3. Electric Potential

(i) **Potential due to a Point Charge**:

- Let a test charge q_0 be brought in from a point A to a point B in an electric field against the repulsive force on q_0 due to the charge q
- When test charge q_0 is at distance x from the charge q, then force on the test charge q_0 due to the electric field of source charge q is $F_e = q_0 E$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_0 \cdot q}{x^2}$$

- Now, if the test charge q_0 is brought in by distance dx, the work done by the external agent is

$$dW = F_{ext} \times dx = -F_e\,dx$$

$$dW = -\frac{1}{4\pi\varepsilon_0}\frac{q\,q_0}{x^2}dx$$

- Hence, the work done to shift the test charge q_0 from A to B is

$$W_{AB} = \int_{x=x_A}^{x=x_B} dW = \int_{x_A}^{x_B} -\frac{1}{4\pi\varepsilon_0}\frac{q\,q_0}{x^2}dx$$

$$W_{AB} = \frac{q\,q_0}{4\pi\varepsilon_0}\left[\frac{1}{x_B} - \frac{1}{x_A}\right]$$

- Hence, the potential difference between points A and B is

$$V_B - V_A = \frac{W_{AB}}{q_0} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x_B} - \frac{1}{x_A}\right]$$

- If point A is at infinity, then work done in bringing test charge q_0 from infinity to point B in the electric field of source charge q will be equal to potential of the point B i.e. $V_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{x_B}$
- So, electric potential of a point distant r from the source charge q is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

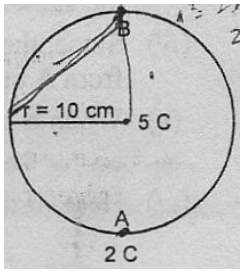
(ii) **Potential due to a Group of Point-Charges**: The potential at any point P due to a group of point-charges $q_1, q_2, \ldots, q_n$ is found by calculating the potential due to each charge and then adding them algebraically

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

, where r_i is the distance of the point P from the charge q_i.

Q1. An ionized helium particle (He^{++}) is situated at the origin (0, 0). How much work is done in taking an electron from x = 3 cm to x = 6 cm?

Q2.: A charge of 5 C is placed at the centre of a circle of radius 10 cm as shown in the figure below. Calculate the work done in moving a charge of 2 C from point A to B on the circumference of the circle.



Q3. Obtain an expression for the electric potential at a point which is at a distance r from the point charge Q.