CHAPTER 2

Electrostatic Potential and Capacitance

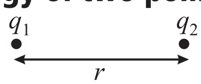
Relation between $\vec{E}$ & V

$$\vec{E} = -\text{grad}\,V = -\nabla V, E = \frac{-\partial V}{\partial r};$$

$$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}, \Delta V = -\int_{\vec{r_1}}^{\vec{r_2}} -\vec{E}.\vec{dr}$$

Electric Potential Energy of two point Charges

$$U = \frac{1}{4\pi \in_0}\frac{q_1 q_2}{r}$$



Electric Potential due to an Electric Dipole

- At a point which is at a distance r from midpoint of dipole and making angle θ with dipole axis.

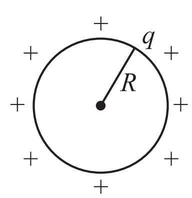
  Potential $V = \frac{1}{4\pi \in_0}\frac{p\cos\theta}{r^2}$

Equipotential Surface and Equipotential Region

In an electric field the locus of points of equal potential is called an equipotential surface. An equipotential surface and the electric field lines meet at right angles. In a region where $E = 0$, potential of the whole region must remain constant as no work is done in displacement of charge in it. It is called as equipotential region. Material of conductors is an equipotential region.

Potential due to Various Bodies

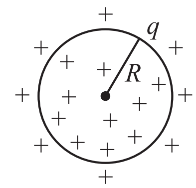
For a Conducting Sphere



For $r \geq R : E = \frac{1}{4\pi \in_0}\frac{q}{r^2}, V = \frac{1}{4\pi \in_0}\frac{q}{r}$

For $r < R : E = 0,\ V = \frac{}{\pi \in}\frac{q}{R}$

For a non-conducting Sphere

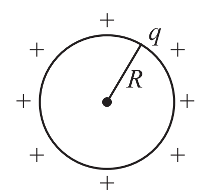


For $r \geq R : E = \frac{1}{4\pi \in_0}\frac{q}{r^2}, V = \frac{1}{4\pi \in_0}\frac{q}{r}$

For $r < R : E = \frac{1}{4\pi \in_0}\frac{qr}{R^3}, V = \frac{1}{4\pi \in_0}\frac{q(3R^2 - r^2)}{2R^3}$

$$V_{\text{center}} = V_{\max} = \frac{3}{2}\frac{kq}{R} = 1.5V_{\text{surface}}$$

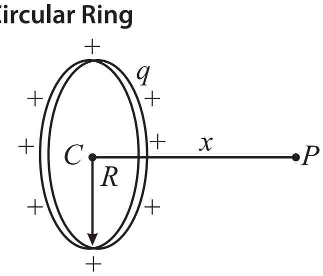
For a Conducting/non Conducting Spherical shell



For $r \geq R : E = \frac{1}{4\pi \in_0}\frac{q}{r^2}, V = \frac{1}{4\pi \in_0}\frac{q}{r}$

For $r < R : E = 0,\ V = \frac{1}{4\pi \in_0}\frac{q}{R}$

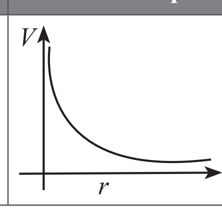
For a Charged Circular Ring

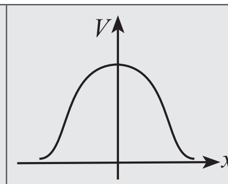
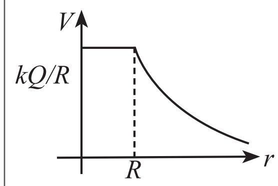
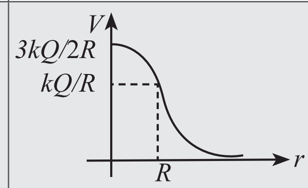


$$E_P = \frac{1}{4\pi \in_0}\frac{qx}{(x^2 + R^2)^{3/2}}, V_p = \frac{q}{4\pi \in_0 (x^2 + R^2)^{1/2}}$$

Electric field will be maximum at $x = \pm\frac{R}{\sqrt{2}}$

Electric potential will be maximum at $x = 0$

Name/Type	Formula for Potential	Note	Graph
Point charge	$\frac{kq}{r}$	❖ q is source charge. ❖ r is the distance of the point from the point charge.	

Ring (uniform/ non uniform charge distribution)	At center: $\frac{kQ}{R}$ At the axis $\frac{kQ}{\sqrt{R^2+x^2}}$	❖ Q is source charge. ❖ x is the distance of the point on the axis from center of ring	
Uniformly charged hollow conducting/ non conducting/solid conducting sphere	For $r \geq R$, $V = \frac{kQ}{r}$ For $r \leq R$, $V = \frac{kQ}{R}$	❖ R is radius of sphere ❖ r is the distance from center of sphere to the point ❖ Q is total charge = $\sigma 4\pi R^2$.	
Uniformly charged solid nonconducting sphere	For $r \geq R$, $V = \frac{kQ}{r}$ For $r \leq R$, $V = \frac{kQ(3R^2 - r^2)}{2R^3}$ $= \frac{\rho}{6\varepsilon_0}(3R^2 - r^2)$	❖ R is radius of sphere ❖ r is distance from center to the point ❖ $V_{\text{center}} = \frac{3}{2} V_{\text{surface}}$. ❖ Q is total charge $= \rho \frac{4}{3}\pi R^3$. ❖ Inside the sphere, potential varies parabolically ❖ Outside the sphere potential varies hyperbolically.	
Infinite line charge	Not defined	❖ Absolute potential is not defined. ❖ Potential difference between two points is given by formula: $V_B - V_A = -2k\lambda \ln(r_B/r_A)$	
Infinite nonconducting thin sheet	Not defined	❖ Absolute potential is not defined. ❖ Potential difference between two points is given by formula $V_B - V_A = -\frac{\sigma}{2\varepsilon_0}(r_B - r_A)$	
Infinite charged conducting thin sheet	Not defined	❖ Absolute potential is not defined. ❖ Potential difference between two points is given by formula $V_B - V_A = -\frac{\sigma}{\varepsilon_0}(r_B - r_A)$	