UACE Physics paper 1 set3 guide

SECTION A

1. (a) (i)State Newton's laws of motion. (03marks)

- A body continues in its state of rest or uniform motion in a straight line unless acted upon by an external force
- The rate of change of momentum of a body is directly proportional to applied force and takes place in the direction of the force
- For every action, there is an equal and opposite reaction

(ii) A molecule of a gas contained in a cube of side L strikes the wall of the cube repeatedly with a velocity u. Show that the average force F on the wall is given by

F =$\frac{mu^2}{L}$; where m is the mass of the molecule (04marks)

Change of momentum = mu – (-mu) = 2mu

Time between collision = $\frac{2l}{u}$

Force = $\frac{change\ in\ momentum}{time}$ = $2mu\ \div\ \frac{2l}{u}$ = $\frac{mu^2}{l}$

(b) (i) Define linear momentum and state the law of conservation of linear momentum. (02marks)

- Linear momentum is the product of mass and its velocity
- The law of conservation of linear momentum: if the resultant force on a system of interacting bodies is zero; total linear momentum is conserved.

(ii) A body of mass m_1 moving with velocity u, collides with another body of mass m_2 at rest. If they stick together after collision, find the common velocity with which they move (04marks)

Initial momentum = $m_1u + m_2 \times 0 = m_1u$

Final total momentum = $(m_1 + m_2)v$

By conservation of linear momentum

$m_1u = (m_1 + m_2)v$

v = $\frac{m_1 u}{(m_1 + m_2)}$

(c) A bullet of mass 10g is fired horizontally with a velocity of 300ms^{-1} into a block of wood of mass 290g which rests on a rough horizontal floor. After impact, the block and the bullet move together and come to rest when the block has travelled a distance of 15m. Calculate the coefficient of sliding friction between the block and the floor. (07marks)

By conservation of linear momentum

$\frac{10}{1000}\ x\ 300 + \frac{290}{1000}\ x\ 0 = \frac{(10+290)v}{1000}$

v = 10ms^{-1}

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

$0 = 10^2 + 2a \times 15$

a = -3.33ms-2

Retarding force = frictional

Force= ma = $\frac{300}{1000} x \frac{10}{3} = 1N$

⇨ $= \frac{F}{mg} = \frac{\frac{1}{300}}{1000} g$= 0.34

2. (a) State Kepler's laws of planetary motion. (03marks)
    - Planets describe ellipses about the sun as one focus
    - The imaginary line joining the sum and planet sweeps out equal areas in equal time intervals
    - The square of the periodic time of revolution of planets about the sun are proportional to the cubes of their mean distance from the sun

   (b) Use Newton's law of gravity to derive the dimension of the universal gravitational constant (03marks)

   F = $\frac{GMm}{r^2}$

   => $[G] = \frac{[F][r^2]}{[M][m]} = \frac{MLT^{-2}.L^2}{M^2}$ =$M^{-1}L^3T^{-2}$

   (c) A satellite is resolving at a height, h, above the surface of the earth with period T.

   (i) Show that the acceleration due to gravity, g, on the earth's surface is given by

   g = $\frac{4\pi^2(r_e+h)^3}{T^2r_e^2}$

   where r_e is the radius of the earth. (06marks)

   $m(r_e + h)\omega^2 = \frac{GM_Em}{(r_e+h)}$ but, ω = $\frac{2\pi}{T}$

   $\frac{4\pi^2}{T^2} = \frac{GM_E}{(r_e+h)^2}$ also, $GM_E = gr_e^2$

   $\frac{4\pi^2}{T^2} = \frac{gr_e^2}{(r_e+h)^2}$

   $g = \frac{4\pi^2(r_e+h)^2}{T^2r_e^2}$

   (ii) What is meant by parking orbit? (02marks)

   Parking orbit of a satellite that it appears to be stationary to the observer on the earth's surface. The period of revolution of the satellite is equal to the period of revolution of the earth; i.e. T = 24hours

   (d) A satellite revolves in a circular orbit at a height of 600kmabove the earth's surface. Calculate the

   (i) speed of the satellite. (03marks)

   v = $\sqrt{\frac{gr_e^2}{R}} = \sqrt{\frac{9.81 x (6.4 x 10^6)^2}{(6.4 x 10^6+6 x 10^5)}}$ = 7.5764 x $10^3$$ms^{-1}$

   (ii) period of the satellite. (03marks)

   T = $\frac{2\pi ((r_e+h)}{v} = \frac{2\pi \left(6.4 x 10^6+6 x 10^5\right)}{7.5764 x 10^3}$ 5802.2s

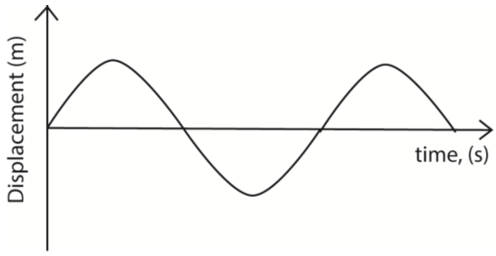
   Or

   $T = \frac{2\pi}{r_e}\sqrt{\frac{(r_e+h)^3}{g}} = \frac{2\pi}{6.4 x 10^6}\sqrt{\frac{6.4 x 10^6+6 x 10^5)^3}{9.81}}$ =5802.2s

3. (a)(i) Define Simple harmonic motion. (01mark)

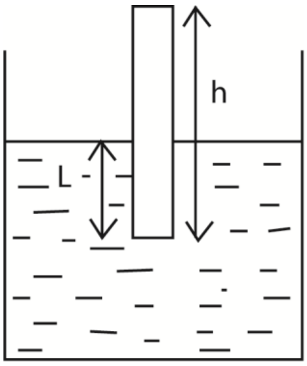
   Simple harmonic motion is the periodic motion of a body whose acceleration is directly proportional to the displacement of a body from a fixed point and it is directed towards the fixed point.

   (ii) Sketch a displacement-time graph for a body performing simple harmonic motion. (01mark)



(b) A uniform cylindrical rod of length 16cm and density 920kgm^{-3} floats vertically in a liquid of density 1000kgm^{-3}. The rod is depressed through a distance of 7mm and then released.

(i) Show that the rod performs simple harmonic motion (06marks)



- Let A be the cross section area of the rod and ρ be the density of the liquid
- Weight of the liquid displaced = up thrust.
- The volume of the liquid displaced = AL and therefore up thrust, u = ALρg
- When the rod is slightly displaced through a distance x, the new up thrust, u' = A(L+ x)ρg
- Resultant force, F + ALρg - A(L+ x)ρg = - Aρgx

But force, F = ma =- Aρgx

∴ a = $-\left(\frac{A\rho g}{m}\right)x$ = -kx

Since a ∝ x; the rod performs simple harmonic motion

(ii) Find the frequency of the resultant oscillations. (04marks)

$\omega^2 = \frac{A\rho g}{m}$; m = Ahσ (σ = density of the rod)

$\omega^2 = \frac{A\rho g}{Ah\sigma} = \frac{\rho g}{h\sigma}$; also ω = 2πf

$f = \frac{1}{2\pi}\sqrt{\frac{\rho g}{h\sigma}} = \frac{1}{2\pi}\sqrt{\frac{1000 \text{ x}9.81}{920\text{x } 0.16}}$ =1.3Hz

(iii) Find the velocity of the rod when is at a distance of 5mm above the equilibrium position (03marks)

v = $\omega\sqrt{(r^2 - x^2)}$ = $2\pi f\sqrt{(r^2 - x^2)}$ = 2π x $1.3\sqrt{0.007^2 - 0.005^2}$ = 0.04ms^{-1}

(c) What is meant by potential energy? (01mark)

Potential energy is the energy possessed by the body by the virtue of its position or state

(d) Describe the energy changes which occur when a

(i) ball thrown upwards in air (03marks)

Chemical energy →P.E → K.E + P.E → P.E → K.E + P.E → K.E → sound + heat

(ii) loud speaker vibrating (01mark)

Electrical energy → mechanical energy → sound

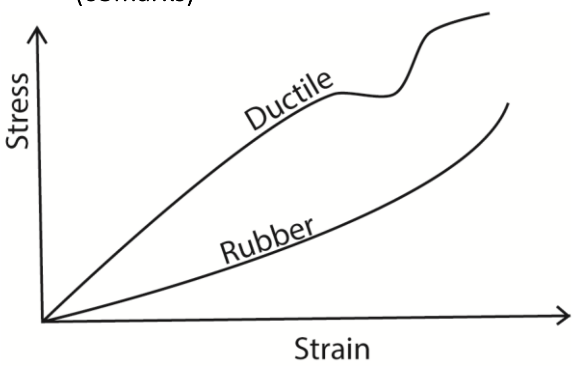
4. (a)(i) Define elastic deformation and plastic deformation (02marks)

- Elastic deformation is when a material is deformed and it regains its original shape and size when the deforming force is removed.
- Plastic deformation occurs when a force is applied and the material does not regain its original shape and size when the force is removed

(ii) Explain what is meant by work hardening. (02marks)

Work hardening is the strengthening of a material by repeatedly deforming it. Atomic planes slide over each other, this increases plane dislocations which prevent further sliding of planes.

(b) (i) Sketch using the same axes, stress-strain curves for ductile material and for rubber (03marks)



(ii) Explain the features of the curve for rubber. (03marks)

Rubber does not obey Hooke's law except for a very small range; it stretches easily without breaking and has a greatest range of elasticity. It does not undergo plastic deformation

Unstretched rubber consist of coiled molecules when a tensile force is applied, they uncoil, become straight and hard. Any further increase in tensile force makes the rubber to break.

(c) A capillary tube is held in a vertical position with one end dipping in a liquid of surface tension γ and density ρ. If the liquid rises to a height, h, derive an expression for h in terms of γ, ρ and radius r of the tube assuming the angle of contact is zero. (04marks)

The liquid rises until the vertical component of the upward forces due to surface tension is equal to the weight of the liquid column.

$F\gamma\cos\theta = W$ but $\theta = 0$

⇨ $F\gamma = W$

$\gamma = \frac{F}{L}$

$F = \gamma L$

$L = 2\pi r$

But $W = mg$ and $m = V\rho$ (where ρ is the density of the liquid in kg/m^3)

$W = v\rho g = 2\pi r^2 h\rho g$

$F\gamma = 2\pi r^2 h\rho g$

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

$h = \frac{2\gamma}{r\rho g}$

γ – coefficient of surface tension
θ – angle of contact
r – radius of capillary tube
ρ – density of the liquid

(d) A mercury drop of radius 2mm falls vertically and on hitting the ground, it splits into two drops each of radius 0.5mm. Calculate the change in surface energy given that the surface tension of mercury is $0.52Nm^{-1}$. (05marks)

Surface area of a drop = $4\pi r^2$

Surface area of a big drop = $4\pi(0.002)^2 = 5.03 \times 10^{-5}m^2$

Surface area of two small drops = $2 \times 4\pi(0.0005)^2 = 6.28 \times 10^{-6}m^2$

Change in area = $5.03 \times 10^{-5} - 6.28 \times 10^{-6}m^2 = 4.402 \times 10^{-5}m^2$

Change in surface energy = change in area x coefficient of surface tension

= $4.402 \times 10^{-5} \times 0.52$

= $2.289 \times 10^{-5}J$

(e) State the effect of temperature on surface tension of a liquid. (01mark)

Increase in temperature lowers surface tension

SECTION B

5. (a) (i) State the thermometric property used in a constant-volume gas thermometer (01mark)

pressure

(ii) Give two characteristic of a good thermometric property, (02marks)

- should vary linearly with change in in temperature
- Should vary continuously with temperature
- Should be sensitive to temperature changes
- Should be measurable
- Should vary over a wide range of temperature.

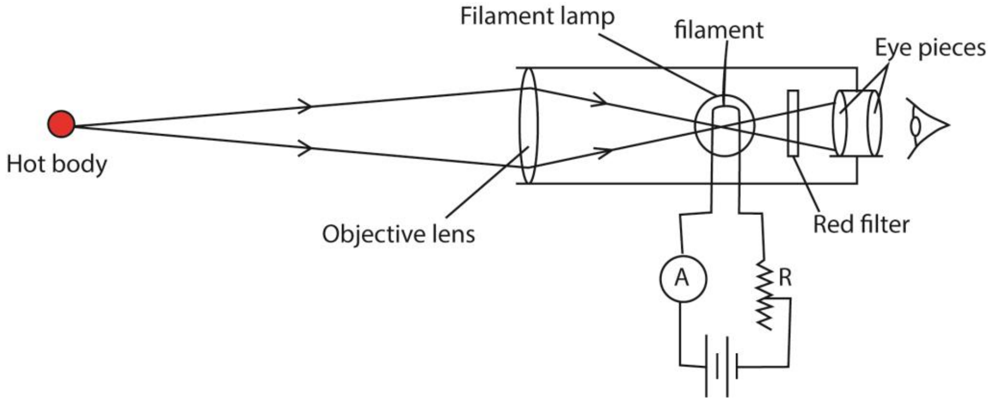
(b) (i) Describe the steps taken to set up a Celsius scale of temperature for a mercury-in glass thermometer. (04marks)

- A bulb is inserted in pure ice-water mixture.
- After some time, the length l_0 of mercury thread is recorded.
- The bulb is inserted in steam and constant length l_{100} of mercury thread is recorded.
- When l_θ is the length of mercury thread inserted in an unknown enclosure of temperature, θ^0, then $\theta = \left(\frac{l_\theta - l_0}{l_{100} - l_0}\right) x\ 100^0C$

(ii) State four disadvantages of a mercury in glass thermometer. (04marks)

- it is not very sensitive
- it cannot measure rapidly changing temperature
- it is delicate, i.e. it breaks easily

(c) Describe with the aid of a diagram the operation of an optical pyrometer (06marks)



- the filament is focused on the eye piece and the objective focuses the object so that the image of the object lies in the same plane as the filament
- Light from the hot object and the filament is passed through the red filter and viewed by the eyepiece.
- Current is adjusted by the rheostat R until the filament and the object are equally bright.
- The temperature of the hot body is then read from the calibrated ammeter, A.

(d) When oxygen is withdrawn from a tank of volume 50L, the reading of pressured gauge attached to the tank drops from 4.4 x 10^5 Pa to 7.8 x 10^5Pa. If the temperature of gas remaining in the tank falls from 30^0C to 10^0C, calculate the mass of oxygen withdrawn.

PV = nRT

$$n_1 = \frac{P_1V}{RT_1} = \frac{21.4 \; x \; 10^5 \; x \; 50 \; x \; 10^{-3}}{8.31 \; x \; 303} = 42.5\text{moles}$$

$$n_1 = \frac{7.8 \; x \; 10^5 \; x \; 50 \; x \; 10^{-3}}{8.31 \; x \; 283} = 16.6\text{moles}$$

Change in mass, Δm = $(n_1 – n_2)$MR

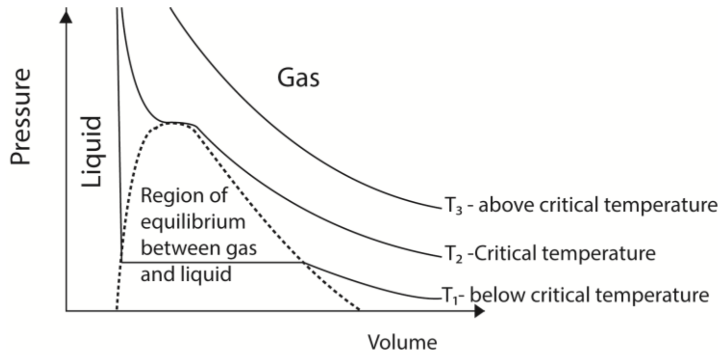
= (42.5 – 16.6) x 32

= 828.8g

6. (a)(i) What is meant by boiling point? (01marks)
The boiling point of a liquid is the temperature at which its saturated vapour pressure equals the external pressure.
(ii) Explain why boiling point of a liquid increases with increase in the external pressure. (05marks)
When the liquid boils its saturated vapour pressure = external pressure and saturated vapour pressure increases with increasing temperature. When external pressure is raised, a liquid will boil at higher saturated pressure which occurs at high temperature.
(b) (Explain how the pressure of a fixed mass of a gas can be increased at
(i) Constant temperature (03marks)
By reducing the volume occupied by a gas, the molecules take less time to move between the walls of the container as the distance is reduced. The number of collisions per unit area increases hence pressure increases at constant temperature.
(ii) Constant volume (03marks)

By heating the gas, the molecules gain more kinetic energy. The molecules will bombard the walls many times per unit time per unit area. The total rate of change of momentum will increase hence pressure will increase

(c) Sketch a pressure versus volume curve for a real gas undergoing compression (03 marks)



- Above the critical temperature a gas obeys Boyle's law.
- Below the critical temperature a gas exist as unsaturated vapour at low pressure when the pressure is increase it condenses until all the gas is turned into a liquid.

(d) The cylinder of an exhaust pump has a volume of $5cm^3$. If it is connected through a valve to a flask of volume 225 cm^3 containing air at a pressure of 75cmHg, calculate the pressure of air in the flask after two strokes of the pump, assuming that the temperature of the air remain constant.

First stroke

$P_1V_1 = P_2V_2$ but $V_2 = 225 + 25 = 250cm^2$

75 x 225 = P_2 x 250

P_2 = 674cmHg

Second stroke

$P_2V_2 = P_3V_3$

$P_3 = \frac{67.5\ x\ 225}{250}$= 60.8cmHG

Alternatively

$P_l = \left(\frac{V_2}{V_1 + V_2}\right)^2 P$, n = number of strokes

$= \left(\frac{225}{225+25}\right)^2 x\ 75 = 60.75cmHg$

7. (a) (i) Define thermal conductivity. (01mark)

Thermal conductivity is the rate of heat flow per unit cross sectional area per unit temperature gradient.

(ii) Explain the mechanism of heat transfer by convention. (03marks)

When a fluid is heated from underneath, it expands and becomes less dense than fluid above. The warm less dense fluid rises to the top and the cool more dense fluid from above moves downwards to take place. This process continues and circulating current of the fluid is established until the whole fluid is heated up.

(b) (i) State Newton's law of cooling (01mark)

It state that the rate of loss of heat is proportional to the excess temperature between the body and the surroundings under forced convections or steady draught.

(ii) Describe briefly an experiment to verify Newton's law of cooling. (05marks)

Hot water in a calorimeter is placed near an open window. The temperature of the water is recorded at suitable time intervals. A graph of temperature against time is plotted. Slope of the graph is obtained at temperature θ_1. More values of the slope are obtained at different temperatures, θ_2, θ_3, θ_4 ………………

For each temperature, excess temperature, (θ -θ_R) is calculated, where θ_R is the room temperature.

A graph of slopes against excess temperature is plotted.

A straight line graph through the origin verifies Newton's law.

(c) A wall is constructed using two types of bricks. The temperatures of the inner and outer surface of the wall are 29^0C and 21^0C respectively. The value of thermal conductivity for the inner brick is $0.4Wm^{-1}K^{-1}$ and that of the outer brick is $0.8Wm^{-1}K^{-1}$.

(i) Explain why in a steady state the rate of thermal energy transfer is the same in both layers. (02marks)

No heat is lost to the surrounding as it flows through the inner and outer surfaces. The temperature gradient across the composite wall is constant.

(ii) If each layer is 12 cm thick, find the temperature at the interface between the layers. (04mrks)

From $\frac{Q}{t} = \frac{KA(\theta_2 - \theta_1)}{l_0}$

$\frac{0.4A(29 - \theta)}{12\ x\ 10^{-2}} = \frac{0.3A(\theta - 21)}{12\ x\ 10^{-2}}$

$\therefore\ \theta = 23.7^0C$

(d) Explain the greenhouse effect and how it leads to rise of the earth temperature. (04marks)

The short wavelength radiation from the sun penetrates the atmosphere and is absorbed by the earth's surface. This absorbed energy warms the earth which then re-radiates long wavelength radiations e.g. infrared radiation. Some of this radiated energy absorbed (trapped) by the atmosphere. This leads to increased temperature on the earth with time referred to as global warming.

SECTION C

8. (a) What is meant by the following

(i) Radioactivity (01mark)

Radioactivity is the spontaneous disintegration of radioactive nuclide or atoms accompanied by emission of radiation

(ii) Isotopes (01marks)

Isotopes are atoms of the same atomic number but difference atomic mass

(b) (i) Define mass defect (01mark)

Mass defect is the difference in mass of constituent nucleons and the nucleus of an atom

(ii) State the conditions for a heavy nucleus to be unstable (01mark)

A heavy nucleus is unstable if there are too many neutrons or too many protons.

(iii) Explain your answer in (b)(ii) (02marks)

- Large number of protons increase electrostatic repulsion between themselves in a nucleus
- Large number of neutrons lead to unbalanced nuclear forces

(c) A sample of $^{226}_{88}Ra$ emits both α-particles and γ-rays. A mass defect of 0.0053u occurs in the decay.

(i) Calculate the energy released in joules. (03 marks)

E =mc^2 = 0.0053 x 1.66 x 10^{-27} x (3 x 10^8)^2 = 7.92 x 19^{-13}J

(ii) If the sample decays by emission of α-particle, each of energy 4.60MeV and γ-rays, find the frequency of the γ-rays emitted. (04marks)

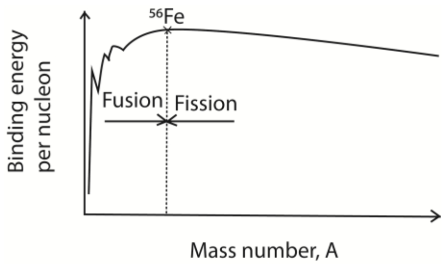
4.60MeV = 4.60 x 10^6 x 1.6 x 10^{-19} = 7.36 x 10^{-13}J

Energy of a photon of γ – rays = 7.9 x 19^{-13} - 7.36 x 10^{-13} = 0.56 x 10^{-13}

From E = hf

f = $\frac{0.56\ x\ 10^{-13}}{6.6\ x\ 10^{-34}}$ = 8.5 x 10^{19}Hz

(d) (i) Sketch a graph showing the variation of binding energy per nucleon with mass number, clearly showing the fusion and fissions. (02marks)



(ii)Use the sketch in (d)(i) to explain how energy is released in each of the process of fusion and fission

- Two small nuclei with atomic mass less than 56 fuse to give a heavier nucleus with a higher binding energy per nucleon to increase nuclear stability
- A nucleus with atomic mass higher than 56 split to form two small nuclei each with higher binding energy per nucleon and thus with higher nuclear stability

(e) State two

(i) applications of radioisotopes (01marks)

- Treatment of cancer
- Production of energy in nuclear reaction
- Detection of links in pipes
- Carbon dating

(ii) health hazards of radioisotopes (01mark)

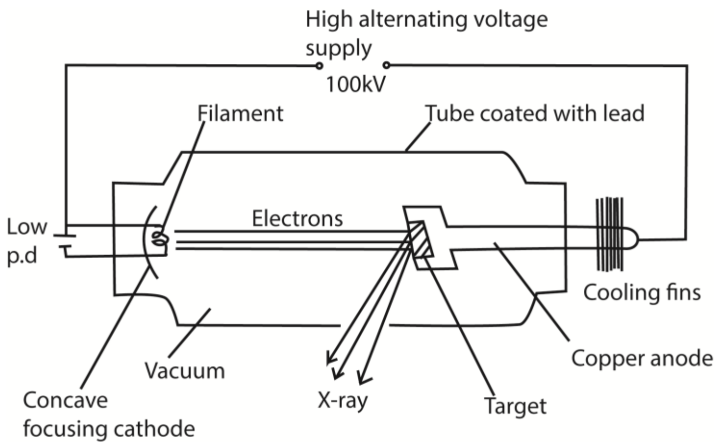
- Cause genetic mutation
- Cause cancer

- Cause deep seated wounds in humans

9. (a) What are X-rays? (01marks)

   X- rays are electromagnetic radiations of very high frequency (short wavelength) produced when cathode rays strike metal target.

(b) (i) With the aid of a diagram explain how X-rays are produced in an X-ray tube (05marks)



Mode of operation

- The filament is heated by a low voltage supply and the electrons are emitted by thermionic emission.
- The concave focusing cathode focuses the electrons from the filament onto the target.
- These electrons are accelerated towards the anode by the high voltage between the filament and the Anode.
- When the electrons (cathode rays) strike the metal target, about only 1% their kinetic energy is converted to X-rays and the 99% of their kinetic energy is converted to heat, which is conducted away by the cooling fins.

(ii) State the energy changes that take place in the production of X-rays in an X-ray tube. (02marks)

Electrical energy → kinetic energy → X-rays + heat

(c) In an X-ray tube, the electrons strike the target with a velocity of $3.75 \times 10^7 ms^{-1}$ after travelling a distance of 5.0cm from the cathode. If a current of 10mA flows through the tube, find the

(i) tube voltage (02marks)

From $eV = \frac{1}{2}mv^2$

$V = \frac{1}{2e}mv^2 = \frac{9.11 x 10^{-31} x (3.75 x 10^7)^2}{2 x 1.6 x 10^{-19}}$ = 4003V

(ii) number of electrons striking the target per second. (02marks)

I = ne

$n = \frac{10 x 10^{-3}}{1.6 x 10^{-19}}$ = 6.25×10^{16} electrons

(iii) Number of electrons within the space of 1cm length between the anode and the cathode. (05marks)

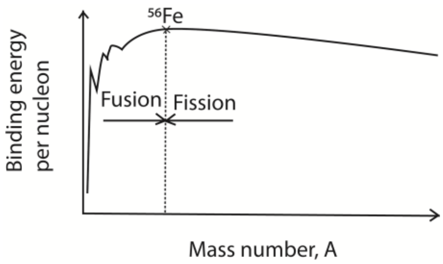
Number of electron in space of 1cm length = $6.25 \times 10^{16} \times \frac{1}{100} = 6.25 \times 10^{14}$

(d) Briefly explain one medical application of x-rays (03marks)

X-rays are used to kill cancer cells

10. (a) (i) Distinguish between mass defect and binding energy of an atomic nucleus (01mark)
Mass defect s the difference between the mass of nucleons that make up a nucleus and the mass of a nucleus.
Binding energy of an atomic nucleus is the minimum energy to break up a nucleus into its constituent nucleons.

(ii) Sketch a graph of nuclear binding energy per nucleon versus mass number for naturally occurring isotopes and use it to distinguish between nuclear fission and fusion. (04marks)

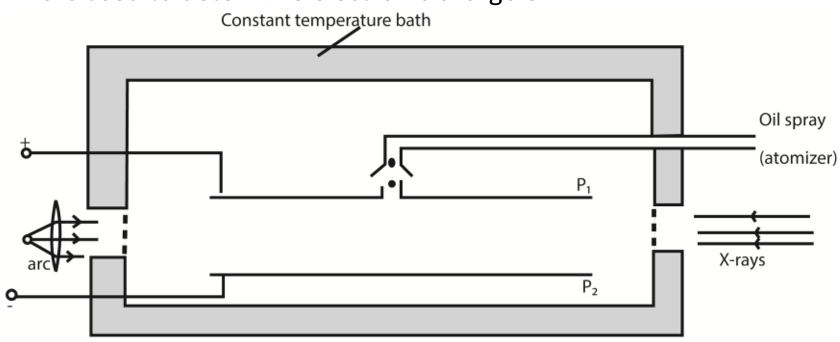


- Two Small nuclei with atomic mass less than 56 each fuse to give a heavier nuclei with smaller mass by higher binding energy to increase stability of nucleon
- A nucleus with atomic mass higher than 56 split to form lighter nuclei of higher binding energy per nuclei.

(b) Describe with the aid of a diagram, Millikan's oil drop experiment to determine charge on oil drop. (07marks)

Millikan's Oil drop experiment

This is used to determine electronic charge e



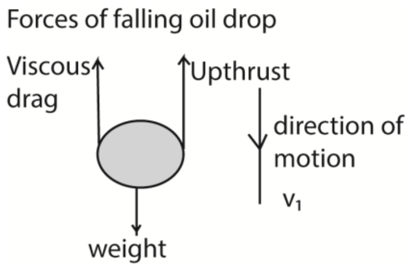
Procedure

- Set up of the apparatus is as shown above
- Oil drops are introduced between the plates P_1 and P_2 by spraying using the atomizer.
- These oil drops are charged in the process of spraying by friction but the charge may be increased further ionization due to X-rays.
- The oil drops are strongly illuminated by an intense light from the arc lamp so that they appear as bright spots when observed through a low power microscope.

- With no electric field between the plates, record the time t_1 taken for drop to fall from P_1 to P_2.
- The electric field between the plates is turned on and adjusted so that the drop becomes stationary.

Case 1

With no electric field, the oil drop falls with a uniform velocity v_1 called terminal velocity



Weight = Upthrust + viscous drag ……………………………… (i)

= volume of the oil drop x density x gravity

= $\frac{4}{3}\pi r^3 \rho g$ (ρ = density of oil, r = radius of oil drop)

Upthrust = weight of air displaced by oil drop

= volume of the air displaced by oil drop x density x gravity

= $\frac{4}{3}\pi r^3 \sigma g$ (σ = density of air)

Viscous drag = $6\pi r\eta v_1$ (From strokes' law)

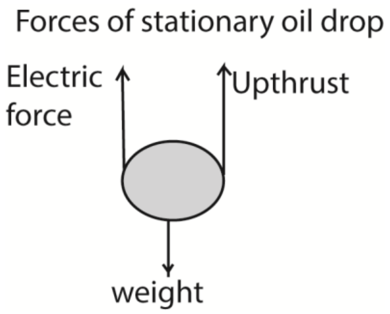
From 1

$\frac{4}{3}\pi r^3 \rho g = \frac{4}{3}\pi r^3 \sigma g + 6\pi r\eta v_1$ …………………… (ii)

$r = \left[\frac{9\eta v_1}{2g(\rho-\sigma)}\right]^{\frac{1}{2}}$

Case 2

When the electric field is applied so that the drop is stationary, the drop has no velocity and no acceleration.



Weight = Upthrust + electric force

$\frac{4}{3}\pi r^3 \rho g = \frac{4}{3}\pi r^3 \sigma g + qE$ …………………… (iii)

From (ii) and (iii)

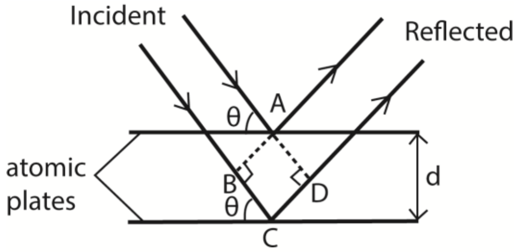
q = $\frac{6\pi r\eta v_1}{E}$ but E = $\frac{V}{d}$

Substituting for r

q = $\frac{6\pi\eta d v_1}{V}\left[\frac{9\eta v_1}{2g(\rho-\sigma)}\right]^{\frac{1}{2}}$

(c) (i) Explain briefly diffraction of X-rays by crystals and derive Bragg's law. (06marks)

- A parallel beam of monochromatic X-rays incident on a crystal is reflected from successive atomic planes and super-imposed, forming an interference pattern.



For constructive interference to occur, the path difference is equal to the whole number of wavelength

Thus BC + CD = nλ

⇨ dsinθ + dsinθ = nλ

or 2dsinθ = nλ where n = 1, 2, 3, 4 …

(ii) A second order diffraction image by reflection of X-rays at atomic plates of crystal for glancing angle of $11^0 24'$. Calculate the atomic spacing of the plates if the wavelength of X-ray is 4.0×10^{-11}m. (02marks)

From 2dsinθ = nλ

$d = \frac{2 \ x \ 4 \ x \ 10^{-11}}{2 \ x \sin 11^0 24'}$ = 2.02×10^{-1}0m

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