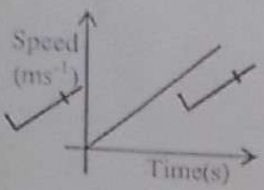
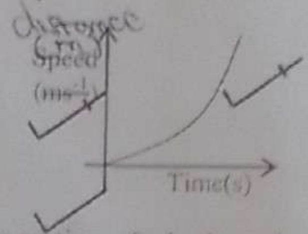
MARKING GUIDE – JJEB P510/1 – 2023

1. (a) (i)



(ii)



(b) (i) Free fall of a body: This is the motion of a body under the influence of gravity as the only force acting on it. Dissipative forces like air resistance are negligible. The body moves with a constant acceleration of 9.81 ms^{-2}.

(ii) 1^{st} stone; $v_1^2 = 2gs_1$ and 2^{nd} stone; $v_2^2 = 2gs_2$

But $v_1 = gt$ and $v_2 = g(t-1)$

By substitution, $v_2 = 23 = 9.81(t-1)$

t = 3.355 seconds

$\therefore v_1 = 9.81 \times 3.355 = 32.8\ ms^{-1}$

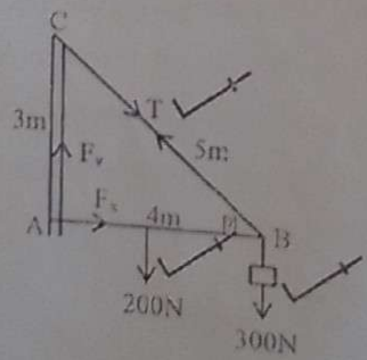
$$s_1 - s_2 = \frac{v_1^2}{2g} - \frac{v_2^2}{2g} = \frac{32.8^2}{2 \times 9.81} - \frac{23^2}{2 \times 9.81}$$

$\therefore s_1 - s_2 = 28.0m$

(c) (i) - The resultant force must be zero.

- The sum of clockwise moments about any pint must be equal to the sum of anticlockwise moments about the same point

(ii)



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Taking moments about A

$(200 \times 2) + (300 \times 4) = T \sin\theta \times 4$

But $\sin\theta = \frac{3}{5}$

$T = \left(\frac{1600 \times 5}{12}\right)$

$T = 667\ N$

$\uparrow F_y = (200 + 300) - T\sin\theta$

$F_y = 500 - \left(\frac{2000}{3} \times \frac{3}{5}\right) = 100N$

$\rightarrow F_x = T\cos\theta = \frac{2000}{3} \times \frac{4}{5}$

$F_x = 533.6\ N$

(d) Conservative force is one for which the work done to move a body from one point to another is independent of the path taken. OR The work done to move a body round a closed path is zero. Mechanical energy is conserved.

WHILE non – conservative force is one for which the work done to move a body from one point to another depends on the path taken. OR Work done round a closed path is not zero and Mechanical energy is not conserved.

Examples

- Conservative force – gravitational, magnetic and electrostatic fore.
- Non – conservative – friction, viscous drag, air resistance.

2. (a) (i) Angular velocity is the rate of change of the angle for an object moving in a circular path about the centre.

(ii) From $F = m\omega^2 r$

$4 = 0.2 \times 5^2 \times r$

$r =$ 0.8m

(b) (i) – It is periodic in nature

- Its acceleration is directly proportional to the displacement from a fixed point.
- Its acceleration is always directed towards a fixed pint in the line of motion
- Mechanical energy is always conserved

(ii) Let the displacement $x = A\cos\omega t \Rightarrow \cos\omega t = \frac{x}{A}$ ……… (1)

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Where A – amplitude, and x – displacement from equilibrium position

Velocity, $v = \frac{dx}{dt} = -\omega A \sin \omega t \Rightarrow \sin \omega t = \frac{-v}{\omega A}$ ....(2)

$$eqn(1)^2 + eqn(2)^2$$

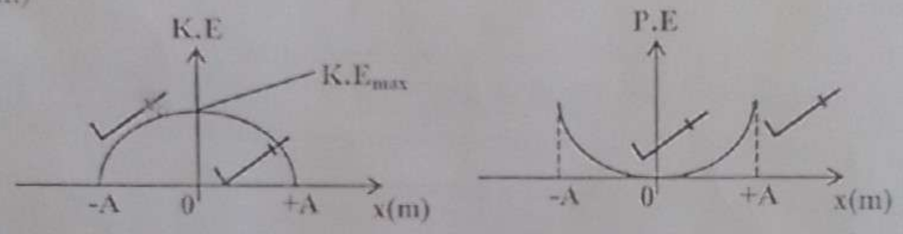
$$\cos^2 \omega t + \sin^2 \omega t = \frac{x^2}{A^2} + \left(\frac{-v}{\omega A}\right)^2$$

$$1 = \frac{x^2}{A^2} + \frac{v^2}{\omega^2 A^2}$$

$$v^2 = \omega^2 (A^2 - x^2)$$

$$v = \omega(A^2 - x^2)^{1/2}$$

(iii)



Where A = amplitude

(c) (i) From $T^2 = \frac{4\pi^2 r^3}{GM_e}$

$$T^2 = \frac{4\pi^2(6.4 \times 10^6 + 0.5 \times 10^6)^3}{6.67 \times 10^{-11} \times (5.97 \times 10^{24})}$$

$$\therefore T = 5.707 \times 10^3 \text{ s}$$

(ii) Total energy $= -\frac{GM_e m}{2r}$

$$T.E = -\frac{6.67 \times 10^{-11} \times (5.97 \times 10^{24}) \times (250)}{2 \times (6.4 \times 10^6 + 0.5 \times 10^6)}$$

$$\therefore Total\ energy = -(7.214 \times 10^9)\ J$$

3. (a) (i) Elastic collision is one where the kinetic energy of the colliding system is conserved while inelastic collision is one in which kinetic energy is not conserved.

Examples

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- Elastic collision – collisions between gas molecules, collision between two steel or glass balls.

- Inelastic collision – collision between pool balls.

(ii) From conservation of linear momentum,

$$\uparrow 0 = 5 \times (V \sin 30) - 8 \times (15 \sin 30)$$

$$V = 24\ ms^{-1}$$

K.E before $= \frac{1}{2} \times 8 \times (30)^2 + \frac{1}{2} \times 5 \times (50)^2 =$ 3600 J + 6250 = 9850

K.E after $= \frac{1}{2} \times 8 \times (15)^2 + \frac{1}{2} \times 5 \times (24)^2 =$ 900 + 1440 = 2340

Since $K.E_B \neq K.E_A$, *then the collision is* is not perfectly elastic

(b) Internal energy of a substance consists of kinetic energy due to the motion of the particles and potential energy due to intermolecular forces. The total sum of P.E and K.E of the particles of a substance is the internal energy.

(c) (i) It states that in any mechanical system, the total energy (P.E + K.E) remains a constant in the absence of dissipative forces.

(ii) The total work done by the net force acting on a body is equal to the change in kinetic energy

From $v^2 = u^2 + 2as$

$\Rightarrow s = \frac{v^2 - u^2}{2as}$ ....(1)

But work done, w = F x s, where F = ma

$\therefore W = mas$ ....(2)

Substituting eqn (1) into eqn (2)

$$W = ma\left(\frac{v^2 - u^2}{2as}\right)$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Hence work done is equal to the change in kinetic energy

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(d) – Place the straight wooden beam such that it is horizontal.

– The wooden block is placed on the straight wooden beam.

– The beam is tilted and each time the block of wood is given a slight push.

– A certain stage will be reached such that when the block of wood continue to move with a constant when given a slight push.

– The angle of tilt (inclination to the horizontal) θ is measured using a protractor and the value of $\tan\theta$ calculated.

– Then $\tan\theta = \mu_k$ coefficient of kinetic friction.

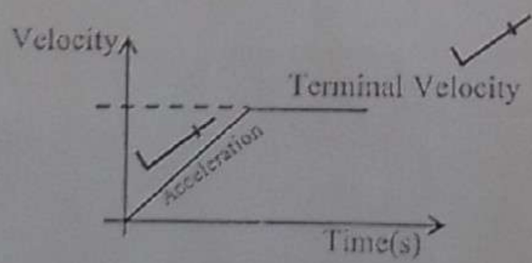
4. (a) (i) Viscosity is the frictional force between adjacent layers of a fluid

(ii) Viscous drag is the frictional force experienced by a body moving in a fluid due to its viscosity.

(iii) Velocity gradient is the change in in velocity between two layers per unit length of separation of the layers/points.

(b) (i) Viscosity in gases is due to transfer of momentum. In a gas, molecules are further apart and have negligible intermolecular forces, molecules move randomly colliding with each other and continuously transfer momentum to the neighboring layers. Increase in temperature of a gas increases the average speed and make frequent collisions of the gas molecules hence increased momentum transfer which results in increase in viscosity of a gas.

(ii)



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(iii) $V_0 = \frac{2r^2g(\rho_s - \rho_a)}{9\eta}$, but $\rho_a = 0\ kgm^{-3}$

$$V_0 = \frac{2 \times (2.5 \times 10^{-4}) \times 9.81 \times (950 - 0)}{9 \times 1.8 \times 10^{-5}}$$

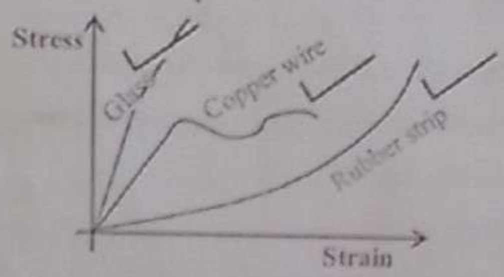
$$V_0 = 6.81 \times 10^{-4}\ ms^{-1}$$ $v = 272.5\ ms^{-1}$

(c) (i) From $E = \frac{Fl}{Ae}$

$[E] = \frac{[F][l]}{[A][e]}$

$\therefore [E] = \frac{MLT^{-2}L}{L^2 L} = ML^{-1}T^{-2}$

(ii)



Glass has a high Young modulus ~~but does not obey Hook's law~~.
Copper obeys hook's law.

(iii) From $F = EA\alpha\theta$

$F = 2.0 \times 10^{11} \times (1 \times 10^{-6}) \times (1.1 \times 10^{-5}) \times (60 - 15)$

$F = 99N$.

5. (a) (i) Specific heat capacity is the amount of heat required to raise the temperature of 1kg of a substance by 1K.

(ii) This means that 4200J of heat energy is required to raise the temperature of 1kg of water by 1K.

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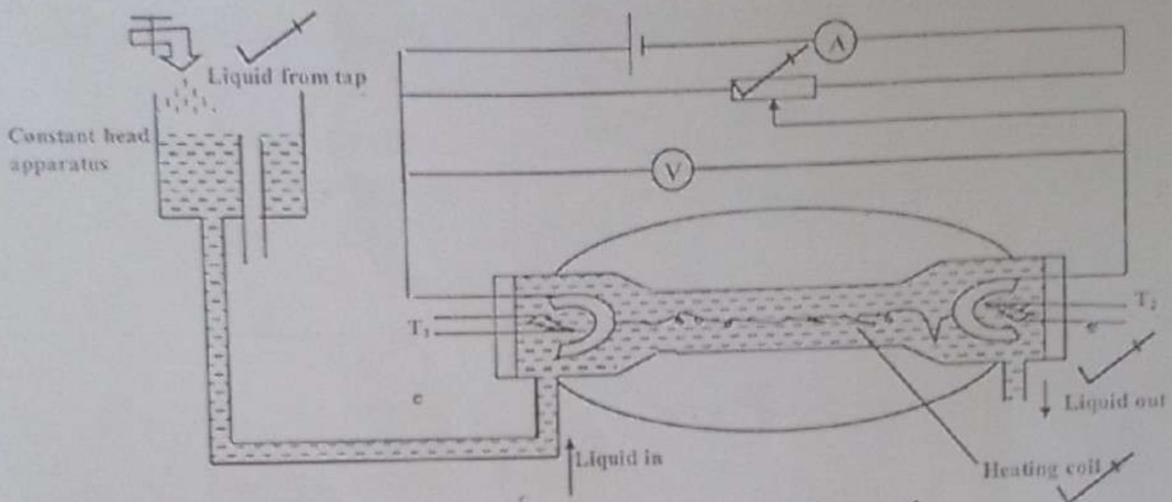
(b) (i)



T_1, T_2 - Thermometers

A steady flow of water is set. The apparatus is left to run until thermometers T_1, T_2 show steady readings. The temperatures θ_1 and θ_2 from T_1 and T_2 respectively are read and recorded. Ammeter and voltmeter readings I_1 and V_1 are read and recorded. The mass of water flowing out in time, t, is determined. The mass, m_1 of water collected per second is calculated.

$I_1V_1 = m_1c(\theta_2 - \theta_1) + h$,

$h \rightarrow$ *rate of heat loss to the surrounding*

The experiment is repeated for different flow rate and the current and voltage are adjusted until the temperatures read by the thermometers are as before. If I_2, V_2 and m_2 are the new current, voltage and mass per second respectively, then $I_2V_2 = m_2c(\theta_2 - \theta_1) + h$,

Thuß, S.H.C c, can be got from $c = \frac{I_1V_1 - I_2V_2}{(m_1 - m_2)(\theta_2 - \theta_1)}$

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(ii)

Advantages	Disadvantages
• Heat capacity of apparatus is not required. • No cooling correction is required. • Temperature can be measured at leisure. • Heat loss by convection is minimized by vacuum *Any 2 @ ½ mark*	• Requires a large quantity of liquid and therefore it is expensive. • Cannot be used to determine S.H.C of solids

(c) From $c = \frac{I_1V_1 - I_2V_2}{(m_1 - m_2)(\theta_2 - \theta_1)}$

$$c = \frac{(16.1 - 100) x (530)}{(0.1 - 0.05)(45 - 15)}$$

$c = 2155.3 \text{ J kg}^{-1}\text{K}^{-1}$

(d) – The length of the alcohol column in the capillary tube L_{tr} is measured and recorded when the bulb is placed in a mixture of pure water, pure ice and pure vapour.

– The length of the alcohol column is also measured at the un temperature T as L_T.

– Assuming a linear variation of length with temperature, then the unknown temperature $T = \frac{L_T}{L_{tr}} x\ 273.16\ K$

6. (a) (i) – Volume of molecules of an ideal gas is negligible while that of a real gas is appreciable.

– Ideal gases have negligible intermolecular forces while in real gases, intermolecular forces are appreciable.

– Ideal gases obey Boyle's law approximately while real gases do not obey approximately.

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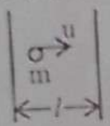
- The volume of ideal gas molecules is constant in between collisions while real gases do no ~~nót~~ have a constant volume due to intermolecular forces.

Any 2 @ 1 mark

(ii) Critical temperature refers to the temperature above which a gas cannot be liquefied however great the pressure on it is.

(b) (i) Consider a molecular mass m moving in a cube of length l at a velocity u.



- Change in momentum = mu - ⁻mu = 2mu
- Rate of change of momentum = $\frac{2mu}{t}$
- But time t between collisions = $\frac{2l}{u}$
- Force on the wall by the molecule $F_1 = \frac{2mu}{2l/u} = \frac{mu^2}{l}$

For N molecules, force on the wall, $F = \frac{mu_1^2}{l} + \frac{mu_2^2}{l} + \frac{mu_N^2}{l}$

But $P = F/_A = \frac{m}{l^3}(u_1^2 + u_2^2 + \cdots + u_N^2)$

Since $A = l^2$

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

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

$$\therefore P = \frac{Nm\overline{u^2}}{l^3} = \rho\overline{u^2},\ Since\ \rho = \frac{Nm}{l^3}$$

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

$$\therefore \overline{c^2} = \overline{u^2},\ \Rightarrow \overline{u^2} = \frac{1}{3}\overline{c^2}$$

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

(ii) O_2 and N_2 are heavier gases. Therefore, the average speeds of their molecules at moderate temperatures are so low, yet the escape velocity for the earth is high $\approx 11kms^{-1}$. These gases can therefore not escape the earth and the molecules of such gases are close to the earth's surface.

(c) Since air obeys gas laws, $\frac{P}{T} = constant$,

Let P_T = total pressure and P_1 = pressure of air alone

$$\Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

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$$\frac{1.01 \times 10^{5} - 3.99 \times 10^{3}}{308} = \frac{P_T - 7.19 \times 10^{4}}{360}$$

$$\therefore P_T = 1.852 \times 10^{5}\,Pa$$

(d) (i) Root mean square speed is the square root of the mean square values of the molecular speeds of the gas molecules at the same temperature.

(ii) – The gas system is enclosed in a thin walled, highly conducting vessel.

– The gas system should be surrounded by a constant temperature bath.

– The process should be carried out in slow steps to allow enough time for heat exchange.

Any 2 @ 1 mark

7. (a) (i) Thermal conductivity is the rate of heat flow per unit area of cross section per unit temperature gradient.

(ii) – Temperature gradient

– Cross sectional area of the material

– Thermal conductivity of the material

(b) (i) From $Q/_t = \frac{KA(\theta_2 - \theta_1)}{l}$

$$\Rightarrow Q/_t = \frac{KA\,\theta_1}{l} \ldots\ldots\ldots (1)$$

Similarly, $Q/_t = \frac{2KA\,\theta_2}{l} \ldots\ldots\ldots\ldots\ldots\ldots (2)$

Equating the two equations, $\frac{2KA\,\theta_2}{l} = \frac{KA\,\theta_1}{l}$

$$\therefore \theta_1 = 2\theta_2$$

(ii) From $\frac{Q}{t} = mL_v = \frac{K_s A(\theta - 100)}{t_s}$

$$2.28 \times 10^{-4} \times (2.26 \times 10^{6}) = \frac{2.06 \times 10^{2} \times \pi \times (8.0 \times 10^{-2})^{2} \times (\theta - 100)}{(4 \times 10^{-2})}$$

$$\therefore \theta = 100.5^{0}C$$

(c) (i) This is because temperature is highest at the center of the fire and this corresponds to the energy intensity where all wavelength radiations are

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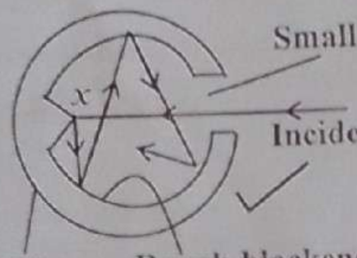
emitted. The combination of all the colors at this temperature makes the fire appear whiter.

(ii) A black body is one which absorbs all radiations of all wavelength falling on it, reflects and transmits none.

Approximation of a black body



– A small hole is punched in a hollow sphere whose inner walls are painted black.

– When a radiation is incident through the hole, it undergoes multiple reflections.

– At each reflection, energy is lost due to many reflections until all the radiation/energy is absorbed by the black walls of the inner sphere.

– The project x prevents any direct reflection and thus the small hole act as a black body radiator.

(d) – Bolometer

– Thermopile

8. (a) During fusion, two small nuclei combine to form a heavier nucleus of small mass but greater binding energy per nucleon. The mass difference account for the energy released.

While during fission, a heavy nucleus splits into lighter nuclei of greater binding energy per nucleon. The mass difference accounts for the energy release.

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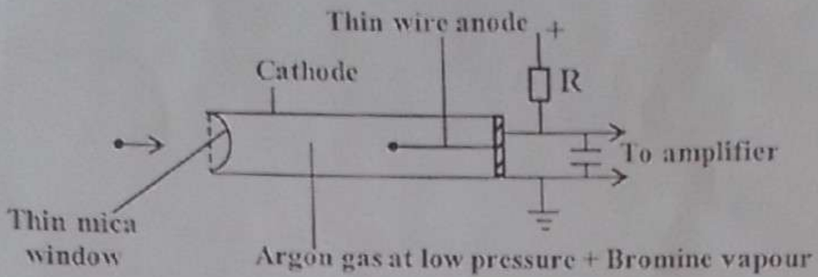
(b)



Any 4 labelled @ ½ mark

When an ionizing particle enters the tube, ion pairs are produced. Electrons are accelerated towards the anode and more ions pairs are produced by repeated collisions, gas amplification takes place (avalanche). On reaching the anode, a discharge occurs and current flows through a high resistor R. The p.d that develops is amplified and operates a counter. Bromine vapour acts as a quenching agent to make the tube ready for the next count. It slows down the positive ions that would have caused secondary discharge on reaching the cathode.

(c) (i) Mass defect is the difference between the mass of the nucleons that makeup the nucleus and mass of the nucleus.

(ii) n = 235 – 92 = 143

Mass defect = (mass of nucleon and electrons) – (mass of nucleus)

Mass defect = [(143 x 1.00767) + (92 x 1.0028) + (92 x 0.0055)] – (235.03076)

Mass defect =

B.E per nucleon = $\frac{\text{B.E}}{\text{mass number}}$

∴ B.E per nucleon =

(d) (i) – Carbon – 14 is radioactive with halflife, $t_{1/2}$ = 56 years. It is absorbed by plants during photosynthesis, when plants die, carbon – 14 starts to decay.

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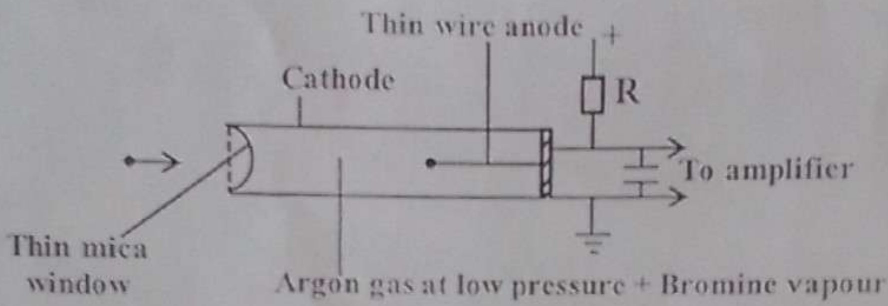
(b)



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Mass defect = (mass of nucleon and electrons) − (mass of nucleus)

Mass defect = [(143 x 1.00767) + (92 x 1.0028) + (92 x 0.0055)] − (235.03076)

Mass defect = 1.82965 x 931 = 1703.404 MeV

B.E per nucleon = $\frac{\text{B.E}}{\text{mass number}}$ = $\frac{1703.404}{235}$

∴ B.E per nucleon = 7.249 MeV.

(d) (i) − Carbon − 14 is radioactive with halflife, $t_{1/2}$ = 56 years. It is absorbed by plants during photosynthesis, when plants die, carbon − 14 starts to decay.

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– The activity, A_0 of living plants is measured. The activity A of dead plants is also measured. The age, t, of the dead plant is deduced from $A = A_0 e^{-\lambda t}$ where $\lambda = \frac{\ln 2}{t_{1/2}}$

(ii) From $A = A_0 e^{-\lambda t}$, where $\lambda = \frac{\ln 2}{5.7 \times 10^3}$

$$\Rightarrow 1.2 \times 10^2 = 2.0 \times 10^2 e^{-\left(\frac{\ln 2}{5.7 \times 10^3}\right)t}$$

$$\therefore t = 4.2 \times 10^3 \text{ years}$$

(a) (i) – Electrons revolve in only allowed orbits and when in these orbits they do not emit radiations.

– The angular momentum is an integral multiple of $h/_{2\pi}$ where h – planks constant.

– When an electron jumps from an orbit of higher energy level to one of lower energy, an electromagnetic radiation of definite frequency is emitted.

(ii) Electric force $F = \frac{e^2}{4\pi\varepsilon_0 r^2}$ and centripetal force $= \frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$

$$\therefore K.E = \frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r}$$

$$\therefore P.E = \frac{-e^2}{4\pi\varepsilon_0 r}$$

$\Rightarrow$ Total energy, $E = P.E + K.E = \frac{-e^2}{4\pi\varepsilon_0 r} + \frac{e^2}{8\pi\varepsilon_0 r} = \frac{-e^2}{8\pi\varepsilon_0 r}$

But angular momentum; $mvr = \frac{nh}{2\pi} \Rightarrow m^2 v^2 r^2 = \frac{n^2 h^2}{4\pi^2}$

$$\Rightarrow r = \frac{n^2 h^2 \varepsilon_0^2}{\pi m e^2}$$

substituting r in the expression for total energy E,

$$E = \frac{-e^2}{8\pi\varepsilon_0} \times \frac{\pi m e^2}{n^2 h^2 \varepsilon_0^2}$$

$$E = \frac{me^4}{8\varepsilon_0^2 h^2 n^2}$$

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(b) (i) Ionization energy = $0 - {}^{-}10.4 = 10.4eV$

$= 10.4 \times 10^{-19}$

$= 1.66 \times 10^{-18} J$

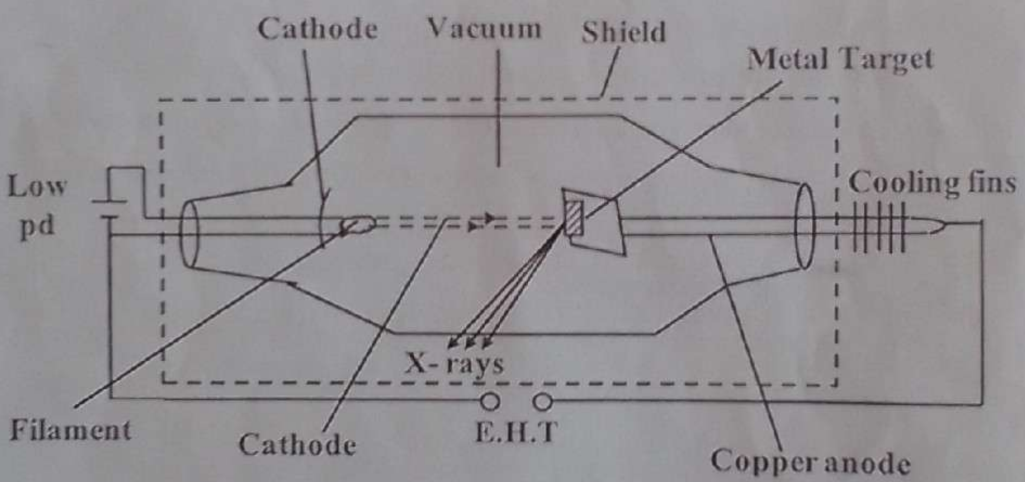
(ii) $hf = 0 - {}^{-}3.7 = 3.7eV$

$$\Rightarrow \frac{6.6 \times 10^{-34} \times 3.0 \times 10^{8}}{\lambda} = 3.7 \times 10^{-19}$$

$\therefore \lambda = (5.37 \times 10^{-7})m$

(d) (i) X – rays are electromagnetic waves of very high frequency and short wavelength produced when fast moving electrons are stopped by matter.

(ii)



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The filament is heated by current from the low p.d. It emits electrons by thermionic emission. The electrons are accelerated by the E.H.T between the cathode and anode. On striking the metal target, electrons lose their energy as heat and x – rays. The heat is conducted by the copper rod and dissipated to the surrounding by the cooling fins.

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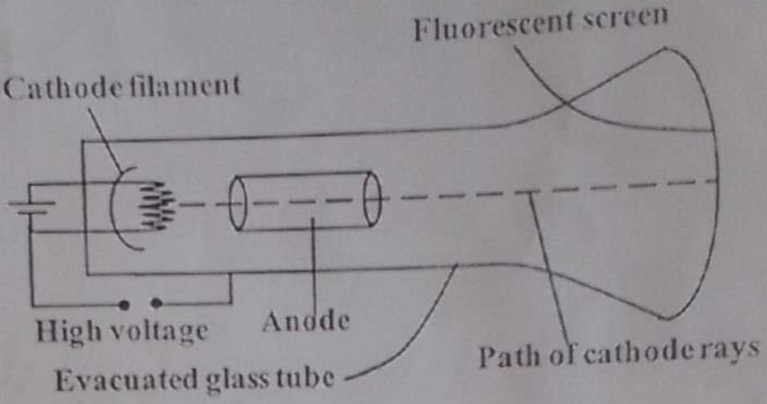
10. (a) (i)



Any 4 labelled @ ½ mark

When the cathode inside an evacuated glass tube is heated by a low voltage supply, electrons are produced by thermionic emission. The electrons are accelerated by a positive high voltage between cathode and anode. The electrons travel un deflected across the vacuum past the anode and produces a glow when they collide with the florescent screen and give up their energy. It is this beam of fast moving electrons from the cathode, which constitute the cathode rays.

(ii) Let the electron beam be made to pass through an electric field between two parallel plates. The electron beam is observed to be deflected towards the positive plate. According to the law of electrostatics, it implies that they carry negative charge.

(iii)

Positive rays	Cathode rays
Streams of fast moving atoms that have lost electrons	Streams of fast moving electrons
Positively charged	Negatively charged
Have a range of velocities	Travel with the same velocities
They are massive	They are light

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Have different specific charge	Have the same specific charge
Do not produce x – rays when they bombard matter	Produce x – rays when they bombard matter

Any 3

(b) (i) From $EQ = \frac{4}{3}\pi r^3 g(\rho_0 - \sigma)$. But $\sigma = 1.29$

$$4 \times 10^4\ Q = \frac{4}{3}\pi \times (9.2 \times 10^{-7})^3 \times 9.81 \times (878.71)$$

$$Q = 7.029 \times 10^{-19}$$

But $n = {Q}/{e} = 4\ electrons$

(ii) From $EQ = 6\pi\eta Vr + \frac{4}{3}\pi r^3 g(\rho_0 - \sigma)$,

$$7.029 \times 10^{-19}\ E =$$

$$6\pi(1.8 \times 10^{-5}) \times (9.2 \times 10^{-7}) \times 0.005 + \frac{4\pi}{3} \times (9.2 \times 10^{-7})^3 \times 9.81 \times (878.71)$$

$$\therefore E = 2.26 \times 10^6 Vm^{-1}$$

(c) Metals contain free electrons in their lattice that are loosely bound to their parent nuclei. When the temperature of the metal is increased, the velocities of the electrons are increased, some of the surface electrons acquire sufficient kinetic energy to overcome the electrostatic attraction force of the atomic nuclei and consequently escape from the metal surface.

(d) Rectification is the conversion of a.c/voltage into direct current/voltage and rectified current flows in one direction and has a constant amplitude

END

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