🔷 Electrostatic Potential

🔸 Definition

- **Electrostatic potential (V)** at a point is defined as the **work done per unit positive test charge** by an external force in bringing the charge **from infinity to that point**, **without acceleration**.

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

- Here,
  - V = electrostatic potential
  - W = work done by external agent
  - q = magnitude of test charge

🔸 Significance

1. **Field-independent quantity**: Potential depends only on **location**, not the nature or magnitude of the test charge.
2. **Scalar quantity**: Unlike electric field, which is a vector, potential is scalar — easier to calculate using superposition.
3. **Relates to energy**:
   - The **potential energy** of a charge q at a point with potential V is:

$$U = qV$$

4. **Used to derive electric field**:
   - Electric field is the **negative gradient** of potential:

$$\vec{E} = -\nabla V$$

🔸 Potential at a Point from Infinity

- The **standard reference point** for defining zero potential is at **infinity**.
- The potential V at a point due to a charge distribution is the **work done** in bringing a **unit positive charge** from **infinity** to that point.

🟦 For a Point Charge Q at the Origin:

$$V(r) = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

- r: Distance from the charge
- ε_0: Permittivity of free space
- The sign of V depends on the sign of Q:
  - $Q > 0 \Rightarrow V > 0$
  - $Q < 0 \Rightarrow V < 0$

🔸 Key Observations

- Potential at **infinity** is taken as **zero**: $V(\infty) = 0$
- Potential is always **path-independent** (only depends on initial and final positions).
- For a system of charges, potentials add up **algebraically** (scalar addition).
