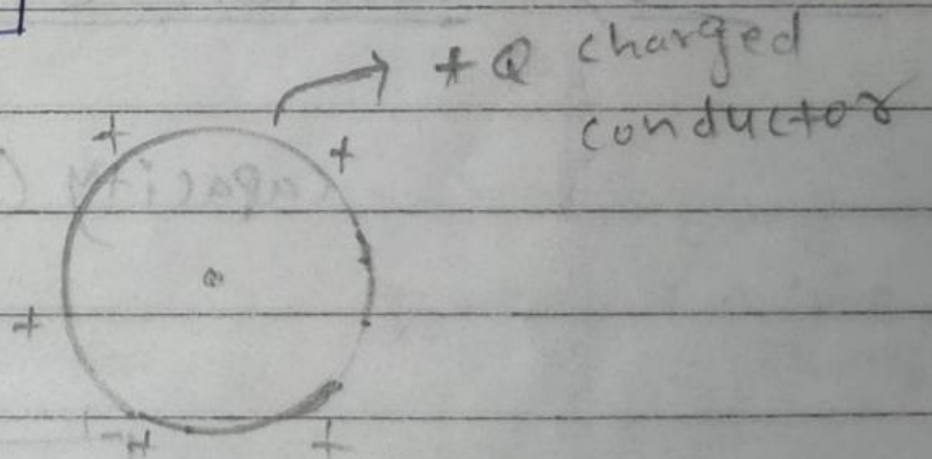
Chapter-2

Electrostatic Potential and Capacitance

Q.1) What do you mean by the electric potential.
Q.2) Define electric potential.
Q.3) write SI unit of Potential.
Q.4) Potential is scalar or Vector?
Q.5) Inlrite the formula for potential.
Q.6) Define Farad (F).
Q.7) unit of capacity.
Q.8) What do you mean by capacity?
Q.9) Write the formula for capacity.

Ans.1) **Electric Potential** :- The ratio of total charge (Q) given and capacity (C) is called electric potential, represented by "V".

Ans. 3) $$\boxed{\text{Electric potential } (V) = \frac{Q}{C}}$$



$\because \quad Q \propto V$

$Q = CV$

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

Unit :- $V = \frac{Q}{C}$

$= \frac{\text{Coulomb}}{\text{Volt}}$

$\boxed{V = C/\text{volt}}$

=) $\boxed{V = \text{Volt}}$

Ans. 4. potential is scalar quantity because it does not have direction."

Ans. 5 Electric potential = $\frac{\text{Total charge Given}}{\text{capacity}}$

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

Ans. 6. Farad :- Farad is the ratio of coulomb and Volt, this is represented by "F".

1 Farad :- The ratio of unit coulomb and unit Volt is 1 Farad.

Ans. 8 The ratio of Total charge given to conductor and potential is called capacity.

Ans. 9) Formula of capacity :-

$$\text{capacity } (C) = \frac{Q}{V}$$

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

Ans. 7) Unit of capacity :-

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

$$C = \frac{\text{Coulomb}}{\text{Volt}}$$

$$\Rightarrow \boxed{C = \text{Coulomb/volt}}$$

Ans.8) The power of any conductor to store charge is also called capacity.

Q.10) Derive an expression for electric potential due to a point charge.

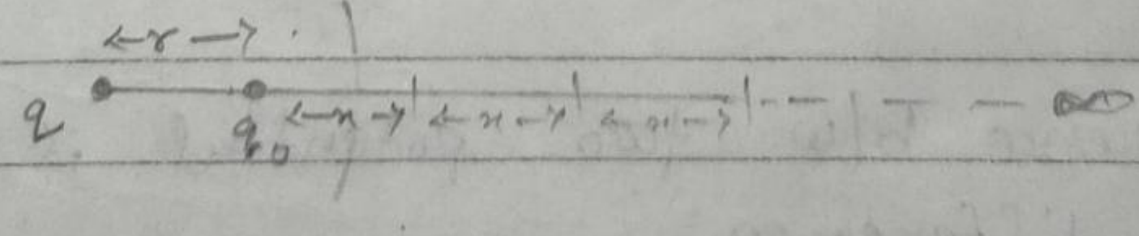
~~Q.11)~~ Ans.9) The total amount of work done to travelling unit positive charge from electric field to infinity, this work done is known as the electric potential. This is represented by "V", it's SI unit is "Volt"

$$\boxed{1 \text{ Volt} = \frac{1}{300} \text{ stat Volt}}$$

Q.11) What is potential difference?

Q.12) Why the potential of the earth is always assuming zero? , $r_E = 6400$ Km

Ans.10)



q → charge
, q_0 → unit positive charge.

⇒ Work done = force × displacement

⇒ $W = E \cdot d$ {E → Intensity of electric field (force)}

⇒ $dW = E \cdot dx$.

⇒ $dW = \frac{kq}{x^2} \cdot dx$

$$\Rightarrow \int dW = \int \frac{kq}{x^2} \cdot dx$$

$$\Rightarrow \cancel{dW} = V = kq \int \frac{1}{x^2} \cdot dx$$

$$\Rightarrow V = kq \int_r^\infty x^{-2}\, dx.$$

$$\Rightarrow V = kq \int \frac{x^{-2+1}}{-2+1}\, dx.$$

$$\Rightarrow V = kq \left[\frac{x^{-2+1}}{-2+1}\right]_r^\infty$$

$$\Rightarrow V = kq \left[\frac{x^{-1}}{-1}\right]_r^\infty$$

$$\Rightarrow V = -kq \left[\frac{1}{x}\right]_r^\infty$$

$$\Rightarrow V = -kq \left[\frac{1}{\infty} - \frac{1}{r}\right]$$

$$\Rightarrow V = -kq \left[0 - \frac{1}{r}\right]$$

$$\Rightarrow \boxed{V = \frac{kq}{r}}$$ where $V \rightarrow$ Electric potential.

Ans. 11) The difference b/w two potential is called potential difference.

$$\boxed{V = V_A - V_B}$$

(or)

The amount of work done to travelling unit positive charge from one point to another point of electric field.

$\Rightarrow$ $\boxed{V = \frac{W}{q}}$ where $V \rightarrow$ potential diff.
$W \rightarrow$ work done.

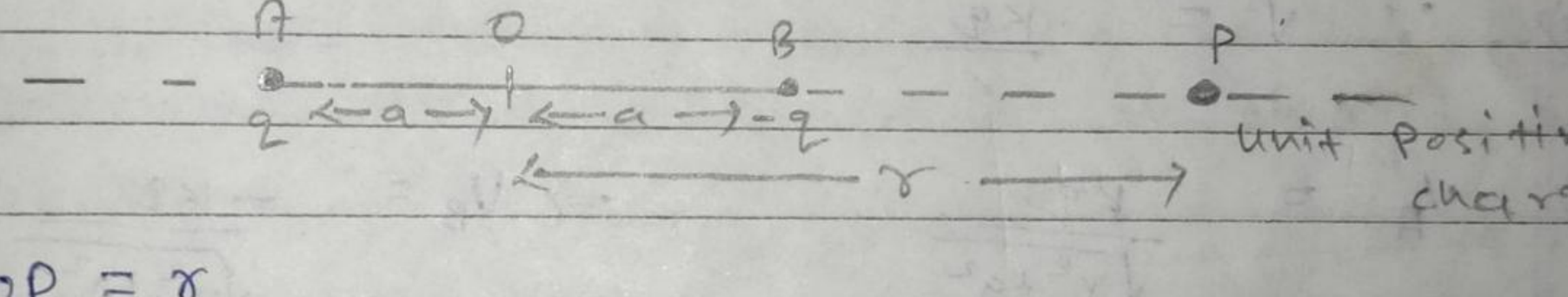
$\Rightarrow$ unit 1:- $= \frac{W}{q} = \frac{\text{Joule}}{\text{coulomb}} =$ Joule/coulomb.

$\Rightarrow$ unit 2:- $= \frac{W}{q} = \frac{\text{Joule}}{\text{coulomb}} =$ Volt

Q.13) Derive an expression for electric potential due to electric dipole in axial position.

Q.14) Derive an expression for electric potential due to electric dipole in equatorial position.

Ans. 13)



$\Rightarrow$ $OP = r$

$\Rightarrow$ $AP = r + a$

$\Rightarrow$ $BP = r - a$

$\therefore$ $V = \frac{Kq}{r}$

$\Rightarrow$ $V_A = \frac{Kq}{r+a}$, $\Rightarrow$ $V_B = \frac{-Kq}{r-a}$

$\Rightarrow$ $V = V_A + V_B$

$\Rightarrow$ $V = \frac{Kq}{r+a} - \frac{Kq}{r-a}$

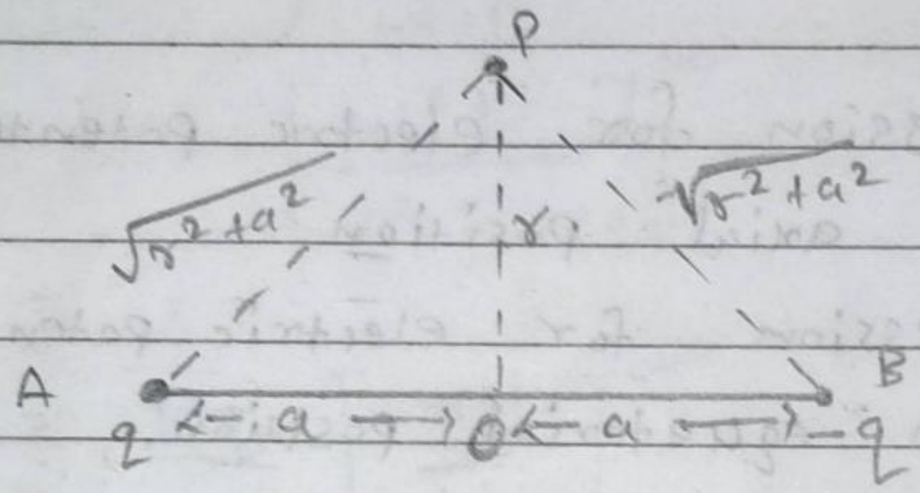
$\Rightarrow$ $V = Kq\left[\frac{r-a-r-a}{r^2-a^2}\right]$

$$\Rightarrow V = kq\left(\frac{-2a}{r^2-a^2}\right)$$

$$\Rightarrow V = \frac{-kq \times 2a}{r^2-a^2}$$

$$\Rightarrow \boxed{V = \frac{-kP}{r^2-a^2}}$$ where P → Dipole moment ~~intensity of electric field.~~

Ans. 14)



$$\Rightarrow \because V = \frac{kq}{r}$$

$$\Rightarrow V_A = \frac{kq}{\sqrt{r^2+a^2}}, \quad \Rightarrow V_B = \frac{-kq}{\sqrt{r^2+a^2}}$$

$$\Rightarrow V = V_A + V_B$$

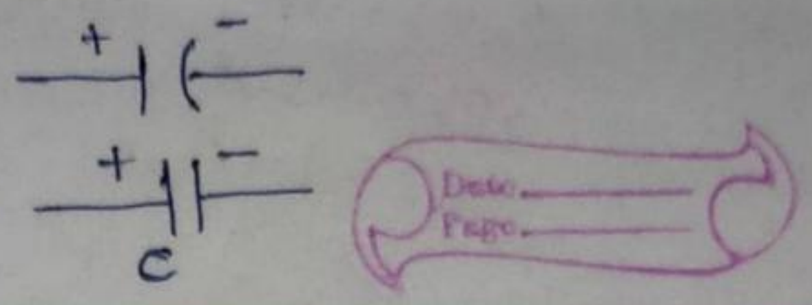
$$\Rightarrow V = \frac{kq}{\sqrt{r^2+a^2}} - \frac{kq}{\sqrt{r^2+a^2}}$$

$$\Rightarrow \boxed{V = 0}$$

Q.15 What do you understand by the capacitor? and capacitance?

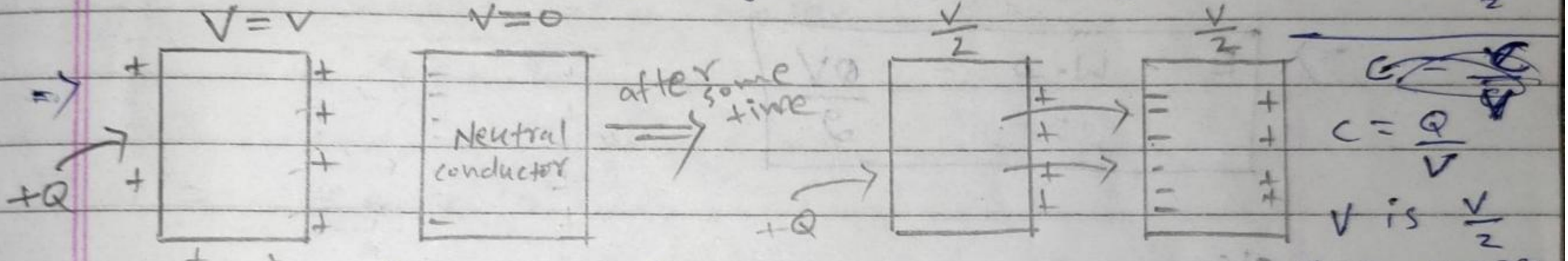
Ans- Capacity or capacitance :-

The power of any conductor to store charge is called capacity or capacitance.

→ Sign of conductor ⇒ 

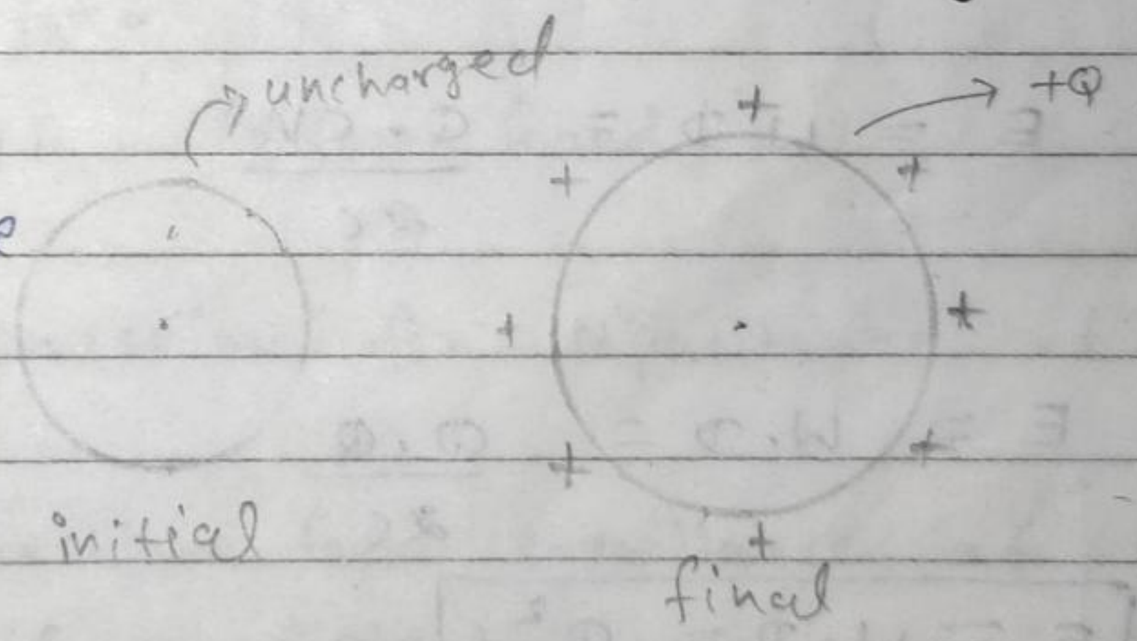
Capacitor :- This is a device, in which without change the shape and size of any conductor only increase the capacity, this device is called capacitor.

⇒ To increase the capacity we place a charged conductor and near this conductor a uncharged conductor is placed, nearest pole of uncharged conductor originate opposite charge of charged conductor and far away pole originate same sign, then charged conductor ~~prov~~ provide equal charge to uncharged conductor, the potential is gained by uncharged conductor '$\frac{V}{2}$'.



⇒ Capacitor used in electrical apparatus.

Q.16. Determine the required energy to charged any conductor.



⇒ Energy = Work done

⇒ Energy = force x d

⇒ ~~E~~ =

⇒ Energy = Work = force x displacement.

for charge system or conductor.

⇒ Energy = Work done = Q . V

⇒ $dE = dW = QV$

⇒ $\int_0^E dE = \int_0^W dW = \int_0^V Q\,dV$

$$\Rightarrow E = W = \int_0^V CV\,dV \qquad \{\because Q = CV\}$$

$$\Rightarrow E = W = C\left[\frac{V^2}{2}\right]_0^V$$

$$\Rightarrow \boxed{E = W.D = \frac{CV^2}{2}}$$

also, $\because Q = CV$

$$\Rightarrow \boxed{E = W.D = \frac{QV}{2}}$$

also,

$\because Q = CV$

$$\Rightarrow E = W.D = \frac{Q.CV}{2C}$$

$$\Rightarrow E = W.D = \frac{Q.Q}{2C}$$

$$\Rightarrow \boxed{E = W.D = \frac{Q^2}{2C}}$$

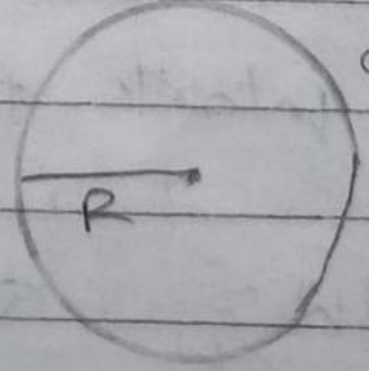
Q. 17 find out the capacity of the earth. (or)

Ans. $\Rightarrow$ prove that capacity of the any shehere is directly proportional to radius.

Ans.

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

$\because V = \frac{KQ}{R}$



Earth.

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

$$\Rightarrow C = \frac{Q}{\frac{KQ}{R}}$$

$$\Rightarrow C = \frac{R}{K}$$

$$\Rightarrow C = \frac{6400 \text{ km}}{9 \times 10^9}$$

$$\Rightarrow C = \frac{6400 \times 1000 \text{ meter}}{9 \times 10^9}$$

$$\Rightarrow C = \frac{64}{9} \times 10^{5-9}$$

$$\Rightarrow C = 7.11 \times 10^{-4}$$

$$\Rightarrow C = 711 \times 10^{-6} \text{ F}$$

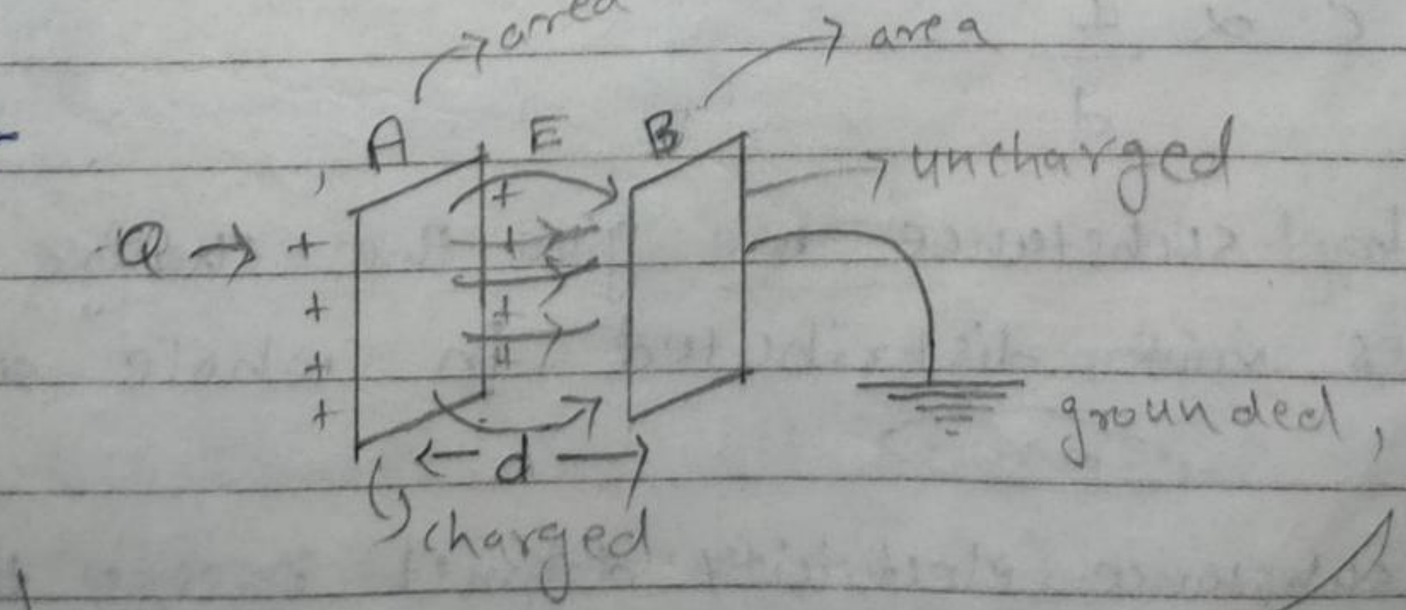
$$\Rightarrow C = 711 \ \mu\text{F} \quad (\text{micro farud})$$

Q.18 Derive an expression for capacitance of parrallel plate capacitor.

Q.19 Derive an expression for capacitance of parrallel plate capacitor if a dielectric medium partially placed between the plates.

Q.20 What is dielectric medium.

Ans. 18)



Parrallel plate capacitor.

$\Rightarrow$ Capacity $(C) = \frac{Q}{V}$ $\longrightarrow$ (1)

$\because V =$ work done

$=$ force $\times$ displacement

$= E \times d$ $\left\{ \because \text{Electric field due to plane sheet } E = \frac{\sigma}{\varepsilon_0} \right\}$

$= \frac{\sigma}{\varepsilon_0} \times d$

$V = \frac{\sigma}{\varepsilon_0} \times d$ $\longrightarrow$ (2)

$\because \sigma = \frac{Q}{A}$ (surface charge distribution)

$Q = \sigma A$ $\longrightarrow$ (3)

from (1), (2) and (3)

$\Rightarrow C = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0} \times d}$

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

then, $C \propto A$

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

Ans. 20.) In which substance we give the charge, and charge does not distributed in whole surface.

or

In which substance electricity doesn't passes through conductor is called insulator and insulator is called.

dielectric medium.

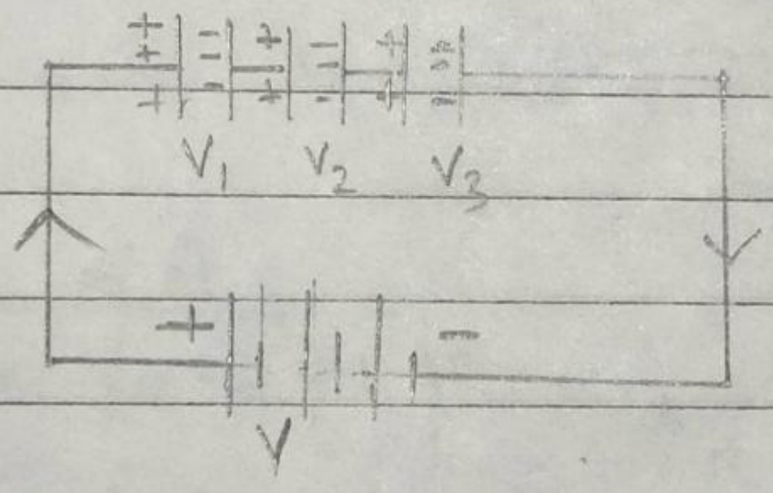
Q.21 Why we need the combination of capacitor

Q.22 How many Type of combination. Explain each.

Ans.21) To find out the exact value of capacitor, we need the combination of capacitor.

Ans.22) 3 Types of capacitor :-

i) Series combination :- such type of conductor in which charge is equally distributed in all the capacitor of the conductor. (charge is constant)



$\because Q = CV \Rightarrow V = \frac{Q}{C}$

$Q_1 = C_1V_1 \Rightarrow V_1 = \frac{Q}{C_1}$

$Q_2 = C_2V_2 \Rightarrow V_2 = \frac{Q}{C_2}$

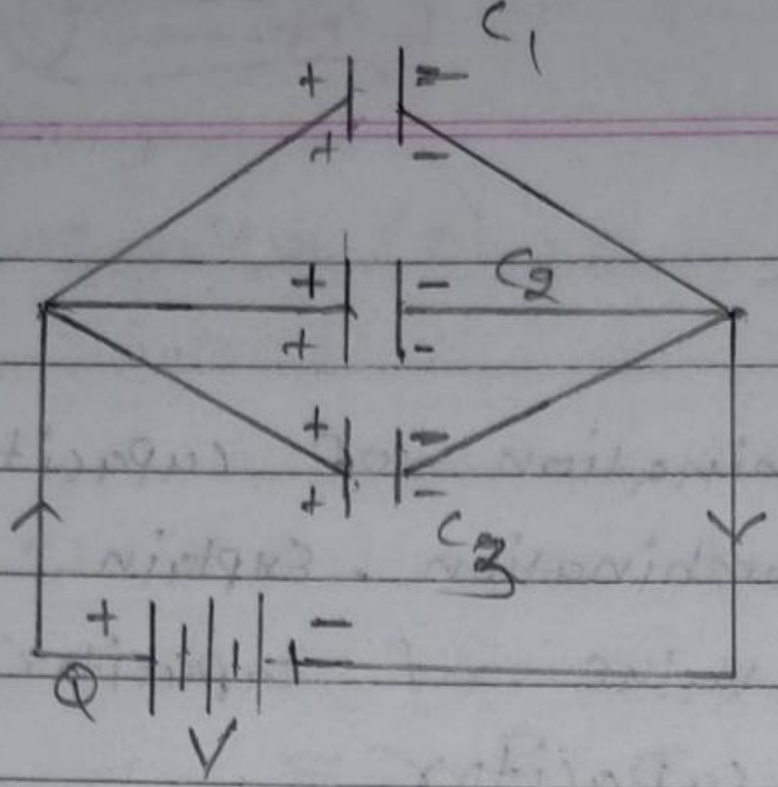
$Q_3 = C_3V_3 \Rightarrow V_3 = \frac{Q}{C_3}$

$\Rightarrow V = V_1 + V_2 + V_3$

$\Rightarrow \frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

$\Rightarrow \boxed{\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}}$

ii) Parrallel combination :- such type of conductor in which ~~charge~~ Potential is equally distributed in all capacitor of conductor. (potential is constant)



$\because Q = CV$

$\Rightarrow Q_1 = C_1 V$

$\Rightarrow Q_2 = C_2 V$

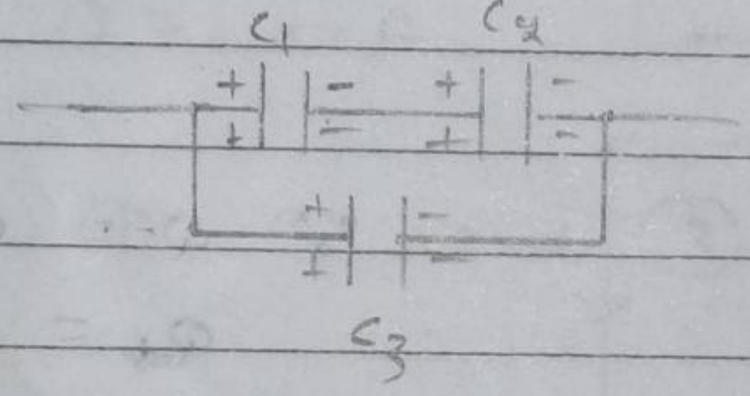
$\Rightarrow Q_3 = C_3 V$

$\Rightarrow Q = Q_1 + Q_2 + Q_3$

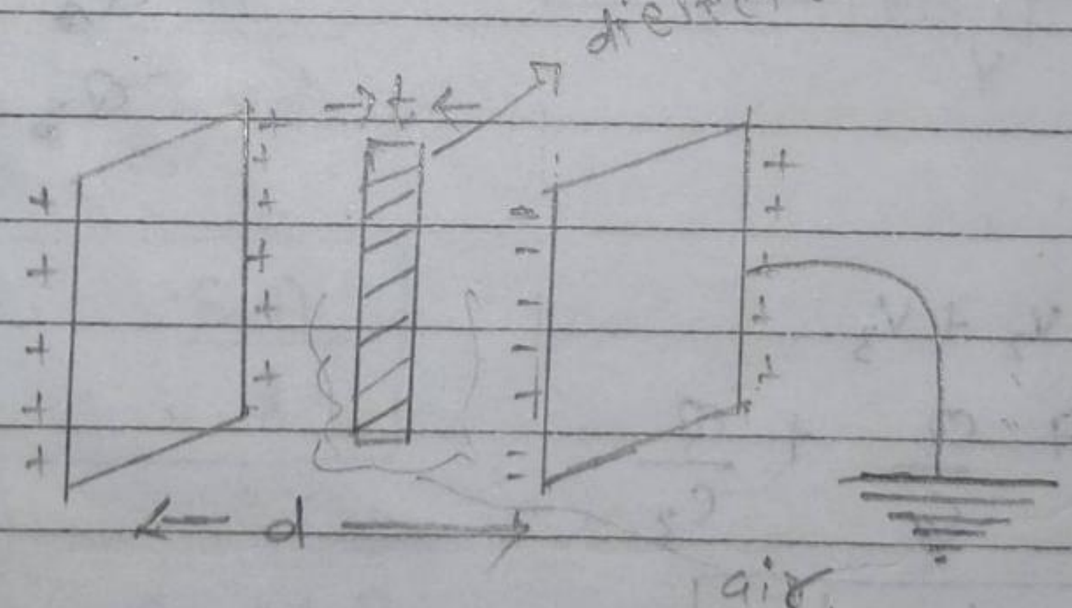
$\Rightarrow CV = C_1V + C_1V + C_1V$

$\Rightarrow \boxed{C = C_1 + C_2 + C_3}$

iii) <u>Mixed combination</u> :- Both series and parrallel combination is included.



Ans. 19



$\Rightarrow \because \sigma = \frac{Q}{A} \longrightarrow (1)$ $\because C = \frac{Q}{V} \longrightarrow (1)$

$\Rightarrow Q = \sigma A \longrightarrow (2)$

↗ for air:

→ Potential (V) = W.D = force × displacement

$$\Rightarrow \quad V_a = E.(d-t)$$

$$\Rightarrow \quad V_a = \frac{\sigma}{\varepsilon_0}(d-t)$$

for medium,

$$V_m = \frac{\sigma}{\varepsilon_0 K} \times t$$

$$\Rightarrow V = V_a + V_m$$

$$\Rightarrow V = \frac{\sigma}{\varepsilon_0}(d-t) + \frac{\sigma}{\varepsilon_0 K} t$$

$$\Rightarrow V = \frac{\sigma}{\varepsilon_0}\left(d - t + \frac{t}{K}\right) \longrightarrow (3)$$

from (1), (2) and (3),

$$\Rightarrow C = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0}\left(d - t + \frac{t}{K}\right)}$$

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

$$\Rightarrow \boxed{C = \frac{K \varepsilon_0 A}{K(d-t) + t}}$$ where $K \rightarrow$ dielectric medium

case-I → dielectric medium is present b/w all place b/w two conductor.

$$\boxed{t = d}$$

$$\Rightarrow \quad C = \frac{K\varepsilon_0 A}{K(d-d)+d}$$

$$\Rightarrow \quad \boxed{C = \frac{K\varepsilon_0 A}{d}}$$

Q.23 prove that if 2 charged conductor join to each other then energy is looses.

Q.24 Define common potential and derive it's formula.

Q.25 What is dielectric medium, write it's type and what is polarization.

Ans. 25 Non conducting material is called dielectric medium.

Dielectric medium is 2 type :-

a) Polar dielectric medium
b) Non-polar dielectric medium

a) Polar dielectric medium :-

Eg. → i) HCl

$H^+ \cdots Cl^-$ } never coincide positive & negative sign.

b) Non-Polar dielectric medium :-

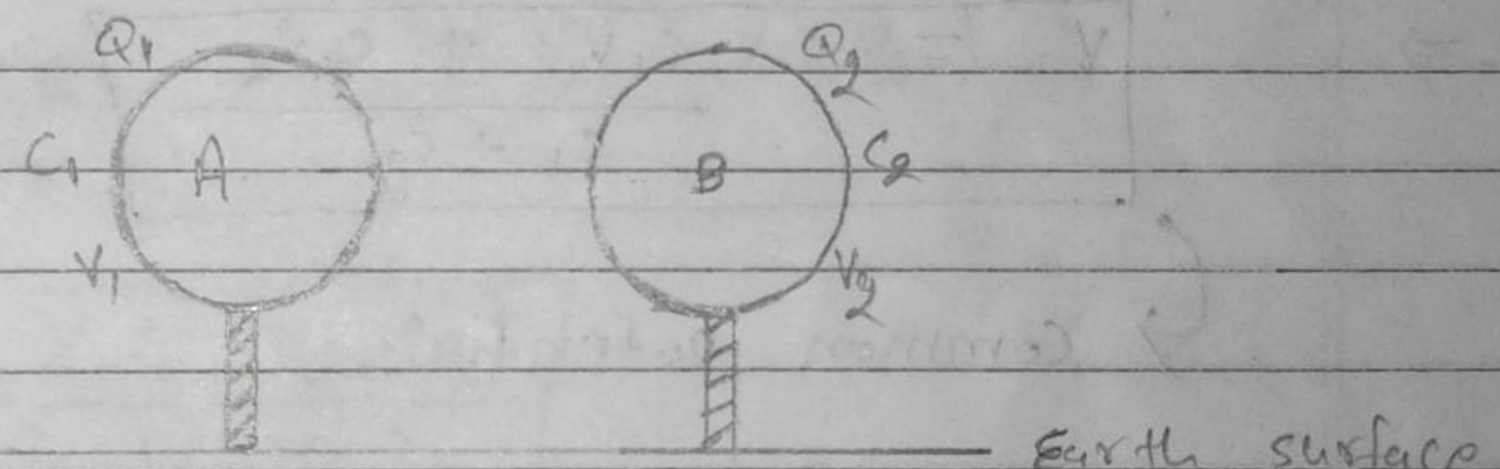
Eg. → i) H_2 → always coincide.

$P \propto E \rightarrow P = \chi E$

Ans. 24) Common potential :- Two charged conductor by ~~with~~ Q_1, Q_2 & potential by V_1 & V_2 & capacity ~~by~~ with C_1 & C_2 respectively, initially they are not connected.

after some time both conductor is joined then ~~Q.~~ charge Q_1, Q_2 & C_1, C_2 remain constant but potential flow from higher value to less value, at a point where potential of both conductor is equal and flowing of potential is stopped that is 'V', this 'V' potential is called common potential.

Initially :-



$Q_1 = C_1V_1$

$Q_2 = C_2V_2$

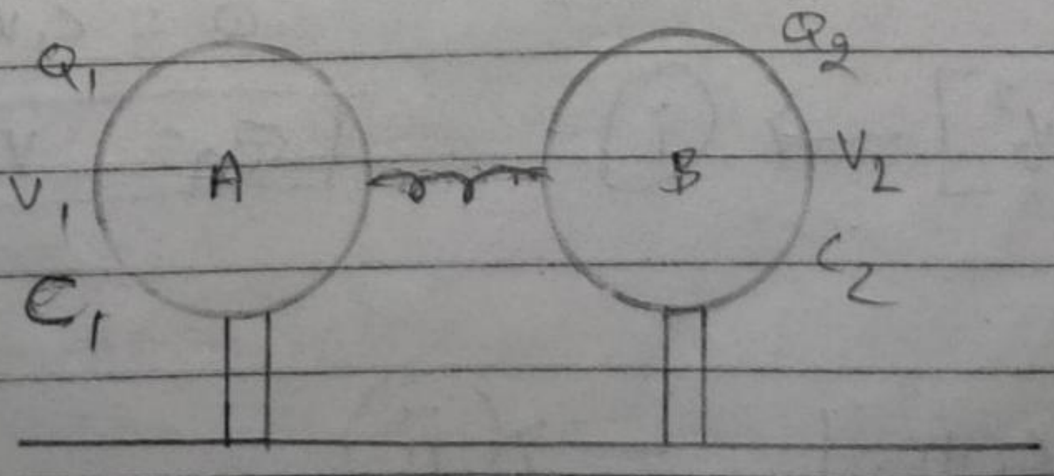
$Q = CV$

$\Rightarrow Q = Q_1 + Q_2$

$\Rightarrow CV = C_1V_1 + C_2V_2$

$\Rightarrow \boxed{Q = C_1V_1 + C_2V_2}$

Final (after connecting) :-



$\Rightarrow V_1 = V_2 = V$

$\Rightarrow Q = C_1V_1 + C_2V_2$

$\Rightarrow Q = C_1V + C_2V$

$\Rightarrow Q = (C_1 + C_2)V$

law of conservation of Energy;

Energy can neither be created nor be destroyed, it can only transfer from one body to another.

then,

$\Rightarrow$ (charge before connecting conductor) = (charge after connecting conductor)

$\Rightarrow$ $C_1V_1 + C_2V_2 = (C_1 + C_2)V$

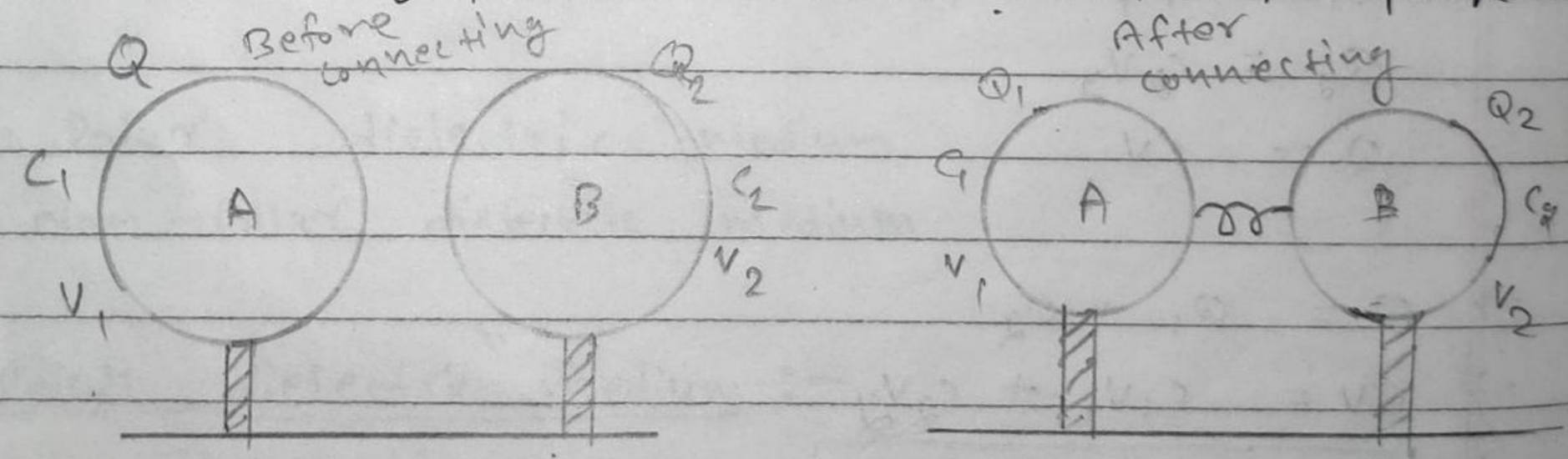
$\Rightarrow$ $\boxed{V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}}$

↳ Common potential

Q. 26 What is equipotential surface ? write it's properties.

Ans. 23.

$\boxed{E = \frac{1}{2}CV^2}$



Total Energy

Before → $E_1 = E_A + E_B$

Before, $E_1 = \frac{1}{2}[C_1V_1^2 + C_2V_2^2]$ → (i)

After → $V_1 = V_2 = V$

$\Rightarrow E_2 = \frac{1}{2}V^2[C_1 + C_2]$ → (ii)

$V_1 = V_2 = V$

$Q = C_1V_1 + C_2V_2$

$Q = C_1V + C_2V$

$\boxed{Q_A = V(C_1 + C_2)}$ → (2)

Loss of Energy :-

$$\Rightarrow \Delta E = E_1 - E_2$$

$$= \frac{1}{2}(C_1V_1^2 + C_2V_2^2) - \frac{1}{2}(C_1 + C_2)V^2$$

$$= \frac{1}{2}\left[(C_1V_1^2 + C_2V_2^2) - (C_1+C_2)\left(\frac{C_1V_1 + C_2V_2}{C_1+C_2}\right)^2\right]$$

$$= \frac{1}{2}\left[\frac{(C_1V_1^2 + C_2V_2^2)(C_1+C_2) - (C_1V_1 + C_2V_2)^2}{(C_1+C_2)}\right]$$

$$= \frac{1}{2(C_1+C_2)}\left[C_1C_2V_2^2 + C_1C_2V_1^2 - 2C_1C_2V_1V_2\right]$$

$$= \frac{C_1C_2}{2(C_1+C_2)}(V_2^2 + V_1^2 - 2V_1V_2)$$

$$\Rightarrow \boxed{\Delta E = \frac{1}{2}\frac{C_1C_2(V_2-V_1)^2}{(C_1+C_2)}}$$