$\boxed{11 - 08 - 22}$

Q. A Non-uniform surface charge density of $\frac{1}{x^2+y^2+4}\frac{nc}{m^2}$ which is defined for $\rho \leq 2.5$ m, $z = 5$ m. Find total charge.

Soln: $Q = \iint \rho_s \, dA \quad \underline{\underline{nc}}$

$\frac{nc}{m^2} \times m^2$

(ρ, ϕ, z)

$1, \rho, 1$

$\overline{dA} = \rho d\rho d\phi \hat{z} + \underbrace{\rho d\phi dz}_{0} \hat{\rho} + \underbrace{dz d\rho}_{0} \hat{\phi}$

$z = 5m, \; dz = 0, \; \overline{dA} = \rho d\rho d\phi \hat{z}$

$dA = \rho d\rho \, d\phi$

we know

$x = \rho \cos\phi$

$y = \rho \sin\phi$

$x^2 + y^2 = \rho^2$

$\rho_s = \frac{1}{\rho^2+4} \, nc/m^2$

$Q = \iint \frac{1}{\rho^2+4} \rho d\rho d\phi$

$Q = \frac{1}{2}\int \frac{2\rho}{\rho^2+4} d\rho \int d\phi$

$Q = \frac{1}{2}\left[\ln(\rho^2+4)\right]_0^{2.5}\left[\phi\right]_0^{2\pi}$

$= \frac{1}{2}\{\ln(2.5^2+4) - \ln(4)\} \times 2\pi$

$= \pi\{\ln(2.5^2+4) - \ln(4)\}$

$Q = \underline{2.95}\, nc.$

Q. Given $\rho_l = 2x + 3y - 4z$ c/m the charge on the line segment extending from (2, 1, 5) to (4, 3, 6) is ________

(a) 10 C

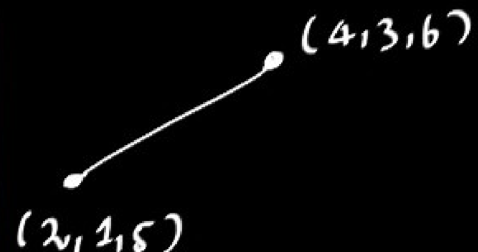
(b) –10 C

(c) 30

(d) –30 C

Soln:

$$Q = \int \rho_l \, dl$$



$$\frac{x-2}{4-2} = \frac{y-1}{3-1} = \frac{z-5}{6-5} = t$$

$$\boxed{0 \le t \le 1}$$

$$x = 2t + 2 \Rightarrow \frac{dx}{dt} = 2$$

$$y = 2t + 1 \Rightarrow \frac{dy}{dt} = 2$$

$$z = t + 5 \Rightarrow \frac{dz}{dt} = 1.$$

$$\rho_l = 2(2t+2) + 3(2t+1) - 4(t+5)$$

$$\rho_l = 6t - 13 \text{ c/m.}$$

$$d\bar{l} = dx\,\hat{x} + dy\,\hat{y} + dz\,\hat{z}$$

$$d\bar{l} = \frac{dx}{dt}dt\,\hat{x} + \frac{dy}{dt}dt\,\hat{y} + \frac{dz}{dt}dt\,\hat{z}$$

$$\overline{dl} = 2dt\,\hat{x} + 2dt\,\hat{y} + dt\,\hat{z}$$

$$dl = \sqrt{(2dt)^2 + (2dt)^2 + (dt)^2}$$

$$dl = 3dt$$

$$Q = \int \rho_l\,dl = \int (6t - 13)\,3dt$$

$$= 3\left[\frac{6t^2}{2} - 13t\right]_0^1$$

$$= 3\left[3 \times 1^2 - 13 \times 1\right]$$

$$= 3[-10] = -30$$

$$Q = -30C$$

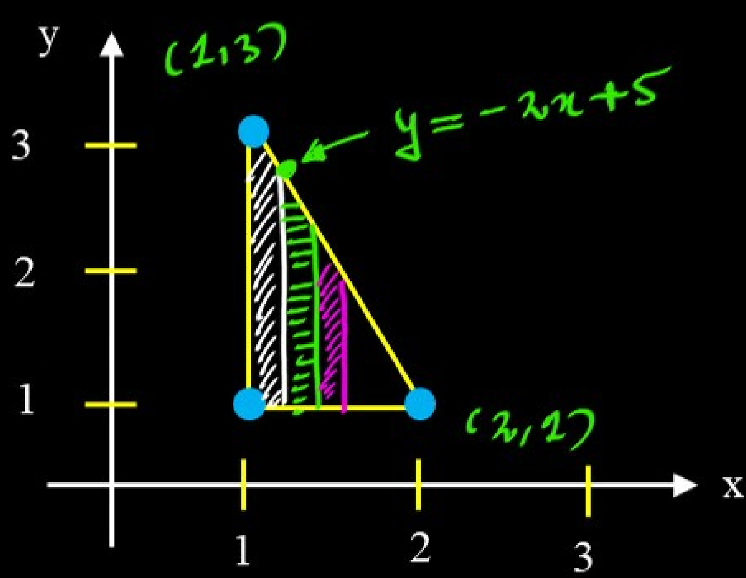
Q. The total charge on the triangle of figure, given surface charge density $\rho_s = 6xy$ c/m² is ___________

$$\frac{x-1}{2-1} = \frac{y-3}{1-3}$$

$$(x-1)(-2) = y-3$$

$$-2x + 2 = y-3$$

$$y = -2x+5$$



Soln:

$$Q = \iint \rho_s \, dA$$

$$Q = \iint 6xy \, dx\,dy$$

$$Q = 6\int_{x=1}^{2}\int_{y=1}^{-2x+5} xy \, dy\,dx$$

$$= 6\int_{x=1}^{2} x\left[\frac{y^2}{2}\right]_1^{-2x+5} dx$$

$$= 3 \int x \left\{ (-2x+5)^2 - 1^2 \right\} dx$$

$$= 3 \int x \left[4x^2 + 25 - 20x - 1 \right] dx$$

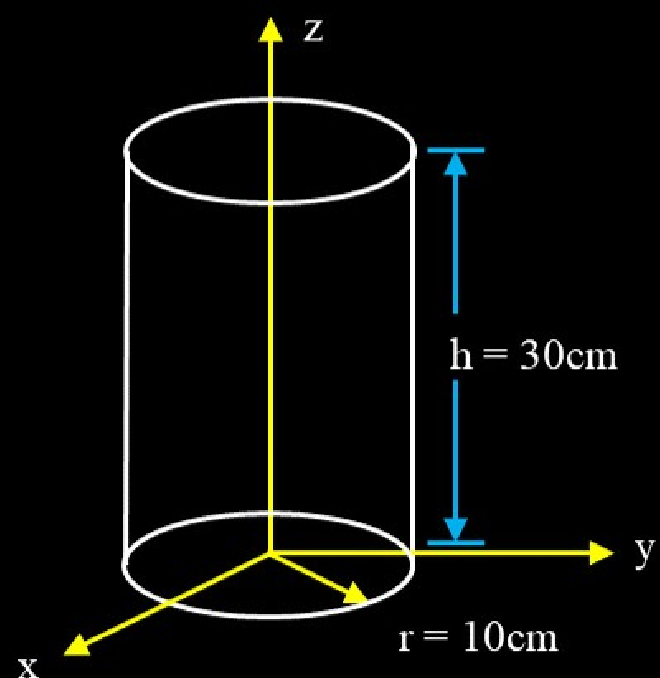
$$= 3 \int \left[4x^3 - 20x^2 + 24x \right] dx$$

$$= 3 \left[\cancel{4} \frac{x^4}{\cancel{4}} - 20 \frac{x^3}{3} + \overset{12}{\cancel{24}} \frac{x^2}{\cancel{2}} \right]_1^2$$

$$= 3 \left\{ \left(2^4 - 20 \times \frac{2^3}{3} + 12 \times 2^2 \right) - \left(1^4 - 20 \times \frac{1^3}{3} + 12 \times 1^2 \right) \right\}$$

$$= 3 \left[16 - \frac{160}{3} + 48 - 1 + \frac{20}{3} - 12 \right] = \underline{13\ C}$$

Q. If the volume charge density is $\rho = 100\, e^{-z}\,(x^2 + y^2)^{-1/4}$ c/m^3, the total charge contained in the cylindrical shown in the figure is ______



Soln:

$$Q = \iiint \rho_v \, dv.$$

$$\rho^2 = x^2 + y^2$$

$$\rho_v = 100\, e^{-z} (\rho^2)^{-1/4}$$

$$\rho_v = 100\, e^{-z} \rho^{-1/2} \text{ c/m}^3.$$

$$Q = \iiint 100 e^{-z} \rho^{-1/2} \cdot \rho \, d\rho \, d\phi \, dz.$$

$$Q = 100 \iiint \rho^{1/2} e^{-z} \, d\rho \, d\phi \, dz$$

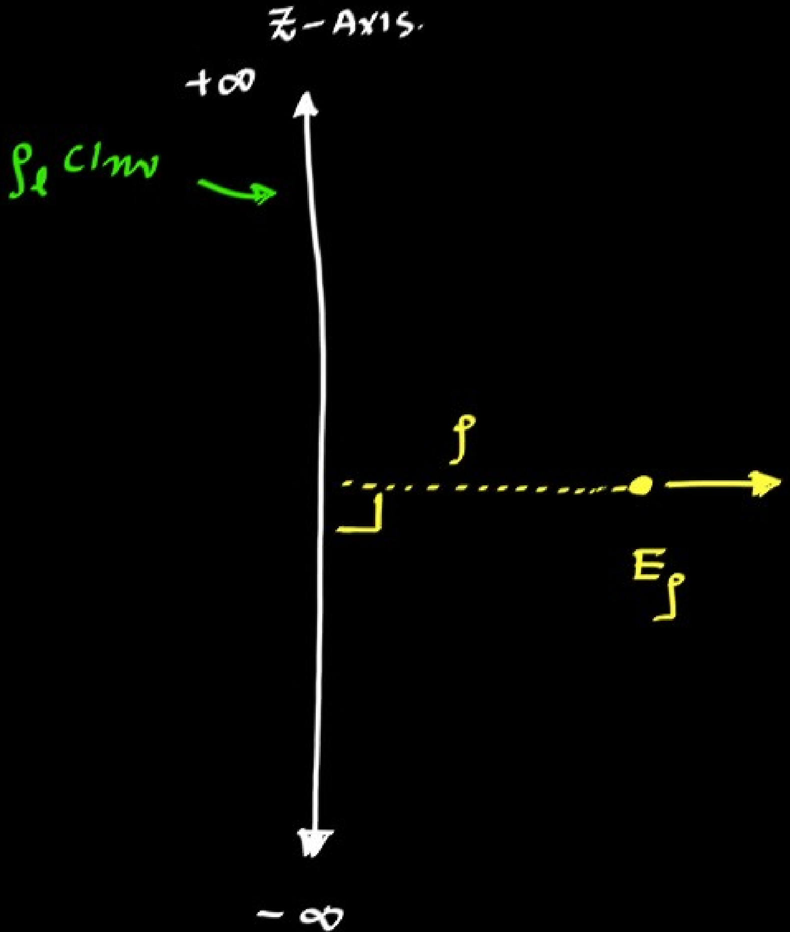
$$= 100 \int \rho^{1/2} d\rho \int d\phi \int e^{-z} dz$$

$$= 100 \left[\frac{\rho^{3/2}}{3/2}\right]_0^{0.1\,m} \left[\phi\right]_0^{2\pi} \left[-e^{-z}\right]_0^{0.3\,m}$$

$$= \frac{100 \times 2}{3} \left[(0.1)^{3/2}\right] \left[2\pi\right] \left\{-\left(e^{-0.3} - 1\right)\right\}$$

$$Q = \underline{\underline{3.433}} \; C$$

Electric Field Due to Infinite Uniform line Charge (ρ_l c/m)



$$\bar{E} = \int \frac{\rho_l \, dl}{4\pi\epsilon R^2} \hat{r}$$

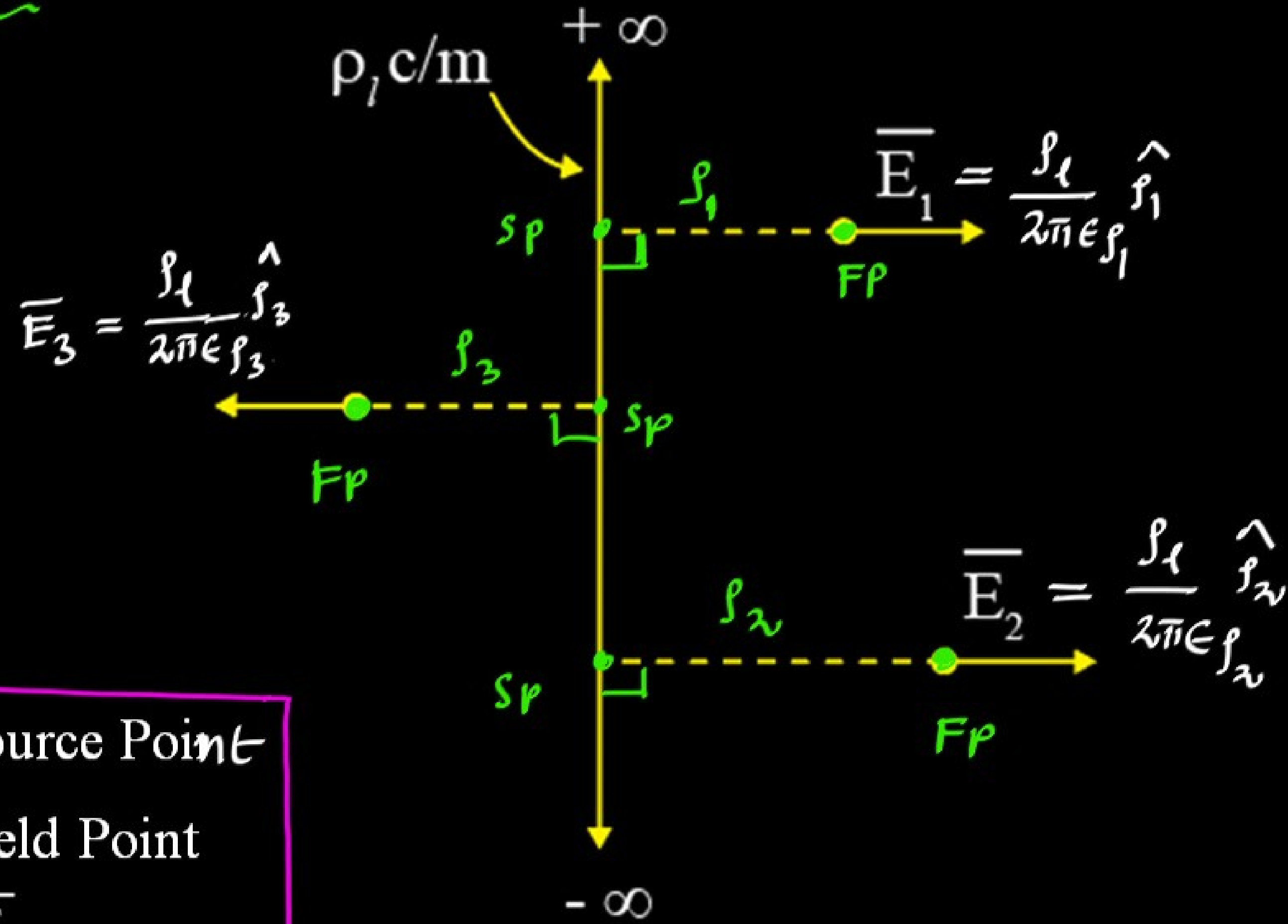
$$\Downarrow$$

$$\boxed{\bar{E} = \frac{\rho_l}{2\pi\epsilon\rho} \hat{\rho}}$$

$\perp^{le}$ DISTANCE

RADIAL DIRECTION

Example

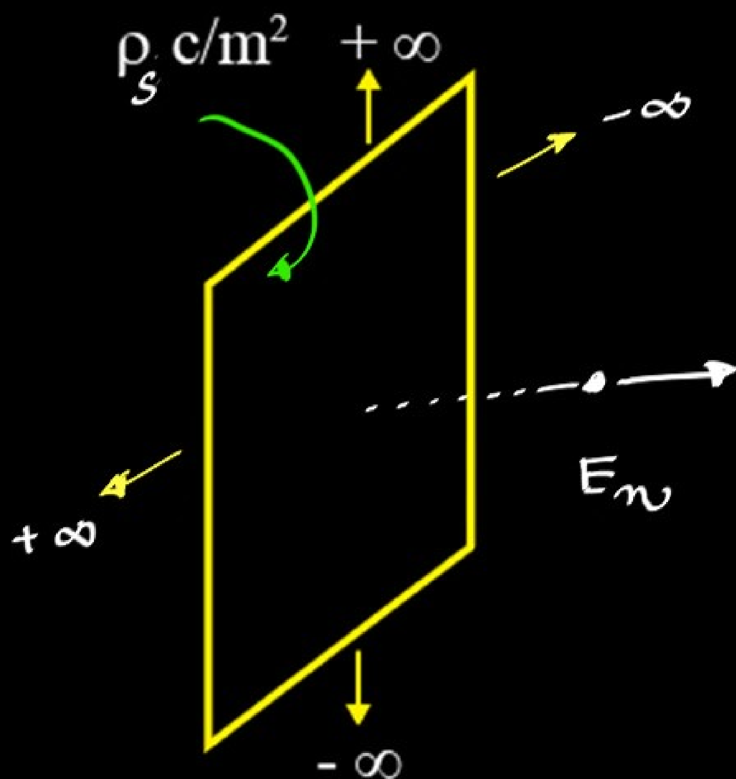


SP: Source Point

FP: Field Point

$$\text{SP} : \xrightarrow[\overline{\rho}]{\overline{E}} : \text{FP}$$

Electric field due to Infinite Uniform Sheet Charge (ρ_s c/m^2)



$$\bar{E} = \iint \frac{\rho_s\, dA}{4\pi\epsilon R^2}\,\hat{r}$$

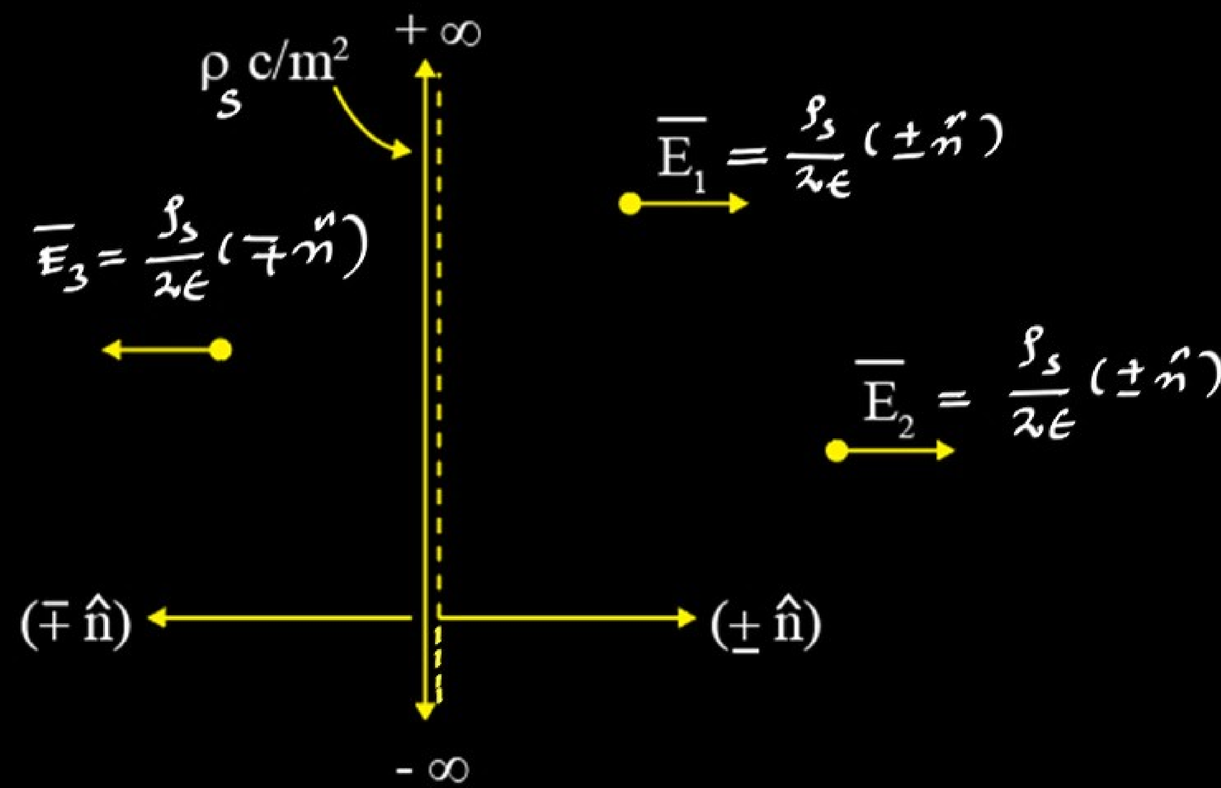
$$\Downarrow$$

$$\boxed{\bar{E} = \frac{\rho_s}{2\epsilon}(\pm\hat{n})}$$

INDEPENDENT OF DISTANCE

NORMAL DIRECTION.

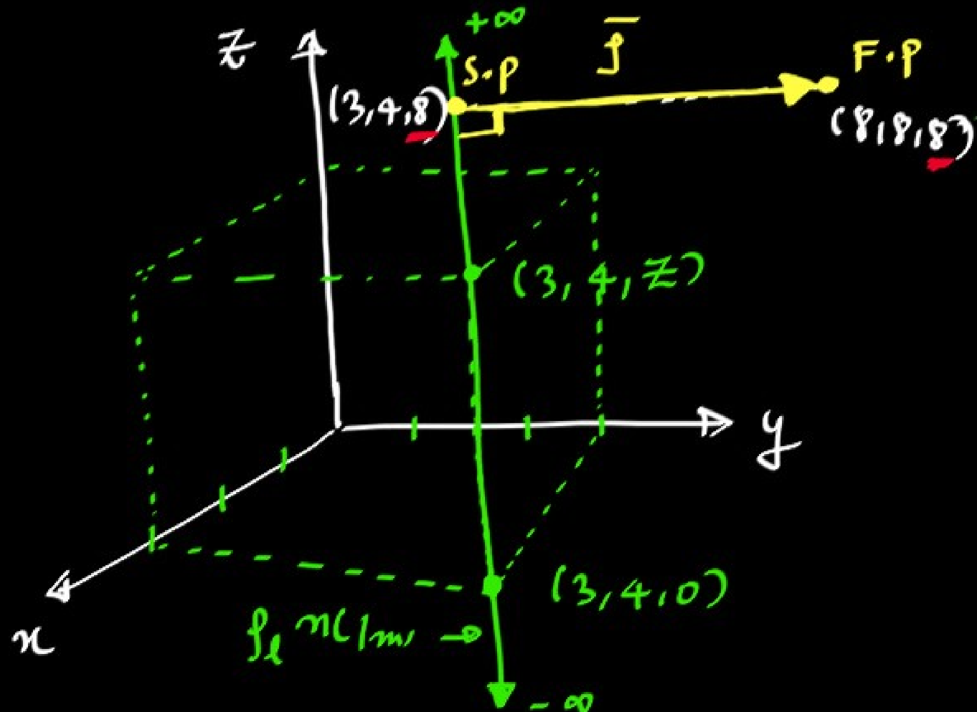
Example



Q. Infinite uniform line charge of 10nc/m is located at x=3m, y=4m, and parallel to z-axis. Find electric field due to this infinite line at following points

(a) (0,0,0) (b) (4,5,6) (c) (8,8,8)

Soln:



$$\bar{E} = \frac{\rho_l}{2\pi\epsilon\rho}\hat{\rho}, \quad \hat{\rho} = \frac{\bar{\rho}}{\rho}$$

$$\bar{E} = \frac{\rho_l}{2\pi\epsilon_0}\left[\frac{\bar{\rho}}{\rho^2}\right]$$

(a) $Sp(3,4,z) \longrightarrow Fp(0,0,0)$, $\bar{\rho}_1$, $z = 0$ (4)

$$\bar{E}_1 = \frac{\rho_l}{2\pi\epsilon_0}\left[\frac{\bar{\rho}_1}{\rho_1^2}\right]$$

$$= \frac{10\times10^{-9}}{2\pi\times\frac{1}{36\pi\times10^9}}\left[\frac{-3\hat{x}-4\hat{y}}{(\sqrt{9+16})^2}\right]$$

$$= \frac{180}{25}\left[-3\hat{x}-4\hat{y}\right]$$

$$\bar{E}_1 = -21.6\,\hat{x} - 28.8\,\hat{y}$$

(b) $Sp(3,4,z) \longrightarrow Fp(4,5,6)$, $\bar{\rho}_2$, $z = 6$ (4)

$$\bar{E}_2 = \frac{\rho_l}{2\pi\epsilon_0}\left[\frac{\bar{\rho}_2}{\rho_2^2}\right]$$

$$\bar{E}_2 = \frac{10\times10^{-9}}{2\pi\times\frac{1}{36\pi\times10^9}}\left[\frac{\hat{x}+\hat{y}}{(\sqrt{1^2+1^2})^2}\right]$$

$$\bar{E}_2 = \frac{180}{2}\left[\hat{x}+\hat{y}\right]$$

$$\bar{E}_2 = 90\,\hat{x} + 90\,\hat{y}$$

(c) $S.P(3, 4, z) \xrightarrow[\bar{\rho}_3]{} F.P(8, 8, 8)$

$z = 8$

$$\bar{E}_3 = \frac{\rho_l}{2\pi\epsilon_0}\left[\frac{\bar{\rho}_3}{\rho_3^2}\right]$$

Q An Infinity long uniform charge of density 30nC/m is located at y=3m, z=5m. The field intensity at (0,6,2) is $\bar{E} = 64.7\hat{y} - 86.3\hat{z}$ V/m, What is the field intensity at (5,6,2)?

(ESE – 04)

(a) $\bar{E}$

(b) $\left[\frac{6^2+1^2}{6^2+5^2+1^2}\right]^{1/2} \bar{E}$

(c) $\left[\frac{6^2+1^2}{6^2+5^2+1^2}\right] \bar{E}$

(d) $\left[\frac{6^2+5^2+1^2}{6^2+1^2}\right]^{1/2} \bar{E}$

ESE - EC

PRELIMS

* ELECTROSTATICS
* MAGNETOSTATICS

(CONNECT FOR PRACTICE)

Soln:

$SP(x, 3, 5) \xrightarrow{\bar{\rho}_1} FP(0, 6, 2)$

$x = 0$

$$\bar{E}_1 = \left[\frac{\rho_l}{2\pi\epsilon_0}\right]\left[\frac{\bar{\rho}_1}{\rho_1^2}\right] = \bar{E}$$

$$\bar{\rho}_1 = 3\hat{y} - 3\hat{z}$$

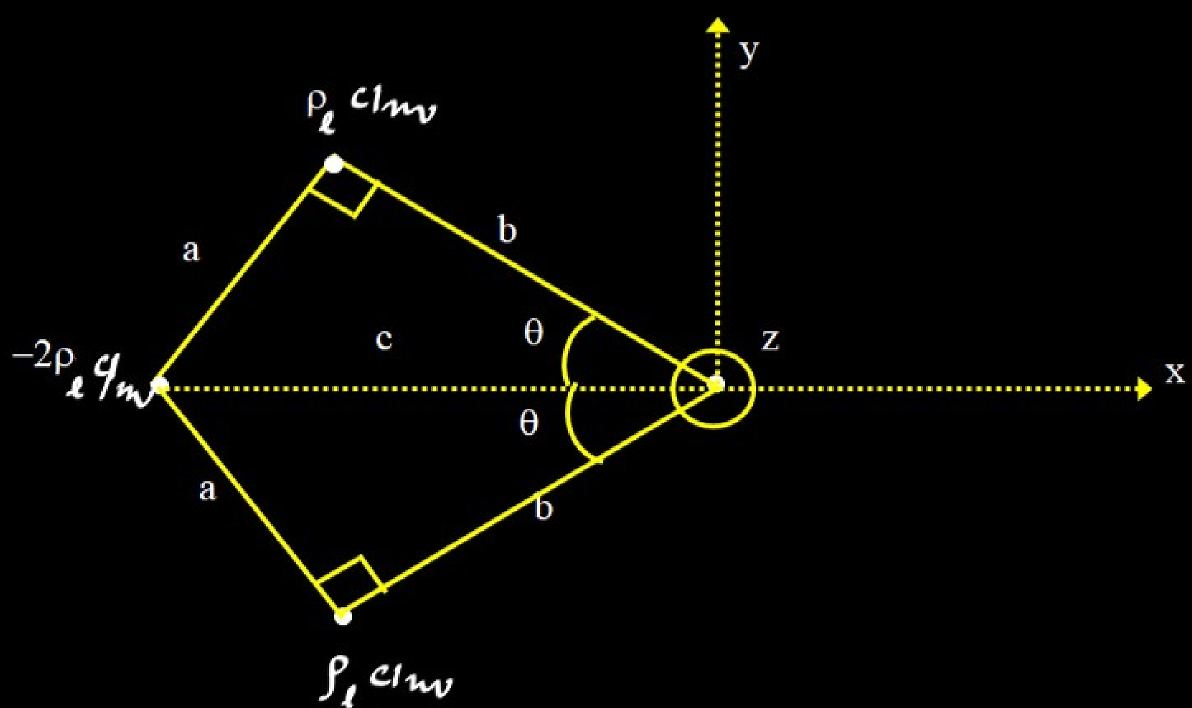
$SP(x, 3, 5) \xrightarrow{\bar{\rho}_2} FP(5, 6, 2)$

$x = 5$

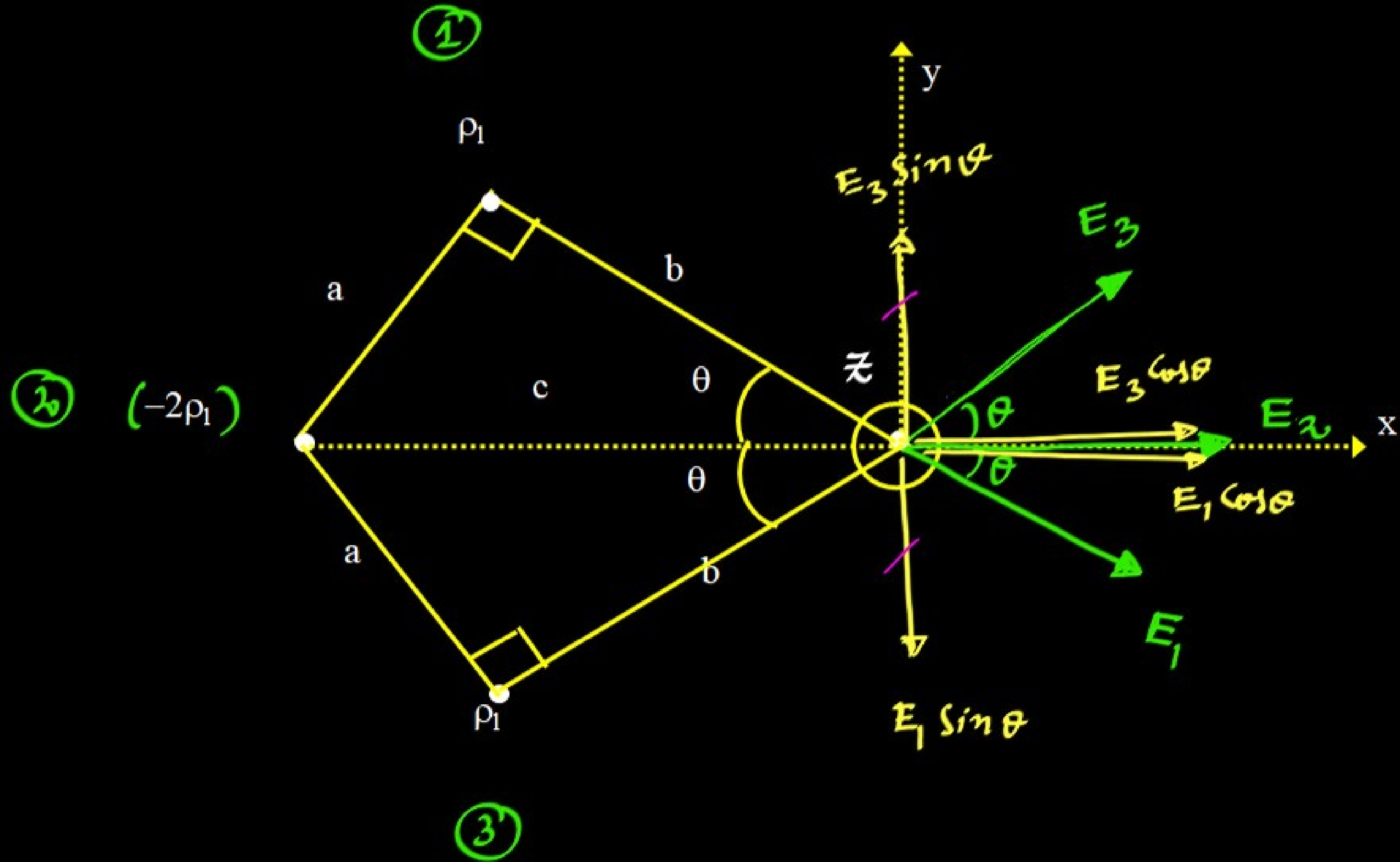
$$\bar{E}_2 = \left[\frac{\rho_l}{2\pi\epsilon_0}\right]\left[\frac{\bar{\rho}_2}{\rho_2^2}\right] = \bar{E}_1 = \bar{E}$$

$$\bar{\rho}_2 = 3\hat{y} - 3\hat{z} = \bar{\rho}_1$$

Q. Figure shows "KITE" shape in the xy-plane having line charges parallel to the z-axis through three of it's corners. Find electric field at the fourth corner



Solution:



1
y
ρ_1
$E_3 \sin\theta$
E_3
b
a
z
$E_3 \cos\theta$
2
$(-2\rho_1)$
c
θ
θ
E_2
x
θ
θ
$E_1 \cos\theta$
a
b
E_1
ρ_1
$E_1 \sin\theta$
3

$$\bar{E}_T = E_1 \cos\theta\, \hat{x} + E_3 \cos\theta\, \hat{x} + E_2\, \hat{x} = 2E_1 \cos\theta\, \hat{x} + E_2\, \hat{x}$$

$$E_1 = E_3 = \frac{\rho_l}{2\pi\epsilon(b)}$$

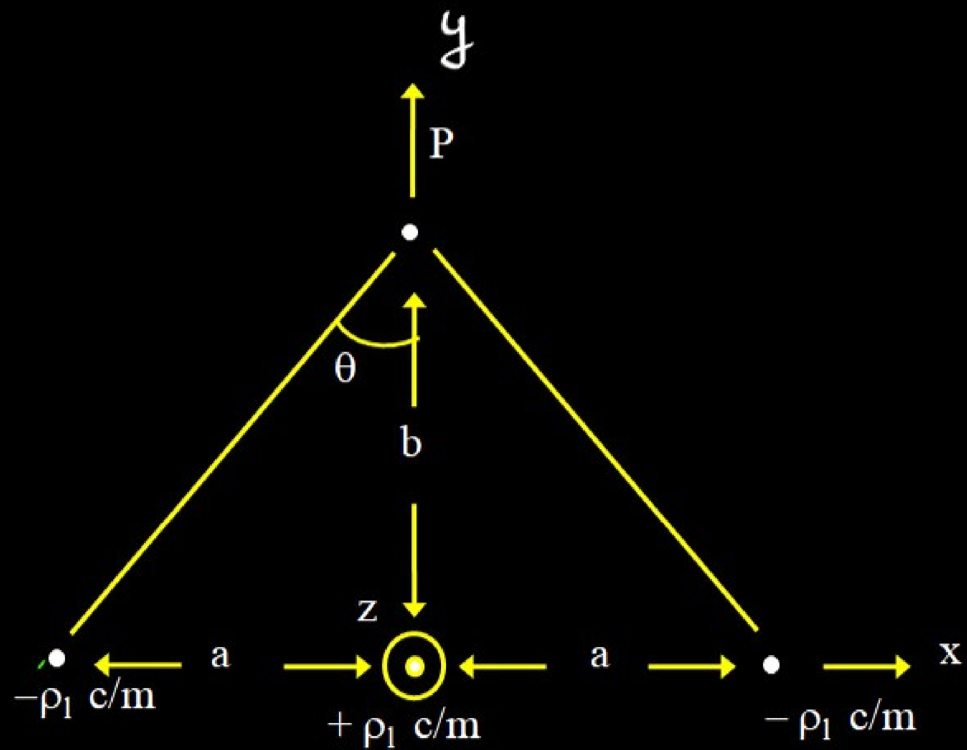
$$E_2 = \frac{(-2\rho_l)}{2\pi\epsilon(c)}$$

$$\cos\theta = \frac{b}{c}$$

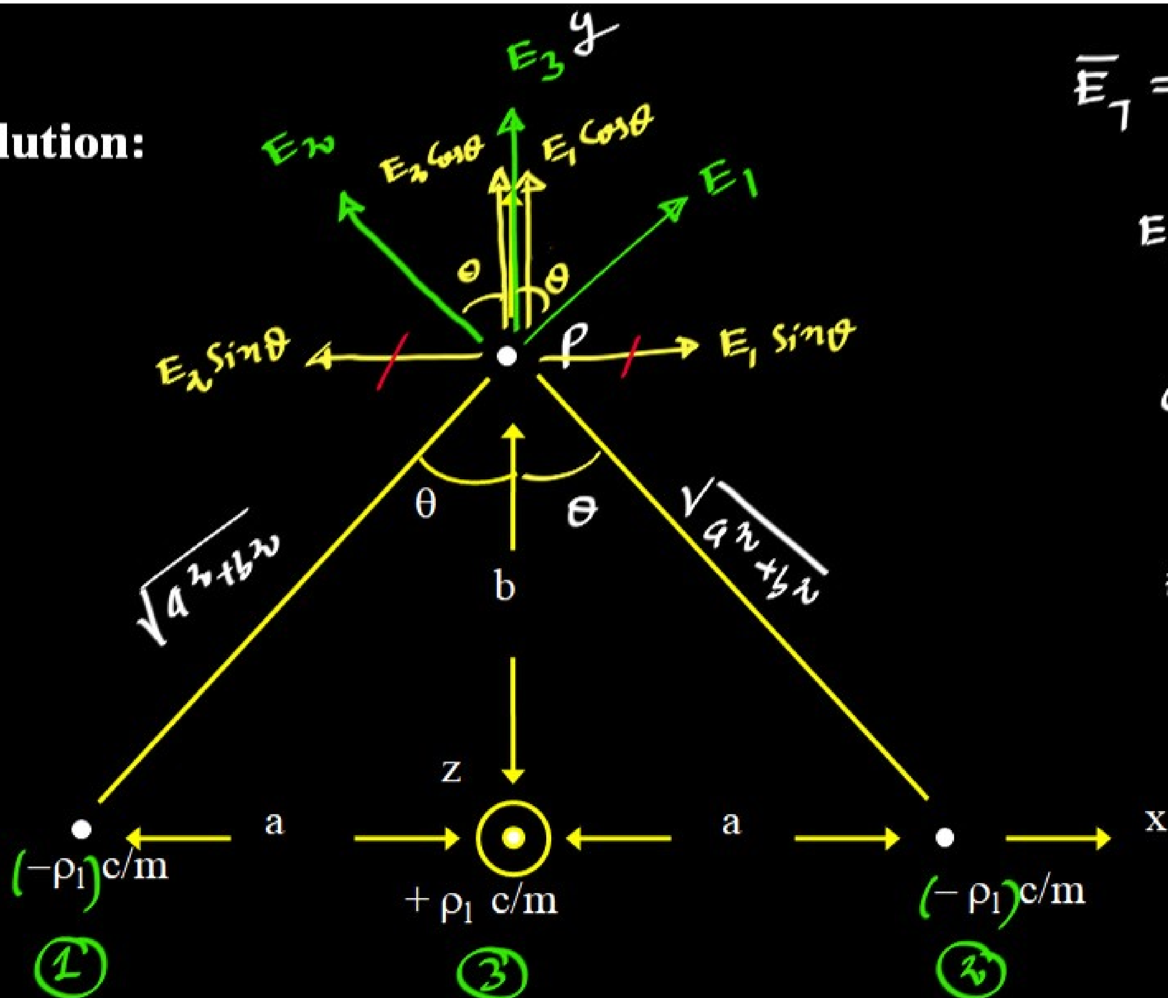
$$\bar{E}_T = 2 \times \frac{\rho_l}{2\pi\epsilon(b)} \cdot \frac{b}{c}\, \hat{x} + \frac{(-2\rho_l)}{2\pi\epsilon(c)}\, \hat{x}$$

$$= \frac{2\rho_l}{2\pi\epsilon(c)}\, \hat{x} + \frac{(-2\rho_l)}{2\pi\epsilon(c)}\, \hat{x} = \underline{\underline{0}}$$

Q. Three infinitely long charged lines run parallel to the z-axis, as shown in figure the lines have uniform charge densities as shown, determine the electric field at P



Solution:



$$\bar{E}_T = 2E_1\cos\theta\,\hat{y} + E_3\,\hat{y}$$

$$E_1 = \frac{(-\rho_l)}{2\pi\epsilon(\sqrt{a^2+b^2})}$$

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

$$E_3 = \frac{\rho_l}{2\pi\epsilon(b)}$$

$$\bar{E}_T = \frac{2(-\rho_l)}{2\pi\epsilon(\sqrt{a^2+b^2})}\cdot\frac{b}{\sqrt{a^2+b^2}}\,\hat{y} + \frac{\rho_l}{2\pi\epsilon(b)}\,\hat{y}$$

$$\bar{E}_T = \frac{-2\rho_l\,\hat{y}}{2\pi\epsilon}\left[\frac{b}{a^2+b^2}\right] + \frac{\rho_l}{2\pi\epsilon b}\,\hat{y}$$

$$\bar{E}_T = \frac{\rho_l}{2\pi\epsilon b}\,\hat{y}\left[1 - \frac{2b^2}{a^2+b^2}\right]$$

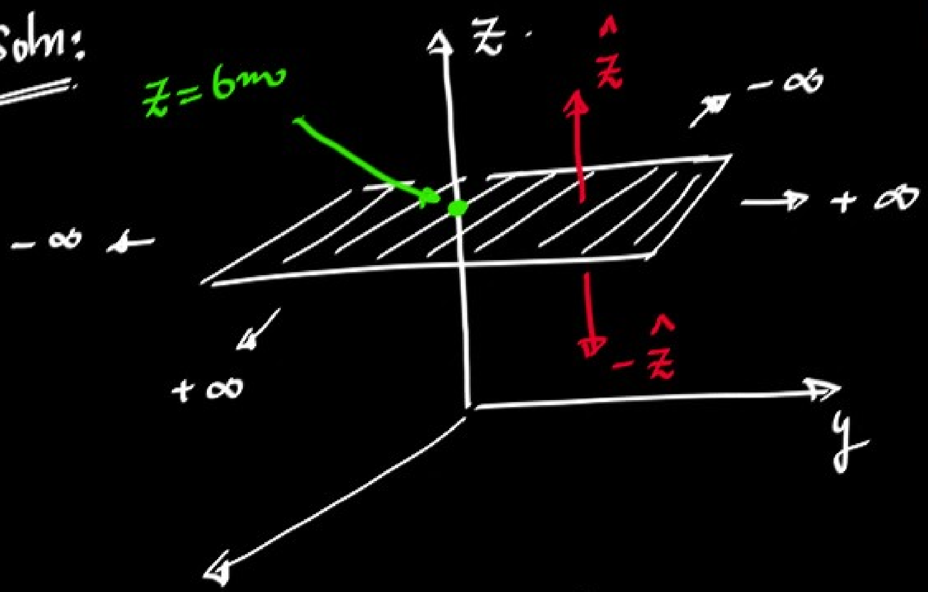
$$\bar{E}_T = \frac{\rho_l\,\hat{y}}{2\pi\epsilon b}\left[\frac{a^2+b^2-2b^2}{a^2+b^2}\right]$$

$$\bar{E}_T = \frac{\rho_l\,\hat{y}}{2\pi\epsilon b}\left[\frac{a^2-b^2}{a^2+b^2}\right].$$

Q. Infinite uniform surface charge of $\frac{1}{\pi} nc/m^2$ is located on z = 6 m plane, find electric field at following points.

(a) (0,0,0) (b) (10,10,10) (c) 20, 20, –20)

Soln:



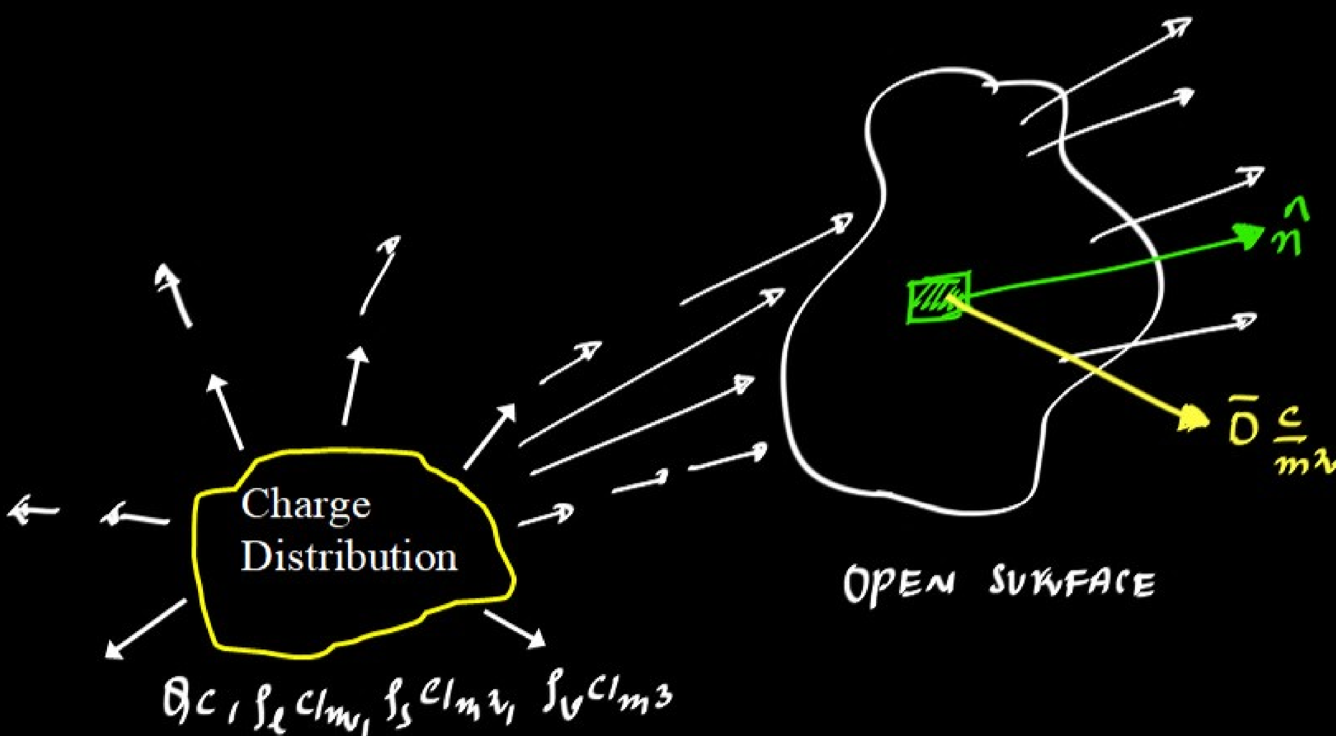
$$\rho_s = \frac{1}{\pi} nc/m^2$$

$$\bar{E} = \frac{\rho_s}{2\epsilon_0}(\pm \hat{n}) = \frac{1/\pi \times 10^{-9}}{2 \times \frac{1}{36\pi \times 10^{9}}} (\pm \hat{z})$$

$$\bar{E} = 18 (\pm \hat{z})$$

AT (0,0,0)	AT (10,10,10)	AT (20, 20, -20)
$\bar{E} = 18(-\hat{z})$	$\bar{E} = 18(\hat{z})$	$\bar{E} = 18(-\hat{z})$

Electric flux (ψ_e C) / Electric flux density ($\bar{D}$ c/m^2)



$$\bar{D} = \frac{d\psi_e}{d\bar{A}} \; C/m^2$$

$$d\psi_e = \bar{D} \cdot \bar{dA}$$

$$\boxed{\underbrace{\psi_e}_{C.} = \iint \underbrace{\bar{D}}_{\frac{C}{m^2}\times} \cdot \underbrace{\bar{dA}}_{m^2}}$$

NOTE:

$$\boxed{\bar{D} = \epsilon \bar{E}}$$

ELECTRIC FLUX DENSITY

(# OF LINES)

$\left(\frac{C}{m^2}\right)$

ELECTRIC FIELD INTENSITY

(* MAGNITUDE

* STRENGTH)

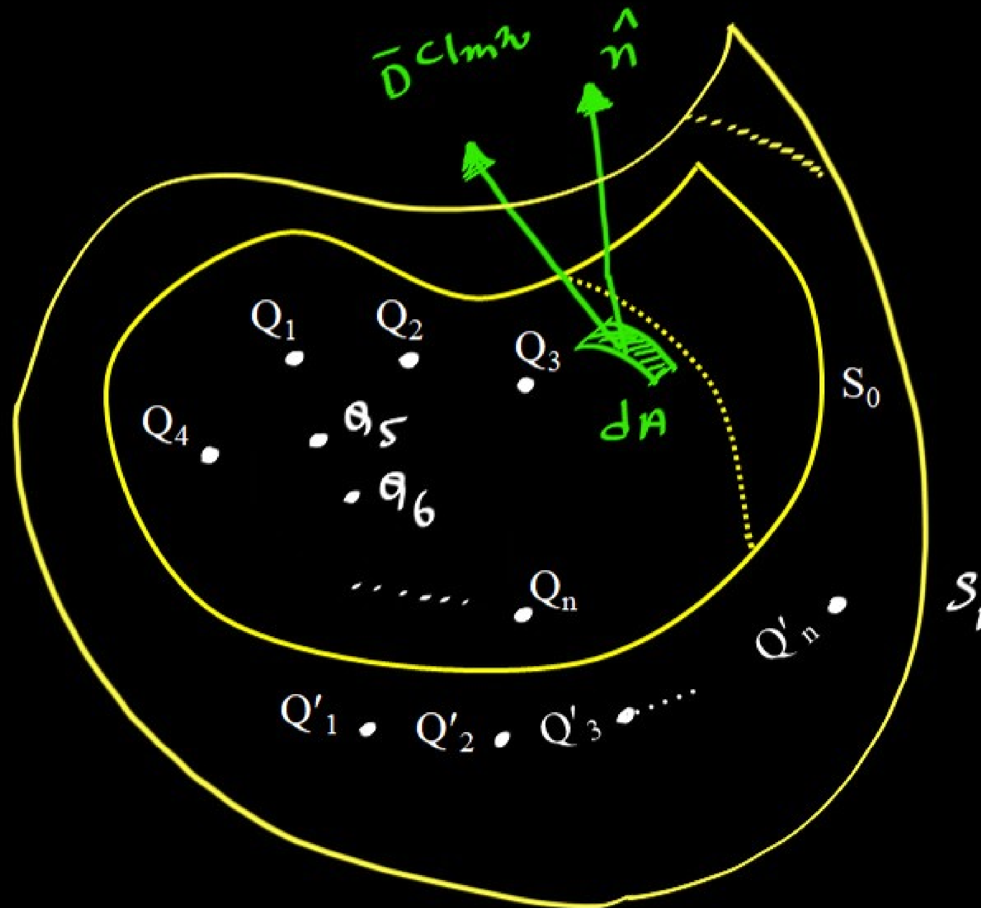
(V/m)

Gauss Law

The net electric flux coming out of any closed surface is equal to total charge enclosed by that surface.

i.e. $\boxed{[\psi_e]_{NET} = Q_{ENCLOSED}}$

$$\oint\!\!\oint \bar{D} \cdot \bar{dA} = Q_{ENC.}$$



$$[\psi_e]_{net_{S_0}} = \oiint_{S_0} \bar{D} \cdot \bar{dA} = Q_{ENC} = Q_1 + Q_2 + Q_3 + \cdots + Q_n$$

$$[\psi_e]_{net_{S_1}} = \oiint_{S_1} \bar{D} \cdot \bar{dA} = Q_{ENC} = (Q_1 + Q_2 + Q_3 + \cdots + Q_n) + (Q_1' + Q_2' + Q_3' + \cdots Q_n')$$

Gauss Law for volume charge (ρ_v c/m^3)

$$[\Psi_e]_{net} = Q_{enc}$$

$$\boxed{\oint\!\!\oint \bar{D} \cdot \bar{dA} = \iiint \rho_v \, dv.}$$

→ GAUSS LAW IN INTEGRAL FORM.

FROM DIVERGENCE THEOREM.

$$\oint\!\!\oint \bar{D} \cdot \bar{dA} = \iiint \underline{\nabla \cdot \bar{D}} \, dv$$

$$= \iiint \underline{\rho_v} \, dv.$$

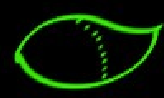
$$\boxed{\nabla \cdot \bar{D} = \rho_v.}$$

→ GAUSS LAW IN DIFFERENTIAL FORM.

NOTE:

1. $[\psi_e]_{net} = Q_{ENC.}$

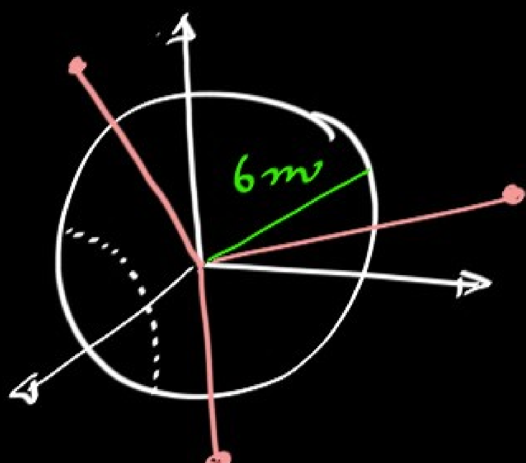
2. $\oiint \bar{D} \cdot \bar{dA} = \iiint \rho_v \, dv$



3. $\nabla \cdot \bar{D} = \rho_v .$

Q. Three charges of 2μc, 8μc, −4μc at (4,8,3), (2, −2, −3) and (−4, 0, 1) flux leaving the sphere. of 6m radius with the centre at origin.

Soln:



$$R_1 = \sqrt{4^2+8^2+3^2} > 6$$

$$R_2 = \sqrt{2^2+(-2)^2+(-3)^2} < 6$$

$$R_3 = \sqrt{(-4)^2+0^2+1^2} < 6$$

$$[\psi_e]_{net} = Q_{enc} = 8\mu C - 4\mu C$$

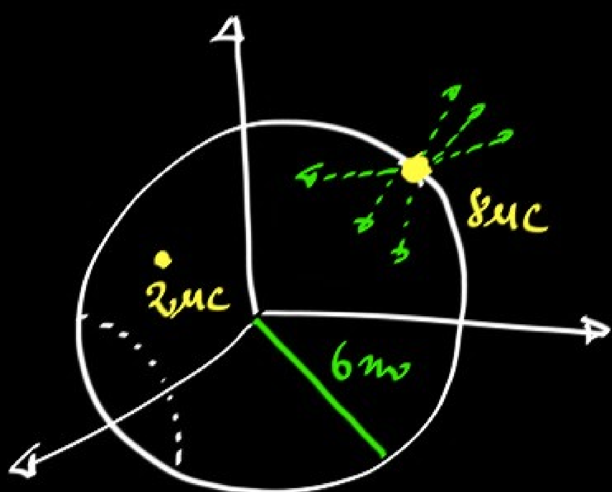
$$= 4\mu C.$$

Ex: $2\mu C\ (2, 1, 0)$

$8\mu C\ (0, 6, 0)$

$$R_1 = \sqrt{2^2 + 1^2 + 0^2} < 6$$

$$R_2 = \sqrt{0^2 + 6^2 + 0^2} = 6$$



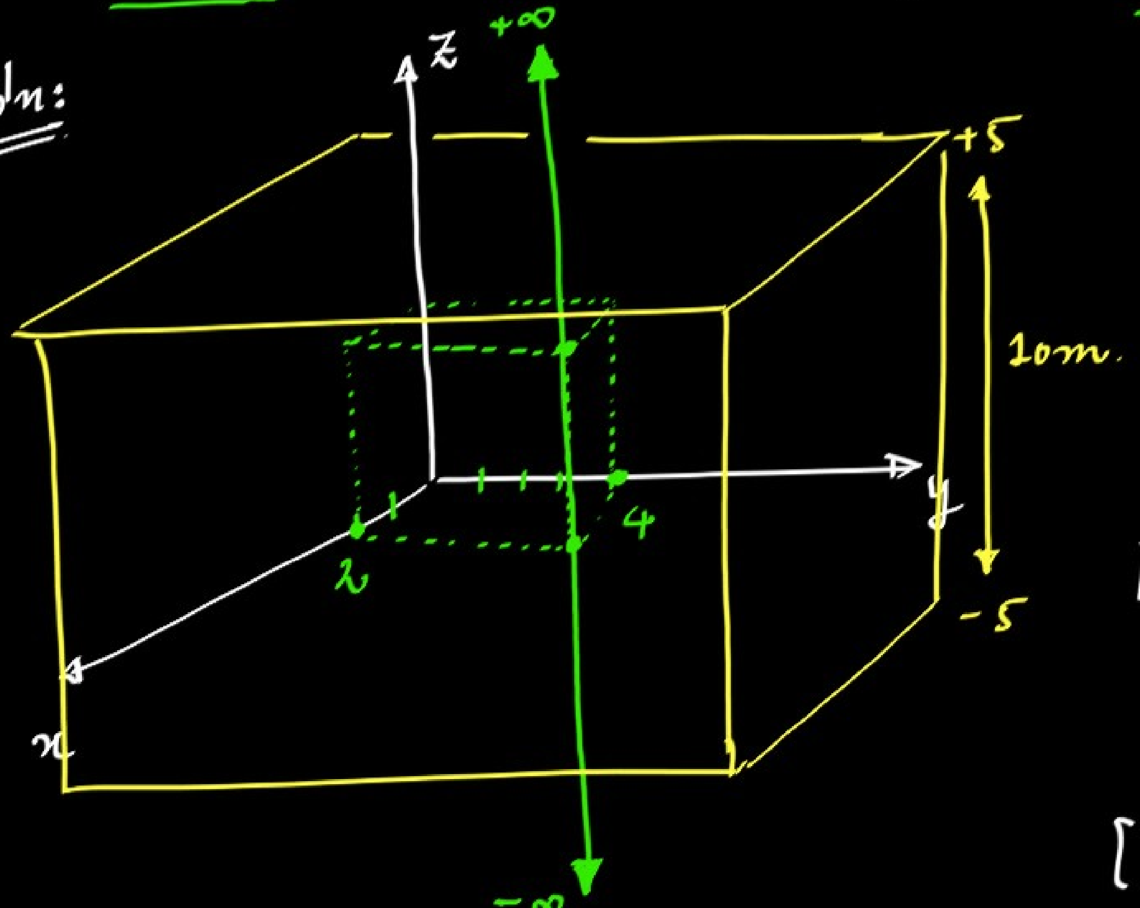
$$[\Psi_e]_{net} = Q_{enc}$$

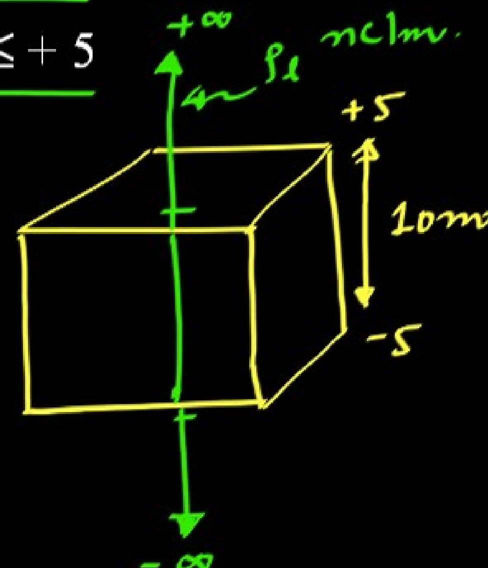
$$= 2\mu + \left[\frac{8\mu C}{2}\right]$$

$$= 6\mu C$$

Q. If a line charge of density $\rho_l = 15$ nc/m exits at x = 2 m, y = 4 m for all Z. Calculate the net flux leaving the cube $-5 \le x, y, z \le +5$

Soln:





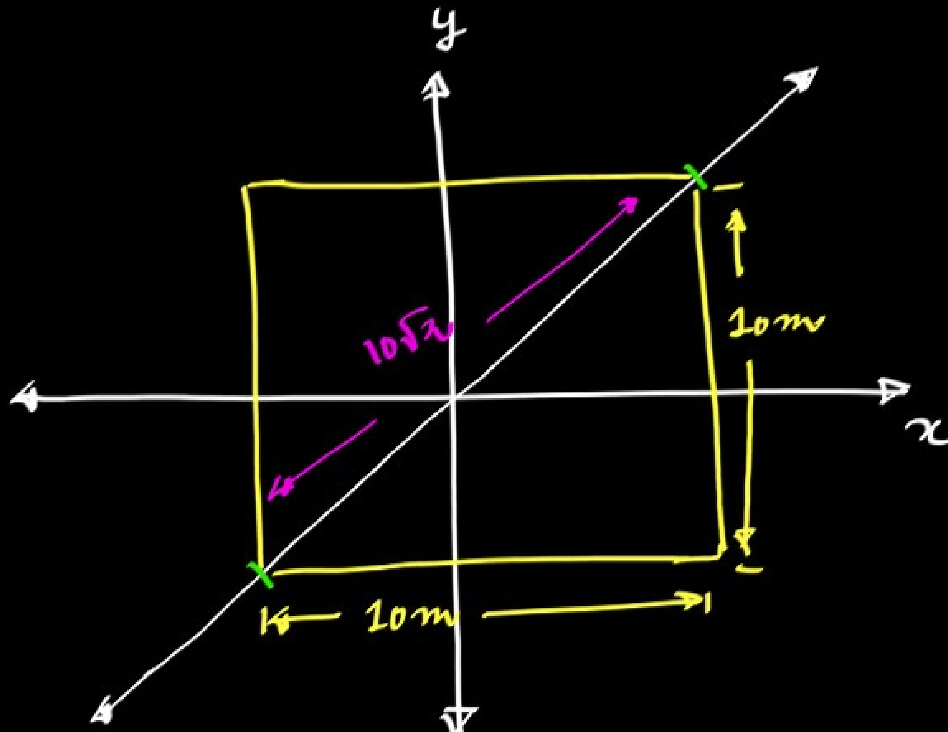
$$[\psi_e]_{net} = Q_{enc} = \int_{-5}^{+5} \rho_l \, dl$$

$$= [15][l]_{-5}^{+5} = (15 \times 10)$$

$$[\psi_e]_{net} = 150 \text{ nc.}$$

Q. If a line charge density $\rho_l = 15$ nc/m exits at $y = x$. In the $z = 0$ plane. Calculate the net flux leaving the cube $-5 \le x, y, z \le +5$

Soln:



$$[\Psi_e]_{net} = Q_{enc}$$

$$= 15 \times 10^{-9} \times 10\sqrt{2}$$

$$= 150\sqrt{2}\ nC$$

$$[\Psi_e]_{net} = 150\sqrt{2}\ nC.$$

Q. Let $\bar{D} = 2\rho^2\hat{\rho} + z\hat{z}$ nc/m^2 exists inside the a cylindrical region enclosed by the surface $\rho \le 1$ m, $z = 0$ and $z = 5$ m. Find total charge enclosed by the surface. **(GATE)**

Soln:

$$Q_{enc} = [\Psi_e]_{net} = \oint\!\!\oint \bar{D}\cdot\bar{dA} = \iiint \nabla\cdot\bar{D}\, dv$$

$$\nabla\cdot\bar{D} = \frac{1}{\rho}\left[\frac{\partial}{\partial\rho}(\rho D_\rho) + \frac{\partial}{\partial\phi}(D_\phi) + \frac{\partial}{\partial z}(\rho D_z)\right]$$

$$= \frac{1}{\rho}\left[\frac{\partial}{\partial\rho}(\rho\cdot 2\rho^2) + \frac{\partial}{\partial\phi}(0) + \frac{\partial}{\partial z}(\rho\cdot z)\right]$$

$$\nabla\cdot\bar{D} = \frac{1}{\rho}\left[2\cdot 3\cdot\rho^2 + \rho\right] = (1 + 6\rho)$$

$$Q_{enc} = \iiint (1+6\rho)\, \rho \, d\rho \, d\phi \, dz$$

$$= \int (6\rho^2 + \rho)\, d\rho \int d\phi \int dz$$

$$= \left[6\frac{\rho^3}{3} + \frac{\rho^2}{2} \right]_0^1 \left[\phi \right]_0^{2\pi} \left[z \right]_0^5$$

$$= \left[2 \times 1^3 + \frac{1^2}{2} \right] [2\pi] [5]$$

$$= \frac{5}{2} \times 2\pi \times 5$$

$$Q_{enc} = 25\pi \ nC.$$

Q) The electric flux density in certain region is given as $\bar{D} = 4r^2 \cos\theta \, \hat{\theta}$ nC/m², find its charge density at $(1, \pi/4, \pi/3)$

Soln: $\rho_v = \nabla \cdot \bar{D}$

$$\nabla \cdot \bar{D} = \frac{1}{r^2 \sin\theta}\left[\frac{\partial}{\partial r}(r^2 \sin\theta \underset{0}{D_r}) + \frac{\partial}{\partial \theta}(r \sin\theta D_\theta) + \frac{\partial}{\partial \phi}(r \underset{0}{D_\phi})\right]$$

$$= \frac{r}{r^2 \sin\theta} \frac{\partial}{\partial \theta}\left[\sin\theta \cdot 4r^2 \cos\theta\right]$$

$$= \frac{2r^2 \cdot r}{r^2 \sin\theta} \frac{\partial}{\partial \theta}\left[\sin 2\theta\right]$$

$$\rho_v = \frac{2r}{\sin\theta} \cdot (\cos 2\theta) 2 = \left[\frac{4r \cos 2\theta}{\sin\theta}\right]$$

AT $(r, \theta, \phi) = (1, \frac{\pi}{4}, \frac{\pi}{3})$

$$\rho_v = \frac{4 \times 1 \times \cos 2 \times \pi/4}{\sin \pi/4}$$

$$\rho_v = 0$$

Finding electric field using Gauss Law

Consider $$\oiint \bar{D} \cdot \bar{dA} = Q_{ENC}$$

$$\bar{D} = \epsilon \bar{E}$$

FOR HOMOGENEOUS MEDIUM

(ϵ : CONSTANT)

$$\oiint \epsilon \bar{E} \cdot \bar{dA} = Q_{ENC}$$

$$\oiint \bar{E} \cdot \bar{dA} = \frac{Q_{ENC}}{\epsilon}$$

$$\oiint \bar{E} \cdot \bar{dA} = \frac{Q_{ENC}}{\epsilon}$$

GAUSSIAN SURFACE.

GAUSSIAN SURFACE

$$\oiint \bar{E}.\overline{dA} = \frac{Q_{ENC}}{\varepsilon}$$

Step 1

Choose Gaussian surface such that

$$\bar{E}.\overline{dA} = \bar{E}.\, dA\, \hat{n} = \text{E dA Cos}\theta$$

→ E dA (θ = 0°)

→ 0 (θ = 90°)

Step 2

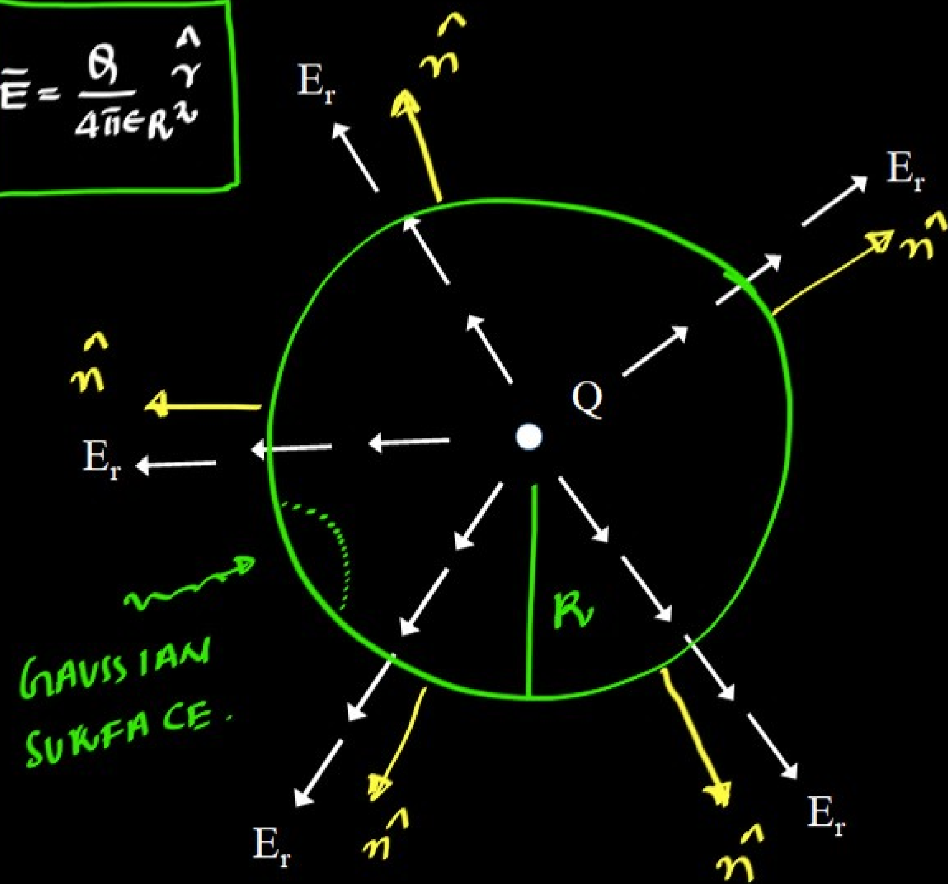
If $\bar{E}.\overline{dA}$ = E dA then E must be constant on Gaussian surface

i.e., $\oiint EdA = \frac{Q_{ENC}}{\varepsilon}$

$$E \oiint dA = \frac{Q_{ENC}}{\varepsilon}$$

Ex-1 Point Charge (QC)

$$\boxed{\bar{E} = \frac{Q}{4\pi\epsilon R^2}\hat{r}}$$



$$\oiint \bar{E}\cdot\bar{dA} = \frac{Q_{ENC}}{\epsilon} = \frac{Q}{\epsilon}$$

$$\oiint E_r\, dA = \frac{Q}{\epsilon}$$

$$E_r \oiint dA = \frac{Q}{\epsilon}$$

$$E_r\, 4\pi R^2 = \frac{Q}{\epsilon}$$

$$E_r = \frac{Q}{4\pi\epsilon R^2}$$

$$\boxed{\bar{E} = \frac{Q}{4\pi\epsilon R^2}\hat{r}}$$

Ex-2 Infinite line charge (ρ_l c/m)

$$\overline{E} = \frac{\rho_\ell}{2\pi\varepsilon\rho}\hat{\rho}$$

H-w