UACE Physics paper 1 2004 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.

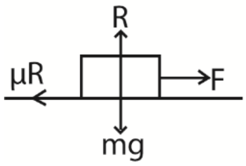
Assume where necessary

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) State the laws of friction (04marks)
   - Friction force oppose relative motion between surfaces in contact.
   - Friction force is independent of area of contact provided normal reaction is constant.
   - The friction force is directly proportional to the normal reaction.

(b) A block of mass 5.0kg resting on the floor is given a horizontal velocity of $5.0ms^{-1}$ and comes to rest in a distance of 7.0m. Find the kinetic friction between the block and the floor. (04marks)



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

$0 = 5^2 - 2a \times 7$

a = 1.79ms-1

F = ma = 5 x 1.79 =8.95N

R = mg = 5 x 9.81 = 49.05N

Also friction force, F = μR

$\mu = \frac{F}{R} = \frac{8.95}{49.05} = 0.18$

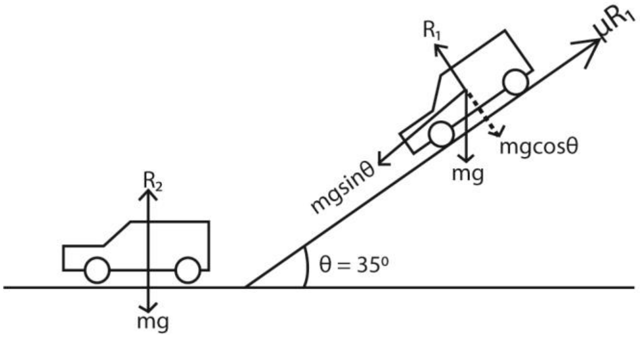
(c) (i) State the law of conservation of linear momentum (01mark)

The law of conservation of momentum states that if no external force acts on a system of colliding objects, the total momentum of the objects in a given direction is constant.

(ii) What are perfectly inelastic collision? (01mark)

Two bodies are said to be perfectly inelastic after collision if
- Momentum is conserved while kinetic energy is not conserved
- The bodies stick together and move with common velocity.
- Coefficient of restitution is equal to zero.

(d) A car of1500kg rolls from rest down a road inclined to the horizontal at an angle 35^0, through 50m. The car collides with another car of identical mass at the bottom of the incline. If the two cars interlock on collision, and the coefficient of kinetic friction is 0.20, find the common velocity of the vehicles. (08marks)



For the vehicle $ma = mg\sin\theta - \mu R_1$

$ma = mg\sin\theta - \mu mg\cos\theta$

$a = 9.81\sin 35^0 - 0.2 \times 9.81\cos 35^0$

$= 4ms^{-2}$

The velocity of the first car before collision

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

$v^2 = 0 + 2 \times 4 \times 50$

$v = 20ms^{-1}$

Horizontal component of velocity, $u1 = 20\cos35^0 = 16.4ms^{-1}$

After collision, momentum conserved.

$m_1u_1 = (m_1 + m_2)v$

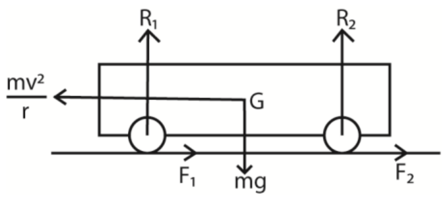
$v = \frac{1500 \; x \; 16.4}{(1500+1500)} = 8.2ms^{-1}$

(e) Discuss briefly the energy transformation which occur in (d) above
The potential energy of the car on the slope is converted to kinetic energy and heat due to friction. Then the kinetic energy is converted to sound and heat due to friction.

2. (a) Define angular velocity (01mark)
Angular velocity is the rate of change of the angle of rotation for an object moving in a circular path about the centre.

(b) A car of mass, m, travels round a circular track of radius, r, with velocity, V.

(i) Sketch a diagram to show the forces acting on the car. (02marks)



(ii) Show that the car does not overturn if $V^2 < \frac{arg}{2h}$, where a is the distance between the wheels, h, is the height of the centre of gravity above the ground and g is acceleration due to gravity. (05marks)

Suppose the car is moving with velocity, v, around a horizontal circular track of radius, r. if m is the mass of the car and R_1 and R_2 are normal reactions at the inner and outer wheels respectively and F_1 and F_2 are the corresponding frictional forces, then for circular motion:

$F_1 + F_2 = \frac{mv^2}{r}$ ………………………………………… (i)

For vertical equilibrium

$R_1 + R_2 = mg$ …………………………………………(ii)

Taking moments about G

Clockwise moments = anticlockwise moments

$(F_1 + F_2)h + R_1\frac{a}{2} = R_2\frac{a}{2}$

$(F_1 + F_2)h = \frac{a}{2}(R_2 - R_1)$ = …………………… (iii)

Substituting Eqn. (i) into Eqn. (iii)

$\frac{mv^2h}{r} = \frac{a}{2}(R_2 - R_1)$ ……………………………………(iv)

From (ii)

$R_1 = mg - R_2$

From equation (iv)

$\frac{mv^2h}{r} = \frac{a}{2}(R_2 - (mg - R_2)) = \frac{a}{2}(2R_2 - mg)$

$2R_2 = \frac{2mv^2h}{ar} + mg = m\left(\frac{2v^2h}{ar} + g\right)$

$R_2 = \frac{m}{2}\left(\frac{2v^2h}{ar} + g\right)$

Also $R_2 = mg - R_1$

From equation (iv)

$\frac{mv^2h}{r} = \frac{a}{2}((mg - R_1) - R_1) = \frac{a}{2}(mg - 2R_1)$

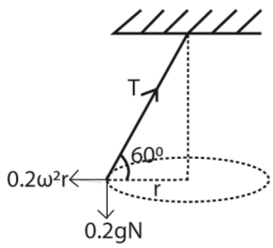
$2R_1 = mg - \frac{2mv^2h}{ar}$

$R_1 = \frac{m}{2}\left(g - \frac{2v^2h}{ar}\right)$

When the car is about to overturn, $g = \frac{2v^2h}{ar}$, $R_1 = 0$, $v^2 = \frac{gar}{2h}$

(c) A pendulum bob of mass 0.2kg is attached to one end of an inelastic string of length 1.2m. The bob moves in a horizontal circle with the string inclined at 30^0 to the vertical. Calculate

(i) the tension in the string(02marks)



Resolving vertically

$T\sin 60^0 = 0.2g = 0.2 \times 9.81$

T = 2.27V

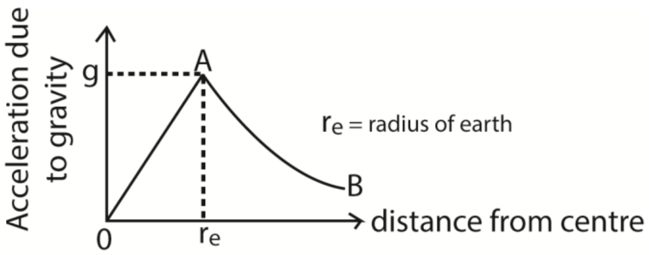
(ii) the period of motion (04marks)

$T\cos 60 = 0.2\omega^2 r$; $\omega = \frac{2\pi}{T}$; r = 1.2cos 60 = 0.6m

2.27cos 60 = 0.2 x $\frac{4\pi^2}{T^2}$ x 0.6

Period, T = 2.04s

(d) Explain and sketch the variation of acceleration due to gravity with distance from the centre of the earth (06marks)



- Inside the earth, assuming uniform density, the acceleration due to gravity varies linearly with distance from the centre.
- For points outside the earth, the acceleration due to gravity varies inversely as the square distance from the centre. i.e. g ∝ $\frac{1}{r^2}$ where r is the distance from the surface of the earth. Therefore outside the earth gravity decreases with height.

3. (a) (i) What is meant by simple harmonic motion? (01mark)

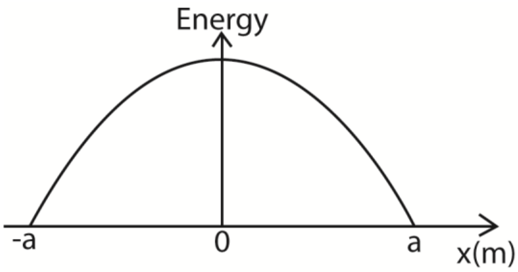
Simple harmonic motion is a periodic motion whose acceleration is directed towards a fixed point and is proportional to the displacement from the fixed point.

(ii) Show with the aid of a suitable sketch graph how kinetic energy of a mass attached at the end of an oscillating light spring changes with distance from equilibrium position. (04marks)

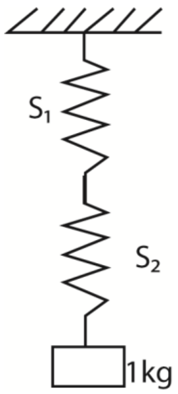
Kinetic energy = $\frac{1}{2}mv^2$; but v = $\pm\omega\sqrt{a^2 - x^2}$

=> K.E = $\frac{1}{2}m\omega^2(a^2 - x^2)$

This yield the following graph



(b)



A mass of 1.0kg is hang from two springs S_1 and S_2 connected in series as shown above.

The force constant of the springs are $100Nm^{-1}$ and $200Nm^{-1}$ respectively. Find

(i) The extension produced in combination. (04marks)
At equilibrium the tension in each spring = T = mg

⇨ $k_1e_1 = mg$

$100 \times e_1 = 1 \times 9.81$

$e_1 = 9.81 \times 10^{-2}m$

Also;

$k_2e_2 = mg$

$200 \times e_2 = 1 \times 9.81$

$e_2 = 4.905 \times 10^{-2}m$

Total extension= e1 + e2 = $(9.81 + 4.905) \times 10^{-2}m = 0.14715$ m

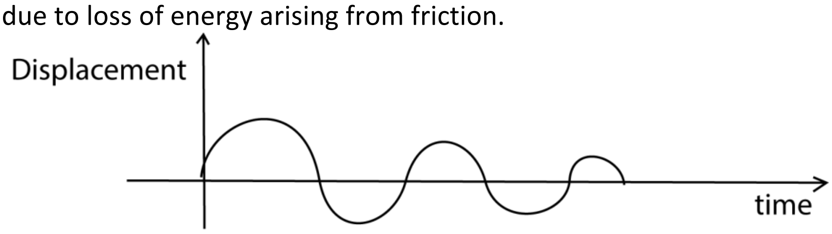
(ii) The frequency of oscillation of the mass if it is pulled downwards through a small distance and released. (06marks)

$T = 2\pi\sqrt{\frac{e}{g}} = 2\pi\sqrt{\frac{0.14715}{9.81}} = 0.77s$

$f = \frac{1}{T} = \frac{1}{0.77} = 1.3Hz$

(c) Explain with the aid of a sketch graph, what would happen to the oscillations in (b)(ii) above if the mass was immersed in a liquid such as water. (04marks)

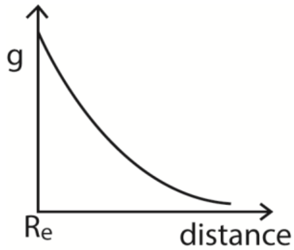
If the mass is immersed in water, the amplitude decreases until the oscillations die away due to loss of energy arising from friction.



4. (a) (i) Define gravitational field strength. (01mark)

The gravitational field strength at any point in gravitational field is the gravitational force experienced by a unit mass placed at that point provided that the unit mass itself does not cause any change in the field

(ii) Draw a sketch graph to show how the gravitational field strength varies with height, h, above the earth's surface. (02marks)



(b) The period of simple pendulum is measured at different locations along a given longitude. Explain what is observed. (06marks)

From the equator towards the pole along a longitude the radius of the earth, R_e, decreases.

Since mg = $\frac{GMm}{R_e^2}$ => g $\propto$ $\frac{1}{R_e^2}$

Therefore, g increases towards the pole.

From period, T = $2\pi\sqrt{\frac{l}{g}}$ => T$\propto$ $\frac{1}{\sqrt{g}}$

Therefore, Period T decrease from the equator towards the pole

(c) Derive the expression for the escape velocity of a rocket fired from earth. (03marks)

The work done in moving a body of mass, m, from the surface of the earth to infinity is given by

W = $-\frac{GMm}{\infty} - \frac{-GMm}{R}$ but$\frac{GMm}{\infty} = 0$

=$\frac{GMm}{R}$

=>$\frac{1}{2}mv^2 \geq \frac{GMm}{R}$

$v = \sqrt{\frac{2GM}{R}}$ where r is the radius of the earth

(d) The rings of the planet Saturn consist of a vast number of small particles, each in a circular orbit about the planet. Calculate the speed of the particles nearest to Saturn if its mass is 6.0 x 10^{26}kg (04marks)

Centripetal force = Gravitational force of attraction between the planet and the particle.

=> $\frac{GMm}{r^2} = \frac{mv^2}{r}$

v = $\sqrt{\frac{GM}{r}}$ = $\sqrt{\frac{6.67\ x\ 10^{-11}\ x\ 6.0\ x\ 10^{26}}{r}} = \frac{2.0\ x\ 10^{8}}{\sqrt{r}}$

(e) The moon moves in a circular orbit of radius 3.84 x 10^8m around the earth with a period of 2.36 x 10^5s.Calculate the gravitational field of the earth at the moon. (04marks)

If r_e and r_0 are the radii of the earth and the moon's orbit around the earth respectively, and g' is the gravitational field strength of the earth at the moon;

From g $\propto$ $\frac{1}{r^2}$

g $\propto$ $\frac{1}{r_e^2}$ also g' $\propto$ $\frac{1}{r_0^2}$

⇨ $\frac{g'}{g} \propto \frac{r_0^2}{r_e^2}$

$g' = \frac{(6.4\ x\ 10^6)^2}{(3.84\ x\ 10^8)^2}\ x$ 9.81 = 2.73 x 10^{-3}ms^{-2}

SECTION B

5. (a) What is meant by:

(i) Thermometric property (01mark)

Thermometric property is a physical property that vary uniformly and continuously with temperature.

(ii) Triple point (01mark)

It the temperature and pressure at which a vapour, liquid and solid of a substance coexist at equilibrium.

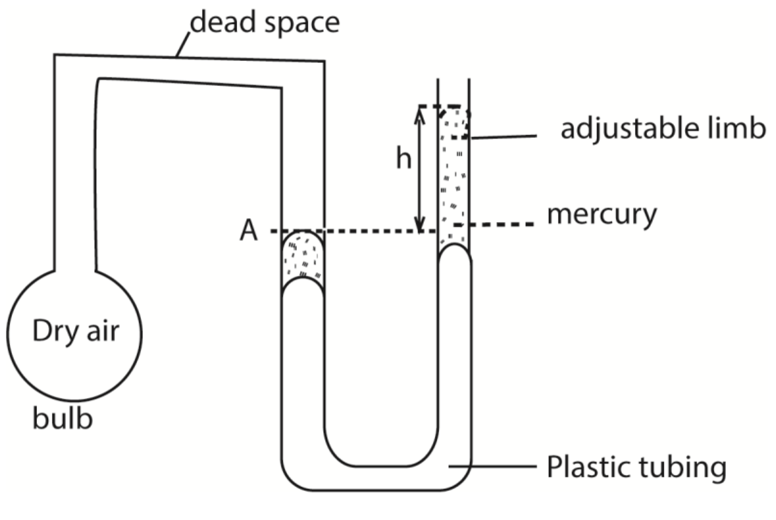
(b) (i) Describe the steps taken to establish a temperature scale. (05marks)

- Choose a thermometric property
- Find its value, x_{100} at steam point and value x_0 at ice point.
- If the value of thermometric property is x_θ at temperature θ
- Then θ = $\frac{x_\theta - x_0}{x_{100} - x_0}$

(ii) Explain why two thermometers may give different values for the same unknown temperature. (02marks)

Two thermometers based on different thermometric property may show different temperatures because thermometric properties vary differently with change in temperature.

(c) (i) Describe, with the aid of a diagram, how a constant-volume gas thermometer may be used to measure temperature. (06mrks)



- Place the bulb inside whose temperature is to be measured.
- Allow some time for the gas to acquire the temperature of the enclosure. The gas in the bulb may expand and forces mercury up the adjustable tube.
- Adjust the adjustable limb to bring back mercury to constant volume at A and record the height of mercury, h_θ.
- The Celsius scale is given by θ = $\left(\frac{h_\theta - h_0}{h_{100} - h_0}\right) x\ 100^0 C$ where h_{100} and h_0 are the heights at steam and ice points

(ii) State three corrections that need to be made when using the thermometer in (c)(i) above. (03marks)

- The bulb should be made of glass with low thermal expansivity
- Dead space should be narrowed
- The bulb should be thin to allow easy penetration of heat

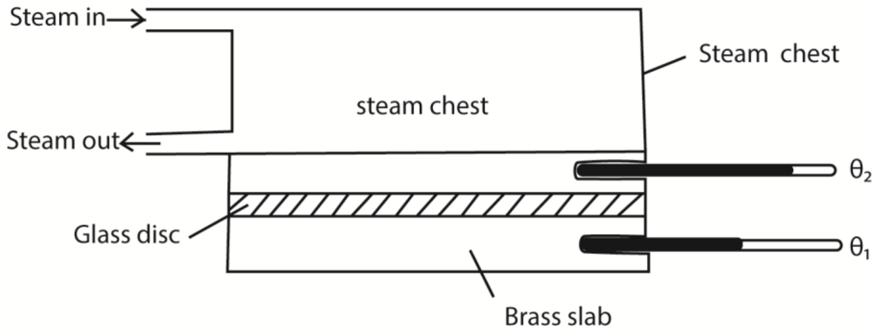
(iii) State and explain the sources of inaccuracies in using mercury in glass thermometer, (02marks)

- Non uniformity the mercury tube
- Temperature of air in dead space being different from that in the bulb

6. (a) Define thermal conductivity of a material and state its units (02marks)

Thermal conductivity is the rate of heat flow per unit cross section area per unit temperature gradient. Units $Wm^{-1}K^{-1}$

(b) Describe with the aid of a diagram how the thermal conductivity of a poor conductor can be determined. (07marks)



- 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

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

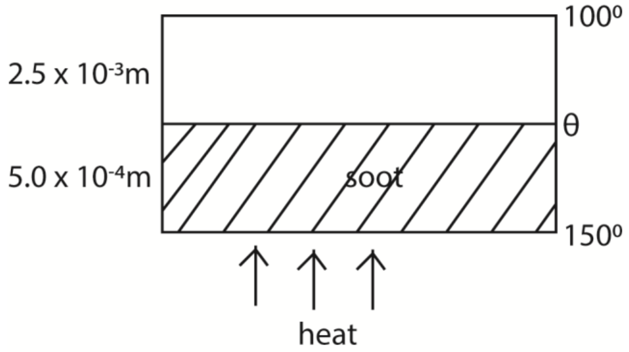
$$\therefore\ kA\left(\frac{\theta_2 - \theta_1}{x}\right) = mcs$$

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

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

(c) A cooking saucepan made of iron has a base area of $0.05m^2$ and thickness of 2.5mm. It has a thin layer of soot of average thickness 0.5mm on its bottom surface. Water in the saucepan is heated until it boils at 100^0C. The water boils away at a rate of 0.60kg per minute and the side of the soot nearest to the heat source is at 150^0C. Find the thermal conductivity of soot.

[Thermal conductivity of iron = 66$Wm^{-1}K^{-1}$and specific latent heat of vaporization =2200kJ/kg)



At steady state

$\frac{dQ}{dt} = \frac{k_1 A(150-\theta)}{l_1} = \frac{k_2 A(\theta-100)}{l_2} = \frac{0.6}{60} x\ 2.2\ x\ 10^6$

⇨ $k_1(150-\theta) = k_2(\theta-100)x\frac{l_1}{l_2}$ = $k_1(150-\theta) = 66(\theta-100)x0.2$ ……(i)

Also,

$k_2 A(\theta-100) = 2.2\ x\ 10^4\ x\ l_2$

$66\ x\ 0.05\ (\theta-100) = 2.2\ x\ 10^4\ \ x\ 2.5\ x\ 10^{-3}$

θ = 116.67^0C

Substituting θ in equation (ii)

$k_1(150-116.67) = 66(116.67-100)x\ 0.2$

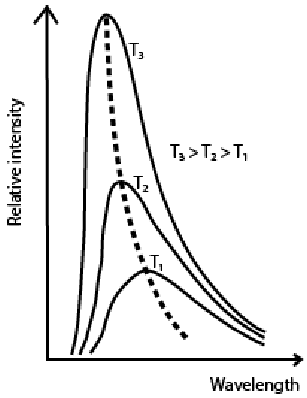
k_1 = 6.6 $Wm^{-1}K^{-1}$

Hence thermal conductivity of shoot = 6.6 $Wm^{-1}K^{-1}$

(d) (i) What is a black body? (01mark)

A black body is one that absorbs all the radiations falling on it, transmits and reflects none.

(ii) Sketch the spherical distribution of black body radiation for three different temperatures and describe their main features. (04marks)



As temperature increases, the intensity increases. The intensity of shorter wavelengths increase more rapidly. The wavelength of the most intense radiation decreases as temperature increases.

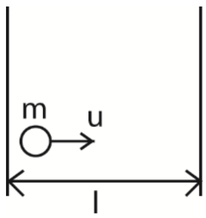
7. (a) Derive the expression P = $\frac{1}{3}\rho \overline{c^2}$ for the pressure, P, of an ideal gas of density ρ and mean square speed, $\overline{c^2}$. State any assumptions made (07marks)

Assumptions

- 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

Derivation

Consider a molecule of mass, m, moving in a cube of length, l and velocity, u.



Change in momentum = mu - $^{-}$mu = 2mu

Rate of change of momentum = $\frac{2mu}{t}$

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

$F_1 = 2mu \div \frac{2l}{u} = \frac{mu^2}{l}$

For N molecules, force on the wall,

F = $\frac{mu_1^2}{l} + \frac{mu_2^2}{l} + \frac{mu_3^2}{l} + \cdots + \frac{mu_N^2}{l}$

Pressure, P = $\frac{F}{A} = \frac{m}{l^3}(u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2)$ since A = l^2

$\overline{u^2} = \frac{u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2}{N}$

$N\overline{u^2} = u_1^2 + u_2^2 + u_3^2 + \cdots + u_N^2$

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

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

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

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

(b) A gas is confined in a container of volume $0.1m^3$ at a pressure of $1.0 \times 10^5 Nm^{-2}$ and temperature of 300K. If the gas is assumed to be ideal, calculate the density of the gas.
(The relative molecular mass of the gas is 32) (05marks)

PV = nRT

n = $\frac{1.0\ x\ 10^5\ x\ 0.1}{8.31\ x\ 300}$ = 4

mass of gas, m =nM =4 x 32 x 10^{-3} =0.128kg

Density = $\frac{m}{V} = \frac{0.128}{0.1}$ = 1.28kgm^{-3}

(c) What is meant by

(i) isothermal change

Isothermal expansion takes place at constant temperature.

(ii) adiabatic change (02marks)

Adiabatic expansion takes place at constant heat.

(d) A gas at a pressure of 1.0×10^6Pa is compressed adiabatically to half its volume and then allowed to expand isothermally to its original volume. Calculate the final pressure of the gas.

[Assume the ratio of the principal specific heat capacities $^{C_p}/_{C_v}, \gamma = 1.4$] (06marks)

For adiabatic change

PV^γ = constant

⇨ $1.0 \times 10^6 \times V^{1.4} = P \times \left(\frac{V}{2}\right)^{1.4}$

P =2.64×10^6Pa

For isothermal change

PV = constant

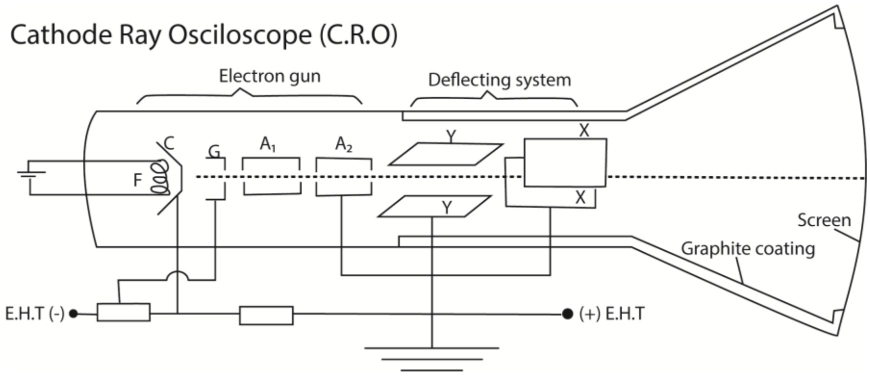
$2.64 \times 10^6 \times \frac{V}{2}$ = PV

P = 1.32×10^6Pa

SECTION C

8. (a) (i) Describe with the aid of a labelled diagram the main features of a cathode ray oscilloscope (C.R.O) (08marks)

Cathode Ray Osciloscope (C.R.O)



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.

(ii) State two uses of C.R.O (01mark)

- Display waveforms
- Measuring both a.c and d.c voltage
- Measuring phase differences

(iii) The gain control of a C.R.O is set on $0.5Vcm^{-1}$ and an alternating voltage produces a vertical trace of 2.0cm long with the time base off. Find the root mean value of the applied voltage. (02marks)

Peak to peak voltage, V = 2 x 0.5V= 1V

Peak voltage $V_0 = \frac{V}{2} = \frac{1}{2} = 0.5V$

$$V_{r.m.s} = \frac{V_0}{\sqrt{2}} = \frac{0.5}{\sqrt{2}} = 0.354V$$

(b) A beam of electrons is accelerated through a potential difference of 2000V and is directed mid-way between two horizontal plates of length 5.0cm and separation of 2.0cm. The potential difference across the plates is 80V.

(i) Calculate the speed of the electron as they enter the region between the plates. (03marks)

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

$$u = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2000}{9.11 \times 10^{-31}}} = 2.65 \times 10^7 ms^{-1}$$

(ii) Explain the motion of the electrons between the plates. (02marks)

It is parabolic

(iii) find the speed of electrons as they emerge from the region between the plates. (04marks)

$v_x = 2.65 \times 10^7 ms^{-1}$

$v_y = at$

$a = \frac{Ee}{m} = \frac{Ve}{dm}$

$t = \frac{L}{u} = \frac{5 \times 10^{-2}}{2.65 \times 10^{7}} = 1.89 \times 10^{-9}s$

⇨ $v_y = \frac{Ve}{dm} \times 1.89 \times 10^{-9}$

$= \frac{80 \times 1.6 \times 10^{-19}}{2 \times 10^{-2} \times 9.11 \times 10^{-31}} \times 1.89 \times 10^{-9}$

$= 1.33 \times 10^{6} ms^{-1}$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(2.65 \times 10^7)^2 + (1.33 \times 10^6)^2} = 2.65 \times 10^{7} ms^{-1}$

9. (a) Explain the term stopping potential as applied to photo electric effect. (02marks)
It is the minimum potential difference between the anode and the cathode that reduces the photocurrent to zero.

(b) Explain how intensity and penetrating power of X-rays from X-ray tube would be affected by changing:

(i) the filament current (02marks)
When the filament current is increased, the intensity of the X-rays increases since the number of electrons hitting the target increases but the penetrating power remains constant since the kinetic energy of the electrons is not changed.

(ii) the high tension potential difference across the tube (02marks)
Penetrating power increases with potential difference.

(c) When a p.d of 60kV is applied across an X-ray tube, a current of 30mA flows. The anode is cooled by water flowing at a rate of $0.060 kgs^{-1}$. If 99% of the power supplied is converted into heat at the anode, calculate the rate at which the temperature of the water rises. {Specific heat capacity of water = $4.2 \times 10^{3} Jkg^{-1}K^{-1}$] (05marks)

Electrical energy supplied per second = $IV = 30 \times 10^{-3} \times 60 \times 10^{3} = 1.8 \times 10^{3}W$

Since 99% of this energy is converted to heat

=> the rate of heat production = $0.99 \times 1800 = 1.782 \times 10^{3}W$

Rate of heat gain by water = $\frac{dm}{dt} \times c \times \Delta\theta$ where Δθ is temperature change

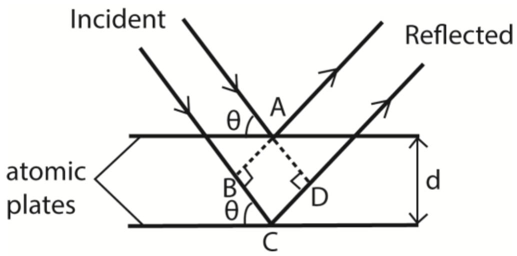
All the heat produced is removed by water.

Then $\frac{dm}{dt} \times c \times \Delta\theta = 1.782 \times 10^{3}W$

$\Delta\theta = \frac{1.782 \times 10^{3}}{0.060 \times 4.2 \times 10^{3}} = 7.07^{0}$

(d) (i) Derive Bragg's law of X-ray diffraction. (05marks)

- 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) Calculate the atomic spacing of sodium chloride if the relative atomic mass of sodium is 23.0 and that of chlorine is 35.5.

[Density of sodium chloride = 2.18 x 10^3kgm^{-3}] (04marks)

From volume = $\frac{mass}{\rho}$

Volume of 1 mole = $\frac{(23+35.5)x\ 10^{-3}}{2.18\ x\ 10^3}\ m^3$

1 mole of NaCl contains 6.02 x 10^{23} molecules

Volume of 1 molecule =$\frac{(23+35.5)x\ 10^{-3}}{2.18\ x\ 10^3\ x\ 6.02\ x\ 10^{23}}$

Volume of 1 atom = $\frac{(23+35.5)x\ 10^{-3}}{2.18\ x\ 10^3\ x\ 6.02\ x\ 10^{23}}\ x\ \frac{1}{2}$ = 2.23 x 10^{-29}m^3

It the interatomic spacing is d,

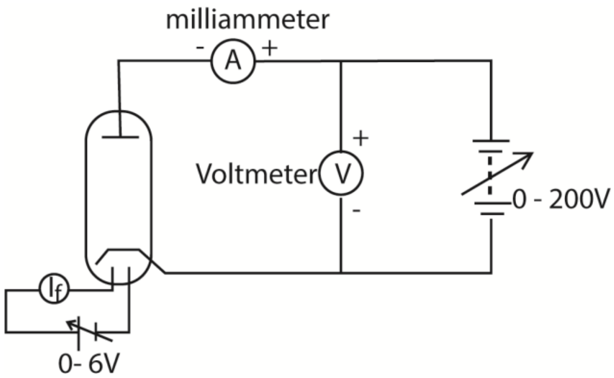
d^3 = 2.23 x 10^{-29}m^3

d = 2.81 x 10^{-10}m

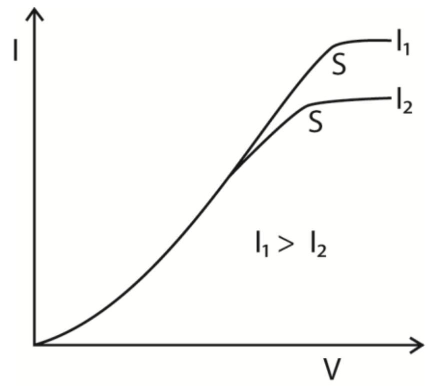
10. (a) (i) Explain briefly the mechanism of thermionic emission. (02marks)

When a metal is heat electron surface electrons acquire enough kinetic energy to overcome the nuclear attraction and escape from the surface. The escape of electrons from hot metal surface is termed thermionic emission.

(ii) Draw a labelled diagram of the circuit used to determine the anode current and anode voltage characteristics of a thermionic diode. (02marks)

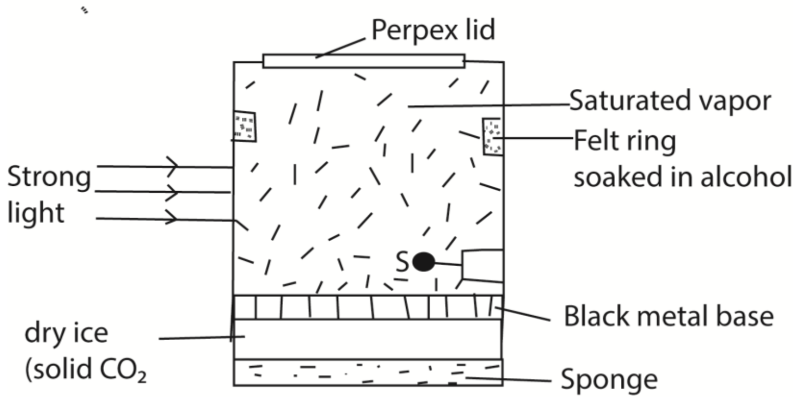


(iv) Sketch the characteristic expected in (a) (ii) at constant filament current, and account for its special features. (04marks)



The current increases with the positive anode potential as far as the point S. Beyond this point the current does not increase, because the anode is collecting all the electrons emitted by the filament ; the current is said to be saturated.

(b) Describe, with the aid of a labelled diagram, the structure and action of a diffusion cloud chamber (06marks)



- The base of the chamber is maintained at low temperature, about -80^{0}c by the solid carbon dioxide while the top of the chamber is at room temperature, and so there is a temperature gradient between the top and the bottom of the chamber.
- The air at the top of the chamber is saturated with alcohol vapor from the felt ring. This vapor continuously diffuse downwards into the cooler regions so that the air at the chamber is super saturated with alcohol vapor.
- Radiations from the radioactive source S cause the ionization of the vapor.
- The ionizations from the radioactive source S cause condensation of the vapor on the ions formed, hence the path of the ionizing radiations are traced by series of small droplets of condensation.
- The thickness and length of the path indicate the extent to which ionization has taken place.
- Alpha particles produce short, thick, continuous straight tracks
- Beta particles which are less massive produce longer, thin but straggly paths owing to collisions with gas molecules
- Gamma radiations are uncharged and for ionization to take place, it must collide with an atom and eject an electron which then ionizes the vapor.

(c) (i) Define radioactivity and half-life of a radioactive substance (02marks)

Radioactivity is the spontaneous disintegration of unstable nucleus acquire a more stable state by emission of α, β or γ –rays.

Half-life of a radioactive substance is the time taken for half the number of radioactive nuclei to disintegrate.

(ii) A radioactive isotope of strontium of mass 5.0μg has a half-life of 28years. Find the mass of the isotope left after 14 years.

[Assume the decay law $N = N_0e^{-\lambda t}$]

$\lambda = \frac{In2}{t_{\frac{1}{2}}}$

$N = 5 x 10^{-6} e^{-\frac{In 2}{28} x 14}$ = 3.54×10^{-6}g = 3.54μg

Compiled by Dr. Bbosa Science