

# Electric Field

Electric Field Intensity ( $E$ ) =  $\lim_{q \rightarrow 0} \frac{F}{q}$   
Force experienced by the test charge / Test charge  
 SI unit:  $NC^{-1}$  or  $VM^{-1}$  (NLT/A)

Due to Point charge

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

Due to System of Charges (superposition principle)

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \dots$$

$$E = \frac{1}{4\pi\epsilon_0} \sum \frac{q_i}{r_i^2}$$

Due to Continuous Charge Distribution

- Linear charge distribution

$$E = \frac{1}{4\pi\epsilon_0} \int \frac{\lambda}{r^2} dl$$

- Surface charge distribution

$$E = \frac{1}{4\pi\epsilon_0} \int \frac{\sigma}{r^2} dS$$

- Surface charge distribution

$$E = \frac{1}{4\pi\epsilon_0} \int \frac{\rho}{r^2} dV$$

At a point on the axis of uniformly charged ring

$$E = \frac{1}{4\pi\epsilon_0} \frac{qx}{(x^2 + R^2)^{3/2}}$$



Electric dipole:

$\vec{p} = q \cdot 2a$   
Electric dipole moment / Vector quantity / SI unit: C.m (NLT/A)

At a point on Axial line of dipole:



If  $x \gg 2a$ , then  $E = \frac{1}{4\pi\epsilon_0} \frac{2p}{x^3}$

$$E = \frac{1}{4\pi\epsilon_0} \frac{2px}{(x^2 - a^2)^2}$$

At a point on equatorial line of dipole:



$$E = \frac{1}{4\pi\epsilon_0} \frac{p}{(x^2 + a^2)^{3/2}}$$

If  $x \gg 2a$ , then

$$E = \frac{1}{4\pi\epsilon_0} \frac{p}{x^3}$$

Electric flux ( $\phi$ ):

Electric flux over an area is equal to the total number of electric field lines crossing this area.

$$\phi = \int \vec{E} \cdot d\vec{S} = \int E dS \cos\theta$$

Applications of Gauss' Theorem

Due to an infinite Line charge

$$E = \frac{1}{4\pi\epsilon_0} \frac{2\lambda}{r} \Rightarrow E = \frac{\lambda}{2\pi\epsilon_0 r}$$

Near an infinite Plane Sheet of charge

$$E = \frac{\sigma}{2\epsilon_0}$$



For thick charged sheet,

$$E = \frac{\sigma}{\epsilon_0}$$

Due to uniformly charged spherical shell (radius  $R$ )

(a) Outside the shell ( $r > R$ )  $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$

(b) At the surface of a shell ( $r = R$ )  $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2}$

(c) Inside the shell ( $r < R$ )  $E = 0$



Due to uniformly charged non-conducting solid sphere

(a) Outside the sphere ( $r > R$ )  $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$

(b) At the surface of a sphere ( $r = R$ )  $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2}$

(c) Inside the sphere ( $r < R$ )  $E = \frac{1}{4\pi\epsilon_0} \frac{Qr}{R^3}$



Gauss' Theorem:

$$\phi = \oint E dS = \frac{1}{\epsilon_0} \cdot q_{enc}$$

- If a charge  $q$  is placed at the center of cube, then total flux linked with the whole cube is  $\phi$  & electric flux linked with one face of cube is  $\phi/6$
- If a charge  $q$  is placed on one corner of cube, then total flux linked with the whole cube is  $\phi/8$

At any point along a line making  $\theta$  angle with dipole axis:

$$E = \frac{1}{4\pi\epsilon_0} \frac{p \sqrt{1 + 3 \cos^2 \theta}}{r^3}$$

Due to two infinite parallel sheets of charge:



Torque on dipole in uniform electric field

$$\tau = pE \sin\theta = \vec{\tau} = \vec{p} \times \vec{E}$$

- If  $\theta = 0^\circ$  - Stable equilibrium
- If  $\theta = 180^\circ$  - Unstable equilibrium

Work done & Potential Energy of dipole in uniform Electric Field:

$$W = -pE (\cos\alpha - \cos\beta) \quad W = pE (1 - \cos\theta)$$

If dipole is rotated by an angle  $\theta = 180^\circ$  to  $\theta = 0^\circ$ , then Potential energy

$$W = U = -pE \cos\theta = -pE$$

# Conceptual Physics Electric Field And Potential

**Brendan G. Carr**



## **Conceptual Physics Electric Field And Potential:**

## Unveiling the Magic of Words: A Review of "**Conceptual Physics Electric Field And Potential**"

In a global defined by information and interconnectivity, the enchanting power of words has acquired unparalleled significance. Their ability to kindle emotions, provoke contemplation, and ignite transformative change is really awe-inspiring. Enter the realm of "**Conceptual Physics Electric Field And Potential**," a mesmerizing literary masterpiece penned by way of a distinguished author, guiding readers on a profound journey to unravel the secrets and potential hidden within every word. In this critique, we shall delve in to the book is central themes, examine its distinctive writing style, and assess its profound impact on the souls of its readers.

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