2024 – 25

Electrostatic Potential and Capacitance

Recall what did you study in previous class

Electric Potential Energy:

(a) The electric potential energy for a point charge q0 in the electric field of a stationary point charge q, with a distance r separating the charges is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_0 q}{r}$$

If electric potential energy at infinity is considered to be zero

(b) Work done by electric force on a charge when it is moved from A to B

$$W_{A\to B} = U_A - U_B$$

Electric Potential:

(a) Potential is equal to potential energy per unit charge

$$V = V = \frac{U}{q_0}$$

The potential for a point charge q at any point at a distance r is

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

(b) Potential due to a collection of charges is the sum of the potentials due to each charge.

$$V_n = \frac{1}{4\pi\varepsilon_0}\sum_i^n \frac{q_i}{r}$$

(c) Potential due to a conducting sphere of radius r with charge q (solid or hollow) at a distance r from the centre

$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{r} \qquad \text{if } (r > R)$$

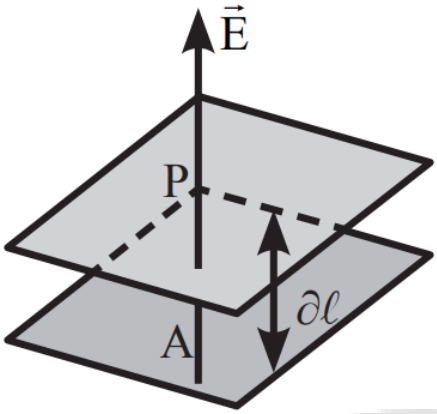
$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{R} \qquad \text{if } (r = R)$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R} \qquad \text{if } (r < R)$$

(d) Relation between electric field and potential

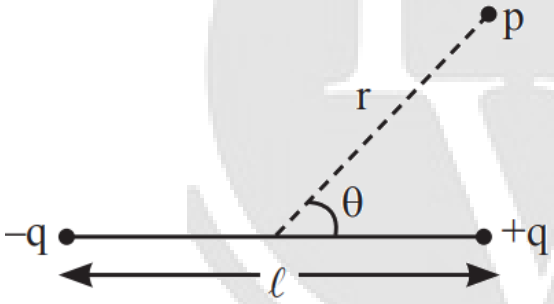
$$|\vec{E}| = -\frac{\partial V}{\partial \ell}|$$

$$= + \frac{|\partial V|}{\partial \ell}$$



Electric Dipole Potential

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



(b) Potential energy of a dipole in an external electric field $U(\theta) = -\vec{p}\cdot\vec{E}$

Capacitors:

- Capacitance of a parallel plate capacitor

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

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

Electric Field Energy

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

(b) Energy density of energy stored in electric field $U = \frac{1}{2}\varepsilon_0 E^2$

Combination of Capacitor

(a) When capacitors are combined in series,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots$$

(b) When capacitors are connected in parallel,

$C_{eq} = C_1 + C_2 + C_3 + \ldots\ldots$

(c) Spherical capacitor,

$C = 4\pi\varepsilon_0 \dfrac{ab}{b-a}$, (When outer shell is earthed)

$C = 4\pi\varepsilon_0 \dfrac{b^2}{b-a}$, (When inner shell is earthed)

$C = 4\pi\varepsilon_0 R$ (For a sphere of radius R)

(d) Cylindrical capacitor, $C = \dfrac{2\pi\varepsilon_0 1}{\ln\left(\dfrac{b}{a}\right)}$

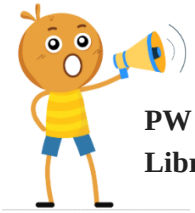
Dielectrics

(a) Induced charge, $q' = q\left(1-\dfrac{1}{K}\right)$

(b) Polarisation $P = \dfrac{\text{Dipole moment}}{\text{Volume}}$

$\vec{P} = \chi_0 \vec{E}$

$\dfrac{\chi_0}{\varepsilon_0} = K - 1$



PW Web/App - https://smart.link/7wwosivoicgd4

Library- https://smart.link/sdfez8ejd80if