NCERT EXERCISE

1.1. Given

$q_1 = 2\times10^{-7}\,C \qquad q_2 = 3\times10^{-7}\,C$

$r = 30\ cm = 30\times10^{-2}\,m$

$F = ?$

By coulomb's law

$$F = k\frac{q_1q_2}{r^2}$$

where k is coulomb constant

$k = 9\times10^{9}\,Nm^2/C^2$

$$F = \frac{9\times10^{9}\times2\times10^{-7}\times3\times10^{-7}}{(30\times10^{-2})^2}$$

$$= \frac{\cancel{9}\times6\times10^{9-14}}{\cancel{900}_{100}\times10^{-4}}$$

$$F = 6\times10^{-3}\,N \text{ (repulsing)}$$

Ans

1.2 Given

$q_1 = 0.4\,\mu C = 0.4\times10^{-6}\,C$

$q_2 = -0.8\,\mu C = -0.8\times10^{-6}\,C$

$F_{12} = 0.2\,N$

(a) $r = ?$

$$F = k\frac{q_1q_2}{r^2}$$

Topic.. Date..........................

or $r^2 = \frac{kq_1q_2}{F_{12}}$

$$r^2 = \frac{9\times10^9 \times 0.4\times10^{-6} \times 0.8\times10^{-6}}{0.2}$$

$$= \frac{9\times 0.\cancel{4}^{2}\times 0.8 \times 10^{9-12}}{0.\cancel{2}}$$

$$= 9\times 1.6 \times 10^{-3}$$

or $r^2 = 9\times16\times10^{-4}$

or $r = 3\times4\times10^{-2}$

$= 12\times10^{-2}$ m

$r = 12$ cm

(b) $F_{21} = ?$

we know that coulomb's law obeys newton's III law. i.e.

$$\vec{F}_{12} = -\vec{F}_{21}$$

therefore the force on second sphere due to first $F_{21} = 0.2$ N

1.3

$$\left[\frac{ke^2}{Gm_em_p}\right] = \left[\frac{Nm^2C^{-2}\cdot C^2}{Nm^2kg^{-2}[kg][kg]}\right]$$

$$= [1] = \text{dimensionless}$$

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Topic................................ Date................

Here

$k = 9 \times 10^{9} \ Nm^2/C^2$

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

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

$m_e = 9.1 \times 10^{-31} kg$

$m_p = 1.67 \times 10^{-27} kg$

$$\frac{ke^2}{G m_e m_p} = \frac{9 \times 10^{9} \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.67 \times 10^{-27}}$$

$$= \frac{9 \times 1.6 \times 1.6 \times 10^{9} \times 10^{-38}}{6.67 \times 9.1 \times 1.67 \times 10^{-11-31-27}}$$

$$= \frac{9 \times 2.56 \times 10^{-29}}{6.67 \times 9.1 \times 1.67 \times 10^{-69}}$$

$$= \frac{23.04 \times 10^{40}}{101.36}$$

$$= 0.227 \times 10^{40}$$

$$= 2.27 \times 10^{39}$$

or $\frac{ke^2}{G m_e m_p} = 2.27 \times 10^{39}$

here $\frac{ke^2}{G m_e m_p} = \frac{F_e}{F_g} = 2.27 \times 10^{39}$

where F_e = Electrostatic force b/w electron and proton

Or $F_e = 2.27 \times 10^{39} F_g$

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Topic..Date..................................

Here

$k = 9 \times 10^{9}\ Nm^2/c^2$

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

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

$m_e = 9.1 \times 10^{-31}\ kg$

$m_p = 1.67 \times 10^{-27}\ kg$

$$\frac{ke^2}{G m_e m_p} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.67 \times 10^{-27}}$$

$$= \frac{9 \times 1.6 \times 1.6 \times 10^{9-38}}{6.67 \times 9.1 \times 1.67 \times 10^{-11-31-27}}$$

$$= \frac{9 \times 2.56 \times 10^{-29}}{6.67 \times 9.1 \times 1.67 \times 10^{-69}}$$

$$= \frac{23.04 \times 10^{40}}{101.36}$$

$$= 0.227 \times 10^{40}$$

$$\frac{ke^2}{G m_e m_p} = 2.27 \times 10^{39}$$

$$\frac{ke^2}{G m_e m_p} = \frac{F_e}{F_g}$$

F_e = Electrostatic force b/w electron and proton

F_g = Gravitational force " " " "

$$\frac{F_e}{F_g} = 2.27 \times 10^{39} \Rightarrow F_e = 2.27 \times 10^{39} F_g$$

ie Electrostatic force is much stronger the F_g

·NCERT Exercise

1.4. (a) The statement means that the total charge on a body is equal to integral multiple of charge on an electron (e)
i.e $q = \pm ne$, where $n = 0, 1, 2, 3, \ldots$

(b) At macroscopic level, the quantisation of charge is ignored because the charge at macroscopic level is very large as compared to elementry charge e. Therefore in such cases charge may be treated as continuous and not quantised.

1.5 When glass rod is rubbed with a silk cloth, the glass rod acquires +ve charge and silk cloth gets -ve charge.
Silk and glass are neutral before rubbing and after rubbing the net charge on both is zero again. i.e charge remains conserved.
Thus charge is not created nor destroyed just transfers one body to the other. This observation consistent with the law of conservation of charges.

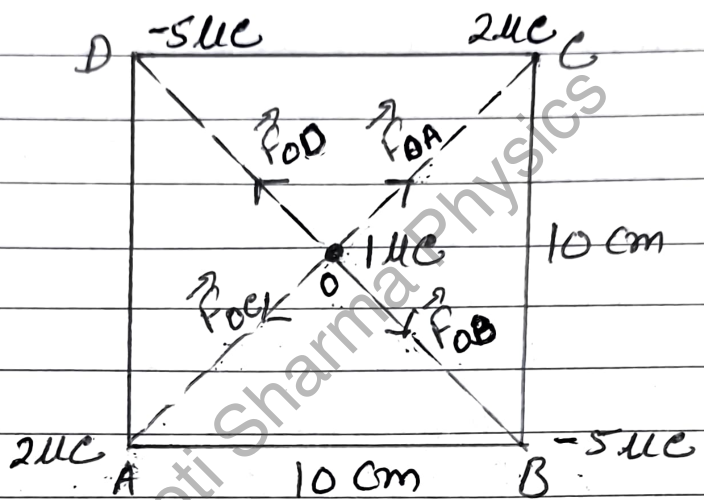
1.6 Given,

Four point charges

$q_A = 2\mu C$, $q_B = -5\mu C$, $q_C = 2\mu C$, $q_D = -5\mu C$

side of the square $l = 10cm$.

charge placed at the centre of square $= 1\mu C$.



By symmetry of fig. it is clear that

$$\vec{F}_{OA} = -\vec{F}_{OC} \Rightarrow \vec{F}_{OA} + \vec{F}_{OC} = 0$$

and $\vec{F}_{OB} = -\vec{F}_{OD} \Rightarrow \vec{F}_{OB} + \vec{F}_{OD} = 0$

i.e. $\vec{F}_{OA} + \vec{F}_{OB} + \vec{F}_{OC} + \vec{F}_{OD} = 0$

i.e. F_{net} on charge $1\mu C = 0$

Net force at 'O' is zero.

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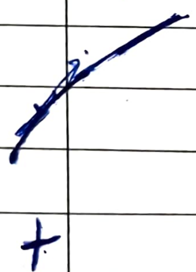
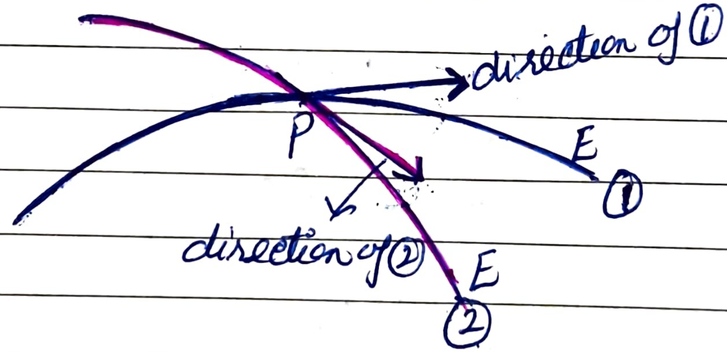
1.7 (a) An electrostatic field line represents the actual path travelled by a unit positive charge in an electric field. If line breaks it means ~~line~~ test charge jumps which is not possible. It also means that electric field becomes zero suddenly which is not possible. So field lines cannot have sudden breaks.

(b) If two electric field lines crosses each other then at the point of intersection there will be two tangents showing the two directions at one point which is not possible. Hence electric field lines never cross each other.

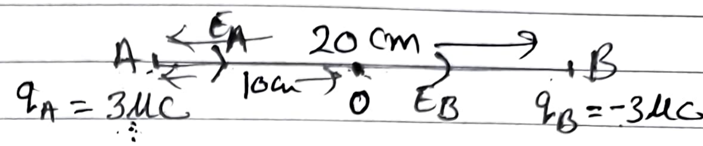




1.8 Given

$q_A = 3\mu C = 3\times10^{-6} C$

$q_B = -3\mu C = 3\times10^{-6} C$



$AB = 20 cm$

$= 20\times10^{-2} m$

$AO = OB = 10\times10^{-2} m$

(a) Here

$|\vec{E_A}| = |\vec{E_B}| = E$ (say)

$E_{net} = E_A + E_B = 2E$

$E_{net} = \dfrac{2\times9\times10^{9}\times3\times10^{-6}}{(10\times10^{-2})^2}$ $\left[\because E = k\dfrac{q}{r^2}\right]$

$= 54\times10^{3+2}$

$= 54\times10^{5}$

$E_{net} = 5.4\times10^{6} NC^{-1}$ [along OB]

Electric field at point 'O' $= 5.4\times10^{6} NC^{-1}$

(b) $F = qE$

$= 1.5\times10^{-9}\times5.4\times10^{6}$ $[\because q = 1.5\times10^{-9} C]$

$= 8.1\times10^{-3} N$

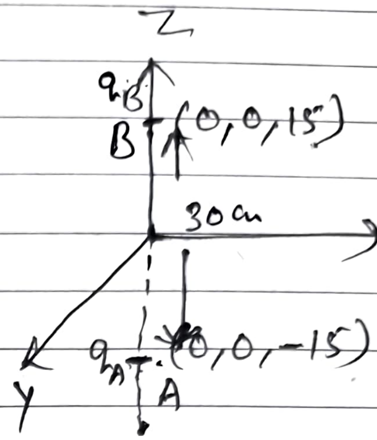
Topic...Date..............................

1.9 Given

$q_A = 2.5 \times 10^{-7} C$

$q_B = -2.5 \times 10^{-7} C$

$AB = 30\ cm = 30 \times 10^{-2} m$



Total charge $= q_A + q_B$

$= 2.5 \times 10^{-7} - 2.5 \times 10^{-7}$

Total charge $= 0$

Dipole moment $p = q(2a)$

$= 2.5 \times 10^{-7} \times 30 \times 10^{-2}$

$= 75 \times 10^{-9}$

$p = 7.5 \times 10^{-8}\ Cm$ [along BA]

Ans

1.10 Given

$p = 4 \times 10^{-9}\ Cm$

$\theta = 30°$

$E = 5 \times 10^{4}\ NC^{-1}$

$\tau = pE \sin\theta$

$= 4 \times 10^{-9} \times 5 \times 10^{4} \sin 30°$

$= 20 \times 10^{-5} \times \frac{1}{2}$

$\tau = 10 \times 10^{-5} = 10^{-4}\ Nm$

Ans

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Topic.. Date.................................

1.11 Given

$$q_p = -3\times10^{-7}C$$

(a) $q = ne$

$$n = \frac{q}{e} = \frac{+3\times10^{-7}}{1.6\times10^{-19}} = \frac{30}{16}\times10^{12} = \frac{15}{8}\times10^{12}$$

$$= 1.87\times10^{12}$$

$$n \simeq 2\times10^{12}$$

i.e 2×10^{12} electrons are transferred from wool to polythene.

(b) Yes but negligible amount of mass is transferred because mass of electron is very small.

$$Me = 2\times10^{12}\times9.1\times10^{-31} = 1.82\times10^{-18}\,kg$$

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Ch. 1

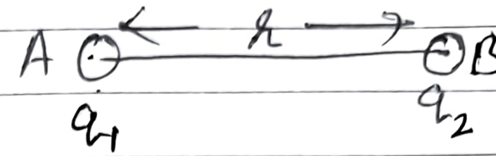
Topic: Electric Charges And Fields Date.................. class XII

1.12 Given,

$q_1 = q_2 = q = 6.5 \times 10^{-7} C$

$r = 50 cm$

$= 50 \times 10^{-2} m$



$$F = \frac{k q_1 q_2}{r^2}$$

$$= \frac{9 \times 10^9 \times (6.5 \times 10^{-7})^2}{(50 \times 10^{-2})^2}$$

$$= \frac{9 \times \cancel{6.5}^{1.3} \times \cancel{6.5}^{1.3}}{\cancel{50}_{10} \times \cancel{50}_{10}} \times 10^{9-14+4}$$

$$= \frac{9 \times 1.69}{100} \times 10^{-1}$$

$$= 15.21 \times 10^{-3}$$

$$F = 1.52 \times 10^{-2} N$$

or $F \simeq 1.5 \times 10^{-2} N$

Topic.......... Date..........

(b) Given,

$$q_1 = q_2 = 2q$$

$$r \rightarrow \frac{r}{2}$$

Now

$$F' = \frac{k q_1 q_2}{r^2}$$

$$= \frac{k(2q)(2q)}{\left(\frac{r}{2}\right)^2}$$

$$= 4 \times 4 \left(\frac{kq^2}{r^2}\right)$$

$$= 16 \times 1.5 \times 10^{-2}$$

$$F' = 24 \times 10^{-2} \text{ N}$$

Ans

1.13 $q_1 = q_2 = 6.5 \times 10^{-7} C = q \text{ (say)}$

When a third uncharged sphere is brought in contact with sphere A and then removed the charge on each sphere becomes

$$= \frac{6.5 \times 10^{-7}}{2} C = \frac{q}{2}$$

Now this sphere is brought in contact with sphere B, the charge on each sphere

$$= \frac{\frac{6.5}{2} \times 10^{-7} + 6.5 \times 10^{-7}}{2}$$

Teacher's Sign ....

Topic...Date.................................

$$= \frac{\frac{q}{2} + q}{2}$$

$$= \frac{3q}{4}$$

Hence spheres A and B now left with charges as

On sphere A $q_1 = \frac{q}{2}$

On sphere B $q_2 = \frac{3q}{4}$

Now the new force

$$F = k\frac{q_1 q_2}{r^2}$$

$$= \frac{k\left(\frac{q}{2}\right)\left(\frac{3q}{4}\right)}{r^2}$$

$$= \frac{3}{8}\left(k.\frac{q^2}{r^2}\right)$$

$$= \frac{3}{8} \times 1.5 \times 10^{-2}\ N$$

$$= \frac{4.5}{8} \times 10^{-2}$$

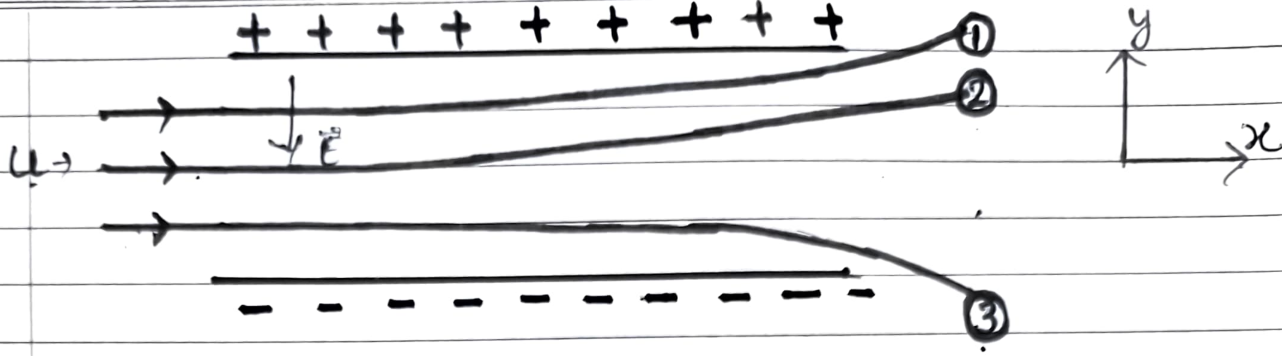
$$= 0.56 \times 10^{-2}$$

$$F = 5.6 \times 10^{-3}\ N$$

Teacher's Sign ....

Topic........................ Date........................

1.14



Particle 1 is -ve
Particle 2 is -ve
Particle 3 is +ve

Now
$$a = \frac{F}{m} = \frac{qE}{m}$$

Motion along x axis
$$x = ut \Rightarrow t = \frac{x}{u}$$

Motion along y axis
$$y = \frac{1}{2}at^2$$
$$y = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{x}{u}\right)^2$$

$$y \propto \frac{q}{m}$$

i.e ratio of charge to mass depends on the deflection along y axis.

From fig deflection of particle 3 is maximum. Therefore the ratio of q and m is highest for particle 3

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1.15 Given $\vec{E} = 3\times10^{3}\,\hat{i}$ N/C

Side of square $= 10$ cm $= 10\times10^{-2}$ m

$= 10^{-1}$ m

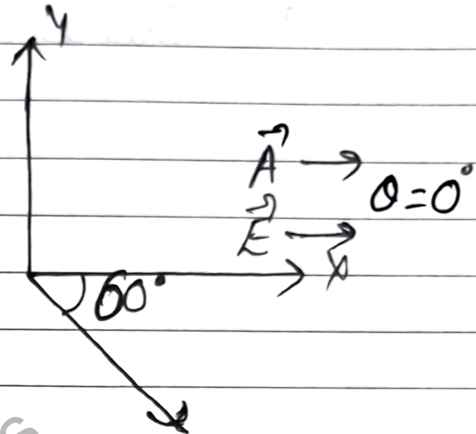
(a)

Flux $\phi = EA\cos\theta$

$\phi = 3\times10^{3}\times(10^{-1})^{2}\cos 0^\circ$

$= 3\times10^{3}\times10^{-2}\times1$

$\phi = 30\ Nm^{2}C^{-1}$ Ans



(b) $\phi = EA\cos\theta$

$= 3\times10^{3}\times10^{-2}\cos 60^\circ$

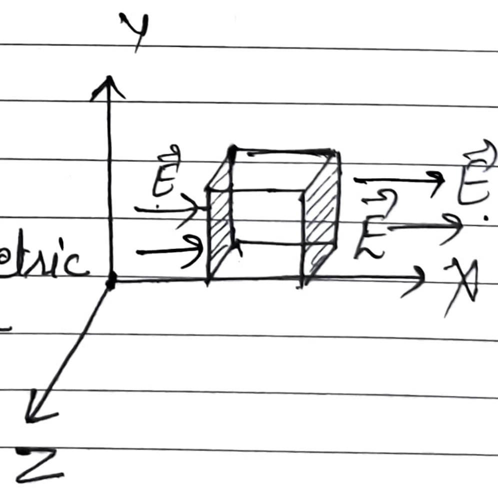
$= 30\times\frac{1}{2}$

$\phi = 15\ Nm^{2}C^{-1}$ Ans

1.16 Here net flux $= 0$

$\phi = 0$

Because the no. of electric field lines entering the cube is same as field lines coming out of the cube.



1.17 Given

$$\phi = 8 \times 10^{3}\ Nm^2/C$$

(a) $q = ?$

We have

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

$$q = \phi \epsilon_0$$

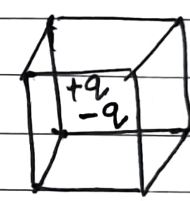
$$= 8 \times 10^{3} \times 8.85 \times 10^{-12}$$

$$= 70.80 \times 10^{-9}$$

$$= 0.07 \times 10^{-6}$$

$$q = 0.07\ \mu C$$ Ans

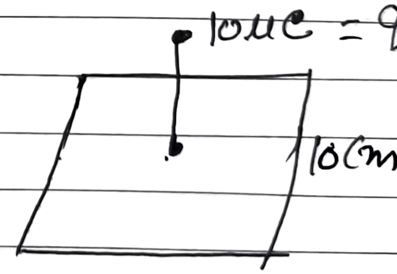
(b) No, it cannot be said so. If there is equal and opposite charges inside the box the net flux will be zero as net charge inside the box is zero.



$q_{net} = 0$

1.18 We know

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



here flux through the one surface

$$\phi = \frac{1}{6}\left(\frac{q}{\epsilon_0}\right)$$

$$= \frac{1 \times 10 \times 10^{-6}}{6 \times 8.85 \times 10^{-12}} = 1.88 \times 10^{5}\ Nm^2/C$$

Ans

Topic........ Date........

1.19 Given

$$q = 2\mu C = 2 \times 10^{-6} C$$

$$\phi = \frac{q}{\epsilon_0} = \frac{2 \times 10^{-6}}{8.85 \times 10^{-12}}$$

$$= \frac{2}{8.85} \times 10^{6}$$

$$\phi = 2.26 \times 10^{5} \, Nm^2/C$$

Ans

1.20 Given,

$$\phi = -1 \times 10^{3} \, Nm^2/C$$

(a) The electric flux is independent of the size of the gaussian surface. Therefore electric flux remains same.

(b)

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

$$q = \phi \epsilon_0$$

$$= -1 \times 10^{3} \times 8.85 \times 10^{-12}$$

$$q = -8.85 \times 10^{-9} C$$

Ans

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1.21 Given,

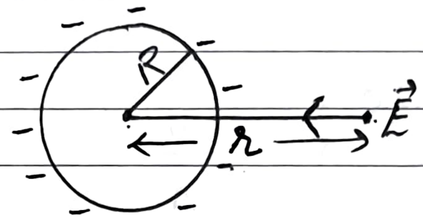
Radius of sphere $R = 10\,cm$

$= 0.1\,m$

Electric field $E = 1.5 \times 10^3\,N/C$ (Inwards)

Distance for which electric field is given $r = 20\,cm$

$= 0.2\,m$



Inward dirn of E shows that q is -ve.

We know electric field outside the charged sphere

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} \qquad \left[\phi = \frac{q}{\epsilon_0} = E \times 4\pi r^2\right.$$

$$1.5 \times 10^3 = \frac{9 \times 10^9 \times q}{(0.2)^2}$$

or $$q = \frac{\cancel{15} \times 10^3 \times 0.04\,2}{\cancel{90} \times 10^9 \times 100}$$

$\cancel{6}$ 3

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

$$= \frac{2}{3} \times 10^{-8}$$

$$= \frac{20}{3} \times 10^{-9}$$

$$q = 6.67 \times 10^{-9}\,C$$

Hence the charge is -ve

~~or~~ $q = -6.67\,nC$

Teacher's Sign ....

Topic.. Date..............................

1.22 Given,

Diameter of the sphere $d = 2.4\ m$

so, radius $r = \frac{2.4}{2} = 1.2\ m$

Surface charge density $\sigma = 80\ \mu C/m^2$

$\sigma = 80 \times 10^{-6}\ C/m^2$

(a) We know

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

or $q = \sigma \times 4\pi r^2$

$= 80 \times 10^{-6} \times 4 \times 3.14 \times (1.2)^2$

$= 320 \times 3.14 \times 1.44 \times 10^{-6}$

$= 320 \times 4.5216 \times 10^{-6}$

$= 14.46 \times 10^{-4}$

$q = 1.44 \times 10^{-3}\ C$

charge on sphere $= 1.44 \times 10^{-3}\ C$ Ans

(b) $$\phi = \frac{q}{\epsilon_0} = \frac{1.44 \times 10^{-3}}{8.85 \times 10^{-12}}$$

$\phi = 1.62 \times 10^{8}\ Nm^2/C$

Teacher's Sign ....

Topic.......................................Date.......................

1.23 Given,

$$E = 9 \times 10^4 \ N/C$$

distance $r = 2\,cm = 0.02\,m$ $\quad \leftarrow 2cm \rightarrow \cdot E$

We know

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

$$\lambda = E \times 2\pi\epsilon_0 \cdot r$$

$$= \frac{E \times 4\pi\epsilon_0 \cdot r}{2}$$

$$= \frac{9 \times 10^4 \times 0.02}{2 \times 9 \times 10^9} \qquad \left[\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \ Nm^2/C^2\right.$$

$$= \frac{0.02}{2} \times 10^{-5}$$

$$= 10 \times 10^{-6} \ C/m$$

$$\lambda = 10\ \mu C/m$$

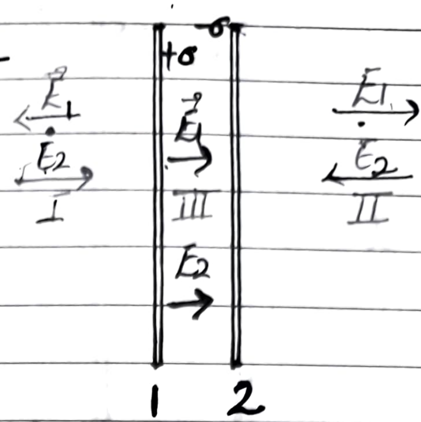
Linear charge density $\lambda = 10\ \mu C/m$

Teacher's Sign ....

Topic........ Date........

1.24 Given,

$\sigma = 17.0 \times 10^{-22}\ C/m^2$



For plate 1

$\sigma_1 = 17 \times 10^{-22}\ C/m^2$

For plate 2

$\sigma_2 = -17 \times 10^{-22}\ C/m^2$

For a given point $|\vec{E_1}| = |\vec{E_2}|$ as plates are close to each other.

(a)

$$E_I = E_1 - E_2 \qquad [\because |\vec{E_1}| = |\vec{E_2}|]$$

$$E_I = 0$$

(b)

$$E_{II} = E_1 - E_2 \qquad [\because |\vec{E_1}| = |\vec{E_2}|]$$

$$E_{II} = 0$$

(c)

$$E_{III} = E_1 + E_2$$

$$= 2E_1$$

$$= \cancel{2}\frac{\sigma}{\cancel{2}\epsilon_0} \qquad [\because E = \frac{\sigma}{2\epsilon_0}]$$

$$= \frac{17 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$$E_{III} = 1.92 \times 10^{-10}\ N/C$$

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