

ELECTROSTATICS

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The study of properties of stationary electric charges and their effects. Electrostatic phenomena arises from the force between electric charges described by Coulomb's law.

Basic Properties of Charges

- Charges are quantised in nature
- Total charge of an isolated system is conserved
- Charges are additive in nature

Electric Dipole

Every dipole is associated with a dipole moment \vec{p} , whose magnitude is equal to the product of the magnitude of either charge (q) and the distance $2a$ between the charges, i.e., $\vec{p} = q \times 2a$

The net force experienced by the dipole is zero. Due to torque so produced, dipole starts in the direction of electric field.
 $\vec{\tau} = \vec{p} \times \vec{E}$ or $\tau = pE \sin \theta$

Charge

Electric Field

The force experienced by a unit positive charge placed at that point.

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2} \hat{r}$$

1 N/C = $\frac{1 \text{ newton}}{1 \text{ coulomb}} = \frac{1 \text{ volt}}{1 \text{ metre}}$
Dimension: $[E] = [MLT^{-2}A^{-1}]$

Electric Flux

Flux of electric field \vec{E} through any area A is defined as:
 $\Phi = EA \cos \theta$
or $\Phi = \int \vec{E} \cdot d\vec{A}$
S.I. unit is Vm
 $\frac{Nm^2}{C}$

Gauss's Theorem

Total normal electric flux out of a closed surface S is equivalent to $1/\epsilon_0$ times the charge (q) contained inside the surface.
 $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$

Basic Characterisation

- Field lines start from positive charges and end at negative charges.
- Electrostatic field lines do not form any closed loops.
- Two field lines can never cross each other.

Coulomb's Law

For two stationary point charges q_1 and q_2 are kept at a distance r ,
 $\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$ (N/C) (N/m)
 $\epsilon_0 = \frac{1}{9 \times 10^9}$

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

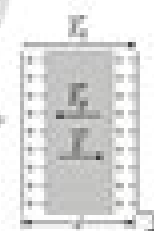
Combination of Capacitors

Series combination
 $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}$

Parallel combination
 $C_p = C_1 + C_2 + C_3 + C_4$

Parallel plate capacitor with dielectric slab of thickness t with dielectric constant K .

$$C = \epsilon_0 K \frac{A}{d}$$

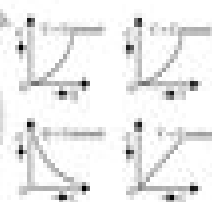


Energy Stored in a Capacitor

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

$$U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} \frac{Q^2}{\epsilon_0 K \frac{A}{d}}$$

Energy Density



Electric field \vec{E} between plates = $\frac{V}{d}$

Charge on the inside of each plate, $+Q$ on the top, $-Q$ on the bottom

Electric Potential due to Uniformly Charged Spherical Shell

Outside the shell
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$
 $r > R$

On the shell
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$
 $r = R$

Inside the shell
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$
 $r < R$

Inside the sphere
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R} \left(\frac{R^2 - r^2}{R} + \frac{r^2}{R^2} \right)$
 $r < R$

Electric Potential due to a Non-Conducting Charged Solid Sphere

Outside the sphere
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$
 $r > R$

On the sphere
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$
 $r = R$

At solid point,
 $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$

Electrostatic Potential due to an Electric Dipole

At any arbitrary point,
 $V = \frac{1}{4\pi\epsilon_0} \frac{\vec{p} \cdot \vec{r}}{r^3}$

At equatorial point,
 $V = 0$

Electric Potential Energy

For a system of two charges
 $U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$

Potential energy of a dipole in external field $E_0 = pE_0 \cos \theta$ when initially $\theta_0 = 0^\circ$, $U = -p \cdot E_0$

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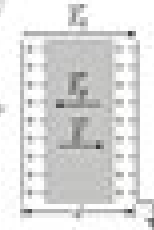
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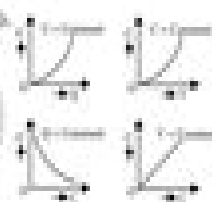


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Conceptual Physics Electrostatics Ch 3

Daniela Niemeyer



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