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Subject - EMT

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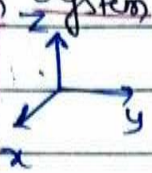
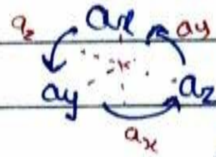
Co-ordinate System

Cartesian System. (x, y, z)

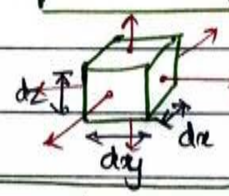




use Right hand thumb rule to get 3rd axis

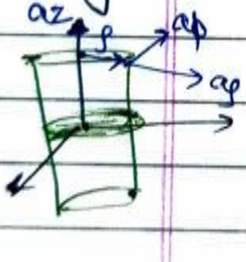
eg: $\vec{a_z} \times \vec{a_x} = \vec{a_y}$

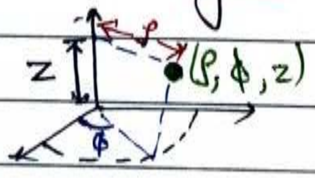
- differential length: $\boxed{\vec{dl} = dx\,\hat{a}_x + dy\,\hat{a}_y + dz\,\hat{a}_z}$
- differential Surface $\boxed{\vec{ds} = dx\,dy\,\hat{a}_z = dx\,dz\,a_y \dots \text{etc.}}$



- diff. volume, $\boxed{dv = dx\,dy\,dz}$

Cylinderical Coordinate system (ρ, ϕ, z)





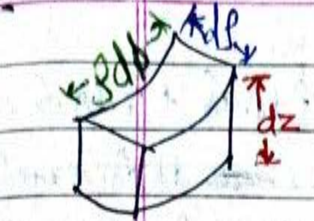
$$\boxed{\begin{aligned} x &= \rho\cos\phi \\ y &= \rho\sin\phi \\ z &= z \end{aligned}}$$

$$\vec{A} = A_\rho\,\hat{a}_\rho + A_\phi\,\hat{a}_\phi + A_z\,\hat{a}_z$$

$$\boxed{\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix}}$$

Transpose $\downarrow$ $\qquad \frac{d}{d\phi}$

$$\left\{ \begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \frac{d}{d\phi} \begin{bmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} \right\}$$



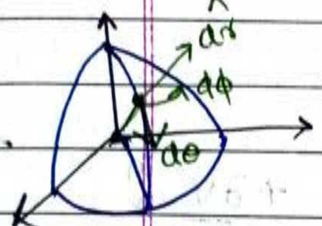
differential length

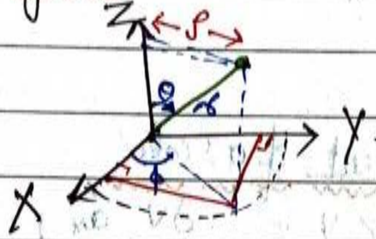
$\vec{dl} = d\rho\,\hat{a}_\rho + \rho\,d\phi\,\hat{a}_\phi + dz\,\hat{a}_z$

$\vec{ds} = \rho\,d\rho\,d\phi\,\hat{a}_z = \rho\,d\phi\,dz\,\hat{a}_\rho$
$= d\rho\,dz\,\hat{a}_\phi$

$\vec{dv} = \rho\,d\rho\,d\phi\,dz$

Spherical co-ordinate system





$x = \rho\cos\phi = r\sin\theta\cos\phi$ $\qquad r = \sqrt{x^2+y^2+z^2}$

$y = \rho\sin\phi = r\sin\theta\sin\phi$ $\qquad \theta = \cos^{-1}\left(\frac{z}{\sqrt{x^2+y^2+z^2}}\right)$

$z = r\cos\theta$ $\qquad \phi = \tan^{-1}\left(\frac{y}{x}\right)$

Transformation of vectors

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \cos\theta\cos\phi & -\sin\phi \\ \sin\theta\sin\phi & \cos\theta\sin\phi & \cos\phi \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$$

d/dθ d/dφ

↓ Transpose

$$\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \sin\theta\sin\phi & \cos\theta \\ \cos\theta\cos\phi & \cos\theta\sin\phi & -\sin\theta \\ -\sin\phi & \cos\phi & 0 \end{bmatrix} \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$$

d/dθ d/dφ

$\nabla\cdot\vec{V} \Rightarrow$ * $\frac{1}{\rho}\frac{\partial V_\phi}{\partial \phi}$ $\Rightarrow$ 1 term me $\frac{1}{\rho}$ extra to $\hat{a}_\rho$

$\therefore \nabla\cdot\vec{V} = \frac{1}{\rho}\frac{\partial(\rho V_\rho)}{\partial \rho} + \frac{1}{\rho}\frac{\partial V_\phi}{\partial \phi} + \frac{\partial V_z}{\partial z}$ | Ke term me ρ multiply & divide hog

$\rho d\phi \hat{a}_\phi + r d\theta \hat{a}_\theta$

Similarly in spherical co-ordinates
$\frac{\partial}{\partial\theta}$ ke sath $\frac{1}{r}$ extra $\Rightarrow$ $\hat{a}_r$ ke sath r mul. & divide
$\frac{\partial}{\partial\phi}$ ke sath $\frac{1}{r\sin\theta}$ extra $\Rightarrow$ $\hat{a}_r$ ke sath r mul. & divide
$\hat{a}_\theta$ ke sath $\sin\theta$ mul & divide

$+ r d\theta \hat{a}_\theta + r\sin\theta d\phi \hat{a}_\phi$

$d\theta d\phi \hat{a}_r$

$r d\phi \hat{a}_\theta$

$= r dr d\theta \hat{a}_\phi$

$\vec{dV} = r^2 \sin\theta \, dr \, d\theta \, d\phi$

⊙ Gradient of a scalar

$$\nabla V = \frac{\partial V}{\partial x}\hat{a}_x + \frac{\partial V}{\partial y}\hat{a}_y + \frac{\partial V}{\partial z}\hat{a}_z$$

$$= \frac{\partial V}{\partial \rho}\hat{a}_\rho + \frac{1}{\rho}\frac{\partial V}{\partial \phi}\hat{a}_\phi + \frac{\partial V}{\partial z}\hat{a}_z$$

$$= \frac{\partial V}{\partial r}\hat{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}\hat{a}_\phi$$

To remember cylindrical

$dl = d\rho \hat{a}_\rho + \rho d\phi \hat{a}_\phi + dz \hat{a}_z$

extra term

$\nabla V = \text{—} + \frac{1}{\rho}\frac{\partial V}{\partial \phi}\hat{a}_\phi + \text{—}$

Similarly spherical $dl = dr\hat{a}_r + r d\theta \hat{a}_\theta + r\sin\theta d\phi \hat{a}_\phi$

extra   extra

$$\nabla V = \frac{\partial V}{\partial r}\hat{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}\hat{a}_\phi$$

∇V {gradient} gives max rate of change per unit distance and direction where max rate of change ~~occurs~~ occurs.

$\vec{dl} = dr\hat{a}_r + \rho d\phi \hat{a}_\phi + r$

$\cancel{= dr\hat{a}_r + r \ldots d\phi \hat{a}_\phi}$

(r, θ, ϕ)

$\vec{dl} = dr\,\hat{a}_r + r d\theta\,\hat{a}_\theta + r$

$\vec{ds} = r^2 \sin\theta \, d\theta \, d\phi \, \hat{a}_r$

$= r \sin\theta \, dr \, d\phi \, \hat{a}_\theta$

$= r \, dr \, d\theta \, \hat{a}_\phi$

$\vec{dv} = r^2 \sin\theta \, dr \, d\theta \, d\phi$

⊙ Gradient of a scalar

$$\nabla V = \frac{\partial V}{\partial x}\hat{a}_x + \frac{\partial V}{\partial y}\hat{a}_y + \frac{\partial V}{\partial z}\hat{a}_z$$

$$= \frac{\partial V}{\partial \rho}\hat{a}_\rho + \frac{1}{\rho}\frac{\partial V}{\partial \phi}\hat{a}_\phi + \frac{\partial V}{\partial z}\hat{a}_z$$

$$= \frac{\partial V}{\partial r}\hat{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}$$

To remember cylindrical

$dl = d\rho\,\hat{a}_\rho + \rho d\phi\,\hat{a}_\phi$

extra term

$\nabla V = \text{—} + \frac{1}{\rho}\frac{\partial V}{\partial \phi}\hat{a}_\phi$

Similarly spherical $dl = dr\hat{a}_r + r d\theta\,\hat{a}_\theta + r\sin\theta\, d$

extra extra

$\nabla V = \frac{\partial V}{\partial r}\hat{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial}{\partial}$

∇V {gradient} gives max rate of change per unit distance and direction where max rate of change ~~occurs~~ occurs.

$$\nabla \times \vec{V} = \begin{vmatrix} \hat{a}_\rho & \hat{a}_\phi & \hat{a}_z \\ \frac{\partial}{\partial \rho} & \frac{1}{\rho}\frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ V_\rho & V_\phi & V_z \end{vmatrix}$$

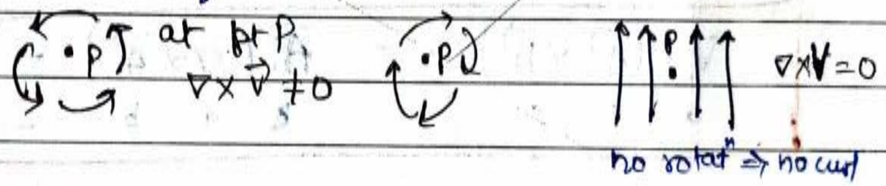
$$= \begin{vmatrix} \hat{a}_r & \hat{a}_\theta & \hat{a}_\phi \\ \frac{\partial}{\partial r} & \frac{1}{r}\frac{\partial}{\partial \theta} & \frac{1}{r\sin\theta}\frac{\partial}{\partial \phi} \\ V_r & V_\theta & V_\phi \end{vmatrix}$$

- Curl of a vector

$$\nabla \times \vec{V} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ V_x & V_y & V_z \end{vmatrix}$$

$$= \frac{1}{\rho}\begin{vmatrix} \hat{a}_\rho & \rho\hat{a}_\phi & \hat{a}_z \\ \partial/\partial\rho & \partial/\partial\phi & \partial/\partial z \\ V_\rho & \rho V_\phi & V_z \end{vmatrix} = \frac{1}{r^2\sin\theta}\begin{vmatrix} a_r & r a_\theta & r\sin\theta\, \hat{a}_\phi \\ \partial/\partial r & \partial/\partial\theta & \partial/\partial\phi \\ V_r & rV_\theta & r\sin\theta V_\phi \end{vmatrix}$$

* Curl is measure of how much a vector field rotates about point.



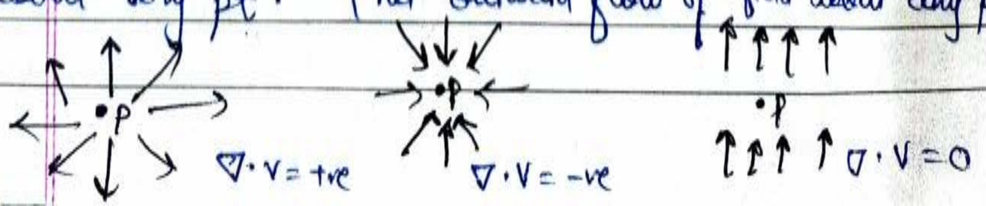
- Divergence of a vector

$$\nabla \cdot \vec{V} = \frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z}$$

$$= \frac{1}{\rho}\frac{\partial(\rho V_\rho)}{\partial \rho} + \frac{1}{\rho}\frac{\partial V_\phi}{\partial \phi} + \frac{\partial V_z}{\partial z}$$

$$= \frac{1}{r^2}\frac{\partial(r^2 V_r)}{\partial r} + \frac{1}{r\sin\theta}\frac{\partial(\sin\theta V_\theta)}{\partial \theta} + \frac{1}{r\sin\theta}\frac{\partial V_\phi}{\partial \phi}$$

- It is a measure of how much vector field diverges about any pt. {net outward flow of field about any pt.}



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Stoke's theorem: $\oint \vec{A}\cdot\vec{dl} = \int_S (\nabla\times\vec{A})\,\vec{ds}$

Divergence theorem: $\oint \vec{D}\cdot\vec{ds} = \int_V (\nabla\cdot\vec{D})\,dv$

(1) $\cancel{\nabla\cdot\vec{D} \neq 0}$ $\quad$ $\cancel{\text{div}(\text{curl}\,\vec{v}) = 0}$

$\cancel{(\nabla\times\vec{V}) = 0}$ $\quad$ $\cancel{\nabla\cdot(\nabla\times v) = 0}$

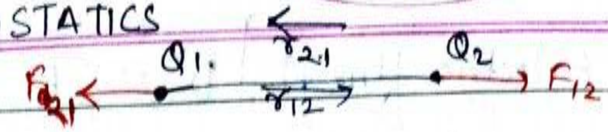
(1) Divergence less or solenoid vector $\Rightarrow \nabla\cdot\vec{D} = 0$

(2) Irrotational or conservative vector $\Rightarrow \nabla\times\vec{V} = 0$

(3) $\nabla\cdot(\nabla\times\vec{V}) = 0$ $\qquad$ $\nabla\times(\nabla\cdot V) = 0$

$$\boxed{\underset{a}{\nabla}\cdot(\underset{b}{\vec{A}}\times\underset{c}{\vec{B}}) = \underset{c}{\vec{B}}\cdot(\underset{a}{\nabla}\times\underset{b}{\vec{A}}) - \underset{b}{\vec{A}}\cdot(\underset{a}{\nabla}\times\underset{c}{\vec{B}})}$$

ELECTROSTATICS



Coulomb's Law:

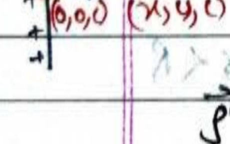
$$\boxed{\vec{F}_{12} = \frac{K Q_1 Q_2}{|\vec{r}_{12}|^3}\,\vec{r}_{12}}$$

$K = 9 \times 10^9$ m/F

$\epsilon_0 = 8.854 \times 10^{-12}$ F/m

Electric field Intensity $\rightarrow$ $\boxed{\vec{E} = \frac{\vec{F}}{q}}$ $= \begin{cases} \frac{KQ}{R^2}\,\hat{a}_R \\ \int \frac{K \rho_L dl}{R^2}\,\hat{a}_R \text{ (line charge)} \\ \int \frac{K \rho_s ds}{R^2}\,\hat{a}_R \text{ (surface charge)} \\ \int \frac{K \rho_v dv}{R^2}\,\hat{a}_R \text{ (volume charge)} \end{cases}$

(i) Infinite long line charge



$$\vec{E} = \frac{\rho_L}{2\pi\epsilon_0 \rho}\,\hat{a}_\rho \;** = \frac{\rho_L\,\vec{\rho}}{2\pi\epsilon_0 \rho^2}$$

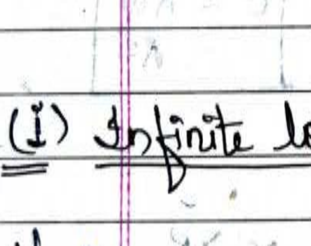
$\vec{E} \cdot 2\pi\rho l = \frac{\rho_L l}{\epsilon_0}$

Derivation Guass law

$\vec{\rho}$ = perpendicular distance from line charge to point charge

(ii) Circular ring

$= \frac{\rho_L (\sin\theta\cos\theta)}{2 L \epsilon_0} = \frac{\rho_L (\sin\theta\cos\theta)}{2\sqrt{\rho^2+h^2}\,\epsilon_0}$



$$\boxed{E = \frac{\rho_L \rho h}{2\epsilon_0 (\rho^2+h^2)^{3/2}}\,\hat{a}_n}$$

(iii) Circular disk

$$E = \frac{\rho_s}{2\epsilon_0}\left[1 - \frac{h}{\sqrt{h^2+R^2}}\right] a_n$$

(iv) Infinite sheet $(R \to \infty)$

$$E = \frac{\rho_s}{2\epsilon_0}\,\hat{a}_n$$

$= \frac{\rho_s}{2\epsilon_0}[1 - \cos\theta]\, a_n$

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Electric flux (ψ) $\boxed{\vec{D} = \varepsilon \vec{E}}$ C/m^2

$\boxed{\psi = \int_S \vec{D} \cdot \vec{ds}}$ C

max flux $\psi = \int D\, ds \cos 0°$
$= D \times \text{area}$

min flux $\psi = \int D\, ds \cos 90°$
$= 0$

Guass law :- $\boxed{\oint \vec{D} \cdot \vec{ds} = \int_V \rho_v\, dV}$

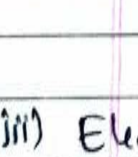
Maxwells 1st eqn (Integral form)

$\oint \vec{D} \cdot \vec{ds} = \int_V (\nabla \cdot \vec{D})\, dv = \int \rho_v\, dv$

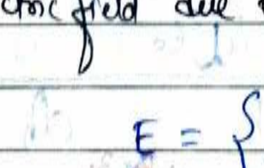
$\boxed{\nabla \cdot \vec{D} = \rho_v}$ {Maxwell 1st eqn Differential or pnt form}

(i) Electric field due to pnt charge : $\boxed{E = \frac{KQ}{R^2}}$

(ii) Electric field due to conducting sphere



$$E = \begin{cases} \frac{KQ}{r^2} & r \geq R \\ 0 & r < R \end{cases}$$

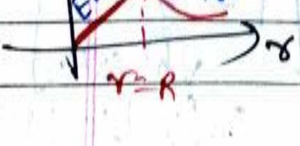


(iii) Electric field due to non-conducting sphere

$$E = \begin{cases} KQ/r^2 & r \geq R \\ \frac{KQr}{R^3} & r < R \end{cases}$$

$= \frac{KQ}{r^2}\left(\frac{r^3}{R^3}\right)$

$V = \frac{4\pi}{3} r^3$



Potential difference

* $\boxed{V_{AB} = -\int_A^B \vec{E}\cdot\vec{dl}}$.

* $\boxed{V_{AB} = \frac{KQ}{r_B} - \frac{KQ}{r_A} = V_B - V_A}$

* If $r_B = r$, $r_A = \infty$, V_{AB} = absolute pot. at B

KVL: * $\oint \vec{E}\cdot\vec{dl} = 0$ {Maxwell 2nd eqn Integral form}

from stoke's theor $\oint \vec{E}\cdot\vec{dl} = \int_S (\nabla\times\vec{E})\cdot\vec{ds} = 0$

$\boxed{(\nabla\times\vec{E}) = 0}$ Maxwell's 2nd eqn. differential form

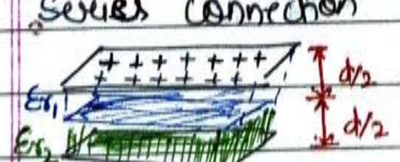
* $E = -\nabla V = -\text{grad}(V)$

Capacitance

(1) Parallel plate Capacitor

⊙ $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$ ⊙ $W_E = \frac{Q^2}{2C} = \frac{1}{2}CV^2$

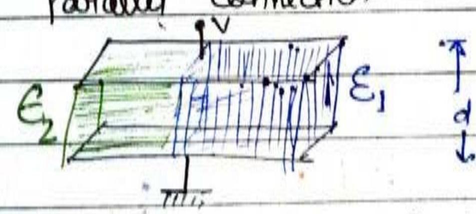
Series connection



$C_1 = \frac{\epsilon_1 A}{d/2}$ $C_2 = \frac{\epsilon_2 A}{d/2}$

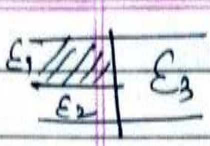
$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

Parallel connection



$C_1 = \frac{\epsilon_1 A/2}{d}$ $C_2 = \frac{\epsilon_2 A/2}{d}$

$C = C_1 + C_2$

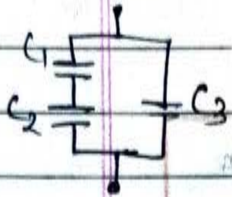


- In series connect^n Q = constant

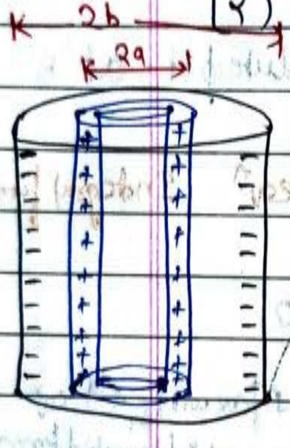
$$C_1 V_1 = C_2 V_2$$

- In shunt connection V = constant

$$\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$$



(2) Co-axial Capacitor



from Guass law $\oint D \cdot ds = Q$

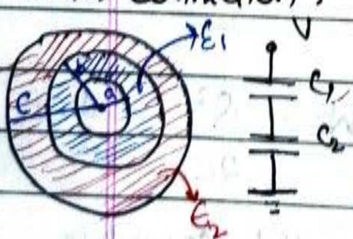
step ① $E = \frac{1}{\varepsilon}\left(\frac{Q}{2\pi r l}\right)$

step ② $V_{21} = -\int_2^1 E\,\hat{a_r} \cdot dr\,\hat{a_r}$

step ③ $C = \frac{Q}{V}$

$$\boxed{C = \frac{2\pi \varepsilon l}{\ln\left(\frac{b}{a}\right)}}$$

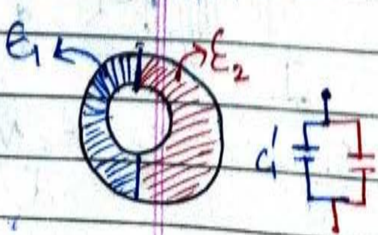
Series Connection :



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_1 = \frac{2\pi \varepsilon_1 l}{\ln b/a} \qquad C_2 = \frac{2\pi \varepsilon_2 l}{\ln\left(\frac{c}{b}\right)}$$

Shunt connection :

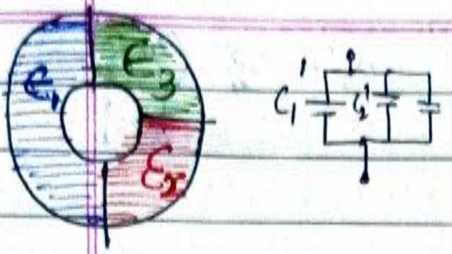


$$C_1' = \frac{1}{2}\left(\frac{2\pi \varepsilon_1 l}{\ln\left(\frac{b}{a}\right)}\right); C_2' = \frac{1}{2}\left(\frac{2\pi \varepsilon_2 l}{\ln\left(\frac{b}{a}\right)}\right)$$

$$C = C_1' + C_2'$$

To remember $C = \frac{\epsilon_0 A}{d}$ Capacitance ka unit aisa hota h, ki uska Area $\propto C$

$\therefore A \to \frac{1}{2} \Rightarrow C \to \frac{1}{2}$

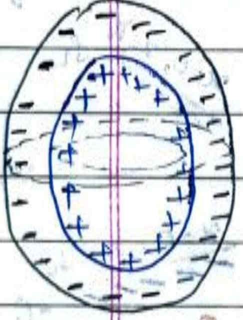


$$C_1' = \frac{1}{2}\left(\frac{2\pi\epsilon_1 l}{\ln\left(\frac{b}{a}\right)}\right) \quad C_2' = \frac{1}{4}\left(\frac{2\pi\epsilon_2 l}{\ln\frac{b}{a}}\right)$$

$$C_3' = \frac{1}{4}\left(\frac{2\pi\epsilon_1 l}{\ln(b/a)}\right)$$

radius change $\rightarrow$ Series
medium change $\rightarrow$ Shunt

(3) Spherical capacitor



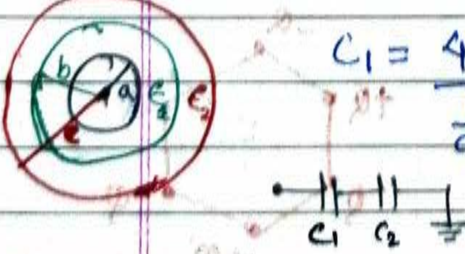
Step (1) $E = \frac{Q}{4\pi\epsilon r^2}$

(2) $V = -\int_a^b E \cdot dl$ (3) $C = \frac{Q}{V}$

$$C = \frac{4\pi\epsilon}{\left(\frac{1}{a} - \frac{1}{b}\right)}$$

If outer conducting sphere at ∞ $\Rightarrow$ Isolated sphere.
$b \to \infty$ $\Rightarrow$ $\boxed{C = 4\pi\epsilon a}$

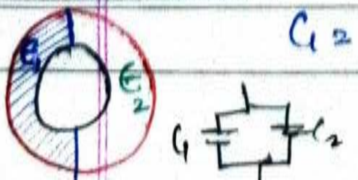
Series connection:



$$C_1 = \frac{4\pi\epsilon_1}{\frac{1}{a} - \frac{1}{b}} \qquad C_2 = \frac{4\pi\epsilon_2}{\frac{1}{b} - \frac{1}{c}}$$

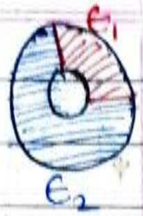
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

Shunt connection:



$$C_1 = \frac{1}{2}\left(\frac{4\pi\epsilon_1}{\frac{1}{a} - \frac{1}{b}}\right) \qquad C_2 = \frac{1}{2}\left(\frac{4\pi\epsilon_2}{\frac{1}{a} - \frac{1}{b}}\right)$$

$C = C_1 + C_2$

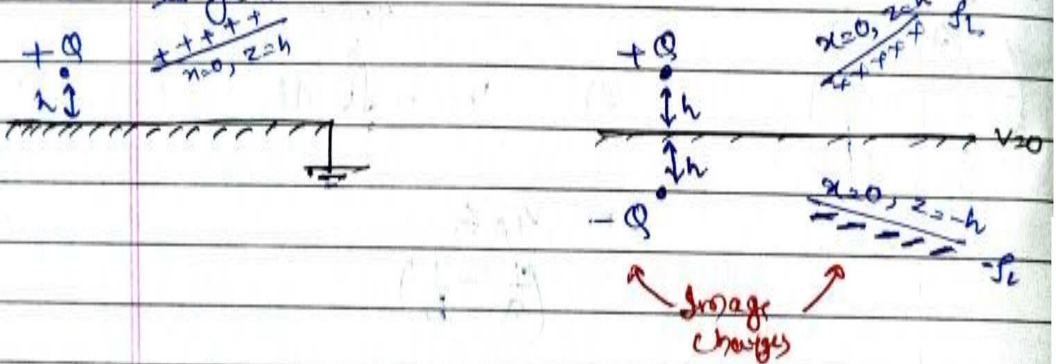


$$C_1 = \frac{1}{4}\frac{(4\pi\epsilon_1)}{\frac{1}{a}-\frac{1}{b}} \qquad C_2 = \frac{3}{4}\frac{(4\pi\epsilon_2)}{\frac{1}{a}-\frac{1}{b}}$$

Method of Images

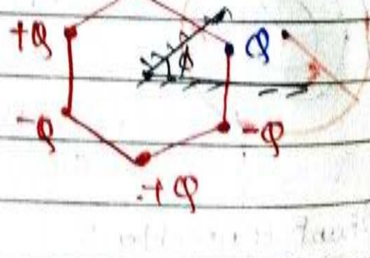
Condition {necessary}

- the image charges must be located in conducting region.
- the image charges must be located such that the potential on the conducting surface is zero.



** when method of images is used for system consisting of point charge b/w two semi-infinite perfect conducting grounded plane inclined at an angle of ϕ then no. of image is given by

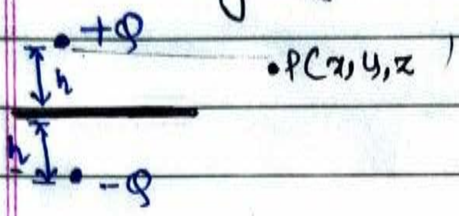
$$\boxed{N = \frac{360^\circ}{\phi^\circ} - 1}$$



No. of sides = N+1 = n

$$\boxed{\theta = \left(\frac{n-2}{n}\right)180^\circ}$$

- A point charge placed above perfect conducting grounded plane.

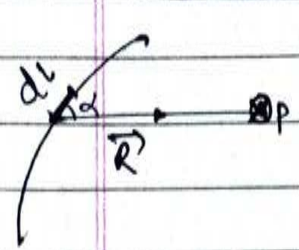


to be continued....

Pages do write it.

Magnetostatics

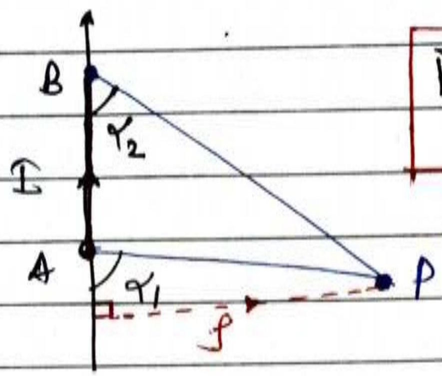
- Biot-Savart law :



$$\boxed{\vec{H} = \int_L \frac{1}{4\pi} \frac{I\vec{dl} \times \vec{R}}{R^3} \ \text{A/m}}$$

$$\boxed{B = \mu H}$$

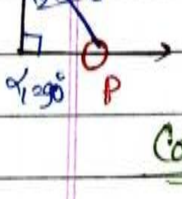
(1) Magnetic field due to straight conductor



$$\boxed{\vec{H} = \frac{I}{4\pi\rho}(\cos\alpha_2 - \cos\alpha_1)\hat{a}_\phi}$$

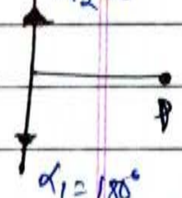
$$\hat{a}_\phi = \hat{a}_l \times \hat{a}_\rho$$

Case 1 : Semi - infinite Long conductor



$$\boxed{\vec{H} = \frac{I}{4\pi\rho}\hat{a}_\phi}$$

Case 2 : Infinite long Conductor



$$\boxed{\vec{H} = \frac{I}{2\pi\rho}\hat{a}_\phi}$$

Also derivable from Ampere's circuital law

Current distribution

$$I\vec{dl} = \vec{K}\,\vec{ds} = \vec{J}\,dv$$

Surface current density

Volume current density

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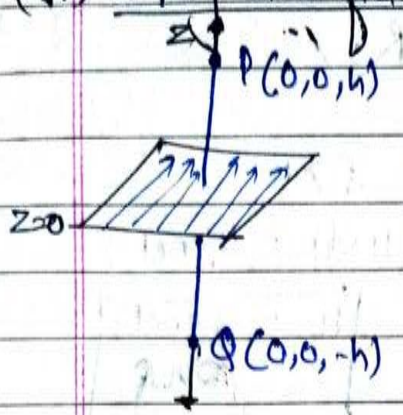
(ii) Magnetic field due to infinite current sheet

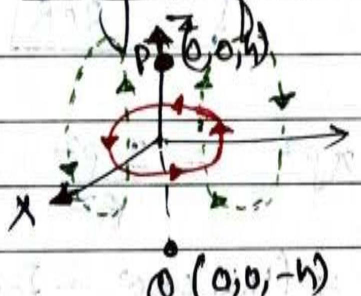


$\vec{K}$ = surface current density

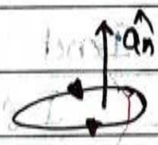
$$\boxed{\vec{H} = \frac{1}{2}(\vec{K} \times \hat{a}_n)}$$

for pt. P $\hat{a_n} = \hat{a_z}$
for pt. Q $\hat{a_n} = -\hat{a_z}$

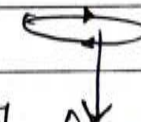
(iii) Magnetic field due to circular conductor



$$\boxed{\vec{H} = \frac{I}{2}\frac{a^2}{(a^2+h^2)^{3/2}}\hat{a_n}}$$



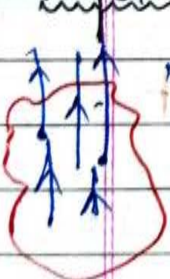
$\hat{a_n} = a_z$



$\hat{a_n} = -\hat{a_z}$

**direct^n of $\hat{a_n}$ from RHTR & not from pos^n of pnt.

Ampere's Law



$$\boxed{\oint \vec{H}\cdot\vec{dl} = I_{encl.}}$$

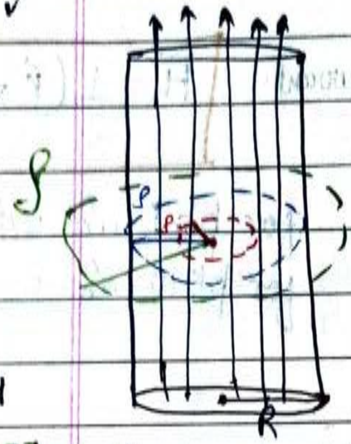
$B\cdot\vec{dl} = \mu_0 I$

$$\boxed{\oint \vec{H}\cdot\vec{dl} = \int_s \vec{J_c}\,\vec{ds}}$$ Maxwell's 3rd eq^n Integral form

$$\Rightarrow \int_s (\nabla \times \vec{H})\,\vec{ds} = \int_s \vec{J_c}\,\vec{ds}$$

$$\boxed{\nabla \times \vec{H} = \vec{J_c}}$$ Maxwell's 3rd eq^n differential form.

(iv) Magnetic field due to current carrying conductor of radius R.



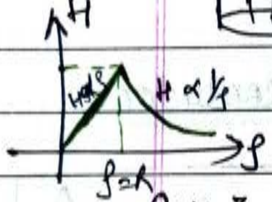
Case 1 $\rho > R$

$$\oint H \cdot dl = I_{encl}$$

$$\boxed{H = \frac{I_{encl}}{2\pi\rho}}$$

Case 2 $\rho = R$

$$\boxed{H = \frac{I_{encl}}{2\pi R}}$$



Case 3 $\rho < R$

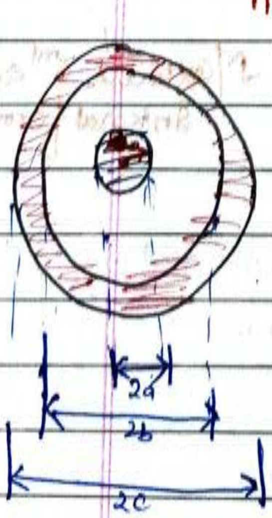
$$I_{encl} = J_c \cdot A = \left(\frac{I}{\pi R^2}\right) \times \pi\rho^2 = \frac{I\rho^2}{R^2}$$

$$\oint H \cdot dl = I_{encl} \Rightarrow \int H\,dl \cos 0^\circ = I_{encl}$$

$$\Rightarrow \boxed{H = \frac{I\rho}{2\pi R^2}} = \frac{\left(\frac{I\rho^2}{R^2}\right)}{2\pi\rho}$$

(v) Magnetic field due to co-axial cond^n

Apply Ampere's circuital law & get



$\rho > c$: $\oint H \cdot dl = I - I = 0$

$$\boxed{H = 0}$$

$b < \rho < c$: $H = \frac{I}{2\pi\rho}\left(\frac{c^2 - \rho^2}{c^2 - b^2}\right)$

$a < \rho < b$: $H = \frac{I}{2\pi\rho}$

$\rho < a$: $H = \frac{I\rho}{2\pi a^2}$

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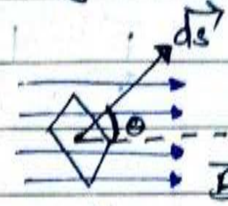
Magnetic flux & flux density

- $\vec{B} = \mu \vec{H}$
- $\psi = \int_s \vec{B} \cdot \vec{ds}$



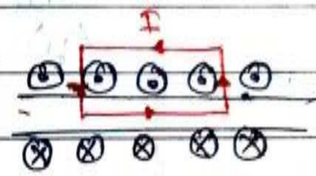
- Total flux passing through a closed surface is zero $\oint \vec{B} \cdot \vec{ds} = 0$

or $\int (\nabla \cdot \vec{B})\, dv = 0$ or $\boxed{\nabla \cdot \vec{B} = 0}$

<i> Solenoid :

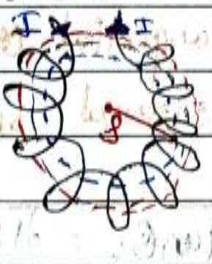
$B \cdot l = \mu_0 N I$

$$\boxed{B = \frac{\mu_0 N I}{l}}$$



(A·[B = 0]
*. $\vec{B}$ exist only inside loop

<ii> Toroid :



$$\boxed{B = \frac{\mu_0 N I}{2\pi \rho}}$$

$$L = \frac{N\psi}{I} = \frac{NBA}{I} = \begin{cases} \dfrac{\mu_0 N^2 A}{l} & \text{Solenoid} \\ \dfrac{\mu_0 N^2 A}{2\pi\rho} & \text{Toroid} \end{cases}$$

Faraday Law :

$$\oint \vec{E} \cdot \vec{dl} = -N \int_s \frac{\partial \vec{B}}{\partial t} \cdot \vec{ds}$$

Maxwell's 2nd eqn (Integral form)

Stokes theorem :

$$\oint \vec{A} \cdot \vec{dl} = \int_s (\nabla \times \vec{A}) \cdot ds$$

$$\boxed{\nabla \times \vec{E} = -N \frac{\partial \vec{B}}{\partial t}}$$

Lorentz Force equation

$\vec{F}_E = Q\vec{E}$ $\quad\quad$ $\vec{F}_M = Q(\vec{v}\times\vec{B})$

$\vec{F} = \vec{F}_E + \vec{F}_M$

$\vec{F} = Q(\vec{E} + \vec{v}\times\vec{B})$

Magnetic Boundary conditions

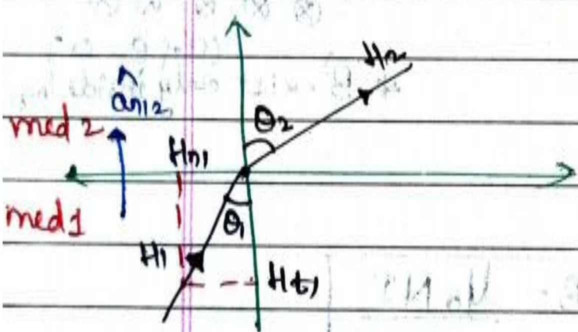
① $B_{n1} = B_{n2}$

② $H_{t1} = H_{t2}$ if $\vec{K} = 0$

$(\vec{H_1} - \vec{H_2}) \times \hat{a}_{n12} = \vec{K}$ if $\vec{K} \neq 0$

where $\vec{K}$: Current density

$\hat{a}_{n12}$: from ~~ed~~ med 1 to med 2



H_t : Tangential components

H_n : Normal component

$$\boxed{\tan\theta_1 = \frac{H_{t1}}{H_{n1}}} \quad\quad \boxed{\tan\theta_2 = \frac{H_{t2}}{H_{n2}}}$$

$$\boxed{\frac{\tan\theta_1}{\tan\theta_2} = \frac{\mu_{r1}}{\mu_{r2}}}$$