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Section :- C
Reg # :- SP25-BCS-147
Course ID :- PHY124
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Assignment

Chapter # 22

Sample Problem 22.01 :-

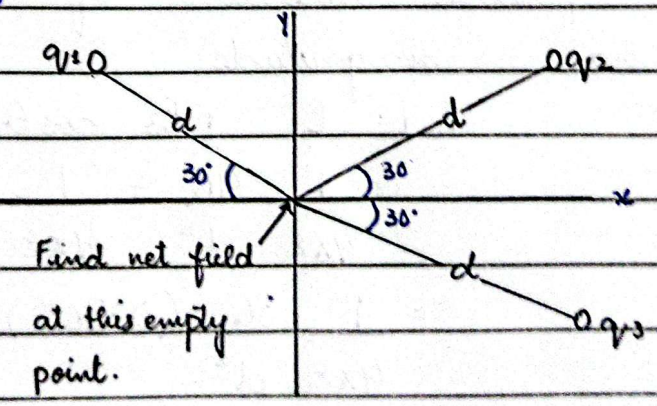
Given Data :-

$$q_1 = +2Q$$
$$q_2 = -2Q$$
$$q_3 = -4Q$$
$$r = d$$

To Find :-

$$E = ?$$

Solution :-



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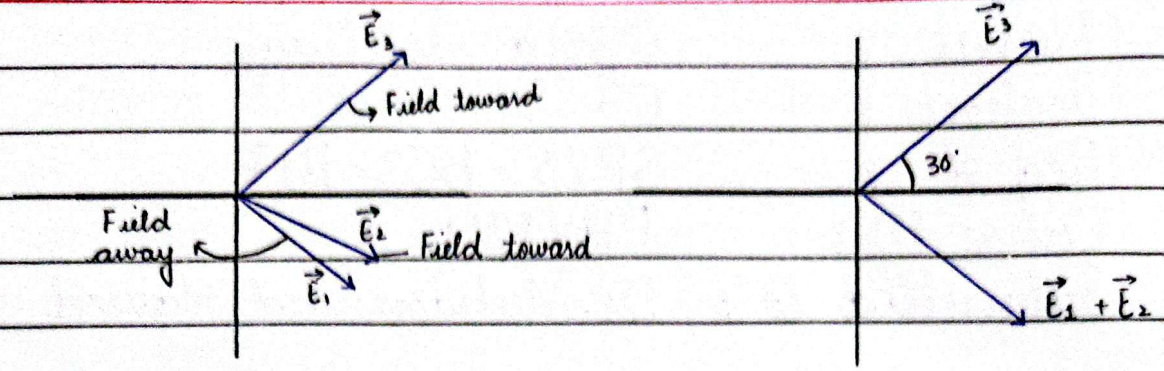

Now,

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2}$$

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2}$$

$$E_3 = \frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}$$

And,

$$E' = E_1 + E_2 = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2} + \frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2}$$

$$E' = \frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}$$

The net electric field $\vec{E}$ at the origin is in the positive direction of the x-axis and has magnitude

$$E_{net} = E' + E_3\cos\theta$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2} + \frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}\cos 30^\circ$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{8Q}{d^2}(0.866)$$

$$E_{net} = \frac{6.93Q}{4\pi\varepsilon_0 d^2}\ NC^{-1}$$

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Sample Problem 22.03 :-

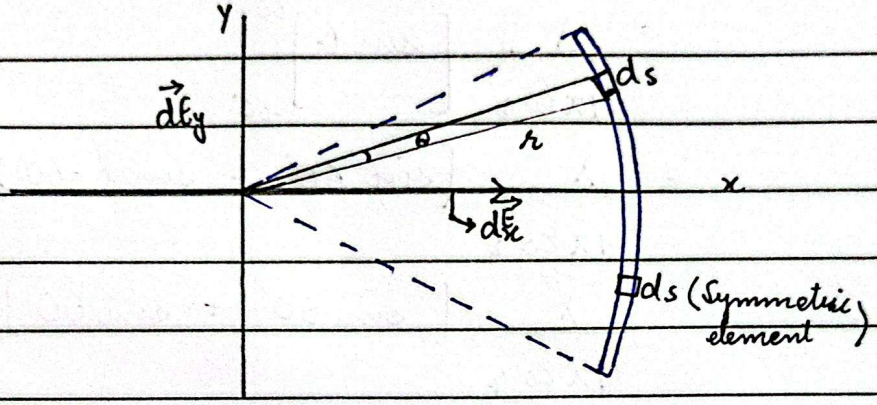
Given Data :-

$\theta = 120^\circ$

To Find :-

$\vec{E} = ?$

Diagram :-



Solution :-

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

$\because dq = \lambda ds$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{\lambda ds}{r^2}$$

Now, for x-component

$$dE_x = dE\cos\theta$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda\cos\theta\, ds}{r^2}$$

$ds = r d\theta$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda\cos\theta\, r d\theta}{r^2}$$

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And,

$$\int d\vec{E}_x = \int_{-60^\circ}^{60^\circ} \frac{1}{4\pi\varepsilon_0} \frac{\lambda}{r} \cos\theta \, d\theta$$

$$= \frac{\lambda}{4\pi\varepsilon_0 r} \int_{-60^\circ}^{60^\circ} \cos\theta \, d\theta$$

$$= \frac{\lambda}{4\pi\varepsilon_0 r} \left[\sin\theta\right]_{-60^\circ}^{60^\circ}$$

$$= \frac{\lambda}{4\pi\varepsilon_0 r} \left[\sin 60^\circ - \sin(-60^\circ)\right]$$

$$= \frac{\lambda}{4\pi\varepsilon_0 r} \left[\sin 60^\circ + \sin 60^\circ\right]$$

$$= \frac{1.73\lambda}{4\pi\varepsilon_0 r} \quad \text{—— (1)}$$

Now, charge density,

$$\lambda = \frac{\text{Charge}}{\text{Length}}$$

$\because L = \frac{2\pi r}{3}$ } cause it is a circular arc

$$= \frac{Q}{2\pi r/3}$$

$$\lambda = \frac{0.477Q}{r}$$

Putting 'λ' in eq. (1)

$$E = \frac{1.73\,(0.477Q/r)}{4\pi\varepsilon_0 r}$$

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$$= \frac{(1.73)(0.477Q)}{4\pi\varepsilon_0 r^2}$$

$$= \frac{0.83Q}{4\pi\varepsilon_0 r^2}$$

$$\vec{E} = \frac{0.83Q}{4\pi\varepsilon_0 r^2} \ NC^{-1}$$

Problem #4 :-

Given Data :-

$Q_1 = -2.00 \times 10^{-7} C$

$x_1 = 6 \ cm$

$= 6 \times 10^{-2} m$

$Q_2 = 2 \times 10^{-7} C$

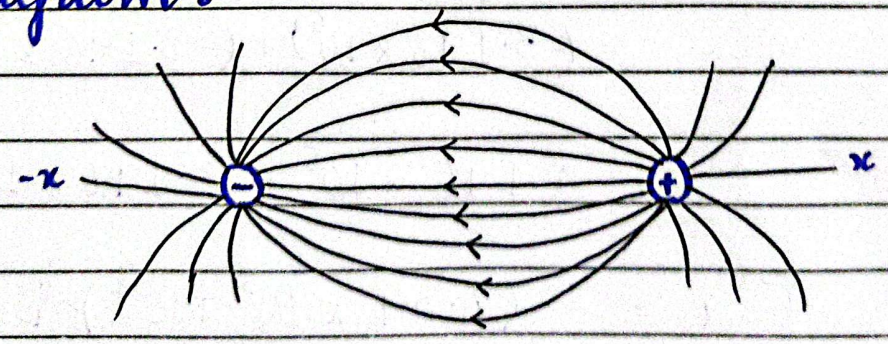
$x_2 = 21 \ cm$

$= 21 \times 10^{-2} m$

To Find:

$\vec{E}_{net} = ?$

Diagram :-



Solution :-

$$x_{mid} = \frac{x_1 + x_2}{2}$$

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$$= \frac{6\,cm + 21\,cm}{2}$$

$$x_{mid} = 13.5\,cm$$

Now,

$$E_1 = \frac{K q_1}{(x - x_1)^2} (-\hat{i})$$

$$= \frac{(9 \times 10^9)(2 \times 10^{-7})}{(13.5 \times 10^{-2} - 6 \times 10^{-2})^2}$$

$$= -(3.196 \times 10^5\ NC^{-1})\ \hat{i}$$

For E_2:

$$E_2 = \frac{K q_2}{(x - x_2)^2} (-\hat{i})$$

$$= \frac{(9 \times 10^9) \times (2 \times 10^{-7})}{(13.5 \times 10^{-2} - 21 \times 10^{-2})^2}$$

$$= -(3.196 \times 10^5\ NC^{-1})\ \hat{i}$$

Ab,

$$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$$

$$= (-3.196 \times 10^5) + (-3.196 \times 10^5)$$

$$= -3.196 \times 10^5 - 3.196 \times 10^5$$

$$\vec{E}_{net} = -(6.39 \times 10^5\ NC^{-1})\ \hat{i}$$

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Problem # 6 :-

Given Data :-

$$E = 1.0\ NC^{-1}$$

$$r = 1.00\ m$$

To Find:

$$Q = ?$$

Solution:-

$$E = \frac{KQ}{r^2}$$

$$Q = \frac{E r^2}{K}$$

$$= \frac{(1)\cdot(1)^2}{9 \times 10^9}$$

$$Q = 1.11 \times 10^{-10}\ C$$

Problem # 22 :-

(a)

Given Data :-

$$Q = -300e$$

$$r = 4cm$$

$$= 4 \times 10^{-2}\ m$$

$$\theta = 40^\circ$$

To Find:

$$\lambda = ?$$

Solution:-

$S = r\theta \rightarrow$ θ should be in radian

$\because S = L$

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$$= (4 \times 10^{-2})\left(40 \times \frac{\pi \text{ rad}}{180^\circ}\right)$$

$$L = 0.279\,m$$

Now,

$$\lambda = \frac{q}{L}$$

$$= \frac{-300e}{0.279}$$

$$e = 1.6 \times 10^{-19}\,C$$

$$= \frac{-300 \times 1.6 \times 10^{-19}}{0.279}$$

$$\lambda = -1.79 \times 10^{-15}\,Cm^{-1}$$

(b)

Given Data:-

$$q = -300e$$

$$r = 2 \times 10^{-2}\,m$$

To Find:-

$$\sigma = ?$$

Solution:-

$$\sigma = \frac{q}{A}$$

$$A = \pi r^2 \quad \text{(disk)}$$

$$\sigma = \frac{q}{\pi r^2}$$

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$$= \frac{-300 \times 1.6 \times 10^{-19}}{\pi (2 \times 10^{-2})^2}$$

$$\sigma = -3.28 \times 10^{-14} \, Cm^{-2}$$

(c)

Given Data :-

$$q = -300e$$

$$r = 2 \times 10^{-2} \, m$$

To Find :

$$\sigma = ?$$

Solution :-

$$\sigma = \frac{q}{A}$$

$$\because A = 4\pi r^2 \text{ (sphere)}$$

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

$$= \frac{-300 \times 1.6 \times 10^{-19}}{4\pi (2 \times 10^{-2})^2}$$

$$\sigma = -9.56 \times 10^{-15} \, Cm^{-2}$$

(d)

Given Data :-

$$q = -300e^-$$

$$r = 2 \times 10^{-2} \, m$$

To Find :-

$$\rho = ?$$

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Solution :-

$$\rho = \frac{q}{V_{sphere}}$$

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

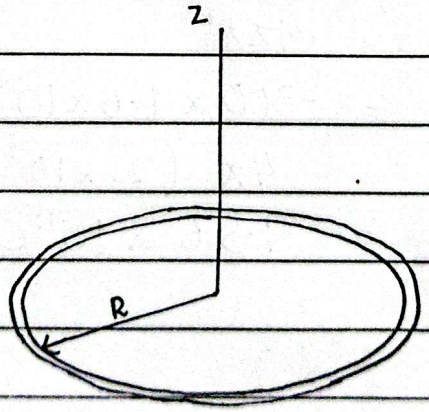
$$\rho = \frac{q}{4/3 \pi r^3}$$

$$= - \frac{300 \times 1.6 \times 10^{-19}}{4/3 \pi (2 \times 10^{-2})^3}$$

$$\rho = - 1.43 \times 10^{-12} \ Cm^{-2}$$

Problem # 24 :-

Diagram :-



(a)

Given Data :-

$$z = 0$$

To Find :

$$E_{ring} = ?$$

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Solution:-

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{qz}{(z^2+R^2)^{3/2}}\right]$$

Now $z = 0$

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(0)}{[(0)^2+R^2]^{3/2}}\right]$$

$$E_{ring} = 0$$

(b)

Given Data:-

$$z = \infty$$

To Find:

$$E_{ring} = ?$$

Solution:-

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{qz}{(z^2+R^2)^{3/2}}\right]$$

As $z = \infty$,

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(\infty)}{(\infty^2+R^2)^{3/2}}\right]$$

$$E_{ring} = 0$$

(c)

To Find:

$z = ?$ in terms of R

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Solution:-

$$dE = \frac{1}{4\pi\varepsilon_0}\left[\frac{dq z}{(z^2+R^2)^{3/2}}\right]$$

Now,

$$\frac{dE_{ring}}{dz} = \frac{d}{dz}\left[\frac{1}{4\pi\varepsilon_0}\frac{qz}{(z^2+R^2)^{3/2}}\right]$$

$$\therefore \left[\frac{dE_{ring}}{dz}\right]_{max} = 0$$

So,

$$\frac{dE_{ring}}{dz} = \frac{q}{4\pi\varepsilon_0}\left[\frac{R^2-2z^2}{(z^2+R^2)^{5/2}}\right]$$

$$\frac{q}{4\pi\varepsilon_0}\left[\frac{R^2-2z^2}{(z^2+R^2)^{5/2}}\right] = 0$$

By solving:

$$R^2 - 2z^2 = 0$$

$$R^2 = 2z^2$$

$$z^2 = \frac{R^2}{2}$$

Taking square root on b/s

$$z = \frac{R}{\sqrt{2}}$$

So,

$$z = 0.707R$$

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(d)

Given Data:-

$R = 2\,cm$

$= 2 \times 10^{-2}\,m$

$Q = 4\,\mu C$

$= 4 \times 10^{-6}\,C$

To Find:

$E_{ring} = ?$

Solution:-

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{qz}{(z^2 + R^2)^{3/2}}\right]$$

$\because z = 0.707R$

$$E_{ring} = \frac{1}{4\pi\varepsilon_0}\left[\frac{(4\times10^{-6})(0.707 \times R)}{[(0.707 \times R)^2 + R^2]^{3/2}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{(4\times10^{-6})(0.707 \times 2\times10^{-2})}{[(0.707\times2\times10^{-2})^2 + (2\times10^{-2})^2]^{3/2}}\right]$$

$$E_{ring} = 3.46 \times 10^{7}\,NC^{-1}$$

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Chapter # 23

Sample Problem 23.03:

$Q = -16e$

$R = 10\,cm$

$= 10 \times 10^{-2}\,m$

$q = +5e$

$r_1 = 6\,cm$

$= 6 \times 10^{-2}\,m$

$r_2 = 12\,cm$

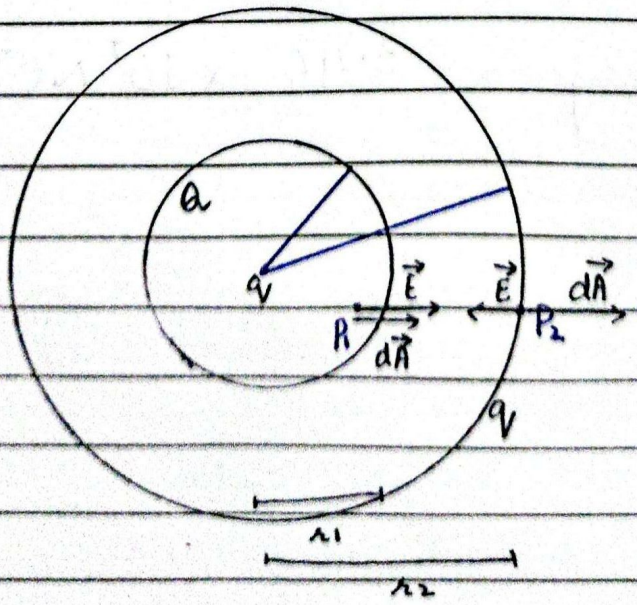
$= 12 \times 10^{-2}\,m$

To Find:

$E_1 = ?$

$E_2 = ?$

Diagram:



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Solution:-

$$E_1 = \frac{q_{enc}}{4\pi\varepsilon_0 r^2}$$

$$= \frac{Kq_{enc}}{r^2}$$

$$= \frac{(9 \times 10^9)(5 \times 1.6 \times 10^{-19})}{(6 \times 10^{-2})^2}$$

$$E_1 = 2 \times 10^{-6} NC^{-1}$$

Now, the net charge for E_2 is

$$q = q + Q$$

$$= 5 + (-16)$$

$$= -11$$

So

$$E_2 = \frac{Kq_{enc}}{r^2}$$

$$= \frac{9 \times 10^9 \times (+11 \times 1.6 \times 10^{-19})}{(12 \times 10^{-2})^2}$$

$$E_2 = 1.1 \times 10^{-6} NC^{-1}$$

Sample Problem 23.07:-

Given Data:

$$\sigma(+) = 6.8 \mu Cm^{-2}$$

$$= 6.8 \times 10^{-6} Cm^{-2}$$

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$$\sigma(-) = 4.3\mu C m^{-2}$$
$$= 4.3 \times 10^{-6} C m^{-2}$$

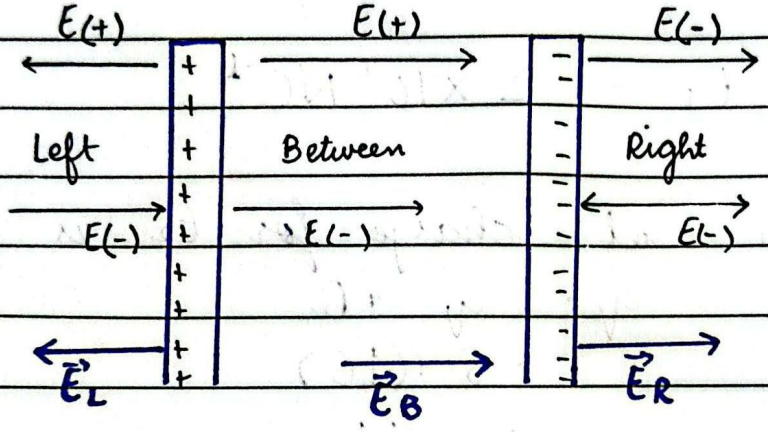
To Find:

$\vec{E}_{left} = ?$

$\vec{E}_{between} = ?$

$\vec{E}_{right} = ?$

Diagram:-



Solution:-

$$\vec{E}(+) = \frac{\sigma +}{2\varepsilon_0}$$
$$= \frac{6.8 \times 10^{-6}}{2(8.85 \times 10^{-12})}$$
$$\vec{E}(+) = 3.84 \times 10^5 NC^{-1}$$

And

$$\vec{E}(-) = \frac{\sigma -}{2\varepsilon_0}$$
$$= \frac{4.3 \times 10^{-6}}{2(8.85 \times 10^{-12})}$$
$$\vec{E}(-) = 2.43 \times 10^5 NC^{-1}$$

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$\vec{E}$ on left:

$$E_{left} = E(+) - E(-)$$
$$= 3.84 \times 10^5 - 2.43 \times 10^5$$

$$E_L = 1.4 \times 10^5 \, NC^{-1}$$

$\vec{E}_L$ is directed towards left side.

$\vec{E}$ on right:-

$$E_{right} = E(-) - E(+)$$
$$= 2.43 \times 10^5 - 3.84 \times 10^5$$
$$= -1.4 \times 10^5 \, NC^{-1}$$

$\vec{E}_R$ is directed towards right side.

$\vec{E}$ in between:-

$$E_{between} = E_+ + E_-$$
$$= 3.84 \times 10^5 + 2.43 \times 10^5$$

$$E_B = 6.3 \times 10^5 \, NC^{-1}$$

$\vec{E}_B$ is directed to the right side.

Problem #4:-

Given Data:-

$$E = 30 \, m \, NC^{-1}$$
$$= 3 \times 10^{-3} \, NC^{-1}$$
$$d = 11 \, cm$$
$$= 11 \times 10^{-2} \, m$$

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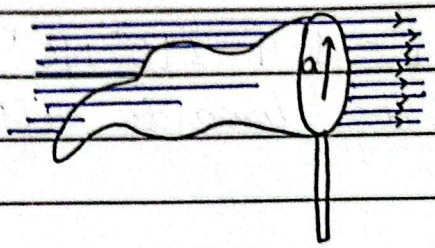
To Find:

$\phi = ?$

Diagram:



Solution:-

$$\phi = EA\cos\theta$$

$\because \theta = 0^\circ$

$\because A = \pi r^2$

$= \pi a^2$

$= E\pi a^2 \cos\theta$

$= E(\pi a^2)\cos 0^\circ$

$= 3 \times 10^{-3} \times \pi \times (11 \times 10^{-2})^2 \cos 0^\circ$

$\phi = 1.13 \times 10^{-4}\ Nm^2C^{-1}$

Problem # 5

Given Data:-

$d = \frac{d}{2}$

$q = 1.6 \times 10^{-19} C$

$\varepsilon_0 = 8.85 \times 10^{-12}\ N^{-1}m^{-2}C^2$

To Find:

$\phi = ?$

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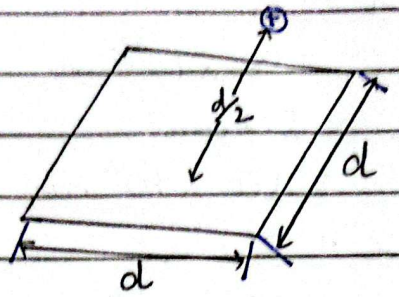
Diagram:-



Solution:-

$$\phi = \frac{q_{enclosed}}{\varepsilon_0}$$

For one side of cube

$$\phi = \frac{1}{6}\frac{q}{\varepsilon_0}$$

$$= \frac{1}{6}\frac{1.6\times10^{-19}}{8.85\times10^{-12}}$$

$$\phi = 3.01\times10^{-9}\ Nm^2C^{-1}$$

Problem # 12:

Given Data:-

Shell 1: $\sigma = 6\mu\ Cm^{-2}$

$= 6\times10^{-6}\ Cm^{-2}$

$r = 3\ cm$

$= 3\times10^{-2}\ m$

Shell 2: $\sigma = 4\mu\ Cm^{-2}$

$= 4\times10^{-6}\ Cm^{-2}$

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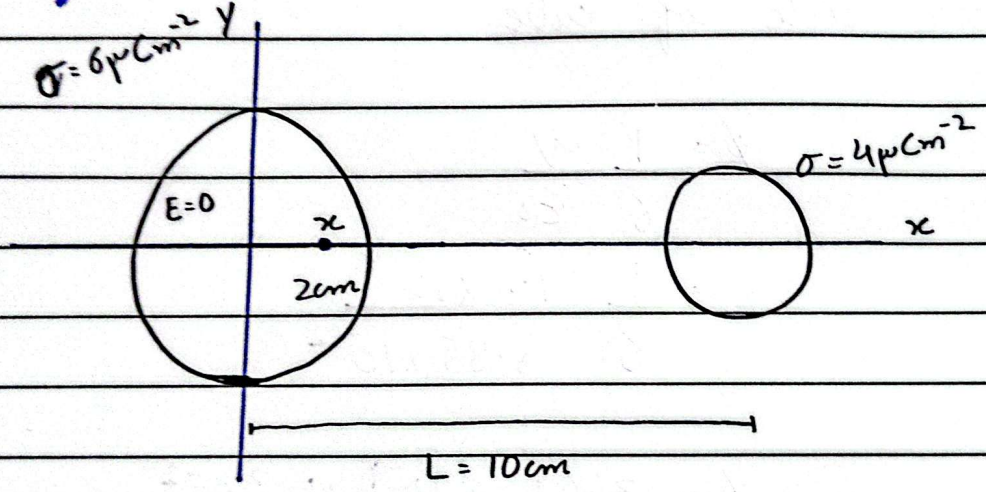
$r = 2\,cm$
$= 2 \times 10^{-2}\,m$
$L = 10\,cm$
$= 10 \times 10^{-2}\,m$
$x = 2\,cm$
$= 2 \times 10^{-2}\,m$

To Find:

$E_{net} = ?$

Diagram:



Solution:-

$$E_{net} = E_1 + E_2$$
$$= 0 + \frac{KQ}{r^2}$$

$$\because \sigma = \frac{Q}{A}$$
$$Q = \sigma A$$
$$= \sigma 4\pi R^2$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\sigma_2 4\pi R_2^2}{r^2}$$

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$$= \frac{\sigma_2 R_2^2}{\varepsilon_0 r^2}$$

$\because r = L - x$

$$= \frac{\sigma_2 R_2^2}{\varepsilon_0 (L-x)^2}$$

$$= \frac{(4\times10^{-6})(2\times10^{-2})^2}{(8.85\times10^{-12})(10\times10^{-2} - 2\times10^{-2})^2}$$

$$E_{net} = -(2.8\times10^{4}\ NC^{-1})\,\hat{j}$$

Problem # 22 :-

Given Data :-

$$r = 9\,cm$$
$$= 9\times10^{-2}\,m$$
$$\sigma = 6\,\mu C m^{-1}$$
$$= 6\times10^{-6}\,C m^{-1}$$

To Find:

$$a = ?$$

Solution :-

$$F = qE$$

$\because F = ma$

$$ma = qE$$
$$ma = eE$$
$$a = \frac{eE}{m}$$

Now,

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$$\therefore E = \frac{\lambda}{2\pi\varepsilon_0 r}$$ } For rod

$$a = \frac{e}{m} \times \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$= \frac{1.6 \times 10^{-19}}{9.1 \times 10^{-31}} \times \left[\frac{(6 \times 10^{-6})}{2\pi(8.85 \times 10^{-12})(9 \times 10^{-2})} \right]$$

$$a = 2.1 \times 10^{17} \, ms^{-2}$$

Problem #25:-

Given Data:-

$$E = 4.5 \times 10^{4} \, NC^{-1}$$

$$r = 2 \, m$$

To Find:-

$$E = ?$$

Solution:-

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

$$\lambda = E 2\pi\varepsilon_0 r$$

$$= 4.5 \times 10^{4} \times 2 \times \pi \times 8.85 \times 10^{-12} \times 2$$

$$\lambda = 5 \times 10^{-6} \, Cm^{-1}$$

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Problem #45

Given Data:-

$r_1 = 10\,cm$

$= 10 \times 10^{-2}\,m$

$r_2 = 15\,cm$

$= 15 \times 10^{-2}\,m$

$Q_1 = 4 \times 10^{-8}\,C$

$q_2 = 2 \times 10^{-8}\,C$

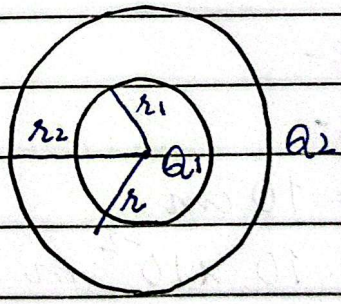
To Find:

$E_1 = ?$ at $r = 12\,cm$

$E_2 = ?$ at $r = 20\,cm$

Solution:-

E1 :-



$$E = \frac{Kq}{r^2}$$

$$= \frac{9 \times 10^9 \times 4 \times 10^{-8}}{(12 \times 10^{-2})^2}$$

$$E_1 = 2.5 \times 10^4\,NC^{-1}$$

E2 :-

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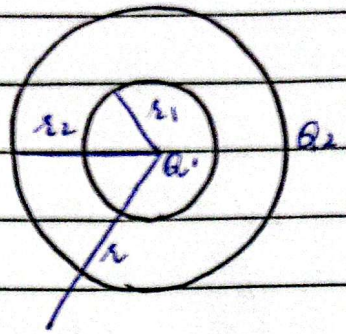

$$E_2 = \frac{KQ}{r^2}$$

$$= \frac{9 \times 10^9 \times (4 \times 10^{-8} + 2 \times 10^{-8})}{(20 \times 10^{-2})^2}$$

$$E_2 = 1.35 \times 10^4 \ NC^{-1}$$

Problem #47:-

Given Data:-

$r_1 = 10 \ cm$

$= 10 \times 10^{-2} \ m$

$r_2 = 15 \ cm$

$= 15 \times 10^{-2} \ m$

$E = 3 \times 10^3 \ NC^{-1}$

To Find:

$Q = ?$

Solution:-

$$E = \frac{KQ}{r^2}$$

Now,

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$$Q = \frac{Er^2}{K}$$

$$= \frac{(3 \times 10^3)(15 \times 10^{-2})^2}{9 \times 10^9}$$

$$= 7.5 \times 10^{-9}$$

$$Q = -7.5 \times 10^{-9} C$$