ELECTROSTATIC POTENTIAL AND CAPACITANCE

BRAIN MAP

CLASS XII

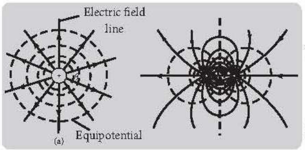
Electrostatic Potential

Work done per unit positive test charge by an external force in bringing a unit positive charge from infinity to a point in the presence of another point charge.

$$V = -\frac{W}{q_0} = \frac{q}{4\pi\varepsilon_0 r}$$

Equipotential Surface

Surface having same electrostatic potential at every point.



Properties

- Do not intersects each other
- At every point $\vec{E} \perp$ surface
- Work done in moving a charge is zero $W_{net} = 0$
- Closely spaced in the region of strong field and vice-versa.

Electric Potential Energy

For a system of two charges

$$U = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

Electrostatic Potential Due to an Electric Dipole

At any arbitrary point; $V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$

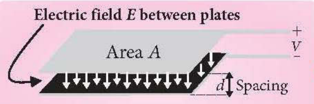
- At axial point $V = \frac{p}{4\pi\varepsilon_0 r^2}$
- At equatorial point $V = 0$

Potential energy of a dipole in external field

$U(\theta) = pE(\cos\theta_0 - \cos\theta)$

$\rightarrow$ When initially at $\theta_0 = 90°$

$\Rightarrow U = -\vec{p}\cdot\vec{E}$



Charge on the inside of each plate: +Q on the top, −Q on the bottom

Relation between $\vec{E}$ and V

$\vec{E} = -\vec{\nabla}V$

$E = -\frac{dV}{dr}$

Capacitor and Capacitance

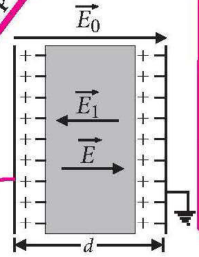
Capacitor is used to store electrical energy. Capacitance is defined as the ratio of the charge stored to the potential between the plates.

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

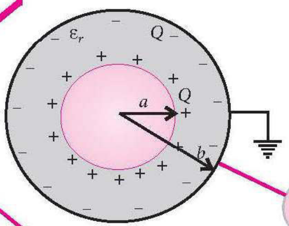
Combination of Capacitor

- Series combination $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$
- Parallel combination $C_p = C_1 + C_2$

Capacitances of different types of capacitors



- Parallel plate capacitor with dielectric slab of thickness t: $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$
- Parallel plate capacitor filled with dielectric: $C = \frac{K\varepsilon_0 A}{d}$
- Air filled parallel plate capacitor: $C = \frac{\varepsilon_0 A}{d}$
- Parallel plate capacitor with metallic conductor inserted in it: $C = \frac{\varepsilon_0 A}{(d-t)}$
- Spherical capacitor: $C = 4\pi\varepsilon_0 \frac{ab}{b-a}$



Electrostatic Shielding

To shield an electronic circuit from external field by surrounding it with conducting walls.

Lightning Conductor

Lightning conductors fitted above the highest part of a building to protect a tall building from being struck by lightning.

Energy Stored in a Capacitor

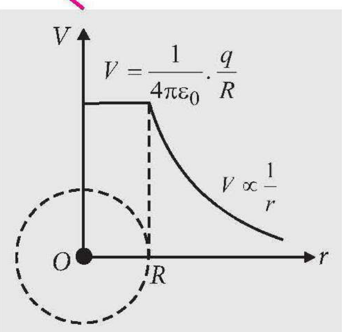
$$U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$$

Energy Density

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

Electric Potential due to Uniformly Charged Spherical Shell

- Outside the shell $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}; r > R$
- On the shell $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}; r = R$
- Inside the shell $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$



Electric Potential Due to a Non-Conducting Solid Sphere

- outside the sphere $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}; r > R$
- on the sphere i.e., $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}; r = R$
- inside the sphere $V = \frac{1}{4\pi\varepsilon_0}\frac{q(3R^2 - r^2)}{2R^3}; r < R$

Van de Graaff Generator

An electrostatic generator design to produce high voltage of the order of 10 million volt, used to accelerate charged particles.

Principle

- If an electric charge is imparted to the inside of a spherical conductor, it is distributed entirely on its outer surface.
- Pointed ends cannot retain charge due to high charge density on them.