

PHYSICS PAPER 1 (1)

MARKING GUIDE P51011

(i) A scalar quantity is a physical quantity defined by magnitude only while a vector quantity is defined by both magnitude and direction.

(ii)

Scalar quantities	Vector quantities
Temperature, volume	Force
Distance, Density	Displacement
Pressure etc	Velocity
Speed	Acceleration
Time	Height
mass	etc

3

(b)

$$F_x = 8 \cos 50^\circ + 7 \cos 30^\circ - 12 \cos 65^\circ - F \sin \theta = 0 \\ 5.142 + 6.062 - 5.071 - F \sin \theta = 0$$

$$6.133 = F \sin \theta$$

$$F_y = 8 \sin 50^\circ + 12 \sin 65^\circ - 8 \times F \cos \theta - 7 \cos 30^\circ = 0 \\ 6.128 + 10.88 - F \cos \theta - 6.062 = 0$$

$$10.946 / 6.062 = F \cos \theta = 13.508$$

$$\frac{F \sin \theta}{F \cos \theta} = \frac{6.133}{13.508} \Rightarrow \tan \theta = \frac{6.133}{13.508}$$

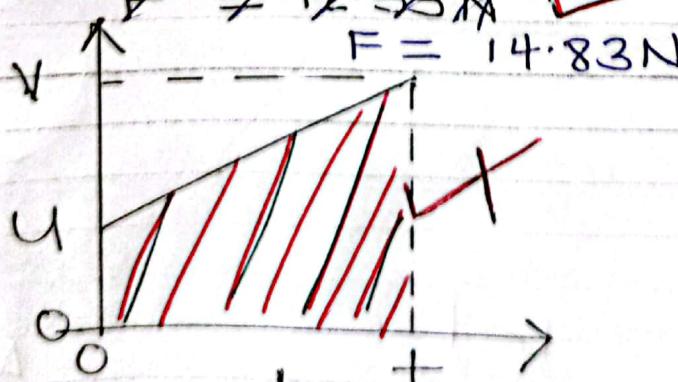
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$$\theta = 29.26^\circ \quad \theta = 24.42^\circ \\ F \sin 29.26^\circ = 6.133 \quad (\text{sub for } \theta \text{ to get } F)$$

$$F = 6.133 / \sin 29.26^\circ = 24.42$$

2

(C)(i)



3

Distance = Area under the velocity-time graph

$$S = \frac{1}{2}(u+v)t \quad \text{but } t = \sqrt{v-u}$$

$$S = \frac{(u+v)(v-u)}{2a} \quad \Rightarrow v^2 = u^2 + 2as$$

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Alternative

Distance = ave speed \times time

$$S = \frac{(u+v)}{2} t \quad \text{but } t = \frac{v-u}{a}$$

$$S = \frac{(u+v)(v-u)}{2a}$$

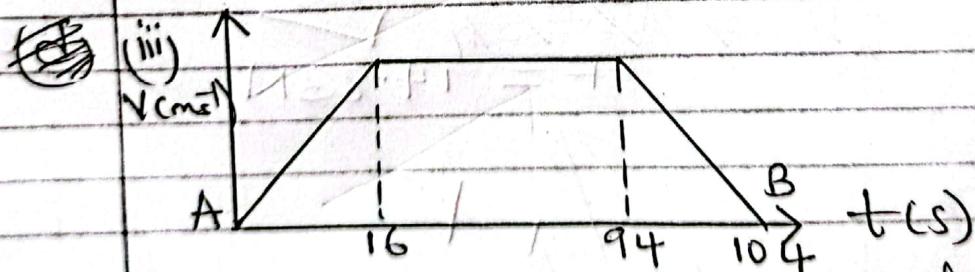
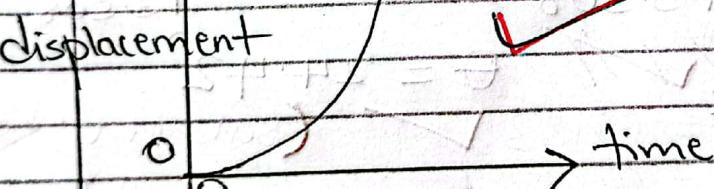
$$\begin{aligned} \text{(ii)} \Rightarrow v^2 &= u^2 + 2as \\ v^2 &= u^2 + 2as \\ \Rightarrow S &= v^2 - u^2 \end{aligned}$$

$$[LHS] = [S] = L$$

$$[RHS] = [v^2 - u^2] = \frac{l^2 T^{-2}}{L^2} = L$$

Since $[LHS] = [RHS]$ it is dimensionally correct.

- (d) i) Uniform acceleration is the uniform rate of change of velocity with time.



1st part of motion

$$v = u + at$$

$$20 = 0 + 1.25t \Rightarrow$$

$$t = 16s$$

2nd Part of motion

$$t = \frac{1.56 \times 1000}{20}$$

$$t = 7.8s$$

Last Part Of motion

$$v = ut + at$$

$$0 = 20 + (-2)t$$

$$t = 10s$$

$S = \text{Area under velocity-time graph}$

$$S = \frac{1}{2} (104 + 78) \times 20$$

$$S = 1820 \text{ m}$$

- 2(a) (i) Young's modulus is the ratio of tensile stress to tensile strain. ✓
- (ii) Vernier reading taken as masses are loaded and unloaded to ensure that the elastic limit is not exceeded ✓
- Two identical wires are used to eliminate errors due to temperature changes. ✓
- Both wires are suspended from the same support to eliminate errors in extension due to the yielding of the support. ✓
- OR**
 - Thin wires are used to produce a measurable or a large extension when a small force is used (applied)
 - Long wires are used to produce measurable or large extension.
 - Average diameter of wire is obtained to obtain accurate cross sectional area.
 - Wires should be free of kinks to obtain accurate original length.
- (b) Rubber consists of coiled molecules while a metal does not. When load is applied to the rubber the molecules unwind leading to a larger extension. ✓
-
- $$e = e_{ext} - e_{init}$$

(i) Surface tension is the force per unit length acting in the liquid surface at right angles to the imaginary line drawn in the liquid surface. 1

(ii) Molecules in the surface are more widely spaced than those in the bulk. The surface molecules experience net attractive force downwards. This puts the molecules in a state of tension. 3

(d) (i) Surface tension is the force per unit length acting in the liquid surface at right angles to one side of the imaginary line drawn in the liquid surface.

(ii) Liquid molecules are fairly close together, have weak forces of attraction and move about variable positions. When temperature is increased, the molecules move faster and farther apart. The force of attraction between the molecules reduces, thus the surface tension of a liquid decreases with increase in temperature. 3

$$(r_1 + r_2) = R$$

$$2(4\pi r_1^2)\gamma + 2(4\pi r_2^2)\gamma = 2(4\pi R^2)\gamma$$

$$r_1^2 + r_2^2 = R^2 \Rightarrow R = \sqrt{r_1^2 + r_2^2}$$

$$\text{Excess pressure } \Delta P = P_i - P_o = \frac{4\gamma}{R}$$

$$R = \sqrt{2.5^2 + 3.5^2} = 4.3 \text{ cm}$$

$$\Delta P = 4 \times 2.5 \times 10^{-2} = 2.33 \text{ Pa}$$

4

Kepler's third law states that the square of the period of revolution of the planet about the sun is directly proportional to the cube of the mean distance between the sun and the planet.

(ii) $\frac{GMm}{R^2} = mR\omega^2$ but $\omega = \frac{2\pi}{T}$ and

on earth $GM = gr^2$

$$\frac{gr^3m}{R^2} = \frac{mR \cdot 4\pi^2}{T^2} \Rightarrow T^2 = \frac{R^3 \cdot 4\pi^2}{gr^2}$$

but $R = h+r$

$$\Rightarrow T^2 = \frac{4\pi^2(h+r)^3}{gr^2}$$

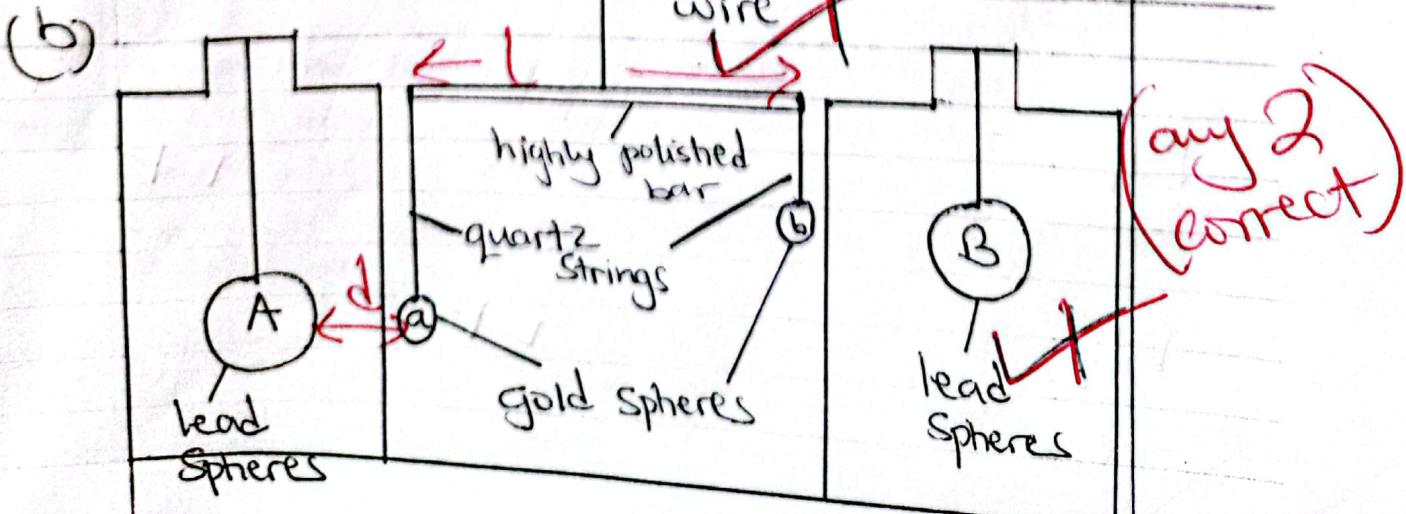
$$T = \sqrt{\frac{4\pi^2(h+r)^3}{gr^2}} \text{ but } \pi^2 = g$$

$$T = \frac{2}{r} (r+h)^{3/2}$$

(iii) Frictional resistance reduces the $m \cdot e = -\frac{GMm}{2r}$

which makes it to drop to an orbit of smaller radius hence its kinetic energy $= \frac{GMm}{2r}$ increases. This results

into an increase in the speed of a satellite.



head
ward
arts
miss
if
 M, m
are not
ined.

Two identical gold spheres a and b , each of mass m are suspended as above from the ends of a highly polished bar of length L . Two large lead spheres A and B each of mass M are brought into position near a and b respectively. Distances d between a and A is measured and the deflection θ of the polished bar is measured by the lamp and scale method. Torque of the couple on $L = \frac{GMm}{d^2} L$

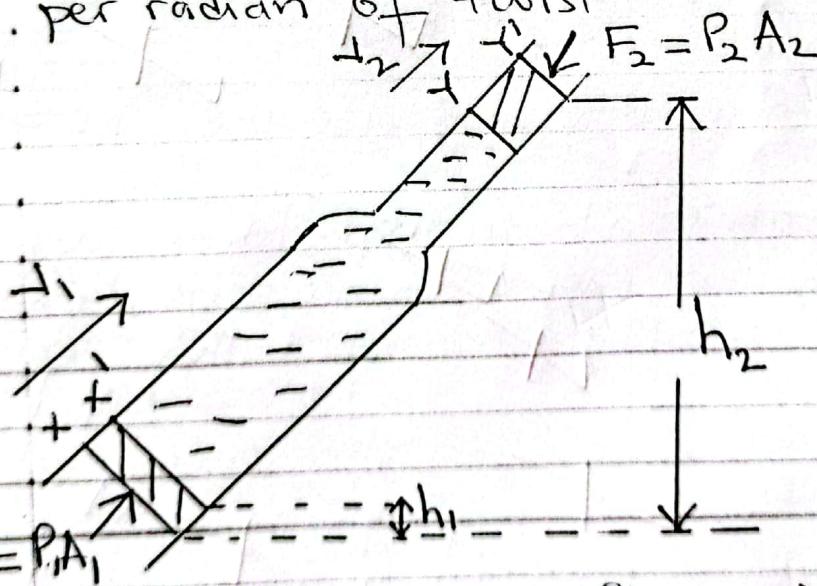
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Torque of couple $= c\theta$

$$\frac{GMm}{d^2} L = c\theta \Rightarrow G = \frac{c\theta d^2}{Mm L}$$

where c = torque in torsion of wire per radian of twist.

(C)



K_1 At x work done during st on XY by $P_1 A_1$ pushing it into the tube $= FxS$
 $= Fx \text{ velocity} \times \text{time} = P_1 A_1 N_s st$

K_2 At y work done during st by fluid XY emerging from the tube against $P_2 A_2 = P_2 A_2 V_2 st$

Net work done during st by the fluid XY emerging from the tube against $P_2 A_2$

$$= P_1 A_1 V_1 \delta t - P_2 A_2 V_2 \delta t$$

$$\Rightarrow W = (P_1 A_1 V_1 - P_2 A_2 V_2) \delta t \quad \checkmark$$

Rate at which mass flows into the tube = rate at which fluid flows out

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2, \text{ For incompressible fluid } \rho_1 = \rho_2 = \rho \Rightarrow A_1 V_1 = A_2 V_2 \quad \checkmark$$

$$W = (\rho_1 - \rho_2) A_1 V_1 \delta t$$

(net work done)

(continuity eqn)

As a result of work done on it the fluid gains P.e and K.e when XY moves to X'Y'

$$\begin{aligned} \text{Gain in P.e} &= \text{P.e of YY'} - \text{P.e of XX'} \\ &= (A_2 V_2 \delta t \rho) g h_2 - (A_1 V_1 \delta t \rho) g h_1 \\ &= A_1 V_1 \delta t \rho g (h_2 - h_1) \quad \checkmark \end{aligned}$$

$$\text{Since } A_1 V_1 \delta t = A_2 V_2 \delta t$$

$$\text{Gain in K.e} = \text{K.e of YY'} - \text{K.e of XX'}$$

$$\begin{aligned} \text{Gain in K.e} &= \frac{1}{2} (A_2 V_2 \delta t \rho) V_2^2 - \frac{1}{2} (A_1 V_1 \delta t \rho) V_1^2 \\ &= \frac{1}{2} A_1 V_1 \delta t \rho (V_2^2 - V_1^2) \quad \checkmark \end{aligned}$$

$$\text{Network done on fluid} = \text{Gain in P.e} + \text{Gain in K.e} \quad 4$$

$$(P_1 - P_2) A_1 V_1 \delta t = A_1 V_1 \delta t \rho g (h_2 - h_1) + \frac{1}{2} A_1 V_1 \delta t \rho (V_2^2 - V_1^2) \quad \checkmark \quad (\text{sub})$$

$$P_1 - P_2 = \rho g (h_2 - h_1) + \frac{1}{2} \rho (V_2^2 - V_1^2)$$

$$P_1 + h_1 \rho g + \frac{1}{2} \rho V_1^2 = P_2 + h_2 \rho g + \frac{1}{2} \rho V_2^2 \quad \checkmark$$

$$(d) \quad \frac{V_p}{V_1} = 1.0 \Rightarrow V_p = V_1$$

$$\frac{V_p}{V_2} = \frac{1}{4} \Rightarrow V_2 = 4V_p$$

$$P_1 + \frac{1}{2} \rho V_1^2 = P_2 + \frac{1}{2} \rho V_2^2 \quad \checkmark \quad (P_1 - P_2) = \frac{1}{2} \rho (V_2^2 - V_1^2)$$

$$(P_1 - P_2) A = \frac{1}{2} \rho A (V_2^2 - V_1^2) \Rightarrow \frac{F}{A} = \frac{1}{2} \rho (V_2^2 - V_1^2)$$

$$\text{but } (P_1 - P_2) A = F = mg = \frac{1}{2} \times 1.3 \times 8 \times (4V_p)^2 - V_p^2 \quad \checkmark \quad \text{sub}$$

net force.

$$V_p = 31.72 \text{ ms}^{-1} \quad \checkmark$$

4

2m

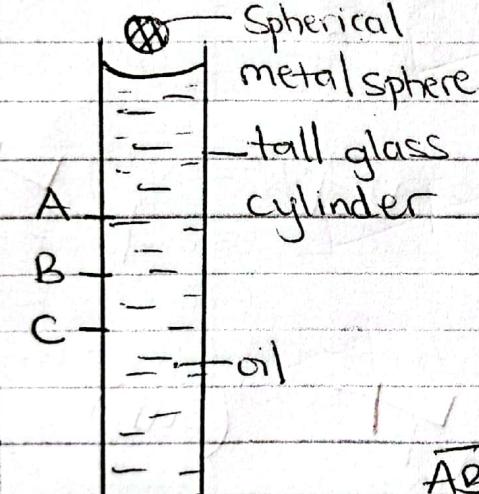
(a) ~~viscous fluid~~ is the tangential force per unit area per unit velocity gradient.

OR is the frictional force per unit area of a liquid in a region of unit velocity gradient.

(b) As temperature increases the viscosity of gases increases and that of liquids decreases.

The viscosity of gases depends on the rate of momentum transfer by gas molecules which increases as temperature increases.

The viscosity of liquids depends on intermolecular forces of attraction which decreases as temperature increases.



A spherical sphere of radius r_s and density ρ_s is released centrally

into the oil of density ρ_o in a tall glass cylinder. The times it takes to fall between \overline{AB} and \overline{BC} are measured

and recorded as t_1 and t_2 respectively. Its terminal velocity $v_o = \frac{(AB + BC)}{t_1 + t_2} / 2$

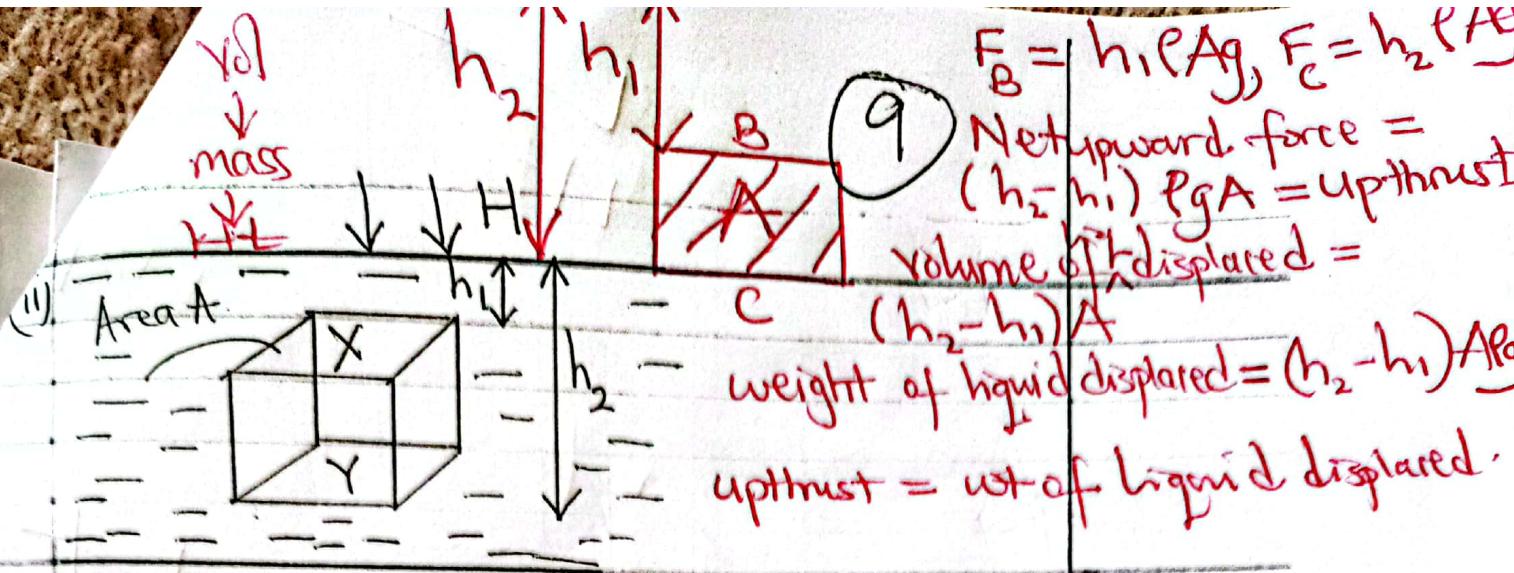
is obtained. At terminal velocity, weight = upthrust + viscous drag

$$\frac{4}{3}\pi r_s^3 \rho_s g = \frac{4}{3}\pi r_s^2 \rho_o g + 6\pi r_s \eta v_o$$

$$2 = \frac{2 r_s^2 g}{9 \eta} (\rho_s - \rho_o)$$

(d) (i) When a body is fully or partially immersed in a fluid it experiences an upthrust equal to the weight of the fluid displaced.

Transfer marks to explanation



Consider a body of a shape of a cuboid immersed in a liquid of density ρ at a distance h_1 below the liquid surface.

$$\text{Pressure at depth, } h_1 = (h_1 \rho g + H) \checkmark$$

$$\text{Force on surface } X, F_x = (h_1 \rho g + H) A \checkmark$$

$$\text{Pressure at depth, } h_2 = (h_2 \rho g + H) \checkmark$$

$$\text{Upward force on surface } Y, F_y = (h_2 \rho g + H) A \checkmark$$

$$\text{Net upward force} = F_y - F_x$$

$$= (h_2 \rho g + H) A - (h_1 \rho g + H) A$$

$$\text{upthrust} = (h_2 - h_1) A \rho g \checkmark$$

$$\text{Also } (h_2 - h_1) A = \text{volume of the solid} \checkmark$$

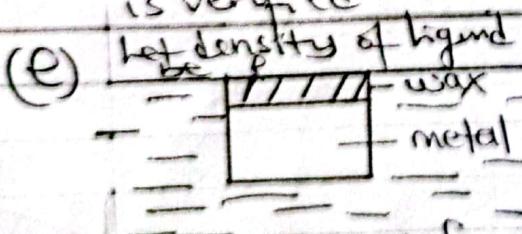
$$= \text{volume of fluid displaced}$$

$$(h_2 - h_1) A \rho = \text{mass of fluid displaced} \checkmark$$

$$(h_2 - h_1) A \rho g = \text{weight of liquid displaced} \checkmark$$

$$\text{Hence weight of fluid displaced} =$$

upthrust, hence Archimedes principle is verified.



$$\text{wt of metal and wax}$$

$$= (2.6 \times 10^3 + 1.0 \times 10^2) g \checkmark$$

$$= \text{weight of liquid displaced} \checkmark$$

$$\text{Also weight of liquid displaced} = \left(\frac{2.6 \times 10^3}{8.4 \times 10^3} + \frac{1.0 \times 10^2}{9.2 \times 10^2} \right) \rho g \checkmark$$

$$= \text{upthrust} \checkmark$$

At equilibrium, Upthrust = weight of liquid displaced

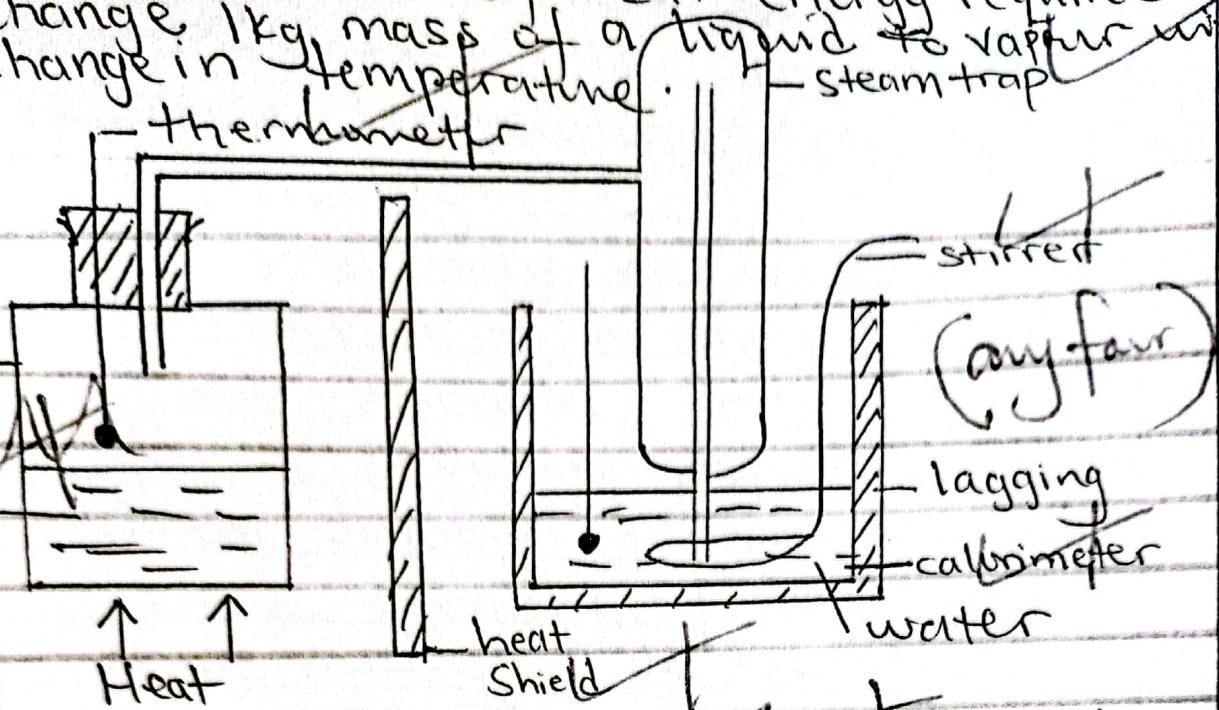
$$\left(\frac{2.6 \times 10^3}{8.4 \times 10^3} + \frac{1.0 \times 10^2}{9.2 \times 10^2} \right) \rho g = (2.6 \times 10^3 + 1.0 \times 10^2) g \checkmark$$

$$\rho = 1.13 \times 10^{-3} \text{ kg m}^{-3} \checkmark$$

Sub and equating

5

1) Is the amount of heat energy required to change 1kg mass of a liquid to vapour without change in temperature.



The initial temperature θ_1 of water and calorimeter is taken. The mass of water m_1 in the calorimeter is determined. The water in the flask is heated to its boiling point of θ_2 . Steam is passed into the calorimeter with water until there is a measurable change in temperature. The temperature θ_3 of the water in the calorimeter is recorded. The mass m of the condensed steam is found by weighing.

$$\text{Heat lost by condensing steam} + \text{Heat lost by condensed water cooling} = \text{Heat gained by water} + \text{Heat gained by the calorimeter.}$$

$$ml + mCw(\theta_3 - \theta_2) = m_1Cw(\theta_2 - \theta_1) +$$

$$L = \frac{(m_1C_w + C)(\theta_2 - \theta_1) - mC_w(\theta_3 - \theta_2)}{m}$$

$$C_w = \text{s.h.c of water}$$

$$C = \text{Heat capacity}$$

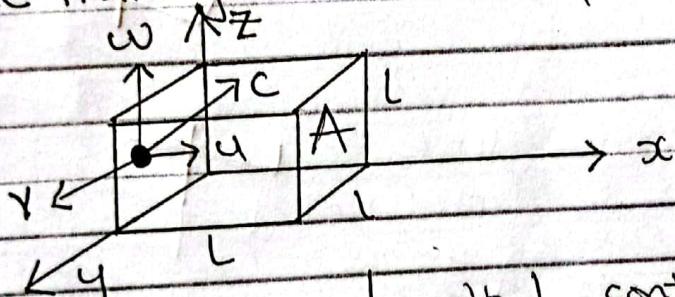
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IV

States that under conditions of forced convection the rate of loss of heat of a body is directly proportional to its excess temperature over that of the surroundings.

- (ii). A small body has a large surface area to volume ratio with small linear dimension. Rate of temperature fall is inversely proportional to the linear dimension L so the small body loses a large quantity of heat in a short time making it to cool faster.

(d)(i)



consider a cube length L containing N molecules of gas each of mass m . Suppose a molecule moves towards A with a velocity u .

On hitting face A it bounces with the same velocity in the opposite direction.
change in momentum = $mu - (-mu) = 2mu$
Time for molecules to move across cube to opposite face and back = $\frac{2L}{u}$

Rate of change of momentum = $2mu$

$$= \frac{2mu^2}{L} \leftarrow \text{Force on } A$$

$$\text{Pressure on } A = \frac{F}{A} = \frac{mu^2}{L^2} = \frac{mu^2}{L^3}$$

For N molecules with velocities u_1, u_2, \dots, u_N

$$\text{Total pressure on } A = \frac{m}{L^3} (u_1^2 + u_2^2 + \dots + u_N^2)$$

$$\text{but } \bar{u}^2 = \frac{u_1^2 + u_2^2 + \dots + u_N^2}{N}$$

$$\Rightarrow u_1^2 + u_2^2 + \dots + u_N^2 = N \bar{u}^2$$

$$P = m N \bar{u}^2$$

$$P = \rho \bar{u}^2$$

If C is the resultant velocity with components

u, v, w in x, y, z directions then

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

$$\bar{C}^2 = \bar{u}^2 + \bar{v}^2 + \bar{w}^2 \text{ but } \bar{u}^2 = \bar{v}^2 = \bar{w}^2$$

$$\bar{u}^2 = \frac{1}{3} \bar{C}^2$$

$$\Rightarrow P = \frac{1}{3} \rho \bar{C}^2$$

(ii) The duration of a collision is negligible compared with the time spent by a molecule b/w collisions.

Intermolecular attractions are negligible.

The volume of the molecules themselves is negligible compared with the volume of the container.

The molecules are like perfectly elastic spheres.

$$(e) P = \frac{1}{3} \rho \bar{C}^2 \text{ but } PV = nRT$$

$$\Rightarrow T = \frac{1}{3} \frac{\rho \bar{C}^2}{nR}$$

$$T = \frac{1}{3} \times 42 \times 9.0 \times 10^2 \times 44.72$$

$$T = 303.2K$$

2

20

1/20)

A saturated vapour is a vapour which is in dynamic equilibrium with its own liquid while unsaturated vapour is a vapour which is not in dynamic equilibrium with its own liquid.

2

- (b) During the day radiation is absorbed from the sun by the earth. At night earth radiates heat into the atmosphere. On cloudless nights the heat is lost to space. On a cloudy night the heat is reflected back to the earth and so feels warmer.

14

- (c) Two cylinders A and B are seen considering tap T closed.

$$\text{For A, } V_1 = 0 \text{ m}^3, T_1 = 60 + 273 = 333 \text{ K}, P_1 = \\ \text{For B, } V_2 = 1.5 \times 10^3 \text{ m}^3, T_2 = 60 + 273 = 333 \text{ K}, P_2 = 200 - P_s \\ \text{from } P_T = P_g + P_s \Rightarrow P_g = 200 - P_s = P_2 \\ PV = nRT \Rightarrow n_1 = \frac{P_1 V_1}{RT_1} = 0$$

$$n_2 = \frac{P_2 V_2}{RT_2} = \frac{(200 - P_s)(1.5 \times 10^3)}{333}$$

When tap is opened.

$$V_1 = V_2 = 1.5 \times 10^3 \text{ m}^3, V = 3 \times 10^3 \text{ m}^3$$

$$T = 60 + 273 = 333 \text{ K}$$

$$P = 150 - P_s$$

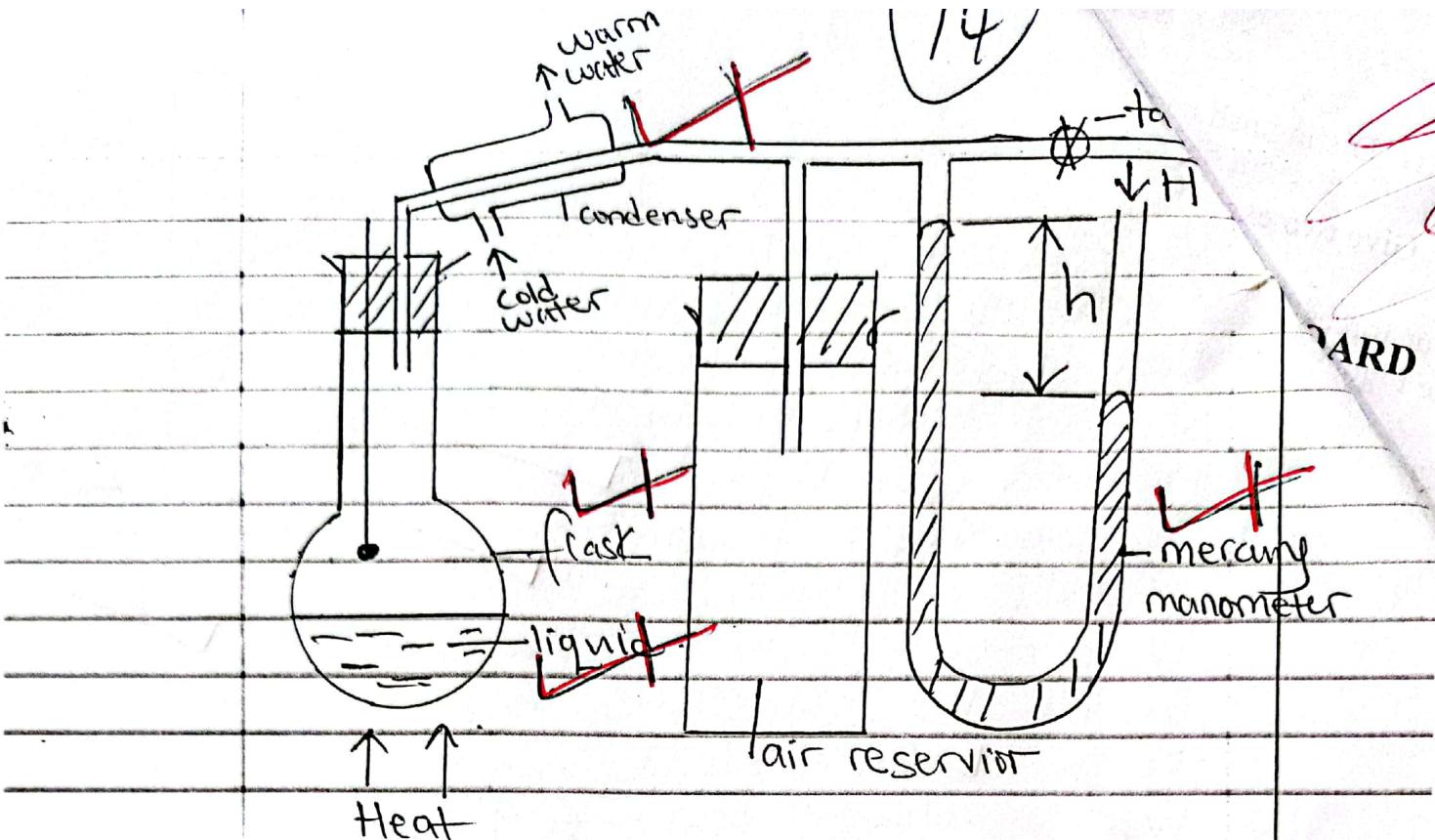
$$\text{Also } n = \frac{PV}{RT} \Rightarrow n = \frac{(150 - P_s)(3 \times 10^3)}{333}$$

$$n = n_1 + n_2$$

$$\frac{(150 - P_s)(3 \times 10^3)}{333} = 0 + \frac{(200 - P_s)(1.5 \times 10^3)}{333}$$

$$P_s = 100 \text{ mmHg.}$$

5



Air is pumped in or out from the reservoir by using the pump by opening the tap.

The tap is closed and the liquid is heated to boiling point.

The temperature θ of the vapour is determined. The difference, h , in mercury levels is noted from the manometer.

The pressure, P of the vapour $P = H + h$ is determined where H is the atm. pressure.

The procedure above is repeated for different pressures.

A graph of P against θ is plotted and the SVP of the liquid at a particular temperature can be obtained.

(e) a is the pressure defect which

V^2 accounts for the existence of inter-molecular forces of attraction b is a constant that accounts for the finite volume of the molecules themselves.

6

3

A body emits radiation at a rate which is determined only by the nature of its surface and its temp, and absorbs radiation at a rate which is determined by the nature of its surface and temp of the surroundings. A body at constant temp is gaining heat by absorption and losing it by radiation at equal rates.

When a body is in thermal equilibrium with its surroundings its rate of emission of radiation to the surroundings is equal to its rate of absorption of the radiation from the surroundings.

$$(b) \text{ Net power absorbed by sphere} = A\sigma(T_2^4 - T_1^4)$$

$$P = A\sigma(T_2^4 - T_1^4) \text{ but } P = Pt \checkmark$$

$$\frac{Q}{At} = \sigma(T_2^4 - T_1^4) \text{ also } Q = mc\delta\theta \checkmark$$

At

$$\frac{mc\delta\theta}{At} = \sigma(T_2^4 - T_1^4) \text{ also } m = \rho V \checkmark$$

At

$$\text{and } A = 4\pi r^2, V = \frac{4}{3}\pi r^3$$

$$\frac{\rho V c \delta\theta}{At} = \sigma(T_2^4 - T_1^4)$$

$$\frac{\rho(4/3\pi r^3)c\delta\theta}{(4\pi r^2)t} = \sigma(T_2^4 - T_1^4)$$

$$\frac{\Delta\theta}{t} = \frac{3\sigma(T_2^4 - T_1^4)}{c\rho r^5}$$

$$\frac{\Delta\theta}{t} = \frac{3 \times 5.56 \times 10^{-8} (290^4 - 150^4)}{3.7 \times 10^2 \times 8.93 \times 10^3 (0.5 \times 10^{-3})}$$

$$\frac{\Delta\theta}{t} = 0.0679 \text{ Ks}^{-1} \checkmark$$

5

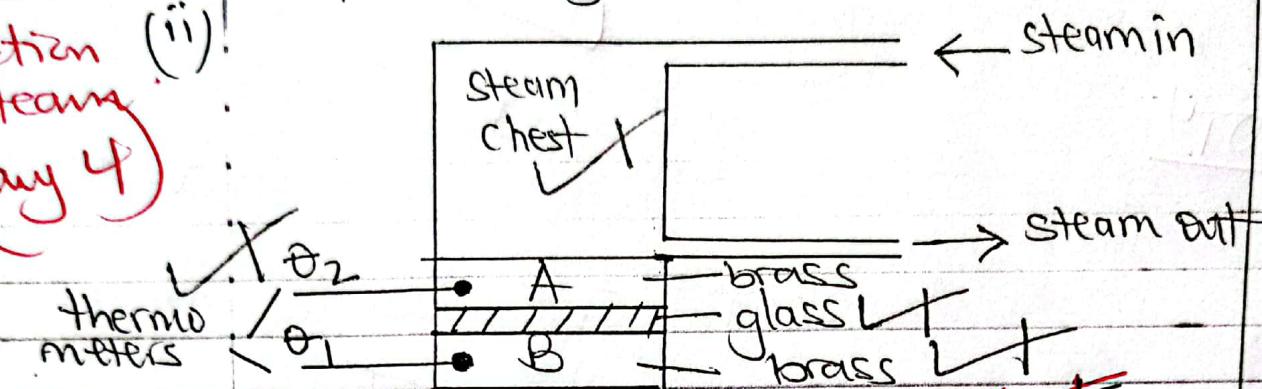
(C)(i) A black body is a body which absorbs all the radiation of every wavelength that falls on it and reflects and transmits none.

(ii). A black body can be realised in practice, by punching a small hole on the lid of an empty tin blackened with soot in the inside. Radiation which enters the tin through the small hole is reflected many times, energy is absorbed at each point of incidence until it is all absorbed.

11

(d)(i) Thermal conductivity is the rate of heat flow through a material per unit cross sectional area in a region of ~~per~~ unit temperature gradient.

Direction of steam (any 4)



~~As~~ Glass of cross sectional area A is made into a thin disc of thickness l and placed between the brass slabs A and B each containing a thermometer. Steam is passed through the chest and the steam is passed through. System is left to run until a steady state is reached. Temperatures θ_1 and θ_2 are recorded. Rate of heat flow $Q = KA(\theta_2 - \theta_1) / l$ where K is the thermal conductivity. The poor conductor is removed and the brass slab B heated directly by steam until its temperature is ~~above~~ raised by about 10°C above θ_1 . The steam chest is removed and the glass is ~~left~~ placed on top of B. The temperature of B is recorded as it cools until its temperature is 10°C below θ_1 . A cooling graph of brass slab B is plotted. The slope of the curve at θ_1 is obtained. Slope $s = \frac{1}{t}$. Rate of loss of heat ~~at~~ at θ_1 by the brass slab B, $\frac{Q}{t} = mc(s)$. The thermal conductivity of glass $K = mcl s$ where $C = S.H.C$ brass and $m = \text{mass of brass}$.

Excitation energy is the energy required to move an electron from a lower energy level to a higher energy level while ionisation energy is the energy required to remove an electron from the ground state to infinity.

$$(b) \Delta E = hf$$

$$\Delta E = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{(-2.71 + 4.87) \times (1.6 \times 10^{-19})}$$

$$\lambda = 5.92 \times 10^{-7} \text{ m}$$

It's in the visible region.

$$(c)(i) \text{ charge on } {}^4\text{He} = 2e$$

$$\text{charge on nucleus} = Ze$$

K.E of ${}^4\text{He}$ = $\frac{1}{2}mv^2$ where v is the speed before collision

$$\text{Electrostatic P.e} = \frac{(Ze)(2e)}{4\pi\epsilon_0 r_0}$$

$$\text{Electrostatic P.e} = \frac{(Ze)(2e)}{4\pi\epsilon_0 r_0}$$

At closest distance of approach

K.E of α -particle = electrostatic P.e of α -particles nucleus system

$$\frac{1}{2}mv^2 = \frac{2Ze^2}{4\pi\epsilon_0 r_0}$$

$$r_0 = \frac{Ze^2}{\pi\epsilon_0 mv^2}$$

$$(ii) \frac{1}{2}mv^2 = \frac{2Ze^2}{4\pi\epsilon_0 r_0} = \frac{9.0 \times 10^9 \times 2 \times 79 \times (1.6 \times 10^{-19})^2}{5 \times 10^{-14}}$$

$$\text{K.E} = 7.28 \times 10^{-13} \text{ J}$$

2

4
1 (Sub)

19 ✓
converting
to joules

4

3

(i) Most of the alpha particles passed through the metal foil undeflected. This is because most space in an atom is empty. A few alpha particles are deflected through small angles less than 90° . This is because of the presence of the positive charge that repelled the α -particles. Very few particles are scattered through large angles greater than 90° because the positive charge is located in a very small portion of the atom making the chance of a head on collision very small.

(ii) The experiment is carried out in a vacuum because the range of alpha particles in air is limited so the vacuum allows the particles to reach the foil and the detector beyond the foil.

a metal surface held at negative potential in a vacuum when an enough frequency falls on it.

photoelectric emission is a process by which electrons are ejected from a metal surface when electromagnetic radiation of high enough frequency falls on them.

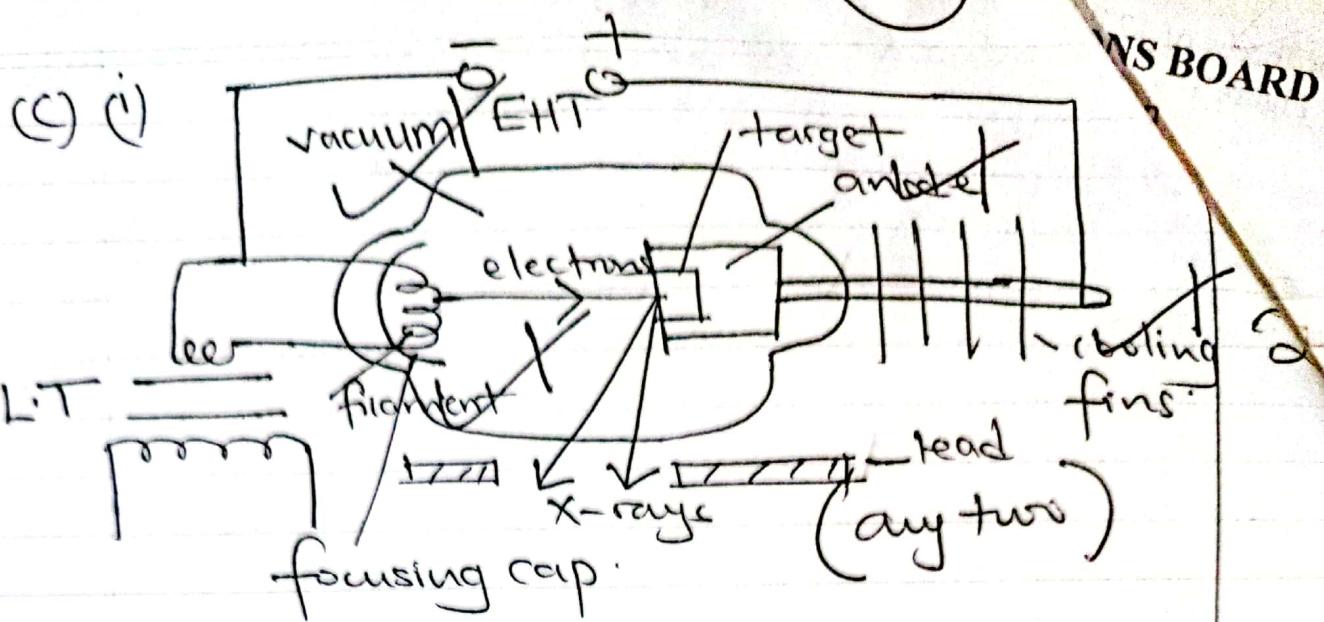
(ii) Threshold frequency is the minimum frequency below which no electrons are emitted.

(b) Quantum theory postulates that light energy exists in discrete packets called quanta and each quantum of energy is carried by a photon $E = hf$. When incident on a metal surface each photon interacts with only one electron giving it all its energy. If the energy is equal or greater than the work function the energy is absorbed and an electron is immediately ejected. This explains the fact that photoelectric emission is instantaneous and that there exists a minimum frequency f_0 for $W = h f_0$. Increasing frequency increases the energy E of each photon and thus the K.E. of the photoelectrons increases. Increasing intensity of radiation does not change the energy of the photons thus intensity does not affect K.E. of photoelectrons. This explains K.E. is proportional to frequency and independent of intensity. Increasing intensity increases the number of photons striking the metal surface per second. Thus more electrons are emitted per second and photocurrent increases. This explains the fact that photocurrent is proportional to intensity.

1

1

5

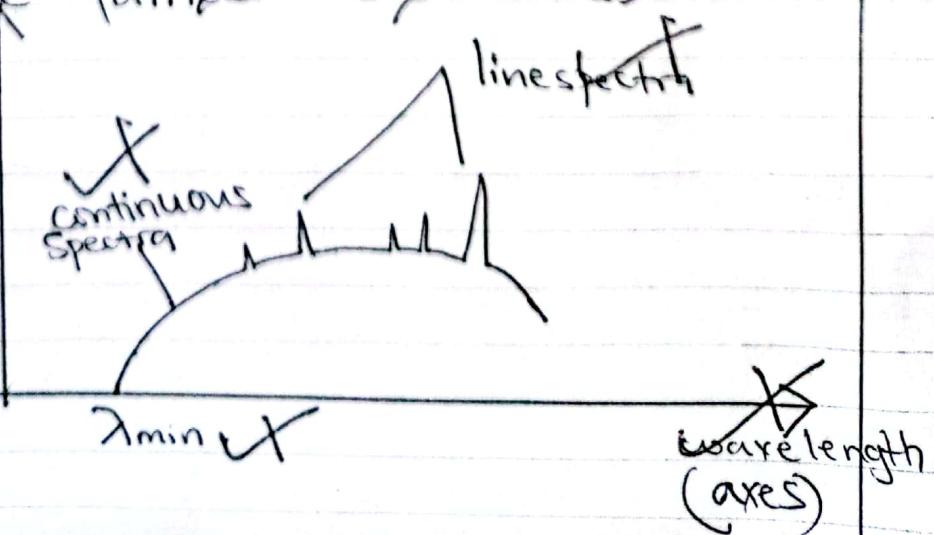


(ii) The filament is heated by a low voltage source. The electrons are emitted and focused to the tungsten target by the focusing cap. The electrons are accelerated by the EHT voltage between the cathode and the anode. When the electrons strike the tungsten target embedded in the anode, a small percentage of the electrons energy is converted to X-rays and a big percentage as heat. The heat generated at the target is removed by the cooling fins attached to the anode.

(d) Explain using suitable sketch graphs how X-ray spectra in an X-ray tube are formed. (6 marks)

(d)

Intensity



21

Continuous spectra is formed as a result of multiple collisions of energetic electrons with target atoms. At each collision X-rays of different wavelengths are emitted. Line spectrum is formed when a highly energetic electron knocks an electron out of the innermost shells. Electron transitions to the vacancies left results in emission of X-rays of definite wavelengths.

$$(e) \quad \frac{2d}{\lambda} \sin \theta = c \quad \checkmark$$

$$2 \times 2.82 \times 10^{10} \sin \theta = 8.42 \times 10^1 \quad \checkmark$$

$$\theta = 8.6^\circ \quad \checkmark$$

6

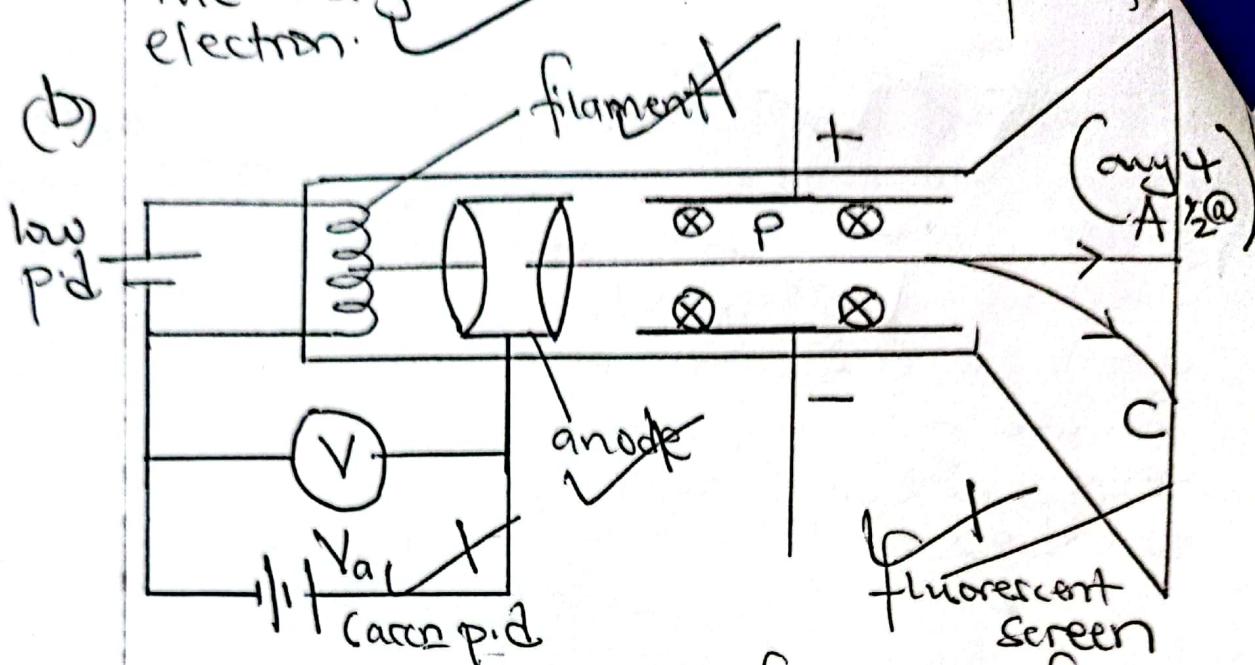
2

20

(20/20)

10(a) Specific charge of an electron is the charge to mass ratio of an electron.

(b)



Electrons are emitted from the filament thermionically and accelerated to the anode by the accelerating p.d. V_a . With no electric or magnetic fields applied at P the electrons will reach point A~~at~~^{at} the screen, position A₁ is noted. The magnetic field of known flux density B is applied at P₂ to deflect the beam to C. Electric field is simultaneously applied at P and adjusted until the beam goes back to A~~at~~^{at} the p.d. across the plates V_d and separation d are noted. The charge to mass ratio $\frac{e}{m} = \frac{V^2}{2V_a d^2 B^2}$ where V_a

is the accelerating p.d.
With the field off:-



$$F \propto$$

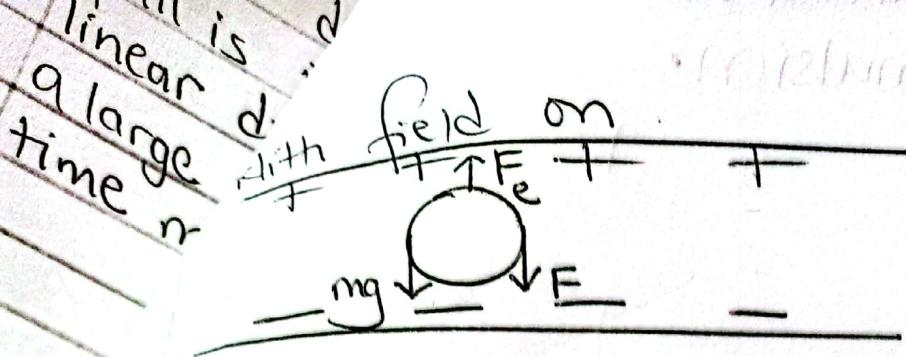
$$F = KV,$$

$$KV = mg$$

$$K(4 \times 10^{-4}) = 1 \times 10^{-14} \times 9.81$$

$$K = 2.45 \times 10^{-10}$$

23



$$F_e = F + W \quad \checkmark$$

$$qE = KN_2 + mg \Rightarrow q\frac{V}{d} = KN_2 + mg$$

$$\frac{q \times 1.6 \times 10^{-19}}{14 \times 10^{-13}} = 2.45 \times 10^{10} \times 8.0 \times 10^{-5} + 9.81 \times 10^{-4}$$

$$q = 1.03 \times 10^{-18} C \quad \checkmark$$

no of electron charges $n = \frac{q}{e}$ \checkmark

$$n = \frac{1.03 \times 10^{-18}}{1.6 \times 10^{-19}} \quad \checkmark$$

$$n = 6.4 \approx 6 \quad \checkmark$$

(d) (i) Half life is the time taken for half of the radioactive nuclei present in a source to disintegrate.

$$N = N_0 e^{-\lambda t} \quad \text{but } N = \frac{N_0}{2}$$

$$t = T_{1/2} \quad \checkmark$$

$$\Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \quad \text{AAHAA} \quad \checkmark$$

$$\ln(\frac{1}{2}) = \ln e^{-\lambda T_{1/2}} \Rightarrow \ln(2^{-1}) = -\lambda T_{1/2}$$

$$T_{1/2} = \frac{\ln 2}{\lambda} \quad \text{AAHAA} \quad \checkmark$$

$$(e) A = A_0 e^{-\lambda t} \quad \text{AAHAA}$$

$$0.25 = e^{-\lambda t} \quad 8 = 32 e^{-\lambda t} \quad \text{AAHAA}$$

$$\ln(0.25) = -\lambda t = \frac{\ln e^{-\lambda t}}{-\ln 0.25} = 0.1386 \text{ per day}$$

$$\text{AAH: } \lambda = 1.60 \times 10^{-6} \text{ s}^{-1}$$

6

1

2

2

3

20