S6 MOCK 1 2017 - PHYSICS PAPER ONE

MARKING GUIDE

1. (a) (i) Relative density - ratio of the mass of any volume of substance to the mass of an equal volume of water. 01

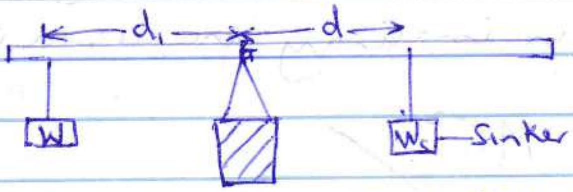
or R.D = ratio of the density of a substance to the density of water.

(ii) A metre rule is balanced horizontally on a knife edge and the position, G, of balance noted.

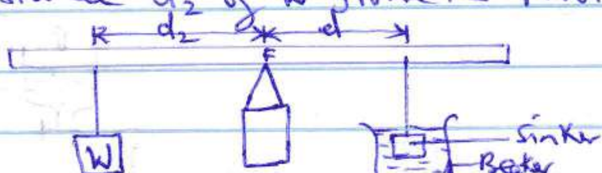
- The knife edge is now fixed at G. A sinker is attached at a distance d from the pivot, and the distance kept constant.
- A weight, W, of any suitable mass, is hung on the opposite side and adjusted until the metre rule balances horizontally. The distance of W is noted as d_1, from G.

Using moments, $W_s \times d = W d_1$; W_s = weight of sinker in air

$$W_s = \frac{W d_1}{d} \quad \text{---- (i)}$$



- With the knife edge still at G, the sinker is immersed in water; the weight W is moved until the metre rule balances horizontally. The distance d_2 of W from the pivot is read and noted.



Using moments and letting W_s' = weight of sinker in water

$$W \times d_2 = W_s' \times d$$

$$W_s' = \frac{W d_2}{d} \quad \text{---- (ii)}$$

- With the knife edge maintained at G, the sinker is the immersed in a liquid. The weight W is adjusted until the metre rule balances horizontally. The distance d_3 of W from

Using moments, $W \times d_3 = W_s'' \times d$; W_s'' = wt of sinker in liquid.

$$W_s'' = \frac{W d_3}{d}$$

Upthrust in water $= W_s - W_s'$

$$= \frac{W d_1}{d} - \frac{W d_2}{d} = \frac{W}{d}(d_1 - d_2)$$

Upthrust in liquid $= W_s - W_s''$

$$= \frac{W d_1}{d} - \frac{W d_3}{d} = \frac{W}{d}(d_1 - d_3)$$

Relative density is then calculated from

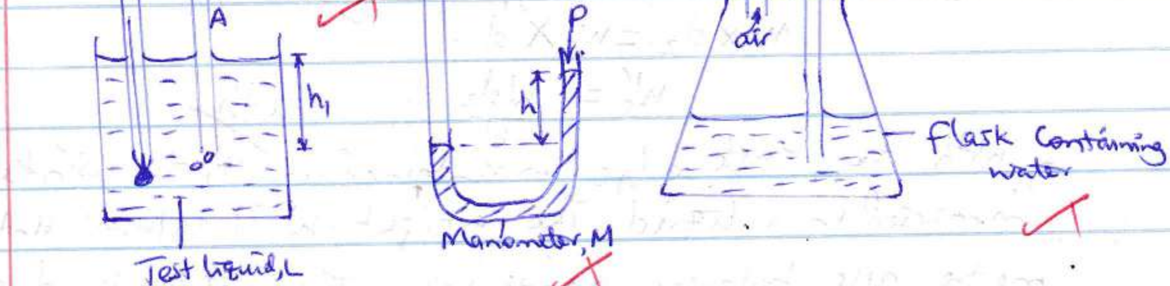
$$R.D = \frac{d_1 - d_3}{d_1 - d_2}$$

b (i) Surface tension - tangential force acting perpendicular to one side of an imaginary line drawn in the liquid surface.
or Surface tension - force per unit length acting normally to one side of an imaginary line drawn in the liquid surface.

$$[\gamma] = \frac{[F]}{[L]} = MT^{-2}$$

02

(ii) The experiment is set up as shown in the figure below with the capillary tube connected to a flask and a manometer M.



The temperature, θ, of L is noted on a thermometer and recorded.

Drops of water are slowly dropped from the funnel into the flask while observing the manometer. This makes a bubble to form slowly at the end of the tube A.

The maximum pressure difference, h, is noted on the manometer.

Now, let P = atmospheric pressure, ρ = density of liquid in manometer, σ = density of the test liquid and r = radius of the orifice of A.

When the radius of the orifice of A equals the radius of the bubble formed, then the pressure is a maximum.

05

Excess pressure inside the bubble, $\frac{2\gamma}{r} = (P + h\rho g) - (P + h_1\sigma g)$

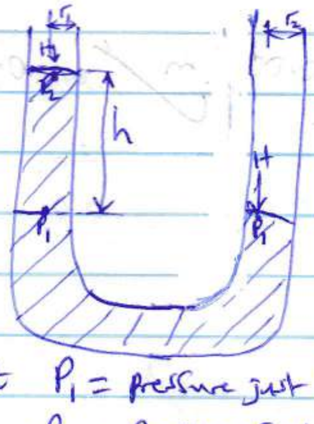
$\gamma = \frac{rg}{2}(h\rho - h_1\sigma)$, and γ is calculated.

The experiment is repeated for various temperatures, θ, of the test liquid and each time calculating the value of the surface tension, γ.

(iii) Variation of surface tension with temperature:

When the temperature of a liquid is increased, the average kinetic energy of its molecules increases. The intermolecular forces of attraction between the molecules decrease. Hence surface tension of a liquid decreases as the temperature increases and vanishes at the critical temperature. 02

(c)



$r_2 = \frac{3}{2}\text{mm} = 1.5 \times 10^{-3}$ m

$r_1 = 10\text{mm} = 1.0 \times 10^{-2}$ m

$\theta = 120°$;

$\rho = 1.36 \times 10^4 \text{ kgm}^{-3}$; $\gamma = 0.4 \text{ Nm}^{-1}$.

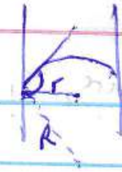
Let P_1 = pressure just below the surface of mercury in ~~larger~~ smaller tube.

P_2 = Pressure just below the surface of mercury in larger tube

H = atmospheric pressure.

(i) $F_\gamma = 2\pi R\gamma$

But $r = R\cos\theta$



; R = radius of curvature of the surface.

(ii) $P_1 - H = \dfrac{2\gamma\cos\theta}{r_1}$

$$P_1 = \frac{2\gamma\cos\theta}{r_1} + H \quad \text{---(i)}$$

Also $P_1 = P_2 + h\rho g = H + \dfrac{2\gamma\cos\theta}{r_2} + h\rho g$ ---(ii).

(i) = (ii);

$$\frac{2\gamma\cos\theta}{r_1} + \cancel{H} = \cancel{H} + \frac{2\gamma\cos\theta}{r_2} + h\rho g.$$

$$h\rho g = 2\gamma\cos\theta\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

04

$$h = \frac{2\gamma\cos\theta}{\rho g}\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$$

$$= \frac{2\times 0.4\cos 120^\circ}{1.36\times10^4\times 9.81}\left[\frac{1}{1.5\times10^{-3}} - \frac{1}{1\times10^{-2}}\right].$$

$$= -1.699\times10^{-3}\,m.$$

Difference in mercury levels $= 0.0017\,m$ (or $0.17\,cm$.)

20

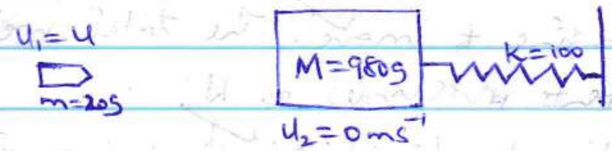
2. (a) - Everybody remains in its state of rest or of uniform motion in a straight line unless an external force acts otherwise.
- The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction of the force.
- For every action there is an equal and opposite reaction.

03

(b) The rocket exerts a strong force on the burning gases, expelling them downward. The exhaust gases also exert an equal and opposite force on the rocket, which propels the rocket to move forward.

03

(c)



; $x = 4.8\,cm = 4.8 \times 10^{-2}\,m$

Let v be the common velocity of the bullet and the block.

KE gained by block + bullet = Electrostatic PE

$$\frac{1}{2}(m+M)v^2 = \frac{1}{2}Kx^2$$

$$\frac{1}{2}(0.02+0.98)v^2 = \frac{1}{2} \times 100 \times (4.8\times10^{-2})^2$$

$$v = \sqrt{0.2304}$$

$$v = 0.48\,ms^{-1}$$

07

Conserving momentum initially

$$m_1u_1 + Mu_2 = (m+M)v$$

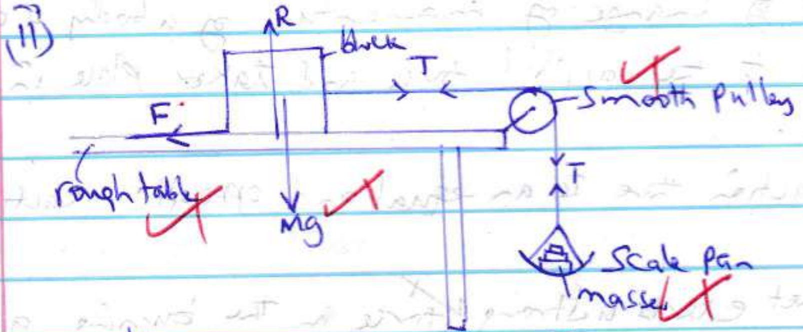
$$0.02u + 0.98 \times 0 = (0.02+0.98) \times 0.48$$

$$u = 24\,ms^{-1}$$

(d) i) - Frictional force between two surfaces opposes their relative or attempted motion.
- Frictional force is independent of the area of contact provided

- Frictional force is directly proportional to the normal reaction (03)

(ii)



(any 2 @ $\frac{1}{2}$ = 01)

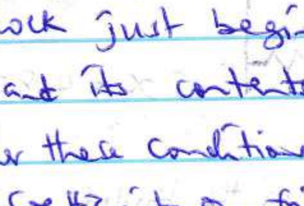
- The ~~sphere~~ block is weighed and its mass recorded as m.
- A light string is attached to the block resting on the table and passes over a pulley to support a scale pan at its free end.
- Small weights are carefully added onto the scale pan until the block just begins to move. The total weight of the pan and its contents is recorded as W.
- Under these conditions, the limiting frictional force, F = W. The coefficient of friction, μ is then calculated from (03)

$$\mu = \frac{F}{R} = \frac{W}{mg}.$$

- The experiment may be repeated for more values of W and the average value of μ calculated.

NB- You may follow through up ~~to~~ if the graphical approach is used. μ = slope of graph of W against m.

ALT: (Follow through)



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Qn 3(a) (i) Elasticity - ability of a material to change in length when a force is applied and to regain its original shape and size when the deforming force is removed.

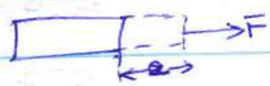
(ii) Young's modulus - ratio of the tensile stress to the tensile strain,

(iii) Plastic deformation - region in which a material stretched to it cannot regain its original shape and size when the stretching force is removed.

03

(b) Consider a material stretched through a length, δe when a force F is applied.

l_0 = original length of the material.



Work done by force, EPE = $F\Delta x$

Total work done, $W = \int_0^e F dx = \int_0^e Kx\,dx$

$= K\frac{e^2}{2}$

EPE per unit volume $= \frac{Ke^2}{2} / Al_0$

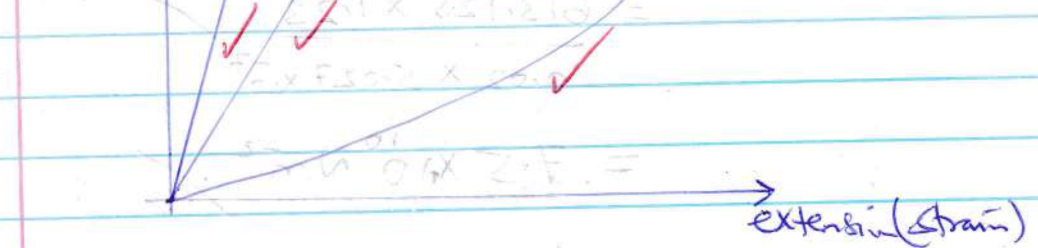
$= \frac{1}{2}\left(\frac{Ke^2}{Al_0}\right)$

$= \frac{1}{2} \times \frac{F}{A} \times \frac{e}{l_0}$

$= \frac{1}{2} \times \text{stress} \times \text{strain}$

03

(c)



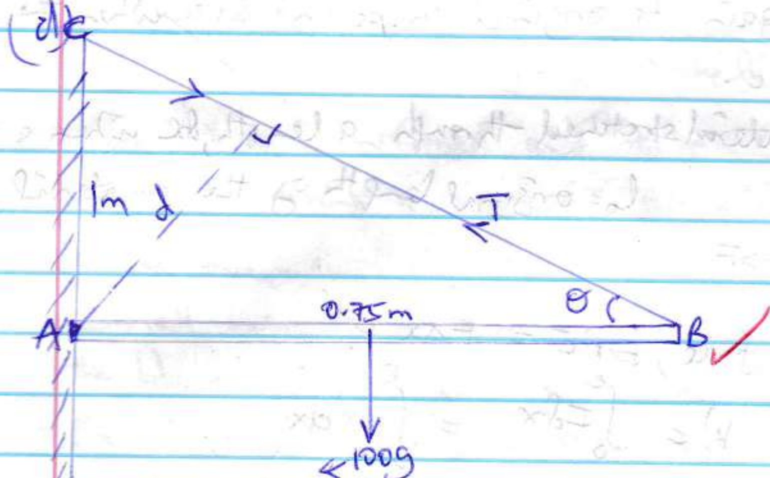
03 (Provided the axes are labelled)

Metal – Undergoes both elastic and plastic deformation. Before the proportional limit, the stress is directly proportional to the strain.

Rubber – Rubber has a greater range of elasticity and does not undergo plastic deformation. Unstretched rubber has coiled molecules which when stretched, they unwind and become straight.

06

(c)



$\tan\theta = \frac{1}{0.75}$

$\tan\theta = 4/3$

$\sin\theta = 4/5$

$\cos\theta = 3/5$

(i) Taking moment about A;

$$100 \times 9.81 \times \frac{0.75}{2} = T \times 0.75 \sin\theta$$

04

$$T = \frac{100 \times 9.81 \times 0.375}{0.75 \times 4/5}$$

$$= 613.125\ N$$

(ii) $AC = \sqrt{1^2 + 0.75^2} = 1.25\ m$

extension, $e = 1.25 - 1.23 = 0.02\ m$

$$A = \frac{\pi d^2}{4} = \frac{\pi}{4}(0.8 \times 10^{-3})^2 = 5.027 \times 10^{-7}\ m^2$$

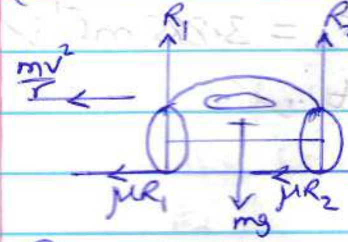
Young's modulus, $E = \frac{F/A}{e/l_0}$

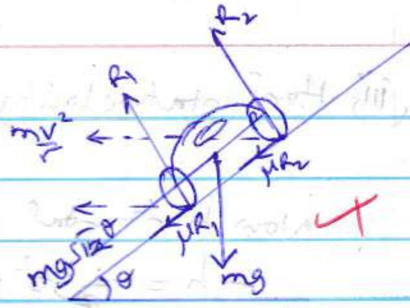
04

$$= \frac{613.125 \times 1.23}{0.02 \times 5.027 \times 10^{-7}}$$

$$= 7.5 \times 10^{10}\ N m^{-2}$$

4. (a)





On a flat track, the centripetal force is provided for by only the frictional force. Thus $\frac{mv^2}{r} = \mu(R_1+R_2)$ — (i).

On a banked track, the centripetal force is provided for by both the component of the normal reactions acting horizontally and the horizontal components of the frictional force.

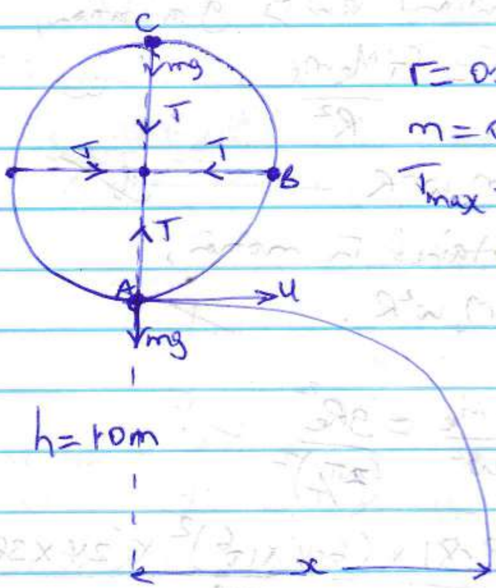
Thus $\frac{mv^2}{r} = (R_1+R_2)\sin\theta + \mu(R_1+R_2)\cos\theta$.

04

$$\frac{mv^2}{r} = (R_1+R_2)[\sin\theta + \mu\cos\theta]$$

Hence a car travels faster on a banked track than on a flat track of the same radius.

(b)



$r = 0.5m$

$m = 0.5kg$

$T_{max} = 20N$

(i) At A (directly below the centre.

$$T - mg = \frac{mv^2}{r}.$$

$$T = mg + \frac{mv^2}{r} \text{ — (i)}$$

At B, $T = \frac{mv^2}{r}$ — (ii)

At C; $T + mg = \frac{mv^2}{r}$.

02

$$T = \frac{mv^2}{r} - mg \text{ — (iii)}$$

Now T is greatest at A and the string will break there.

(ii) $20 = 0.5[9.81 + w^2 r]$.

$40 = 9.81 + 0.5w^2$.

03

(iii) Horizontal velocity, $u = \omega r$.

$$= 7.77 \times 0.5 = 3.885\ ms^{-1}$$

Now, horizontal distance, $x = ut$.

$$-h = -\tfrac{1}{2}gt^2$$

$$1.0 = \tfrac{1}{2} \times 9.81 t^2$$

$$t = \sqrt{\left(\tfrac{2}{9.81}\right)} = 0.452\ s$$

03

$$x = 3.885 \times 0.452$$

$$= 1.756\ m$$ ~~from~~ vertical through the centre of rotation of the circle.

(d) (i) Parking orbit — path in space in which a satellite appears to be in the same position relative to a point on the earth's surface as the earth rotates about its axis.

01

(ii)

Let M_e = mass of the earth,

m_s = mass of the satellite

By Newton's law of gravitation,

$$F = \frac{GM_e m_s}{R^2} \quad \text{—— (i)}$$

Centripetal force, $F_c = m_s \omega^2 R$ —— (ii)

For satellite to be maintained in motion,

$$\frac{GM_e m_s}{R^2} = m_s \omega^2 R.$$

$$R^3 = \frac{GM_e}{\omega^2} = \frac{gR_e^2}{\left(\frac{2\pi}{T}\right)^2}$$

$$R^3 = \frac{9.81 \times (6.4 \times 10^6)^2 \times (24 \times 3600)^2}{4\pi^2}$$

04

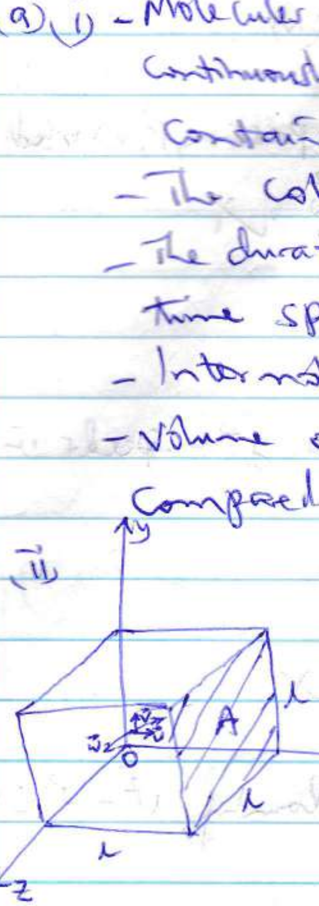
$$R = 42.35 \times 10^6\ m$$

$$h = 42.35 \times 10^6 - 6.4 \times 10^6$$

$$= 35.95 \times 10^6\ m$$

5. (a) (i) - Molecules of a gas are randomly moving about, continuously colliding with each other and the walls of the container.
- The collisions are perfectly elastic
- The duration of a collision is negligible compared to the time spent between collisions.
- Intermolecular forces of attraction are negligible (04)
- Volume occupied by molecules themselves is negligible compared to the volume occupied by the gas.

(ii)



Consider N molecules of a gas contained in a cube of side, l, each molecule having a mass, m. The molecules are considered to be in a state of continuous random motion.

Consider one molecules having a velocity $\vec{c}$ at any instant where $\vec{c}$ has components $\vec{u}$, $\vec{v}$ and $\vec{w}$ in the OX, OY and OZ - directions respectively. Then

$$c^2 = |\vec{c}|^2 = |\vec{u}|^2 + |\vec{v}|^2 + |\vec{w}|^2.$$

Let $|\vec{u}| = u$; $|\vec{v}| = v$ and $|\vec{w}| = w$.

$$\Rightarrow c^2 = u^2 + v^2 + w^2 \quad \text{(i)}$$

Consider the speed u of a molecule perpendicular to the face A of the cube.

Change in momentum of the molecule $= mu - (-mu) = 2mu$ (ii)

Let t be the time taken for the molecule to move from one face to another and back,

Then $t = 2l/u$.

The rate of change of momentum, $F = \frac{2mu}{2l/u}$

$$F = \frac{mu^2}{l} \quad \text{(iii)}$$

$$P = \frac{mu^2/l}{l^2} = \frac{mu^2}{l^3} \quad \text{(iv)}$$

For N molecules of the gas, the total pressure, P, exerted will be

$$P_T = \frac{mu_1^2}{l^3} + \frac{mu_2^2}{l^3} + \dots + \frac{mu_N^2}{l^3}$$

$$= \frac{m}{l^3}\left(u_1^2 + u_2^2 + \dots + u_N^2\right).$$

Let $\overline{u^2}$ be the mean of the squares of the speeds in the ox-direction.

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

$$\Rightarrow u_1^2 + u_2^2 + u_3^2 + \dots + u_N^2 = N\overline{u^2}.$$

$$\Rightarrow P = \frac{mN\overline{u^2}}{l^3} \quad \text{(iv)}$$

Since the molecules are moving randomly, $u^2 = v^2 = w^2$.

$$\Rightarrow \overline{u^2} = \overline{v^2} = \overline{w^2}.$$

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

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

$$\overline{u^2} = \frac{1}{3}\overline{c^2}.$$

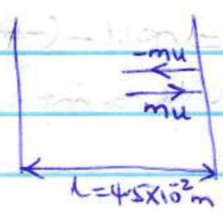
$$\therefore P = \frac{mN}{l^3} \cdot \frac{1}{3}\overline{c^2}.$$

06

But density, $\rho = \frac{mN}{l^3}$

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

(b)



$m = 2.32 \times 10^{-26}\,kg$; mean speed, $u = 500\,ms^{-1}$.

$N = 2 \times 10^{22}$ molecules

change in momentum of each molecule $= mu - (-mu) = 2mu$.

Time taken to move from one end to another and back

$$t = 2l/u.$$

Pressure exerted by one molecule, $P = \frac{mu^2}{l/l^2} = \frac{mu^2}{l^3}$ ✓

Now total pressure exerted by N molecules

$$P_T = \frac{Nmu^2}{l^3}$$

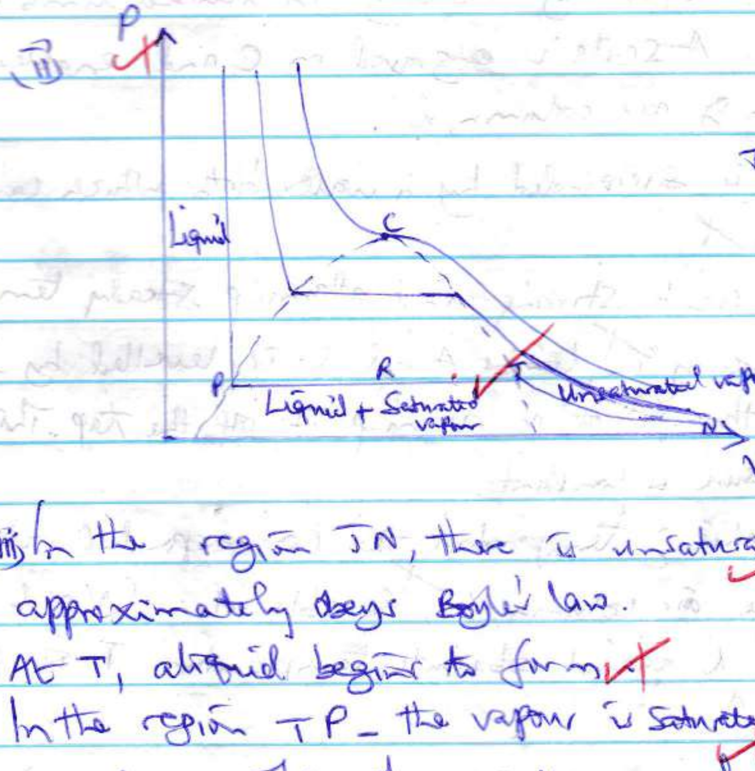
$$= \frac{2\times10^{22} \times 2.32\times10^{-26} \times 500^2}{(4.5\times10^{-2})^3}$$ ✓

04

$$= 1.273\times10^{6}\ Nm^{-2}$$ ✓

(c) i) - The rate of evaporation equals the rate of condensation
- They do not obey gas laws. ✓ 02
- The vapour pressure is independent of the volume.

(ii)



T_c = Critical temperature

✓ Label of axes

02

(iii) In the region TN, there is unsaturated vapour which approximately obeys Boyle's law.
At T, a liquid begins to form ✓
In the region TP - the vapour is saturated and the pressure remains constant. The volume of the gas reduces as more of it becomes liquid. 02
At P, all the gas becomes liquid ✓ and the the Pressure increases rapidly since liquids are almost incompressible.

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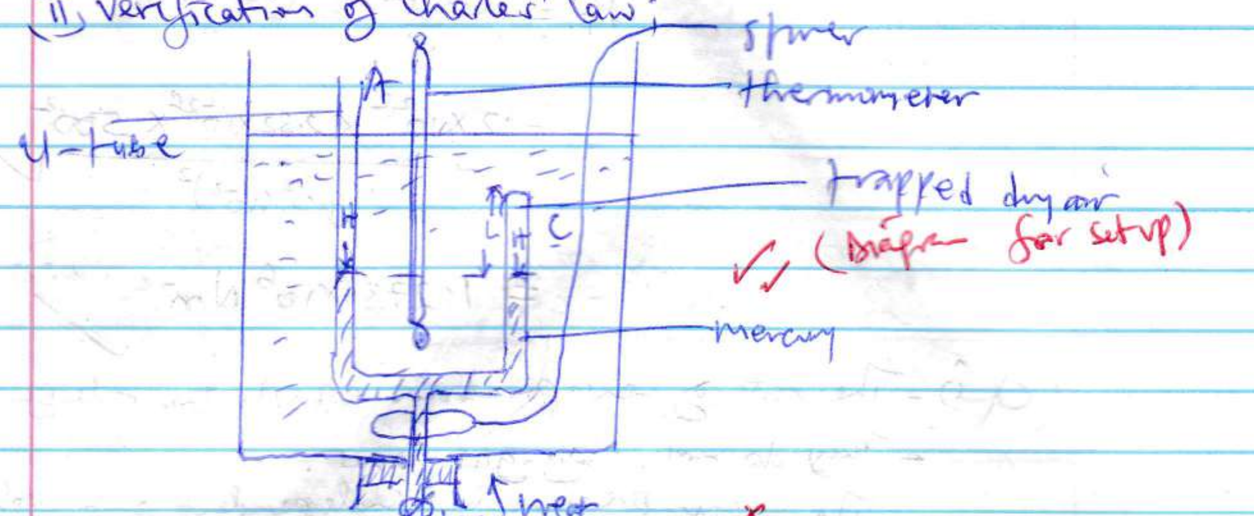
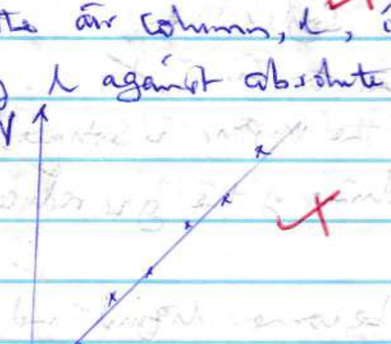
6. (a) i) Charles' law - the volume of a fixed mass of gas at constant pressure is directly proportional to the absolute temperature. 07

(ii) Verification of Charles' law;



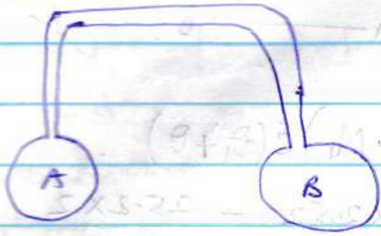
- Dry air is trapped by mercury in a closed limb C of the U-tube AC. A scale is engraved on C and enables measurement of the length of air column, l.
- The tube is surrounded by a water bath which can be heated using steam
- After sufficient stirring and attaining steady temperature of the bath, mercury in limbs A and C is levelled by either pouring in mercury through A or running it off the tap. This ensures that the pressure is constant.
- For each value of temperature the corresponding value of the length of the air column, l, is obtained. ($V \propto l$) 04
- A graph of l against absolute temperature T is plotted.



A straight line through the origin is obtained, hence verifying Charles' law.

b. (i) Dalton's law of partial pressures – In a mixture of gases which do not interact chemically the total pressure equals the sum of the partial pressures of the constituent gases. 07

(ii)



Let n_A and n_B be the number of moles ~~molecules~~ of the gas in the bulbs respectively.

Initially; $n_A = \frac{P_1 V_A}{RT_1}$; $n_B = \frac{P_1 V_B}{RT_1}$

Total number of moles,

$$n_T = \frac{P_1 V_A}{RT_1} + \frac{P_1 V_B}{RT_1} \quad ; V_A = V_B = V.$$

$$n_T = \frac{2P_1 V}{RT_1} \text{ ——— (1).}$$

After immersing one bulb;

$$n_A = \frac{P_2 V}{RT_1} ; \quad n_B = \frac{P_2 V}{RT_2} \quad ; n = n_A + n_B.$$

$$\Rightarrow \frac{2P_1 V}{RT_1} = \frac{P_2 V}{RT_1} + \frac{P_2 V}{RT_2}$$

$$\frac{V}{R}\left[\frac{2P_1}{T_1}\right] = \frac{V}{R}\left[\frac{P_2}{T_1} + \frac{P_2}{T_2}\right]$$

04

$$\frac{P_2}{T_2} = \frac{2P_1}{T_1} - \frac{P_2}{T_1}$$

$$\frac{P_2}{T_2} = \frac{2P_1 - P_2}{T_1}$$

$$T_2 = \frac{P_2 T_1}{2P_1 - P_2}$$

c) Specific heat capacity – Amount of heat required to ~~the~~ raise

(d) $C_w = 4150\ J\,kg^{-1}K^{-1}$; $\theta_1 = 15°C$.

Let the out flow temperature be θ.

(i) $VI = Mc(\theta_1 - \theta_2) + h$.

$V_1I_1 = M_1c(\theta_1 - \theta) + h$ — (i)

$V_2I_2 = M_2c(\theta_1 - \theta) + h$ — (ii)

(ii) − (i);

$V_2I_2 - V_1I_1 = (M_2 - M_1)c(\theta_1 + \theta)$

$$-15+\theta = \frac{30 \times 2.52 - 25.2 \times 2}{\left(\frac{115.9\times10^{-3}}{60} - \frac{75\times10^{-3}}{60}\right)\times 4150}$$ 03

$-15+\theta = 8.91$

$\theta = \cancel{6.09}\ 23.91°C$.

(ii) $25.2 \times 2 - \frac{75}{60}\times10^{-3}\times4150(15-6.09) = h$.

$h = 50.4 - 46.22$ 02

$h = 4.18\ J\,s^{-1}$ (or W)

(e) (i) - Measure the ~~temperature~~ resistance R_θ at the unknown temperature, θ.

- Measure the resistance R_{tr} at the triple point of water

- The unknown temperature is given by $\theta = \frac{R_\theta}{R_{tr}} \times 273.16\ K$ 03

(ii) - Thermocouple can measure temp at a point where as the resistance thermometer cannot.

- Thermocouple has a small heat capacity, hence can measure rapidly changing temperatures where as the resistance thermometer cannot. 01

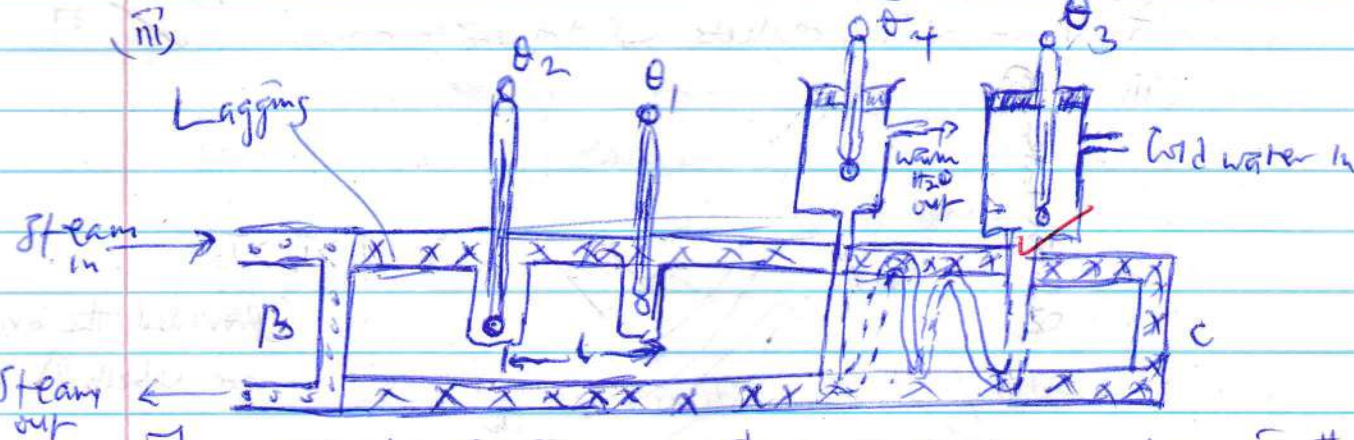
7.(a)(i) Thermal Conductivity — rate of heat flow across opposite face of 1m of a parallel sided slab when the temperature difference across the faces is one Kelvin. (01)

Or; K — heat flow rate normal to one square metre area of a sample whose faces are maintained at a temperature gradient of one Kelvin per metre.

(ii) Conduction in metals is mainly due to free moving electrons. When one end is heated, the free electrons gain thermal energy and move with increased (kinetic energy) velocities. They dissipate this energy upon collision with the ions in the lattice. (03)

Also energy can be transmitted through molecular vibration where heat energy is transmitted to neighbouring molecules.

(iii)



The apparatus is set up as shown in the figure above, with the specimen metal rod AB long compared to its diameter.

A heater is placed at one end of the bar while the bar (rod) is cooled by circulating water at the end B.

Two holes are drilled and thermometers placed there at a measured distance, l. (06)

The holes are filled with mercury to ensure good thermal contact.

The whole apparatus is left running until the temperatures have become steady. The circulating water is collected over a measured time interval is recorded.

Let m = mass of water collected per second and θ_1 and θ_2 be the respective thermometer readings at C and D.

The diameter, d, of ~~the~~ metal bar is obtained at atleast three positions of the bar and the area, A, calculated $\left(A = \frac{\pi d^2}{4}\right)$.
The rate of heat flow is also given by

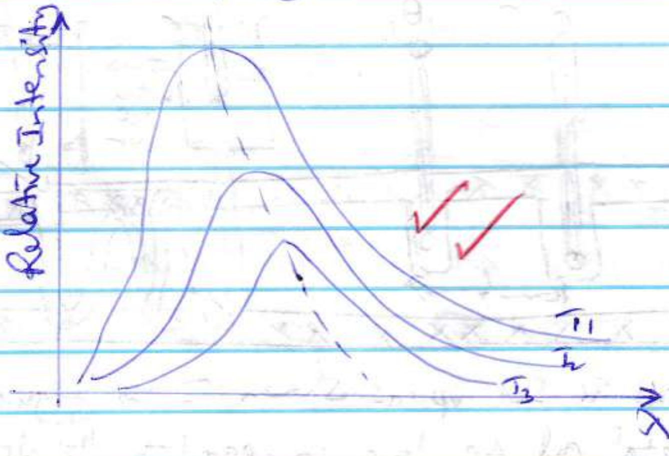
$$Q/t = mc_w(\theta_4 - \theta_3)$$

$$\Rightarrow \frac{KA(\theta_2 - \theta_1)}{l} = mc_w(\theta_4 - \theta_3)$$

$$K = \frac{mc_w(\theta_4 - \theta_3) \cdot l}{A(\theta_2 - \theta_1)}$$ from which K can be calculated, θ_3, θ_4 are the entrance and exit temps of water.

(b) (i) Black body – one that absorbs all radiations of all wavelengths incident on it, reflects and transmits none. 07

(ii)



$T_1 > T_2 > T_3$

(provided the axes are labelled)

(iii) – At first, the ball is invisible.

– It becomes dull red, then bright red and finally less red tending to white.

03

– This is because as the temp. rises, the intensity of the shorter wavelengths increases more rapidly. So the peak intensity shifts from the red of the spectrum into the visible spectrum with green and blue colours coming into play.

(C) At equilibrium,
Power radiated by filament = Power generated

$$1800 = 85\,\sigma A T^4$$

But $A = 2\pi r l = \pi D l$

$= \pi \times 1.5\times10^{-2} \times 30\times10^{-2}$

$= 0.01414\ m^2$

$\therefore\ 1800 = \frac{85}{100} \times 5.7\times10^{-8} \times 0.01414\ T^4$

04

$T^4 = 2.628\times10^{12}$

$\therefore T = 1273.2\ K$

20

8. (a) (i)

X-rays	Cathode rays
- Carry no charge	Carry a negative charge
- Travel at the speed of light	- Have a relatively low speed
- Have a higher penetration power	- Have a relatively low penetration power
- Have a relatively low ionisation power	- Have a relatively higher ionisation power.
- not Deflected by electric & magnetic fields	- Deflected by electric & magnetic fields

02

(ii) The anode is a high melting point material so that it does not melt easily when struck by fast moving electrons. 03 At one end of it are cooling fins that help to get rid of the heat gained by the anode (or there is circulating water).

(b) (i) $2d\sin\theta = n\lambda$ where d = interplanar spacing

θ = glancing angle

n = order of diffraction

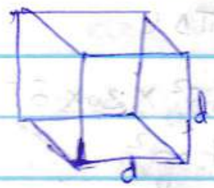
λ = wavelength

07

(ii) The wavelength of the incident radiation must be of the same order as the interplanar spacing. 01

(iii) $\lambda = 1.10\times10^{-10}\ m$; $n=1$; $\theta = 19°$

RMM = 75.5



Let d = interplanar spacing
Using $2d\sin\theta = n\lambda$.

$$d = \frac{1 \times 1.10 \times 10^{-10}}{2\sin 19^\circ}$$
$$= 1.69 \times 10^{-10}\,m$$

Volume associated with one atom $= d \times d \times d = d^3$.
Volume associated with KCl crystal, $V = 2d^3$
Now mass of one molecule, $m = \frac{M}{N_A}$.

Density, $\rho = \frac{m}{V} = \frac{M}{N_A} / 2d^3$

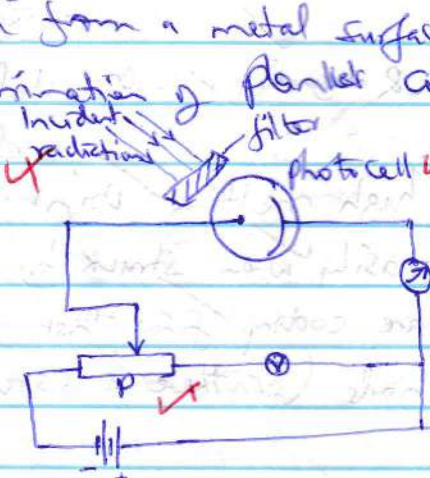
(04)

$$\rho = \frac{75.5 \times 10^{-3}}{6.02 \times 10^{23} \times 2 \times (1.69 \times 10^{-10})^3}$$
$$= 1.299 \times 10^{4}\ Kgm^{-3}$$

(c)(i) Work function – minimum energy required to eject an electron from a metal surface.

(01)

(ii) Determination of Planck constant.

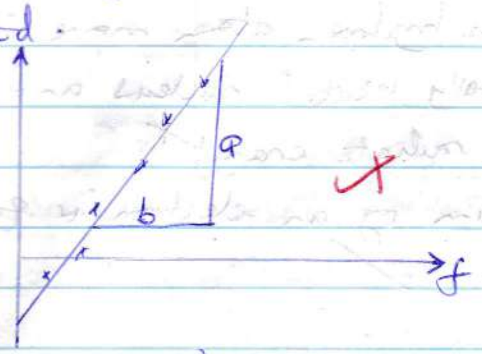


any $2 \times \frac{1}{2} = (01)$

- An incident beam of electromagnetic radiation is passed through colour filters onto a photocell
- The potential divider P is used to vary the p.d V between the anode and the cathode and the d.c amplifier is used for measuring small currents.

The p.d. V is increased negatively until the current becomes zero, and the stopping potential, V_s, is read and recorded from a voltmeter.

- A graph of V_s against f is now plotted and its slope, S, calculated.



- Planck's constant, h, is then calculated from
$$h = e \times \text{slope}, \text{ where } e = \text{electronic charge}.$$

04

(iii) $f_1 = 6.0 \times 10^{14}\,Hz,\ V_s = 0.6\,V$
~~$f_2 = 1.0 \times 10^{15}\,Hz,\ V_s = 2.2\,V$.~~

From Einstein's equation

$$eV_s = hf - W_0.$$
$$W_0 = 6.64 \times 10^{-34} \times 6.0 \times 10^{14} - 0.6 \times 1.6 \times 10^{-19}$$
$$= 3.024 \times 10^{-19}\,J.$$
$$\frac{hc}{\lambda_0} = 3.024 \times 10^{-19}\,J.$$
$$\lambda_0 = \frac{6.64 \times 10^{-34} \times 3.0 \times 10^{8}}{3.024 \times 10^{-19}}$$
$$= 6.59 \times 10^{-7}\,m.$$

04

9. (a) Bohr's postulates;

- Electrons in the hydrogen atom move in circular orbits about a centrally located nucleus and while in these orbits they do not radiate energy. (02)

- Angular momentum of an electron is quantised. ie

$$mvr = \frac{nh}{2\pi}.$$

(b) Ionisation energy – energy required to remove an electron from an atom in its ground state to infinity so that it is completely lost. (01)

Excitation energy – energy required to remove an electron from an atom in its ground state to a higher energy level. (01)

(c) (i) Ionization energy $= 0 - {-10.4}\,eV.$

$= 10.4\,eV.$

$= 10.4 \times 1.6 \times 10^{-19}$ (02)

$= 1.664 \times 10^{-18}\ J$

(ii) For 4.0eV.

$\Delta E = -10.4 + 4.0$

$= -6.4\,eV$

The atom remains unexcited.

For 11.0eV.

$\Delta E = -10.4 + 11.0$ (04)

$= +0.6\,eV.$

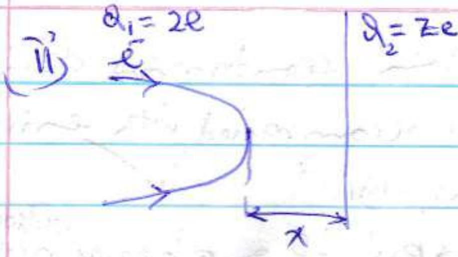
The atom will become ionised.

(d) (i) Successes:

- It accounts for the observations of alpha-particle scattering by a metal foil

- Using the model, the radius of the atom can be estimated

Failure – It fails to account for existence of stable atoms (03) ii)



At distance of closest approach,
Kinetic energy of α-particle = Electrostatic potential energy.

$$\frac{1}{2}mv^2 = \frac{Q_1 Q_2}{4\pi\varepsilon_0 x}$$

$$\frac{1}{2}mv^2 = \frac{2e \times Ze}{4\pi\varepsilon_0 x}$$

$$x = \frac{4Ze^2}{4\pi\varepsilon_0 m v^2}$$

03

$$\therefore x = \frac{Ze^2}{\pi\varepsilon_0 m v^2}$$

(e) Emission spectrum of hydrogen
- Continuous spectrum – Is the one ~~set~~ in which all the wavelengths of the radiation emitted are spread over a wide range. It occurs in solids and dense gases.
- Line spectrum – This consists of a number of well defined lines each with a particular wavelength. It is common with excited gases which emit radiation of only certain wavelengths.
- Band spectrum – Is the one in which the band consists of a series of lines very close together at one end and far apart at the other end.

04

20

10. (a) (i) Radioactivity - Is the random spontaneous disintegration an unstable radioactive nuclei accompanied with emission of any of α, β - particles or gamma rays ✓ 02

While nuclear fission is the splitting of a heavy radioactive nuclide into lighter nuclei. ✓

(ii) B.E - Is the work done to take all the nucleons of an atom apart so that they are completely separated. ✓ 01

(or Is the energy required to bring the constituent nucleons together to form a nucleus.)

(b) (i) Half life - Is the time taken for the mass of a radioactive nuclide to reduce to half its original value. ✓ 01

(ii) Let N be the number of atoms present at a time t.

$-\frac{dN}{dt} \propto N$ ✓ (decay law)

$-\frac{dN}{dt} = \lambda N.$

$\int \frac{dN}{N} = \int -\lambda dt.$

$\ln N = -\lambda t + c.$ ✓

At $t = 0$, $N = N_0$

$\ln N_0 = c.$

$\ln N = -\lambda t + \ln N_0.$ ✓

At $t = t_{1/2}$ (half life, $N = N_0/2$).

$\ln\left(\frac{N_0}{2}\right) = -\lambda t_{1/2} + \ln N_0.$ ✓ 03

$\ln\left(\frac{N_0/2}{N_0}\right) = -\lambda t_{\frac{1}{2}}.$ ✓

$\lambda t_{\frac{1}{2}} = \ln 2.$

$t_{1/2} = \frac{\ln 2}{\lambda}$ ✓ or $t_{\frac{1}{2}} = \frac{0.693}{\lambda}.$

(c) (i) ${}^{238}_{92}U \longrightarrow {}^{234}_{90}X + {}^{4}_{2}He$ ✓ 01 (c)(ii) Mass defect $= 238.12492 - (234.11650 + 4.00387)$

$= 0.00455\ u$

$= 0.00455 \times 1.66 \times 10^{-27}\ kg$

$= 7.553 \times 10^{-30}\ kg$

Energy released $= (\Delta m)c^2$

$= 7.553 \times 10^{-30} \times (3.0 \times 10^{8})^2$

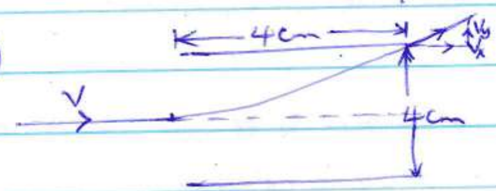
$= 6.798 \times 10^{-13}\ J.$

$= \dfrac{6.798 \times 10^{-13}}{1.6 \times 10^{-19}} \times \dfrac{1}{10^{6}}$

$= 4.25\ MeV.$

05

(d)



(i) $\frac{1}{2} m_e v^2 = eV$

$v^2 = \dfrac{2eV}{m_e}$

$v = \sqrt{\dfrac{2 \times 1.6 \times 10^{-19} \times 1800}{9.11 \times 10^{-31}}}$

$= 2.51 \times 10^{7}\ ms^{-1}$

03

(ii) The electron beam describes a parabolic path.

01

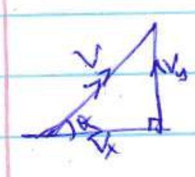
(iii) $V_x = 2.51 \times 10^{7}\ ms^{-1}.$

$V_y = a_y t = \left(\dfrac{Ee}{m_e}\right) \cdot \dfrac{L}{v}$

$V_y = \dfrac{V}{d} \cdot \dfrac{e}{m_e} \cdot \dfrac{L}{v}.$

$= \dfrac{90}{4 \times 10^{-2}} \times \dfrac{1.6 \times 10^{-19}}{9.11 \times 10^{-31}} \times \dfrac{4 \times 10^{-2}}{2.57 \times 10^{7}} = 6.30 \times 10^{5}\ ms^{-1}$

03



$\tan\theta = \dfrac{V_y}{V_x}.$

$\tan\theta = \dfrac{6.30 \times 10^{5}}{2.51 \times 10^{7}}$