UACE Physics paper 1 2005 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	$9.11 \times 10^{-31}kg$
Mass of the earth	$5.97 \times 10^{24}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Stefan's-Boltzmann's constant, σ	$5.67 \times 10^{-8}Wm^{-2}K^{-1}$
Radius of the earth	6.4 x 106m
Radius of the sun	$7 \times 10^{8}m$
Radius of the earth's orbit about the sun	$1.5 \times 10^{11}m$
Speed of light in the vacuum, c	$3.0 \times 108ms^{-1}$
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	$6.67 \times 10^{-11}Nm^{2}Kg^{-2}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
Surface tension of water	$7.0 \times 10^{-2}Nm^{-1}$
Density of water	$1000kgm^{-3}$
Gas constant, R	$8.31Jmol^{-1}K^{-1}$
Charge to mass ratio, e/m	$1.8 \times 10^{11}Ckg^{-1}$
The constant, $\frac{1}{4\pi\varepsilon_0}$	$9.0 \times 10^{9}F^{-1}m$
Faraday's constant, F	$9.65 \times 10^{4}Cmol^{-1}$

SECTION A

-

1. (a) Distinguish between scalar and vector quantities giving two example each. (03marks)
   - A scalar quantity has magnitude but not direction e.g. volume, mass
   - A vector quantity has both magnitude and direction, e.g. velocity, acceleration, displacement , force.

(b) The equation for volume, V, of a liquid flowing through a pipe in time t, under steady flow is given by $\frac{V}{t} = \frac{\pi r^4 P}{8\eta L}$ where

r = radius of the pipe

P = pressure difference between two point of the pipe

L = length of the pipe

η = coefficient of viscosity of the liquid

If the dimensions of η are $ML^{-1}T^{-1}$, show that the above equation is dimensionally consistent.

[L.H.S] = $\left[\frac{V}{t}\right]$ = L^3T^{-1}

[R.H.S] = $\frac{[r^4][P]}{[\eta][L]}$ = $\frac{L^4 \; x \; MLT^{-2}L^{-2}}{ML^{-1}T^{-1} \; x \; L}$ = L^3T^{-1}

Since [L.H.S] = [R.H.S], the equation is dimensionally consistent.

(c) (i) define linear momentum. (01mark)

Momentum of a body is the product of its mass and velocity

(ii) State the law of conservation of linear momentum. (01mark)

When bodies in a system interact, the total momentum remains constant provided no external force on the system.

(iii) Show the law in (c)(ii) above follows from Newton's law of motion. (03marks)

Let bodies A and B collide

From Newton's second law of motion,

Force on A due to B, $F_A = \frac{m_a v_a - m_a u_a}{t}$

Force on B due to A, FB = $\frac{m_b v_b - m_b u_b}{t}$

From Newton's third law; $F_A = -F_B$

$\frac{m_a v_a - m_a u_a}{t} = -\frac{m_b v_b - m_b u_b}{t}$

⇨ $(m_a v_a - m_a u_a) - (m_b v_b - m_b u_b) = 0$

(iv) Explain why, when catching a fast moving ball, the hands are drawn back while the ball is being brought to rest. (02marks

Drawing hands back allows for a longer time of action reducing force of impact and damage to hands.

(d) A car of mass 100kg travelling at uniform velocity of $20ms^{-1}$ collides perfectly inelastically with a stationary car of mass 1500kg. Calculate the lass in kinetic energy of the car as a result of the collision. (04marks)

$m_1u_1 = (m_1 + m_2)v$

$v = \frac{m_1 u_1}{(m_1 + m_2)} = \frac{1000 \; x \; 20}{2500} = 8ms^{-1}$

loss in K.E = $\frac{1}{2}m_1u^2 - \frac{1}{2}(m_1 + m_2)v^2$

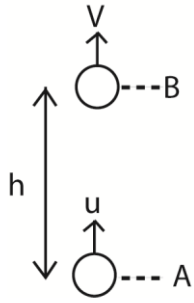
= $\frac{1}{2}\ x\ 1000\ x\ 20^2 - \frac{1}{2}\ x\ 2500\ x\ 8^2$

= 1.2 x 10^5J

(e) (i) What is meant by conservation of energy? (01mark)

Energy changes from one form to another, the total amount of energy after the change must be equal to the initial amount of energy.

(ii) Explain how conservation of energy applies to an object **falling** from rest in a vacuum. (02marks)



At A, K.E = $\frac{1}{2}mu^2$, P.E = 0

Total energy at A = K.E + P.E = $\frac{1}{2}mu^2 + 0 = \frac{1}{2}mu^2$

At B, K.E = $\frac{1}{2}mv^2$; P.E = mgh

Total energy at B, = $\frac{1}{2}mv^2$ + mgh

But $v^2 = u^2 - 2gh$

Total energy at B = $\frac{1}{2}m(u^2 - 2gh)$ + mgh = $\frac{1}{2}mu^2$

∴Total energy at A = total energy at B

2. (a) Explain the term

(i) Ductility (01mark)

Ductility is the ability of a material to be transformed into different shapes without crumbling

(ii) Stiffness (01mark)

Stiffness is the ability of a material to oppose change in shape

(b) A copper wire and steel wire each of length 1.0m and diameter 1.0mm are joined end to end to form a composite wire 2.0m long. Find the strain in each when the composite stretches by 2.0 x 10^{-3}m.

[Young's Modulus for copper and steel are 1.2 x 10^{11}Pa and 2.0 x 10^{11}Parespectively] (07marks)

$F_1 = k_1e_1$; $F_2 = k_2e_2$

But $F_1 = F_2$

$\therefore$ $k_1e_1 = k_2e_2$ => $e_1 = \frac{k_2e_2}{k_1} = \frac{Y_2e_2}{Y_1} = \frac{2 \, x \, 10^{11}}{1.2 \, x \, 10^{11}} e_2 = 2 \, x \, 10^{-3}$

$e_2 = 0.75 \, x \, 10^{-3}$ m

$strain \; in \; steel \; wire = \frac{e_2}{l_2} = \frac{0.75 \, x \, 10^{-3}}{1} = 0.75 \, x \, 10^{-3}$

$e_1 = 1.25 \, x \, 10^{-3} m$

Strain in copper wire = $\frac{e_1}{l_1} = \frac{1.25 \, x \, 10^{-3}}{1} = 1.25 \, x \, 10^{-3}$

(c) (i) Define centre of gravity (01mark)

Centre of gravity is the point through which the gravitational forces act.

(ii) Describe an experiment to find the centre of gravity of a flat irregular piece of cardboard. (03marks)

- three holes are drilled around the edge of the sheet of irregular object.
- The cardboard is suspended from a pin through one of the holes. When the cardboard is freely suspended, a plumb line is suspended from the same pin.
- A line is drawn to mark the line where the plumb line passes.
- The procedure is repeated for the other two holes.

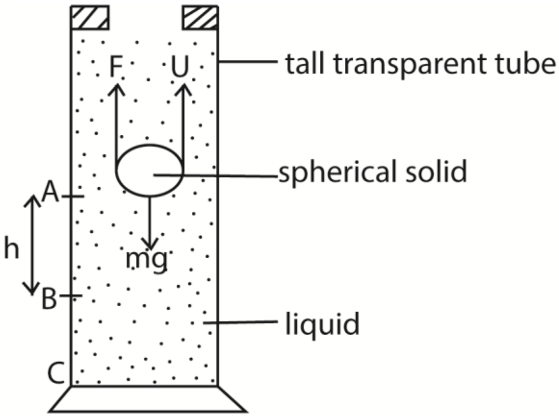
(d) Explain the laws of solid friction using molecular theory (07marks)

- The frictional force between two surfaces opposes their relative motion, this because the actual area of contact between solid surfaces is very small. Therefore pressure at points of contact is very high; projections emerge to produce adhesion or welding. The force which oppose motion is obtained
- The frictional force is independent of the area of contact of the given surfaces when the normal reaction is constant, because the actual area of contact is the sum of the areas of tiny projections that adhere to each other and are nearly independent of the surface areas of contact.

- The limiting frictional force is proportional to the normal reaction for the case of static friction. The frictional force is proportional to the normal reaction for the case of kinetic (dynamic) friction, and is independent of the relative velocity of the surfaces. This is because increase in weight increases the actual area of contact and hence greater limiting frictional force.

3. (a) What is meant by the following terms?
   (i) Velocity gradient. (01mark)
   Velocity gradient is the change of velocity between two points per unit length of separation of the points.
   Or
   It is the rate of change of velocity with change in distance of separation.
   (ii) Coefficient of viscosity (01mark)
   Coefficient of viscosity is the tangential force per unit area of fluid which resists the motion of one layer over another in a region of unit velocity gradient.

(b) Derive an expression for terminal velocity of a steel ball-bearing of radius, r, and density, ρ, falling through a liquid of density, σ, and coefficient of viscosity, η. (05marks)



- A liquid of known density, ρ, is put in a tall transparent glass with reference marks A and B, h metres apart
- A spherical solid of radius a and density, σ, is dropped into the liquid and time t taken to drop from A to B is determined.
- Terminal velocity, $v_0 = \frac{h}{t}$

  The coefficient viscosity, $\eta = \frac{2r^2(\sigma-\rho)g}{9v_0}$

  Assumptions

  The spherical solid moves with terminal velocity by the time it reaches A

  Precautions

  - The glass tube should be very wide compared to the diameter of the ball.
  - The point C should be far away from the top of the tube
  - Temperature is constant

(c) (i) Define surface tension (01mark)

Is the force acting at right angle at one side of immaginary line of length 1m drawn in the surface of a liquid.

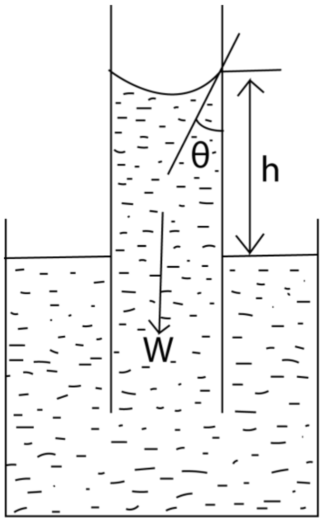
(ii) Explain the origin of surface tension. (03marks)

- Liquid molecules attract each other.
- The molecules within the body of the liquid (bulk) molecules is attracted equally by neighbors in all direction, hence, the force on the bulk molecules is zero,
- For a surface molecule, there is a net inward force because there are no molecules above the surface to attract them equally.

- To the surface, work must be done against the inward attractive force, hence, a molecule in the surface of a liquid has a greater potential energy than a molecule in the bulk. The potential energy stored inmolecules at the surface is called free surface energy or surface tension.

- Due to the attractive forces experienced by surface molecules due to their neighbours put in a state of tension; the liquid surface behave as a stretched skin.

(iii) Describe an experiment to measure surface tension of a liquid by capillary method. (06marks)



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

$F\gamma\cos\theta = W$

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

$F = \gamma L$

$L = 2\pi r$

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

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

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

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

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

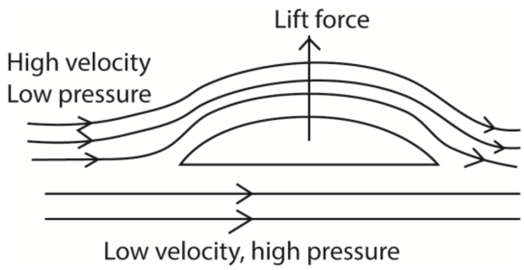
γ – coefficient of surface tension

θ – angle of contact

r – radius of capillary tube

ρ – density of the liquid

(d) Explain, with the aid of a diagram why air-flow over the wings of an aircraft at take-off cause a lift. (03marks)



- Air flows above the wing of a plane at high velocity hence low pressure.
- Below the wings, air flows at low velocity and hence high pressure.

- The difference in pressure cause a lift force, therefore net upward force.

4. (a) (i) Define angular velocity. (01marks)

Angular velocity is the rate of change of angle of rotation of an object moving in a circular path about the centre.

(ii) Derive an expression for the force, F, on a particle of mass, m, moving with angular velocity, ω, in a circle of radius, r. (03marks)

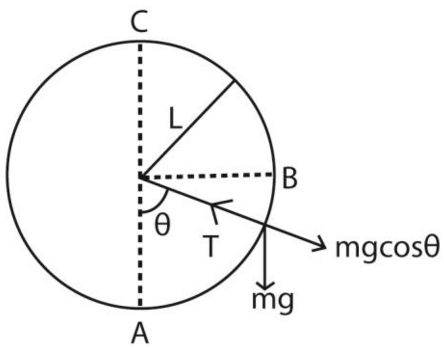
F = ma = $\frac{mv^2}{r}$ since a = $\frac{v^2}{r}$

But v = ωr

∴ F = $\frac{m(\omega r)^2}{r}$ = mω^2r

(b) A stone of mass 0.5kg is attached to a string of length 0.5m which will break if the tension in it exceeds 20N. The stone is whirled in a vertical circle, the axis of rotation being at a vertical height of 1.0m above ground. The angular speed is gradually increased until the string breaks.

(i) In what position is the string most likely to break? (02marks)



At A, θ = 0

=> T = $\frac{mv^2}{L}$ + mg

At B, θ = 90^0

=> T = $\frac{mv^2}{L}$

At C, θ = 1800

=> T = $\frac{mv^2}{L}$ - mg

The string breaks at the lowest point, A of the circle because tension the string is highest.

(ii) At what angular speed will the string break? (03marks)

String breaks T = mω^2r + mg

20 = 0.5 x 0.5 x ω2 + 0.5 x 9.81

Ω = 7.77rads^{-1}

v = ωr=7.77 x 0.5 = 3.9ms^{-1}

(iii) Find the position where the stone hits the ground when the string breaks. (03marks)

Vertical distance to be covered = 0.5m

s = ut + $\frac{1}{2}at^2$

but initial component of vertical velocity = 0

=> 0.5 = $\frac{1}{2}$ x 9.81 x t^2

t = 0.3s

Horizontal distance = 3.9 x 0.3 = 1.17m

(c) Explain briefly the action of a centrifuge. (03marks)

Consider a body falling through a viscous fluid. For small speed, the liquid opposes motion with a resisting force, f, proportional to the velocity, v.

f = kv where k is a constant of proportionality.

At terminal velocity, $v_t = \frac{mg}{k}$

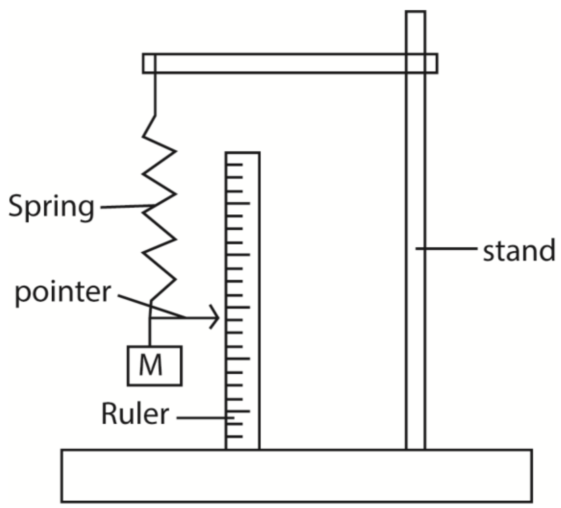
If a container is whirled at high speed, the particles will move approximately in circles with speed, v, and acceleration= $\frac{v^2}{r}$.

When they reach their terminal velocity, v_t, relative to the fluid, the resisting force of the fluid on the particle, f = kv_t must be equal to the mass of the particle multiplied by its acceleration such that the terminal velocity, vt of the particles relative to the fluid is given by v_t = $\frac{mv^2 \div r}{k}$

The terminal speed or sedimentation rate is increased by a factor of $\frac{v^2}{rg}$ which may be in thousands.

Centrifuges are used to separate cream from milk, silt from river water, blood cells from plasma, e.t.c

(d) Describe how the acceleration due to gravity can be measured using helical spring of unknown force constant, and the other relevant apparatus. (05marks)



- Suspend a spiral spring from the clamp of a retort stand.
- Attach the pointer to the free end of the spring such that it is horizontal.

- Read and record the initial pointer position on a meter rule supported vertically.
- Suspend a mass, m, from the spring and record the new position of the pointer and calculate the extension, x, of the spring
- Displace the mass, m, through a small vertical distance and release it.
- Measure the time for a reasonable number of oscillations
- Calculate the period T of oscillations. Repeat the procedure for different value of masses.
- Plot a graph of T^2 against x, and find the slope, S, of the graph
- Calculate g from g = $\frac{4\pi^2}{S}$

SECTION B

5. (a)(i) What is meant by term fixed point in thermometry? Give two examples (02marks)
Fixed points are temperatures at which water changes from one phase to the other, i.e. melting and boiling points.

(ii) How is temperature on Celsius scale defined on a platinum resistance thermometer? (02marks)
$\theta = \frac{R_\theta - R_0}{R_{100} - R_0}$ where R_θ is the resistance at unknown temperature, R_0 and R_{100} are resistances at ice and steam points respectively

(b) Explain the extent to which two thermometers based on different properties but calibrated using the same fixed points are likely to agree when used to measure temperature.

(i) near one of the fixed point (02marks)

They do not agree since different thermometric properties vary differently with temperature changes

(ii) mid-way between two fixed points (02marks)

They agree because the choice of fixed points is definite.

(c) The continuous flow method is used in determination of the specific heat capacity of liquids.

(i) What are the principal advantages of this method compared to the method of mixtures? (03marks)

- The heat capacity of the apparatus is not required in the apparatus
- Heat losses are not required in the calculation
- Temperatures read at leisure.

(ii) In such a method, 50gof water is collected in 1 minute. The voltmeter and ammeter readings are 12.0V and 2.50A respectively, while the inflow and outflow temperatures are 20^0C and 28^0C respectively. When the flow rate is reduced to $25gmin^{-1}$, the voltmeter and ammeter read 8.8V and 1.85A respectively while the temperatures remain constant. Calculate the specific heat capacity of water. (05marks)

From VIt = mcθ + h

12 x 2.5 x 1 x 60 = 50 x 10^{-3} x c x (28 – 20) + h …………. (i)

8.8 x 1.85 x 1 x 10 = 25 x 10^{-3} x c x (28 – 20) + h ………. (ii)

Subtracting (ii) from (i)

c = 4.1 x 10^{3} $Jkg^{-1}K^{-1}$

(d) What are the advantages of a thermocouple over a constant volume thermometer for measuring temperature? (04marks)

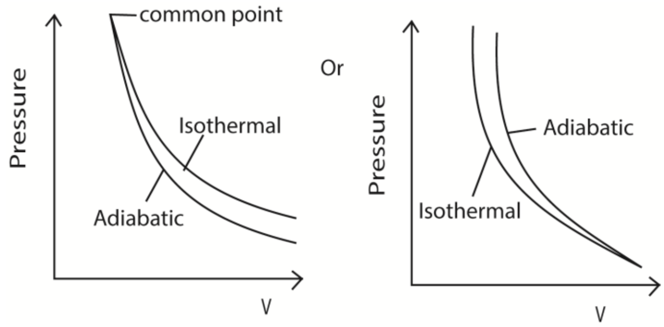
- Use to measure rapidly changing temperature
- It can give direct readings
- It is not bulky
- It can measure temperature at a point

6. (a)(i) What is meant by isothermal and adiabatic changes? (02marks)

Isothermal expansion takes place at constant temperature.

Adiabatic expansion takes place at constant heat.

(ii) Using same axes and point, sketch graphs of pressure versus volume for fixed mass of a gas undergoing isothermal and adiabatic changes. (03marks)



(b) An ideal gas is trapped in a cylinder by a movable piston. Initially it occupies a volume of 8 x $10^{-3}m^3$ and exerts a pressure of 108kPa. The gas undergoes an isothermal expansion until its volume is 27 x $10^{-3}m^3$. It is then compressed adiabatically to the original volume of the gas.

(i) Calculate the final pressure of the gas (06marks)

Under isothermal, $P_1V_1 = P_2V_2$

$$108 \times 10^3 \times 8 \times 10^{-3} = P_2 \times 27 \times 10^{-3}$$

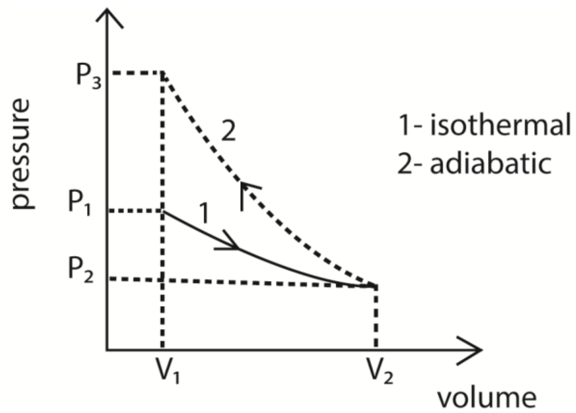
$$P_2 = 3.2 \times 10^3 Pa$$

Under adiabatic, $P_3V_3^{\gamma} = P_2V_2^{\gamma}$

$$P_3(8 \, x \, 10^{-3})^{\frac{5}{3}} = 32 \, x \, 10^3 \, x \, (27 \, x \, 10^3)^{\frac{5}{3}}$$

$$P_3 = 243 \, x \, 10^3 \text{ Pa}$$

(i) Sketch and label the two stages on a p-v diagram. (02marks)



[The ratio of the principal molar heat capacities of the gas = 5:3]

(c) (i) Define molar heat capacities at constant pressure. (01mark)

The specific heat capacity of a gas at constant pressure is the heat required to warm unit mass of it by one degree, when its pressure is kept constant.

(ii) Derive the expression $C_p - C_v = R$, for 1mole of a gas (05marks)

From $dQ = dU + dW$……………. (i)

But $dQ = C_p dT$, $dU = C_v dT$ and $dW = PdV = RdT$

Substituting in (i)

$C_p dT = C_v dT + RdT$

$\therefore C_p - C_v = R$

(iii) In which ways does a real gas differ from an ideal gas? (02marks)

Real gas	Ideal gas
Intermolecular force are appreciable	Intermolecular forces are negligible
Volume of molecules compared to the volume of the container is not negligible	Volume of molecules compared to the volume of container is negligible
Obey Boyle's law at high temperature and very low pressure	Obey Boyle's law at all temperatures and pressures.

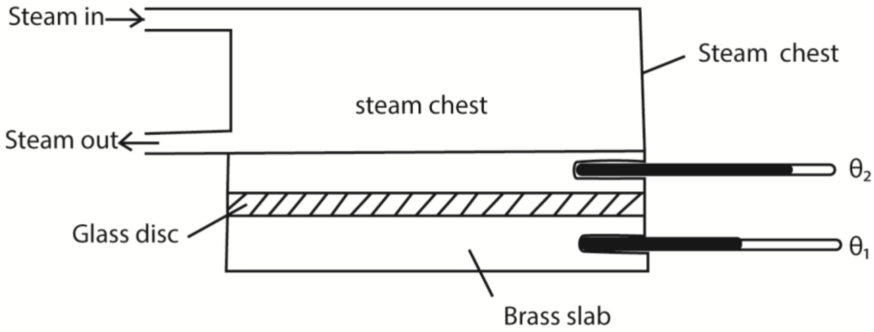
7. (a) (i) Define thermal conductivity. (01mark)

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

(ii) State two factors which determine the rate of heat transfer through a material (02marks)

- Temperature gradient
- Thermal conductivity of a material
- Cross section area.

(b)(i) Describe with the aid of a diagram an experiment to measure the thermal conductivity of glass. (08marks)



- Glass s 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 = $\frac{\pi D^2}{4}$

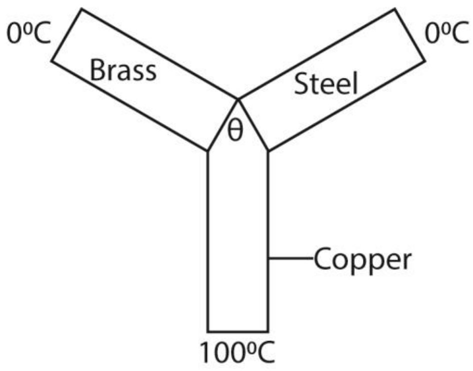
  $\therefore k = \frac{4mcsx}{\pi D^2(\theta_2 - \theta_1)}$

(ii) Briefly discuss the advantages of the apparatus in (b)(i). (02marks)

- Temperature read at steady state
- The heat capacity of the apparatus not required

(c) Metal rods of copper, brass are welded together to form Y shaped figure.
The cross-section area of each rod is 2cm^2. The free end of copper rod are maintained at 100^0C, while the free ends of brass and steel rods are maintained at 0^0C. If there is no heat loss from the surfaces of the rods and the length of the rods are 0.46m, 0.13m and 0.12m respectively.

(i) Calculate the temperature of the junction (05marks)



At the junction, $\frac{Q}{t} = kA\left(\frac{\theta_2 - \theta_1}{l}\right)$

$\frac{dQ}{dt} = \frac{k_1 A}{l_1}(100 - \theta) = \frac{k_2 A}{l_2}(\theta - 0)$

$\frac{dQ}{dt} = \frac{k_1 A}{l_1}(100 - \theta) = \frac{k_3 A}{l_3}(\theta - 0)$

Eqn. (i) and Eqn. (ii)

$\frac{k_1 A}{l_1}(100 - \theta) = A\theta\left(\frac{k_2}{l_2} + \frac{k_3}{l_3}\right)^{-1}$

$\theta = \frac{200k_1}{l_1}\left(\frac{2k_1}{l_1} + \frac{k_2}{l_2} + \frac{k_3}{l_3}\right) = \frac{200\ x\ 385}{0.46}\left(\frac{2\ x\ 385}{0.46} + \frac{109}{0.13} + \frac{50.2}{0.12}\right)^{-1} = 57.11^0C$

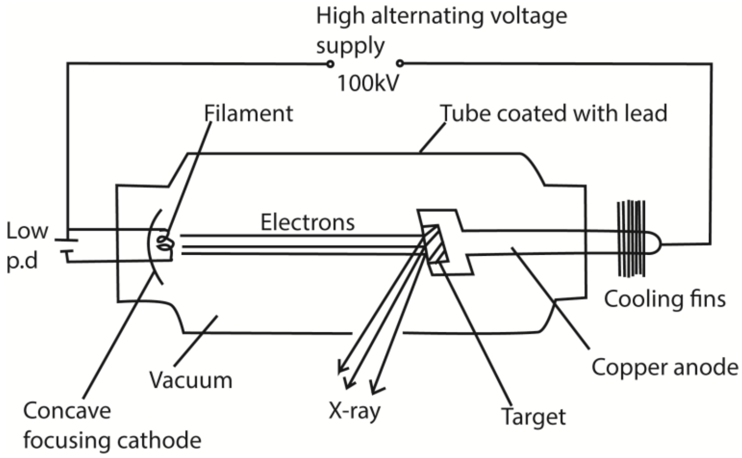
(ii) Find the heat current in the copper rod. (02marks)

$\frac{dQ}{dt} = \frac{kA}{l_1}(100 - \theta) = \frac{385\ x\ 10^{-4}(100-57.11}{0.46} = 7.2Js^{-1}$

[Thermal conductivities of copper, brass and steel are $385Wm^{-1}K^{-1}$, $109\ Wm^{-1}K^{-1}$ and $50.2\ Wm^{-1}K^{-1}$respectively.]

SECTION C

8. (a)(i) Draw a labelled diagram of an X-ray tube. (02marks)



(ii) Use the diagram in (a)(i) to describe how X-rays are produced. (03marks)

- 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.

(iii) State one industrial and one biological use of X-rays. (01marks)

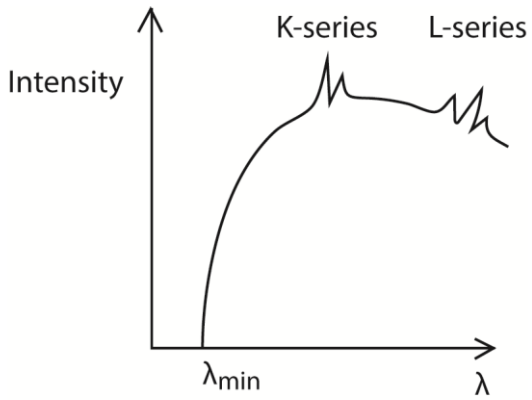
Industrial use

1. Inspecting metal casting and welding joints for perfection
2. Structural analysis, stresses, fractures in solids, castings and welded joints can be analyzed by examining X-ray photograph.
3. Crystallography; Orientation and identification of minerals by analysis of diffraction patterns using Bragg's law.

Biological use

- Identifying fractures
- Treatment of cancer

(b)(i) Sketch a graph of intensity versus wavelength of X-rays from an X-ray tube and describe its main features. (04marks)



The spectrum consists of two major components, i.e. the continuous (background) spectrum and the very sharp line spectrum superimposed onto the background spectrum.

The continuous spectrum is produced when electrons make multiple collisions with the target atoms in which they are decelerated. At each deceleration, X-rays of differing wavelength are produced.

The shortest Wavelength X-rays are produced when electrons lose all their energy as X-ray photon in a single encounter with the target atoms. The wavelength of the X-rays at this point is known as the cut off wavelength. At cut off wavelength, energy in an X-ray photon equals kinetic energy of the electron; i.e. hf = eV or $\frac{hc}{\lambda_{max}} = eV$ where V = p.d

The line spectrum

At high tube voltages, the bombarding electrons penetrate deep into the target atoms and knock out electrons from inner shell. The knocked out electrons occupy vacant spaces in higher unfilled shells putting the atom in excited state and making them unstable.

Transition of an electron from higher to lower energy levels results in an emission of X-ray photon of energy equal to energy difference between the energy levels.

If the transition ends in the K-shell, it produces K-series and if the transition ends in L-shell. It produces L-series.

(ii) Calculate the maximum frequency of X-rays emitted by an X-ray tube operating on voltage of 34.0kV. (03marks)

From $hf_{max} = eV$

$f_{max} = \frac{1.6 \ x\ 10^{-19}\ x\ 34\ x\ 10^{3}}{6.63\ x\ 10^{-34}}$ = 8.205 x 10^{18}Hz

(c) In the measurement of electron charge by Millikan's apparatus, a potential difference of 1.6kV is applied between two horizontal plates 14mm apart. With the potential difference switched off, an oil drop is observed to fall with constant velocity 4.0 x 10^{-4}ms^{-1}. When the potential difference is switched on, the drop rises with constant velocity 8.0 x 10^{-5}ms^{-1}. If the mass of the oil drop is 1.0 x 10^{-14}kg, find the number of electron charges on the drop. [assume air resistance is proportional to velocity of the oil drop and neglect the up thrust due to air] (07marks]

Neglecting up thrush due to air resistance

mg = $6\pi\eta a v_0$

$\eta a = \frac{mg}{6\pi v_0} = \frac{1.0\ x\ 10^{-14} x\ 9.81}{6\pi\ x\ 4\ x\ 10^{-4}}$ = 1.3 x 10^{-11}Nsm^{-1}.

When p.d of 1.6 x 10^{3}V is applied, v = 8 x 10^{-5}ms^{-1}

mg = F + F_E

mg = $6\pi\eta a v$ + qE

q = $\frac{mg-6\pi\eta a\ v}{E} = \frac{mg-6\pi\eta a\ v}{V} d = \frac{(1.0\ x\ 10^{-14} x\ 9.81-\ (6\pi\ x\ 1.3\ x 10^{-11} x\ 8.5\ x\ 10^{-5}\ ))\ x\ 14\ x\ 10^{-3}}{1.6\ x\ 10^{3}}$

= 6.76 x 10^{-19}C

But q = ne

n = $\frac{q}{e} = \frac{6.76\ x\ 10^{-19}}{1.6\ x\ 10^{-19}}$ =4

9. (a) (i) State the laws of photo-electric emission. (04marks)

- The time lag between irradiation of the metal surface and emission of the electrons by the metal surface is negligible.
- For a given metal, surface there is a minimum value of frequency of radiation called threshold frequency (f_0) below which no photo electrons are emitted from the metal however intense the incident radiation may be.
- The number of photoelectrons emitted from the surface per second is directly proportional to the intensity of incident radiation for a particular incident frequency
- The K.E of the photoelectrons emitted is independent of the intensity of the incident radiation but depends only on its frequency

(ii) Write down Einstein's equation for photo electric emission. (02marks)

hf= w_0 + ½ mv^2 ;

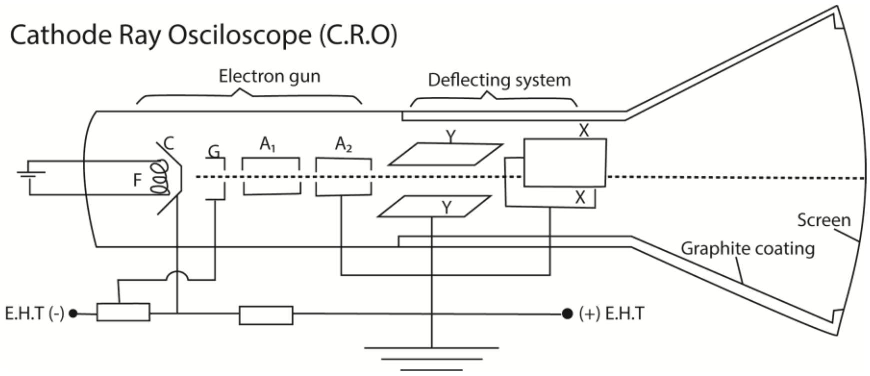
where h = Plank's constant, f = frequency of radiation, w0 = work function, m = mass of electron, v = velocity of electron

(iii) Ultra –violet light of wavelength 3.3 x 10^{-8}m is incident on a metal. Given the work function of the metal is 3.5eV, calculate the maximum velocity of the liberated electron. (03marks)

From hf = w0 + $\frac{1}{2}mv^2$

$$v = \sqrt{\frac{2\left(\frac{hc}{e\lambda} - w_0\right)e}{m}} = \sqrt{\frac{2\left(\frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 3.3 \times 10^{-8}} - 3.5\right) \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}} = 3.47 \times 10^{6} ms^{-1}$$

(b) Describe, with aid of a diagram, the structure and mode of operation of a cathode ray oscilloscope (C.R.O) (06marks)



The following are the main features of CRO

- a hot filament emits electrons
- The grid G has a negative potential with respect to the filament and controls the number of electrons entering and reaching anode A_1
- Anodes A1 and A2 accelerate the electron beam at a high speed the screen
- Deflecting system consist of Y- and X-plates; Y-plated deflect the beam vertically while X- plates deflect the beam horizontally.
- The screen is coated with zinc sulphide to display the arrival of the beam by emitting light when struck by the beam
- Carbon coating prevents the electron beam from the influence of any external electric field.

(c) A C.R.O has its y-sensitivity set to 10Vm^{-1}. A sinusoidal input voltage is suitably applied to give a steady trace with time base switched on so that the electron beam takes 0.01s to traverse the screen. If the trace seen has a peak-to-peak height of 4.0cm and contains two complete cycles, find the

(i) r.m.s value of the input voltage. (03marks)

Peak to peak voltage = y-sensitivity x height

= 10 x 4

= 40V

$$V_{r.m.s} = \frac{V_{max}}{\sqrt{2}} = \frac{20}{\sqrt{2}} = 14V$$

(ii) frequency of the input signal. (02marks)

Period T = time for one oscillation

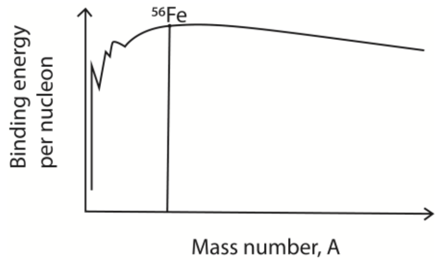
= $\frac{0.01}{2}$ = 0.005s

Frequency, f = $\frac{1}{T} = \frac{1}{0.005}$ = 200Hz

10. (a) Define binding energy of nuclide (01mark)

Binding energy is the energy required to split the nucleus into its individual nucleons, i.e. protons and neutrons.

(b) (i) Sketch a graph showing how binding energy per nucleon varies with mas number (01mark)



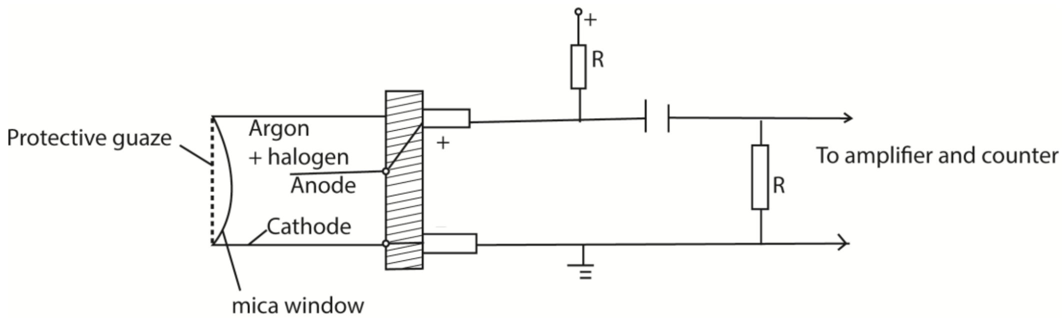
(ii) Describe the main features of the graph in (b)(i). (03marks)

Binding energy per nucleon increases with a few peaks up to the maximum mass number = 56 and then decreases gradually.

(c) Distinguish between nuclear fission and nuclear fusion and account for the energy released. (03mark)

- Nuclear fusion is the combination of two light nuclei to form heavier nucleus accompanied with release of energy.
- Nuclear fission is the splitting of a heavy unstable nucleus into small stable nuclei accompanied by release of energy.

(d) (i) with the aid of a labelled diagram describe the working of the Geiger-Muller tube. (05marks)



The thin mica window allows the passage and detection of the weak penetrating alpha particles. The GM tube is first evacuated then filled with Neon, Argon plus Halogen gas which is used as a quenching agent.

Mode of operation

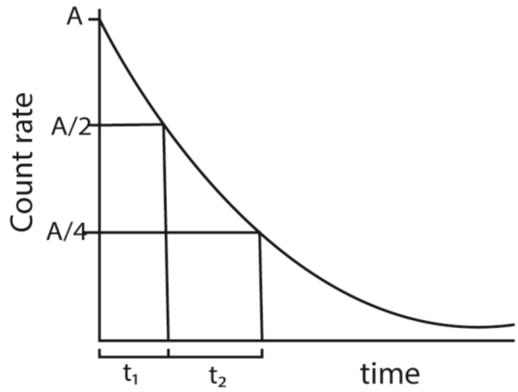
Mode of operation

- When an ionizing particle enters the tube through the window, argon atoms are ionized.
- The electrons move to the anode while the positive ions drift to the cathode.
- A discharge occurs and the current flows in the external circuit.
- A p.d is obtained across a large resistance, R which is amplified and passed to the scale.
- The magnitude of the pulse registered gives the extent to which ionization occurred.

(ii) How would you use a Geiger-Muller tube to determine the half-life of a radioactive sample? (04marks)

Experiment to determine a half-life of radioactive substance using GM- tube

- Switch on the GM-tube, note and record the background count rate, A.
- Place a source of ionizing radiation near the GM-window.
- Note and record the count rate recorded the count rate at equal intervals.
- For each count rate recorded subtract the background count rate to get the true rate.
- Plot a graph of the count rate against time.



Find time t_1 taken for the activity to reduce to A/2 and t_2 taken for activity to reduce to A/4 from A/2

Half-life = $\frac{1}{2}(t_1 + t_2)$

(e) A radioactive source produces alpha particles each of energy 60eV. If 20% of the alpha particles enter an ionization chamber a current of 0.2μA flows. Find the activity of the alpha source, if the energy needed to make an ion pair in the chamber is 32MeV. (03marks)

The charge of 1e = 1.6×10^{-19} per second is produced by an energy of 32eV

Ie amperes is produced by 32MeV

0.2μA is produced by $\frac{32MeV}{e}$ x 0.2μA = y

$\therefore 20\%\ of\ x = y$

Where x is the energy that would be required to ionize all alpha particles

⇨ X =5y

Number of alpha particles = $\frac{x}{60MeV} = \frac{5x\ 32MeV\ x\ 0.2\ x\ 10^{-6}}{e\ x\ 60MeV}$ = 3.3×10^{12}Bq

Compiled by Dr. Bbosa Science