11. Electrostatics

Electric flux

- It is the total number of electric field lines of force crossing the unit surface area in a direction normal to the surface.
- The flux Φ of an electric field *E*, through a small area element *ds* is given by $\phi = \int_s \vec{E} \cdot \vec{ds} = \int_s \vec{E}_n \, ds$

Gauss's law

- It states that the total electric flux through a closed surface enclosing a charge *q* is equal to $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed.
- $\phi = \frac{q}{\varepsilon_0}$
- $\phi = \oint_s \vec{E} \cdot \vec{ds}$

Applications of Gauss's Law

- Electric field intensity due to an infinitely long straight wire of linear charge density *λ* at a point which is at a perpendicular distance *r* from the wire is given by
  λ2πε0r n^, where n^ is the radial unit vector in the plane normal to the wire passing
- Electric field intensity due to a uniformly charged infinite plane sheet of surface charge density *s* is given by
  σ2ε0n^ , where n^ is a unit vector normal to the plane, acting outward on either side.
- Electric field intensity due to a total charge q distributed along its surface is given by
  q4πεr2 (r≥R), 0 (r<R)

  Here, *r* is the distance of the point from the centre of the shell and *R* is the radius of the shell.
- Mechanical force per unit area of a charged conductor, f=12εE2.
- Energy density per unit volume of a charged conductor, dudv=12εE2.

Electrostatics of conductors

- Inside a conductor, the electric field is zero.
- The interior of a conductor can have no excess charge in static situation.
- The electric field on the surface of a charged conductor is perpendicular to the surface of the conductor at every point.

- Electrostatic potential is constant throughout the volume of the conductor, and has the same value as on its surface.

Non-Polar Dielectrics

- When the Non-polar dielectric is placed in an external electric field the two centres of positive and negative charges in the molecule are separated and the non-polar molecule gets polarised.

Polar Dielectrics

When an external electric field is applied, the individual dipole moments tend to align with the field.
A net dipole moment in the direction of the external field is developed
Induced dipole moment P acquired by the molecule may be written as

$$P = \alpha\varepsilon_0 E_0$$

When a dielectric is placed in an external electic field $\vec{E}_0$ due to polarisation there is developmentof an electric field $\vec{E}_P$ opposite to the $\vec{E}_0$

∴ Effective electric field in a polarised dielectric = $E = E_0 - E_P$

Capacitor

- A capacitor is a system of two conductors separated by an insulator.
- Its capacitance, $C = Q/V$, where Q *and* $-Q$ are the charges on the two conductors and V is the potential difference between them.
- C is determined purely geometrically, by the shapes, sizes and relative positions of the two conductors. For a parallel plate capacitor (with vacuum between the plates),

  C=ε0Ad
  Here, A is the area of each plate and d is the separation between them.

- If the medium between the plates of a capacitor is filled with an insulating substance (dielectric), the electric field due to the charged plates induces a net dipole moment in the dielectric. This effect is called polarisation and it gives rise to a field in the opposite direction.
- The net electric field inside the dielectric, and hence the potential difference between the plates, is thus reduced. Consequently, the capacitance C increases from its value C_0 {when there is no medium (vacuum)} to $C = KC_0$. Here, K is the dielectric constant of the insulating substance.
- Capacitors are of the following types:
  - Parallel plate capacitor
  - Cylindrical capacitor
  - Spherical capacitor
- Capacitance of cylindrical capacitor without dielectric is given as C=2πεollnba
- Capacitance of spherical capacitor without dielectric is given as C=4πεoabb-a

Capacitors in Series

- In series connection the potential difference applied across the combination is the sum of the resulting potential differences across each capacitor.
- In series combination the charge in all of the capacitors is same.
- Total capacitance in a series combnination of the capcitors is given as:

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

Capacitors in parallel

- In parallel connection the potential difference is same across each capacitor.
- Total capacitance in parallel combination of the capacitors is given as:

$$C_P = C_1 + C_2 + C_3$$

The Energy U stored in a capacitor of capacitance *C*, with charge *Q* and voltage *V* is

- $U = \frac{Q^2}{2C}$
- $U = \frac{1}{2}CV^2$

Van de Graff generator

It works on the principle that charge given to a hollow conductor is transferred to the outer surface and is distributed uniformly on it.

It is a device used for building up high potential differences of the order of a few million volts.

It consists of a large spherical conducting shell. By means of a moving belt and suitable brushes,charge is continuously transferred to the shell and potential difference of the order of several million volts is built up.

It is used as a particle accelerator.