ELECTROSTATIC POTENTIAL AND CAPACITANCE

ELECTRIC POTENTIAL & ELECTRIC POTENTIAL ENERGY

- Work done By External charge to move from postion 1 to 2 in static Electric Field E.

$$W_{ext} = \int \vec{F}.\vec{dl} = -q\int_1^2 \vec{E}.\vec{dl}$$

- Electric potential

$$\rightarrow V_p = \frac{W_{ext}(\infty \rightarrow P)}{q} = -\int_{\infty}^{P} \vec{E}.\vec{dl}$$

- Electric Potential due to a point charge in its surrounding:

$$\rightarrow V_p = \frac{Kq}{r}$$

- Electric Potential due to a point charged ring at its center:

$$V = \int dv = \int \frac{Kdq}{R} = \frac{KQ}{R}$$

- Electric potential Energy of a system of charges:

$$U_{total} = kq_1q_2\frac{1}{r_{12}} + kq_2q_3\frac{1}{r_{23}} + \frac{kq_3q_4}{r_{34}} + \ldots..$$

- Relation Between Electric Field and Potential:
- Electric Field at a point is negative of potential gradient.

potential gradient $\rightarrow \left[E = \frac{-dv}{dr}\right]$

Potential Due to Surface Charge Distribution

- **Electric potential Energy**: Amount of work done(w) required to be done to move a charge from infinity to any given point inside the Field.

$$U_A = W_{\infty \to A} = -q\int_{-\infty}^{A} \vec{E}\cdot d\vec{l} = qV_A$$

- Work done in moving charge from A to B will be:.

$$W_{ext} = \Delta U = (U_B - U_A) = q(V_B - V_A)$$

- Electric potential Energy due to two point charges:

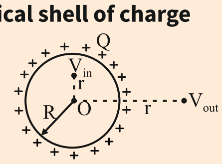
$$U = \frac{kq_1q_2}{r}$$

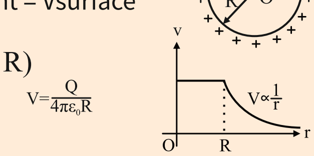
- **Metallic sphere or hollow spherical shell of charge**

$$V_{out} = \frac{Q}{4\pi\varepsilon_0 r} \quad (r > R)$$

Vin = Constant = Vsurface

$$= \frac{Q}{4\pi\varepsilon_0 R} \quad (r \le R)$$



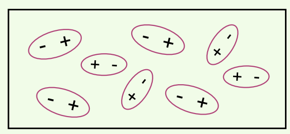


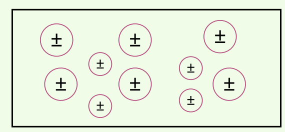
ELECTROSTATIC PRESSURE $(P) = \frac{F}{A} = \frac{QE}{A} = \frac{\sigma A}{A}\left(\frac{\sigma}{2\varepsilon}\right) = \frac{1}{2}\frac{\sigma^2}{\varepsilon_0}$

DIELECTRIC

Dielectric is a material which behaves as non conductor upto certain value of External electric Field. If the Field crosses the limiting value (Called dielectric strength) then it begins to conduct Dielectric constant (k or ε_r). $\varepsilon_r = K = \frac{\varepsilon}{\varepsilon_0}$

POLAR DIELECTRIC	NON-POLAR DIELECTRIC
✦ Centers of +ve and –ve charge do not coincide due to asymmetric shape of molecules.	✦ Centers of +ve and –ve charge coincide due to symmetric shape of molecules.
✦ Each molecule has permanent dipole moment In presence of External electric Field.	✦ Each molecule has permanent dipole moment only in presence of External electric Field.

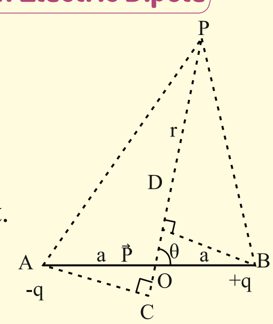




Potential due to an Electric Dipole

$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{P\cos\theta}{(r^2 - a^2\cos^2\theta)}$$

where P is dipole moment.



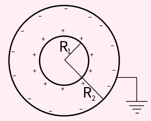
Electric potential due to conducting and Non-Conducting sphere:

	Hollow conducting	Solid Non-Conducting
(i) Inside (r < R)	$V_p = \frac{Kq}{R}$	$V_p = \frac{Kq}{2R^3}[3R^2 - r^2]$
(ii) Outside (r > R)	$V_p = \frac{Kq}{r}$	$V_p = \frac{Kq}{r}$
(iii) At surface (r = R)	$V_p = \frac{Kq}{R}$	$V_p = \frac{Kq}{R}$

Other Types of Capacitor's

Spherical Capacitor outer surface Earthed:

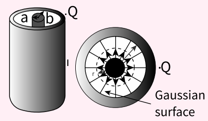
$$C = \frac{Q}{V} = \frac{4\pi\varepsilon_0}{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$



Cylindrical Capacitor:

$$C = \frac{2\pi\varepsilon_0 L}{\ln\left(\frac{b}{a}\right)}$$

L, b and a - Parameters of Cylinder



Force Between the Plates of Capacitor

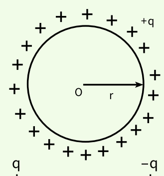
$$F = \frac{Q\sigma}{2\varepsilon_0} \Rightarrow F \frac{Q^2}{2A\varepsilon_0} = \frac{1}{2}\varepsilon_0 A E^2$$

F = Force; Q = charge

E = electric field between plates

σ = surface charge density

Types Of Capacitance's



- Capacitance of spherical conductor: $C = 4\pi\varepsilon_0 r$
- Capacitance of Earth: $C = 4\pi\varepsilon_0 r$; $r = 6.4 \times 10^6$ m

∴ $C = 4\pi \times 8.854 \times 10^{-12} \times 6.4 \times 10^6 = 7.11 \times 10^{-6}$ F

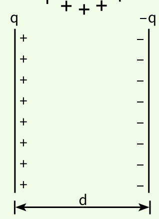
- Capacitance of parallel plate Capacitor:

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

Where—

ε_0 = Free space permitivity

A = Plate Area , d = Separation between plates



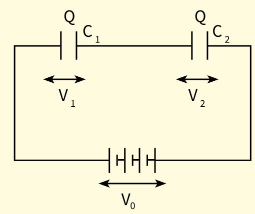
Combination Of Capacitor's

Series Equivalent of Capacitor's

In series—$Q = C_1V_1 = C_2V_2$

∵ $V_0 = V_1 + V_2$

∵ $\frac{1}{C_{equi}} = \frac{1}{C_1} + \frac{1}{C_2}$

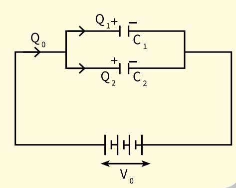


Parallel Equivalent of Capacitor's

In parallel—$V = V_1 = V_2$

$Q = Q_1 + Q_2$

$C_{Equi} = C_1 + C_2$



Energy Stored in a Charged Capacitor

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

CAPACITOR

A capacitor is a device which can store more electric charge or potential energy compared to an isolated conductor.

Capacitance: Capacitance of a conductor measure of its ability to store charge.

$$V \propto q \Rightarrow V = \frac{q}{C} \Rightarrow C = \frac{q}{V}$$

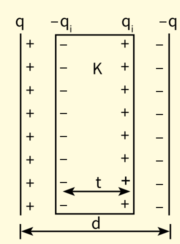
S.I. Unit Farad (F) = $\frac{\text{Coulomb}}{\text{Volt}}$

Capacitor with Dielectric

- **Capacitance of capacitor having dielectric constant** (k) **and** (t<d)**:**

$$C = \frac{A\varepsilon_0}{d - t + \frac{t}{k}}$$

t = thickness , k= Dieletric Constant



- **Capacitance of Capacitor having dielectric constant** (K) **and** (t = d)**:**

$$C = \frac{A\varepsilon_0}{d - d + \frac{d}{k}} = \frac{kA\varepsilon_0}{d} = kC_0$$