10. Electrostatics

- **Charging by induction:** This is a process of charging an uncharged body with the help of a charged body without any actual contact.
- A charge of opposite sign develops on uncharged body.

Basic Properties of Electric Charges

- The total electric charge on an object is equal to the algebraic sum of all the electric charges distributed on the different parts of the object
- The total charge of an isolated system remains constant with time.
- All observable charges are always some integral multiple of elementary charge, e (= $\pm$ 1.6 × 10^{-19} C)

Coulomb's Law

- Two point charges attract or repel each other with a force which is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.
- F=Kq1q2r2,K=14πε0=9×109 Nm2C-2

Principle of Superposition

- It is based on the property that the forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s).
- The total force on a given charge due to number of charges is equal to the vector sum of the individual forces exerted on the given charge by all the other charges.

Electric Field

- It is the space around a charge, in which any other charge experiences an electrostatic force.

Electric Field Intensity

- The electric field intensity at a point due to a source charge is defined as the force experienced per unit positive test charge placed at that point without disturbing the source charge.
- Electric field due to a point charge at distance r from it is E= q4πε0r2
- Electric field due to a number of charges is found by adding the individual electric fields vectorially.

Electric Field Lines

- An electric line of force is the path along which a unit positive charge would move, if it is free to do so.
- Properties of electric field lines

- They are continuous curves without any breaks
- They cannot cross each other.
- They cannot form closed loops.

Continuous Charge Distribution

- **Linear charge density** − When charge is distributed along a line then charge density is given by λ.
  - $\lambda = \frac{q}{L}$
- **Surface charge density-**When charge is distributed along a surface, the charge density is given by σ.
  - $\sigma = \frac{q}{A}$
- **Volume charge density-**When charge is distributed along a volume, the charge density is given by δ.

$\delta = \frac{q}{V}$

Electric Dipole

- System of two equal and opposite charges separated by a certain small distance.

Electric Dipole Moment

- It is a vector quantity, with magnitude equal to the product of either of the charges and the length of the electric dipole and direction from the negative charge to the positive charge.

$\vec{p} = q(\overrightarrow{2a})$

Electric Field on Axial Line of an Electric Dipole

E=⟶2 p4πε0r3

Electric Field for Points on the Equatorial Plane

E=⟶- p4πε0r3

Dipole in a Uniform External Field

In a uniform electric field *E*, a dipole experiences a torque *t*, due to two equal and unlike parallel forces acting on dipole

τ = Force × Perpendicular distance between the two forces

$\tau = pE \sin\theta$

$\therefore \bar{\tau} = \bar{p} \times \vec{E}$

Electrostatic Potential energy

- Work done by an external force in bringing a charge q from a point R to a point P in electric field of a certain charge configuration is UP-UR, which is the difference in potential energy of charge q between the final and initial points.
- Potential energy at a point is the work done by an external force in moving a charge from infinity to that point.

Electrostatic Potential

- Electrostatic potential at any point in a region of electrostatic field is the minimum work done in carrying a unit positive charge (without acceleration) from infinity to that point.
- Electric potential due to a point charge of magnitude *q* at a distance r from the charge is given as V=q4πε0r
- Potential difference between two points P and R can be written as VP-VR =UP-URq

Equipotential Surfaces

An equipotential surface is that surface at every point of which, the electric potential is same.

No work is done in moving a test charge from one point of the equipotential surface to the other.

The equipotential surface for a point charge are concentric spherical surfaces centered at the charge.

Potential due to a System of Charges

- For a system of point charges $q_1, q_2, q_3, \ldots q_n$ at distances $r_1, r_2, r_3, \ldots r_n$ respectively from the point P,
- The potential at a point P is given by the superposition principle

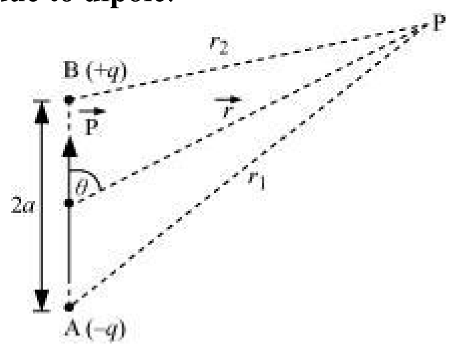
$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \ldots + \frac{q_n}{r_n}\right)$$

$$\boxed{V = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}}$$

Dipole

- A dipole is a system of two charges of equal magnitude *q* and opposite polarity separated by a distance 2*a* .The dipole moment of the dipole is p→ with magnitude p=q×2a and direction - *q* to + *q*.

Potential due to dipole.



- Potential at point P due to charge at point A is given as:

$$V_1 = \frac{-q}{4\pi\varepsilon_0 r_1}$$

- Potential at point P due to charge at point B is given as:

$$V_2 = \frac{q}{4\pi\varepsilon_0 r_2}$$

- Total Potential at point P due to dipole

$$V = V_1 + V_2$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$$

V at position vector r can be expressed as

$$\boxed{V = \frac{\vec{p}\cdot\hat{r}}{4\pi\varepsilon_0 r^2}} \qquad \text{for}\,(r >> a)$$

Potential Energy of a Single Charge

It is the work done in bringing a charge q from infinity to a point P whose position vector is r→and V(r→) is potential due to external field there.

The magnitude of work done $= q\cdot V(\vec{r})$.

Potential Energy of a System of Two Charges in an External Field

- It is the sum of the work done in bringing q_1 and q_2 from infinity to r1⇀ and r2→ respectively and assembling the charges at their respective locations.

$$U = W_1 + W_2 + W_3$$

$$\boxed{U = q_1 \cdot V(\vec{r}_1) + q_2 \cdot V(\vec{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}}$$

Potential Energy of an Electric Dipole, When Placed in a Uniform Electric Field

- The potential energy of an electric dipole in a uniform electric field is given as $U = -\vec{p} \cdot \vec{E}$

  where p→= dipole moment of the dipole
  E→ = strength of external electric field