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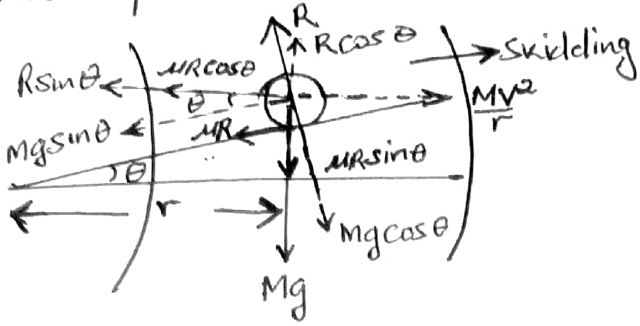
MATIGO MOCKS 2024 UACE
MARKING GUIDE PHY P510/1

1 (a) Rate of change of angle swept persecond at the Centre of the circle

(b) (i)



(ii) Resolving forces horizontally

$$\frac{mv^2}{r} = \mu R\cos\theta + R\sin\theta$$

$$\frac{MV^2}{r} = R(\mu\cos\theta + \sin\theta) \text{ ——— (i)}$$

Resolving forces vertically:

$$Mg = R\cos\theta - \mu R\sin\theta$$

$$Mg = R(\cos\theta - \mu\sin\theta) \text{ ——— (ii)}$$

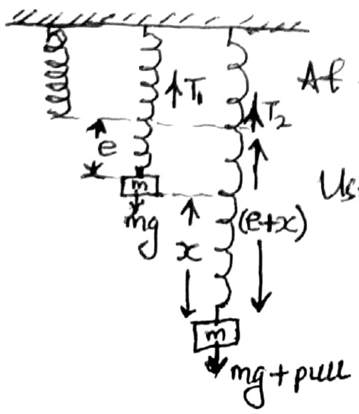
(i) ÷ (ii)

$$\frac{\frac{mV^2}{r}}{Mg} = \frac{R(\mu\cos\theta + \sin\theta)}{R(\cos\theta - \mu\sin\theta)}$$

$$\frac{V^2}{rg} = \frac{\mu + \tan\theta}{1 - \mu\tan\theta}$$

$$V_{max} = \sqrt{rg\left(\frac{\mu+\tan\theta}{1-\mu\tan\theta}\right)}$$, θ is the banked angle.

(C) (i) Before the mass is displaced vertically downwards



At equilibrium when the mass is suspended.

$T_1 = mg$

Using Hooke's law, $T_1 \propto e$, $T_1 = ke$.

$Ke = mg$.

New extension is $(e+x)$ when the mass is given a small downward pull through a small distance x and new tension is $T_2 = K(e+x)$.

When the mass is released, resultant force produces acceleration and motion is s.h.m.

$$mg - T_2 = ma$$

$$Ke - K(e+x) = ma$$

$$\cancel{Ke} - \cancel{Ke} - Kx = ma$$

$a = -\frac{K}{m}x$, which confirms s.h.m according to $a = -\omega^2 x$

– By comparison $\omega^2 = \frac{K}{m^2}$, $\frac{4\pi^2}{T^2} = \frac{K}{m}$, $T^2 = \frac{4\pi^2 m}{K}$, $T = 2\pi\sqrt{\frac{m}{K}}$.

(ii) – With no mass suspended on the spring, initial position X_0 of the pointer is read from the metre rule and recorded.

– Small mass is suspended on the spring, new position X of the pointer read and recorded.

– Extension is calculated from $e = X - X_0$ and recorded in metres.

– Mass given small downward displacement and released to oscillate.

– Time t for 20 oscillations measured using a clock, periodic time calculated from $T = \frac{t}{20}$ including the value of T^2 and recorded.

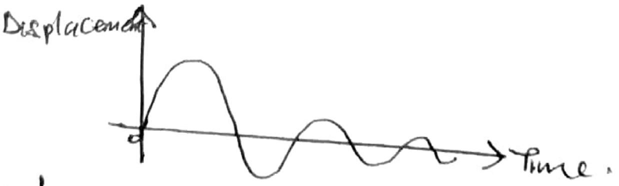
– Experiment is repeated for increasing masses and values of e, t, T and T^2 obtained and recorded

– A graph of values of T^2 is plotted against values of e and slope S determined

– Acceleration due to gravity is calculated from $g = \frac{4\pi^2}{S}$ in ms^{-2}.

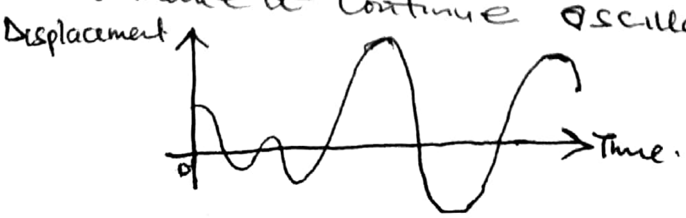
Damped oscillations:

(d) (i) Oscillations where a system loses energy causing the amplitude of its oscillation decrease progressively with time



(ii) Forced oscillations:

Oscillations where a system has a damping effect, a periodic external force is applied to the system to make it continue oscillating.

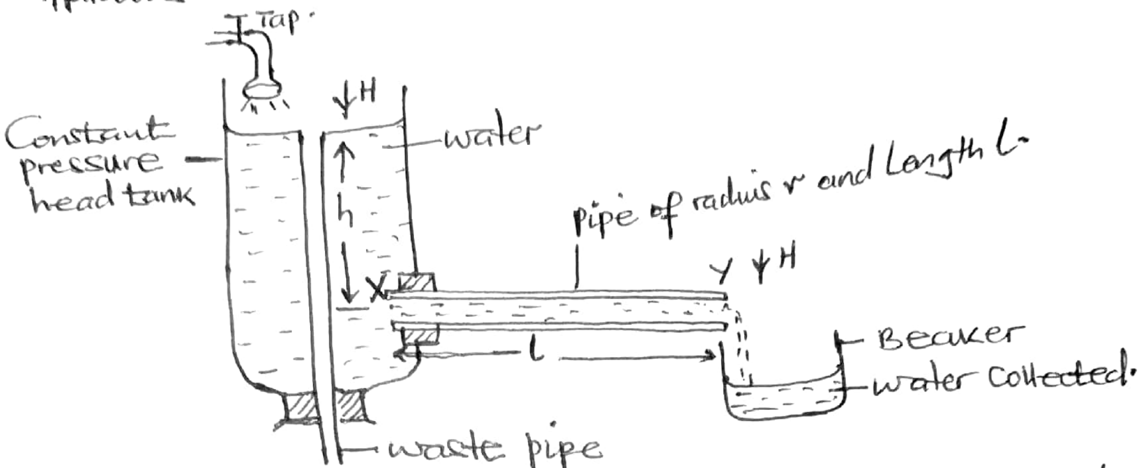


2. (a) (i) Coefficient of viscosity of the liquid

- pressure gradient across the pipe
- radius of the pipe.

(ii) Poiseulle's formular is $\frac{V}{t} = \frac{\pi r^4 p}{8\eta L} = \left(\frac{\pi r^4 \rho g}{8\eta L}\right) h$.

Apparatus:



- Water is run into a constant pressure head tank from the tap to a height h.
- The pressure at end X of the pipe inside the tank is $H + \rho hg$ and at end Y is H, H is atmospheric pressure and ρ is density of water.
- The pressure difference ρhg between ends X and Y forces the water to flow through the pipe and is collected in a beaker.
- In a time t (seconds) Volume V of water collected in the beaker is measured using a measuring cyclinder and the rate of volume flow $\frac{V}{t}$ of the water calculated and recorded.
- The experiment is repeated for different water heights h and corresponding values of volume V and $\frac{V}{t}$ obtained in equal time intervals.
- A graph of values of $\frac{V}{t}$ is plotted against values of h and slope S determined.
- Coefficient of viscosity of water is calculated from

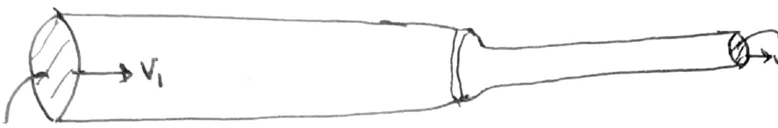
$$\eta = \frac{\pi r^4 \rho g}{8SL} \text{ in } Nsm^{-2}.$$

Assumptions

- Flow of water through the pipe must be Laminar
- Temperature is taken to be Constant
- Water is assumed to be an Incompressible liquid

(b) - Blowing over the paper creates fast moving air Leading to Low pressure. The slow moving air below the paper causes high pressure according to Bernoulli's principle. So the high upward pressure from below the paper is balanced by the downward low pressure from above the paper making the paper to stay horizontal.

(c)



$A_2 = 0{\cdot}2m^2$
$P_2 = ?$
$V_2 = ?$
$H = 1{\cdot}01 \times 10^5 pa.$

$A_1 = 0{\cdot}4m2$
$P_1 = 8{\cdot}0 \times 10^4 Nm^{-2}$
$V_1 = 1{\cdot}2ms^{-1}$
$H = 1{\cdot}01 \times 10^5 pa.$

Equation of Continuity

(i) $A_1V_1 = A_2V_2$

$0{\cdot}4 \times 1{\cdot}2 = 0{\cdot}2 \times V_2$

$0{\cdot}48 = 0{\cdot}2V_2$

$V_2 = \frac{0{\cdot}48}{0{\cdot}2} = 2{\cdot}4ms^{-1}.$

(ii) $P + \frac{1}{2}\rho v^2 = \text{Constant.}$

$\cancel{H} + P_1 + \frac{1}{2}\rho V_1^2 = \cancel{H} + P_2 + \frac{1}{2}\rho V_2^2$

$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$8 \times 10^4 + \frac{1}{2} \times 1000 \times 1{\cdot}2^2 = P_2 + \frac{1}{2} \times 1000 \times 2{\cdot}4^2$

$80000 + 720 = P_2 + 2880$

$80720 = P_2 + 2880$

$P_2 = 77{,}840 \text{ pa.}$

(d) Temperature increase weakens intermolecular forces of attraction between the molecules of the, molecular separation increase causing viscosity of the liquid to decrease.

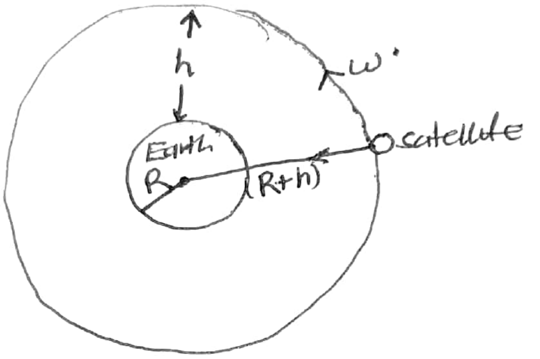
3.(a)(i) Force of attraction between two bodies in space is directly proportional to the product of their masses and inversely proportional to the square of their separation distance.

(ii) Volume of the Earth $= \frac{4}{3}\pi R^3$

Mass of the Earth $M = \frac{4}{3}\pi R^3 \rho$

Let m be mass of the satellite.

Radius of orbit $= (R+h)$.



Gravitation force of attraction between the Earth and satellite = Centripetal force on the Satellite.

$$\frac{G \times \frac{4}{3}\pi R^3 \rho \times \cancel{m}}{(R+h)^2} = \cancel{m}(R+h)\omega^2$$

$$\frac{4}{3}G\pi R^3 \rho = (R+h)^3 \times \left(\frac{2\pi}{T}\right)^2$$

$$\cancel{4}G\cancel{\pi}R^3\rho = \frac{3(R+h)^3 \times \cancel{4}\pi^{\cancel{2}}}{T^2}$$

$$T^2 G R^3 \rho = 3\pi (R+h)^3$$

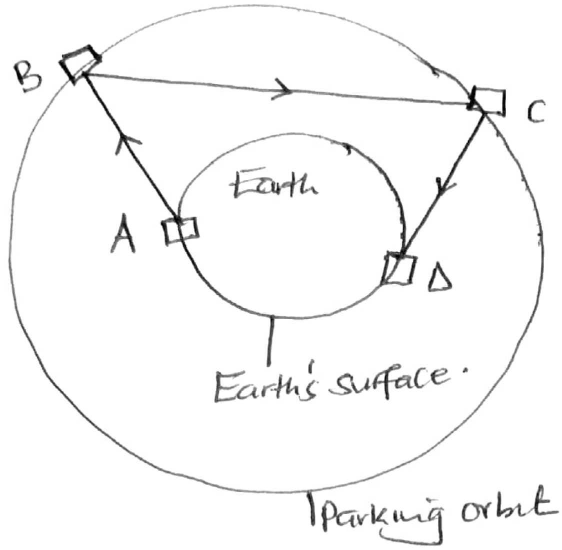
$$T^2 = \frac{3\pi(R+h)^3}{G\rho R^3}$$

$$\therefore \quad T = \sqrt{\frac{3\pi(R+h)^3}{G\rho R^3}}.$$

CamScanner

b) (i) Parking Orbit: An orbit where a satellite is observed to be stationary from one point on the Earth's Surface if its period of motion round the Earth is equal to that of rotation of the Earth about its axis which is 24hrs.

(ii)



- World-wide radio or TV Communication is achieved using four Satellites.
- Satellite A on the Earth's Surface sends Communication signals to satellite B in a parking orbit. Satellite B then sends the signals to satellite C also in the parking orbit. finally satellite C sends the same signals to satellite Δ on the Earth's Surface and Communication is Complete.

(c) Radius of the Earth $r_e = 6.4 \times 10^6 m$.
Height above Earth's Surface $h = 500km = 0.5 \times 10^6 m$.
Distance of the body from the centre of the Earth;
$r = r_e + h = (6.4 \times 10^6 + 0.5 \times 10^6) = 6.9 \times 10^6 m$.

- Inside the Earth to its Surface, $GM = g r_e^2$
- Beyond the Earth's surface, $GM = g' r^2$

$$g' r^2 = g r_e^2$$
$$g' = \frac{g r_e^2}{r^2} = \frac{9.81 \times (6.4 \times 10^6)^2}{(6.9 \times 10^6)^2}$$
$$g' = 8.44 ms^{-2}.$$

(ii) Mechanical energy = P.e + K.e

$$M.E = -\frac{GMm}{r} + \frac{GMm}{2r}$$

$$M.E = -\frac{GMm}{2r}$$

$$M.E = -\frac{6.67\times10^{-11}\times5.97\times10^{24}\times1200}{2\times6.9\times10^{6}}$$

$$M.E = \underline{\underline{-3.462\times10^{10}J.}}$$

(d) (i) For the wires P and q to have the same stress (S)

For wire P:

$$S = \frac{F_p}{A_p}, \quad A_p = 1mm^2 = 1\times10^{-6}m^2$$

$$F_p = S\times A_p.$$
$$= S\times1\times10^{-6}$$
$$= 1\times10^{-6}S$$

For wire Q.

$$S = \frac{F_Q}{A_Q}, \quad A_Q = 2mm^2 = 2\times10^{-6}m^2$$

$$F_Q = S\times A_Q$$
$$= S\times2\times10^{-6}$$
$$= 2\times10^{-6}S.$$

- At equilibrium:

$$F_p + F_Q = W$$

$$1\times10^{-6}S + 2\times10^{-6}S = W$$

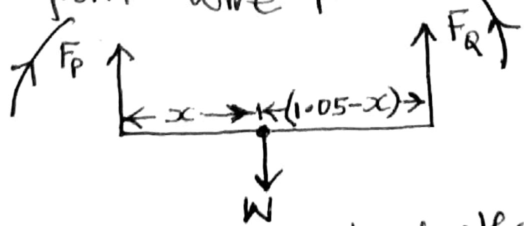
$$3\times10^{-6}S = W$$

$$S = \frac{W}{3\times10^{-6}} = \frac{W}{3}\times10^{6}Nm^{-2}.$$

- $F_p = 1\times10^{-6}\times\frac{W}{3}\times10^{6} = \frac{W}{3}N.$

- $F_Q = 2\times10^{-6}\times\frac{W}{3}\times10^{6} = \frac{2W}{3}N$

- Let the weight W be suspended at a distance x from wire P.



- Taking moments about the point of suspension of the weight

$$F_p\times x = F_Q\times(1.05-x)$$

$$\frac{W}{\cancel{3}} \times x = \frac{2W}{\cancel{3}} \times (1.05 - x)$$

$$x = 2(1.05 - x)$$

$$x = 2.1 - 2x$$

$$3x = 2.1$$

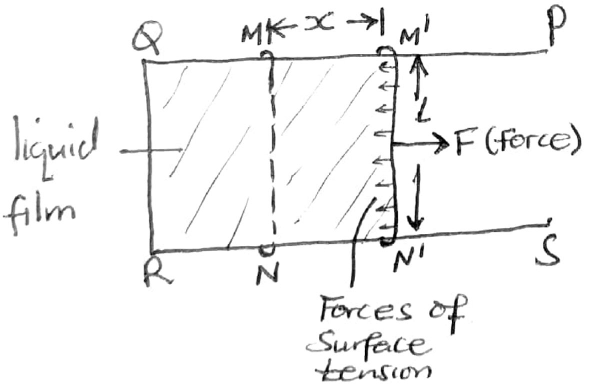
$\underline{x = 0.7m}$ from wire P or 0.35m from wire Q, where weight W should be suspended.

(ii) Strain $= \dfrac{\text{extension}}{\text{original Length}} = \dfrac{e}{L}$ for each wire.

– Since wires P and Q are of equal length, weight W should be suspended midway between P and Q so that the same extension is produced in both wires and strain will be the same.

4. a)(i) Surface ~~tens~~ tension is a tangential force acting normally per unit Length on one side of an Imaginary Line drawn in the Liquid Surface while Surface tension is the work done per unit Surface area to enelarge a liquid surface under isothermal Conditions.

(ii) – A Liquid Surface (film) is formed in the space between a loop wire of Length l and wire frame PQRS.



– Surface tension forces act on both sides of the looping wire for a total length $l + l = 2l$.

– Coefficient of Surface tension $= \dfrac{\text{Surface tension force}}{\text{Length}}$

$$\gamma = \frac{F}{2l}$$

$$F = \gamma \times 2l$$

$$F = 2\gamma l$$

- when the looping wire is pulled by force F from position MN to $M'N'$ through a distance x, surface area of the liquid film increases by $A = 2(L \times x) = 2lx$.
- Workdone by the force to pull the looping wire is

$$\text{Workdone} = \text{Force} \times \text{Distance}.$$

$$\text{workdone} = F \times x = 2\gamma l \times x = \gamma(2lx) = \gamma A$$

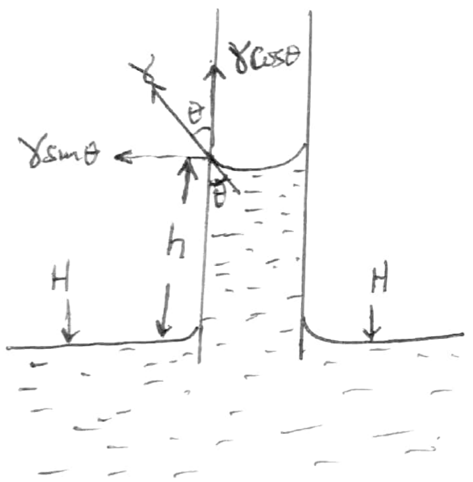
$$\frac{\text{Workdone}}{\text{Surface area}} = \frac{\gamma \cancel{A}}{\cancel{A}}$$

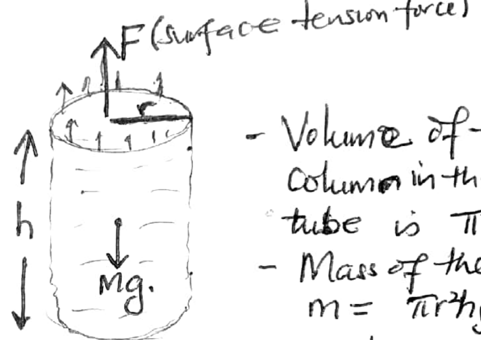
$$\sigma = \gamma.$$

$\therefore$ Surface energy = Surface tension.

(iii) Surface tension makes the liquid drop to have a spherical shape since a sphere has minimum surface area in order to increase its surface energy.

(b)





- Volume of the liquid column in the capillary tube is $\pi r^2 h$.
- Mass of the liquid column; $m = \pi r^2 h \rho$.
- Length of liquid surface on which surface tension forces act = Circumference of the circular ring.

$$l = 2\pi r.$$

$$\text{Surface tension coefficient} = \frac{\text{Surface tension force}}{\text{Length}}$$

$$\gamma \cos\theta = \frac{F}{2\pi r}$$

$$F = 2\pi r \gamma \cos\theta$$

Force of surface tension = weight of liquid column

$$F = mg.$$

$$2\pi r \gamma \cos\theta = \pi r^2 h \rho g.$$

P.T.O

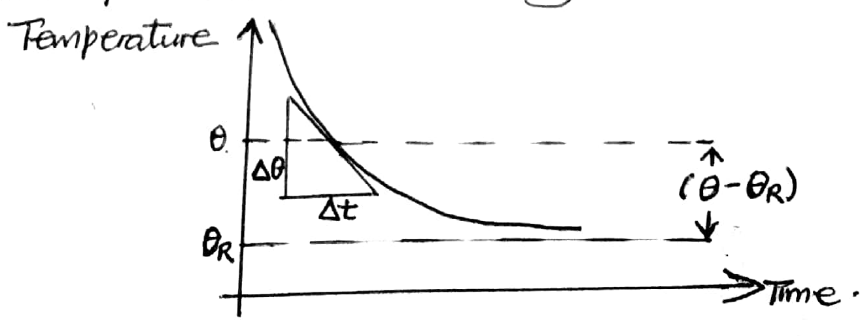
5 a) (i) Absolute zero is temperature at which molecules of a substance (gas) have zero kinetic energy
Specific heat capacity is amount of heat needed to change temperature of 1kg mass of a substance by 1K.

(ii) Temperature is the measure of the average kinetic energy of the particles of a substance. Absolute zero which is 0K or −273°C is the lowest possible temperature at which molecular motion temporarily stops. Therefore any temperature below 0K doesn't support kinetic theory of matter.

(iii) A car coolant should have a high specific heat capacity so that its temperatures takes longer time to rise in order to make it conduct heat away from the engine hence cooling it.

(b) (i) Rate of temperature fall of a body is directly proportional to the excess temperature over the surrounding under conditions of forced convection.
Accept: Rate of heat loss....

(ii) – A thermometer is suspended in air and room temperature θ_R noted from it.
– Hot water is poured in a copper calorimeter standing on a wooden block and the calorimeter is moved close to an open window and the thermometer is inserted in the water.
– The water is stirred to obtain a steady temperature.
– Temperature (θ) of the water is recorded from the thermometer in equal time intervals as it cools.
– A graph of values of temperature θ is plotted against values of time (t) and a cooling curve obtained.



- Tangents are drawn on the curve at different points and their slopes (Rates of temperature fall), $\frac{\Delta\theta}{\Delta t}$ determined and recorded including their corresponding excess temperatures $(\theta-\theta_R)$.
- A graph of values of the slopes is plotted against excess temperature and gives a straight line.
- From the graph, the rate of temperature fall is directly proportional to excess temperature, hence Newton's law of cooling.

(c) $P = 2kW = 2000W$

$M_w = 500g = 0.5kg$

$\theta_1 = 20°C$

$C = 400JK^{-1}$

$\theta_2 = 100°C$

(i) Electric energy = Heat gained by the water and kettle raising their temperature from 20°C to 100°C

$$Pt = (M_w C_w + C)(100-20)$$

$$2000t = (0.5 \times 4200 + 400)(80)$$

$$2000t = (2500)(80)$$

$$t = \frac{2500 \times 80}{2000} = \underline{\underline{100 \text{ seconds}}}.$$

(ii) Electric energy = Heat needed to raise temperature of water and kettle from 20°C to 100°C + Heat lost by evaporating water

$$Pt = (M_w C_w + C)(100-20) + M_s l_v$$

$$2000 \times 5 \times 60 = (2500)(80) + 2.26 \times 10^6 \times M_s$$

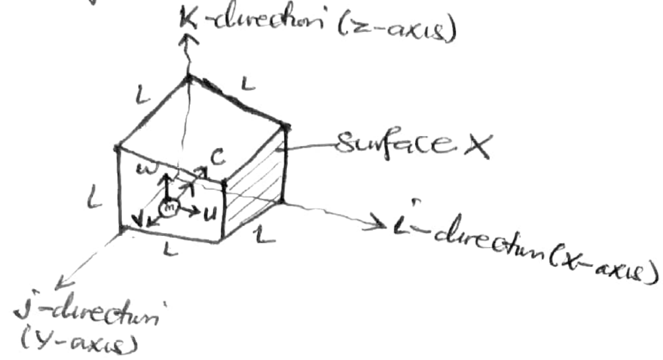
$$600.000 = 200{,}000 + 2.26 \times 10^6 M_s$$

$$\frac{\cancel{2.26 \times 10^6} M_s}{\cancel{2.26 \times 10^6}} = \frac{400{,}000}{2.26 \times 10^6}$$

$$M_s = \underline{\underline{0.177kg}}.$$

6 a) (i) – Intermolecular forces of of attraction are negligible.
- Volume of molecules is negligible compared to volume of the gas container
- Molecules of the gas make perfectly elastic collisions
- Duration of collision is negligible compared to the time between collision.

(ii) – Consider a gas whose molecules have have mass m contained in a cube of side l.



- Velocity of a molecule is $\underset{\sim}{c} = u\underset{\sim}{i} + v\underset{\sim}{j} + w\underset{\sim}{k}$, with u, v, w components in i, j, k directions respectively.
- Speed of the molecule is $c = |\underset{\sim}{c}| = \sqrt{u^2+v^2+w^2}$

$$c^2 = u^2+v^2+w^2$$

- In case of averages of the squares of the velocities;

$$\overline{c^2} = \overline{u^2} + \overline{v^2} + \overline{w^2}$$

- At constant temperature, the averages of the squares of velocities in all directions are equal, $\overline{u^2} = \overline{v^2} = \overline{w^2}$

$$\overline{c^2} = 3\overline{u^2}$$

$$\overline{u^2} = \frac{\overline{c^2}}{3} \quad \text{——— (i)}$$

- Momentum of the molecule towards surface X is mu.
- Reverse momentum after collision on surface X is $-mu$.
- Change of momentum is $|-mu - mu| = 2mu$.
- Total distance covered to and from surface X is $l+l = 2l$.
- Average velocity $= \frac{\text{Total distance}}{\text{Time taken}}$

$$\frac{u+u}{2} = \frac{2l}{t}$$

$$t = \frac{2l}{u}$$

- Force of collision on Surface X = $\frac{\text{change of momentum}}{\text{Time taken}}$

$$F = \frac{2mu}{\frac{2L}{u}} = \frac{mu^2}{L}.$$

- pressure on collision = $\frac{\text{Force}}{\text{Area of Surface X}} = \frac{mu^2/L}{L \times L} = \frac{mu^2}{L^3}.$

- Total pressure exerted by N-molecules with velocities $u_1, u_2, u_3, \ldots, u_N$ towards Surface X is

$$P = \frac{mu_1^2}{L^3} + \frac{mu_2^2}{L^3} + \frac{mu_3^2}{L^3} + \cdots + \frac{mu_N^2}{L^3}$$

$$P = \frac{m(u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2)}{L^3}$$

- Average square speed is

$$\overline{u^2} = \frac{u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2}{N}$$

$$u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2 = N\overline{u^2}$$

$$P = \frac{m \times N\overline{u^2}}{L^3} = \frac{Nm\overline{u^2}}{L^3},$$ $Nm = M$, mass of the gas, $L^3 = V$, volume of the gas.

$$P = \frac{M\overline{u^2}}{V}, \quad \frac{M}{V} = \rho, \text{ density of the gas}$$

$$P = \rho\overline{u^2} \text{ ——— (ii)}$$

- Substituting (i) in (ii)

$$P = \rho \times \frac{\overline{c^2}}{3} = \frac{1}{3}\rho\overline{c^2}$$

(b) $M = 4g$, $V = 0.004m^3$, $P = 2 \times 10^5 pa$, $T = 27°C = 300K$

(1) $PV = nRT$

$$n = \frac{PV}{RT} = \frac{2 \times 10^5 \times 0.004}{8.31 \times 300} = 0.3209 \text{ moles.}$$

$$n = \frac{m}{M}$$

$$m = n \times M = 0.3209 \times 4 = 1.2836g$$
$$= 1.2836 \times 10^{-3} kg.$$

Density $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{1.2836 \times 10^{-3}}{0.004} = 0.321 \, Kgm^{-3}$.

$$P = \frac{1}{3}\rho \overline{c^2}$$

$$c = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 2 \times 10^5}{0.321}} = \underline{\underline{1369.31 ms^{-1}}} = 1.37 \times 10^3 ms^{-1}$$

(ii) Total kinetic energy $= \frac{3}{2}RT$

$$= \frac{3}{2} \times 8.31 \times 300$$

$$= 3739.5J$$

$$= \underline{\underline{3.74 \times 10^3 J}}$$

(iii) $\frac{1}{2}M\overline{c^2} = \frac{3}{2}RT$, $T = 159°c = 432K$

$$M\overline{c^2} = 3RT$$

$$c = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.31 \times 432}{1.2836 \times 10^{-3}}}$$

$$= 2896.598 ms^{-1}$$

$$= \underline{\underline{2.90 \times 10^3 ms^{-1}}}$$

c) (i) A vapour which is in dynamic equlbrium with its own Liquid.

(ii) Increase in temperature Increases the Kinetic energy of the liquid molecules hence Increase ~~in~~ of the rate of evaporation of liquid molecules. The number of evaporating liquid molecules increases the density of the saturated vapour hence Increase of saturated Vapour pressure according to $P = \rho hg$, where ρ is vapour density and h is altitude.

7 a) (i) Total pressure exerted by a mixture of gases which do not chemically react is the sum of the partial pressures of its constituents.

(ii)

$$P = \frac{1}{3}\rho\bar{c^2}, \quad \rho = \frac{M}{V} \left(\frac{\text{Mass of the gas}}{\text{Volume of the gas}}\right)$$

$$P = \frac{1}{3}\frac{M}{V}\bar{c^2}$$

$$3PV = M\bar{c^2}, \quad M = Nm$$ N is number of molecules, m is mass of a molecule.

$$3PV = Nm\bar{c^2}$$

$$\frac{1}{2}\times 3PV = N\times\frac{1}{2}m\bar{c^2}, \quad \frac{1}{2}m\bar{c^2} = \frac{3}{2}K_BT,$$ K_B is Boltzmann constant; T is temperature of the gas.

$$\frac{3}{2}PV = N\times\frac{3}{2}K_BT$$

$$PV = NK_BT; \text{ (i)}$$ for mixture of two gases of N-moles, pressure P, occupying Volume V at a temperature T.

- If a gas of N_1 moles is allowed to occupy Volume V of the mixture at a temperature T, it exerts a partial pressure P_1.

$$P_1V = N_1K_BT, \quad N_1 = \frac{P_1V}{K_BT}.$$

- If a second gas of N_2 moles is also allowed to occupy Volume V at temperature T, it exerts a partial pressure P_2.

$$P_2V = N_1K_BT, \quad N_2 = \frac{P_2V}{K_BT}.$$

- But

$$N = N_1 + N_2$$

$$N = \frac{P_1V}{K_BT} + \frac{P_2V}{K_BT}$$

$$N = \frac{(P_1+P_2)V}{K_BT} \text{ ——— (ii)}$$

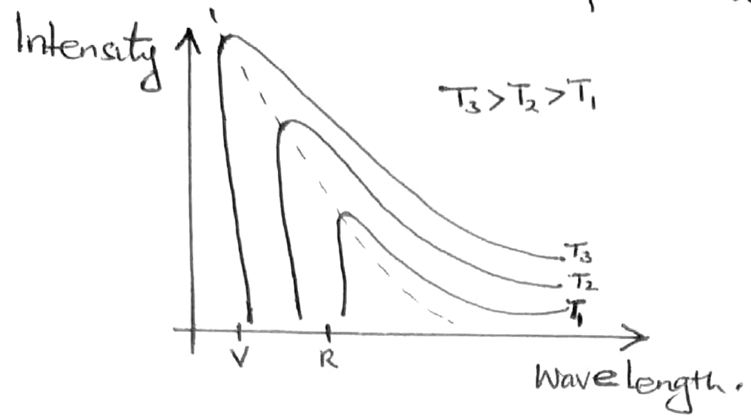
- substituting (ii) in (i)

$$P\cancel{V} = \left(\frac{P_1+P_2}{\cancel{K_BT}}\right)\cancel{V}\times \cancel{K_BT}$$

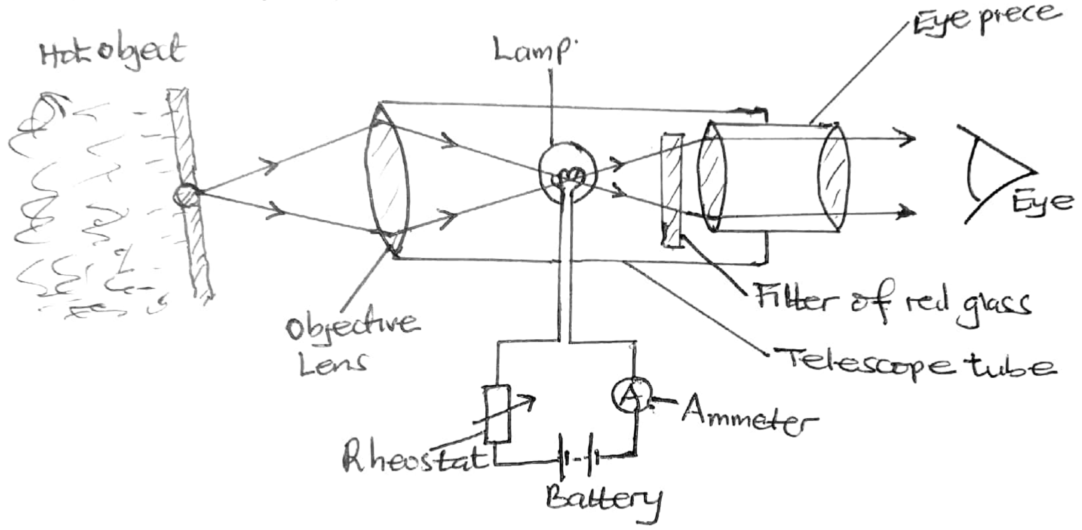
$$\therefore P = P_1 + P_2,$$ which is Dalton's law of partial pressures.

(b) (i) A black body is a body which absorbs all heat radiations incident on it reflects and transmits none.

(ii)

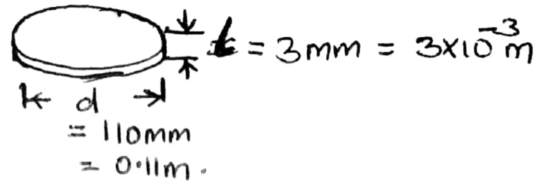


(c) Apparatus of optical pyrometer.

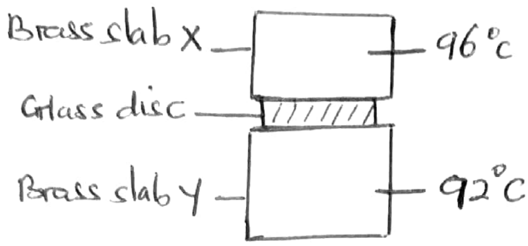


- The filament of the Lamp is focused first using the eye piece so that parallel light rays are received from it by the eye.
- The hot object is then focused using the objective lens so that its Image is formed at the plane of the filament of the lamp.
- If the object is hotter than the lamp, its Image appears bright on a dark background.
- If the lamp is hotter than the object, the Image of the object appears dark on a bright background.
- The rheostat is adjusted until the brightness of the object and the lamp can not be distinguished (the same)
- The ammeter reading is read and recorded as the temperature in degrees of the hot Object since the ammeter is calibrated.

d) Circular glass disc



Cross-section area $A = \frac{\pi d^2}{4} = \frac{\pi(0.11)^2}{4} = 9.503\times10^{-3} m^2.$



Rate of temperature fall (Cooling) $\frac{\Delta\theta}{\Delta t} = 0.42Ks^{-1}$ at $92°c.$

Mass of Y, $m = 0.94kg$ and s.h.c, $c = 400Jkg^{-1}k^{-1}$

Rate of heat flow through the glass disc is

$$\frac{dQ}{dt} = \frac{KA(\theta_x - \theta_y)}{l} \quad \text{———(i)}$$

Rate of heat loss by brass slab Y:

$$\frac{dQ}{dt} = mc\frac{\Delta\theta}{\Delta t} \quad \text{———(ii)}$$

$\therefore$ (i) = (ii)

$$\frac{KA(\theta_x - \theta_y)}{l} = mc\frac{\Delta\theta}{\Delta t}$$

$$\frac{K\times9.503\times\cancel{10^{-3}}\times(96-92)}{3\times\cancel{10^{-3}}} = 0.94\times400\times0.42$$

$$\frac{38.012K}{3} = 157.92$$

$$38.012K = 3\times157.92$$

$$38.012K = 473.76$$

$$\underline{\underline{K = 12.463Wm^{-1}K^{-1}}}$$

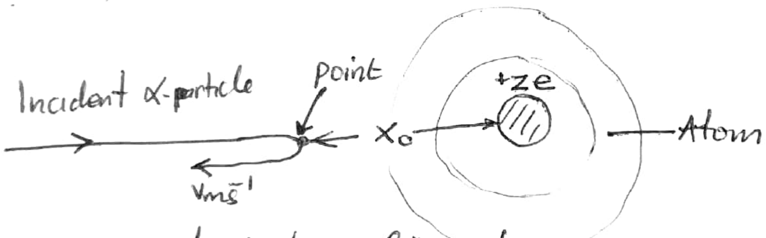
8. a) – Most alpha particles passed through the atom undeviated (undeflected). This is because the biggest percentage of the atom is free space.

- Few alpha particles deviated (deflected) through angles less than 90°. This was caused by the force of repulsion between the alpha particles and the positive nucleus at the centre of the atom.

- Very few alpha particles were deviated (deflected) through angles greater than 90°. These were moving to have a head on collision with the nucleus in which all the positive charge of the atom is concentrated.

(b) (i) – Charge of an alpha particle is $2e$, Z is atomic number

- charge in the nucleus of the atom is Ze
- Let m be mass of α-ple and $v\,ms^{-1}$ be its velocity towards the nucleus of the atom.



due to charge of the nucleus

- Electric potential at a point whose distance is X_o from the nucleus is $V = \frac{+Ze}{4\pi\varepsilon_0 X_o}$

- Potential energy of the α-ple when it reaches the point is

$$P.e = \text{Electric potential} \times \text{Charge of } \alpha\text{-particle}$$

$$P.e = V \times 2e = \frac{Ze}{4\pi\varepsilon_0 X_0} \times 2e = \frac{2Ze^2}{4\pi\varepsilon_0 X_0}.$$

- Kinetic energy of the α-particle is $K.e = \frac{1}{2}mv^2$.
- Applying the principle of conservation of energy at the point,

$$\text{Kinetic energy} = \text{potential energy}$$

$$\frac{1}{\cancel{2}}mv^2 = \frac{\cancel{2}Ze^2}{\cancel{2}\cancel{4}\pi\varepsilon_0 x_0}$$

$$\frac{mv^2}{1} = \frac{Ze^2}{\pi\varepsilon_0 x_0}$$

$$\pi\varepsilon_0 mv^2 x_0 = Ze^2$$

$$x_0 = \frac{Ze^2}{\pi\varepsilon_0 mv^2}.$$

(ii) $Z = 79$, $x_0 = 5.2\times10^{-14}$ m, $\pi\varepsilon_0 = 3.142\times8.85\times10^{-12}$

$$= 2.781\times10^{-11}$$

$$mv^2 = \frac{Ze^2}{\pi\varepsilon_0 x_0} \qquad \frac{1}{\pi\varepsilon_0} = \frac{1}{2.781\times10^{-11}} = 3.6\times10^{10}$$

$$mv^2 = \frac{1}{\pi\varepsilon_0}\times\frac{Ze^2}{x_0}$$

$$= \frac{36\times10^9\times79\times(1.6\times10^{-19})^2}{5.2\times10^{-14}}$$

$$mv^2 = 5.07813\times10^{-12}$$

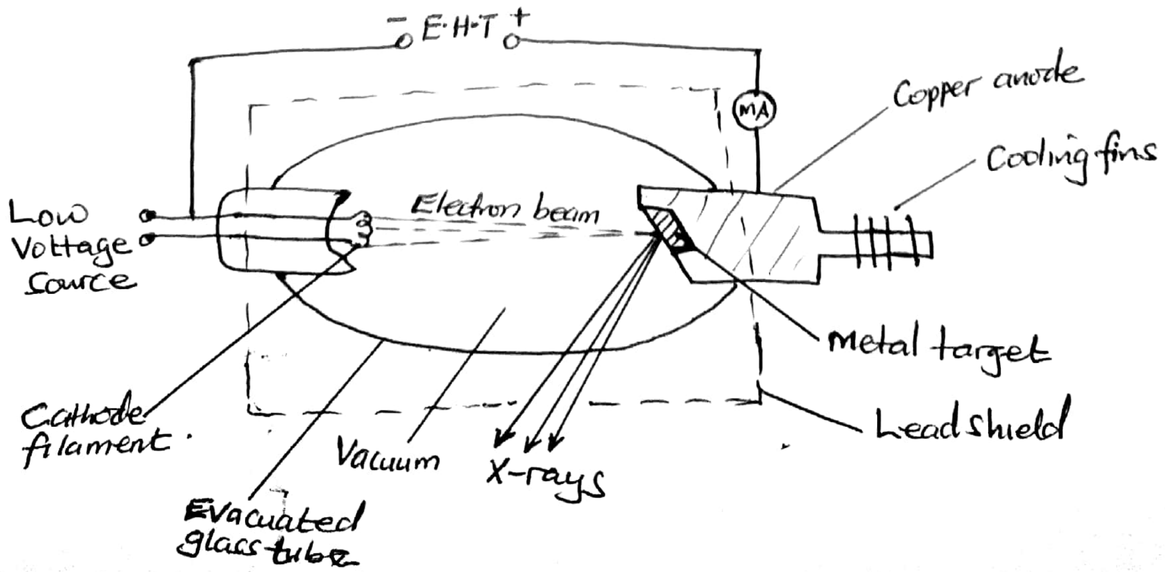
$$\frac{1}{2}\times mv^2 = \frac{1}{2}\times5.07813\times10^{-12}$$

$$K.e = 2.54\times10^{-12}\ \text{J}.$$

$$= \frac{2.54\times10^{-12}}{1.6\times10^{-13}16}$$

$$\text{Energy} = 15.88\ \text{Mev}$$

C(i)



- The cathode filament is heated by a low voltage source and it produces electrons by thermionic emission. The electrons are accelerated towards the copper anode by the E.H.T voltage source. When electrons strike the metal target, a small percentage of their kinetic energy is converted into X-rays and the biggest percentage is converted into heat. The heat generated in the anode is conducted away by a cold liquid circulating in the cooling fins.

(ii) $\lambda = 2.3 \mathring{A} = 2.3 \times 10^{-10} m.$

$M = 58.5g = 58.5 \times 10^{-3} kg$

$\rho = 2.18 \times 10^{3} Kgm^{-3}.$

6.02×10^{23} molecules $\xrightarrow{\text{Have}}$ $58.5 \times 10^{-3} kg.$

Mass of one molecule $= \dfrac{58.5 \times 10^{-3}}{6.02 \times 10^{23}} kg$

$= 9.718 \times 10^{-26} kg.$

- Sodium chloride has half a number of sodium and chlorine atoms.
- Mass in a unit molecule $m = \frac{1}{2} \times 9.718 \times 10^{-26} kg$

$m = 4.859 \times 10^{-26} kg.$

- Volume $V = \dfrac{m}{\rho} = \dfrac{4.859 \times 10^{-26}}{2.18 \times 10^{3}}$

$= 2.229 \times 10^{-29} m^3.$

- Atomic plane separation $d = \sqrt[3]{V}$

$d = \sqrt[3]{2.229 \times 10^{-29}}$

$d = 2.814 \times 10^{-10} m.$

$2d\sin\theta = n\lambda$

$$\sin\theta = \frac{n\lambda}{2d}$$

$$\sin\theta = \frac{\cancel{2} \times 2.3 \times 10^{-10}}{\cancel{2} \times 2.814 \times \cancel{10^{-10}}}$$

$$\sin\theta = 0.81734$$

$$\theta = \sin^{-1}(0.81734)$$

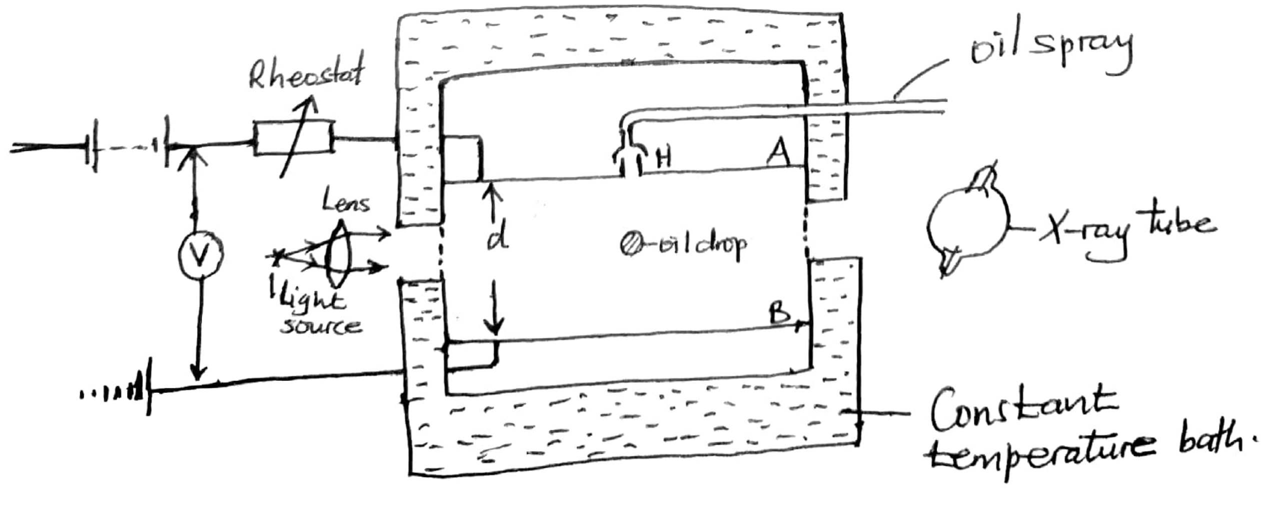
$$\theta = 54.82^\circ.$$

9 a) (i) Positive rays is a beam of positively charged ions produced when cathode rays collide with atoms of a residue gas in a discharge tube.

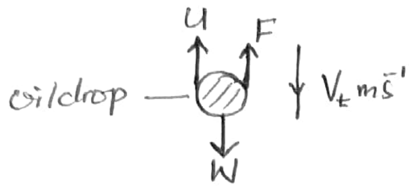
(ii)

Positive rays	Cathode rays.
- positively charged	- Negatively charged
- Have different velocities	- Have uniform velocity
- Massive	- Less massive.
- Have low specific charge	- Have high specific charge.
- Have low penetrating power	- Have high penetrating power.

(b) (i) Apparatus



- With no p.d applied the electric plates A and B, oil is sprayed over hole H in electric plate A and oil drops find their way through the whole.
- A suitable oil drop is identified and its time t of fall through a measured distance S is determined and terminal velocity is calculated from $V_t = \frac{S}{t}$ and recorded.
- During fall, the oil drop experiences three forces, weight (W), upthrust (U) and viscous force (F).



$$W = U + F$$

$$\frac{4}{3}\pi r^3 \rho g = \frac{4}{3}\pi r^3 \sigma g + 6\pi \eta r V_t$$

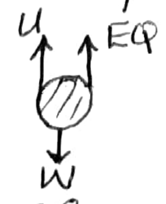
$$\frac{2}{3} r^2 \rho g = \frac{2}{3} r^2 \sigma g + 3\eta V_t$$

$$2r^2 g(\rho - \sigma) = 9\eta V_t$$

$$r = \left(\frac{9\eta V_t}{2g(\rho-\sigma)}\right)^{1/2}$$, is the radius of the oil drop

where η is coefficient of viscosity of air, ρ is the density oil oil and σ is density of air.

- The experiment is repeated by applying a p.d between the electric plates and spraying more oil over the hole.
- One oil drop through the hole is identified, and the p.d between the plates is adjusted using a rheostat until the oil drop becomes stationary between the plates.
- The oil drop is experiencing three forces, weight (W), upthrust (U) and electric force (EQ)



$$W = U + EQ$$

$$EQ = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g$$

$$EQ = \frac{4\pi r^3 g(\rho - \sigma)}{3}$$

$$Q = \frac{4\pi r^3 g(\rho-\sigma)d}{3V},$$

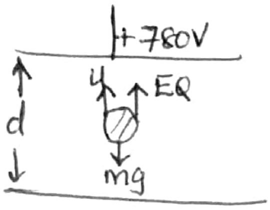
where $E = \frac{V}{d}$ (p.d between the plates) / (Distance between the plates)

From this expression, charge is calculated

Oil drops should be small so that they can easily attain terminal velocity and also become stationary.

(c) $d = 5mm = 0.005m$
$V = 780V$

Case 1



$$U + EQ = mg \quad \text{—— (1)}$$

Case 2:
$S = 1.50mm = 0.0015m$
$t = 11.2 \text{ sec}$

$$V_t = S/t = \frac{0.0015}{11.2} = 1.34 \times 10^{-4} ms^{-1}$$

$\rho = 900 kgm^{-3}$
$\eta = 1.8 \times 10^{-5}$

$$U + F = mg \quad \text{—— (2)}$$

$$0 + 6\pi\eta r V_t = \frac{4}{3}\pi r^3 \rho g$$

$$3\eta V_t = \frac{2}{3} r^2 \rho g$$

$$r = \left(\frac{9\eta V_t}{2\rho g}\right)^{1/2}$$

$$r = \left(\frac{9 \times 1.8 \times 10^{-5} \times 1.34 \times 10^{-4}}{2 \times 900 \times 9.81}\right)^{1/2}$$

$$r = 1.109 \times 10^{-6} m.$$

Mass $M = \frac{4}{3}\pi r^3 \rho$

$$= \frac{4\pi (1.109 \times 10^{-6})^3 \times 900}{3}$$

$$= \underline{\underline{5.142 \times 10^{-15} kg.}}$$

(ii) $U + EQ = mg.$

$$0 + \frac{VQ}{d} = mg$$

$$Q = \frac{mgd}{V} = \frac{5.142 \times 10^{-15} \times 9.81 \times 0.005}{780}$$

$$Q = \underline{\underline{3.234 \times 10^{-19} C}}$$

d) Accelerating potential energy = Kinetic energy of the ion.

$$qV = \frac{1}{2}mu^2, \quad u \text{ is the velocity}$$

$$u^2 = \frac{2qV}{m} \quad \text{——— (i)}$$

In the magnetic field,

Magnetic force = Centripetal force

$$Bqu = \frac{mu^2}{r}$$

$$Bqr = mu$$

$$u = \frac{Bqr}{m} \quad \text{——— (ii)}$$

Substituting (ii) in (i)

$$\left(\frac{Bqr}{m}\right)^2 = \frac{2qV}{m}$$

$$\frac{B^2q^{\cancel{2}}r^2}{m^{\cancel{2}}} = \frac{2\cancel{q}V}{\cancel{m}}$$

$$\frac{B^2qr^2}{m} = 2V$$

$$r^2 = \frac{2Vm}{qB^2}$$

$$r = \sqrt{\frac{2Vm}{qB^2}}.$$

10 a) i) Natural radioactivity is the emission of radioactive radiations by natural radioactive Isotopes eg (U-238, Th-232, K-40) etc while artificial radioactivity is the emission of radioactive radiations by radioactive Isotopes produced by human activities such as, in Nuclear reactors, production of atomic weapons etc.

ii) Stability of heavy nuclides

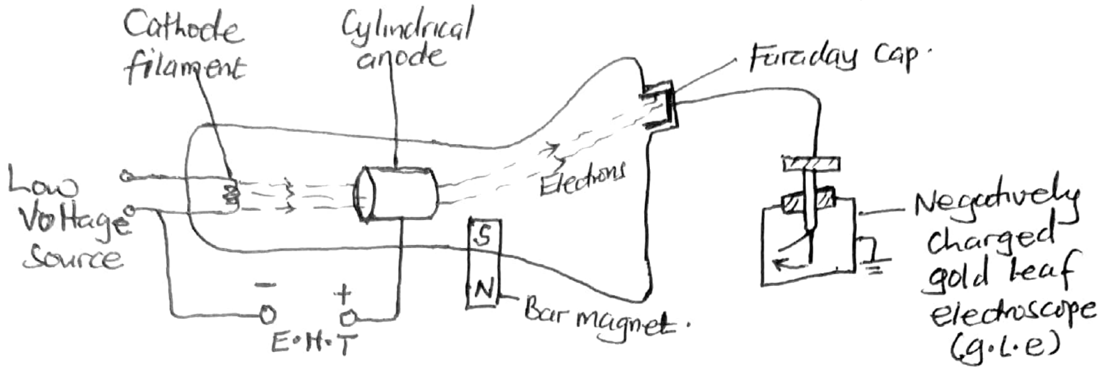
- Pairing energy (Energy for formation of proton-proton or neutron-neutron pairs)
- Deformation
- Neutron to proton ratio (Not more than 1.5)
- Shell effects (Nuclides with filled Shells are stable)

- Unbalanced number of neutrons and protons.
- Imbalance between electrical force of repulsion between protons and the strong nuclear force of attraction between protons and neutrons.

Stability of light nuclides
- Neutron to proton ratio (Ratio 1)
- Binding energy
- Shell effects (filled up shells)

(b) (i) Thermionic emission is the process of emitting electrons from a metal surface by application of heat.

(ii)



- The cathode filament is heated by a low voltage source and emits electrons by thermionic emission.
- Electrons are accelerated by the E.H.T source towards the cylindrical anode.
- On emerging out of the anode, electrons are deflected using a south pole of a bar magnet to enter a faraday cap connected to the brass cap of a negatively charged g.l.e.
- The gold leaf is observed to increase in divergence confirming that cathode rays carry a negative charge.

(c) (i) $N = N_0 e^{-\lambda t}$

where N_0 is original number of radioactive atoms
N is the number of radioactive atoms present after a time t.
λ is the decay constant.

At time $t = t_{\frac{1}{2}}$, half life, $N = \frac{N_0}{2}$.

$$\frac{N_0}{2} = N_0 e^{-\lambda t_{\frac{1}{2}}}$$

$$\frac{1}{2} = e^{-\lambda t_{\frac{1}{2}}}$$

$$2^{-1} = e^{-\lambda t_{\frac{1}{2}}}$$

$$-\ln 2 = -\lambda t_{\frac{1}{2}} \ln e, \quad \ln e = 1$$

$$\ln 2 = \lambda t_{\frac{1}{2}}, \quad t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

Activity of living wood $A_0 = 16$ Counts/minute/gram.

Activity of dead wood $A = 18.4$ Counts/minute for 4.0 grams.

$$A = \frac{18.4 \text{ Counts/minute}}{4 \text{ grams}}$$

$$A = 4.6 \text{ Counts/minute/gram.}$$

Half life $t_{\frac{1}{2}} = 5568$ years.

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{5568} = 1.245 \times 10^{-4} \text{ per year}$$

$$A = A_0 e^{-\lambda t}$$

$$4.6 = 16 e^{-1.245 \times 10^{-4} t}$$

$$\frac{4.6}{16} = e^{-1.245 \times 10^{-4} t}$$

$$0.2875 = e^{-1.245 \times 10^{-4} t}$$

$$t = \frac{-\ln(0.2875)}{1.245 \times 10^{-4}}$$

$$t = 10012 \text{ years.}$$