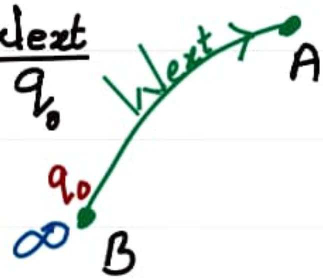
FORMULA SHEET

ELECTROSTATIC POTENTIAL AND CAPACITANCE

1. Electrostatic Potential

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



$V \rightarrow$ Potential
$W \rightarrow$ Work done
$q_0 \rightarrow$ charge

2. Potential difference

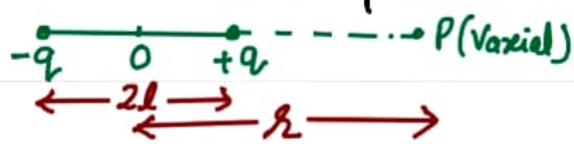
$$V_A - V_B = \frac{W_{ext}(B \rightarrow A)}{q_0}$$

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



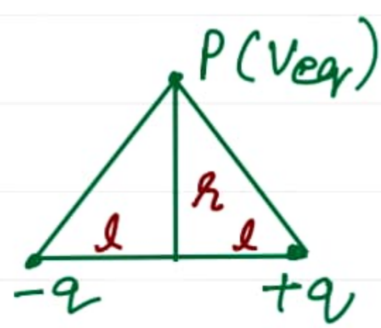
$$V_{axial} = k\frac{p}{(r^2 - l^2)}$$

For small dipole ($l << r$)

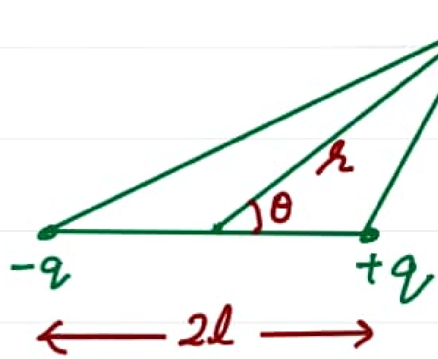
$$V_{axial} = k\frac{p}{r^2}$$

(II) On equatorial line

$$V_{eq} = 0$$



(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

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

* For -ve charge, potential is -ve

6. Relation b/w electric field and potential

$$E = -\frac{dV}{dr} = -\frac{dV}{dl}$$

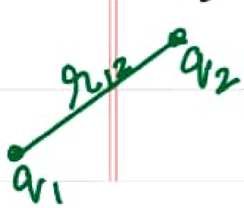
[-ve sign shows decrease in V in the dir^n of E]

$\vec{E}$ = − Potential gradiant

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

7. Potential energy of a system of charges.

(i) For a system of two charges



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

(ii) For a system of n charges

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

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

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

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

8. Potential energy of a dipole in external electric field

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

(i) 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'

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

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

10. For a capacitor

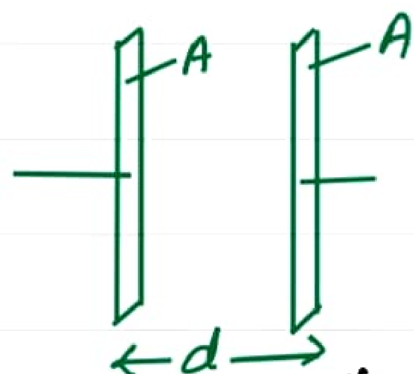
$$Q = CV$$

$Q \rightarrow$ charge
$C \rightarrow$ capacitance
$V \rightarrow$ Potential

11. Capacitance of parallel plate capacitor

(i) Filled with air/vac.

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



capacitor

(ii) Filled with dielectric (completely)

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

$\epsilon \rightarrow$ permittivity of medium

$[\epsilon = K\epsilon_0]$

$K \rightarrow$ 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

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

(ii) Series combination

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_n}$$

For two capacitors

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

13. Energy stored in a capacitor

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

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

$$u = \frac{U}{V} = \frac{1}{2} \epsilon_0 E^2$$

Effect of dielectric on various parameter -

Battery disconnect from the capacitor	Battery remains connected
Charge $q = q_0$ (const)	$q = kq_0$
Potential $V = \frac{V_0}{K}$	V constant
Electric field $E = \frac{E_0}{K}$	E constant
capacitance $C = kC_0$	$C = KC_0$
Energy stored $U = \frac{U_0}{K}$	$U = KU_0$