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Electron

Properties of cathode rays does not depend upon the material of electrodes & nature of gas used so electrons are the basic constituent of all atoms.

Discovery of electron (Not for exam)

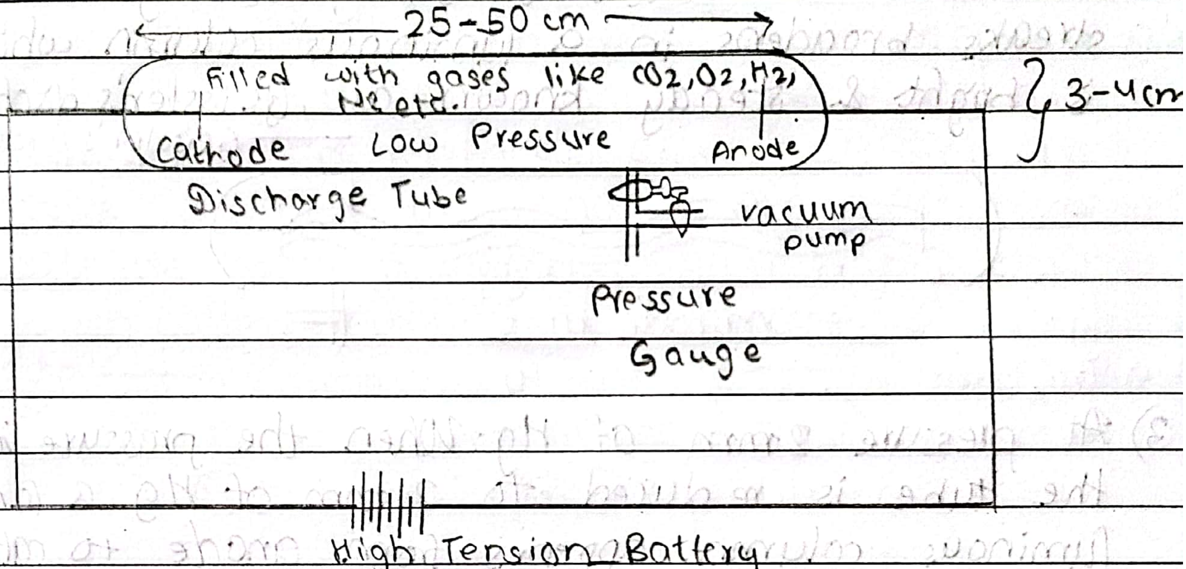
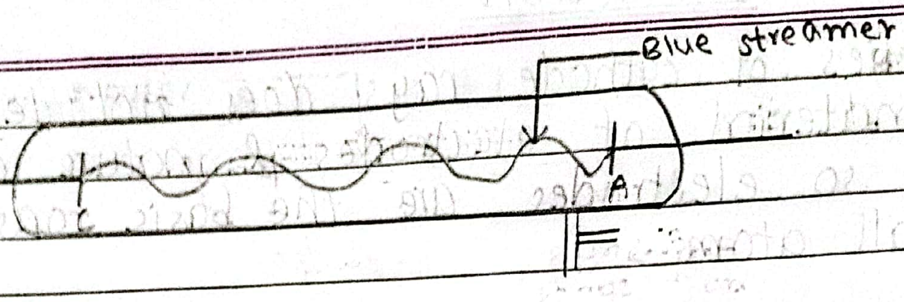


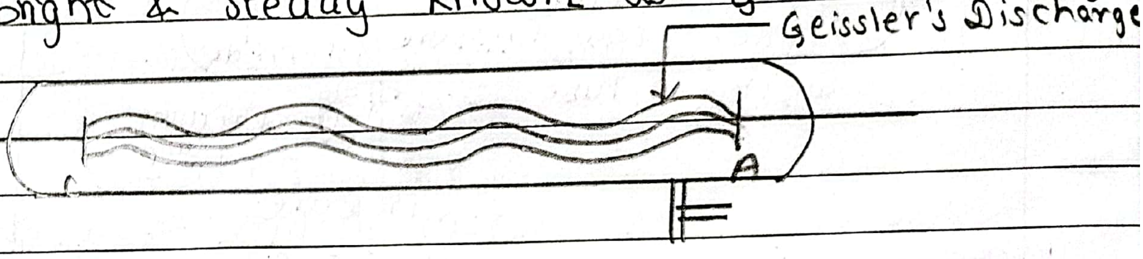
fig: Discharge Tube Experiment

A normal gas at NTP doesn't conduct electric current through it because there will be no free electrons or ions present. However the gas can be made conducting
i) By reducing pressure
ii) By applying high voltage of 30 kV/cm.

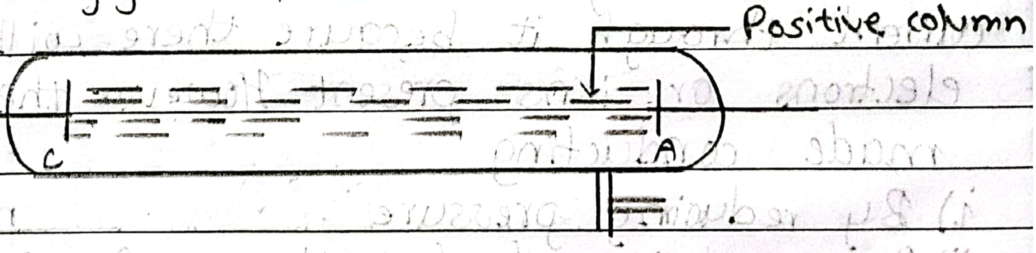
1) At pressure 10 mm of Hg: When the pressure inside the tube is reduced to 10 mm of Hg cracking sound is produced inside the tube & a luminous streak appears between electrodes called blue streamer.



2) At pressure 5 mm of Hg: When the pressure inside the tube is reduced to 5 mm of Hg a blue streaks broadens in a luminous column which is bright & steady known as Geissler's discharge.



3) At pressure 2 mm of Hg: When the pressure inside the tube is reduced to 2 mm of Hg a long luminous column appears from anode to cathode called positive column & colour depends upon nature of gas used. For eg:- blue for hydrogen, red for oxygen & bluish white for carbon dioxide.



4) At pressure 1 mm of Hg: When the pressure inside the tube is reduced to 1 mm of Hg a positive column gets detach from cathode & moves towards anode. A blue glow appears at cathode known as negative glow. A dark space between positive column & negative glow is called faraday's dark space.

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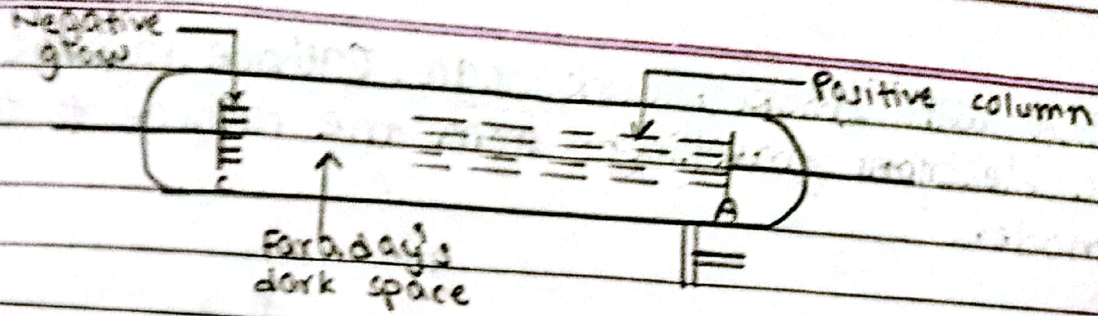
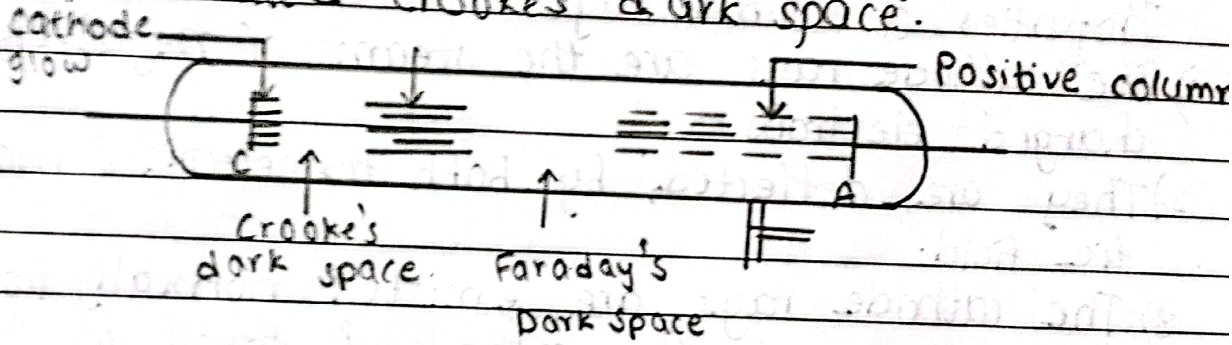
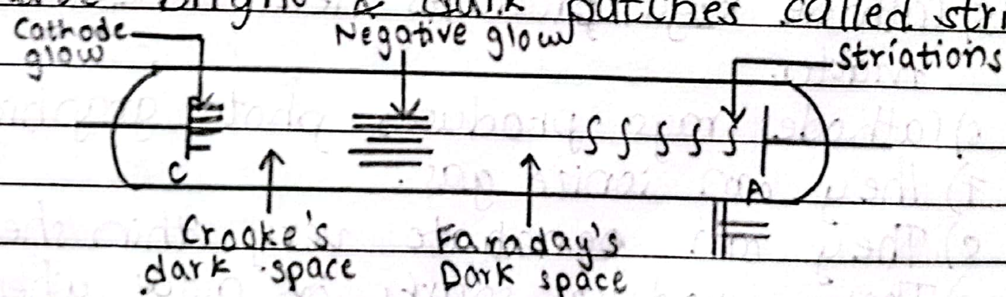


5) At pressure 0.5 mm of Hg: When the pressure inside the tube is reduced to 0.5 mm of Hg a positive column gets shorten, negative glo leaves the cathode & another glow appears on cathode called cathode glow. Negative glow moves towards the anode. The space between cathode glow & negative glow appears dark & is called Crooke's dark space.

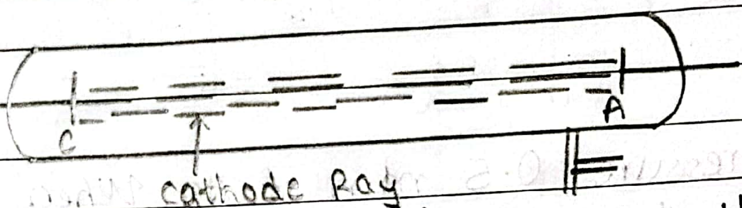


6) At pressure 0.05 mm of Hg: When the pressure inside the tube is reduced to 0.05 mm of Hg a positive column shortens & breaks into alternative bright & dark patches called striations.



7) At pressure 0.01 mm of Hg: When the pressure inside the tube is reduced to 0.01 mm of Hg the negative glow, cathode glow, Faraday's dark space; striations vanishes & the whole tube is

filled with crooke's dark space. Cathode rays are the electrons travelling from the cathode to the anode.



8) At pressure 0.001 mm of Hg: When the pressure inside the tube is reduced to 0.001 mm of Hg again the electric discharge gets stops because there will be no free electrons or ions to carry the electric charges.

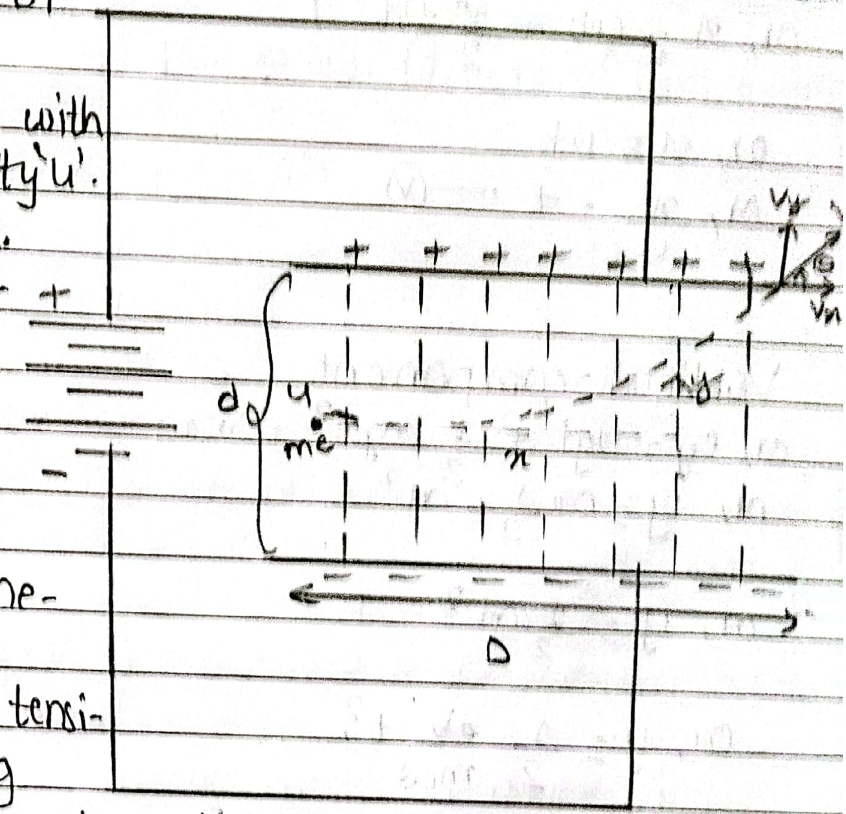
electrons
Properties of cathode rays

1) The cathode rays are the steams of negatively charged electrons.
2) They are deflected by both the electric & magnetic field.
3) The cathode rays are emitted normally from the surface of the cathode & travel in straight line.
4) The cathode rays put shadow of the object on which they fall.
5) Cathode rays produces heat when they fall on matter.
6) Cathode rays produces photo graphic effect.
7) They can ionize gas.
8) They can penetrate very thin sheet of matter
9) They produce sparks or glow when they fall on fluorescence material like phosphorus.
10) The cathode rays travel very fast almost with 1/10 of speed of light in vacuum.
11) When fast moving cathode rays strike a solid

target of high atomic number like tungsten x-rays are produced.

Motion of an electron beam inside the electric field:

Consider a beam of an electron having mass 'me' moving with a uniform velocity 'u' in a straight line. Consider two parallel metal plates, where upper plate is connected to positive terminal & lower plate is connected to negative terminal of high tension battery having potential 'V' & 'd' be the distance between two horizontal parallel plates.



Then, the electric field intensity is

$$E = \frac{V}{d} \quad \text{--- (i)}$$

Also, force due to the electric field

$$F_e = eE \quad \text{--- (ii)}$$

And, vertical acceleration experienced by electron

$$F = ma \quad \text{--- (iii)}$$

Now, Equating eq^{ns} (ii) & (ii) we get,

$$F = F_e$$

or, $m_e a = eE$

or, $a = \frac{eE}{m_e}$

or, $a = \frac{eV}{m_e d}$ --- (iv)

For the path of an electron,

Horizontal component :

or, $S_x = u_x t + \frac{1}{2} a_x t^2$

or, $x = ut + \frac{1}{2} \cdot 0 \cdot t^2$

or, $x = ut$

or, $\frac{x}{u} = t$ —— (v)

Vertical component

or, $S_y = u_y t + \frac{1}{2} a_y t^2$

or, $y = 0 + \frac{1}{2} at^2$

or, $y = \frac{1}{2} at^2$

or, $y = \frac{1}{2} \frac{eV}{med} t^2$

or, $y = \frac{1}{2} \frac{eV}{med} \left(\frac{x}{u}\right)^2$

or, $\boxed{y = \frac{1}{2} \frac{eV}{med} \frac{x^2}{u^2}}$ —— (vi)

or, $\boxed{y \propto x^2}$

Hence, the path of an electron beam inside electric field is parabolic in nature.

For velocity of an electron

Horizontal component of velocity

or, $V_x = u_x + a_x t$

or, $V = u + 0$

or, $V = u$ —— (vii)

Vertical component of velocity

or, $V_y = u_y + a_y t$

or, $V_y = 0 + at$

or, $V_y = \frac{eV}{med} \cdot t$

or, $V_y = \frac{eV}{med} \cdot \frac{x}{u}$ $\therefore x = D$ [length of horizontal plate]

or, $V_y = \frac{eV}{med} \cdot \frac{D}{u}$ — (viii)

Resultant velocity

$V_r = \sqrt{V_x^2 + V_y^2 + 2V_x \cdot V_y \cdot \cos\theta}$ $\because \theta = 90°$

$V_r = \sqrt{V_x^2 + V_y^2}$

$V_r = \sqrt{u^2 + \left(\frac{eV}{med} \times \frac{D}{u}\right)^2}$

For kinetic energy:

$(KE)_{Initial} = \frac{1}{2} mu^2$

$(KE)_{Final} = \frac{1}{2} m_e V_r^2$

KE inside the electric field

$KE = (KE)_{final} - (KE)_{Initial}$

$KE = \frac{1}{2} m_e V_r^2 - \frac{1}{2} m_e u^2$

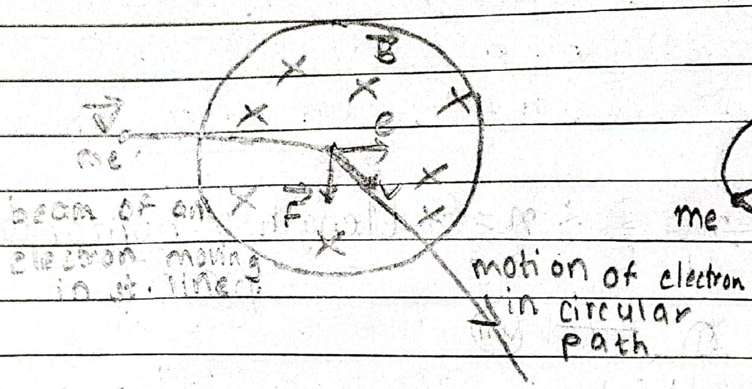
$KE = \frac{1}{2} m_e \left\{ \sqrt{u^2 + \left(\frac{eV}{med} \times \frac{D}{u}\right)^2} \right\}^2 - \frac{1}{2} m_e u^2$

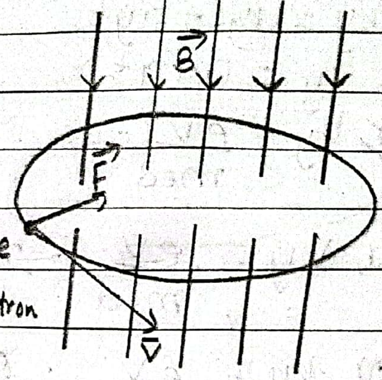
$KE = \frac{1}{2} m_e \left\{ u^2 + \left(\frac{eV}{med} \times \frac{D}{u}\right)^2 \right\} - \frac{1}{2} m_e u^2$

$KE = \cancel{\frac{1}{2} m_e u^2} + \frac{1}{2} m_e \left(\frac{eV}{med} \times \frac{D}{u}\right)^2 - \cancel{\frac{1}{2} m_e u^2}$

$KE = \frac{1}{2} m_e \left(\frac{eV}{med} \times \frac{D}{u}\right)^2$

Motion of an electron beam inside Magnetic field:-





Consider a beam of an electron is moving with uniform velocity 'v' inside a magnetic field where 'e' be the charge of the electron, 'B' be the magnetic flux then Llowerence Force experienced by the electron

$$\vec{F} = e(\vec{v} \times \vec{B})$$

$$F = e\,vB\sin\theta \qquad \because \sin\theta = \sin 90^\circ = 1$$

$$F = eBv \quad \text{--- (i)}$$

When electron beam moves inside the magnetic field the magnitude of velocity remains constant but its direction changes. Hence, inside the magnetic field electrons moves in a circular path.

We know, from the centripetal force,

$$F = \frac{mv^2}{r} \quad \text{--- (ii)}$$

where 'r' be the radius of a circular path.

Now, comparing eqn (i) & (ii), we get,

or, $eBv = \frac{mv^2}{r}$

or, $eB = \frac{mv}{r}$

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or, $eB = \frac{m \omega r}{r}$

or, $eB = m\, 2\pi f$

$\boxed{\therefore \frac{eB}{2\pi m} = f}$ which is the required frequency of motion of an electron beam inside Magnetic field.

Short Questions. Lesson: 1 Pg: 50-

1. a) Why are soldiers ordered to break steps while crossing a bridge?

→ When frequency of steps becomes equal to the natural frequency of the bridge, then the resonance occurs & the bridge starts to oscillate with maxmimum amplitude. This may collapse the bridge. Hence, the soldiers are ordered to break steps while crossing a bridge.

c) Why are bells made of metal & not of wood?

→ The damping occurs quickly in wood than in metals. Due to this, wood doesn't vibrate for a long time but the metal bells vibrote for a long time. Therefore, the bells are made of metal.

4. a) A pendulum is taken to moon. Will it gain or lose time?

→ The time period of a pendulum is $T = 2\pi\sqrt{\frac{l}{g}}$. When the pendulum is taken to moon, then the value of g decreases & hence value of T increases. Hence, the pendulum clock loses the time.

b) How does the frequency of a simple pendulum related with its length? Hence estimate the frequency of a second's pendulum.

→ The time period T is, $T = 2\pi\sqrt{\frac{l}{g}}$

And, frequency f is, $f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$.

This shows that frequency f of a simple pendulum is inversely proportional to the length of the pendulum.

Also, for a second's pendulum,
T = 2 secs. So, frequency f of second's pendulum is,
$f = \frac{1}{T} = \frac{1}{2} = 0.5\ Hz$.

c) What are the drawbacks of simple pendulum?

→ Followings are the drawbacks of a simple pendulum.
i) No heavy point mass as we assume.
ii) The suspension point may not be perfectly rigid.
iii) No string is weightless & perfectly inextensible.
iv) The amplitude of vibration may be large.
v) The effective length can not be calculated exactly.

7. a) A pendulum clock is in an elevator that descends at constant velocity. Does it keep correct time? If the same clock is in an elevator in free fall, does it keep correct time?

→ The time period of a pendulum clock is, $T = 2\pi\sqrt{\frac{l}{g}}$
When the elevator descends at constant velocity, the effective value of acceleration due to gravity 'g' is constant neglecting variation of

g with altitude. Hence the clock keeps correct time. When the elevator falls freely, then the effective value of acceleration due to gravity is zero. Hence the time period becomes infinite & the clock doesn't keep correct time.

c) Why do we say that velocity & acceleration of a particle executing SHM are out of phase?
⇒ Since, in SHM, velocity (v) & acceleration (a) are given by, $v = r\omega \cos \omega t$
&, $a = -\omega^2 y = -\omega^2 r \sin\omega t = r\omega^2 \cos\left(\omega t + \frac{\pi}{2}\right)$

The phase difference between v & a is $\pi/2$. So, v & a are out of phase in SHM.

10. a) A SHM is represented as $y = a\cos(\omega t + \phi)$ in usual notation. Find its acceleration.
→ Given, the displacement y in SHM is,
$y = a\cos(\omega t + \phi)$
The velocity v is,
$v = \frac{dy}{dt} = \frac{d}{dt}[a\cos(\omega t + \phi)]$

or, $v = -a\omega \sin(\omega t + \phi)$
And, the acceleration "a" is,
$a = \frac{dv}{dt} = \frac{d}{dt}[-a\omega \sin(\omega t + \phi)]$

$= -a\omega.\omega.\cos(\omega t + \phi) = -\omega^2[a\cos(\omega t + \phi)]$
$\therefore a = -\omega^2 y$

b) Distinguish between periodic motion & oscillatory motion.
⇒ The motion, which repeats itself after equal

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interval of time, is called a periodic motion.
If a body moves back & forth (to & fro) repeatedly about a mean position, then it is said to ~~pro~~ possess oscillatory motion. For example, the revolution of a planet around the sun is a periodic motion but not an oscillatory motion. Therefore, all oscillatory motion are periodic but all periodic motion may not necessarily to be oscillatory.

5. a) A man sitting on swing stands up. What will be the effect on the periodic time of the swing?

→ Since, $T = 2\pi\sqrt{\frac{l}{g}}$. When the man stands up the centre of mass (c.m) is raised upward & hence the effective length (l) of the pendulum decreases. Due to this, the time period (T) of the swing decreases.

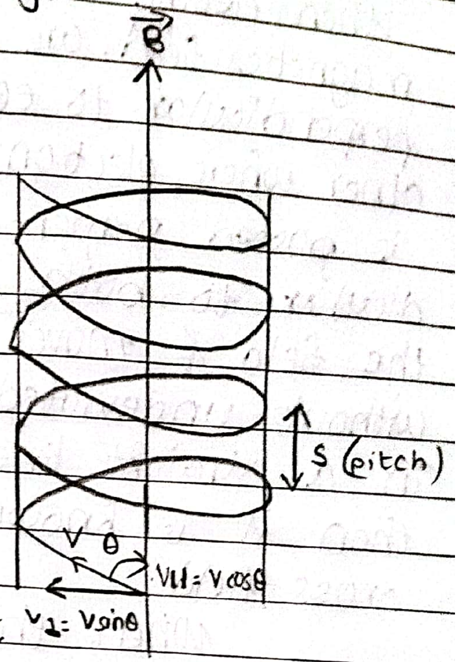
c) What do you understand by a second's pendulum? If it is taken to moon, will it gain or lose time? Why?

→ A simple pendulum having time period 2 seconds is called a second's pendulum. We have,

$T = 2\pi\sqrt{\frac{l}{g}}$

And, T = 2 sec for a second pendulum on earth. At moon, value of g decreases but l remains same. So, T increases when it is taken to moon. This means the pendulum loses time when taken to moon.

Motion of an electron beam inside Magnetic field by making certain angle:



Consider an electron beam moving with velocity V by making certain angle θ with the magnetic field then velocity resolves into two components where parallel component, $V_{\parallel} = V\cos\theta$ & perpendicular component, $V_{\perp} = V\sin\theta$.

The parallel component of velocity helps electron to move in a straight path whereas perpendicular components helps to move in a circular path.

We have,

$$\text{or, } r = \frac{mV_{\perp}}{Be}$$

$$\text{or, } r = \frac{mV\sin\theta}{Be}$$

Also,

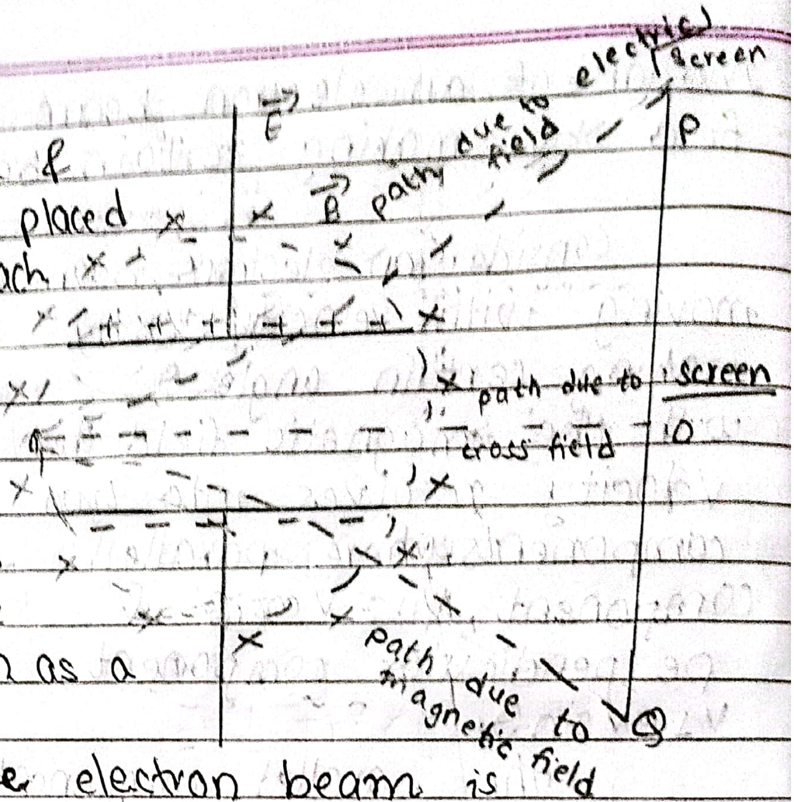
$$T = \frac{2\pi m}{eB}$$

The linear distance travel by electron when it completes one circular path is known as pitch & denoted by 's' which is also known heliax.

$$s = V_{\parallel} \times T$$

$$s = V\cos\theta \times \frac{2\pi m}{eB}$$

Cross field :
When electric field & magnetic field are placed perpendicular to each other where electron is passed perpendicular to both the field & moves without undeviated in a straight line then it is known as a cross field.



When the electron beam is passed through only the electric field then it moves in a parabolic path & strikes on the position P on the screen.

i.e. $F_e = eE$ — (i)

Now, when the electron beam is passed through only magnetic field then it moves in a circular path & strikes at the position Q on the screen

i.e. $F_B = BeV$ — (ii)

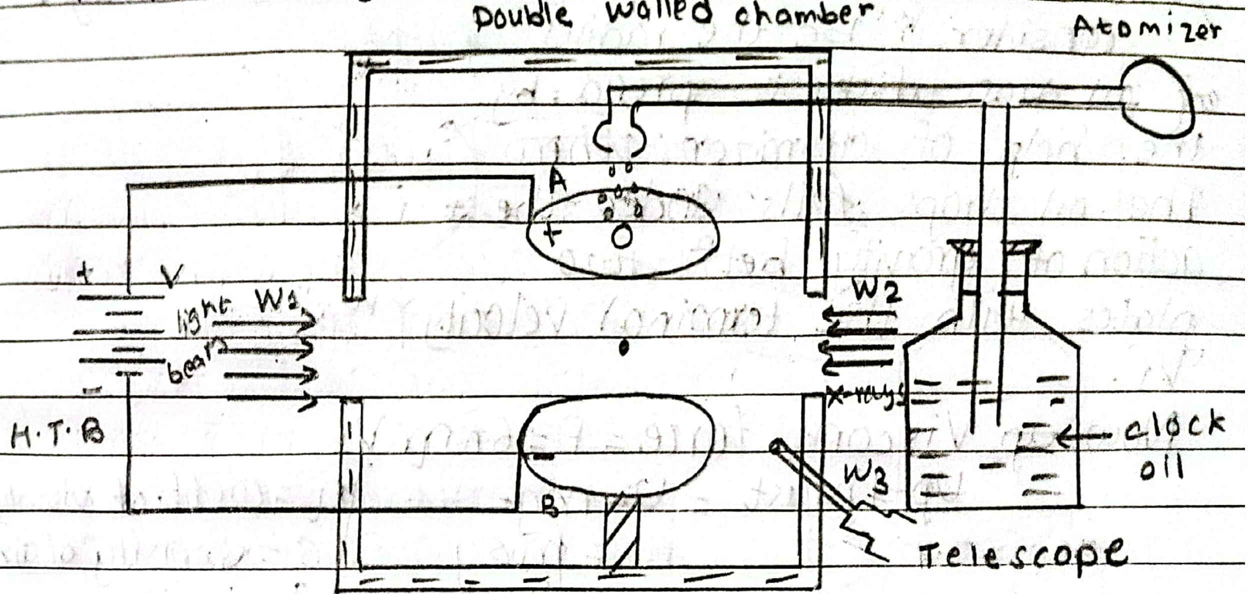
When the electron beam is passed through the cross field i.e. (electric field & magnetic field are perpendicular to each other) then electrons moves in a straight path without undeviated due to equal force acting on it

i.e. $F_e = F_B$

$\cancel{e}E = B\cancel{e}V$

$\frac{E}{B} = V$

Millikan's oil drop Experiment:



Millikan's oil drop experiment consists of a thick double wall chamber inside which water is circulating, to balance the temperature. Two circular metal plates about diameter 20 cm is placed. Upper plate A has a small hole for oil drops to pass which is connected with positive terminal of high tension battery & lower plate is connected with negative terminal. Clock oil is spread inside the chamber by the help of atomizer. Light is passed through a window 'W_1' & x-rays are passed through a window 'W_2' for which helps for ionization & the motion of oil drops are observed by window 'W_3' with the help of microscope/telescope.

By using the stoke's law, millikan's determine the radius of an oil drop & charge of an electron.

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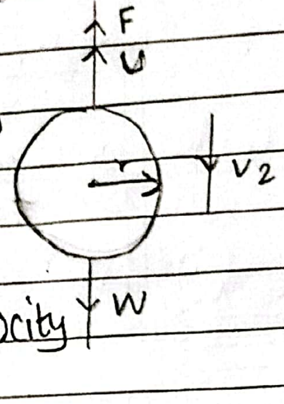
1) Motion of an oil drop under action of gravity:



Consider 'r' be the radius of oil drop which is spread by the help of atomizer. ~~When~~ The oil drops falls under the action of gravity betn two plates with the terminal velocity 'V_1'.

Now, ~~up~~ Viscons force $= F = 6\pi\eta r V_1$

Up-thrust $= U = mg$
$= m\sigma g$
$= \frac{4}{3}\pi r^3 \sigma g$

η = coeff. of viscosity
σ = density of air
ρ = density of oil drop

Force acting upward $= F + U$
$= 6\pi\eta r V_1 + \frac{4}{3}\pi r^3 \sigma g$

Force acting downward $= W$
$= mg$
$= V\rho g$
$= \frac{4}{3}\pi r^3 \rho g$

Under equilibrium condition
Force acting upward = force acting downward

or, $F + U = W$

or, $F = W - U$

or, $6\pi\eta r V_1 = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g$

or, $6\pi\eta r V_1 = \frac{4}{3}\pi r^3 g(\rho - \sigma)$

or, $3\eta V_1 = \frac{2}{3} r^2 g(\rho - \sigma)$

or, $\frac{9\eta V_1}{2g(\rho - \sigma)} = r^2$

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$$\text{or, } r = \sqrt{\frac{9\eta v_1}{2g(\rho-\sigma)}}$$

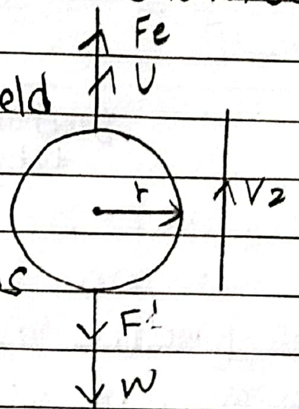
2) Motion of oil drop under action of electric field

When the oil drop is spread between the plates & high tension battery is connected & x-rays are passed inside the chamber which ionizes the gas.

When, F_e = force due to electric field

F' = Viscous force

Oil drop is moving with terminal velocity v_2 towards upper +ve plate.



Force acting upward = $F_e + U$

Force acting downward = $W + F'$

Under equilibrium condition,

Force acting upward = Force acting downward

$$\text{or, } F_e + U = W + F'$$

$$\text{or, } F_e = W - U + F'$$

$$\cancel{\text{or, } F_e = F + F'}$$

$$\text{or, } qE = 6\pi\eta r v_1 + 6\pi\eta r v_2 \qquad \because E = \frac{V}{d}$$

$$\text{or, } \frac{qV}{d} = 6\pi\eta(v_1 + v_2) r$$

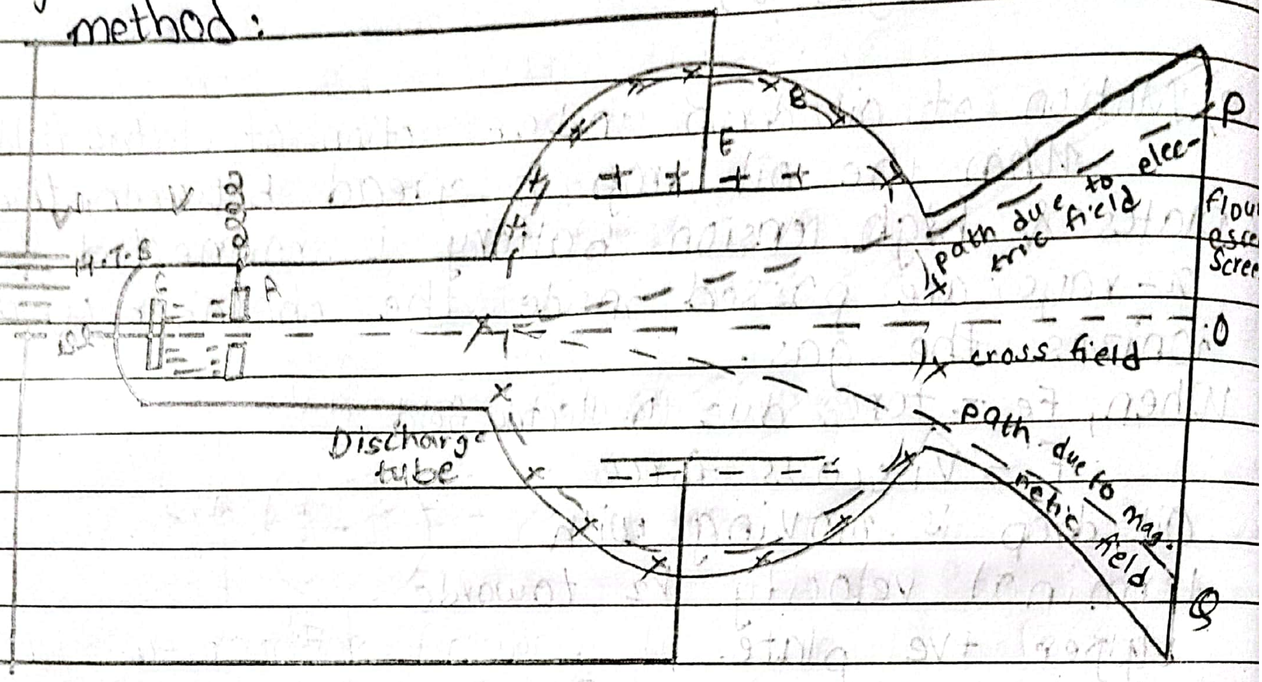
$$\text{or, } q\frac{V}{d} = 6\pi\eta(v_1 + v_2)\sqrt{\frac{9\eta v_1}{2g(\rho-\sigma)}}$$

$$\text{or, } q = \frac{6\pi\eta d}{V}(v_1 + v_2)\sqrt{\frac{9\eta v_1}{2g(\rho-\sigma)}}$$

$$\cancel{\text{or, } q = \frac{6\pi\eta d}{V}(v_1 - v_2)\sqrt{9\eta}}$$

which is the req. eqn for Millikan's oil drop experiement from which charge of an electrons can be determined.

Specific charge (e/m) of an electron by J.J thomsons method:



J.J thomsons determines the speific charge $\left(\frac{e}{m}\right)$ of an electron by using discharge tube experiment. Appartus of an experiment consists of a discharge tube where cathode & anode is placed which is connected with potential 'V' A small hole is made in anode for electrons to pass through it.

Electric field & magnetic field are applied perpendicular to each other & a flouresent screen is placed to observe the motion an electron.

When the electron beam is passed through only the electric field where 'V'' is potential. Then, it follows parabolic path & strikes on the position P on the screen.

i.e. $F_e = eE$ —(1) $\therefore E = \frac{V'}{d}$

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When the electron is passed through only the magnetic field then it moves in a circular path & strikes on the position 'g' on the screen

i.e. $F_B = Bev$ — (ii)

When the electron is passed through a cross field then it moves without deviating in a straight line.

i.e. $F_e = F_B$

or, $eE = Bev$

or, $\frac{E}{B} = v$ — (iii)

Now, the kinetic energy of an electron $= \frac{1}{2}mv^2$

Work done by accelerating potential energy $V = eV$

Now,

KE of electron work done by accelerating potential

or, $\frac{1}{2}mv^2 = eV$

or, $\frac{1}{2}\frac{v^2}{V} = \frac{e}{m}$

or, $\frac{\frac{E^2}{B^2}}{2V} = \frac{e}{m}$

or, $\frac{E^2}{2VB^2} = \frac{e}{m}$

$$\boxed{\text{or, } \frac{V'^2}{2VB^2d^2} = \frac{e}{m}}$$

× (or, $\frac{e}{m} = 1.67 \times 10^{11}$ C/kg) ×

Hence, the specific charge of electron is calculated to be

or, $\frac{e}{m} = 1.76 \times 10^{11}$ C/kg

Mass of an electron:

We know,

charge of an electron $(e) = 1.6 \times 10^{-19}$ C

Specific charge of an electron $(e/m) = 1.76 \times 10^{11}$ C/kg

$$m = \frac{e}{e/m} = \frac{1.6 \times 10^{-19} \text{ C}}{1.76 \times 10^{11} \text{ C/kg}}$$

$$= \frac{1.6}{1.76} \times 10^{-19-11} \text{ kg}$$

$$= 0.9 \times 10^{-30} \text{ kg}$$

$$= 9.01 \times 10^{-31} \text{ kg}$$

Hence, 9.01×10^{-31} kg is the mass of an electron

Short question Answers. Pg: 495

1. b) Compare the specific change of an electron with that of a proton.

→ We know that,

$$\frac{\text{Specific charge of electron}}{\text{Specific charge of proton}} = \frac{\frac{e}{me}}{\frac{e}{mp}} = \frac{mp}{me}$$

$$= \frac{1.67 \times 10^{-27}}{9.1 \times 10^{-31}}$$

$$= 1835$$

Therefore, specific charge of electron = 1835 × specific charge of proton.

c) The value of specific charge (e/m) is constant for cathode rays but not for positive rays. Why?

→ cathode rays are streams of electrons. The values of charge & mass of an electron are constant whatever be the method of its origin. Hence, the specific charge (e/m) of cathode rays is constant. But on the other hand, positive rays consists of positive ions which have different masses for different gases. Due to this, the value of specific charge is not constant for positive rays.

3. a) Beams of electrons & protons having the same initial K.E. enter normally into an electric field, which beam will be more curved?

→ The deflection of a beam of charge entered perpendicularly to the electric field is given by $\tan\theta = \frac{eVD}{dmv^2} = \frac{eVD}{2dE_K}$, where $E_K = \frac{1}{2}mv^2$. Since, the K.E & other parameter for the both electron & proton are same, so both beams will have same curvatures.

Long Questions with Answers.

1. a) What is the reason we can not use water in place of the clock oil in Millikan's experiment?

→ There are two major reasons for which the clock oil is ~~used~~ in Millikan's oil drop experiment. They ~~are~~ (a) the clock oil is low vapor pressure oil which does not evaporate during the experiment & (b) it is likely to give small droplets which are required in this experiment to attain terminal velocity in order to apply stoke's law. If water is used in place of the clock oil in Millikan experiments in the one hand, the water may evaporate during the experiment; & on the other hand, the droplets of water are quite large to obtain terminal velocity. Due to this reason, water cannot be used ~~its~~ Millikan's experiment in which the clock oil is used.

2.a) Bigger drops cannot be used in Millikan's oil drop experiment. Why?

→ In the one hand, with bigger drops, the terminal velocity cannot be obtained soon after the drops are sprayed in Millikan's apparatus. If the terminal velocity is not obtained, Stokes's formula cannot be applied. On the other hand, with such large drops, very high electric field is required to be applied across the plates of Millikan apparatus. The very high electric field is very difficult to obtain. Therefore, in Millikan's oil drop experiment, bigger drops cannot be used.

3. a) What is the importance of Millikan's oil drop experiment?

→ The importance of Millikan's oil drop experiment is as follows:-

i) It establishes the quantum nature of electric charges.

ii) It helps to determine the charge & mass of an electron.

iii) It helps to determine the mass of hydrogen atom

iv) It helps to determine the value of Avogadro's number.

5. a) In cross field, what is the meaning of $Bev = eE$.

→ A region having two fields, electric field & magnetic field perpendicular to each other, is called a region of cross field. When the charge particle (like electron) is moving in the cross field, that particle moves without deviation by experiencing zero net force if the magnitudes of electric

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force (eE) & magnetic force (Bev) are equal. Therefore, in the cross field, force ~~ee~~ on electron due to magnetic field is equal to force on electron du to electric field. So, $Bev = eE$. Where, B & E are magnitudes of magnetic & electric field intensity respectively.

Numericals:

1) An electron moves in a circular path of radius 20 cm in a uniform magnetic field of 2×10^{-3} T. Find the speed of an electron & period of revolution. (Mass of electron $= 9.1\times10^{-31}$ kg)

Solⁿ: Here:

Radius (r) = 20 cm = 20×10^{-2} m

Magnetic field (B) = 2×10^{-3} T

Mass of electron (me) = ~~9x~~ 9.1×10^{-31} kg

velocity (v) = ?

Time taken (t) = ?

We know,

$$eB = \frac{mv}{r}$$

$$e\times2\times10^{-3} = \frac{9.1\times10^{-31}\times v}{20\times10^{-2}}$$

or, $$\frac{1.6\times10^{-19}\times2\times10^{-3}\times20\times10^{-2}}{9.1\times10^{-31}} = v$$

or, $$\frac{2\times1.6\times20}{9.1}\times10^{-3-19-2+31} = v$$

$$\therefore v = 7.03\times10^{7}\ m/s$$

Now,

$$\frac{2\pi m}{eB} = T$$

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$$\frac{2\pi \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 2 \times 10^{-3}} = T$$

$\therefore T = 1.786 \times 10^{-8}$ sec

Again,

$$f = \frac{1}{T}$$

$$= \frac{1}{1.7} \times 10^{8}$$

$$= 0.58 \times 10^{8} \text{ Hz}$$

$$= 5.8 \times 10^{7} \text{ Hz}$$

2) A beam of electron moving with a velocity of 10^7 m/sec enters midway between two horizontal parallel plates in the direction ~~plate~~ parallel to the plates which are 5 cm long & 2 cm apart & have a potential difference of V volt between them. Calculate V if the beam is deflected so that it just grazes the edge of the plate.

Sol^n: Here;

$$\frac{e}{m} = 1.76 \times 10^{11} \text{ c/kg}$$

Distance bet^n two horizontal plates (d) = 2cm = 0.02 m

$y = 1$ cm $= 0.01$ m

$D = 5$cm $= 0.05$ m

initial velocity (u) = 10^7 m/s

Now,

$$y = \frac{1}{2} \frac{eV}{m \times d} \left(\frac{D}{u}\right)^2$$

or, $0.01 = \frac{1}{2} \times 1.76 \times 10^{11} \times \frac{V}{0.02} \times \left(\frac{0.05}{10^7}\right)^2$

or, $0.01 = \frac{1.76 \times 10^{11}}{2} \times \frac{V}{0.02} \times 2.5 \times 10^{-17}$

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or, $\frac{0.01\times 2\times 0.02}{1.76\times 2.5} = 10^{11-17}\times V$

or, $9.09\times 10^{-5} = 10^{-6}\,V$

or, $9.09\times 10^{-5+6} = V$

$\therefore V = 90.9$ volt

3) In a Millikan's oil drops experiment, horizontal plates are 1.5 cm apart. With the electric field is switched off & oil drops is observed to fal with steady velocity of 2.5×10^{-2} cm/sec. When the field is switched on upper plate is being positive the drop just remains stationary. When the potential difference between the plate is 1500 v. Calculate the radius of drop & the number of electric charges neglecting the air density

Soln: Here,

Density of air $(\sigma) = 0$

Density of oil $(\rho) = 900\ kg/m^3$

$d = 1.5\ cm = 1.5\times 10^{-2}\ m$

Viscosity of air $(\eta) = 1.8\times 10^{-5}\ Nsm^{-2}$

Now,

$V_1 = 2.5\times 10^{-2}\ cm/s = 2.5\times 10^{-4}\ m/s$

$v_2 = 0\ m/s$

$V = 1500\ V$

$r = ?$

$q = ?$

We know that,

$$r = \sqrt{\frac{9\eta V_1}{2g(\rho-\sigma)}}$$

$$= \sqrt{\frac{9\times 1.8\times 10^{-5}\times 2.5\times 10^{-4}}{2\times 10(900-0)}}$$

$$= 1.5\times 10^{-6}\ m$$

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Now,

$$q = \frac{6\pi\eta(V_1+V_2)d}{V}\sqrt{\frac{9\eta V_1}{2g(\delta-\sigma)}}$$

$$= \frac{6\pi \times 1.8\times10^{-5}(2.5\times10^{-4}+0)\times1.5\times10^{-2}\times1.5\times10^{-6}}{1500}$$

$$= \frac{6\pi\times1.8\times2.5\times1.5\times1.5\times10^{-5-4-2-6}}{1500}$$

$$= 0.127\times10^{-17}$$

$$= 1.27\times10^{-18}\ C$$

Now,

$q = ne$

$\frac{q}{e} = n$

or, $\frac{1.27\times10^{-18}}{1.6\times10^{-19}} = n$

$\therefore n = 8$

4) An electron is moving with the speed of 10^7 m/s is passed into a magnetic field of intensity 0.1T. normally ($\perp$ar). What is the radius of the path of electron inside the field? If the strength of magnetic field is double, what is the radius of the new path. $e = 1.6\times10^{-19}$ C & $m = 9.1\times10^{-31}$ kg

Sol^n: Here,

Velocity(v) $= 10^7$ m/s , $e = 1.6\times10^{-19}$ C , $B = 0.1$ T

$m = 9.01\times10^{-31}$ kg

radius(r) = ?

We know,

$$Be\cancel{v} = \frac{mv^{\cancel{2}}}{r}$$

$$r = \frac{mv}{Be}$$

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$$= \frac{9.1 \times 10^{-31} \times 10^{7}}{0.1 \times 1.6 \times 10^{-19}}$$

$$= \frac{9.1}{0.1 \times 1.6} \times 10^{-31+7+19}$$

$$= 56.875 \times 10^{-5} \text{ m}$$

$$= 5.68 \times 10^{-4} \text{ m}$$

When the magnetitude of magnetic field is double,

$B = 2 \times 0.1 T = 0.2 T$

$$r = \frac{mv}{Be}$$

$$= \frac{9.1 \times 10^{-31} \times 10^{7}}{0.2 \times 1.6 \times 10^{-19}}$$

$$= 2.8 \times 10^{-4} \text{ m}$$

5) An electron is moving with velocity of 10^7 m/s enters a region of uniform magnetic flux density of 0.10 T, the angle betⁿ the direction of field & the initial path of electron is 25°. Find the actual distance betⁿ the two turns of helical path.

Solⁿ: Here,

Velocity(v) = 10^7 m/s, $B = 0.10$ T, $\theta = 25°$

$V_1 = V\sin\theta$, $V_{11} = V\cos\theta$, $m = 9.01 \times 10^{-31}$ kg

$r = ?$, $T = ?$, $s = ?$ & $f = ?$

We know that,

$$r = \frac{mv\sin\theta}{Be} = \frac{9.01 \times 10^{-31} \times 10^{7} \sin 25}{0.10 \times 1.6 \times 10^{-19}} = 2.37 \times 10^{-4} \text{ m}$$

$$T = \frac{2\pi r}{v\sin\theta} = \frac{2\pi \cdot 2.37 \times 10^{-4}}{10^{7} \cdot \sin(25)} = 3.52 \times 10^{-10} \text{ sec}$$

$S = V_{11} \times T$

$$= V\cos\theta \times \cancel{\frac{2\pi r}{v\sin\theta}} \; \frac{2\pi m}{eB}$$

$$= \frac{10^7 \times \cos 25 \times 2\pi \times 9.01\times10^{-31}}{\cancel{10^7} \sin 25 \; 1.6\times10^{-19} \times 0.10}$$

$= 9.06\times10^{6} \times 3.5\times10^{-10}$

$= 31.7 \times 10^{-4}$ m/s

Now, $f = \frac{1}{T} =$

$= \frac{1}{3.52\times10^{-10}}$

$= 2.84\times10^{9}$ m/s

6) Two plane metal plates 4cm long are held horizontally 3 cm apart in vaccum, one being vertically above the other, the upper plate is at potential of 300 V & lower is earthed. Electrons having the velocity of 10^7 m/s are injected horizontally midway betⁿ the plates & in a direction parallel to 4 cm edge. calculate the vertical deflection of electron beam as it emerges from the plate.

Solⁿ: Here,

$V = 300$ V, $u = 10^7$ m/s, $x = 4$cm $= 0.04$ m.

$d = 3$cm $= 0.03$ m, $m = 9.01\times10^{-31}$ kg, $e = 1.6\times10^{-19}$C

Now, from motion of electrons in electric field,

$$y = \frac{1}{2}\left(\frac{eV}{med}\right)\times\left(\frac{x}{u}\right)^2$$

$$= \frac{1}{2}\left(\frac{1.6\times10^{-19}\times300}{9.01\times10^{-31}\times0.03}\right)\times\left(\frac{4\times10^{-2}}{10^7}\right)^2$$

$$= \frac{1}{2}\times\frac{4.8\times10^{-17}}{2.73\times10^{-32}}\times(4\times10^{-9})^2$$

$$= \frac{1}{2}\times1.75\times10^{15}\times1.6\times10^{-17}$$

$$= \frac{1}{2}\times2.8\times0.01$$

$\therefore y = 1.4\times10^{-2}$ m

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7) Find the electric field to give the water drop of radius 10^{-5} cm just suspend in vaccum when charge in one electron?
$e = 1.6\times10^{-19}$ C, ρ water $= 1000$ kg/m^3

Soln: Here,

radius $(r) = 10^{-5}$ cm $= 10^{-7}$ m

$e = 1.6\times10^{-19}$ C & ρ water $= 1000$ kg/m^3

No. of electron $(n) = 1$

Now,

$F_e = W$

$e.E = mg$

$e.E = \frac{4}{3}\pi r^3 \rho \times g$

$1.6\times10^{-19} . E = \frac{4}{3}\pi(10^{-7})^3 \times 1000 \times 9.8$

$1.6\times10^{-19} . E = \cancel{4\pi}\ 4.105\times10^{-17}$

$E = \frac{4.105\times10^{-17}}{1.6\times10^{-19}}$

$\therefore E = 256.56 \approx 257$ V/m

8) Calculate the potential difference in volt necessary to be maintain between two horizontal conducting plates, one 5mm above the other so that small oil drop of mass 1.31×10^{-14} kg with 2 electron attached to it remains in equillibrium.

Soln: Here,

$m = 1.31\times10^{-14}$, $d = 5$ mm $= 5\times10^{-3}$ m, $g = 9.8$ m/s

$n = 2$, $e = 1.6\times10^{-19}$ C

Now,

$q = ne$

$= 2\times1.6\times10^{-19}$ C

base : $\cos\theta$
$\perp r$: $\sin\theta$

$F_e = W$

or, $qE = mg$

or, $q \times \frac{V}{d} = mg$

or, $ne \times \frac{V}{d} = mg$

or, $2 \times 1.6 \times 10^{-19} \times \frac{V}{5 \times 10^{-3}} = 1.31 \times 10^{-14} \times 9.8$

or, $V = \frac{1.31 \times 10^{-14} \times 9.8 \times 5 \times 10^{-3}}{2 \times 1.6 \times 10^{-19}}$

or, $V = \frac{1.31 \times 9.8 \times 5 \times 10^{-14-3+19}}{2 \times 16}$

or, $V = 2006\ V$

9) An oil drop of mass 3.25×10^{-15} kg falls vertically with uniform velocity, through air between vertical parallel plates which are 2 cm apart. When the potential difference of 1000 V is applied to the plate the drop move through +ve charge plate being inclined at 45° to vertical.

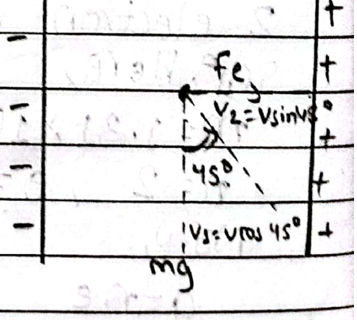
Soln: Here;

$m = 3.25 \times 10^{-15}$ kg , $d = 2\text{cm} = 2 \times 10^{-2}$

$V = 1000\ V$

$F_e = 6\pi\eta r v_2$ — (i)

$mg = 6\pi\eta r v_1$ — (ii)



Dividing eqn (i) by (ii), we get,

$$\frac{F_e}{mg} = \frac{6\pi\eta r v_2}{6\pi\eta r v_1}$$

$$\frac{qE}{mg} = \frac{v_2}{v_1}$$

$$\frac{qE}{mg} = \frac{\cancel{v}\sin 45}{\cancel{v}\cos 45}$$

$$\frac{q \times \frac{V}{d}}{3.25\times10^{-15}\times 9.8} = 1$$

$$\text{or, } q \times \frac{1000}{2\times10^{-2}} = 3.25\times10^{-15}\times 9.8$$

$$\text{or, } q = \frac{31.85\times10^{-15}\times 2\times10^{-2}}{1000}$$

$$\therefore q = 6.37\times10^{-19}\ C$$