L-10 / 27.02.2023

Electric Flux (φ_E)

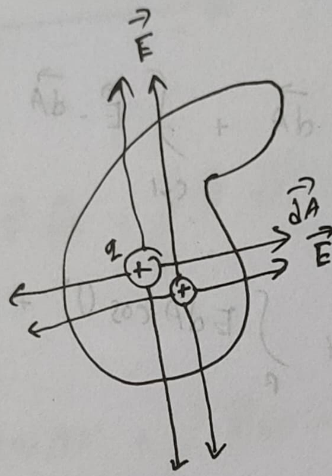
$$\varphi_E = \vec{E} \cdot \vec{A}$$

Open: $\varphi_E = \int \vec{E} \cdot \vec{dA}$

Closed: $\varphi_E = \oint \vec{E} \cdot \vec{dA}$

Closed Surface:

$$\oint dA = A$$



$\varphi_{E_1} \to q$

$\varphi_{E_2} \to 2q$

$\varphi_{E_2} > \varphi_{E_1}$

$\varphi_E = \oint \vec{E}\, \vec{dA}$

E Flux $\propto$ Charge inside

$\varphi_E = \propto q_{inside}$

$\varphi_E = k q_{inside}$

$k = \frac{1}{\epsilon_0}$

$\varphi_E = \frac{1}{\epsilon_0} q_{inside}$

$\varphi_E = \frac{1}{\epsilon_0} q$ inclosed $\cdot$ $\frac{1}{\epsilon_0} \cdot q_{enc}$

'Gaus Law'

$$\phi_E = \frac{1}{\epsilon_0} \cdot q_{enc}$$

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

$$= \frac{1}{\epsilon_0} q_{enc}$$

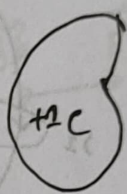
$$\phi_E = \oint \vec{E} \cdot d\vec{A}$$

⊛ Gaussian closed Surface:

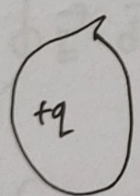
⊛

Example-1:

$$\phi_E = \frac{q_{enc}}{\epsilon_0} = \frac{+1C}{\epsilon_0}$$

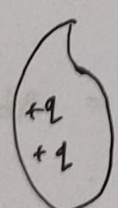


Example-2:



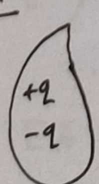
$$\phi_E = \frac{+q}{\epsilon_0}$$

Example-3



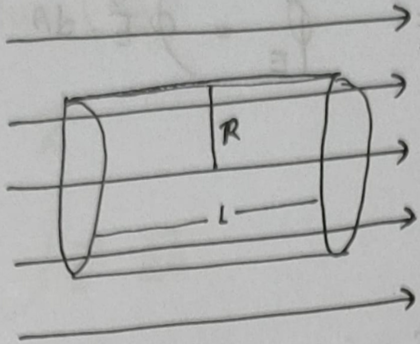
$$\phi_E = \frac{q_{\text{isi}}}{\epsilon_0} = \frac{+q+q}{\epsilon_0} = \frac{2q}{\epsilon_0}$$

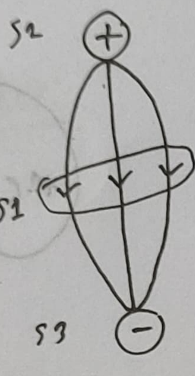
Example-4:



$$\phi_E = \frac{q_{enc}}{\epsilon_0} = \frac{+q-q}{\epsilon_0} = 0$$

Using Gauss Law:



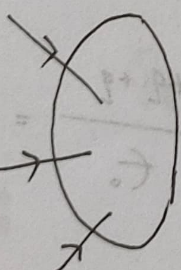


S1: $\Phi_E = \dfrac{q_{enc}}{\epsilon_0} = 0$

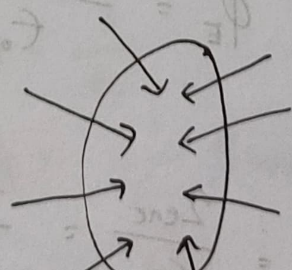
S2: $\Phi_E = \dfrac{q_{enc}}{\epsilon_0} = \dfrac{+q}{\epsilon_0}$

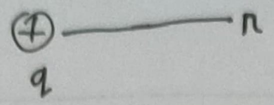
S3: $\Phi_E = \dfrac{q_{inc}}{\epsilon_0} = \dfrac{+q-q}{\epsilon_0} = 0$

Example:



negative change inside



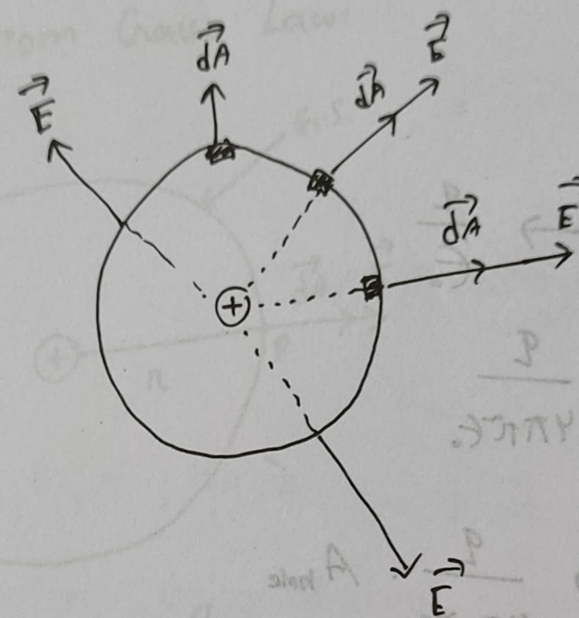


$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

Application of Gauss Law:

① Derive Coulomb's Law from Gauss Law:

Spherical
Gaussian
Closed Surface



$$\phi_E = \oint \vec{E} \cdot \vec{dA} = \frac{q_{enc}}{\epsilon_0} = \frac{+q}{\epsilon_0}$$

$$= \oint E\, dA \cos 0^\circ = \frac{+q}{\epsilon_0}$$

$$= \oint E\, dA = \frac{q}{\epsilon_0}$$

$$= E \oint dA = \frac{q}{\epsilon_0}$$

$$= EA = \frac{q}{\epsilon_0}$$

$$\phi_E = E\,4\pi r^2 = \frac{q}{\epsilon_0}$$

$$\therefore E = \frac{q}{4\pi r^2 \epsilon_0}$$

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

$$\boxed{\oint dA = A = 4\pi r^2}$$

(*) $$\phi_E = \frac{q}{\epsilon_0}$$

$$A = 4\pi r^2 \longrightarrow \frac{q}{\epsilon_0}$$

$$1 \longrightarrow \frac{q}{4\pi r^2 \epsilon_0}$$

$$\therefore A_{hole} \longrightarrow \frac{q}{4\pi r^2 \epsilon_0}\cdot A_{hole}$$

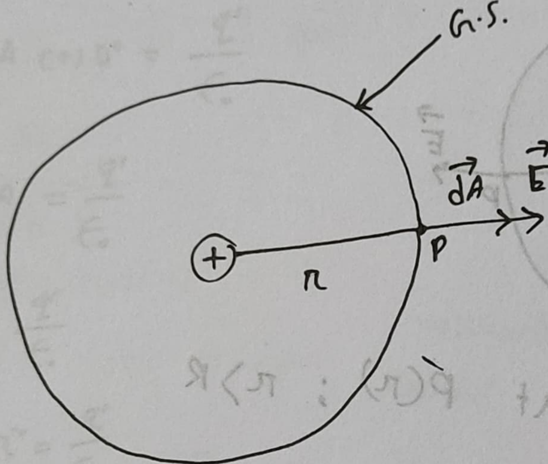
L-1 / 01.03.2023 /

⊛ Gauss' Law:

$$\phi_E = \oint \vec{E} \cdot \vec{dA} = \frac{q_{enc}}{\epsilon_0}$$

⊛ Application of Gauss' Law:

(i) Coulomb's Law from Gauss Law:



$$\phi_E = \oint \vec{E}\, \vec{dA} = \frac{q_{enc}}{\epsilon_0} = \frac{q}{\epsilon_0}$$

$$= \oint E\, dA \cos 0^\circ = \frac{q}{\epsilon_0}$$

$$= E \oint dA = \frac{q}{\epsilon_0}$$

$$= EA = \frac{q}{\epsilon_0}$$

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

$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

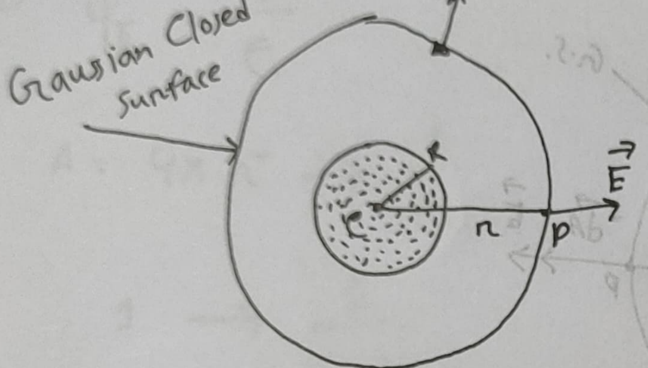
② Spherical Charge dist^n

Radius $= R$

Charge $= q$

Volume charge density $= \rho = \frac{q}{V}$

$$\rho = \frac{q}{\frac{4}{3}\pi r^3}$$



Find electric field at $P(r)$; $r > R$

outside points; using Gauss' Law

$$\phi_E = \oint \vec{E}\, d\vec{A} = \frac{q_{enc}}{\epsilon_0} = \frac{q}{\epsilon_0}$$

$$= \oint E\, dA \cos 0^\circ = \frac{q}{\epsilon_0}$$

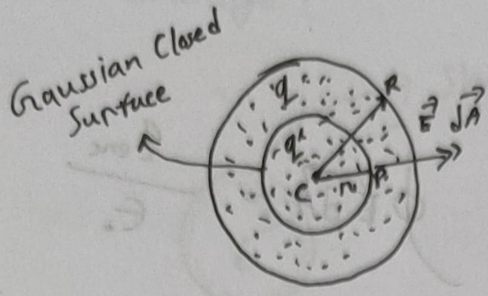
$$= E \oint dA = \frac{q}{\epsilon_0}$$

$$= EA = \frac{q}{\epsilon_0}$$

$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

$$= E\, 4\pi r^2 = \frac{q}{\epsilon_0}$$

(*)



$r < R$

inside points:

$$\phi_E = \oint \vec{E}\,\vec{dA} = \frac{q_{enc}}{\epsilon_0} = \frac{q'}{\epsilon_0}$$

$$= \oint E\,dA \cos 0^\circ = \frac{q'}{\epsilon_0}$$

$$= E \oint dA = \frac{q'}{\epsilon_0}$$

$$= EA = \frac{q'}{\epsilon_0}$$

$$= E\,4\pi r^2 = \frac{q'}{\epsilon_0}$$

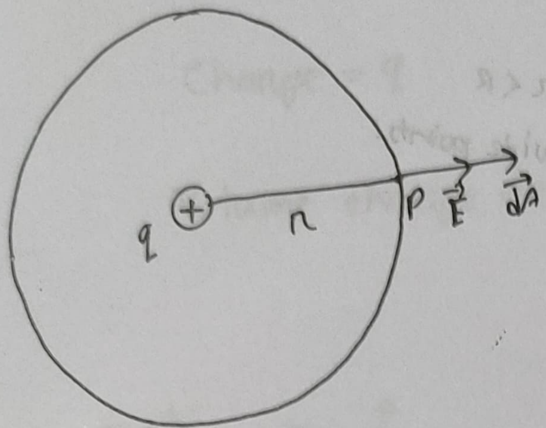
$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q'}{r^2}$$

$$\frac{q}{\frac{4}{3}\pi R^3} \times \frac{4}{3}\pi r^3$$

$$= \frac{qr^3}{R^3}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{qr^3}{R^3 r^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{qr}{R^3}$$

L-12 / 06.03.2023 /

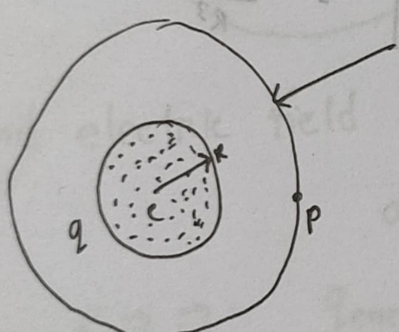


$$\oint \vec{E}\,\vec{dA} = \frac{q_{enc}}{\epsilon_0}$$

$$\Rightarrow EA = \frac{q}{\epsilon_0}$$

$$\Rightarrow E = \frac{q}{\epsilon_0 A}$$

$$\therefore E = \frac{q}{\epsilon_0 4\pi r^2}$$

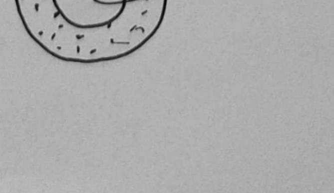


$$\phi_E = \oint \vec{E}\,\vec{dA} = \frac{q_{enc}}{\epsilon_0}$$

$$\Rightarrow EA = \frac{q}{\epsilon_0}$$

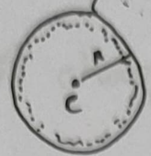
$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

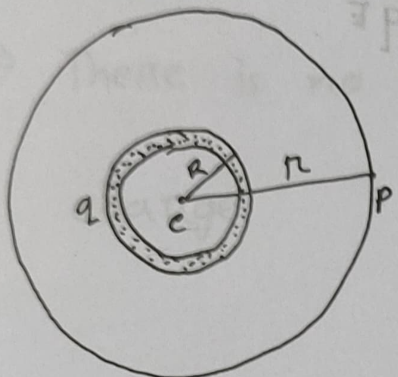
(*) Shell of charge:



⊛ Shell of charge :

shell of a coconut full of charge





⊛ Find the electric field at point P(r) due to this shell charge.

r > R, outside points. (Using Gauss Law)

R = radius

q = total charge

c = center

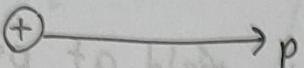
$$\Phi_E = \oint \vec{E}\, \vec{dA} = \frac{q_{enc}}{\epsilon_0}$$

$$= E \int \vec{dA} = \frac{q}{\epsilon_0}$$

$$= EA = \frac{q}{\epsilon_0}$$

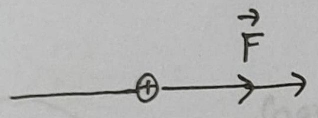
$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

⊛ Shell of change behaves like a point change as if all the change of the shell is connected at the centen of the shell.

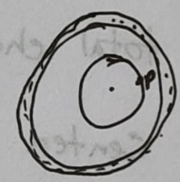


$\vec{F} = q\vec{E}$

⊛ $\vec{F} = \vec{E}q$



$\vec{F} = \vec{E}q$



⊛ Inside the shell, $r < R$

$$\phi_E = \oint \vec{E}\,d\vec{A} = \frac{q_{enc}}{\epsilon_0} = \frac{q}{\epsilon_0} = \frac{0}{\epsilon_0}$$

$$= E\,4\pi r^2 = 0$$

$$\therefore E = 0$$

⊛ Forrce on point change q_1 inside the shell

$$F = Eq$$

$$= 0 \cdot q_1 = 0$$

⊛ Innershell Theorem:

⇒ A shell of charge doesn't exert force on point charge inside the shell.

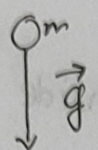
⇒ There is no electric field inside the shell of charge.

Electric Potential

We know,

$\vec{F} = m\vec{g}$

$\hookrightarrow$ Force



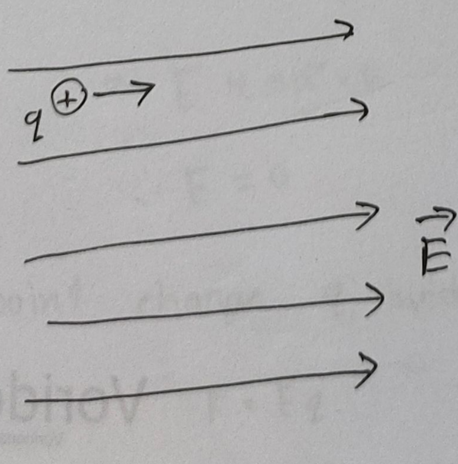
mgh

mass = m

Gravity field $\Rightarrow g$

Grav. Pot. Energy $\Rightarrow$ mgh

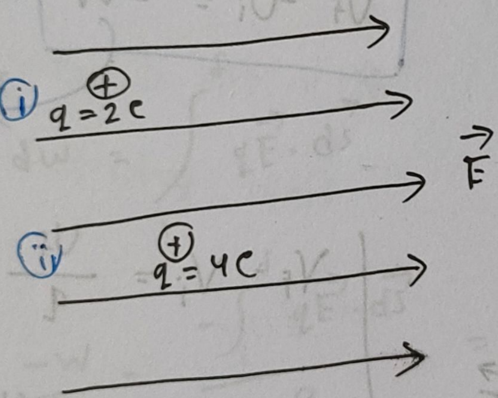
mass	Gr. Field	Force	Gv. Pot. Ener	E/mass
m	$\vec{g}$	$\vec{F_g} = m\vec{g}$	mgh	$\frac{mgh}{h} = gh$
2m	$\vec{g}$	$2m\vec{g}$	2mgh	$\frac{2mgh}{2m} = gh$



Charge	Electric Field	Force	Energy	Energy/Charge
q	$\vec{E}$	$\vec{F} = q\vec{E}$	U	$\frac{U}{q}$
$2q$	$\vec{E}$	$2q\vec{E}$	$2U$	$\frac{2U}{2q} = \frac{U}{q}$

$\therefore$ Electric Potential : $\boxed{V = \frac{U}{q}}$ .... (i)

Example:



(i) $U = 20$ Joule

$V = \frac{U}{q} = \frac{20}{2} = 10$ J/C

$= 10$ volt

(ii) $q = 4C$

$U = 40$ joule

$\therefore V = \frac{U}{q} = \frac{40}{4} = 10$ J/C

$= 10$ volt

(iii) $q = 2C$

$U = 10$ joule

$V = \frac{U}{q} = \frac{10}{2} = 5$ J/C

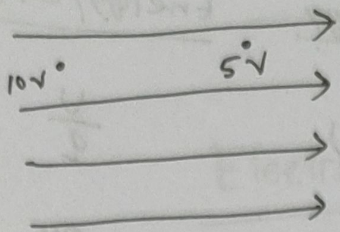
$= 5$ volt

(iv) $q = 4C$

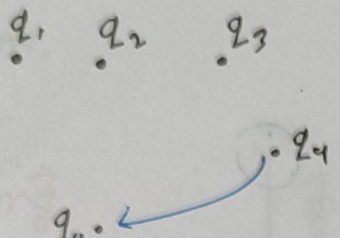
$U = 20$ joule

$V = \frac{U}{q} = \frac{20}{4} = 5$ J/C

$= 5$ volt



$\therefore$ Potential difference $= 10-5 = 5\,v$



$i \rightarrow$ initial

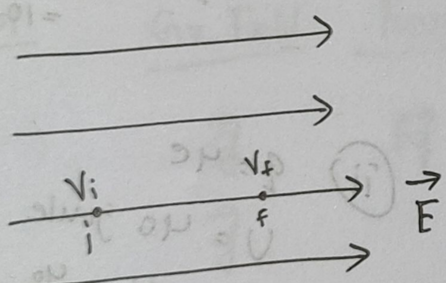
$U_i \rightarrow$ initial Energy

$f \rightarrow$ final

$U_f \rightarrow$ final Energy

$$\boxed{U_f - U_i = -W} \quad \cdots \text{(ii)}$$

Work done



$$V_f - V_i = \frac{U_f}{q} - \frac{U_i}{q}$$

$$= \frac{U_f - U_i}{q} = \boxed{\frac{-W}{q}} \quad \cdots \text{(iii)}$$

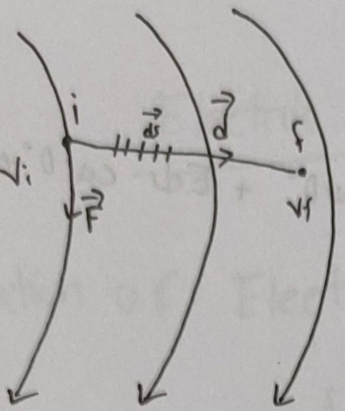
Equation:

(i) $V = \frac{U}{q}$

(ii) $U_f - U_i = -W$

(iii) $V_f - V_i = \frac{-W}{q}$

⊛



$i \rightarrow$ initial point

$f \rightarrow$ final point

$V_i \rightarrow$ Potential at i

$V_f \rightarrow$ Potential at f

$V_f - V_i$ = Potential difference between i and f

$$\vec{F} = q\vec{E}$$

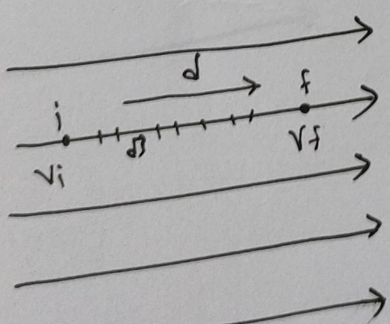
$$V_f - V_i = \frac{-W}{q}$$

$$dW = \vec{F}\cdot\vec{ds} = q\vec{E}\cdot\vec{ds}$$

$$\therefore W = \int_i^f dW = \int_i^f q\vec{E}\cdot\vec{ds}$$

$$\therefore V_f - V_i = \frac{-W}{q} = \frac{-\int_i^f q\vec{E}\cdot\vec{ds}}{q} = -\int_i^f \vec{E}\cdot\vec{ds}$$

⊛



$\vec{E}$

$$V_f - V_i = -\int_i^f \vec{E} \cdot \vec{ds}$$

$$= E\,ds \cos 0° + E\,ds \cos 0° + E\,ds \cos 0° + \text{---}$$

$$= -\int_i^f E\,ds \cos 0°$$

$$= -\int_i^f E\,ds$$

$$= -E\int_i^f ds$$

$$= -E \cdot d$$

$$\boxed{\therefore V_f - V_i = -E \cdot d}$$

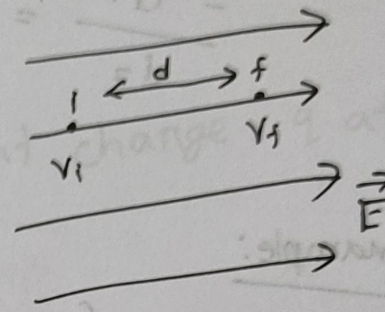
* in the direction of Electric field, potential decrease.

L-14/15.03.2023

Electric Potential

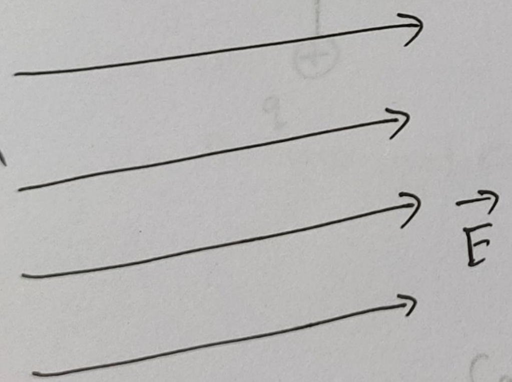
⊛ Calculation of Electric Field from Electric Field.

$$V_f - V_i = -\int_i^f \vec{E}\cdot\vec{ds}$$



⊛ Calculation of Electric Field from Electric Potential.

⇒



$$V = V_f - V_i = -\int_i^f \vec{E}\cdot\vec{ds}$$

$$-dV = \vec{E}\cdot\vec{ds}$$

$$\vec{E} = \hat{i}E_x + \hat{j}E_y + \hat{k}E_z$$

$$\vec{ds} = \hat{i}dx + \hat{j}dy + \hat{k}dz$$

$$\therefore -dV = [\hat{i}E_x + \hat{j}E_y + \hat{k}E_z]\cdot[\hat{i}dx + \hat{j}dy + \hat{k}\cdot dz]$$

$$-dV = E_x dx + E_y dy + E_z dz$$

$$-\frac{dV}{dx} = E_x ;$$

$$-\frac{dV}{dy} = E_y ;$$

$$-\frac{dV}{dz} = E_z ;$$

Example:

$$V(x, y, z) = x^2 + 2y^2 - 3z$$

$$E_x = -2x$$

$$E_y = -4y$$

$$E_z = +3$$

$$\vec{E} = -2x\hat{i} - 4y\hat{j} + 3\hat{k}$$

Example:

$$V(x, y) = 2x^2 - 3y^2$$

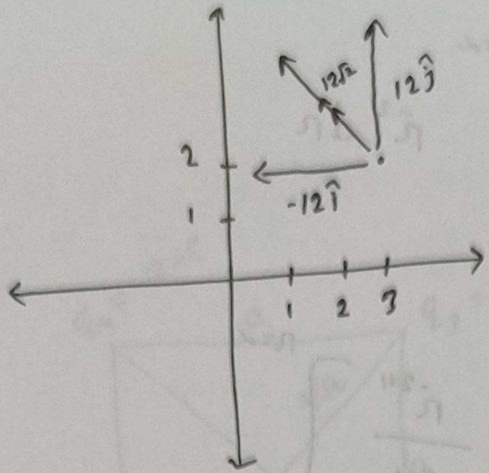
Find Electric field at $P(3, 2)$

$$E_x = \frac{d}{dx}(2x^2 - 3y^2)$$

$$E_x = -4x$$

$$E_y = \frac{d}{dy}(2x^2 - 3y^2)$$

$$= +6y$$



$$E = \sqrt{(12)^2 + (12)^2}$$

$$= 12\sqrt{2}$$

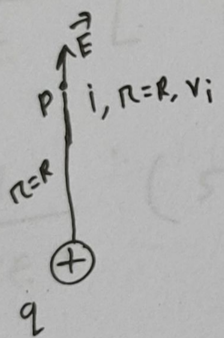
$$\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right)$$

⊛ Electric Potential due to a point charge q at point P.

$f \to \infty,\ V_f = 0,\ \vec{E} = 0$

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

$\Rightarrow$



$$\overset{0}{V_f} - V_i = -\int_i^f \vec{E} \cdot \vec{ds}$$

$$-V_i = -\int_{i, r=R}^{f, r=\infty} E\, ds \cos 0^\circ$$

$$-V_i = -\int_{i, r=R}^{f, r=\infty} E\, ds$$

$$= -\int_{i, r=R}^{f, r=\infty} \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \cdot dr$$

$$\therefore -V_i = -\frac{q}{4\pi\epsilon_0} \int_{i, r=R}^{f, r=\infty} \frac{1}{r^2}\, dr$$

$$V_i = \frac{q}{4\pi\epsilon_0} \int_{r=R}^{r=\infty} r^{-2}\, dr$$

$$= \frac{q}{4\pi\epsilon_0} \cdot \frac{r^{-2+1}}{-2+1} \Bigg]_{r=R}^{r=\infty}$$

$$= \frac{-q}{4\pi\epsilon_0} \left[r^{-1} \right]_{r=R}^{r=\infty}$$

$$= \frac{-q}{4\pi\epsilon_0} \left(0 - \frac{1}{R} \right)$$

$$\therefore \boxed{V_i = \frac{q}{4\pi\epsilon_0 R}}$$

$$\boxed{V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}} \rightarrow \text{For any } r$$

※ For Point Charge,

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

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

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

$-q$ /

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

q_1, q_2 /

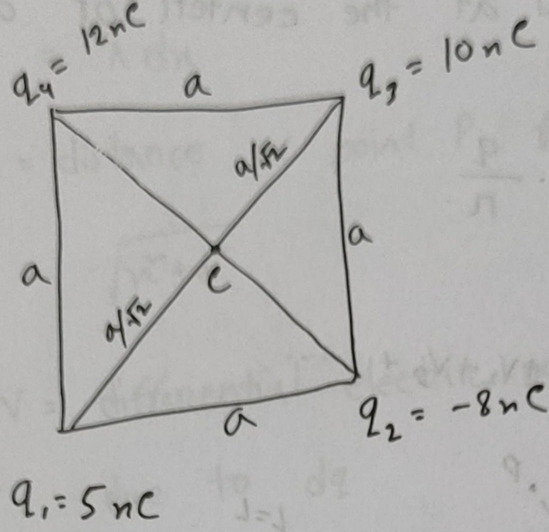
$$V_1 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r_1}$$

$$V_2 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{r_2}$$

$$\Sigma V_i = V_1 + V_2$$

$1\,nC = 10^{-9}\,C$

Example:



$$\therefore V = \frac{1}{4\pi\epsilon_0}\left[\frac{5c}{r} - \frac{8c}{r} + \frac{10c}{r} + \frac{12c}{r}\right] \times 10^{-9}$$

$$= \frac{1}{4\pi\epsilon_0 r}(5 - 8 + 10 + 12) \times 10^{-9} \text{ Volt}$$

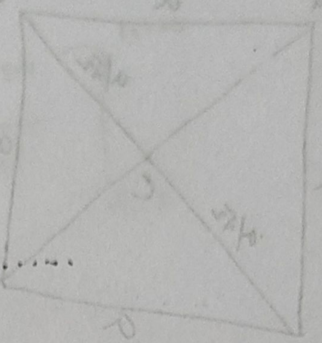
$$= \ldots\ldots \text{ Volt.}$$

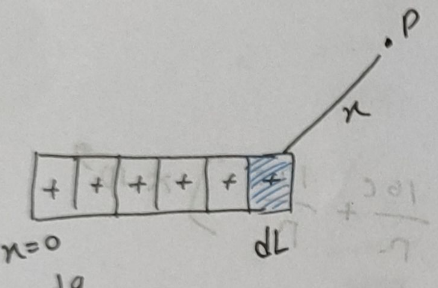
L-15/20.03.2023/

(*) Find the potential at the center of a square:

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

$$\sum_i V_i = V_1 + V_2 + V_3 + \dots\dots$$





$$dq = \lambda\, dL$$

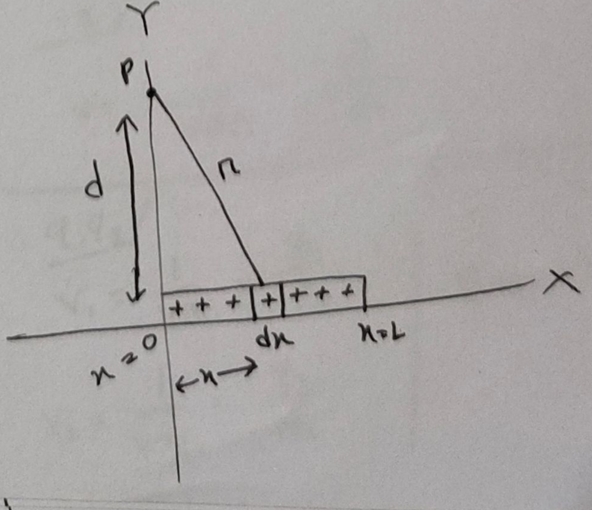
$$\int_{L=0}^{L=L} dE = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda\, dL}{r^2}$$

$$V = \int dV = \int \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r} = \int_{L=0}^{L=L} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda\, dL}{r}$$

(*) Find Electric Potential in a line charge at point P.

Length = L

charge = q



dx = differential Line element

dq = differential charge element

$= \lambda dx$

r = distance or point P from dq

$= \sqrt{x^2+d^2}$

dV = differential electric potential at point P

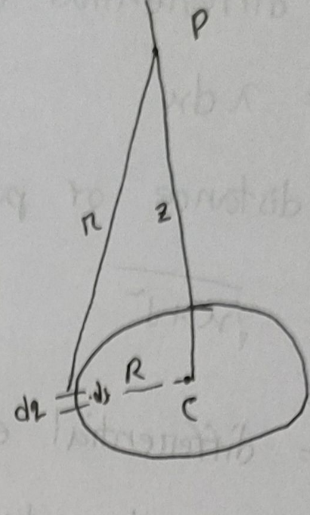
due to dq

$$\therefore dV = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dx}{\sqrt{x^2+d^2}}$$

$$\therefore V = \int dV = \int_{x=0}^{x=L} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda dx}{\sqrt{x^2+d^2}}$$

$$= \frac{\lambda}{4\pi\epsilon_0} \int_{x=0}^{x=L} \frac{dx}{\sqrt{x^2+d^2}}$$

⊛ Find electric potential due to a ring charge at point P.



⇛

Radius $= R$

Charge $= q$

Length $= L = 2\pi R$

Charge density $= \lambda = \dfrac{q}{L}$

$= \dfrac{q}{2\pi R}$

$\therefore q = \lambda\, 2\pi R$

ds = differential line element

dq = differential charge element

$= \lambda ds$

r = distance of point P from dq

$= \sqrt{R^2 + z^2}$

dV = differential potential at P

$$dV = \frac{1}{4\pi\epsilon_0} \cdot \frac{dq}{r} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{\sqrt{R^2+z^2}}$$

$$\therefore V = \int dV = \int_{s=0}^{s=2\pi R} \frac{1}{4\pi\epsilon_0} \cdot \frac{\lambda ds}{\sqrt{R^2+z^2}}$$

$$= \frac{\lambda}{4\pi\epsilon_0 \cdot \sqrt{R^2+z^2}} \int_0^{2\pi R} ds$$

$$= \frac{\lambda}{4\pi\epsilon_0 \cdot \sqrt{R^2+z^2}} \cdot s \Big]_0^{2\pi R}$$

$$= \frac{\lambda \, 2\pi R}{4\pi\epsilon_0 \cdot \sqrt{R^2+z^2}}$$

$$\therefore V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{\sqrt{R^2+z^2}} \quad \left[\because \lambda = \frac{q}{2\pi R}\right.$$

(*) Find electric field at point P from this expression of electric potential.

$$\Rightarrow \quad E_x = \frac{-dV}{dx} = 0$$

$$E_y = -\frac{dV}{dy} = 0$$

$$E_z = -\frac{dV}{dz} = -\frac{d}{dz}\left[\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{\sqrt{R^2+z^2}}\right)$$

$$= -\frac{q}{4\pi\epsilon_0} \cdot \frac{d}{dz}(R^2+z^2)^{-\frac{1}{2}}$$

$$= -\frac{q}{4\pi\epsilon_0}\left(-\frac{1}{2}\right)(R^2+z^2)^{-\frac{1}{2}-1} \cdot (2z)$$

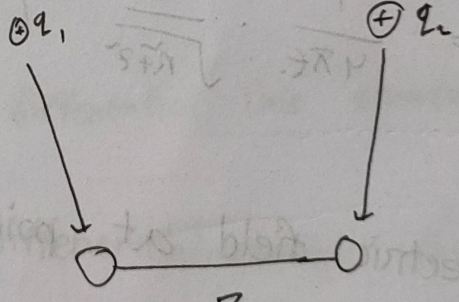
$$E_z = \frac{1}{4\pi\epsilon_0} \cdot \frac{qz}{(R^2+z^2)^{3/2}}$$

$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{qz}{(R^2+z^2)^{3/2}}$$

⊛ Electric Potential Energy for Point Charge:

$$V = \frac{U}{q}$$

$$U = Vq = W$$



$$W_1 = Vq = 0 \cdot q_1 = 0$$

$$V_1 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r}$$

$$W_2 = Vq = V_1 q_2$$

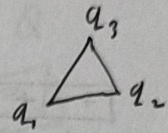
$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r} \cdot q_2$$

$$W = W_1 + W_2$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r} = U$$

$$\therefore U_{12} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r}$$

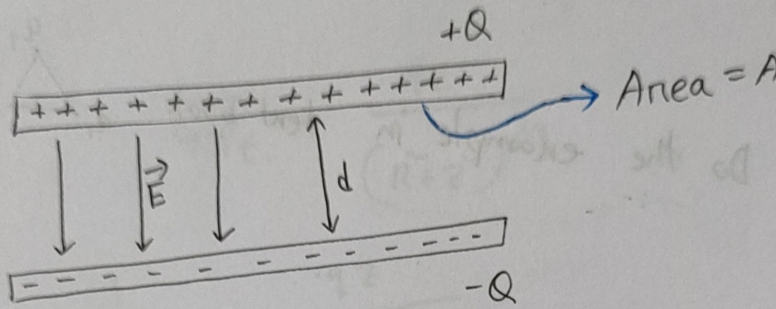
(*) Do the example in text book



Midterm

L-16/ 22.03.2023/

⊛ Parallel Plate Capacitor:



(i) Capacitor is a device can store charge

(ii) Electric Field

(iii) Store potential energy.

Charge	Potential Difference
0	0
1	1 Volt
2	2 Volt
3	3 Volt

$\therefore$ Potential Difference $\propto$ Charge

$\Rightarrow$ P.D = k . Charge

$$V = k.Q$$

$$\frac{1}{k} = \frac{Q}{V} = C = \frac{\text{Coulm}}{\text{Volt}} = \text{Farad}$$

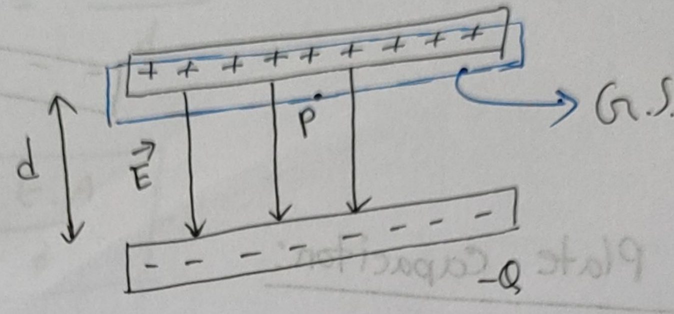
$$\therefore C = \left|\frac{Q}{V}\right|$$

① Parallel Plate Capacitor:

$$C = \left|\frac{Q}{V}\right|$$

Plate Area = A

Plate Separation = d



$$\phi_E = \oint \vec{E}\cdot\vec{dA} = \frac{q_{enc}}{\epsilon_0} = \frac{+Q}{\epsilon_0}$$

$$= \int_D \vec{E}\,\vec{dA} + \int_R \vec{E}\,\vec{dA} + \int_T \vec{E}\,\vec{dA} + \int_L \vec{E}\,\vec{dA} + \int_F \vec{E}\,\vec{dA} + \int_B \vec{E}\,\vec{dA}$$

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

$$= \int_D E\,dA\cos 0^\circ + \int_R E\,dA\cos 90^\circ + \int_T \overset{0}{E\,dA} + \int_L E\,dA\cos 90^\circ + \int_F E\,dA\cos 90^\circ + \int_B E\,dA\cos 90^\circ$$

$$= EA + 0 + 0 + 0 + 0 + 0 = \frac{Q}{\epsilon_0}$$

$$\therefore EA = \frac{Q}{\epsilon_0}$$

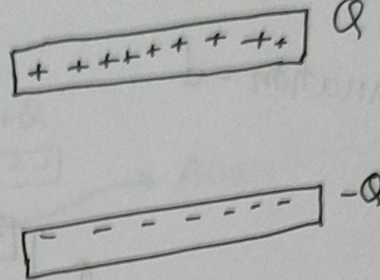
$$\therefore Q = \epsilon_0 EA$$

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

L-17/ 27.03.2023/

Capaciton:

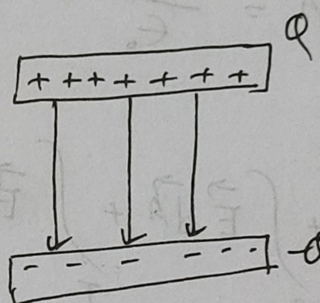
$C = \left|\frac{Q}{V}\right|$ $\qquad C = \frac{Q}{V}$



⊛ Parzallel Plate capaciton:

Plate arzea = A

Plate Separzation = d



$Q = \epsilon_0 AE$ --(i)

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

⊛

i ⇒ initial point

V_i = Electric Potential at i

f ⇒ final point

V_f ⇒ Electric Potential at f.

$$V = V_f - V_i = -\int_i^f \vec{E} \cdot \vec{ds} = -\int_i^f E ds \cos 180°$$

$$= \int_i^f E ds$$

$$V_f - V_i = Ed$$

$$\therefore V = Ed \quad \cdots \text{(ii)}$$

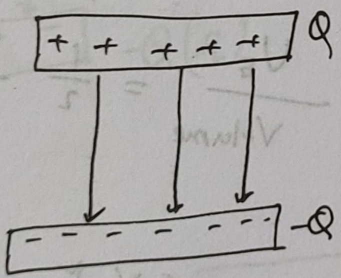
Potential diffenence between the plates or the capaciton.

$$C = \frac{Q}{V} = \frac{\epsilon . AE}{Ed} = \frac{\epsilon . A}{d}$$

$$\boxed{\therefore C = \frac{\epsilon . A}{d}}$$

(28) Energy stoned in the capaciton:

$$U = VQ = W$$



$$dq' = up$$

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

at time $t = t$

P.D. between plates $= V' = \frac{q'}{C}$

$$dW = d' \, dq'$$

$$W = \int dW = \int_{q'=0}^{q'=Q} V' \, dq'$$

$$W = VQ$$

$$= \int_{q'=0}^{Q} \frac{q'}{C}\, dq' = \frac{1}{C} \left. \frac{(q')^2}{2} \right]_{q'=0}^{q'=Q}$$

$$W = \frac{Q^2}{2C} = U$$

$$\therefore U = \frac{Q^2}{2C}$$

$$\boxed{\therefore U_E = \frac{Q^2}{2C} = \frac{1}{2} C V^2}$$

$V = Ed$

$E = \frac{V}{d}$

Energy Density : (u_E):

$$u_E = \frac{\text{Total Energy}}{\text{Total Volume}} = \frac{U_E}{\text{Volume}} = \frac{1}{2} \frac{\epsilon_0 A}{d} \frac{V^2}{d}$$

$$= \frac{1}{2} \epsilon_0 \left(\frac{V}{d}\right)^2$$

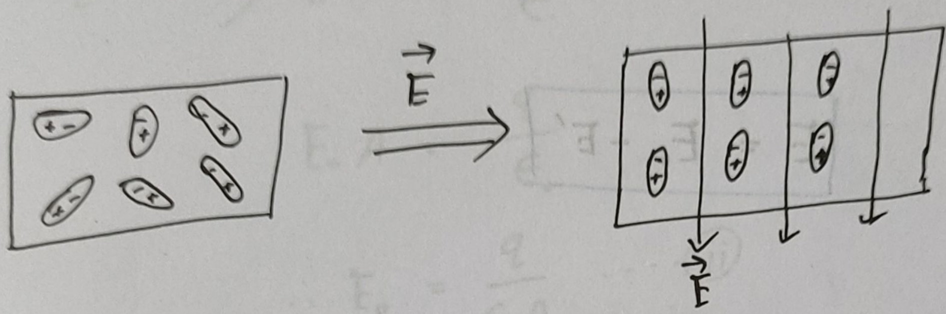
$$= \frac{1}{2} \epsilon_0 E^2$$

$$\boxed{\begin{aligned} U_E &= \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C} \\ u_E &= \frac{1}{2} \epsilon_0 E^2 \end{aligned}}$$

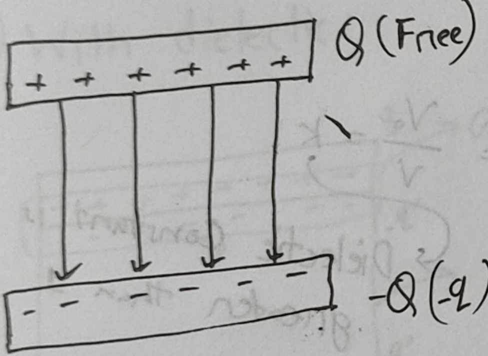
L-18/29.03.2023/

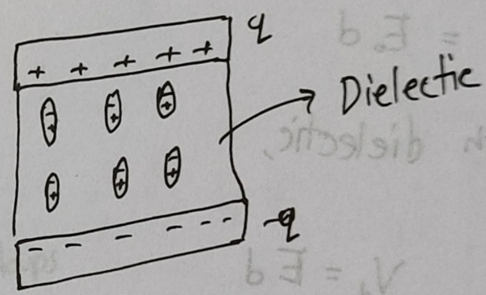
Capacitance :

Dielectics & Capaciton :

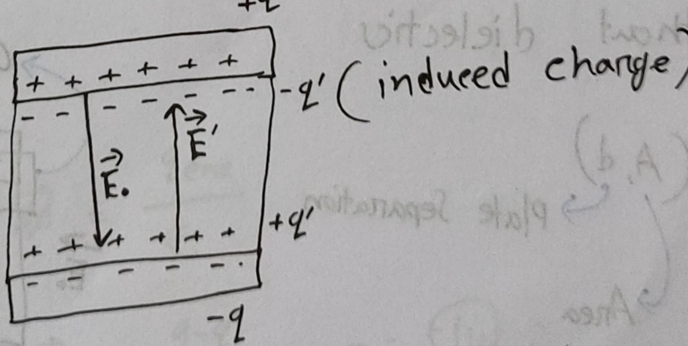


P.D = $E_0 d$





$$C = \frac{q}{E_0 d}$$



$$C = \frac{q}{Ed}$$

$$P.D = (E_0 - E').d = Ed$$

$\vec{E}_0 \rightarrow$ Down $\rightarrow$ Free change q

$\vec{E}' \rightarrow$ Vp $\longrightarrow$ Induced q'

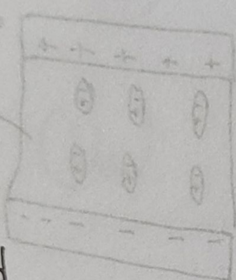
$E_0 > E'$ because $q > q'$

$$\boxed{E = E_0 - E'}$$

⊛ Without,

$V_0 = E_0 d$

with dielectic,



$V_d = E d$

$$\frac{E_0}{E} = \frac{V_0}{V} = k$$

Dielectic Constant is greater than 1

⊛ Gauss' Law & Dielectics

(i) Without dielectics

(A, d)

d → Plate Separation

A → Area