SIR CV RAMAN COACHING CENTRE – IDAPPADI,SALEM

XLL PHYSICS

UNIT – 1

ELECTROSTATICS

ENGLISH MEDIUM

VERY IMPORTANT JUST PASS MATERIAL

PASS MATERIAL – 2024

PREPARED BY

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UNIT – 1

PHYSICS

ELECTROSTATICS

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QUESTIONS :

1.Electric field due to an electric dipole at points on the axial line

2.Electric field due to an electric dipole at a point on the equatorial plane

3.Torque experienced by an electric dipole in the uniform electric field

4.Electric potential due to a point charge

5.Electrostatic potential at a point due to an electric dipole

6.Electric field due to an infinitely long charged wire

7.Electric field due to charged infinite plane sheet

8.Electric field due to two parallel charged infinite sheets

9.Electric field due to a uniformly charged spherical shell

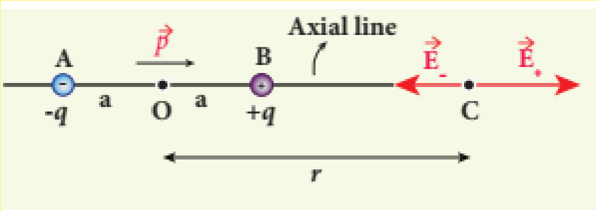
10.Capacitance of a parallel plate capacitor

11.Energy stored in the capacitor

12.Capacitor in series and parallel

13.Van de Graaff Generator

1. Electric field due to an electric dipole at points on the axial line :



$$\vec{E}_{+} = \frac{1}{4\pi\epsilon_0}\frac{q}{(r-a)^2}\hat{p}$$

$$\vec{E}_{+} = \frac{1}{4\pi\epsilon_0}\frac{q}{(r-a)^2} \text{ along BC}$$

$$\vec{E}_{-} = -\frac{1}{4\pi\epsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

$$\vec{E}_{tot} = \vec{E}_{+} + \vec{E}_{-}$$

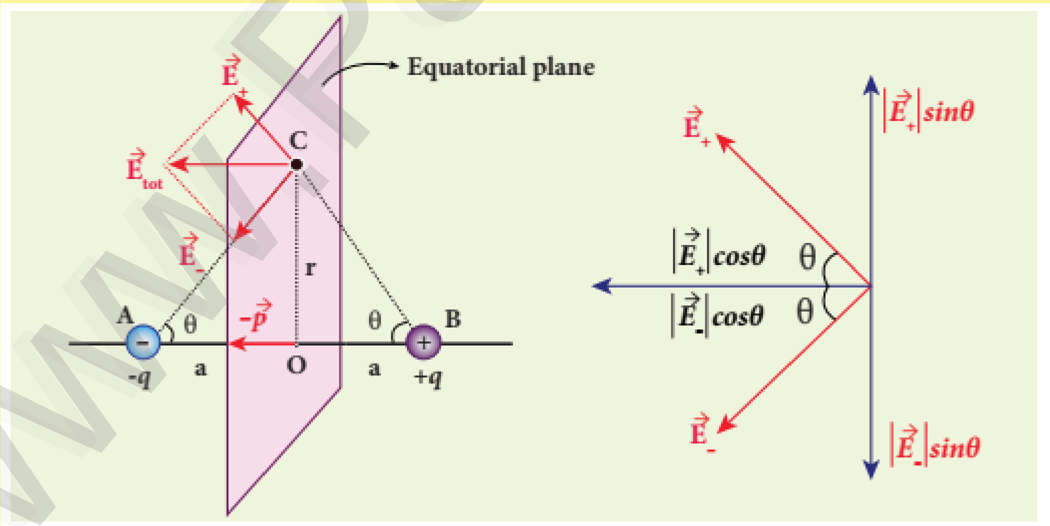
$$= \frac{1}{4\pi\epsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\epsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\epsilon_0}\left(\frac{4aq}{r^3}\right)\hat{p} \quad (r >> a)$$

$$\text{since } 2aq\,\hat{p} = \vec{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} \quad (r >> a) \qquad (1.17)$$

2.Electric field due to an electric dipole at a point on the equatorial plane :



$$\vec{E}_{tot} = -|\vec{E}_+|\cos\theta\,\hat{p} - |\vec{E}_-|\cos\theta\,\hat{p}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\epsilon_0}\frac{2q\cos\theta}{(r^2+a^2)}\hat{p}$$

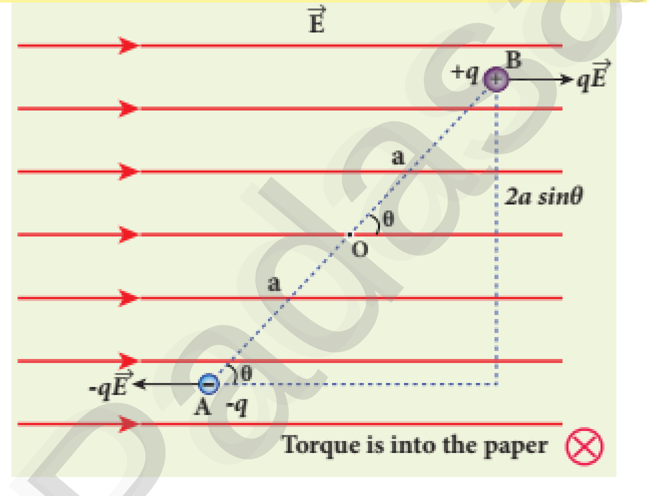
$$= -\frac{1}{4\pi\epsilon_0}\frac{2qa}{(r^2+a^2)^{\frac{3}{2}}}\hat{p}$$

since $\cos\theta = \frac{a}{\sqrt{r^2+a^2}}$

$$|\vec{E}_+| = |\vec{E}_-| = \frac{1}{4\pi\epsilon_0}\frac{q}{(r^2+a^2)}$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\epsilon_o}\frac{\vec{p}}{r^3} \qquad (r >> a)$$

3.Torque experienced by an electric dipole in the uniform electric field ;



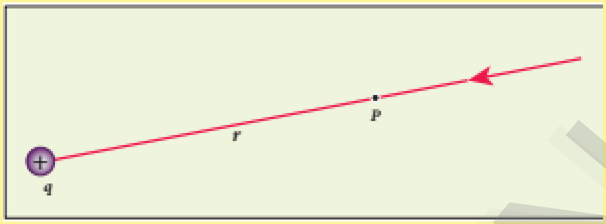
$$\vec{\tau} = \overline{OA}\times(-q\vec{E}) + \overline{OB}\times q\vec{E}$$

$$\tau = qE\cdot 2a\sin\theta$$

$$\vec{\tau} = \vec{p}\times\vec{E}$$

4.Electric potential due to a point charge ;

$$V=\int_{\infty}^{r}(-\vec{E})\cdot d\vec{r}=-\int_{\infty}^{r}\vec{E}\cdot d\vec{r}$$



$$\vec{E}=\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

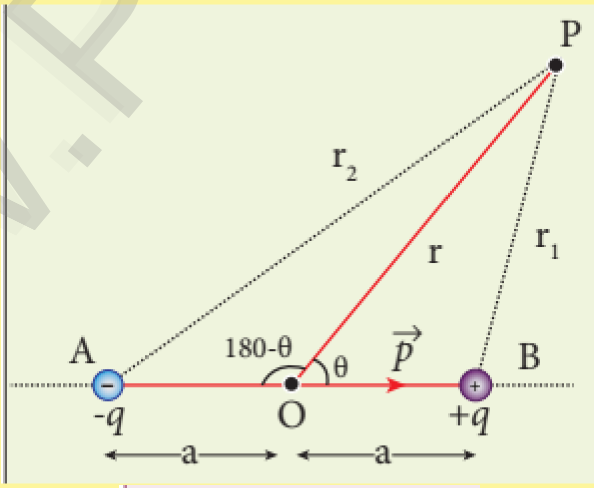
$$V=\frac{-1}{4\pi\epsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r}.d\vec{r}$$

$$V=-\frac{1}{4\pi\epsilon_\circ}\int_{\infty}^{r}\frac{q}{r^2}\hat{r}\cdot dr\hat{r}\quad=-\frac{1}{4\pi\epsilon_\circ}\int_{\infty}^{r}\frac{q}{r^2}dr$$

$$V=-\frac{1}{4\pi\epsilon_\circ}q\left\{-\frac{1}{r}\right\}_{\infty}^{r}=\frac{1}{4\pi\epsilon_\circ}\frac{q}{r}$$

$$V=\frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

5.Electrostatic potential at a point due to an electric dipole :



$$V=\frac{1}{4\pi\epsilon_\circ}q\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

$$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right)$$

$$\frac{1}{r_2} = \frac{1}{r}\left(1 - a\frac{\cos\theta}{r}\right)$$

$$V = \frac{1}{4\pi\epsilon_o}\frac{2aq}{r^2}\cos\theta$$

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{p\cos\theta}{r^2}\right)$$

$$V = \frac{1}{4\pi\epsilon_o}\frac{\vec{p}\cdot\hat{r}}{r^2} \quad (r>>a)$$

Special case :

Case (i) If the point P lies on the axial line of the dipole on the side of $+q$, then $\theta = 0$. Then the electric potential becomes

$$V = \frac{1}{4\pi\epsilon_o}\frac{p}{r^2}$$

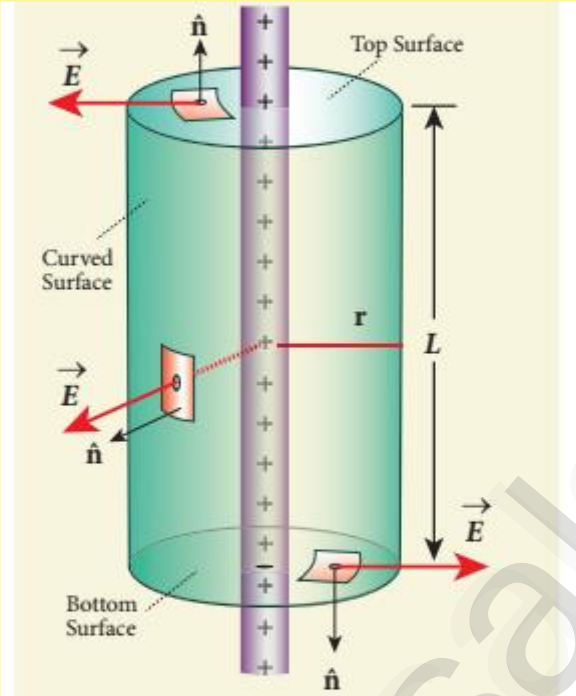
Case (ii) If the point P lies on the axial line of the dipole on the side of $-q$, then $\theta = 180^o$. Then

$$V = -\frac{1}{4\pi\epsilon_o}\frac{p}{r^2}$$

Case (iii) If the point P lies on the equatorial line of the dipole, then $\theta = 90^o$. Hence

$$V = 0$$

6.Electric field due to an infinitely long charged wire ;



$$\Phi_E = \oint \vec{E}\cdot d\vec{A}$$

$$= \int_{\substack{Curved\\surface}} \vec{E}\cdot d\vec{A} + \int_{\substack{top\\surface}} \vec{E}\cdot d\vec{A} + \int_{\substack{bottom\\surface}} \vec{E}\cdot d\vec{A}$$

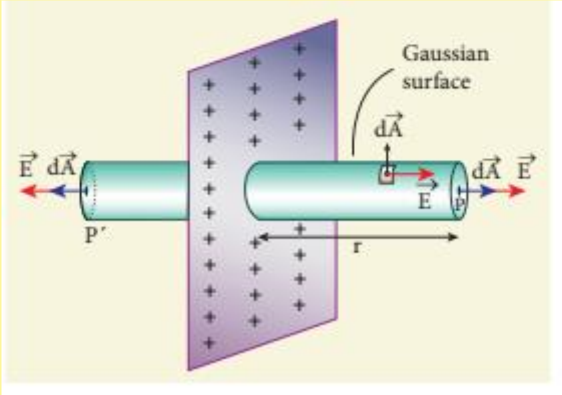
$$\Phi_E = \int_{\substack{Curved\\surface}} E\,dA = \frac{Q_{encl}}{\epsilon_\circ}$$

$$E\int_{\substack{Curved\\surface}} dA = \frac{\lambda L}{\epsilon_\circ}$$

$$E\cdot 2\pi rL = \frac{\lambda L}{\epsilon_\circ}$$

$$\vec{E} = \frac{1}{2\pi\epsilon_\circ}\frac{\lambda}{r}\hat{r}$$

7.Electric field due to charged infinite plane sheet ;



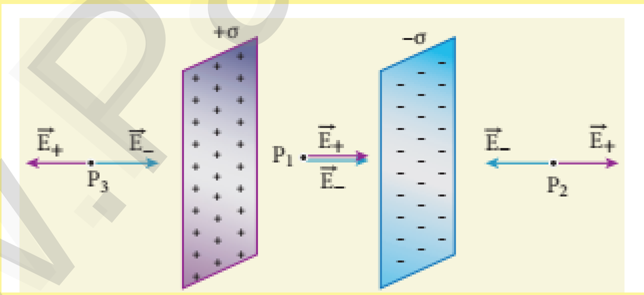
$$\Phi_E = \oint \vec{E}\cdot d\vec{A}$$

$$= \int_{\substack{Curved\\surface}} \vec{E}\cdot d\vec{A} + \int_{P} \vec{E}\cdot d\vec{A} + \int_{P'} \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

$$\Phi_E = \int_{P} E\,dA + \int_{P'} E\,dA = \frac{Q_{encl}}{\epsilon_0}$$

$$\vec{E} = \frac{\sigma}{2\epsilon_\circ}\hat{n}$$

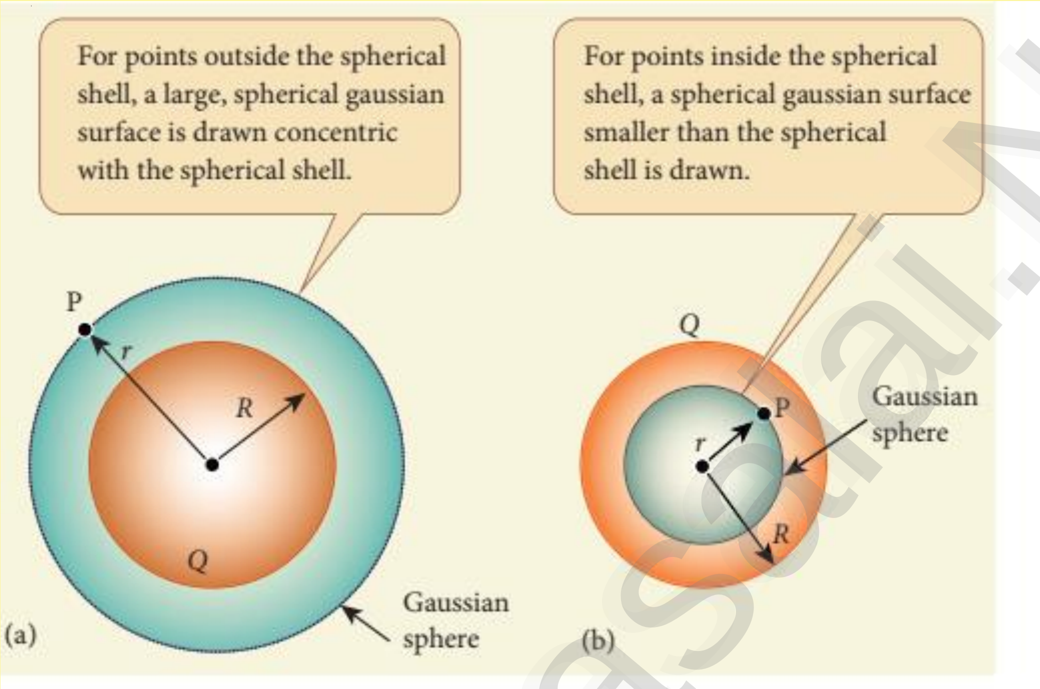
8.Electric field due to two parallel charged infinite sheets ;



$$E_{inside} = \frac{\sigma}{2\epsilon_\circ} + \frac{\sigma}{2\epsilon_\circ} = \frac{\sigma}{\epsilon_\circ}$$

9.Electric field due to a uniformly charged spherical shell ;

Case (a) At a point outside the shell (*r* > *R*)



$$\oint_{\text{Gaussian surface}} \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_\circ}$$

$$E = \frac{1}{4\pi\epsilon_\circ}\frac{Q}{r^2}$$

Case (b): At a point on the surface of the spherical shell (*r* = *R*)

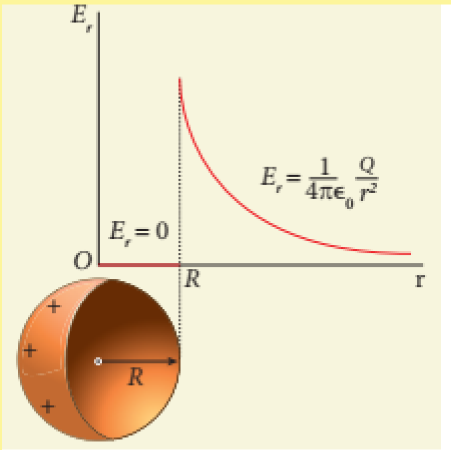
$$\vec{E} = \frac{Q}{4\pi\epsilon_\circ R^2}\hat{r}$$

Case (c): At a point inside the spherical shell (*r* < *R*)

$$\oint_{\text{Gaussian surface}} \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_\circ}$$

$$E\cdot 4\pi r^2 = \frac{Q}{\epsilon_\circ}$$

$$E = 0 \qquad (r < R)$$

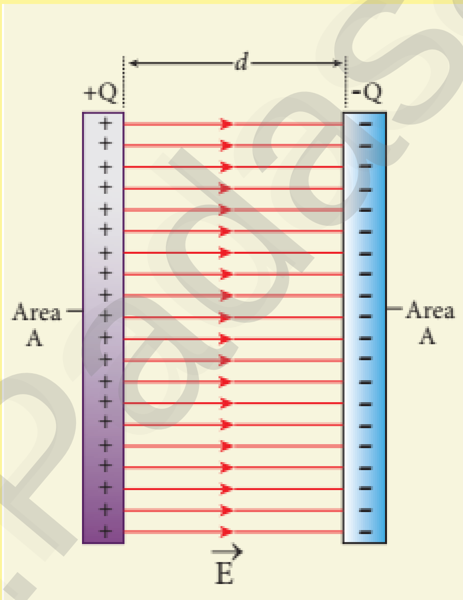


10.Capacitance of a parallel plate capacitor ;

$Q \propto V$

so that $Q = CV$

$$C = \frac{Q}{V}$$



$$E = \frac{Q}{A\epsilon_0}$$

$$V = Ed = \frac{Qd}{A\epsilon_0}$$

$$C = \frac{Q}{V} = \frac{Q}{\left(\frac{Qd}{A\epsilon_0}\right)} = \frac{\epsilon_0 A}{d}$$

11.Energy stored in the capacitor ;

$$dW = V\,dQ$$

where $V = \frac{Q}{C}$

$$W = \int_0^Q \frac{Q}{C}\,dQ = \frac{Q^2}{2C}$$

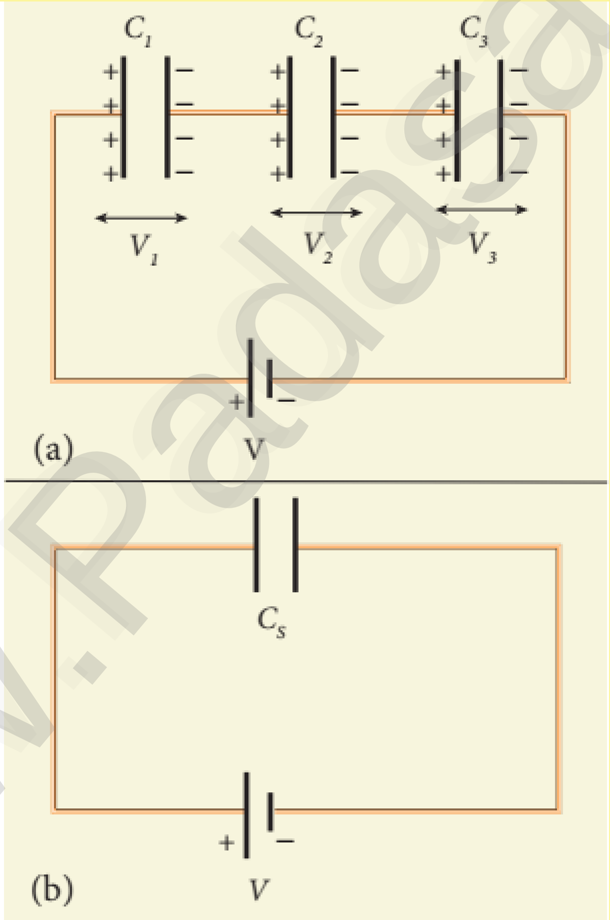
$$U_E = \frac{Q^2}{2C} = \frac{1}{2}CV^2 \quad (\because Q = CV)$$

$$U_E = \frac{1}{2}\left(\frac{\epsilon_0 A}{d}\right)(Ed)^2 = \frac{1}{2}\epsilon_0 (Ad)E^2$$

$$u_E = \frac{1}{2}\epsilon_0 E^2$$

12.Capacitor in series and parallel ;

(i) Capacitor in series



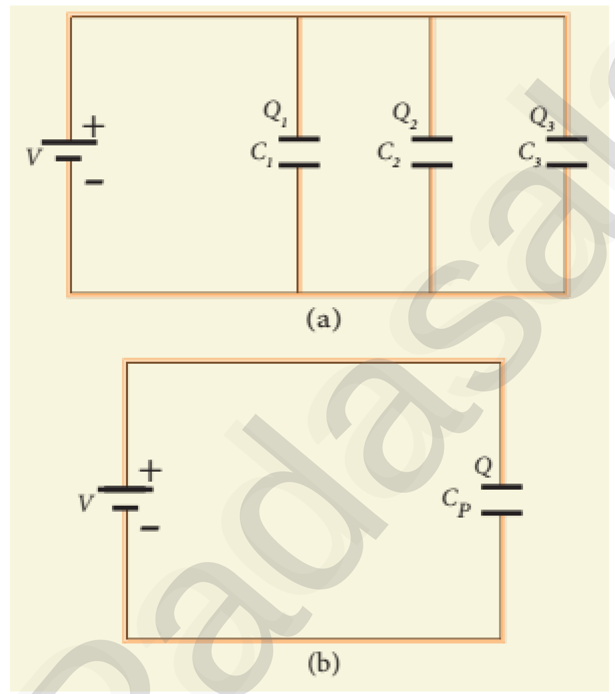
$$V = V_1 + V_2 + V_3$$

Since, $Q = CV$, we have $V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$ $= Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$

$$\frac{Q}{C_S} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(ii) Capacitance in parallel ;



(a)
(b)

$$Q = Q_1 + Q_2 + Q_3$$

$$Q = C_1V + C_2V + C_3V$$

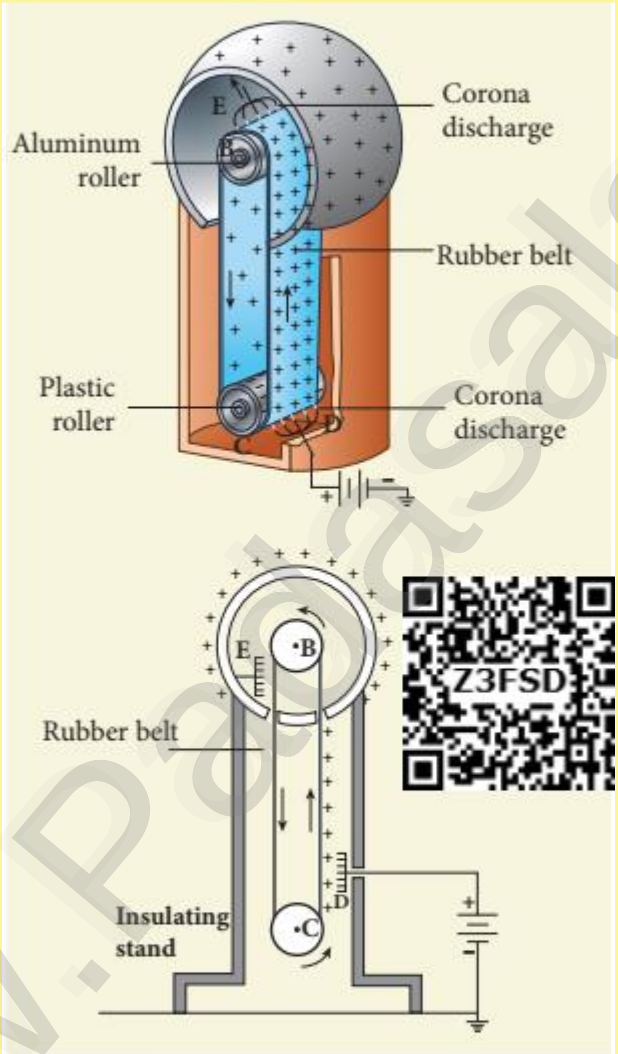
$$C_PV = C_1V + C_2V + C_3V$$

$$C_P = C_1 + C_2 + C_3$$

13.Van de Graaff Generator ;

. This Van de Graff generator works on the principle of electrostatic induction and action at points

The high voltage produced in this Van de Graaff generator is used to accelerate positive ions (protons and deuterons) for nuclear disintegrations and other applications.



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