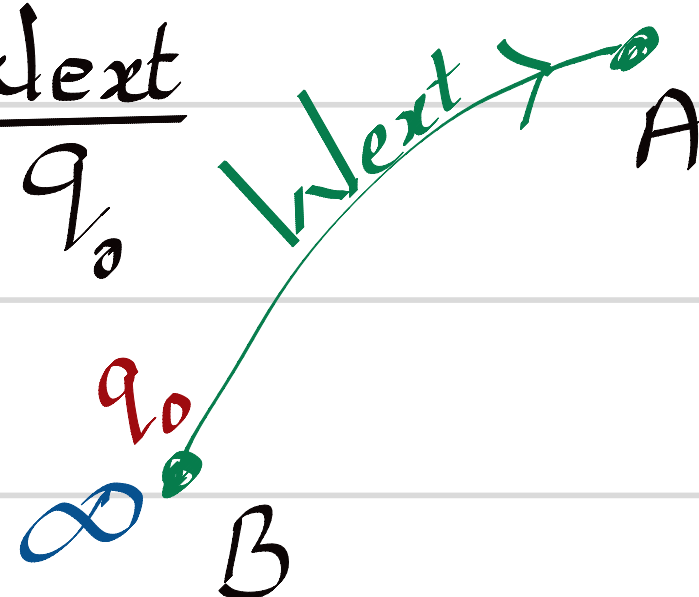


FORMULA SHEET

ELECTROSTATIC POTENTIAL AND CAPACITANCE

1. Electrostatic Potential

$$V = \frac{W_{\text{ext}}}{q_0}$$



$V \rightarrow$ Potential

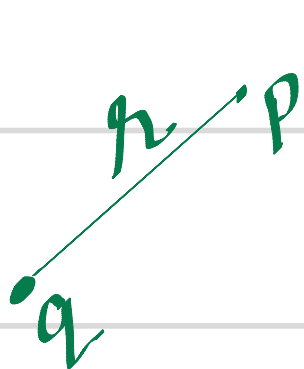
$W \rightarrow$ Work done

$q_0 \rightarrow$ charge

2. Potential difference

$$V_A - V_B = \frac{W_{\text{ext}}(B \rightarrow A)}{q_0}$$

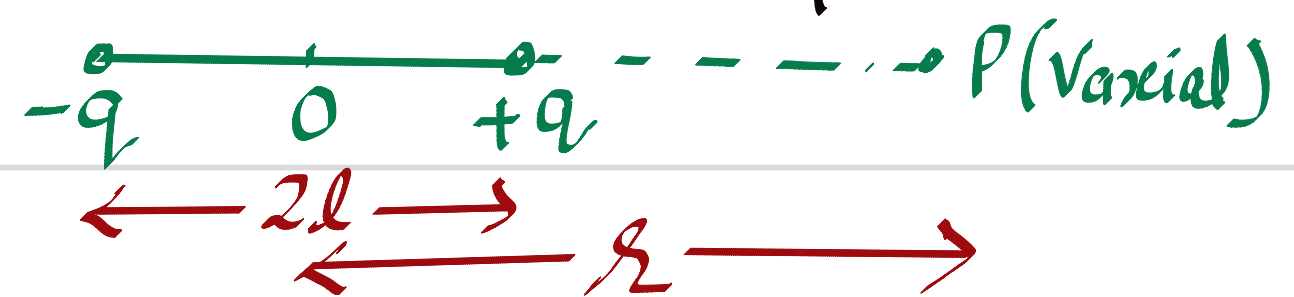
3. Potential due to a point charge 'q'



$$V = k \frac{q}{r} = \frac{1}{4\pi\epsilon_0} \frac{q}{r} \quad \left[k = \frac{1}{4\pi\epsilon_0} \right]$$

4. Potential due to an electric dipole -

(i) On its axis



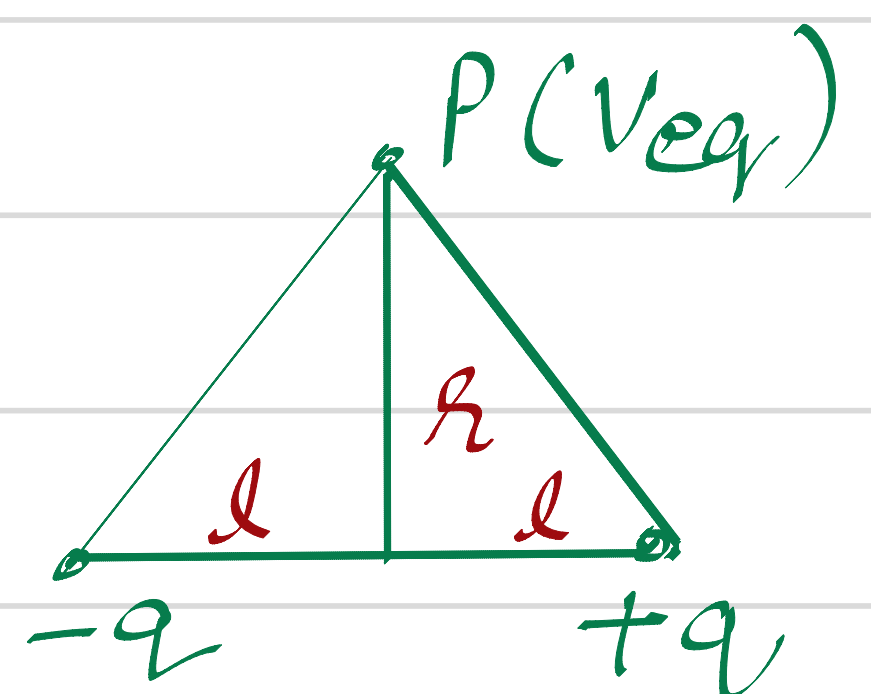
$$V_{\text{axial}} = k \frac{p}{(r^2 - l^2)}$$

For small dipole ($l \ll r$)

$$V_{\text{axial}} = k \frac{p}{r^2}$$

(ii) On equatorial line

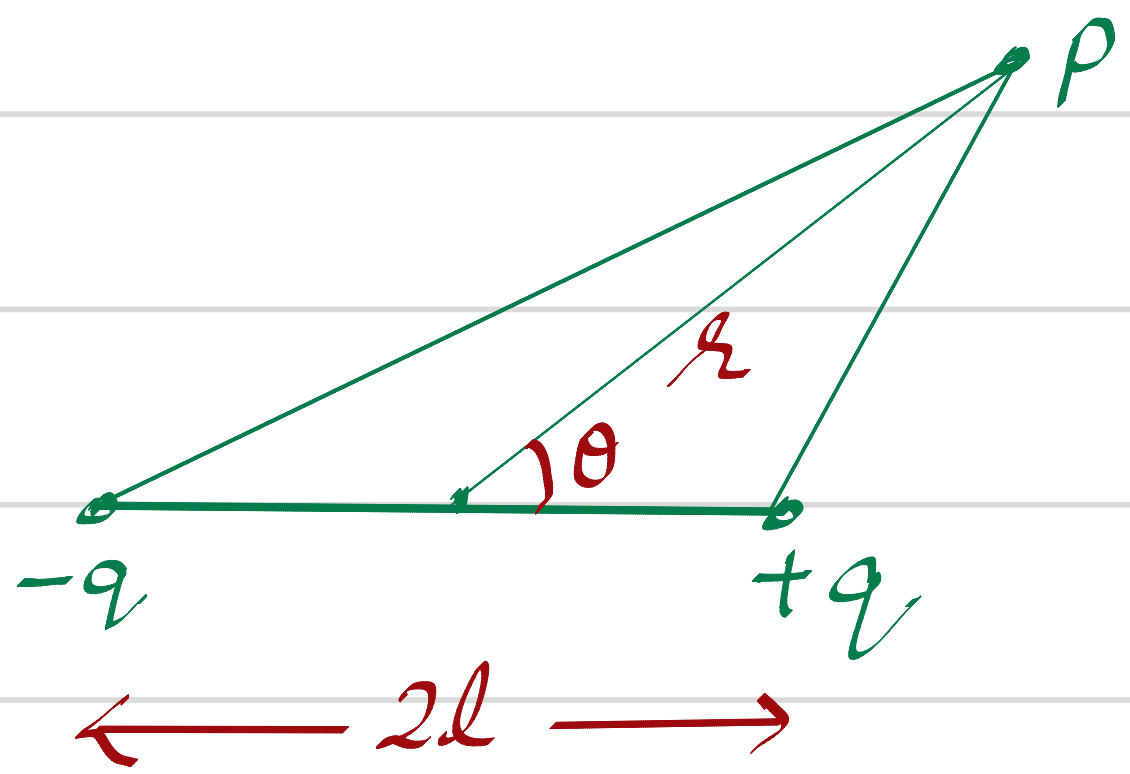
$$V_{\text{eq}} = 0$$



(iii) At any point

$$V = k \frac{p \cos \theta}{r^2}$$

$$= k \frac{\vec{p} \cdot \hat{r}}{r^2}$$



5. Potential due to multiple charges

$$V = k \left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \dots \right]$$

* For -ve charge, potential is -ve

6. Relation b/w electric field and potential

$$\vec{E} = -\frac{dV}{dr} = -\frac{dV}{dl} \left[\begin{array}{l} \text{-ve sign shows} \\ \text{decrease in } V \text{ in} \\ \text{the dir}^n \text{ of } \vec{E} \end{array} \right]$$

$\vec{E} = -$ Potential gradient

or $\vec{E} = -\frac{dV}{dl}$

7. Potential energy of a system of charges.

(i) For a system of two charges

$W = U = k \frac{q_1 q_2}{r_{12}} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}}$

A diagram showing two point charges, q_1 and q_2 , separated by a distance r_{12} .

(1) For a system of n charges

$$W = U = K \left[\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_1 q_3}{r_{13}} + \dots \right]$$

$$W = W_1 + W_2 + W_3 + \dots$$

$$U = U_1 + U_2 + U_3 + \dots$$

* P.E is +ve for $q_1 q_2 > 0$ and -ve for $q_1 q_2 < 0$.

@jyotisharmaphysics

8. Potential energy of a dipole in external electric field

$$U = W = -pE [\cos \theta_2 - \cos \theta_1]$$

(1) for $\theta_1 = 90^\circ$, $\theta_2 = \theta$

$$U = -pE \cos \theta$$

$$U = -\vec{p} \cdot \vec{E}$$

* At $\theta = 0^\circ$, $U = -pE$ [stable equilibrium]

* At $\theta = 180^\circ$, $U = +pE$ [unstable equilibrium]

9. Electric field at the surface of charged conductor of charge density ' σ '

$$\vec{E} = \frac{\sigma}{\epsilon_0} \hat{n} \quad [\hat{n} \rightarrow \text{unit vector in the dir}^n \text{ of } \vec{E}]$$

- * E is $\perp$ to the surface.
- * If $\sigma > 0$, E is outward
- * If $\sigma < 0$, E is inward

10. For a capacitor

$$Q = CV$$

$Q \rightarrow$ charge

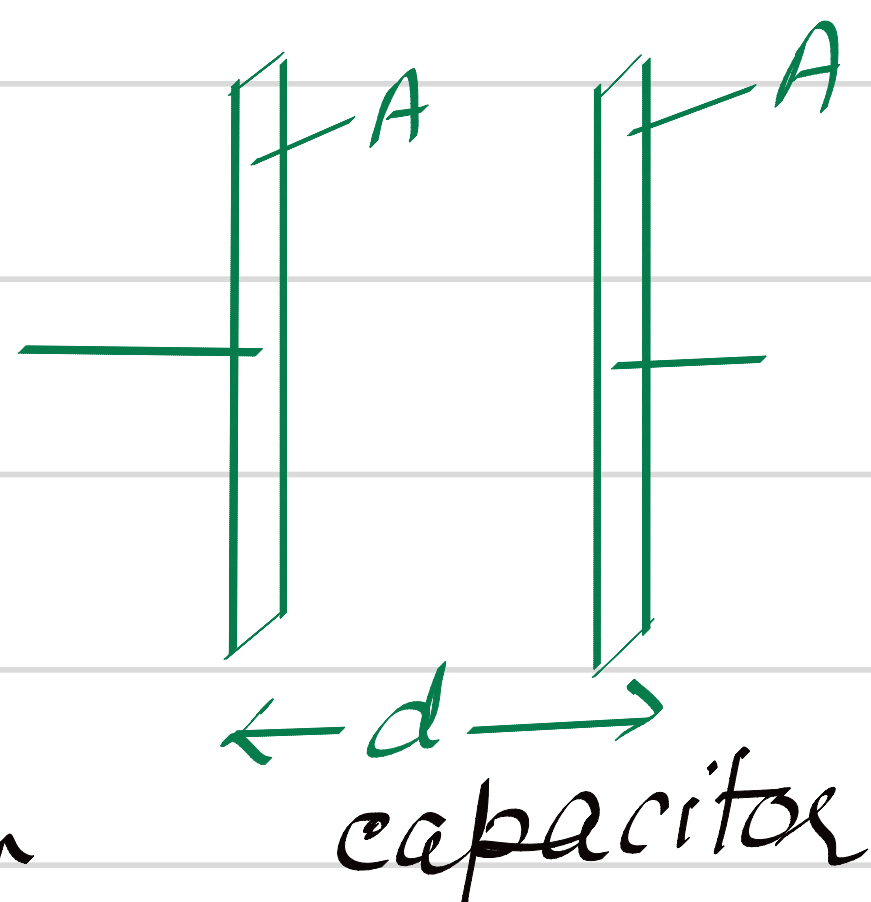
$C \rightarrow$ capacitance

$V \rightarrow$ potential

11. Capacitance of parallel plate capacitor

(i) Filled with air/vac.

$$C = \frac{A\epsilon_0}{d}$$



(ii) Filled with dielectric

(completely)

$$C = \frac{A\epsilon}{d}$$

$\epsilon \rightarrow$ permittivity of medium

$$[\epsilon = K\epsilon_0]$$

$\downarrow$
dielectric constant

(iii) Filled with dielectric of thickness ' t '

$$C = \frac{A\epsilon_0}{(d-t) + \frac{t}{K}}$$

12. Combination of capacitors -

(i) Parallel combination of 'n' capacitors

$$C_{11} = C_1 + C_2 + C_3 + \dots + C_n$$

(ii) Series combination

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$$

For two capacitors

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

13. Energy stored in a capacitor

$$U = \frac{q^2}{2C} = \frac{1}{2} C V^2 = \frac{1}{2} q V$$

14. Common Potential

$$V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

15. Loss of energy on sharing charges

$$U_i - U_f = \frac{C_1 C_2}{C_1 + C_2} (V_1 - V_2)^2$$

16 Loss of energy when a capacitor is charged by a battery of energy $U (= Vq)$
$$U - U' = \frac{1}{2} qV$$

* 50% of energy is lost.

17. Energy density
$$u = \frac{U}{V} = \frac{1}{2} \epsilon_0 E^2$$