Electric Charges and Fields

1. Electric Charge

- Fundamental property of matter that causes it to experience a force in an electric field.
- **Types**: Positive charge (+) and negative charge (-).
- **Like charges** repel; **unlike charges** attract.
- **Unit**: Coulomb (C).
- **Quantization of Charge**: Charge exists in discrete amounts, given by $q = ne$, where $e = 1.6 \times 10^{-19}$ C.
- **Conservation of Charge**: Total charge in an isolated system remains constant.

2. Coulomb's Law

- Describes the force between two point charges.
- **Formula**:
  $$F = k_e \frac{|q_1 \cdot q_2|}{r^2}$$
  where F is the force, q_1 and q_2 are the charges, r is the distance between them, and k_e is Coulomb's constant, $k_e = 8.99 \times 10^9 , \text{Nm}^2/\text{C}^2$.

3. Electric Field (E)

- A region around a charge where other charges experience a force.
- **Formula**:
  $$E = \frac{F}{q} = k_e \frac{|Q|}{r^2}$$

where (Q) is the source charge and (r) is the distance from the charge.
- **Unit**: Newton per Coulomb (N/C) or Volt per meter (V/m).

4. Electric Field Lines

- Imaginary lines that represent the direction and strength of the electric field.
  - Field lines point **away** from positive charges and **towards** negative charges.
  - **Denser** lines indicate a stronger field.

5. Electric Dipole

- A pair of equal and opposite charges separated by a small distance.
- **Dipole moment (p)**:
  [
  p = q \cdot d
  ]
  where (q) is the magnitude of the charge and (d) is the distance between charges.

6. Electric Flux ((\Phi_E))

- A measure of the number of electric field lines passing through a surface.
- **Formula**:
  [
  \Phi_E = E \cdot A \cdot \cos \theta
  ]
  where (A) is the area and (\theta) is the angle between (E) and the normal to the surface.
- **Unit**: (\text{Nm}^2/\text{C}).

7. Gauss's Law

- States that the electric flux through a closed surface is proportional to the charge enclosed.
- **Formula**:
  [
  \Phi*E* = *frac{q*{\text{enc}}}{\epsilon*0}*
  ]
  where (q{\text{enc}}) is the enclosed charge and (\epsilon_0) is the permittivity of free space, (\epsilon_0 = 8.85 \times 10^{-12} , \text{C}^2/\text{Nm}^2).

8. Applications of Gauss's Law

- Used to calculate electric fields for symmetric charge distributions:
  - **Point charge**: (E = \frac{k_e Q}{r^2})
  - **Infinite line of charge**: (E = \frac{\lambda}{2\pi \epsilon_0 r})
  - **Infinite plane of charge**: (E = \frac{\sigma}{2\epsilon_0})

9. Conductors in Electrostatic Equilibrium

- Electric field inside a conductor is zero.
- Any excess charge resides on the surface.
- The electric field just outside a charged conductor is perpendicular to the surface.

10. Capacitance

- The ability of a system to store charge per unit voltage.
- **Formula**:
  [
  C = \frac{Q}{V}
  ]

where (C) is the capacitance, (Q) is the charge, and (V) is the potential difference.

Key Constants:

- Coulomb's constant (k_e = 8.99 \times 10^9 , \text{Nm}^2/\text{C}^2)
- Elementary charge (e = 1.6 \times 10^{-19} , \text{C})
- Permittivity of free space (\epsilon_0 = 8.85 \times 10^{-12} , \text{C}^2/\text{Nm}^2)