Toppersnotes
Unleash the topper in you

CSIR-NET

Council of Scientific & Industrial Research

PHYSICAL SCIENCE

VOLUME - III

ELECTROMAGNETICS

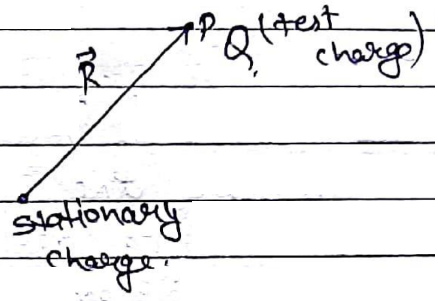
SIERRA INNOVATIONS

ELECTROMAGNETIC

Electrostatics

Field due to stationary charges.

Coulomb's Law :-

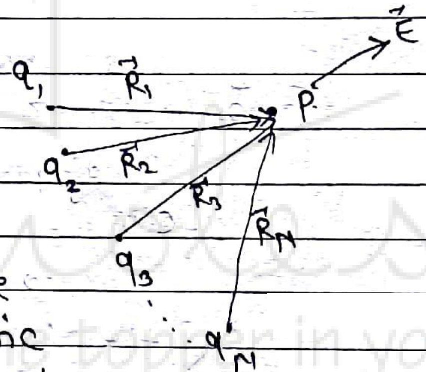


Force $\boxed{\vec{F} = \dfrac{1}{4\pi\epsilon_0} \dfrac{qQ}{|\vec{R}|^2} \hat{R}}$

ϵ_0 - permittivity of free space

$\epsilon_0 = 8.85 \times 10^{-12}\ C^2/N\text{-}m^2$

$$\boxed{\vec{E}(P) = \frac{\vec{F}}{Q} = \frac{1}{4\pi\epsilon_0} \frac{q}{|\vec{R}|^2} \hat{R}}$$



Superposition Theorm :-

If there we have set of N charges find the electric field due to indervisual charge and take vector sum.

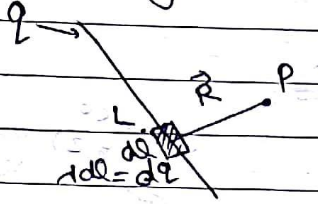
$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \cdots$$

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0} \sum_{i=1}^{N} \frac{q_i}{|\vec{R}_i|^2} \hat{R}_i}$$

For continuous charges -

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{|\vec{R}|^2} \hat{R}}$$

i) Line Charge (λ) — charge per unit length.



Charge q distributed over the wire this distribution may be uniform or nonuniform

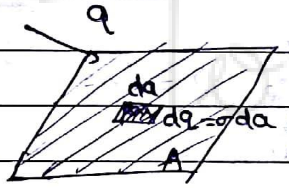
let charge q uniformly distributed -

$$\lambda = \frac{q}{L} = \text{const (uniform)}$$

$\lambda(r)$ — non-uniform.

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\int \frac{\lambda d\ell}{|\vec{R}|^2}\hat{R}$$

(ii) Surface charge (σ) — charge per unit area.



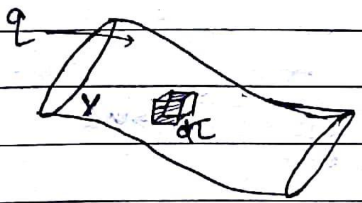
total charge is distributed over the surface.

$$\sigma = \frac{q}{A} = \text{const (uniformly distributed)}$$

$\sigma(r)$ — (Non uniformly)

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\int \frac{\sigma da}{|\vec{R}|^2}\hat{R}}$$

(iii) Volume charge (ρ) - Charge per unit volume.



Charge q is distributed through out the volume.

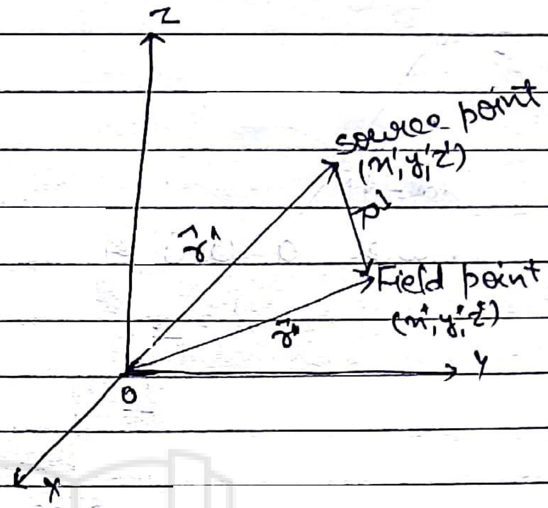
$$\rho = \frac{q}{V} = \text{const. (uniform)}$$

$\rho(r)$ (Non-uniform)

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\int \frac{\rho d\tau}{|\vec{R}|^2}\hat{R}}$$

Co-ordinate Notation :-

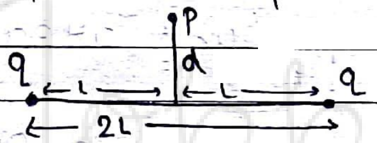
$$\boxed{\vec{E}(r) = \frac{1}{4\pi\epsilon_0}\int_V \frac{\rho(r')\,d\tau'}{|\vec{R}|^2}\hat{R}}$$

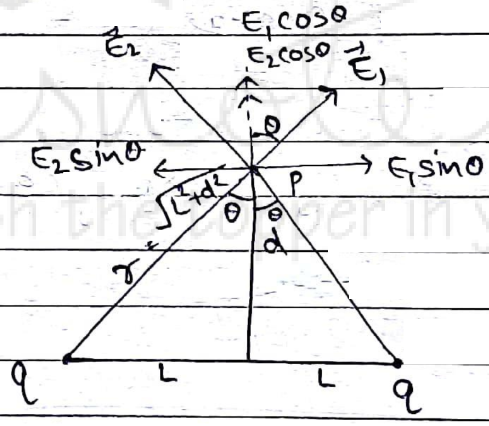


$$\vec{r}' + \vec{R} = \vec{r}$$

$$\boxed{\vec{R} = \vec{r} - \vec{r}'}$$

Ex- Find the electric field at a distance d above the mid point b/w two equal charges q a distance 2L apart.





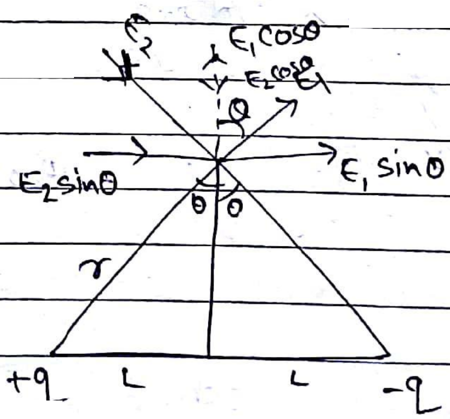
$$|\vec{E}| = |\vec{E}_1| = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

$$\vec{E} = 2|E_1|\cos\theta\,\hat{y}$$

$$= 2 \cdot \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\cdot\frac{d}{\sqrt{L^2+d^2}}\hat{y}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2qd}{(L^2+d^2)^{3/2}}\hat{y}$$

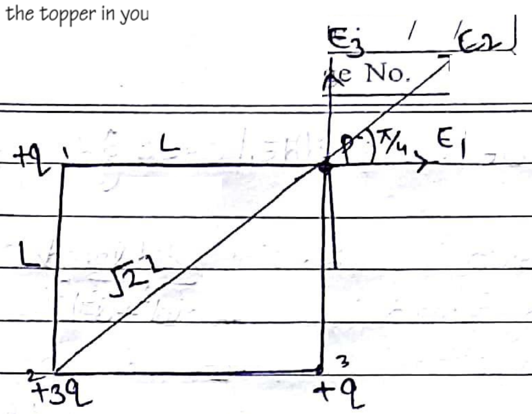
Ex -



$$\vec{E} = 2|E_1|\sin\theta\,\hat{x}$$

$$= 2 \cdot \frac{1}{4\pi\epsilon_0}\frac{q}{(\sqrt{L^2+d^2})^2}\frac{L}{(L^2+d^2)^{1/2}}\hat{x}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2qL}{(L^2+d^2)^{3/2}}\hat{x}$$



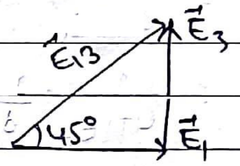
ex-

$$|\vec{E_1}| = \frac{1}{4\pi\epsilon_0}\frac{q}{L^2} = |\vec{E_3}|$$

$$|\vec{E_2}| = \frac{1}{4\pi\epsilon_0}\frac{3q}{2L^2}$$

$$\vec{E}' = |\vec{E_1}|\hat{x} + |\vec{E_3}|\hat{y}$$
$$= |\vec{E_1}|(\hat{x}+\hat{y})$$

$$\vec{E_2} = |E_2|\cos 45^\circ\,\hat{x} + |E_2|\sin 45^\circ\,\hat{y}$$
$$= \frac{|E_2|}{\sqrt{2}}(\hat{x}+\hat{y})$$



$$|\vec{E_{13}}| = \sqrt{E_1^2+E_3^2+2E_1E_3\cos 90^\circ}$$
$$= \sqrt{2}|E_1|$$

$$|\vec{E}| = |\vec{E_{13}}| + |\vec{E_2}|$$
$$= \frac{\sqrt{2}}{4\pi\epsilon_0}\frac{q}{L^2} + \frac{1}{4\pi\epsilon_0}\frac{3q}{2L^2}$$
$$\left(\frac{2\sqrt{2}+3}{2}\right)\cdot\frac{1}{4\pi\epsilon_0}\frac{q}{L^2}$$

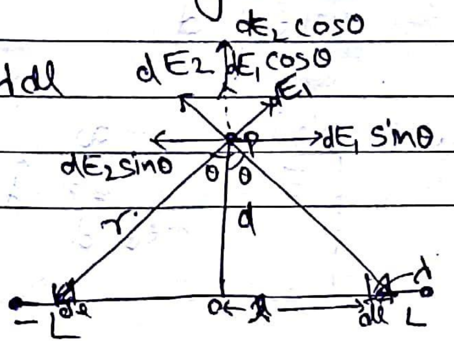
$$\vec{E} = \left(|\vec{E_1}| + \frac{|\vec{E_2}|}{\sqrt{2}}\right)\hat{x} + \left(|\vec{E_3}| + \frac{|\vec{E_2}|}{\sqrt{2}}\right)\hat{y}$$

Ex- Find the E.F. at a distance d above the mid point of a straight line sagment of length 2L which carries a uniform line charge λ.

Sol^n $q_{total} = \lambda 2L$

$dq = \lambda dl$

$$|d\vec{E_1}| = |d\vec{E_2}| = \frac{1}{4\pi\epsilon_0}\frac{\lambda\,dl}{r^2}$$



$$|d\vec{E}| = 2|dE_1|\cos\theta\,\hat{y}$$

$$= 2\cdot\frac{1}{4\pi\epsilon_0}\frac{\lambda\,dl\cdot d}{(d^2+l^2)^{3/2}}\,\hat{y}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\int_0^L \frac{2\lambda d}{(d^2+l^2)^{3/2}}\,dl$$

$$= \frac{1}{4\pi\epsilon_0}\cdot 2\lambda d\int_0 \frac{-d\sin\theta\,d\theta}{d^3\sin^3\theta}$$

$l = d\cos\theta$
$dl = -d\sin\theta\,d\theta$

$$= \frac{1}{4\pi\epsilon_0}\cdot\frac{2\lambda d}{d}\int -\mathrm{cosec}^2\theta\,d\theta$$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda d}{d}\left[\cot\theta\right]$$

$\frac{\cos\theta}{\sin\theta} = \frac{l}{d}$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda d}{d}\left(\frac{l}{\sqrt{d^2-l^2}}\right)_0^L$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\lambda d}{d}\frac{L}{\sqrt{d^2-L^2}}\,\hat{y}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\int \frac{2\lambda d\cdot d\sec^2\phi\,d\phi}{d^3\sec^3\phi}$$

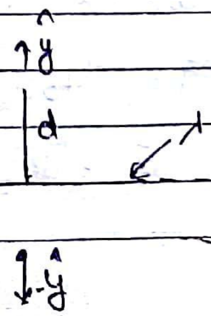
$l = d\tan\phi$
$dl = d\sec^2\phi\,d\phi$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{d}\int\cos\phi\,d\phi$$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{d}\left[\sin\phi\right]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{d}\left[\frac{l}{\sqrt{l^2+d^2}}\right]_0^L$$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{d}\left[\frac{L}{\sqrt{L^2+d^2}}\right]\hat{y}$$

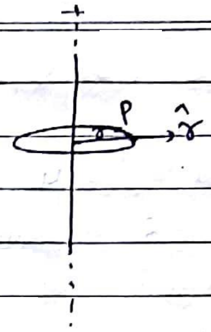


Infinite wire $L\to\infty$

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{d}\hat{y} = \frac{\lambda}{2\pi\epsilon_0 d}\hat{y}}$$

A wire has cylendrical symmtri

$$\boxed{\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}\hat{r}}$$

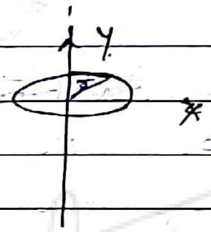


Ex- An infinite wire whose charge per unit length is 10nC/m displaced along z-axis. Find the E.F. at point P co-ordinates are (6, 8, 12) in meter.

Solⁿ

$$\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}\hat{r}$$

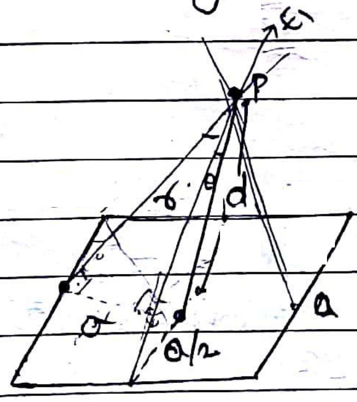
$$= \cancel{\frac{2\times10\times10^{-9}\times9\times10^{9}}{8}}$$



$$= \frac{2\times10\times10^{-9}\times9\times10^{9}}{\sqrt{6^2+8^2}}$$

$$= \frac{18\times10\hat{r}}{10} = \underline{18\hat{r}\ \text{V/m}}$$

Ex- Find the E.F. a distance d above the center of a ~~circu~~ square loop ~~out~~ of side a carry a uniform line charge λ.



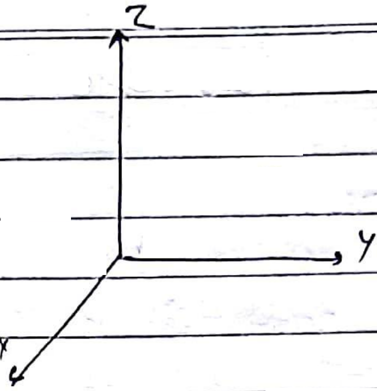
$$E = 4|\vec{E}_1|\cos\theta \qquad (2L=a)$$

$$|\vec{E}_1| = \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{r}\left[\frac{a}{\sqrt{a^2+r^2}}\right]$$

$$= \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{\sqrt{d^2+a^2/4}}\left(\frac{a/2}{\sqrt{d^2+a^2/2}}\right)$$

$$|\vec{E}_1| = |\vec{E}_2| = |\vec{E}_3| = |\vec{E}_4|$$

$$\vec{E} = 4|\vec{E}_1|\cos\theta\,\hat{z}$$

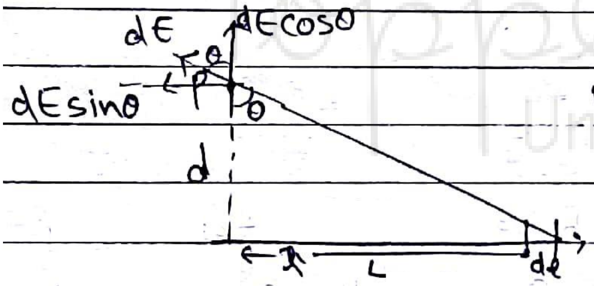


$$= 4\cdot\frac{1}{4\pi\epsilon_0}\frac{\lambda a}{\sqrt{a^2/4+d^2}\,\sqrt{a^2/2+d^2}}\cos\theta\,\hat{z}$$

$$= 4\cdot\frac{1}{4\pi\epsilon_0}\frac{\lambda a}{\sqrt{a^2/4+d^2}\,\sqrt{a^2/2+d^2}}\cdot\frac{d}{\sqrt{d^2+a^2/4}}\,\hat{z}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{4\lambda a d}{(a^2/4+d^2)\sqrt{a^2/4+d^2}}\,\hat{z}$$

Q. Find the E.F at a distance d above the one end of ~~state~~ is stright line segment of length L which carries a uniform line charge λ.



$$|d\vec{E}| = \frac{1}{4\pi\epsilon_0}\frac{\lambda\,dl}{(\sqrt{d^2+l^2})^2}$$

$$\vec{E} = |E|\cos\theta\,\hat{j} - |E|\sin\theta\,\hat{i}$$

$$E_x = dE\sin\theta$$

$$= \int_0^L \frac{1}{4\pi\epsilon_0}\frac{\lambda\,dl}{(\sqrt{d^2+l^2})^2}\cdot\frac{l}{\sqrt{d^2+l^2}}$$

$$= \frac{1}{4\pi\epsilon_0}\lambda\int_0^L \frac{l\,dl}{(d^2+l^2)^{3/2}}$$

$$d^2+l^2 = t^2$$
$$2l\,dl = 2t\,dt$$

$$= \frac{1}{4\pi\epsilon_0}\lambda\int\frac{t\,dt}{t^3}$$

$$= \frac{1}{4\pi\epsilon_0}\lambda\left(-\frac{1}{t}\right) = \frac{-\lambda}{4\pi\epsilon_0}\left(\frac{1}{\sqrt{d^2+l^2}}\right)_0^L$$

$$= \frac{\lambda}{4\pi\epsilon_0}\left(\frac{1}{d} - \frac{1}{\sqrt{d^2+L^2}}\right)$$

$$E_y = dE\cos\theta$$

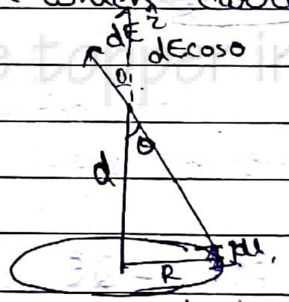
$$= \int_0^L \frac{1}{4\pi\epsilon_0}\frac{\lambda\, dl}{(d^2+l^2)}\frac{d}{\sqrt{d^2+l^2}}$$

$$= \int_0^L \frac{1}{4\pi\epsilon_0}\frac{\lambda d}{(d^2+l^2)^{3/2}}\, dl. \qquad l = d\tan\phi \quad dl = d\sec^2\phi\, d\phi$$

$$= \frac{1}{4\pi\epsilon_0}\frac{\lambda}{d}\left(\frac{L}{\sqrt{L^2+d^2}}\right)$$

$$\vec{E} = \frac{-\lambda}{4\pi\epsilon_0}\left(\frac{1}{d} - \frac{1}{\sqrt{d^2+L^2}}\right)\hat{x} + \frac{1}{4\pi\epsilon_0}\frac{\lambda}{d}\frac{L}{\sqrt{L^2+d^2}}\hat{y}$$

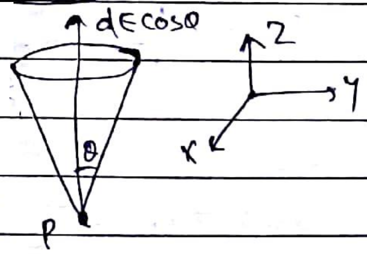
ex- Find the electric field at a distance d above the center of circular loop of radius R which carries a uniform line charge λ



(a)

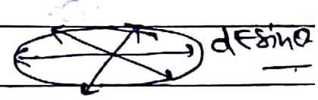
$$q_{ring} = \lambda \times 2\pi R$$

$$\vec{E} = \int_0^{2\pi R} dE\cos\theta\,\hat{z}$$



$$= \frac{1}{4\pi\epsilon_0}\int_0^{2\pi R}\frac{\lambda\, dl}{(\sqrt{R^2+d^2})^2}\frac{d}{\sqrt{R^2+d^2}}\,\hat{z}$$

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{\lambda d}{(R^2+d^2)^{3/2}} \cdot 2\pi R\,\hat{z}}$$



$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q_{ring}\, d}{(R^2+d^2)^{3/2}}\,\hat{z}}$$

At the center of the ring E.F. − $\boxed{\vec{E} = 0}$

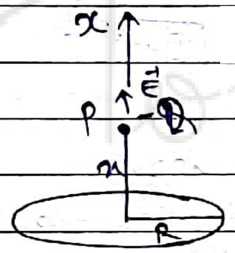
(b) A test charge $-Q$ is placed at point p such that $d << R$. Show that test charge will perform simple harmonic motion about the center of the ring. Also find the frequency of oscillation.

Sol

$$F = -kx$$

$$m\frac{d^2x}{dt^2} + kx = 0$$

$$\frac{d^2x}{dt^2} + \omega^2 x = 0 \qquad \omega = \sqrt{k/m}$$



$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{\lambda x \times 2\pi R}{(R^2+x^2)^{3/2}} \hat{x}$$

$$\vec{E} \approx \frac{1}{4\pi\epsilon_0} \frac{\lambda x \times 2\pi R}{R^3} \hat{x}$$

$$\approx \frac{\lambda x}{2R^2\epsilon_0}$$

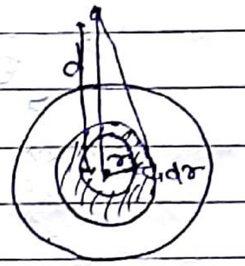
$$F = -QE$$

$$= -\frac{Q\lambda x}{2R^2\epsilon_0} = -kx$$

$$k = \frac{Q\lambda}{2\epsilon_0 R^2}$$

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{Q\lambda}{2m\epsilon_0 R^2}}$$

Q. Find the E.F. at a distance d above the center of flat circular disc of radius R which carries a uniform surface charge σ.



$$\sigma\, da = \lambda \cdot dl$$

$$\sigma (2\pi r) dr = \lambda \cdot 2\pi r$$

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{\lambda d\, 2\pi r}{(r^2+d^2)^{3/2}} \hat{z}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int_0^R \frac{\sigma (2\pi r) dr \cdot d}{(r^2+d^2)^{3/2}} \hat{z}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \sigma (2\pi) d \int \frac{r\, dr}{(r^2+d^2)^{3/2}} \hat{z}$$

$$= \frac{1}{4\pi\epsilon_0} \sigma (2\pi) d \int \frac{t\, dt}{t^3} \hat{z} \qquad r^2+d^2 = t^2, \quad 2r\,dr = 2t\,dt$$

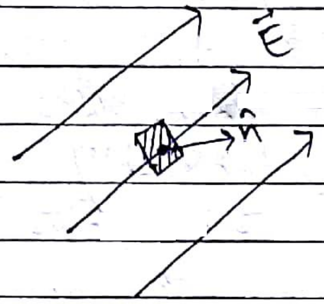
$$= \frac{1}{4\pi\epsilon_0} \sigma \cdot 2\pi d \left[\frac{-1}{t}\right] \hat{z}$$

$$= \frac{1}{4\pi\epsilon_0} \sigma\, 2\pi d \left[\frac{-1}{\sqrt{r^2+d^2}}\right]_0^R \hat{z}$$

$$\vec{E}_{disc} = \frac{\sigma d}{2\epsilon_0} \left[\frac{1}{d} - \frac{1}{\sqrt{R^2+d^2}}\right] \hat{z}$$

Gauss law & its Applications:

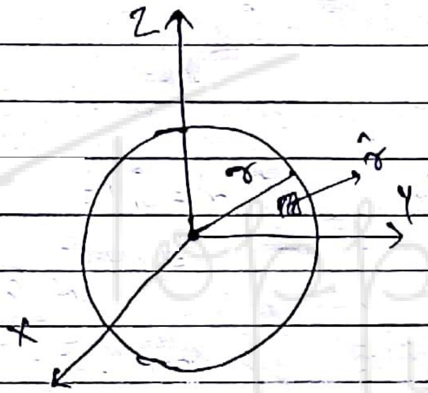
Electric flux (ϕ_E)



$$\phi_E = \int_S \vec{E} \cdot d\vec{a}$$

Flux through close surface -

$$\boxed{\phi_E = \oint_S \vec{E} \cdot d\vec{a}}$$



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

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

$$= \int_0^{\pi}\int_0^{2\pi} \left(\frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}\right)\left(r^2 \sin\theta \, d\theta \, d\phi\right)$$

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

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

$$\boxed{\oint_S \vec{E} \cdot d\vec{a} = \frac{q}{\epsilon_0}}$$

Flux through close surface depends on charge inside the surface.

$$\boxed{\oint \vec{E} \cdot d\vec{a} = \frac{Q_{enc}}{\epsilon_0}}$$

Q_{enc} - total charge enclosed

This is valid for all the surfaces ~~wether~~ whether symmetrical or unsymmtrical but it is useful symmtrical surfaces only.

- Spherical Symmetry
- Cylenderical symmetry
- planner Symmetry.

- Using integral form we can find electric field if symmtrical charge distribution is given.
- if electric field given we can use diffential form of Gauss law. to find charge distribution

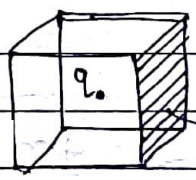
Differential Form of Gauss law :-

$$\oint_S \vec{E}\cdot d\vec{a} = \frac{Q_{enc}}{\epsilon_0}$$

$$\int_V (\vec{\nabla}\cdot\vec{E})\, d\tau = \frac{1}{\epsilon_0}\int \rho\, d\tau$$

$$\boxed{\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\epsilon_0}}$$

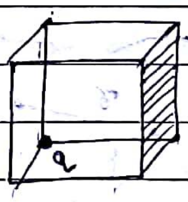
Ex A charge q is placed at the center of cube.

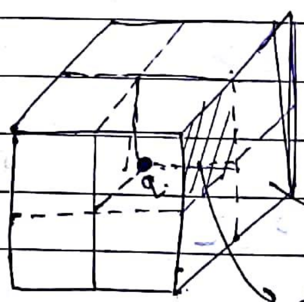


$$\phi_{total} = q/\epsilon_0$$

$$\phi = \frac{q}{6\epsilon_0}$$

Ex -



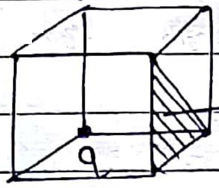


$$\phi_{total} = q/\epsilon_0$$

through one surface

$$\phi = \tfrac{1}{6}\, q/\epsilon_0$$

$$\phi = \tfrac{1}{4}\times\tfrac{1}{6}\, q/\epsilon_0$$

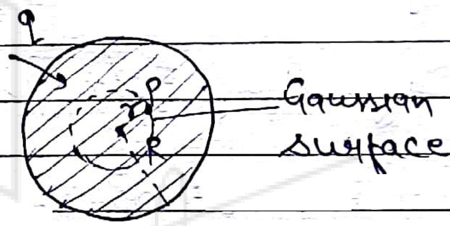


$$\phi = \frac{1}{2}\cdot\frac{q}{24\epsilon_0} = \frac{q}{48\epsilon_0}$$

1. Spherical Symmetry :-

Q. Find the E.F. inside and outside are uniformly charged solid sphere of radius R and total charge q.

Sol^n $\rho = \dfrac{q}{\frac{4}{3}\pi R^3}$



$$\oint_S \vec{E}\cdot d\vec{a} = \frac{q_{enc}}{\epsilon_0}$$

r<R →

$$\vec{E}\cdot 4\pi r^2 = \int_0^{\pi}\int_0^{2\pi} |\vec{E}|\hat{r}\cdot(r^2\sin\theta\, d\theta\, d\phi\, \hat{r}) = \frac{1}{\epsilon_0}\int \rho\, d\tau$$

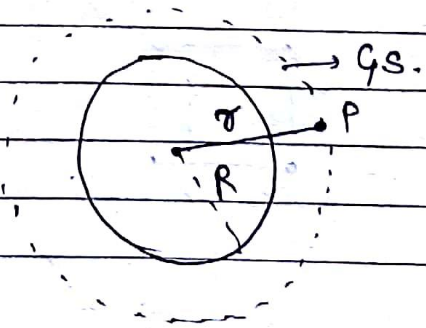
$$= |\vec{E}|\times 4\pi r^2 = \frac{1}{\epsilon_0}\rho\int_0^{r}\int_0^{\pi}\int_0^{2\pi} r^2\sin\theta\, dr\, d\theta\, d\phi$$

$$= \frac{1}{\epsilon_0}\rho\cdot\frac{4}{3}\pi r^3$$

$$|\vec{E}| = \frac{\rho r}{3\epsilon_0}$$

$$\boxed{\vec{E} = \frac{\rho r}{3\epsilon_0}\hat{r}} \qquad \boxed{\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q r}{R^3}\hat{r}}$$

ii) r>R



$$\oint_S \vec{E}\cdot d\vec{a} = \frac{q_{enc}}{\epsilon_0}$$

$$|\vec{E}|\, 4\pi r^2 = \frac{1}{\epsilon_0}\int \rho\, d\tau$$

$$|\vec{E}|\cdot 4\pi r^2 = \frac{1}{\epsilon_0}\rho \int_0^R\int_0^\pi\int_0^{2\pi} r^2 \sin\theta\, dr\, d\theta\, d\phi$$

$$= \frac{1}{\epsilon_0}\rho\, \frac{4}{3}\pi R^3$$

$$|\vec{E}| = \frac{\rho R^3}{3\epsilon_0 r^2} \Rightarrow \boxed{\vec{E} = \frac{\rho R^3}{3\epsilon_0 r^2}\hat{r}}$$

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

ex- Find the E.F inside & outside are known uniformly charge solid sphere of radius R and charge density $\rho = kr$

Sol^n $r<R$

$$\oint_S \vec{E}\cdot d\vec{a} = \frac{1}{\epsilon_0}\int \rho\, d\tau$$

$$|\vec{E}|\cdot 4\pi r^2 = \frac{1}{\epsilon_0}\int_V k r r^2 \sin\theta\, dr\, d\theta\, d\phi$$

$$= \frac{1}{\epsilon_0} k\cdot 4\pi\cdot \frac{r^4}{4}\Big|_0^r$$

$$\boxed{\vec{E} = \frac{kr^2}{4\epsilon_0}\hat{r}}$$

$r>R$

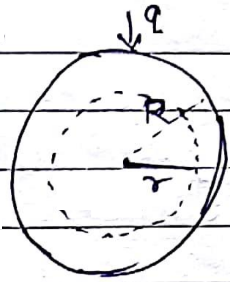
$$\oint_S \vec{E}\cdot d\vec{a} = \frac{1}{\epsilon_0}\int \rho\, d\tau$$

$$|\vec{E}|\cdot 4\pi r^2 = \frac{1}{\epsilon_0}\int_0^R\int_0^\pi\int_0^{2\pi} k r r^2 \sin\theta\, dr\, d\theta\, d\phi$$

$$|\vec{E}|\cdot 4\pi r^2 = \frac{4\pi k R^4}{4\epsilon_0}$$

$$\boxed{\vec{E} = \frac{kR^4}{4r^2\epsilon_0}\hat{r}}$$

Ex- Thin Spherical Shell -



$r < R$ $\qquad Q_{enc} = 0$

$$\oint \vec{E} \cdot d\vec{a} = \frac{Q}{\epsilon_0}$$

$$|\vec{E}| \cdot 4\pi r^2 = 0$$

$$\boxed{\vec{E} = 0}$$

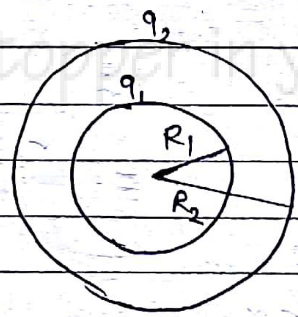
$r > R$

$$\oint \vec{E} \cdot d\vec{a} = \frac{Q_{enc.}}{\epsilon_0}$$

$$|\vec{E}| \cdot 4\pi r^2 = q/\epsilon_0$$

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

Ex- Concentric spherical shell :-



$r < R_1$ $\qquad Q_{enc} = 0$

$$|\vec{E}| \cdot 4\pi r^2 = \frac{Q_{enc}}{\epsilon_0}$$

$$\vec{E} = 0$$

$R_1 < r < R_2$

$$|\vec{E}| \cdot 4\pi r^2 = \frac{Q_{enc}}{\epsilon_0}$$

$$\vec{E} = \frac{q_1}{4\pi\epsilon_0 r^2}\hat{r}$$

$r > R_2$

$$|\vec{E}| \cdot 4\pi r^2 = \frac{Q_{enc}}{\epsilon_0} = \frac{q_1 + q_2}{\epsilon_0} \Rightarrow \boxed{\vec{E} = \frac{(q_1 + q_2)}{4\pi\epsilon_0 r^2}\hat{r}}$$