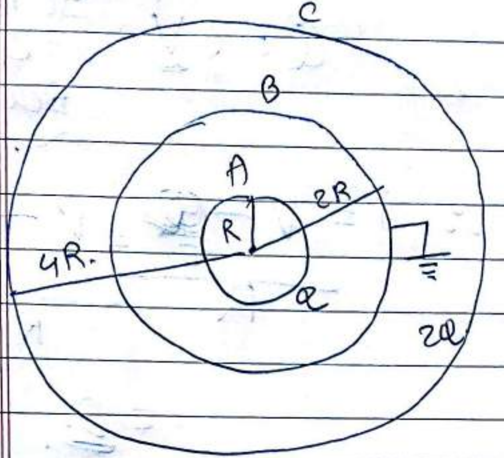
$$= \frac{\lambda}{2\pi\epsilon_0} [\log r]_a^b = \frac{\lambda}{2\pi\epsilon_0} \log_e \frac{b}{a}$$

$$\therefore \frac{C}{l} = \frac{\lambda}{\frac{\lambda}{2\pi\epsilon_0} \log_e \frac{b}{a}}$$

$$\boxed{\frac{C}{l} = \frac{2\pi\epsilon_0}{\log_e (b/a)}}$$

$q_B = ?$

Q:-



$\therefore V_B = 0$

$\therefore V_{B_A \, out} + V_{B \, surf} + V_{B \, inside}^{C} = 0$

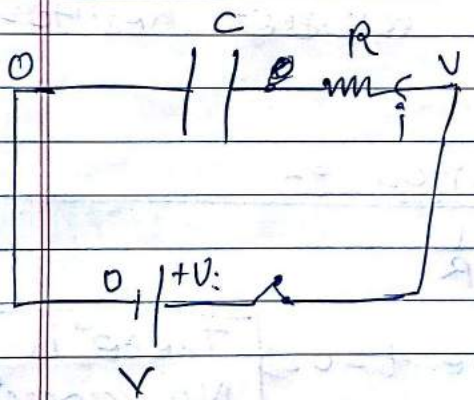
$\therefore \frac{kQ}{2R} + \frac{kq}{2R} + \frac{k(2Q)}{4R} = 0$

$\therefore Q + q + \frac{1}{2} 2Q = 0$

$\therefore 2Q = -q$

$\therefore \boxed{q = -2Q}$

* Circuit with Capa + Resistor :-

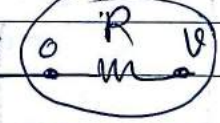


• initial → switch is closed:

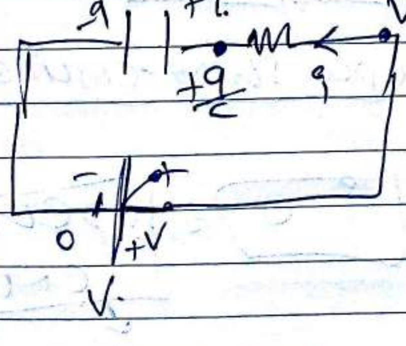
$\hookrightarrow t=0 \Rightarrow (q=0)_{capa.}$

$\rightarrow \therefore (\Delta V)_C = \frac{q}{C} = 0 \ldots$

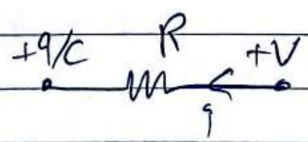
$\rightarrow \therefore \boxed{i = \frac{V}{R}}$



at $t = t$



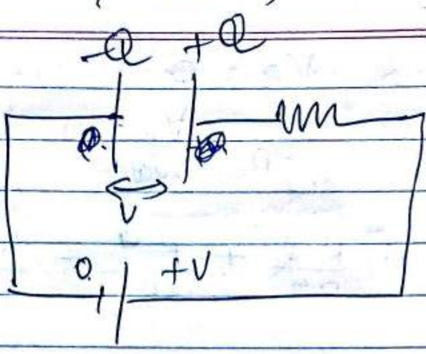
$\Rightarrow$



$\boxed{i = \frac{V - \frac{q}{C}}{R}}$ ↓

completely charged

$t=\infty$



$Q = C\underline{V}$ same as Battery

$\therefore i = \dfrac{V - \frac{Q}{C}}{R} = \dfrac{V - \frac{CV}{C}}{R}$

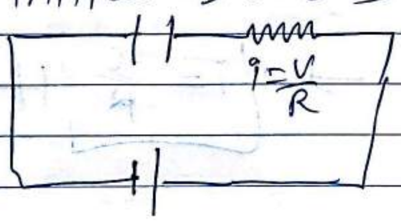
$= \underline{0}.$

i.e. capa Fully charged ⇒ $i = 0$ from ckt.

i.e. No need ~~to~~ of ~~connect~~ Resistor.

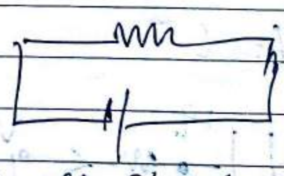
Two states of capacitor :-

1). initial ⇒ $t=0$ ⇒ $i = \frac{V}{R}$



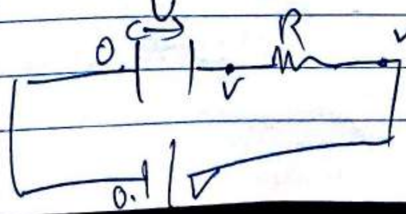
i.e. $t=0$ ⇒ There is No capacitor

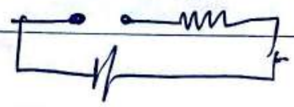
⇓



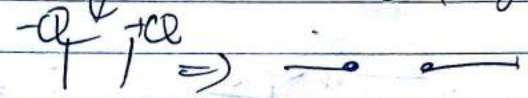
capa. short-circuited

(ii) $t=\infty$, steady state $\boxed{i=0}$ ⇒ $\boxed{\text{open ckt}}$

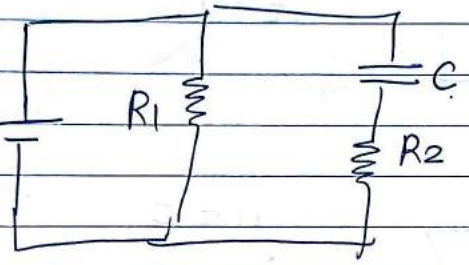




Capa. ⇒ Fully charged ⇒ No current will flow



Q.2)

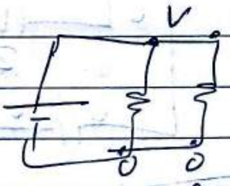


• Find current i_1 & i_2 in each resistor at

i) $t=0$

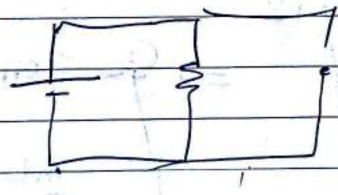
ii) Steady state

i) $t=0$ ⇒ (C → short) ⇒



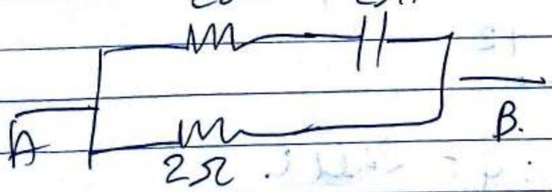
∴ ~~$R_{eq} = \frac{R_2R_1}{R_1+R_2}$ ⇒ $i = \frac{V(R_1+R_2)}{R_2R_1}$~~ $i_1 = \frac{V}{R_1}$, $i_2 = \frac{V}{R_2}$.

ii) $t =$ steady ⇒ capa is open ckted.

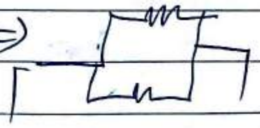


⇒ i.e. $i = \frac{V}{R_1}$

2) Find Eq. Resistance at i) $t=0$ ii) steady state

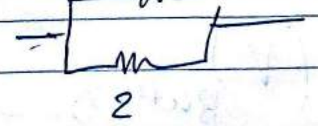


i) $t=0$ ⇒



∴ 1Ω

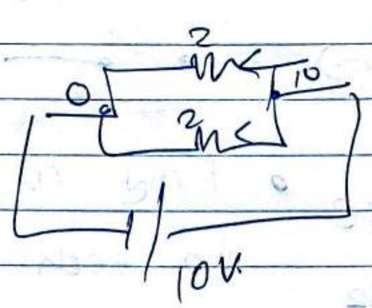
ii)



⇒ 2Ω.

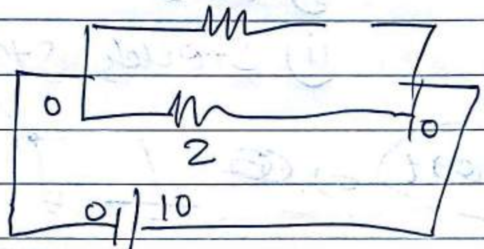
Q.3) Find current in each branch in prev. eg for both cases $\boxed{10V\ Batt}$

$t=0 \Rightarrow$



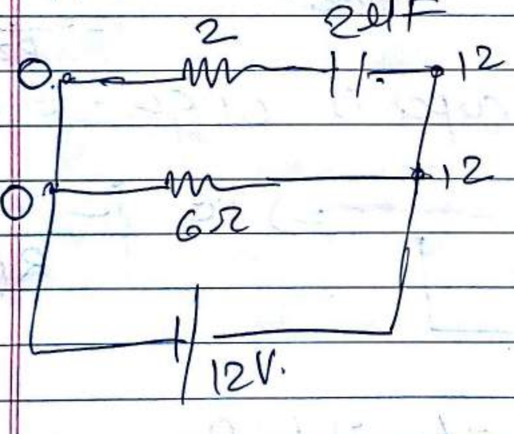
$i_1 = 5$
$i_2 = 5$

$t=\infty \Rightarrow$

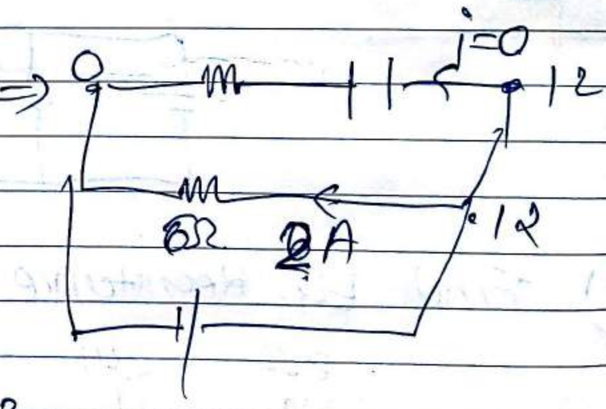


$i_1 = 0$
$i_2 = 5$

Q.4.) Find the charge stored on capa. in steady state.

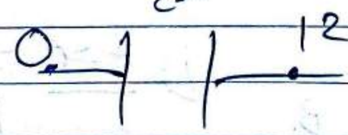


$\Rightarrow$



2μF

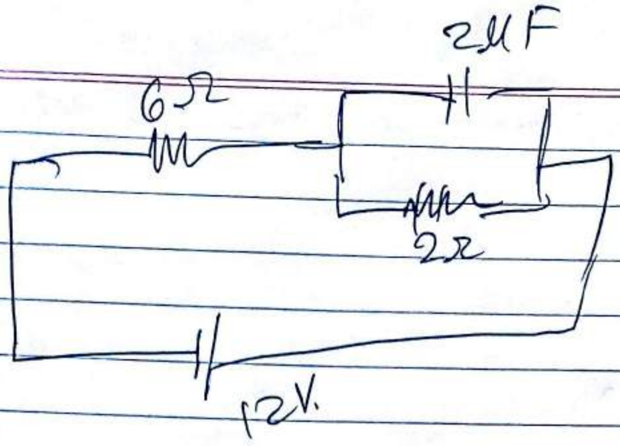
i.e.



$\because V = 12$
$C = 2\mu F$
$\Rightarrow \therefore Q = 24\mu C.$

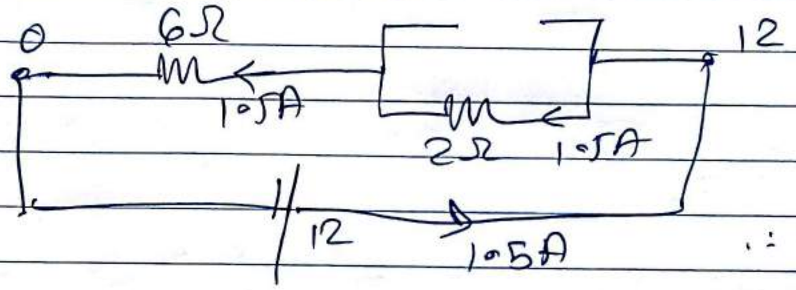
$\Rightarrow$ Steady state $(V)_{capa} = (V)_{Battery}$

(5)



* Find charge on capa. in steady state ?

→ steady state ⇒ open capa.



$i = \frac{V}{R}$

$\therefore i = \frac{12}{6+2} = \frac{12}{8}$

$\therefore i = \frac{3}{2} = 1.5A$

$\therefore V_{2\Omega} = IR$

$= 1.5 \times 2$

$\boxed{V_{2\Omega} = 3 \text{ volt}} \Rightarrow \boxed{V_c = 3V.}$

$Q = CV$

$= 2\mu \times 3 = \underline{6\mu C}$.