Electric flux :

$\phi_E = E \cdot A$

$\boxed{\phi_E = EA\cos\theta}$

$\theta \rightarrow$ angle btw $\vec{E}$ & Area vector.

$\boxed{d\phi = \int E\,dA}$ Nm^2/C

Guass law :

$$\boxed{\phi_{\text{closed 3-D surface}} = \frac{q_{\text{net inside charge}}}{\varepsilon_0}}$$

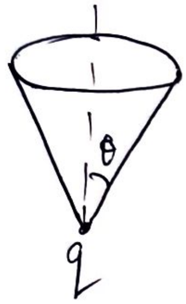
$\lambda \rightarrow \frac{\text{charge}}{\text{length}}$

$\sigma \rightarrow \frac{\text{charge}}{\text{Area}}$

$\rho \rightarrow \frac{\text{charge}}{\text{Volume}}$

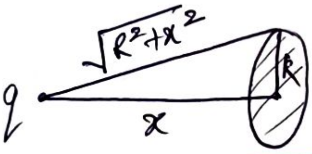
Application of Guass law :

① Cone



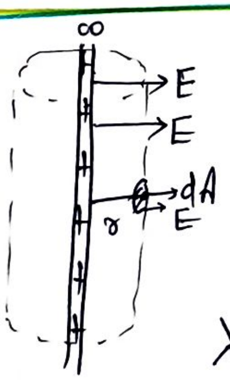
$$\boxed{\phi_{Cone} = \frac{q}{2\varepsilon_0}(1-\cos\theta)}$$

② Disc at a dist. x



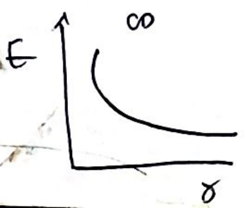
$$\boxed{\phi_{Disc} = \frac{q}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2+R^2}}\right]}$$

③



$$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$$

$\lambda \rightarrow \frac{\text{charge}}{\text{length}}$



④ $\vec{E}$ due to cylinders :

i) Hollow (Conducting + Non-conducting cylinder) + Solid (conducting cylinder)

inside $(r<R)$

$\boxed{E = 0}$ V/m

Outside $(r>R)$

$$\boxed{E = \frac{\sigma R}{\varepsilon_0 r}}$$

$R \rightarrow$ Radius of cylinder

$r \rightarrow$ distance from point

ii) Solid (Non-conducting)

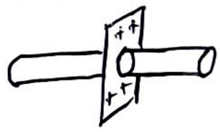
inside $(r<R)$

$$\boxed{E = \frac{\rho r}{2\varepsilon_0}}$$

Outside $(r>R)$

$$\boxed{E = \frac{\rho R^2}{2\varepsilon_0 r}}$$

⑤ $\vec{E}$ due to plane sheet :



$$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

$\frac{1}{\pi} = 0.318$

① Coulomb's law:

$\boxed{F_{net} = 0}$

$\therefore$ momentum = constant

$$F \propto \frac{q_1 q_2}{r^2}$$

$$\boxed{F_{vacc} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}}$$

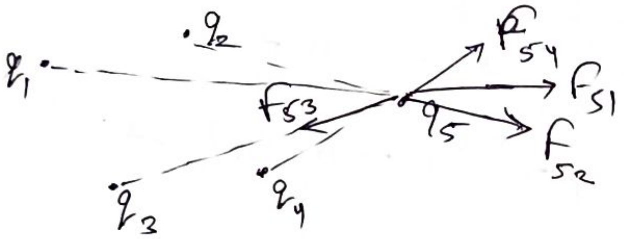
$$\boxed{F_{medium} = \frac{1}{4\pi\varepsilon_0 k} \frac{q_1 q_2}{r^2}}$$

k = dielectric constant of that medium.

$$\boxed{k = \frac{\varepsilon_{med}}{\varepsilon_0} = \frac{F_{vacc}}{F_{med}}}$$

ε_{med} = Permittivity of medium , ε_0 = permittivity of free space.

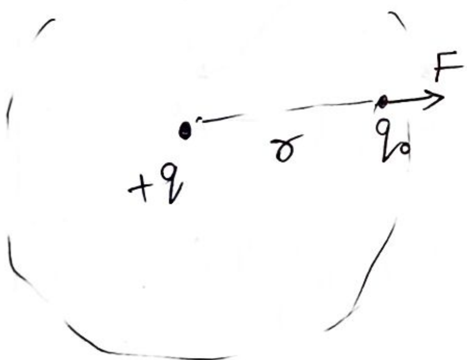
② Superposition of force



$$F = \vec{F}_{s1} + \vec{F}_{s2} + \vec{F}_{s3} + \dots \vec{F}_{sn}$$

③ Electric Intensity ($\vec{E}$)

$\vec{E}$ due to point charge.



$$\boxed{\vec{E} = \frac{\vec{F}}{q_0}}$$

$$\boxed{E = \frac{kq}{r^2} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}}$$

→ $\vec{E}$ tells us about strength of electric field

→ +q → away $\vec{E}$ & -q → towards $\vec{E}$

$\vec{E}$ due to spheres:

i) Hollow (Conducting + Non-conducting) spheres/shells + solid (conducting sphere)

inside ($r<R$)

$$\boxed{E = 0} \ V/m$$

Outside ($r>R$)

$$\Rightarrow \boxed{E = \frac{\sigma R^2}{\varepsilon_0 r^2}} \ V/m$$

$$\Rightarrow \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}}$$

ii) Solid (Non-conducting spheres)

inside ($r<R$)

$$\Rightarrow \boxed{E = \frac{\rho r}{3\varepsilon_0}}$$

$$\Rightarrow \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}}$$

outside ($r>R$)

$$\Rightarrow \boxed{E = \frac{\rho R^3}{3\varepsilon_0 r^2}}$$

$$\Rightarrow \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}} \ V/m$$

1) Electric Potential Difference

$$\boxed{V_A - V_B = \frac{W_{B\to A}}{q_0}}$$

→ Scalar quantity

→ J/C

2) Electric Potential at a point

$$V_A - V_B = \frac{W_{B\to A}}{q_0}$$

$V_B \to \infty \therefore V_B = 0$

$$\boxed{V_A = \frac{W_{\infty\to A}}{q_0}}$$

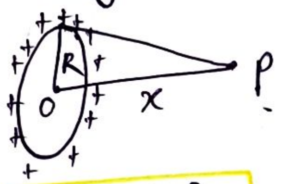
3) E. Potential due to point Q

Q —— r —— P ← is point pe potential

$$\boxed{V_P = \frac{KQ}{r}}$$

Q → with sign

4) E. Potential due to U. charged Ring:



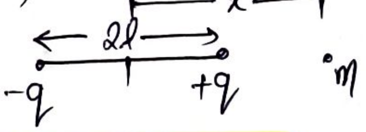
$$\boxed{V_P = \frac{KQ}{\sqrt{x^2+R^2}}}$$

at centre, $x=0$

$$\boxed{V_0 = \frac{KQ}{R}}$$

5) E. Potential due to dipole:

i) On axis:

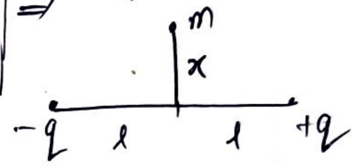


$$\boxed{V_{axis} = \frac{KP}{x^2}}$$

$$\vec{P} = q(2l)$$

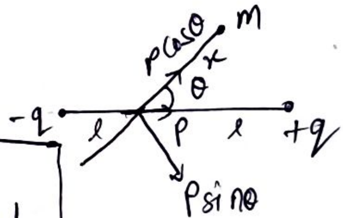
⊖ → ⊕

ii) On ⊥ bisector



$$\boxed{V_{\perp\,bisector} = 0}$$

iii) any point:



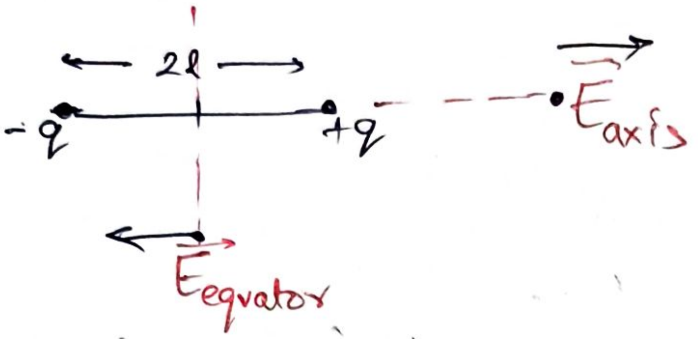
$$\boxed{V_m = \frac{KP\cos\theta}{x^2}}$$

6) Relationship $\vec{E}$ & V

$$\therefore \boxed{\Delta V = -\vec{E}\,\Delta r}$$

$$\boxed{|\Delta V| = E\,\Delta r}$$

Electric field due to dipole:



$$\boxed{\vec{E}_{axis} = \frac{1}{4\pi\varepsilon_0} \frac{2p}{r^3}}$$

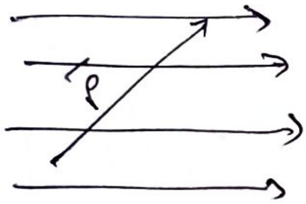
$$\boxed{E_{equator} = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^3}}$$

$$\boxed{\vec{P} = q \times \vec{2l}}$$

$\ominus \longrightarrow \oplus$

$$\boxed{E_{eq} = \frac{1}{2} E_{axis}}$$

Torque in Electric Dipole:



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

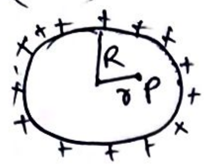
$$\tau = pE \sin\theta$$

$$\omega = pE [$$

...tric Potential due to charged spheres

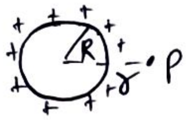
① Hollow (conducting + Non conducting) + Solid (conducting)

(r < R) inside



$$\boxed{V_p = \frac{KQ}{R}}$$

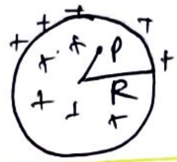
Outside (r > R)



$$\boxed{V_p = \frac{KQ}{r}}$$

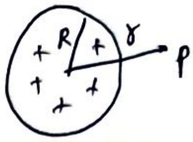
② Solid (Non-conducting)

inside (r<R)



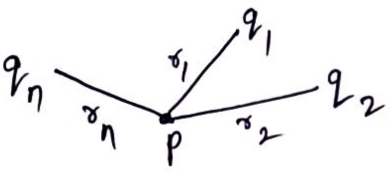
$$\boxed{V_p = \frac{KQ}{R}\left[\frac{3}{2} - \frac{r^2}{R^2}\right]}$$

Outside (r>R)



$$\boxed{V_p = \frac{KQ}{r}}$$

Electrostatic potential due to system of charge



$$V_{net\ at\ P} = V_1 + V_2 + V_3 + \cdots V_n$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2} + \cdots \frac{1}{4\pi\varepsilon_0}\frac{q_n}{r_n}$$

$$\boxed{V_{net\ at\ P} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \cdots \frac{q_n}{r_n}\right]}$$

Electrostatic Potential Energy (U)

final $\longleftarrow$ initial

$q_1 \overset{r}{—} q_2$ $\qquad$ $q_1 \quad q_2$

$$\boxed{U = \frac{Kq_1q_2}{r}} \Rightarrow \text{scalar}$$

Capacitor

$$\boxed{C = \frac{Q}{V}}$$ C/V or F

Energy stored in a cap.

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

Parallel Plate C

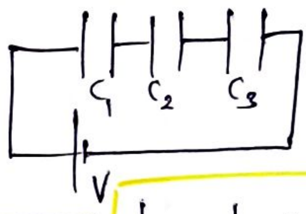
$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

Force on one plate of C. due to other

$$\boxed{f = \frac{q^2}{2A\varepsilon_0}}$$

Combination of Capacitors

i) Series:



$$\boxed{\frac{1}{C_E} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

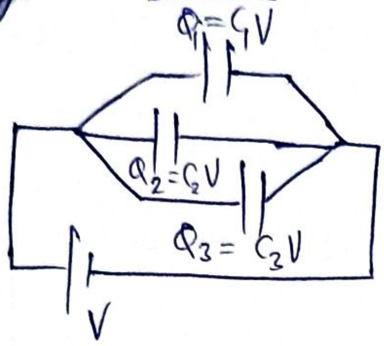
2 capacitors

$$C_E = \frac{C_1C_2}{C_1+C_2} \begin{matrix}\to \text{product} \\ \to \text{sum}\end{matrix}$$

q → Same

V → different

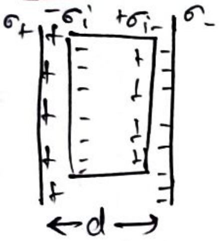
Parallel:



$$\boxed{C_e = C_1 + C_2 + C_3}$$

Q → different
V → same

Parallel Plate C with dielectric.



Induced charge density

$$\boxed{\sigma_i = \sigma\left(1 - \frac{1}{k}\right)}$$

$\vec{E_0}$ decrease → $E_0 \to \frac{E_0}{k}$

V decrease $V_0 \to \frac{V_0}{k}$

C increase $C_0 \to C_0 k$

$$\boxed{C = \frac{A\varepsilon_0 k}{d}}$$

For vaccum = $\boxed{k = 1}$

for metal/conductors

$$\boxed{k = \infty}$$

Case I: Battery removed & Dielectric Inserted

$$\boxed{Q = \text{constant}}$$

Before

$Q_i = Q_0$

$V_i = V_0$

$E_i = E_0$

$C_i = C_0$

$U_i = \frac{1}{2}\frac{Q_0^2}{C_0}$

$F_i = \frac{Q_0^2}{2\varepsilon_0 A}$

After

$Q_f = Q_0$ (Constant)

$V_f = V_0/K$ (Decrease)

$E_f = E_0/K$ (Decrease)

$C_f = C_0 K$ (Increase)

$U_f = \frac{Q_0^2}{2KC_0}$ (Decrease)

$F_f = \frac{Q_0^2}{2\varepsilon_0 A}$ (does not chang i.e constant)

Case II: Battery connected & Dielectric inserted.

$$\boxed{V = \text{constant}}$$

Before

$C_i = C_0$

$V_i = V_0$

$Q_i = Q_0$

$E_i = E_0$

$U_i = \frac{1}{2} C_0 V_0^2$

After

$C_f = kC_0$ ↑

$V_f = V_0$ (constant)

$Q_f = kQ_0$ (increase)

$E_f = E_0$ (constant)

$U_f = \frac{1}{2} kC_0 V_0^2$ (Increase)

① If n charged droplets, each of capacity C, are charged to the potential V with charge q, then

i) total charge $= nq$

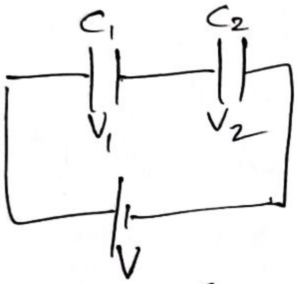
ii) total capacity $= n^{1/3} C$

iii) Potential $= n^{2/3} V$

② If two capacitors are connected, then the resultant potential after joining them will be given by

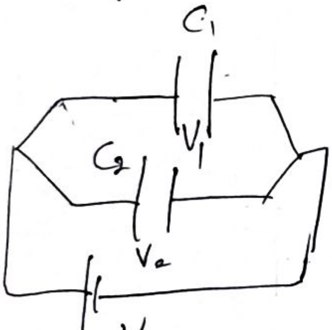
$$V = \frac{C_1 V_1 + C_2 V_2}{C_{eff}}$$, for series, $C_{eff} = \frac{C_1 C_2}{C_1 + C_2}$ & for $\parallel$ $C_{eq} = C_1 + C_2$

①



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

②



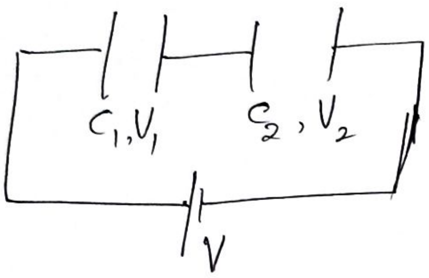
$$\boxed{V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}}$$

③ If the phrase "Battery is disconnected" or "charged capacitor are in series", then the formula for energy will be

$$\boxed{E = \frac{1}{2} \frac{q^2}{C}}$$

④ If the phrase "Battery is connected" or capacitors are in $\parallel$. then the formula for Energy will be $\boxed{E = \frac{1}{2} C V^2}$

Trick: To find Potential drop:



$$\boxed{V_1 = \frac{C_2}{(C_1 + C_2)} V}, \quad \boxed{V_2 = \frac{C_1}{(C_1 + C_2)} V}$$

⇒ Condenser is a device used to store large charge at low V.