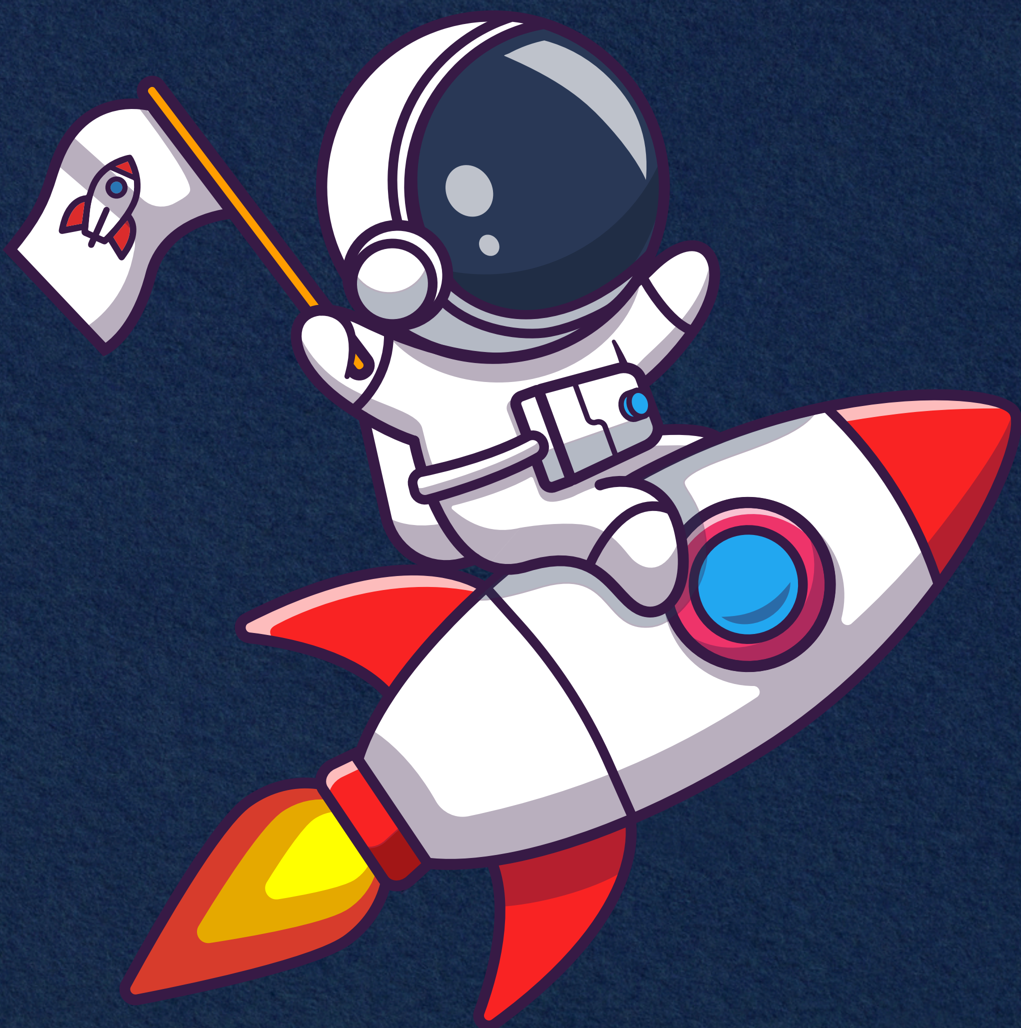
Class 12

PHYSICS

SHORT NOTES

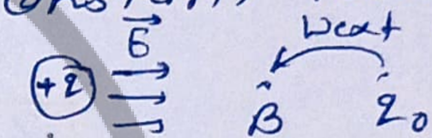


÷ Chapter 2 :-

Electric Potential & Capacitor

Electric Potential Difference :- The amount of work done to bring a unit Positive charge from one Point to another point without change its kinetic energy

→ Charge should move slowly with constant velocity



$$V_B - V_A = \frac{W_{A \to B}}{q_0} = \frac{U_B - U_A}{q_0}$$

Electric Potential difference → Scalar quantity

Unit of Electric Potential → J/C (volt)

Dimension. $M^1 L^2 T^{-3} A^{-1}$

Electric Potential :- The total work done to bring a unit positive charge from infinity to a point against electrostatic force without change in K.E is called Electric Potential.

$$V_B - V_\infty = \frac{W_{\infty \to B}}{q_0} = \frac{U_B - U_\infty}{q_0}$$

($V_\infty \to 0$ for infinity, $U_\infty \to 0$ for infinity.)

$$\boxed{V_B = \frac{U_B}{q_0}}$$

Note :- ① The work done by electrostatic force always depends on initial and final positions, & does not depend on path.

② $W_{ext} + W_{elect} = 0$

$W_{ext} = -W_{elec}$.

Electrostatic Potential due to a Point charge

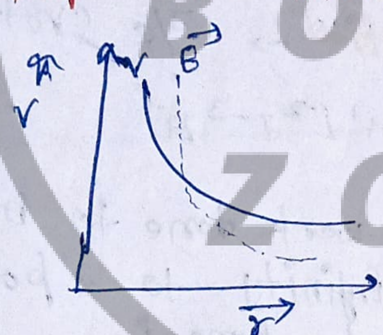
$$W_{\infty \to P} = \frac{KQq_0}{r}$$

Now Potential at Point P

$$V_P = \frac{W_{\infty \to P}}{q_0} = \frac{KQq_0}{rq_0}$$

$$V_P = \frac{KQ}{r}$$

Graph b/w Potential & distance :-



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

$E \propto \frac{1}{r^2}$

Note :- for '+q' charge → $V = \frac{+Kq}{r}$

for '−q' charge → $V = \frac{-Kq}{r}$

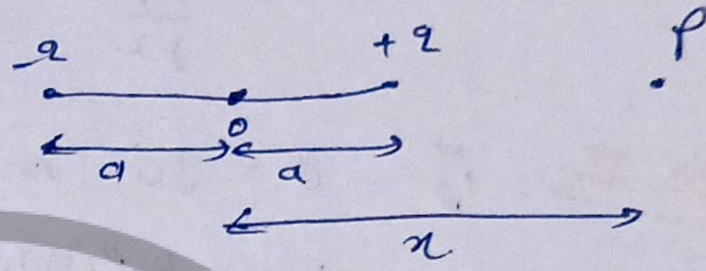
Note :- ① For potential eqbm, we always have to choose two points

② Point should be always near to lower potential charge

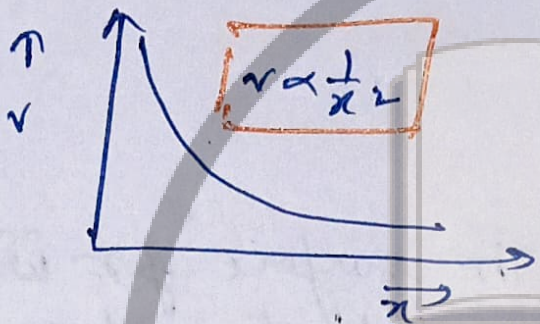
★ Electric Potential due to Dipole :-

(i) On the axial line of Dipole

$$V = \frac{kq}{x^2}$$



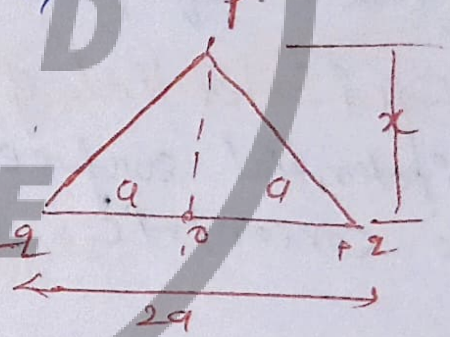
Graph b/w V & x



$V \propto \frac{1}{x^2}$

(ii) On the equatorial line of Dipole

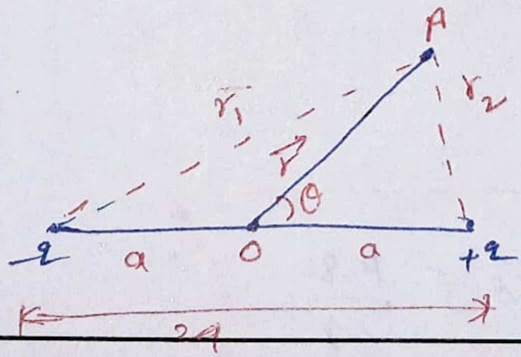
at Point P $V = 0$

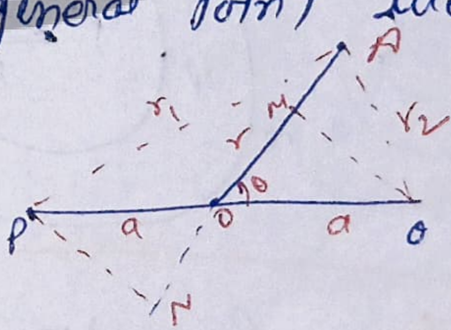


Note: $V_{axial} = \frac{kq}{x^2}$

$V_{equitorial} = 0$.

(iii) Electric Potential at general Point due to Dipole:





$$V = \frac{KP\cos\theta}{r^2}$$

Case ① if $\theta = 0^\circ$ (at axial line)

$$V = \frac{KP\cos 0^\circ}{r^2}$$

$$V = \frac{KP}{r^2}$$

Case II. if $\theta = 90^\circ$ (on equitorial line)

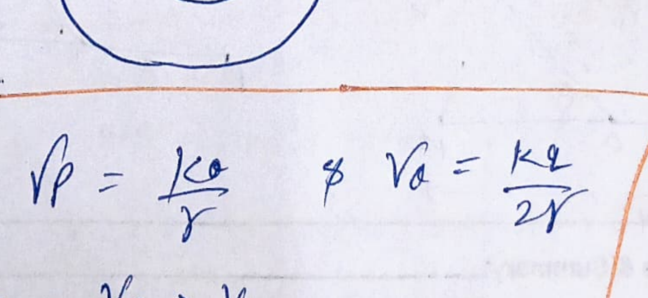
$$V = \frac{KP\cos 90^\circ}{r^2}$$

$$V = 0$$

(2013, 19)

★ **Equipotential Surfaces:-** The surface for which Potential is equal at each point of surface is called equipotential surface.

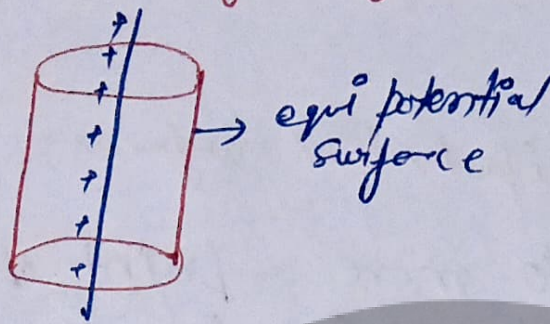
★ **Equipotential of surface for a Point charge:-** Equipotential surface for a Point charge is always all the concentric sphere around the charge



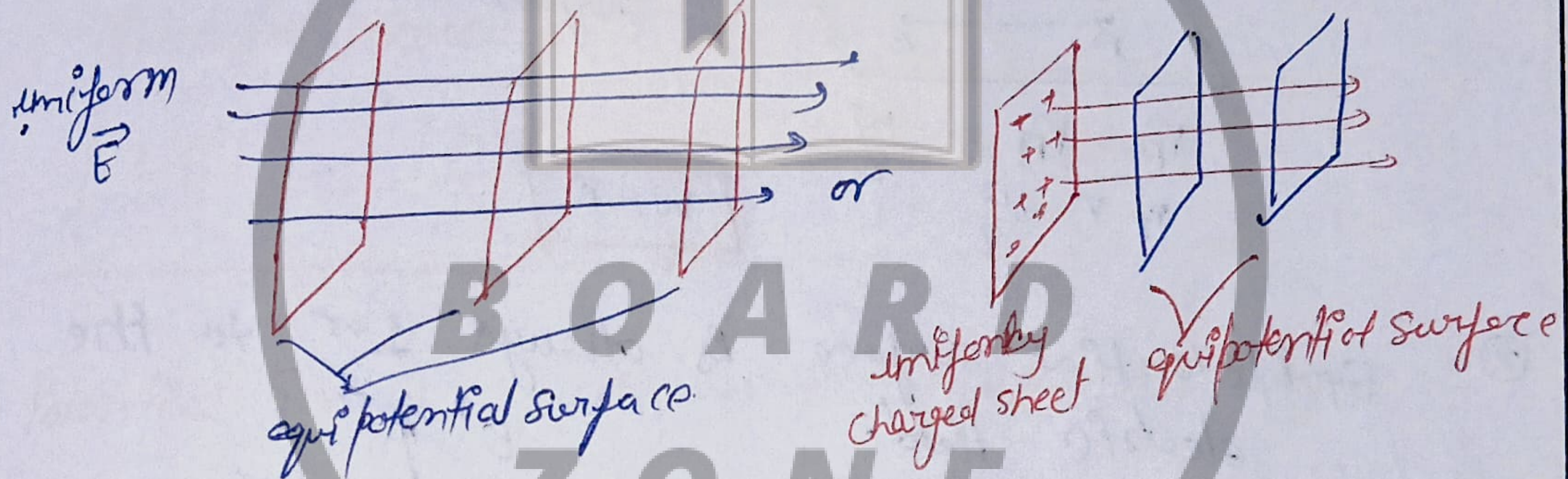
Note:- $V_P = \frac{Kq}{r}$ & $V_Q = \frac{Kq}{2r}$

so $V_P > V_Q$

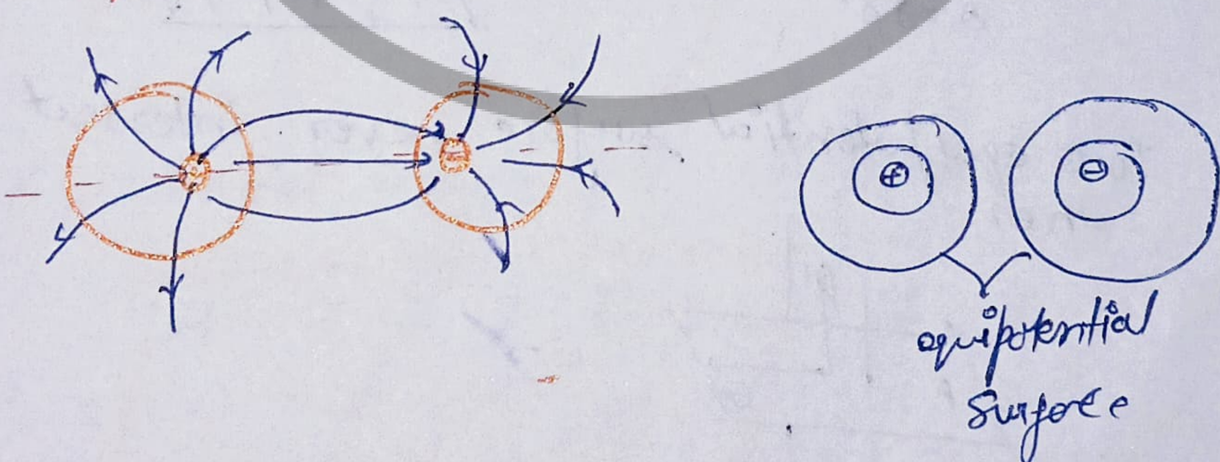
★ Equipotential surface for infinite linear charge:-



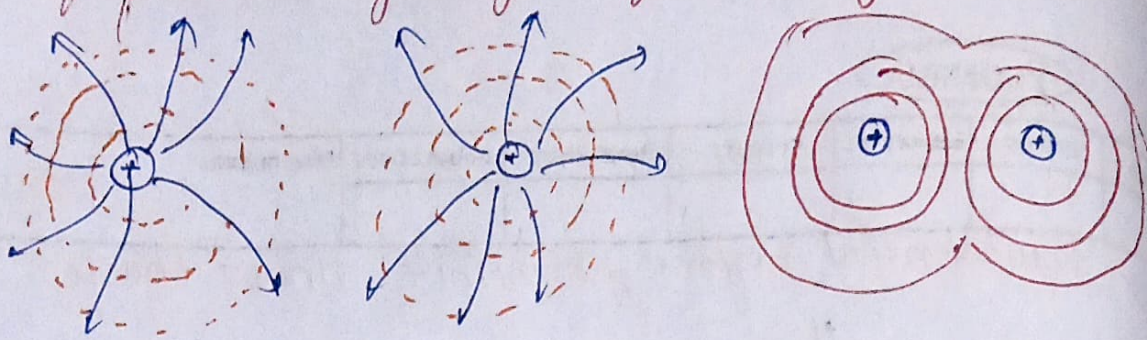
for uniform electric field or sheet



★ Equipotential surfaces for Dipoles:-

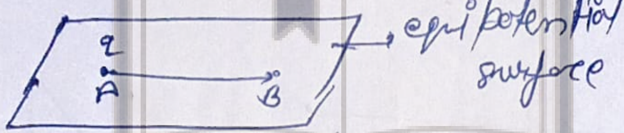


Equipotential surface for infinite charges:-



Properties of equipotential surfaces:-

① The work done to move a point charge from one point to another point is always zero on equipotential surface.



$V_B - V_A = \frac{W}{q}$

$\Delta V = \frac{W}{q}$

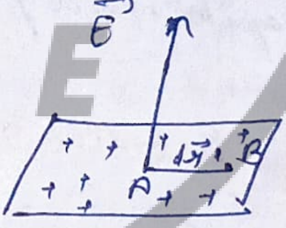
$W = 0$

② Equipotential surface is always ⊥ar to the electric field.

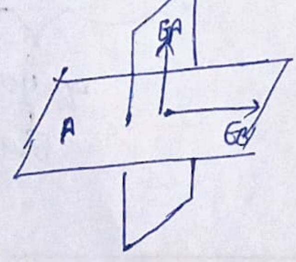
$dV = -\vec{E}\cdot d\vec{r}$

$0 = E\, dr \cos\theta$

$\theta = 90°$



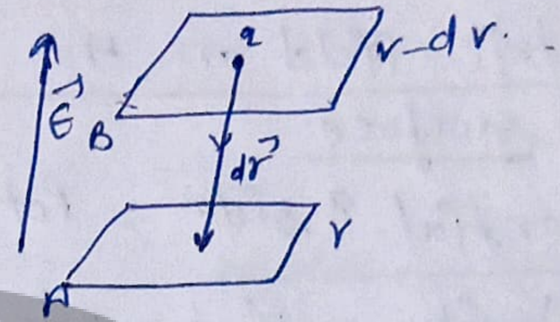
③ Two equipotential surface never intersect each other



→ Two dirⁿ of $\vec{E}$ not possible, it show that equipotential surfaces never intersect each other.

Relation b/w electric field and electric Potential

$$E = -\frac{dV}{dr} \text{ or } E = \frac{\Delta V}{\Delta r}$$



Note :- Sign shows that in the dirn of $\vec{E}$ electric Potential decreases.

☆ Potential Gradient

$$|\vec{E}| = -\left|\frac{dV}{dr}\right| = -(\text{Potential Gradient})$$

Potential Energy of ~~charges~~ for 'n' system of charges :-

Total work done for 'n' charges :-

$$W = K \sum \frac{q_m q_n}{r_{mn}}$$

so Potential Energy for 'n' system

$$U = K \sum_{n} \frac{q_m q_n}{r_{mn}}.$$

Electrostatic in Conductors.

1. **No charge inside a conductor**

In static condition; charge stays on the surface.

2. **Electric field inside a conductor is zero.**

$$\boxed{E = 0}$$

3. **Electric field on the surface is perpendicular to the surface**

4. **Potential inside = Potential on the surface**

$$\boxed{V_{inside} = V_{outside}}$$

5. **Surface electric field formula.**

$$\boxed{\vec{E} = \frac{\sigma}{\varepsilon_0} \hat{n}}$$

6. **Electrostatic Shielding.**

Conductor block external electric fields (Faraday cage).

Example:- Staying inside a car / bus during a thunderstorm is safe due to electrostatic shielding.

Dielectrics and Polarization.

1. Dielectrics:-

These are insulating materials that transmit electric effects but do not conduct electricity.

2. Types of Dielectrics.

(i) No-Polar Dielectrics:

- The centers of positive and negative charges coincide.
- Molecules have a symmetrical shape.
- Examples: O_2, CO_2, CH_4.

(ii) Polar Dielectric:

The centers of positive and negative charges are separate.

- Molecules have an asymmetrical shape.
- Examples : HCl, H_2O, NH_3

3. Dielectric Polarization.

(i) In Non-Polar Dielectrics:-

When an external electric field is applied, the charges get displaced, and the dielectric becomes polarized.

(ii) In Polar Dielectrics:-

- Without a field, dipole moments are randomly arranged and cancel out
- When E is applied, dipoles align, leading to polarization

4. Electric Susceptibility (χ_e)

- Polarization (P) is directly related to the effective electric field (E)

$$P \propto E_{net} \quad , \quad P = \chi_e E$$

$$\boxed{\chi_e = \frac{P}{E}}$$

For vacuum $\chi_e = 0$

5. Effective Electric field in a Polarized Dielectric

The net field decreases, bcz the dielectric creates a field in the opposite dirⁿ

$$\boxed{E_{net} = E_0 - E_p}$$

Types of Polarization:- seperation of charges in a dielectric when placed in an external electric field.

$$\boxed{P = \chi_e E}$$

P = Polarization χ_e = Electric susceptibility
E = Electric field.

Types of Polarization.

1. Electronic Polarization – shifting of electron cloud.
   e.g. Neon, Argon.
2. Ionic Polarization:- Displacement of Positive & negative ions. e.g NaCl, KCl
3. Orientation Polarization:- Alignment of permanent dipoles (e.g H_2O, NH_3)
4. Space charge Polarization:-
   Charge accumulation at material interface

Effect on Dielectric

Internal field opposes E_0, reducing net field:

$$\boxed{E_{net} = E_0 \cdot K}$$

Capacitor :- A capacitor is a system of two conductors separated by an insulator. It is responsible for storing large amount of electric charge and also electrical energy.

Capacitance :- The ability of a conductor to store electric charge is called capacitance.

$Q \propto V \Rightarrow \boxed{Q = CV}$

C = Electric capacitance is constant.

Capacitance does not depend on Q & indirectly on V.

Dimension of $C = M^{-1}L^{-2}T^{+4}A^{2}$

Unit of Capacitance $\frac{C}{V}$ or $\frac{C^2}{J}$

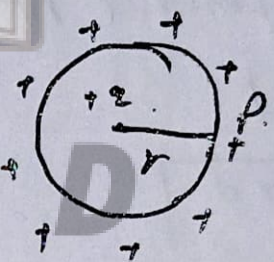
↳ Farad (F)

★ One Farad.

$$1 \text{ Farad} = \frac{1 \text{ Coulomb}}{1 \text{ Volt}}$$

Capacitance of isolated spherical conductor.

$$C = \frac{q}{V} = \frac{q}{\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r}}$$



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

★ Capacitance of earth. $R_e = 6400\,km$

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

Note: Spherical capacitor are not much used bwz to get high capacitance very large size conductor is used.

Remember

$mF = 10^{-3} F$

$\mu F = 10^{-6} F$

$nF = 10^{-9} F$

$pF = 10^{-12} F$

Types of Capacitor

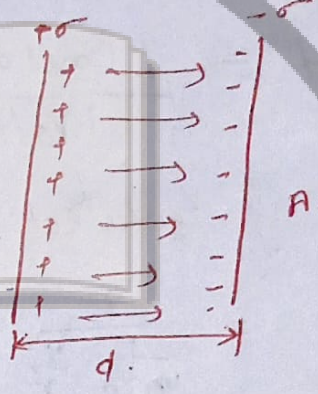
- Parallel Plate Capacitor
- Spherical Capacitor
- Cylindrical capacitor

Charging of Capacitor :-

When battery is 'on' then charge start to flow and capacitor start to charge
After complete charging. capacitor stops to be charge.

☆ Parallel plate capacitor.

Electric fied btw the plates.



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

Potential difference btw the plates.

$$V = E \times d$$

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

Capacitance.

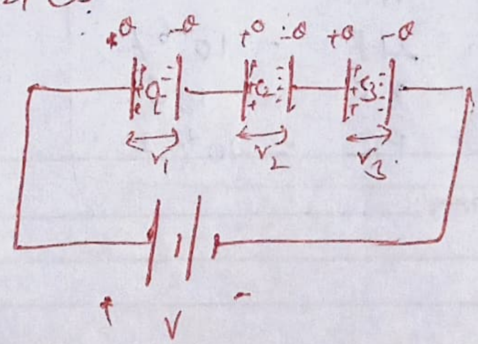
$$C = \frac{Q}{V}$$

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

Note.
$C \propto$ Area of Plates
$C \propto \frac{1}{d}$

Combination of Capacitors.

(i) Capacitors in series.



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

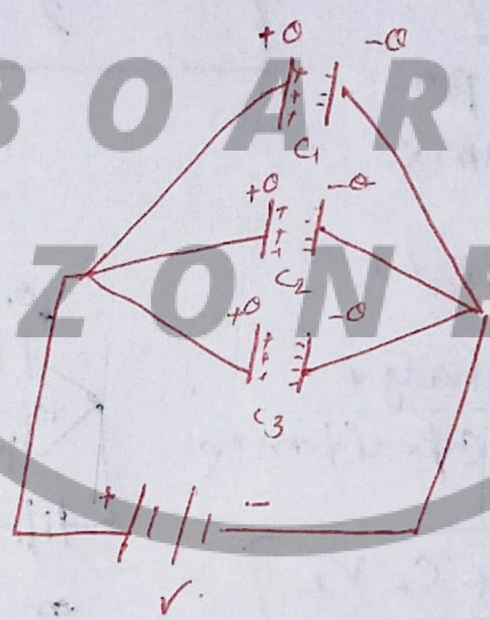
for 'n' no of same capacitors:-

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

for two different capacitance:-

$$C_S = \frac{C_1 C_2}{C_1 + C_2}$$

② Capacitors in Parallel



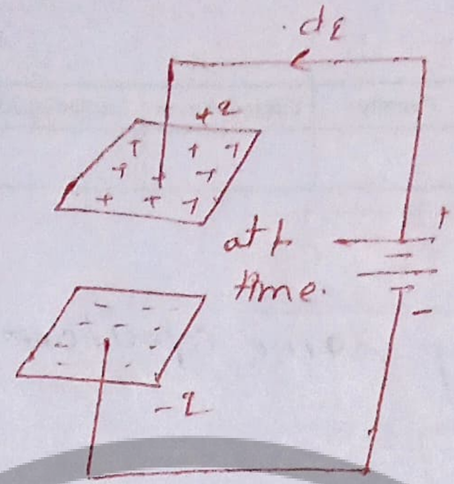
$$C_P = C_1 + C_2 + C_3.$$

for n capacitors in Parallel Combination.

$$C_P = \sum_{i=1}^{i=n} C_i$$

Energy stored in a Parallel plate capacitor :-

Potential difference.



$$\Delta V = \frac{q}{C}$$

Work done by battery to transfer next 'dq' charge to plate

$$dW = V\,dq$$

$$W = U = \frac{1}{2}\frac{Q^2}{C}$$

Work don by battery = Potential energy stored.

Another form of Energy :-

$$U = \frac{1}{2}\varepsilon_0 E^2$$

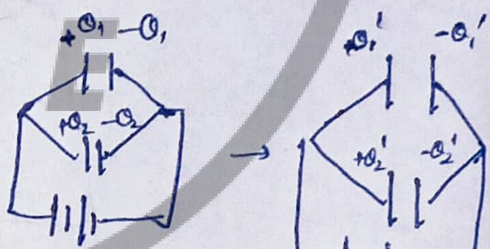
↳ Energy stored per unit volume

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

☆ Common Potential :-

Case I.

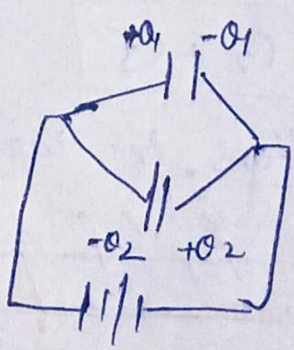
$$V = \frac{\text{Total charge}}{\text{Total capacitance}}$$



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

Case II

$$V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$$



Effect of Dielectric on Capacitor :-

* Effect on E_{net} due to dielectric.

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

* effect on Potential.

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

* effect on Capacitance :-

$$C = KC_0$$

* Dielectric constant for Capacitor :-

$$K = \frac{C}{C_0}$$

Application of Dielectric :-

1. Dielectric is used to avoid stick of both plates.
2. Dielectric increases the capacitance of capacitor.

BOARD ZONE.