UACE Physics paper 1 2002 Guide Time 2½ marks

Instructions the candidates:

Answer **five** questions, including at least **one**, but **not more than two** from each sections **A, Band C**.

Any additional question(s) answered will not be marked.

Non programmable scientific calculators may be used.

Assume where necessary

Acceleration due to gravity, g	9.81ms^{-2}
Electron charge, e	1.6 x10^{-19}C
Electron mass	9.11 x 10^{-31}kg
Mass of the earth	5.97 x 10^{24}kg
Plank's constant, h	6.6 x 10^{-34}Js
Stefan's-Boltzmann's constant, σ	5.67 x 10^{-8}Wm^{-2}K^{-1}
Radius of the earth	6.4 x 106m
Radius of the sun	7 x 10^{8}m
Radius of the earth's orbit about the sun	1.5 x 10^{11}m
Speed of light in the vacuum, c	3.0 x 108ms^{-1}
Thermal conductivity of copper	390Wm^{-1}K^{-1}
Thermal conductivity of aluminium	210Wm^{-1}K^{-1}
Specific heat capacity of water	4.200Jkg^{-1}K^{-1}
Universal gravitational constant	6.67 x 10^{-11}Nm^{2}Kg^{-2}
Avogadro's number, N_A	6.02 x 10^{23}mol^{-1}
Surface tension of water	7.0 x 10^{-2}Nm^{-1}
Density of water	1000kgm^{-3}
Gas constant, R	8.31Jmol^{-1}K^{-1}
Charge to mass ratio, e/m	1.8 x 10^{11}Ckg^{-1}
The constant, $\frac{1}{4\pi\varepsilon_0}$	9.0 x 10^{9}F^{-1}m
Faraday's constant, F	9.65 x 10^{4}Cmol^{-1}

SECTION A

1. (a) (i) what is meant by the dimensions of a physical quantity? (01mark)

Dimensions of a physical quantity is the way a physical quantity is related to the fundamental quantities of mass (M), length (L) and time (T)

(ii) For stream line flow of non-viscous, incompressible fluid, the pressure, P, at a point is related to height, h, and the velocity, V by the equation $(P-a) = \rho g(h-b) + \frac{1}{2}(v^2-d)$ where a, b, and d, are constants and ρ is the density of the fluid and g is the acceleration due to gravity. Given that the equation is dimensionally consistent, find the dimensions of a, b and d. (03marks)

$[a] = [P] = ML^{-1}T^{-2}$

$[b] = [h] = L$

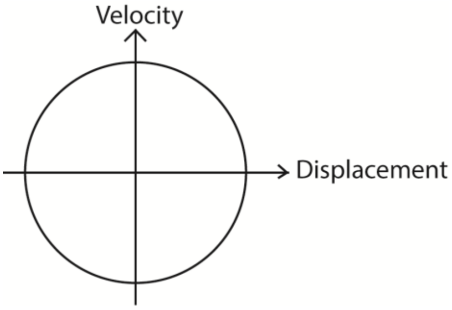
$[d] = [V^2] = (LT^{-1})^2 = L^2T^{-2}$

(b) Define simple harmonic motion. (01marks)

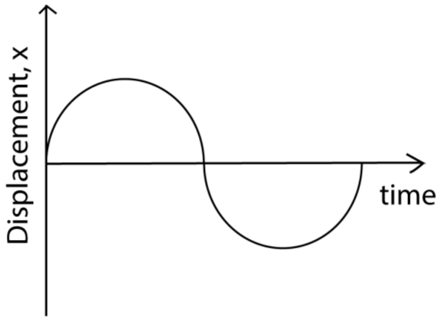
Simple harmonic motion is a periodic motion whose acceleration is directed towards a fixed point and is proportional to the displacement from the fixed point.

(c) Sketch the following graphs for a body performing simple harmonic motion:

(i) velocity against displacement (01mark)

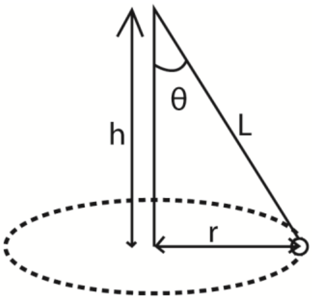


(ii) displacement against time (01mark)



(d) The period of oscillation of a conical pendulum is 2.0s. If the string makes 60^0 to the vertical at the point of suspension, calculate the

(i) vertical height of the point of suspension above the circle. (03marks)



For conical pendulum, T =$2\pi\sqrt{\frac{h}{g}}$

h = $\frac{T^2g}{4\pi^2} = \frac{2^2\ x\ 9.81}{4\pi^2}$ = 0.994m

(ii) length of the string (01 mark)

h = Lcosθ

L = $\frac{0.994}{\cos 60}$ = 1.1.99m

(iii) Velocity of the mass attached to the string (03marks)

V = ωr; r = Lsinθ = 1.99 sin 60 = 1.723m

ω = $\frac{2\pi}{T}$ = π => V = 1.723πx= 5.41ms^{-1}

(e) (i) give one example of an oscillatory motion which approximates simple harmonic motion

- Simple pendulum
- Mass of helical spring
- Liquid oscillating in U-tube

(ii) What approximation is made in (e)(i) above? (01mark)

- For simple pendulum, the angle of displacement is small and air friction is negligible
- Helical spring, displacement is small
- Oscillating liquid is U tube experience negligible friction and small displacement

(f) Explain why the acceleration of a ball bearing falling through a liquid decreases continuously until it become zero. (04marks).

Viscous force increases with velocity until the Upthrust + viscous force = weight of the ball reducing acceleration to zero

2. (a) (i) State Newton's law of universal gravitation. (01mark)

The gravitational force of attraction between two bodies in the universe is proportional to the product of their masses and inversely proportional to the square of their distance apart.

(i) Show that this law is consistent with Kepler's third law. (03marks)

By Newton's law of gravitation, F = $\frac{GMm}{r^2}$

From uniform circular motion, mrω^2 = $\frac{GMm}{r^2}$; but ω =$\frac{2\pi}{T}$

Thus$\frac{GMm}{r^2} = \left(\frac{mr\ x\ 4\pi^2}{T^2}\right)$

⇨ T^2 = $\left(\frac{4\pi^2}{GM}\right)r^3$

Thus $T^2 \propto r^3$- Kepler's law.

(iii) Two alternative units for gravitational field strength are Nkg^{-1} and ms^{-2}. Use the method of dimensions to show that the two units are equivalent. (03marks)

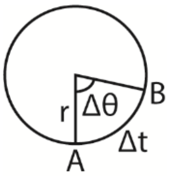
Nkg^{-1} is the unit of $\frac{Force}{mass}$

$\frac{[Force]}{[mass]} = \frac{MLT^{-2}}{M} = LT^{-2}$

Also $[ms^{-2}] \equiv LT^{-2}$

Hence the two units are equivalent

(b) (i) Derive an expression for speed of a body moving uniformly n a circular path. (03marks)



Let the body move from A to B in time Δt such that the radius sweeps through a small angle Δθ

Average speed = $\frac{distance}{time} = \frac{r\Delta\theta}{\Delta t}$

For small values of Δθ and Δt, $\frac{d\theta}{dt} = \omega$

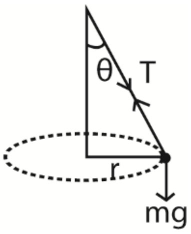
Hence average speed, v =rω

(ii) Explain why a force is necessary to maintain a body moving with constant speed in a circular path. (02marks)

To provide centripetal force

(c) A small mass attached to a string suspended from a fixed point moves in a circular path at constant speed in horizontal plane.

(i) Draw a diagram showing the force acting on the mass. (01mark)



(ii) Derive an equation showing the angle of inclination of the string depends on the speed of the mass and radius of the circular path. (03marks)

Resolving horizontally, $T\sin\theta = \frac{mv^2}{r}$ ……… (i)

Resolving vertically, $T\cos\theta = mg$ ……………(ii)

Combining eqn. (i) and eqn (ii)

$\tan\theta = \frac{v^2}{rg}$

(d) (i) Define moment of force. (01mark)

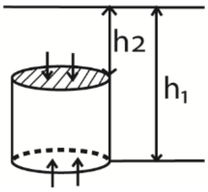
Moment of force is the product of force and the perpendicular distance from axis of rotation to the line of action of force.

(ii) A wheel of radius 0.2m is pivoted at its centre. A tangential force of 4.0N acts on the wheel so that the wheel rotates with uniform velocity. Find the work done by the force to turn the wheel through 10 revolutions. (03marks)

Work done = Fx2πr x number of revolutions = 4 x 0.5 x 2π x 10 =151J

3. (a) (i) Show that the weight of a fluid displaced by an object is equal to up thrust on the object. (05marks)

Consider a vertical cylinder of cross section area, A, immersed n a liquid of density ρ as shown in the diagram below



If H is the atmospheric pressure.
Pressure on top = $h_2\rho g + H$
Pressure at the base = $h_1\rho g + H$
Force on the base = $(h_1\rho g + H)A$
Force on the top = $(h_2\rho g + H)A$
Resultant force = $(h_1 - h_2)\rho gA$
But $(h_1 - h_2)A$ = volume of the cylinder = volume of liquid displaced.
$\therefore (h_1 - h_2)\rho gA$ =weght of the liquid displaced = Upthrust.

(ii) A piece of metal of mass 2.60×10^{-3}kg and density 8.4×10^{3}kgm^{-3} is attached to a block of wax of mass 1.0×10^{-2}kg and density 9.2×10^{2}kgm^{-3}. When the system is placed in a liquid, it floats with wax just submerged. Find the density of the fluid. (04marks)
Let the density of the liquid = ρ
Upthrust = weight of the system
$V\rho g = (2.6 \times 10^{-3} + 1 \times 10^{-2})g$
$\left(\frac{2.6\ x\ 10^{-3}}{8.4\ x\ 10^{3}} + \frac{1.0\ x\ 10^{-2}}{9.2\ x\ 10^{2}}\right)\rho = 1.26 \times 10^{-2}$
$P = 1.13 \times 10^{3}$kgm^{-3}

(b) Explain the

(i) term laminar flow and turbulent flow. (04marks)

Laminar flow: Equidistant fluid layers from the axis of flow have the same velocity. Lines of flow are always parallel to the to the axis of flow

Turbulent flow: equidistant fluid layers from the axis of flow have different velocities. Lines of flow cross each other.

(ii) effects of temperature on viscosity of liquids and gases. (03marks)

- In liquids increasing temperature increases molecular speed and separation. This reduces the molecular attractive forces and viscosity reduces.
- In gases increase in temperature increases molecular speed and therefore momentum transfer when they collide increases. This increases viscosity.

(c) (i)distinguish between static pressure and dynamic pressure. (02marks)

- **Static pressure** at a point is the pressure which the fluid would have if were at rest.
- **Dynamic pressure** is the pressure due to fluid motion.

(ii) A pilot-static tube fitted with a pressure gauge is used to measure the speed of a boat at sea. Given that the speed of the boat does not exceed 10mms^{-1} and the density of water is 1000kgm^{-3}, calculate the minimum pressure on the gauge. (02marks)

Maximum pressure = $\frac{1}{2}\rho^2 = \frac{1}{2}\ x\ 1050\ x\ 10^2$ = 5.25 x 10^4Pa

4. (a) Define the terms surface tension and surface energy. (01mark)

   It is the work done per unit area in increasing surface area of a liquid under isothermal conditions.

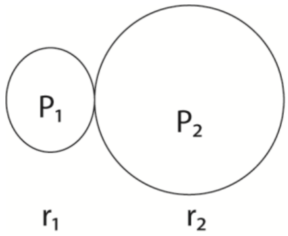
   (b) (i) Calculate the work done against surface tension in blowing a soap bubble of diameter 15mm, if the surface tension of soap solution is 3.0 x 10^{-2}Nm. (03marks)

   New surface area created = 2 x $4\pi r^2$

   Energy required = γA = 3.0 x 10^{-2} x 2 x 4π x (7.5 x $10^{-3})^2$

   = 4.24 x 10^{-5}J

   (ii) A soap bubble of radius r_1 is attached to another bubble of radius r_2. If r_1 is less than r_2. Show that the radius of curvature of the common interface is $\frac{r_1 r_2}{r_2 - r_1}$. (05marks)



For A

$$P_1 - H = \frac{4\gamma}{r_1} \text{ .... (i)}$$

For B

$$P_2 - H = \frac{4\gamma}{r_2} \text{ .... (ii)}$$

From equations (i) and (ii)

$$P_1 - P_2 = \frac{4\gamma}{r_1} - \frac{4\gamma}{r_2} \text{ .... (iii)}$$

$$P_1 - P_2 = \frac{4\gamma}{r} \text{ .... (iv)}$$

From equation (iii) and (iv)

$$\frac{4\gamma}{r} = \frac{4\gamma}{r_1} - \frac{4\gamma}{r_2}$$

$$\frac{1}{r} = \frac{1}{r_1} - \frac{1}{r_2}$$

$$\frac{1}{r} = \frac{r_2 - r_1}{r_2 r_1}$$

$$r = \frac{r_2 r_1}{r_2 - r_1}$$

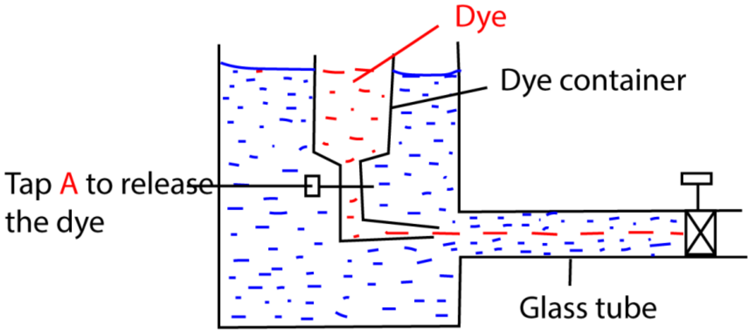
   (c) (i) Define coefficient of viscosity of a liquid. (01mark)

   It is the tangential stress per unit velocity gradient.

   (ii) Describe an experiment to demonstrate streamline and turbulent flow in liquids. (06marks)

Experiment to demonstrate laminar and turbulent flow

Reynold's experiment



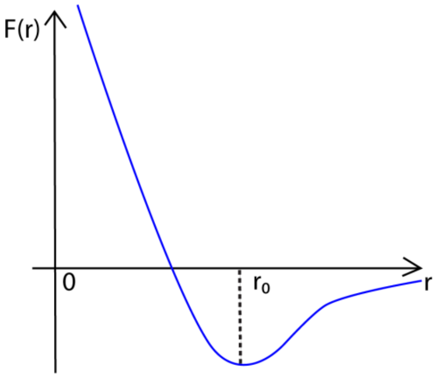
- Water is kept flowing at a constant velocity from a constant water tank.

- The rate of flow of a dye is controlled by a tap A.

- At low water velocity a streamline of a dye is observed flowing through water. This is laminar flow

- A turbulent flow is observed when the velocity of water is increased here the dye mixes with water.

(d) (i) Sketch a graph of potential energy against separation of two molecules of a substance. (01mark)



(ii) Explain the main features of the graph in (d)(i). (03marks)

At $r = r_0$, the resultant force is zero and the corresponding potential energy is minimum. So r_0 is the equilibrium separation

For $r < r_0$, the net force is repulsive, whereas $r > r_0$, the net force is attractive in order to restore the e separation to the equilibrium separation of r_0.

SECTION B

5. (a) State the assumption made in the derivation of the expression P = $\frac{1}{3}\rho \overline{c^2}$ for pressure of an

ideal gas (02marks)

- The intermolecular forces are negligible
- The volume of the gas is negligible compared the volume of the container
- Collision are perfectly elastic
- The duration of collision is negligible

(b) Use the expression in (a) above to deduce Dalton's law of partial pressures. (03marks)

P = $\frac{1}{3}N\frac{m}{V}\overline{c^2} = \frac{2}{3}N\left(\frac{1}{2}m\overline{c^2}\right)$

For gas 1, $P_1V_1 = \frac{2}{3}N_1\left(\frac{1}{2}m_1\overline{c_1^2}\right)$

=> $N_1 = \frac{3}{2}P_1V_1.\frac{1}{K_1}$

Similarly for gas 2

$N_2 = \frac{3}{2}P_2V_2.\frac{1}{K_2}$

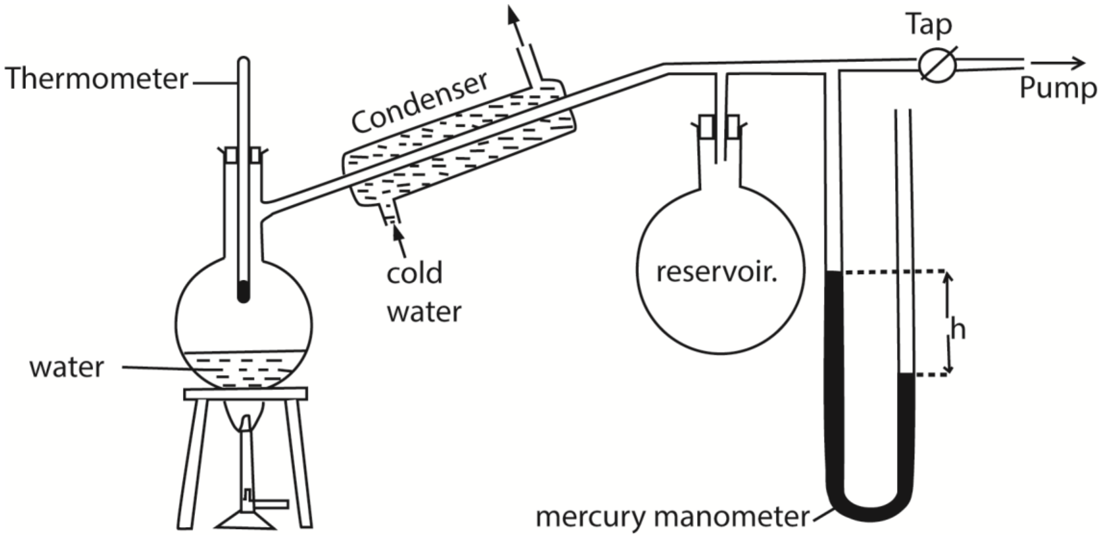
For a mixture of gases, N = $\frac{3}{2}PV.\frac{1}{K}$; but N = $N_1 + N_2$

$\frac{3}{2}PV.\frac{1}{K} = \frac{3}{2}P_1V_1.\frac{1}{K_1} + \frac{3}{2}P_2V_2.\frac{1}{K_2}$

Since temperature is constant, $K_1 = K_2 = K$

- $PV = P_1V_1 + P_2V_2$
- But $V = V_1 = V_2$
- $\therefore P = P_1 + P_2$

(c) Describe an experiment to determine the saturation vapor pressure of a liquid. (06marks)



- The pressure of the air in R is shown by the mercury manometer; if its height is h, the pressure in mm mercury is P = H-h, where H is the barometer height.
- The tap is opened and the pressure above water varied using the pump to a suitable value.
- The tap is closed and water in the flask in heated until it boil.

- The temperature θ and difference in mercury levels, h, are noted and recorded.
- The saturated vapour pressure, P = $(H\pm h)$ is calculated
- The procedure is repeated other values of θ and h
- A graph of P versus θ is plotted and the saturated vapour pressure at a particular temperature is obtained.

(d) (i) What is meant by a reversible isothermal change? (02marks)

The change taking place at constant temperature and can be taken back from the final to initial states through exactly the same values of pressure and volume at every stage.

(ii) State the conditions for achieving a reversible isothermal change. (02marks)

Use vessels with thin good conducting walls having a frictionless piston, surrounded by constant temperature bath and the process must occur slowly.

(e) An ideal gas at 27^0C and at a pressure of 1.01×10^5Pa is compressed reversibly and isothermally until its volume is halved. It is then expanded reversibly and adiabatically to twice its original volume. Calculate the final pressure and temperature of the gas if γ=1.4 (05marks)

For isothermal: $P\frac{V}{2} = 1.01\ x\ 10^5 V$; P = 2.02×10^5Pa

For adiabatic; 2.02 x 105$\left(\frac{V}{2}\right)^{1.4}$ = $P_1(2V)^{1.4}$; $P_1 = 2.9 \times 10^4$Pa

Final pressure = 2.9×10^4Pa

Also,

$TV^{\gamma-1}$ = constant.

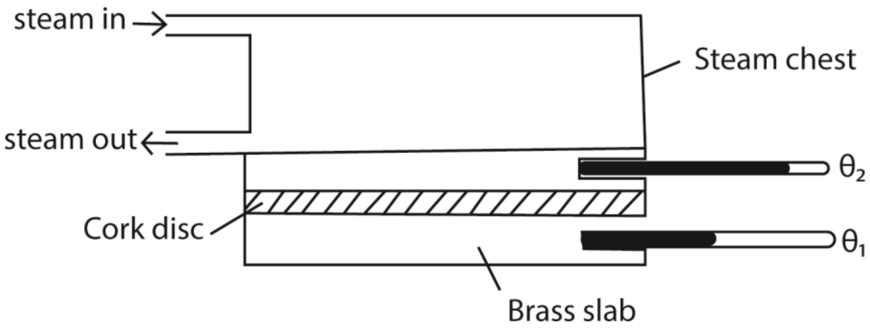
⇨ $(300.15)\left(\frac{V}{2}\right)^{0.4} = (2V)^{0.4}$; T = 172K

6. (a) Explain the mechanism of heat conduction in solids. (03marks)

Atoms or molecules at the heated end vibrate more vigorously about their fixed positions. They collide and pass on heat to the neighboring atoms which in turn vibrate vigorously; collide and pass on heat to their neighboring atoms. In this way heat is transferred from the hot end to the cold end.

Also, good conductors have free electrons that acquired high kinetic energy when heat, move ant transfer heat collide with atoms in the cold

(b) Describe a method of determining the thermal conductivity of cork in form of a thin sheet. (06marks)



- Cock disc cut in form of a thin disc of cross section area, A and thickness, x.
- The disc is sandwiched between a steam chest and brass slab of mass, m and specific heat capacity, c.

- Steam is passed through the chest until the thermometers register steady temperatures, θ_1 and θ_2.
- Then, $\frac{\theta}{t} = kA\left(\frac{\theta_2 - \theta_1}{x}\right)$
- The glass disc is removed and brass slab is heated directly by steam chest, until its temperature is about 10^0C above θ_1.
- Steam chest is removes and the top of the glass slab is covered by the glass disc.
- The temperature of the slab is recorded at suitable time interval until its temperature is about 10^0C below θ_1.
- A graph of temperature against time is plotted and its slope s determined at θ_1

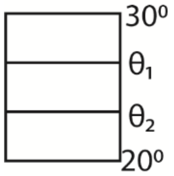
  $\frac{\theta}{t} = mcs$

  $\therefore\ kA\left(\frac{\theta_2 - \theta_1}{x}\right) = mcs$

  $k = \frac{mcsx}{A(\theta_2 - \theta_1)}$ but A = $\frac{\pi D^2}{4}$

  $\therefore k = \frac{4mcsx}{\pi D^2(\theta_2 - \theta_1)}$

(c) A window of height 1.0m and width 1.5m contains a double grazed unit consisting of two single glass panes, each of thickness 4.0mm separated by an air gap of 2.0mm. Calculate the rate at which heat is conducted through the window if the temperatures of external surfaces of glass are 20^0C and 30^0Crespectively.
[Thermal conductivities of glass and air are $0.72Wm^{-1}K^{-1}$ and $0.025\ Wm^{-1}K^{-1}$ respectively] (07marks)



$\frac{dQ}{dT} = \frac{kA(\theta_2 - \theta_1)}{L}$ = mc x slope

$$\frac{k_1A(30 - \theta_1)}{4\ x\ 10^{-3}} = \frac{k_2A(\theta_2 - \theta_1)}{2\ x\ 10^{-3}} = \frac{k_1A(\ \theta_1 - 20)}{4\ x\ 10^{-3}}$$

=> $\theta_1 + \theta_2 = 50$

$$\frac{0.72A(30 - \theta_1)}{4\ x\ 10^{-3}} = \frac{0.025A(\ \theta_1 - \theta_2)}{2\ x\ 10^{-3}}$$

$$\frac{0.72A(30 - \theta_1)}{4\ x\ 10^{-3}} = \frac{0.025A(\ \theta_1 - (50 - \theta_1)}{2\ x\ 10^{-3}}$$

$\theta_1 = 29.4^0$C

Hence $\frac{dQ}{dT} = \frac{0.72A(30 - 29.4)}{4\ x\ 10^{-3}}$ =162W

(d) (i) State Stefan's law. (01mark)

Stefan's law states that the total energy radiated per square meter per second by a black body is directly proportional to the fourth power of its absolute temperature.

(ii) The element of a 1.0kW electric fire is 30.0cm long and 1.0cm in diameter. If the temperature of the surroundings is 20^0C, estimate the working temperature of the element. [Stefan's constant, $\sigma = 5.7\ x\ 10^{-18}Wm^{-1}K^{-1}$] (03marks)

$P = A\sigma T^4$

$= 2\pi rl\sigma(T^4 - T_s^4)$

$= 2\pi rl\sigma T^4 - 2\pi r^2 l\sigma T_s^4$

$$T = \sqrt[4]{\frac{1 x 10^3 + 2\pi (0.5 x 10^{-2})(30 x 10^{-2}) x 5.67 x 10^{-8} x 273^4}{2\pi (0.5 x 10^{-2})(30 x 10^{-2}) x 5.67 x 10^{-8}}} = 1169K$$

7. (a) (i) Define specific heat capacity of a substance (01mark)

Specific heat capacity is the quantity of heat required to raise the temperature of 1kg mass of a substanceby1K without change of state

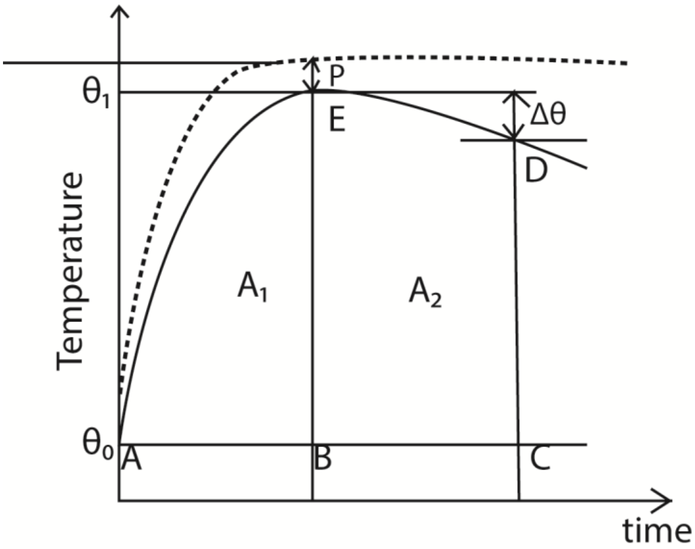
(ii) State how heat losses are minimized in calorimetry (02mark)

- Surrounding the calorimeter vacuum
- Using a highly polished surface
- By lagging the calorimeter using insulating material
- Surrounding the calorimeter with a layer of still air.

(b) (i) What is meant by cooling correction? (01marks)

This is the extra temperature difference to be added to the observed maximum temperature of the mixture to make up for the heat lost to the surrounding during the experiment.

(ii) Explain how the cooling correction may be estimated in the determination of the heat capacity of poor by the method of mixtures (05marks)



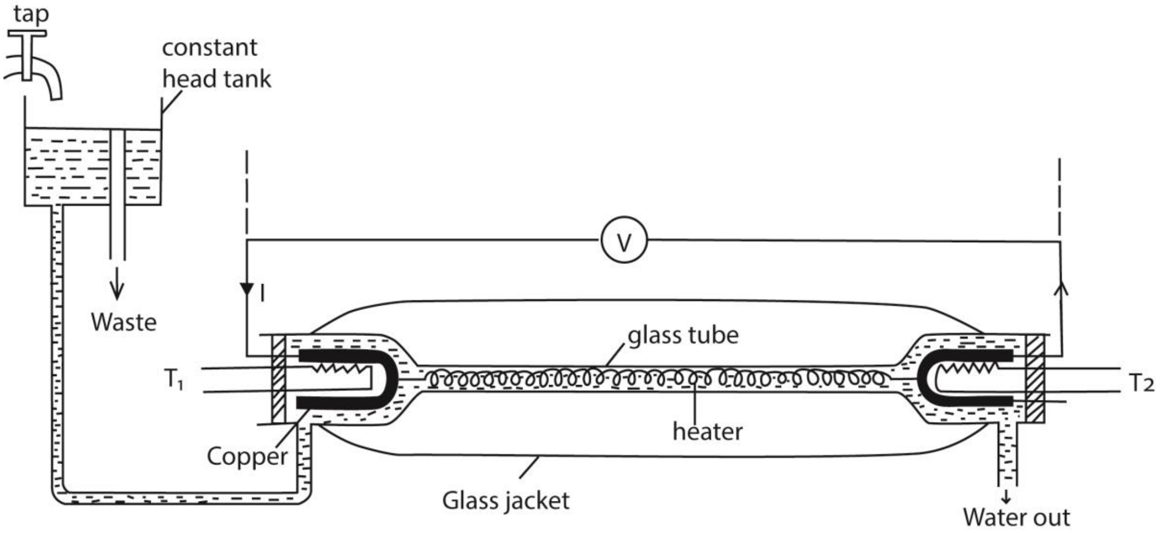
- The broken line shows how we would expect the temperature to rise if no heat were lost and the difference, P, between the plateau of this imaginary curve, and the crest of the experimental curve, E. is known as the 'cooling correction'
- Draw a line AC through θ_0 parallel to the time axis.
- Draw a line BE through θ_1 parallel to the temperature axis.
- Draw a line CD beyond BE parallel to the temperature axis and note $\Delta\theta$
- Estimate the area A_1 and A_2 under the graph by counting the square on the graph paper
- Cooling correction, P s given by the graph

  Cooling correction, P = $\frac{A_1}{A_2} x \Delta\theta^0$C

(iii) Explain why a small body cools faster than a larger one of the same material. (04marks)

Small body has a large surface area to volume ratio and small quantity of heat compare to the bod body. And the rate of heat is proportional to the surface area while the rate of temperature fall is inversely proportional to the quantity of heat held by the body

(c) Describe how you would determine the specific heat capacity of a liquid by the continuous flow method. (07marks)



- A liquid is allowed to flow at constant rate
- Power is switched on and the liquid is heated until temperatures registered by T_1 and T_2 are steady and the values θ_1 and θ_2 respectively are recorded.
- The p.d V and current I are recorded from the voltmeter and ammeter respectively
- The mass, m of a liquid collected in time t is recorded
- At steady state; $VIt = mc(\theta_2 - \theta_1) + h$ …………. (i)
  where h is heat lost to the surrounding
- The rate of flow is changed and the voltage and current are adjusted until the steady readings of T_1 and T_2 are θ_1 and θ_2 respectively
- If m_1, V_1 and I_1 are the values mass of liquid collected in time t, voltmeter and ammeter readings respectively, then
  $V_1I_1t = m_1c(\theta_2 - \theta_1) + h$ …………. (ii)
  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

SECTION C

8. (a) What is meant by
   (i) Bohr atom (01mark)
   A Bohr atom is an atom with small central positive nucleus with electrons resolving round it only in certain allowed orbits; while in orbits they do not emit radiations.
   (ii) binding energy of a nucleus (02marks)
   Binding energy is the energy required to split the nucleus into constituent nucleons

(b) The total energy, E, of an electron n an atom may be expressed as

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

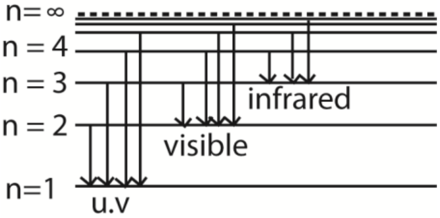
(i) Identify the quantities, m, q, n and h in this expression (02marks)

m- mass of electron
q- charge on electron
n – principle quantum number
h – Plank's constant

(ii) Explain the physical implication of the fact that E is always negative (02marks)

Electrons are bound to the nucleus. Work must be done to remove an electron from the atom. This work is done against nuclear attraction binding electrons in the atom.

(iii) Draw an energy level diagram for hydrogen to indicate emission of ultraviolet, visible and infrared spectral lines. (03marks)



(c)(i) Explain briefly the sources and absorption of infrared radiation. (04 marks)

Source: Surfaces of all bodies emit infrared radiations in continuous range of wavelengths with relative amount of each wavelength depending mainly on temperature and nature of the surface.

Absorption: Infrared radiations is absorbed by matter. Like all other types of electromagnetic radiations, it causes increase of internal energy which leads to temperature rise. They thus produce a sensation of warmth when they fall on the skin.

Except red wavelength near to that of red light, infrared is absorbed by glass but transmitted by rock salt. Water vapour and carbon dioxide in the lower layers of the atmosphere collectively absorb infrared emitted by the earth.

(ii) Describe briefly, the method of detecting infrared radiation (03marks)

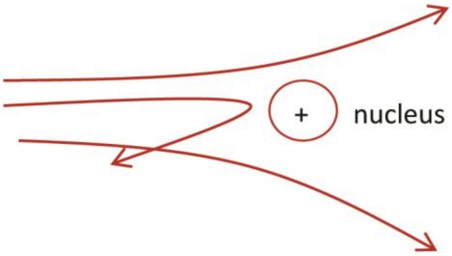
By thermopiles radiation falling on a hot junction produces e.m.f. the e.m.f is detected by the galvanometer connected across thermopile

(d) The atomic nucleus may be considered to be a sphere of positive charge with a diameter very much less than that of an atom. Discuss the experimental evidence which supports this view. (03marks)

In alpha particle experiment by Rutherford, most α- alpha particles passed through with negligible deflection. Some suffered various deviations. Very few were deflected back through angles greater than 90^0 due to head on collision with nucleus.

Majority of α-particles went through undeflected implying that most part of the atom is empty space.

About 1 in 8000 suffered deflection greater than 90^0 implying that the nucleus has a very small diameter compared to that of an atom



9. (a) (i) What are cathode rays? (01mark)

Cathode rays are abeam of fast moving electrons

(ii) An electron gun operating at 3×10^3V is used to project electrons into the space between two oppositely charged parallel plates of length 10cm and separation 5cm.

Calculate the deflection of the electrons as they emerge from the region between the charged plates when the potential difference is 1×10^3V. (03marks)

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

$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 x 1.6 x 10^{-19} \ x 3 x 10^3}{9.11 x 10^{-31}}}$ = $3.25 \times 10^7 ms^{-1}$

$v_x = 3.25 x 10^7 ms^{-1}$

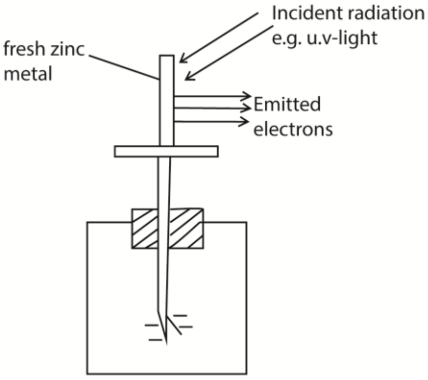
Deflection, y = $\frac{1}{2}at^2$ where t = $\frac{L}{u}$, a = $\frac{eE}{m}$, E = $\frac{V}{d}$

$= \frac{1.6 x 10^{-19} x 1 x 10^3 x (10 x 10^{-2})^2}{2 x 9 x 10^{-31} x 5 x 10^{-2} x (3.25 x 10^7)^2}$

= 1.67×10^{-2}m

(b) (i) Describe a simple experiment to demonstrate photoelectric emission. (04marks)

- A freshly cleaned Zinc plate is connected to the cap of a negatively charged gold leaf electroscope.
- Ultra violet radiations are allowed to fall on the zinc plate



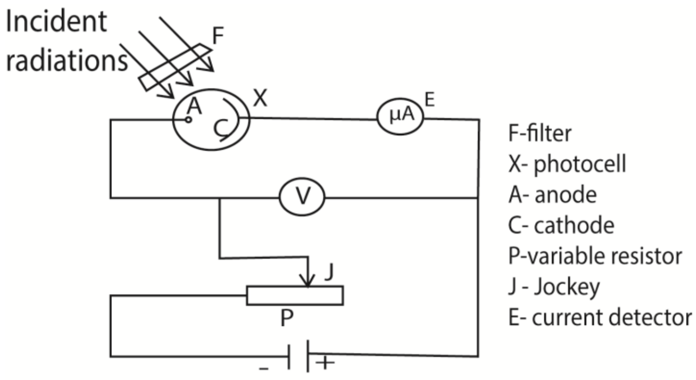
Observations

- The leaf of the electroscope gradually falls
- This shows that both the zinc plate and the electroscope have lost charges.
- The lost charges are found to be electrons, hence photoelectric effect has occurred.

(ii) Explain why the wave theory of light fails to account for the photoelectric effect. (06marks)

- Instantaneous emission: according to the wave theory radiation energy is uniformly spread over the whole wave front. Since the amount of energy incident on any electron would be extremely small, sometime would elapse before an electron escapes from the metal surface. On the contrary, no such a time lag between the start of radiation and start of emission is observed even when the radiation is weak.
- Variation of kinetic energy: by the wave theory, increasing intensity would mean more energy and hence greater value of maximum kinetic energy. But maximum kinetic energy depends on frequency of incident radiation and not intensity.
- Existence of threshold frequency: the wave theory predicts continuous absorption and accumulation of energy. Radiation of high enough intensity should cause emission even when the frequency is below minimum value. Hence the theory cannot account for threshold frequency.

(iii) Describe an experiment to verify Einstein's equation for the photoelectric effect and explain how Plank's constant may be obtained from the experiment. (06marks)



- A radiation of known frequency, f, is made incident on the photocathode
- Emitted electrons travel to the anode and cause a current to flow, detected at E.
- The p.d V is adjusted until the reading of E is zero (i.e. no current flows).
- The value of this p.d is the stopping potential (Vs) and is recorded from the voltmeter V.
- The procedure is repeated with light of different frequencies, f.
- A graph of stopping potential (Vs) against frequency (f) is plotted
- A straight line graph is obtained which verifies Einstein's equation; $V_s = \frac{h}{e}f - \frac{h}{e}f_0$
- The slope of the graph is $\frac{h}{e}$ from which Plank's constant, h, can be obtained.

10. (a) What is meant by
    (i) half-life of radioactive element (01mark)
    This the time taken for the number of active nuclei present in the source at a given time to fall to half its value
    (ii) nuclear fission (01mark)

Nuclear fission is the splitting of heavy unstable nucleus into two nuclei accompanied by release of energy.

(iii) Nuclear fusion

Nuclear fusion is the combination of light nuclei to form a heavier nucleus accompanied by release of energy.

(b) An atom of ^{222}Ra emits an α-particle of energy 5.3eV. Given that the half-life of ^{222}Ra is 3.8days. Use the decay law, $N = N_0e^{-\lambda t}$ to calculate the:

(i) decay constant (03marks)

Decay constant, $\lambda = \frac{In\,2}{t_{\frac{1}{2}}} = \frac{0.693}{3.8\,x\,24\,x\,60\,x\,60} = 2.11 \times 10^{-6}s^{-1}$

(ii) amount of energy released by 3.0×10^{-9}kg of ^{222}Ra after 3.8days (05marks)

1mole of Radium weighs 222g = 0.222kg ≡ 6.02×10^{23} atoms

1.0×10^{-9}kg ≡ $\frac{6.02\,x\,10^{23}\,x\,3\,x\,10^{-9}}{0.222}$ = 8.135×10^{15} atoms

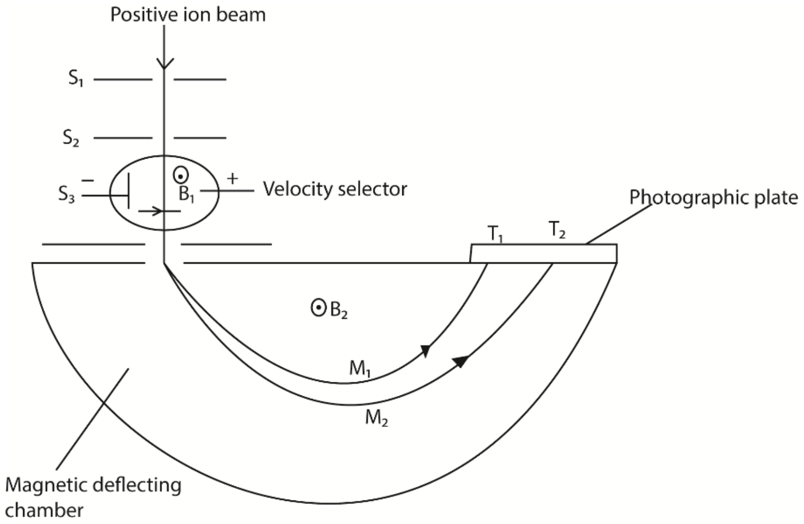
After 3.8 days, the number decays to half its original value

=> number of decayed atoms = $\frac{N_0}{2} = \frac{8.135\,x\,10^{15}}{2}$ = 4.068×10^{15}

0ne atom releases 5.3MeV = $5.3 \times 10^6 \times 1.6 \times 10^{-19} = 8.48 \times 10^{-13}$J

∴ 4.068×10^{15} atoms release $4.068 \times 10^{15} \times 8.48 \times 10^{-13}$ = 3449J

(c) Describe a simple form of a mass spectrometer and explain how it is used to distinguish between isotopes (07marks)



T_1 and T_2 are tracers on photographic plate, S_1, S_2 and S_3 are slits

Mode of Action

- Positive ions are produced in a discharge tube and admitted as a beam through slits S_1 and S_2.

- The beam then passes between insulated plates P, Q, connected to a battery, which create an electric field of intensity E.
- A uniform magnetic field B_1, perpendicular to E is applied over the region of the plates and all ions, charge e with the same velocity, v given by $B_1ev = Ee$ will then pass undeflected through the plates and through a slit S_3.
- The selected ions are deflected in a circular path of radius r by a uniform perpendicular magnetic field B_2 and an image is produced on a photographic plate as shown.
  In this case
  $$\frac{mv^2}{r} = B_2ev$$
  But for the ions selected v = $\frac{E}{B_1}$ from above
  $$\therefore \frac{m}{e} = \frac{rB_2B_1}{E}$$
  $$r = \left(\frac{E}{B_1B_2Q}\right)m$$
  thus different isotopes strike the photographic plate at different points.

(d) the nucleus of ${}^{37}_{17}Cl$ emits an α-particle followed by two β-particles. Show that the final nucleus is an isotope of chlorine (02mark)

$${}^{37}_{17}Cl \rightarrow {}^{4}_{2}He + 2{}^{0}_{-1}e + {}^{33}_{17}Cl$$

Compiled by Dr. Bbosa Science