1. What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air?

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

$r = 30\,cm = 0.30m, K = 1$

Note that K=1 for vacuum. in numerical prob. lems, the value of K for air is also taken as 1.

We know that F = $\frac{1}{4\pi\varepsilon_0 K}\frac{q_1q_2}{r^2}$

F = $F = 9\times10^9\times\frac{2\times10^{-7}\times3\times10^{-7}}{0.30\times0.30}N$

$= 6\times10^{-3}N$

The force is repulsive.

2. The electrostatic force on a small sphere of charge 0.4 μC due to another small sphere of charge –0.8 μC in air is 0.2 N. (a) what is the distance between the two spheres? (b) what is the force on the second sphere due to the first?

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

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

(a) Force on q_1 due to q_2

F_{12} = 0.2 N, r=?, K=1

$F_{12} = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1q_2}{r^2}$

Note that the electrostatic force between two charges are Newtonian i.e., equal in magnitude and opposite in direction,

Substituting values,

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

$$r^2 = \frac{9\times0.4\times0.8\times10^{-3}}{0.2}m^2 = 0.0144m^2$$

$r = 0.12m$

(b) Force on q_2 due to q_1, F_{21}=0.2N

This force is attractive in nature.

3. Check that the ratio $ke^2/G\,m_em_p$ dimensionless. Look pu a Table of Physical constant and determine the value of this ratio. What does the ratio signify?

Ans. Given ratio is $\frac{\left[Nm^2C^{-2}\right]\left[C^2\right]}{\left[Nm^2kg^{-2}\right][kg][kg]}$ i.e., no unit and no dimensions.

Now, $\frac{ke^2}{Gm_em_p}$

$$= \frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{6.67\times10^{-11}\times9.1\times10^{-31}\times1.67\times10^{27}}$$

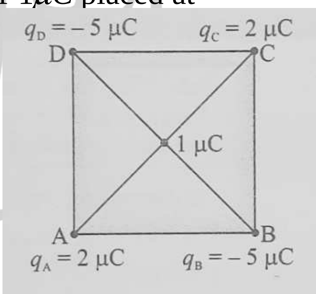
$= 2.3 \times 10^{39}$

This signifies **the ratio of electrostatic and gravitational force between a proton and an electron.**

4. (a) Explain the meaning of the statement electric charge of a body is quantised'.
(b) Why can one ignore quantisation of electric charge when dealing with macroscopic i.e., Large scale charges?
Ans. (a) Charge contained or transferred to ant object is due to fundamental particles electron and protons which always transferred as whole not in fraction hence charge is integral multiple of electron (Q = n x e) hence charge is quantised.
(b) The charge on an electron is extremely small. If a few electrons are added or removed, the charge on the charged body changes by only a very small amount. So, it appears to vary is a continuous manner.

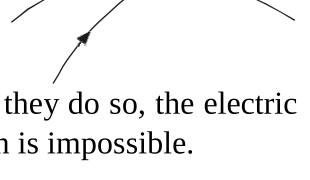
5. When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.
Ans. Initially, both the glass rod and silk cloth are electrically neutral. Net charge is zero; finally, the positive charge on glass rod is exactly equal to the negative charge on the silk cloth. So, net charge is again zero Thus, the appearance of charges an glass rod and silk is accordance with the law of conservation of charge.

6. For point charges $q_A = 2\mu C, q_B = -5\mu C, q_c = 2\mu C$ and $q_D = -5\mu C$ are located at the corners of a square ABCD of side 10 cm. what is the force on a charge of $1\mu C$ placed at the centre of the square?



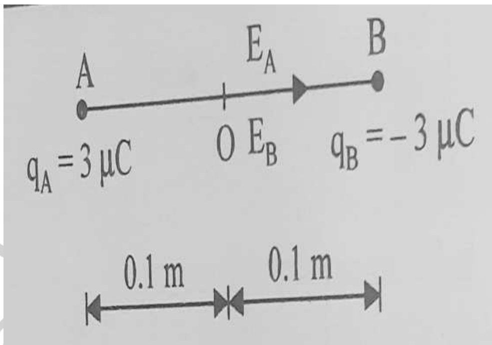
Ans. We know force between charge is given as F=$\frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2}$
Forces F_A and F_C on $1\mu C$ charge due to q_A and q_C are equal in magnitude and opposite in direction. So, they cancel out.
Similarly, the forces F_B and F_D on $1\mu C$ charge due to q_B and q_D are equal in magnitude and opposite in direction. These also cancel out.
Thus, the net force on $1\mu C$ charge is **zero.**

7. (a) An electrostatic field line is a continuous curve. That is, field line cannot have sudden breaks. Why not?
(b) Explain why two field lines never cross each other at any point?
Ans. (a) we know electric field line originates from positive charge and terminates at negative charge; hence it is continuous curve between charge particles.



(b) The electric lines of force never cross each other, because if they do so, the electric field should have two directions at the point of intersection which is impossible.

8. Two point charges $q_A = 3\mu C$ and $q_B = -3\mu C$ are located 20 cm apart in vacuum.
(a) what is the electric field at the midpoint O of the line AB joining the two charges?
(b) If a negative test charge of magnitude $1.5\times10^{-9} C$ is placed at this point, what is the force experienced by the test charge?



Ans. For electric field we keep +1C charge at O,
(a) Electric field at O due to charge at A,

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q_A}{r^2}\ E_A = 9\times10^9 \frac{3\times10^{-6}}{(0.1)^2} NC^{-1}$$

$$= 2.7\times10^6 NC^{-1}(\text{along OB})_{\text{repulssive}}$$

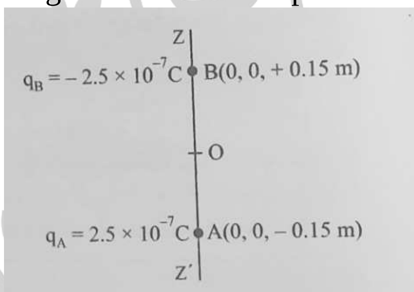
Electric field at O due to charge at B,

$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q_B}{r^2} = 9\times10^9 \frac{3\times10^{-6}}{(0.1)^2} NC^{-1}$$

$$= 2.7\times10^6 NC^{-1}(\text{along OB})_{\text{attractive}}$$

(b) Force on negative test charge at O, F= q_0 E=($1.5\times10^{-9}\times5.4\times10^6$)N=$8.1\times10^{-3}$N
This force will be directed along OA.

9. A system has two charges $q_A = 2.5\times1$ and $q_B = 2.5\times10^{-7} C$ located at points A: (0,0,–14 cm) and B: (0,0+15cm), respectively. what are the charge and electric dipole moment of the system?



Ans. Total charge = $2.5\times10^{-7} - 2.5\times10^{-7} = 0$

Note that the net charge of an electric dipole is zero

Electric dipole moment,
P=Either charge ×Separation between charges
= 2.5×10^{-7}
[0.15+0.15] C m
=7.5×10^{-8}C m
The direction dipole moment is from B to A i.e., along negative z-axis.

10. An electric dipole with moment 4×10^{-9} C m is aligned at 30° with the direction uniform electric field of magnitude 5×10^4 N. Calculate the magnitude of the torque acting of dipole.

Ans. p=$4\times10^{-9} C\,m, E = 5\times10^4 N\,C^{-1}, \theta = 30°$
Magnitude of torque, $\tau = pE\sin\theta$

$$\tau = 4\times10^{-9}\times5\times10^4 N\,m\times\frac{1}{2} = 10^{-4} N\,m.$$

11. A polythene piece rubbed with wool is to have a negative charge of 3×10^{-7} C.
(a) Estimate the number of electrons transfer (from which to which?)
(b) Is there a transfer of mass from wool to polythene?

Ans. (a) $q = -3\times10^{-7} C$
$q = ne$

or $n = \frac{q}{e} = \frac{-3\times10^{-7}}{-16\times10^{-19}} = 1.875\times10^{12}$

Since the polythene acquires negative charge therefore it is clear that the polythene gains electrons.
So, electrons are transferred from wool to polythene.
(b) Mass gained by polythene

$$=1.875\times10^{12}\times9.1\times10^{-31}$$

$$=1.71\times10^{-18}kg$$

This mass is of course negligible and small.

12. (a) Two insulated charged spheres A and B have their centres separated by a distance of 50 cm. what is the mutual force of electrostatic repulsion if the charge on each is 6.5×10^{-7} C? the radii of A and B re negligible compared to their separation.
(b) What is the force of repulsion, if each sphere is charged double the above amount, and the distance between them is halved?

Ans. (a) $q_1 = 6.5\times10^{-7}C$,

$$q_2 = 6.5\times10^{-7}C, r = 0.5m, F = ?$$

$$F = 9\times10^9 \frac{\left(6.5\times10^{-7}\right)\left(6.5\times10^{-7}\right)}{(0.5)^2}N$$

$$=1.5\times10^{-2}N$$

(b) Each of the two charges is doubled and the distance is halved. Clearly, the new force will sixteen times the original force.

$\therefore$ New force $= 1.5\times10^{-2}\times16N = 0.24N$.

13. Suppose the spheres A and B in Q. 12 have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B?

Ans. Initially, the charge on sphere A is 6.5×10^{-7}C. Sphere C has no charge. When A and C are brought in electrostatic contact, charge is sphere equally between them because they are of the same size. So, after the contact, each of the two spheres A and C has 3.25×10^{-7} C.

Now, the sphere C (having charge 3.25×10^{-7}C) is brought in contact with B having charge of 6.5×10^{-7} C. The charge is now shared equally between B and C. $\frac{3.25\times10^{-7}+6.5\times10^{-7}}{2}C, i.e., 4.875\times10^{-7}C$

Now, $q_1 = 3.25\times10^{-7}C$,

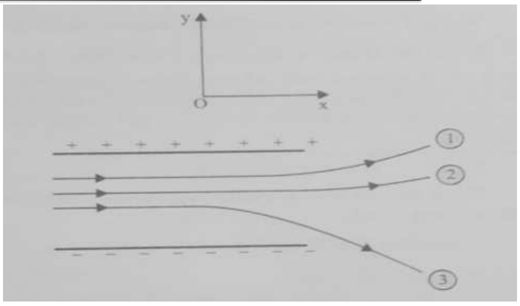
$$q_2 = 4.875\times10^{-7}C \text{ and } r = 0.5m,$$

$$\therefore \quad F = 9\times10^9\times\frac{3.25\times10^{-7}\times4.875\times10^{-7}}{(0.5)^2}N$$

$$= 5.7\times10^{-3}N.$$

14. Figure shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio?

Ans. From figure we observe that particle 1 and 2are deflected toward positive plate and it carry negative charge where as particle 3



defelcted towards negative plate so it carry posive charge.Also particle 3 suffers more deflection so this particle has maximum charge and minimum mass. Thus particle 3 has hghest charge by mass ratio. Calculated as follows:

we know that $y = ut + \frac{1}{2}at^2$ asssume u=0

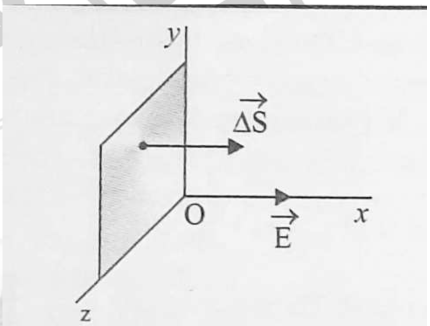
then $y = \frac{1}{2}at^2 = \frac{1}{2}\frac{qE}{m}t^2$, Assume t is equal to all particles, then $\frac{q}{m}\,\alpha\, y$

15. Consider a uniform electric field $\vec{E} = 3\times10^3\hat{i}\,N\,C^{-1}$. (a) What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the *yz* plane? (b) What is the flux through the same square if the normal to its plane makes a 60º angle with the *x*-axis?

Ans. $\vec{E} = 3\times10^3\hat{i}\,N\,C^{-1}$

Since the plane is parallel to *yz* plane therefore area vector is along *x*-axis.

$\therefore\ \overrightarrow{\Delta S} = (0.10)^2\hat{i}\,m^2$



(a) $\phi_E = \vec{E}\cdot\overrightarrow{\Delta S}$

$\phi_E = 3\times10^3\times0.10\times0.10\left(\hat{i}\cdot\hat{i}\right)$

$\phi_E = 30\,N\,m^2C^{-1}$

Note that dot product of $\hat{i}$ and $\hat{i}$ is 1.

(b) When normal to the plane makes an angle of 60º with x-axis, then the angle between $\overrightarrow{\Delta S}$ and $\vec{E}$ is 60º.

Note that $\overrightarrow{\Delta S}$ is along the normal to the plane of the coil.

$\phi_E = E\cdot\Delta S\cos60º = 3\times10^3\times10^{-2}\times\frac{1}{2}\,Nm^2C^{-1} = 15Nm^2C^{-1}$

16. What is the net flux of the uniform electric field of Question 15 through a cube of side 20 cm oriented so that its faces are parallel to the co-ordinate planes?

Ans. Zero, The number of lines entering the cube is the same as the number of lines leaving the cube.

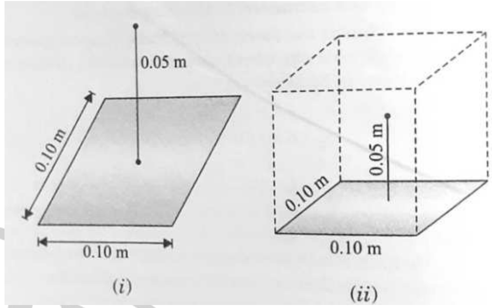
17. Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0×10^3 N m^2 C^{-1}. (a) What is the net charge inside the box? (b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or Why not?

Ans. (a) $\Phi_E = \frac{q}{\varepsilon_0}$

Or $q = \varepsilon_0\Phi_E = 8.85\times10^{-12}\times8.0\times10^3C = 0.07\,\mu C$

(b) If the net outward flux is zero, then there are possibilities: Either the charge is zero or there are amount of positive and negative charge inside the both we cannot conclude that there are no charges inside the close surface.

18. A point charge $+10\mu C$ is at a distance directly above the centre of a square of side 10 cm shown in Fig. (i). What is the magnitude of the electro flux throuogh the square?
Ans. The given square can be imagined as one six faces of a cube of side 0.10 m (Fig. (ii)). The given can be imagined to be at the centre of this cube.



The electric flux through the square

$$=\frac{1}{6}\frac{q}{\varepsilon_0}=\frac{1}{6}\times\frac{10\times10^{-6}}{8.85\times10^{-12}}\,N\,m^2C^{-1}$$

$$=1.88\times10^5\,Nm^2C^{-1}$$

19. A point charge of $2.0\mu C$ is at the centre cubic Gaussian surface $9.0\,cm$ on edge. What is the electric flux through the surface?

Ans. $\Phi_E=\frac{q}{\varepsilon_0}=\frac{2\times10^{-6}}{8.85\times10^{-12}}Nm^2C^{-1}=2.26\times10^5\,N\,m^2C^{-1}$

20. A point charge causes an electric flux $-1.0\times10^3\,N\,m^2C^{-1}$ to pass through a spherical Gaussian surface of 10 cm radius centred on the charge.
(a) If the radius of the Gaussian surface doubled, how much flux would pass through the face?
(b) What is the value of the point charge?

Ans. (a) The electric flux would remain unchanged $-10\times10^3\,Nm^2C^{-1}$. This is because, in both cases, the same charge is enclosed by the Gaussian surface.

(b) $\Phi_E=\frac{q}{\varepsilon_0}$ *or* $q=\varepsilon_0\Phi_E$

$$=8.85\times10^{-12}\times\left(-1.0\times10^3\right)C=-8.85\times10^{-9}C=-8.85nC$$

21. A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 NC^{-1} and points radially inward, what is the charge on the sphere?

Ans. R=1.10m, r=0.20 m, $E=1.5\times10^3NC^{-1}$

$$E=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2};q=4\pi\varepsilon_0r^2E$$

Or $q=-\frac{0.20\times0.20\times1.5\times10^3}{9\times10^9}C=6.67\times10^{-9}C=-6.67nC$

22. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 $\mu C/m^2$. (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere?

Ans. D = 2.4 m, r=1.2 m,

$$\sigma=80\times10^{-6}Cm^{-2}$$

(a) $q=\sigma\times4\pi r^2=80\times10^{-6}\times4\times\frac{22}{7}\times1.2\times1.2C=1.45mC$

(b) $\Phi_E = \frac{q}{\varepsilon_0} = \frac{1.45\times10^{-3}}{8.85\times10^{-12}} Nm^2C^{-1} = 1.6\times10^8 Nm^2C^{-1}$

23. An infinite line charge produces a field of $9\times10^4\, NC^{-1}$ at a distance of 2 cm. Calculate the linear charge density.

Ans. $E = \frac{\lambda}{2\pi\varepsilon_0 r} = \frac{2\lambda}{4\pi\varepsilon_0 r}$

Or $\lambda = \frac{E(4\pi\varepsilon_0 r)}{2}$

Or $\lambda = 9\times10^4 \times \frac{1}{9\times10^9} \times \frac{0.02}{2} Cm^{-1} = 10^{-7} Cm^{-1}$

Some measure of electric charge		
Name	Symbol	SI unit
Charge	q	c
Linear charge density	λ	Cm^{-1}
Surface charge density	σ	Cm^{-2}
Volume charge density	ρ	Cm^{-3}

24. Two large, thin metal plates are parallel and close to each other. One their inner face, the plates have surface charge densities of opposite signs and of magnitude $17.0\times10^{-12} C m^{-2}$. What is $\vec{E}$ (a) in the outer region of the first plate, (b) in the outer region of the second plate, and (c) between the plates?

Ans. (a) and (b), One the left and right of the plants, the electric field is zero. (c) In between the plates,

$E = \frac{\sigma}{\varepsilon_0} = \frac{17\times10^{-12}}{8.85\times10^{-12}} NC^{-1} = 1.9 NC^{-1}$

25. An oil drop of 12 excess electrons is held stationary under a constant electric field of 2.55×10^4 N C^{-1} in Millikan's oil drop experiment. The density of the oil is 1.26 g cm^{-3}. Estimate the radius of the drop. $\left(g = 9.81 m s^{-2}; e = 1.60\times10^{-19} C\right)$.

Ans. n=12, e=1.6×10^{-19} C,
E= 2.55×10^4 N C^{-1}
$\rho = 1.26\times10^3 kg\, m^{-3}, g = 9.81 m s^{-2}$,

Radius of drop, r =?

In the given problem, mg =ne E

Or $\frac{4}{3}\pi r^3 \rho g = neE$

Or $r = \left\{\frac{3neE}{4\pi\rho g}\right\}^{1/3}$

$= \left[\frac{3\times12\times1.6\times10^{-19}\times2.55\times10^4}{4\times3.14\times1.26\times10^3\times9.81}\right]^{1/3} m$

$= 9.8 \times 10^{-4}\, mm$

26. Which among the curves shown in the following figure cannot possible electrostatic field lines?

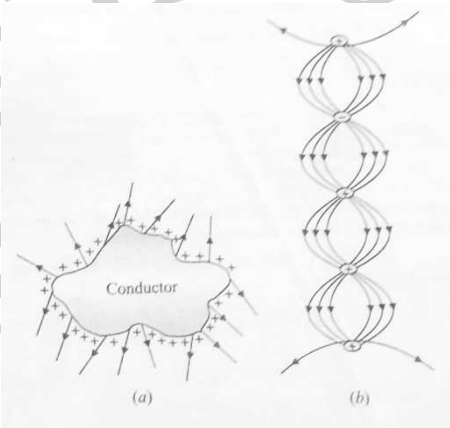
Ans. (a) Wrong. The electrostatic field lines must be normal to the surface of the charged conductor.

(b) Wrong. The field lines cannot start from negative charge and cannot end on positive charge.

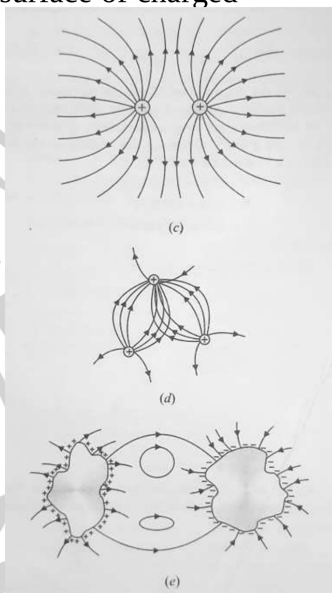
(c) Right. The lines of force start from positive charge and leave the surface of charged conductors normally.

(d) Wrong. The field lines cannot intersect each other.

(e) Wrong. The electrostatic field lines cannot form closed loops.



(a) (b)


(c) (d) (e)

27. In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is, however, not constant but increases uniformly along the positive z-direction, at the rate of 10^5 NC^{-1} per metre. What are the force and torque experienced by a system having a total dipole moment equal to 10^{-7} C m in the negative z-direction?

Ans. In a non-uniform electric field, the force on the electric dipole is given by

$$F = p_x \frac{\partial E}{\partial x} + p_y \frac{\partial E}{\partial y} + p_z \frac{\partial E}{\partial z}$$

$$\frac{\partial E}{\partial z} = 10^5\, NC^{-1} m^{-1},\ p_z = -10^{-7}\, Cm,\ p_x = 0,$$

$$p_y = 0, \frac{\partial E}{\partial x} = 0, \frac{\partial E}{\partial y} = 0$$

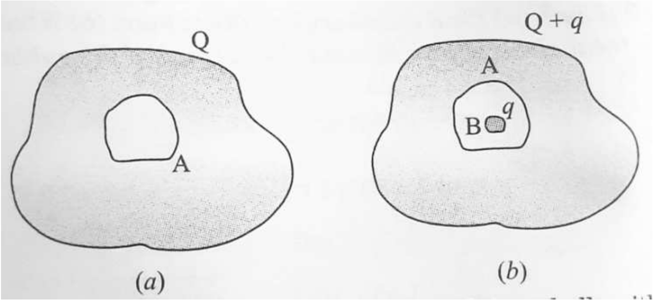
$$F = 0 + 0 - 10^{-7} \times 10^5\, N = -10^{-2}\, N$$

The negative sign indicates that the force is along negative Z-axis.

Let us now calculate torque. Both $\vec{P}$ and $\vec{E}$ are Z-axis.

$\therefore \sin\theta = 0 \quad \therefore \tau = pE\sin\theta = 0$

28. A conductor A with cavity as shown Fig. (i) is given a charge Q. shown that the entire must appear on the outer surface of the connect (b) Another conductor B with charge Q is insert the cavity keeping B insulated from A. Sown Total charge on the outside surface of A is Q + e sensitive instrument is to be shielded from the electrostatic fields its environment. Suggest way.



Ans. (a) Choose a Gaussian surface lying wholly the conductor and enclosing cavity. We may take this gravity surface just inside the outer surface of the conductor. What that the net electric field inside a conductor is zero gauss's law, $\oint \vec{E} \cdot \vec{dS} = \frac{q}{\epsilon_0}$, we get q=0. Clearly, the charge Q lies on the outer surface of the conductor

(b) The charge +q on conductor B will induce conductive charge on the inner wall, of the conductor, form cavity. The positive induced charge +q will move to the surface of conductor A. thus, the total charge on the surface of the conductor will be (Q + q).

(c) A sensitive instrument can be shielded from strong electrostatic field by keeping that instrument metal conductor.

29. A hollow charged conductor has a cut into its surface. Show that the electric field hole is $(\sigma/2\varepsilon_0)\hat{n}$, where $\hat{n}$ is the unit vector in forward normal direction, and σ is the surface charge sity near the hole.

Ans. consider the conductor with the hole. Then the field just outside is $(\sigma/2\varepsilon_0)\hat{n}$ and is zero inside this field as s superposition of the field due to the hole plus the field due to the rest of the charged side, they are equal both in magnitude and direction the field due to the rest of the conductor is $(\sigma/2\varepsilon_0)\hat{n}$

30. Obtain the formula for the electric due to a long thin wire of uniform linear charge λ without using Gauss's law.

Ans. Let dE be the electric field at P due to charge element dq = λ dx,

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

$$dE_x = dE\sin\theta$$

and $$dE_y = dE\cos\theta$$

$$\sum dE\sin\theta = 0$$

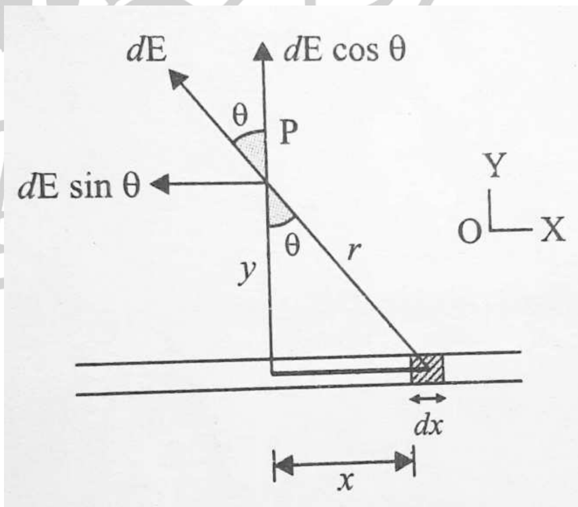
Now, $dE\cos\theta$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda dx}{r^2}\frac{y}{r}$$

Again, $x = y\tan\theta$

$$dx = y\sec^2\theta d\theta$$

$$= \frac{y}{\cos^2\theta}d\theta$$



Also, $\cos\theta = \frac{y}{r}$ or $r = \frac{y}{\cos\theta}$ or $\frac{1}{r} = \frac{\cos\theta}{y}$

Now, $dE\cos\theta = \frac{\lambda}{4\pi\varepsilon_0}\left(\frac{y}{\cos^2\theta}d\theta\right)\left(\frac{\cos\theta}{y}\right)^2\cos\theta$

Or $dE\cos\theta = \frac{\lambda}{4\pi\varepsilon_0 y}\cos\theta\, d\theta$ $E = \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \frac{\lambda}{4\pi\varepsilon_0 y}\cos\theta\, d\theta = \frac{\lambda}{4\pi\varepsilon_0 y}\left|\sin\theta\right|_{-\pi/2}^{+\pi/2}$

$= \frac{\lambda}{4\pi\varepsilon_0 y}\left[\sin\frac{\pi}{2} - \sin\left(-\frac{\pi}{2}\right)\right] = \frac{\lambda}{2\pi\varepsilon_0 y}$

31. It is now believed that protons and neutrons (which constitute nuclei of ordinary matter) are themselves built out of more elementary units called quarks, A proton and a neutron consist of three quarks each. Two types of quarks, the so called up' quark (denoted by u) of charge +(2/3) e, and the down quark composition of a proton and neutron.

Ans. (i) Suppose there are n up quarks in a proton. Then, the number of down quarks is (3–n). We are considering quarks composition of proton.

Now, $+e = \frac{2e}{3}n - \frac{e}{3}(3-n)$

Or $\frac{2ne}{3} + \frac{ne}{3} = 2e \text{ or } ne = 2e \text{ or } n = 2$

So, there are 2 up quarks and 1 downquarks. Thus, the possible composition of a proton **uud**.

(ii) Suppose there are n up quarks in a neutron. Then, the number of down quarks is (3-n).

Now, $0 = \frac{2e}{3}n - \frac{e}{3}(3-n)$

Or $\frac{2ne}{3} + \frac{ne}{3} = e \text{ or } ne = e \text{ or } n = 1$

So, there is 1 up quark and 2 down quarks. Thus, the possible quark composition a neutron is **udd**.

32. (a) consider an arbitrary electrostatic field configuration. A small test charge is placed at a null point (i.e., where $\vec{E} = 0$) of the configuration. Show that the equilibrium of the test charge is necessarily unstable.

(b) Verify this result for the simple configuration of two charges of the same magnitude and sign placed a certain distance apart.

Ans. (a) Let us prove it by contradiction. Suppose that equilibrium is stable. Then the test charge displaced slightly in any direction will experience a restoring force towards the null-point. So, all field lines near the null point should be directed inwards towards the null-point. That is, there is a net inward flux of electric field through a closed surface around the null-point. But by Gauss's law, the flux of electric field through a surface, not enclosing any charge, must be zero hence, the equilibrium cannot be stable

(b) The mid-point of the line joining the two charges is a null-point. Displace a test charge from the null-point slightly along the line. There is a restoring force. But when it is displaced normal to the line, the net force takes it away from the null-point. Note that the stability of equilibrium needs restoring force in all direction.

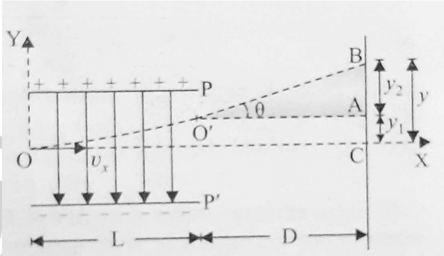
33. A particle of mass m and charge (–q) enter the region between the two charged plates, initially moving along *x*-axis with speed v_x (like particle 1 in Fig of Q 14. The length of plate is L and an uniform electric field E is maintained between the plates. Show that the vertical deflection of the particle at the far edge of the plate is $\frac{qEL^2}{2mv_x^2}$

Ans. Concept: this is the theory part of motion of charge particle in uniform electric field.

Gravitational force mg is neglected and the electric field is constant throughout the plate along vertical. X component is zero. And hence charge (–q) has only vertical acceleration $a_y = \frac{F_e}{m} = \frac{qE}{m}$, intial velocity in y direction is zero.

For horizontal uniform motion $x = v_x t \; or \; t = \frac{x}{v_x}$

$$y = u + \frac{1}{2}at^2 \; here(u_y = 0)$$



Put the value of a_y & t in this equation we get $y = \frac{1}{2}\frac{qE}{m}(\frac{x}{v_x})^2$

Here within the range of plate particle follow parabolic path, hence vertical deflection of particle at x=L, y=y_1

Hence $y_1 = \frac{1}{2}\frac{qE}{m}(\frac{L}{v_x})^2 = \frac{qE}{2mv_x^2}L^2$

34. Suppose that the particle in Question 33 an electron projected with velocity $v_x 2.0\times10^6 \, ms^{-1}$. If between the plate separated by 0.5 cm is $9.1\times10^2 \, NC^{-1}$ where will the electron strike the upper plate? Given: $|e| = 1.6\times10^{-19}C, m_e = 9.1\times10^{-31}kg$

Ans. $v_x = 2.0\times10^6 ms^{-1}, d = 0.5cm = 5\times10^{-3}m$

Suppose, the electron strikes the upper plate

At $x = L, \; y = \frac{d}{2} = \frac{5\times10^{-3}}{2}m = 2.5\times10^{-3}m$

$y = \frac{1}{2}\frac{qE}{m}\left(\frac{L}{v_x}\right)^2 \; or \; L = \sqrt{\frac{2my}{qE}}v_x$

$L = \sqrt{\frac{2\times9.1\times10^{-31}\times25\times10^{-3}}{16\times10^{-19}\times9.1\times10^2}}\times2\times10^5 m$

$= 1.12\times10^{-2}m = 1.12\,cm$

Note: For Discussions of all detailed solutions please visit my YouTube channel *<u>SinghRajeshPhysics</u>*

Thank You