UACE Physics paper 1 2008 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

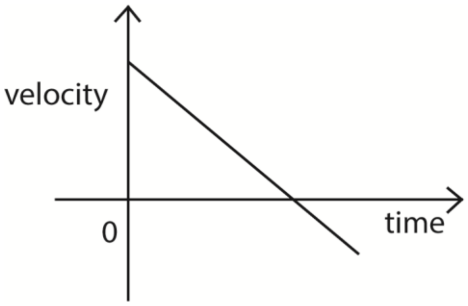
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 \times 10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Mass of the earth	$5.97 \times 10^{24}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Stefan's-Boltzmann's constant, σ	$5.67 \times 10^{-8}Wm^{-2}K^{-1}$
Radius of the earth	6.4 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

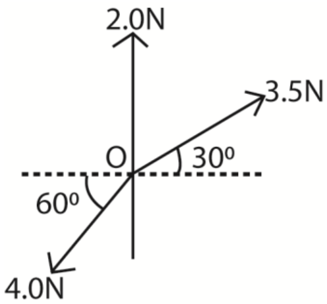
1. (a) (i) Define the term velocity and displacement. (02marks)

Velocity is the rate of change of displacement
Displacement is the distance moved in specified direction

(ii) Sketch velocity against time for an object thrown vertically upwards. (02marks)



(b)



Three forces of 3.5N, 4.0N and 2.0N, act at O as shown in the figure above. Find the resultant force. (04marks)

Suppose the components of the resultant force of the x and y direction are X and Y respectively;

$F_x = 3.5\cos 30^0 - 4\cos 60^0 = 1.031N$

$F_y = 2.0 + 3{,}5\sin30^0 - 4.0\sin60^0 = 0.286N$

$F = \sqrt{F_x^2 + F_y^2} = \sqrt{1.031^2 + 0.286^2} = 1.07N$

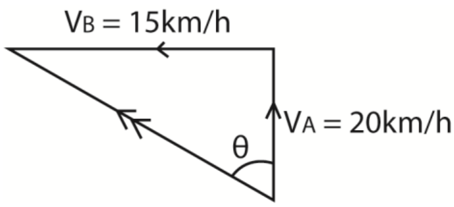
$\theta = \tan^{-1}\left(\frac{0.286}{1.031}\right) = 15.5^0$

the resultant force is 1.07N making 15.5^0 with the horizontal.

(c) (i) What is meant by saying that a body is moving with velocity relative to another? (01marks)

If a body is moving with a velocity, v, relative to another means that it has velocity, v, as seen by an observer from another body.

(ii) A ship, A is travelling due north at $20kmh^{-1}$ and ship B is travelling due east at $15kmh^{-1}$. Find the velocity of A relative to B. (03marks)

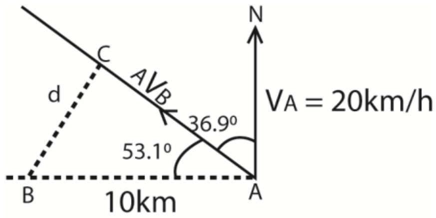


$_AV_B = \sqrt{20^2 + 15^2}$ = 25mkm/h

θ = $tan^{-1}\left(\frac{15}{20}\right)$ = 36.9^0

the relative velocity of A relative to B = 25km/h in the direction N36.9^0W

(iii) If the ship B in (c)(ii) is 10km due west of A at noon. Fins the shortest distance apart and when it occurs. (05marks)



d is the shortest distance of approach

d = 10sin53.1^0 = 8km

Time taken = $\frac{distance\ along\ the\ relative\ path}{relative\ velocity} = \frac{10\cos 53.1^0}{25}$ = 0.24hours.

(d) (i) What is meant by a couple in mechanics? (01mark)

A couple is a pair of equal parallel and opposite forces whose line of action do not coincide.

(ii) State the conditions for equilibrium of a system of coplanar forces

The vector sun of all forces must be zero i.e. in translational equilibrium

Or

The algebraic sum of all the moments of the forces about any point is zero, i.e. there is not rotation equilibrium.

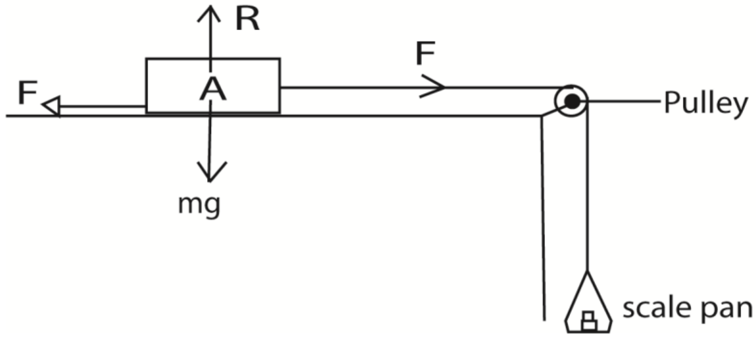
2. (a) (i) State the laws of friction between solid surfaces (03marks)

- The frictional force between two surfaces opposes their relative motion.
- The frictional force is independent of the area of contact of the given surfaces when the normal reaction is constant,
- 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.

(ii) Explain the origin of friction force between two solid surfaces in contact. (03marks)

- For any two solid surfaces in contact, there are small humps and hollows that form contact points.
- Therefore, the actual area of contact is indeed small which creates very high pressure at the points of contact.
- This pushes the molecules very close that the forces of attraction between them welds the surfaces at these points.
- Thus, a force that opposes motion in any direction is created.

(iii) Describe an experiment to measure the coefficient of kinetic friction between two solid surfaces. (03marks)



- A block of mass m is placed on a flat table and connected to a scale pan as shown in the diagram above.
- Weights are added to the scale-pan, and each time A is given a slight push.
- At one stage A continues to move with a constant velocity.
- The coefficient of kinetic friction, μ = $\frac{W_f}{mg}$; where W_f = weight of the scale pan plus added weights.

(b) (i) A car of mass 1000kg moves along a straight surface with speed 0f 20ms^{-1}. When brakes are applied steadily, the car comes to rest after travelling 50m. Calculate the coefficient of friction between the surface and the tyre. (04marks)

Initial kinetic energy of the car = work done against friction

$\frac{1}{2}mu^2 = F\ x\ s$

$\frac{1}{2}\ x\ 1000\ x\ 20^2 = F\ x\ 50$

F = 4000N

But F = μR = μmg

⇨ 4000 = μ x 1000 x 9.81
μ = 0.408

(ii) State the energy changes which occur from the time brakes are applied to the time the car comes to rest. (02marks)

Kinetic energy → heat and sound

(c) (i) State two disadvantages of friction (01mark)

- Wears machines
- Wears shoes
- Causes unnecessary noise in moving parts of a machines.

- Produces unnecessary heat

(ii) Give one method of reducing friction between solid surfaces. (01mark)

- By lubrication
- Using ball bearings or rollers
- Making surfaces smooth

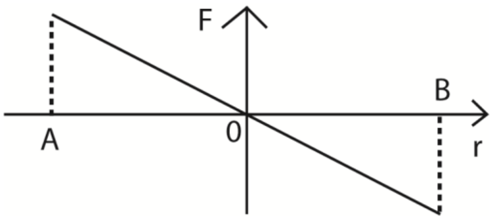
(d) Explain what happens when a small steel ball is dropped centrally in a tall jar containing oil. (03marks)

- It experiences a drag force, F and an up thrust, U, upwards and weight, W, downwards.
- Initially, W> F + U, so the ball accelerates downwards.
- As velocity increases, F increases until a time when W = F + U, and consequently ball moves with a constant terminal velocity.

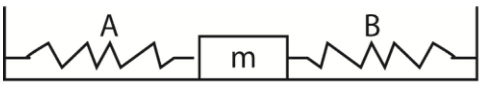
3. (a) (i) Define simple harmonic motion. (01mark)

It is periodic motion in which the acceleration of the body along the path of the body is directed towards a fixed point in the line of motion and is proportional to the displacement of the body from a fixed point

(ii) A particle of mass m executes simple harmonic motion between two points A and B about equilibrium position O. sketch a graph of the restoring force acting on the particle as a function of distance, r, moved by the particle. (02marks)



(b)



Two springs A and B of spring constant K_A and K_B respectively are connected to mass m as shown in the figure above. The surface on which the mass slides is frictionless.

(i) Show that when the mass is displaced slightly, it oscillates with simple harmonic motion of frequency, f given by $f = \frac{1}{2\pi}\sqrt{\frac{K_A + K_B}{m}}$ (04marks)

If the body is displaced through a small displacement, x towards B;

⇨ Resultant fore F = $(K_A + K_B)x$

From F = ma

ma = $-(K_A + K_B)x$

a = $-\left(\frac{K_A + K_B}{m}\right)x$

This is of the form a = $-\omega^2 x$ where $\omega = \sqrt{\left(\frac{K_A + K_B}{m}\right)}$, hence simple harmonic motion.

(ii) If the two springs in the figure above are identical such that $K_A = K_B = 5.0Nm^{-1}$ and mass m =50g, calculate the period of oscillation (03marks)

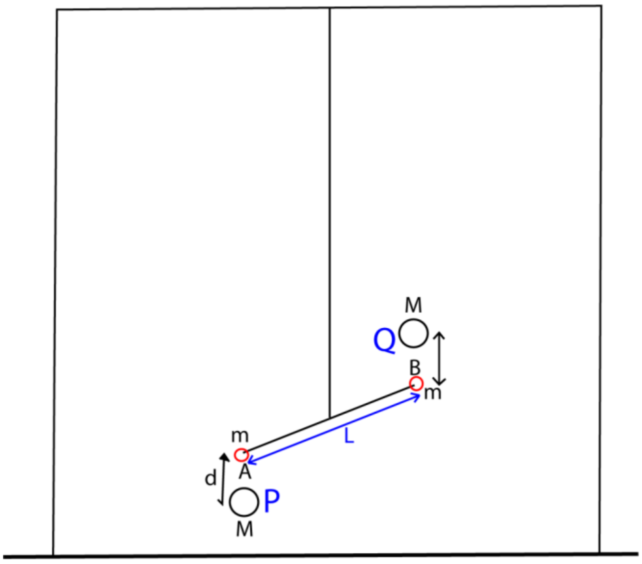
$$\omega = 2\pi f = \sqrt{\left(\frac{K_A + K_B}{m}\right)}$$

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{K_A + K_B}{m}\right)}$$

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{K_A + K_B}} = 2\pi\sqrt{\frac{50 \ x\ 10^{-3}}{5.0 + 5.0}} = 0.44s$$

(c) (i) With the aid of a diagram, describe an experiment to determine the universal gravitational constant, G. (06marks)

Determining gravitational constant



- Two equal lead spheres A and B each of mass, m, are attached to end of a bar AB of length, L.
- The bar AB is suspended from a ceiling.
- Large spheres P and Q are brought towards A and B respectively from the opposite side
- Large spheres P and Q altered small spheres A and B respectively by equal and opposite gravitational forces give rise to gravitational torque, F, which in turn twist the suspended through angle θ.
- A resting torque of the wire opposes the twisting of the wire from equilibrium position

Then

$F = C\theta = \frac{GMm}{d^2}$

$G = \frac{C\theta d^2}{MmL}$

Where

d = distance between the centre of A and P or B and Q.

C = the twisting couple per unit twist (θ = 1)

(ii) If the moon moves round the earth in a circular orbit of radius = 4.0×10^8m and takes exactly 27.3 days to go round once, calculate the value of acceleration due to gravity, g, at the earth's surface. (04marks)

$\frac{GmM}{R^2} = m\omega^2 R$; But GM = gr_s^2

⇨ $\frac{gr_s^2}{R^2} = \omega^2 R$

g = $\frac{\omega^2 R^3}{r_s^2}$

ω = $\frac{2\pi}{T}$

g = $\frac{4\pi^2 R^3}{T^2 r_s^2}$ = $\frac{4\pi^2(4.0 \times 10^8)^3}{(27.3 \times 24 \times 60 \times 60)^2(6.4 \times 10^6)^2}$ = $11.09ms^{-2}$

4. (a) State

(i) Newton's laws of motion (03marks)

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

(ii) The principle of conservation of momentum (01mark)

When a body is in mechanical equilibrium, the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point

(b) A bod A of mass m_1 moves with velocity u_1 and collides head on elastically with another body B of mass m_2 which is at rest. If the velocities of A and B are v_1 and v_2 respectively and given that X = $\frac{m_1}{m_2}$, show that

(i) $\frac{u_1}{v_1} = \frac{X+1}{X-1}$ (04marks)

From principle of conservation of momentum

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ but $u_2 = 0$

⇨ $m_1u_1 = m_1v_1 + m_2v_2$

$v_2 = \frac{m_1u_1 - m_1v_1}{m_2}$ =Xu1 – Xv_1 = X(u_1 – v_1) .... (i)

For an elastic collision, total kinetic energy is conserved.

Hence: $\frac{1}{2}m_1u_1^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$m_1u_1^2 = m_1v_1^2 + m_2u_2^2$......................... (ii)

Substituting Eqn. (i) in eqn (ii)

$m_1u_1^2 = m_1v_1^2 + m_2(X(u_1 - v_1))^2$

Divide both sides by m2

$Xu_1^2 = Xv_1^2 + (X(u_1 - v_1))^2$

⇨ $X(u_1^2 - v_1^2) = X^2(u_1 - v_1)^2$

$(u_1 + v_1)(u_1 - v_1)$ = $X(u_1 - v_1)^2$

$(u_1 + v_1) = X(u_1 - v_1)$

Collecting like terms

$v_1(X+1) = u_1(X-1)$

$\frac{u_1}{v_1} = \frac{X+1}{X-1}$

(ii) $\frac{v_2}{v_1} = \frac{2X}{X-1}$(03marks)

From $\frac{u_1}{v_1} = \frac{X+1}{X-1}$

$u_1 = v_1\left(\frac{X+1}{X-1}\right)$

Substituting for u1 in Eqn. (b)(i)

$v_2 = X(v_1\left(\frac{X+1}{X-1}\right) - v_1)$

$\frac{v_2}{v_1} = X\left(\left(\frac{X+1}{X-1}\right) - 1\right) = X\left(\left(\frac{X+1-X+1}{X-1}\right)\right)$

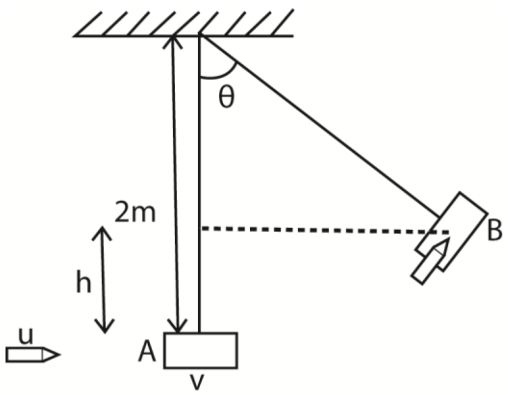
$= \frac{2X}{X-1}$

(c) Distinguish between conservative and non-conservative forces. (02marks)

For conservative forces, the work done by the force through a closed path is zero whereas for non-conservative forces, the work done through a closed path is not zero

(d) A bullet of mass 40g is fired from a gun at $200ms^{-1}$ and hit a block of wood of mass 2kg which is suspended by a light vertical string 2m long. If the bullet gets embedded in the wooden block.

(i) Calculate the maximum angle the string makes with the vertical. (06marks)



From principle of conservation of linear momentum

$m_1u = (m_1 + m_2)v$

$(40 \times 10^{-3}) \times 200 = [2 + (40 \times 10^{-3})]v$

$v = 3.92ms^{-1}$

If the block after collision moves to height h to B, from the principle of conservation of mechanical energy

K.E at A = Potential energy at B

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

$\therefore h = \frac{v^2}{2g} = \frac{3.92^2}{2 \, x \, 9.81}$ = 0.78m

$\cos\theta = \frac{2-h}{2}$ = 0.61

θ = 52.4^0

(ii) State a factor on which the angle of swing depends. (01mark)

- Speed of the bullet
- Length of the string
- Mass of the block

SECTION B

5. (a) Define the following terms

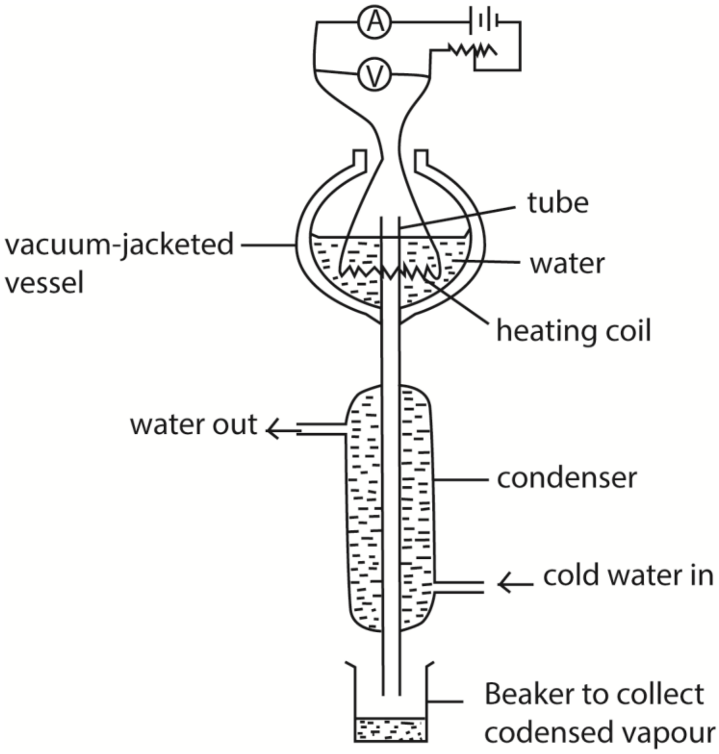
(i) Specific latent heat of vaporization (01mark)

Specific latent heat of vaporization is the amount of heat energy required to change 1kg mass of a liquid to vapour at constant temperature.

(ii) Coefficient of thermal conductivity

Thermal conductivity is heat flow per second per unit area per unit temperature gradient.

(b) With the aid of a labelled diagram, describe an experiment to measure the specific latent heat of vaporization of water by electrical method (07marks)



- Put the liquid whose specific latent heat of vaporization is required in a vacuum jacketed vessel as shown above.
- The liquid is heated to boiling point.
- The current, I, and voltage, V are recorded.
- The mass of condensed water, m, condensed in time, t, is determined.
- Then IV = $\frac{m}{t}L + h$, where h is the rate of heat loss to the surroundings
- To eliminate, h, the experiment is repeated for different values of I' and V' and the mass of the condensed water, m' condensed in tie t is determined.
- Again I'V' = $\frac{m\prime}{t}L + h$

  Latent heat of vaporization, L =$\frac{(I'V'-IV)t}{(m'-m)}$

(c) An appliance rated 240V, 200W evaporates 20g of water in 5 minutes. Find the heat loss if specific latent heat of vaporization is 2.26 x 10^6Jkg^{-1}. (03marks)

Electrical energy supplied = mlv + h

Power x time = mlv + h

200 x 5 x 60 = 20 x 10^{-3} x 2.26 x 10^6 + h

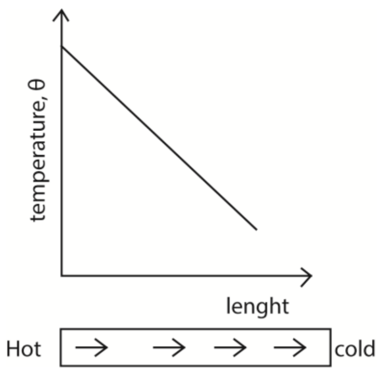
h = 14800J

(d) Explain why at a given external pressure a liquid boils at constant temperature. (04marks)

A liquid boils when its saturated vapour pressure equals the external pressure. Since saturated vapour pressure depends on temperature of a liquid, it implies that for a given external pressure, boiling occurs at constant temperature.

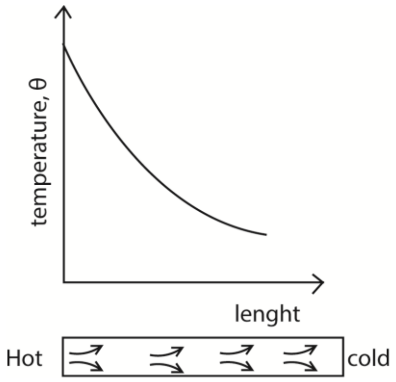
(e) With the aid of a suitable sketch graphs, explain the temperature distribution along lagged and unlagged metal rods, heated at one end. (04marks)

(i) lagged



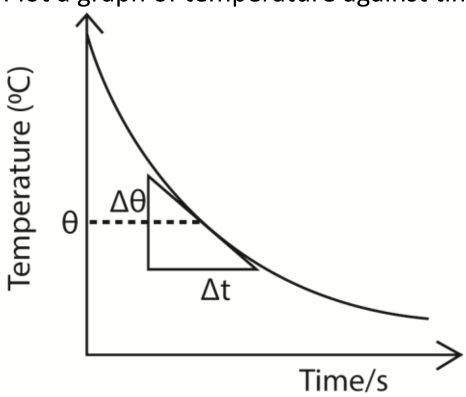
The rate of heat flow along the bar is constant since heat loss is negligible.

(ii) unlagged bar



The rate of heat flow decrease with length due to heat losses

6. (a) Describe an experiment to verify Newton's law of cooling. (05marks)
   - Hot water is placed in a calorimeter that is standing on an insulating surface and is put in a draught.
   - The temperature, θ, of the water is recorded at suitable intervals.
   - The room temperature θ_R is recorded.
   - Plot a graph of temperature against time to get a graph similar to the one below.



   -
   - Draw tangent at various temperatures, θ and obtain their slopes. These slopes give the rate of temperature fall.
   - Plot these slopes with corresponding excess temperatures $(\theta - \theta_R)$

- A straight line graph is obtained implying that the rate of heat loss is proportional to excess temperature.

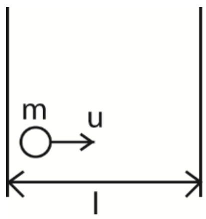
(b) (i) Distinguish between a real and an ideal gas. (03marks)

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.

(ii) Derive the expression

$P = \frac{1}{3}\rho^{\overline{2}}$ for the pressure of an ideal gas of density, ρ, and mean square speed $c^{\overline{2}}$

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

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

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

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

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

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

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

(c) (i) Explain why the pressure of a fixed mass of a gas in a closed container increases when the temperature of the container is raised. (02marks)

When the temperature of the container increases, the average velocity of the molecules increases. So the number and force of collisions with the walls of the container per second increases. Consequently the momentum change per second increases as they bombard the walls. This leads to increase in the impulsive force exerted on the walls causing increase in pressure.

(ii) Nitrogen gas is trapped in a container by a movable piston. If the temperature of the gas is raised from 0^0C to 50^0C at constant pressure of 4.0×10^5Pa and the total heat added is 3.0×10^4J, calculate the work done by the gas. [The molar heat capacity of nitrogen at constant pressure is $29.1Jmol^{-1}K^{-1}$, $C_p/C_v = 1.4$]

$\Delta Q = \Delta U + \Delta w$ ……………………(i)

$Cv = \frac{C_p}{1.4} = \frac{29.1}{1.4} = 20.79Jmol^{-1}$

$\Delta Q = nC_1\Delta T$

$n = \frac{\Delta Q}{C_1 \Delta T} = \frac{3 \times 10^4}{29.1 \times 50} = 20.62$

From equation (i)

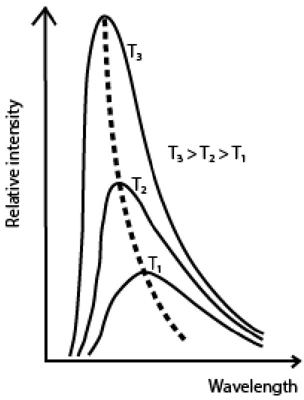
$3 \times 10^4 = 20.62 \times 20.79 (50-0) + \Delta w$

$\Delta w = 8.57 \times 10^3J$

7. (a) (i) State the laws of black body radiation (02marks)

- The wavelength λ_m at which maximum energy is radiated for temperature, T ia such that $\lambda_m T$ = constant. (Wien's displacement law)
- If $E_{\lambda m}$ is the height of the peak of the curve for a temperature T, then $E_{\lambda m} \propto T^6$
- The total energy radiated per square meter per second by a black body at temperature, T, is proportional to T^4 (Stefan's Boltzmann law)

(ii) Sketch the variation of intensity with wavelength in a black for different temperatures. (03marks)

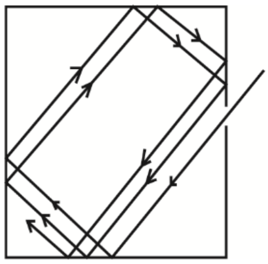


- For every wave length, relative intensity increases as temperature is increased.
- The wavelength at which maximum intensity occur shifts to the shorter wavelength as temperature is increased.
- λ_{max} is the wavelength of radiation emitted at maximum intensity/emission of a black body at a particular temperature.

(b) (i) What is a perfectly black body? (01marks)

A perfect black body is one that absorbs all the radiation incident on it, but reflects and transmits none.

(ii) How can a perfectly black body be approximated in reality? (04marks)



When radiation enters a black container through a hole, it undergoes multiple reflections. At each reflection, part of the radiation is absorbed. After several reflections, all the radiation is retained inside the container. Hence it approximates to a black body.

(c)(i) The energy intensity received by a spherical planet from a star is 1.4 x 10^3Wm^{-2}. The star is of radius 7.0 x 10^5km and is 14.0 x 10^7km from the planet.

(i) Calculate the surface temperature of the star. (04marks)

Incident energy per second (power) on a unit of planet = $\frac{4\pi r_s^2 \sigma T^4}{4\pi R^2}$

$= \left(\frac{r_s}{R}\right)^2 \sigma T^4$

Where r_s and R are the radii of the star and the distance of the star from the planet respectively.

$1.4 \times 10^3 = = \left(\frac{r_s}{R}\right)^2 \sigma T^4$

$T = \left[\frac{1.4 \times 10^3}{\sigma} x \left(\frac{R}{r_s}\right)^2\right]^{\frac{1}{4}} = \left[\frac{1.4 \times 10^3}{5.67 \times 10^{-8}} x \left(\frac{14 \times 10^{10}}{7 \times 10^8}\right)^2\right]^{\frac{1}{4}}$ = 5605.98K

(ii) State any assumptions you have made in (c)(i) above (01marks)

- The star is spherical
- The star radiates as a black body
- There is no heat loss to the sphere

(d) (i) What is convection? (01mark)

Convection is the transfer of heat in fluids by bulk movement of the fluid itself.

(ii) Explain the occurrence of land and sea breeze. (04marks)

During day, the land is heated to a high temperature than the sea. Hot air expands and rises from land. A stream of cool air from the sea blows towards the land to replace the uprising air, hence sea breeze occurs.
At night the land cools faster because it is no longer heated by the sun. The sea retains the warmth because it is heated deeply. Warm less dense air rises from the sea surface and air from land blows to replace it leading to land breeze.

SECTION C

8. (a) What is meant by a line spectrum? (02marks)
Line spectrum are discontinuous lines produced by electronic transitions within the atom as the electrons fall back to lower energy levels.

(b) Explain how line spectrum accounts for existence of discrete energy levels in an atom. (04marks)

Atoms of a particular element emit radiation with definite frequencies or wavelengths. When an atom is in excited state, an electron may fall into a vacant position in lower energy level. This is accompanied by emission of electromagnetic radiation with the characteristic E= hf;

Where E is the difference in the energy of involved energy level and h is Plank's constant. Since the frequencies are definite for a particular element, it implies that the energy levels are discrete.

(c) The energy levels in mercury atom are -10.4eV, -5.5eV, -3.7eV and -1.6eV.

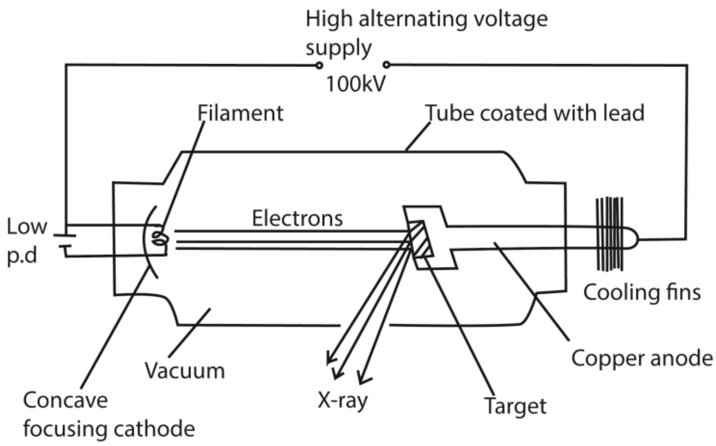
(i) Find the ionization energy of mercury in joules (02marks)

$10.4 \times 1.6 \times 10^{-19} = 1.664 \times 10^{-18}$J

(ii) What is likely to happen if mercury atom in unexcited state is bombarded with an electron of energy 4.0eV, 6.7eV or 11.0eV? (03marks)

- With 4.0eVand 11.0eV no observable change
- With 6.7eV electron transits from -3.7eV to -10.4eV energy level.

(d) Describe with the aid of a diagram, the action of an X-ray tube. (05marks)



Mode of operation

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

(e) An X-ray tube is operated at 20kVwith electron current 16mA in the tube. Estimate the:

(i) the number of electrons hitting the target per second. (02marks)

$n = \frac{I}{e} = \frac{16 \times 10^{-3}}{1.6 \times 10^{-19}} = 1.0 \times 10^{17}$ electrons per second

(ii) rate of production of heat, assuming 99.5% of the kinetic energy of electron is converted to heat. (e = 1.6 x 10^{-19}C)

For single electron, energy = eV

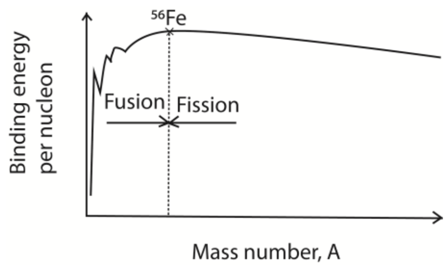
Energy per second = 1.0 x 10^{17}eV

$$= 1.0 \times 10^{17} \times 1.6 \times 10^{-19} \times 20 \times 10^{3} = 320W$$

The rate of heat production = $\frac{99.5}{100}\ x\ 320 = 318.4W$

9. (a) (i) Define the term binding energy (01marks)
Binding energy of the nucleus is the energy required to split the nucleus into its constituent nucleons.

(ii) Sketch a graph showing the variation of binding energy per nucleon with mass number (02marks)



(ii) Use the sketch in (d)(i) to explain how energy is released in each of the process of fusion and fission. (03marks)

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

(b) Explain why a high temperature is required during fusion of nuclides. (01mark)

High temperature provides enough kinetic energy to fusing particles to overcome electrostatic repulsive forces

(c) The isotope $^{238}_{92}U$ emits an alpha particle and forms an isotope of thorium (Th), while the isotope $^{235}_{92}U$ when bombarded by a neutron, forms $^{144}_{56}Ba$, $^{90}_{36}Kr$ and neutrons.

(i) Write the nuclear equation for the reaction of $^{238}_{92}U$ and $^{235}_{92}U$. (02marks)

$^{238}_{90}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th + Energy$

$^{235}_{90}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + 2{}^{1}_{0}n$ + energy

(ii) How does the reaction of $^{235}_{92}U$ differ from that of $^{238}_{92}U$ (03marks)

Uranium-235	Uranium-238
Non-radioactive	Radioactive since it emits alpha particles
It undergoes chain reaction (since it is initiated by a neutron and neutrons are part of the product.	It does not undergo chain reaction
It is artificial, so it is controllable	It is natural and cannot be controlled.

(d) A steel piston ring contains 15g of radioactive iron, ${}^{54}_{26}Fe$. The activity of ${}^{54}_{26}Fe$ is 3.7 x 10^5 disintegration per second.

After 100 days of continuous use, the crankcase oil was found to have a total activity of 1.23 x 10^3 disintegrations per second. Find the

(i) Half-life of ${}^{54}_{26}Fe$ (05marks)

Activity, A = λN, but λ = $\frac{In\ 2}{t_{\frac{1}{2}}}$

A = $\frac{In\ 2}{t_{\frac{1}{2}}}N$

$t_{\frac{1}{2}} = \frac{N}{A}In2$ .... (i)

54g of Fe has 6.02 x 10^{23} atoms

15g contain $\frac{15}{54}\ x\ 6.02\ x\ 10^{23}$ = 1.67 x 10^{23} atoms

Thus, N_0 = 1.67 x 10^{23} atoms

$t_{½}$ = $\frac{1.67\ x\ 10^{23}\ x\ In2}{3.7\ x\ 10^5}$ = 3.13 x 10^{17}s

(ii) Average mass of iron worn off the ring per day, assuming that all the metal from the ring accumulates in the oil. (03marks)

From A = $\frac{In\ 2}{t_{\frac{1}{2}}}N$

1.23 x 10^{23} = $\frac{In\ 2}{3.13\ x\ 10^{17}}N$

N = 5.55 x 10^{20}atoms

6.02 x 10^{23} atoms ≡ 54g

5.55 x 10^{20} atoms ≡ $\frac{5.55\ x\ 10^{20}}{6.02\ x\ 10^{23}}\ x\ 54$ = 4.9 x 10^{-2}g

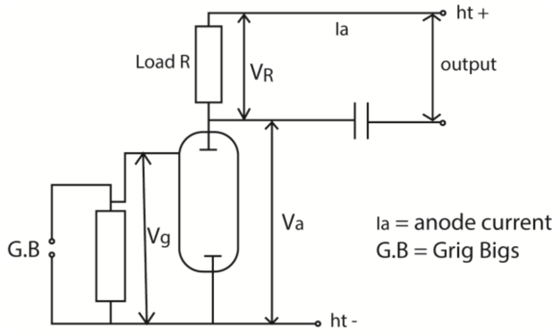
Mass worn off in 100days = 4.9 x 10-2g

For 1day, mass worn off = $\frac{4.9\ x\ 10^{-2}}{100}$ = 4.9 x 10^{-4}g

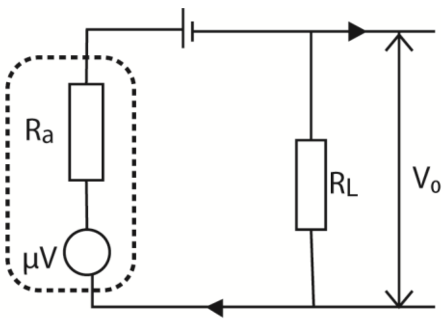
10. (a) Describe briefly the mechanism of thermionic emission (03marks)

High temperature raises the kinetic energy of free electrons in metallic lattice and make electrons to escape from the surface of the metal against the attraction of positive ions

(b) (i) Draw a labelled circuit to show a triode being used as a single-stage voltage amplifier. (03maks)



(ii) With the aid of an equivalent circuit of a triode as an amplifier, obtain an expression for voltage gain (04marks)



If V_i is input voltage, μ amplification factor,

⇨ e.m.f = μV_i

Output voltage = $I_a R_L$

Ia = $\frac{\mu V_i}{R_a + R_L}$

Thus V_0 = $\frac{\mu V_i R_L}{R_a + R_L}$

Voltage gain = $\frac{V_0}{V_i} = \frac{\mu V_i}{R_a + R_L}$

(iii) A triode with mutual conductance of 3.0×10^{-3} AV^{-1} and anode resistance of $1 \times 10^4 \Omega$, is used as a single-stage amplifier. If the load resistance is $3 \times 10^4 \Omega$, calculate the voltage gain of the amplifier. (05marks)

From $\mu = R_a g_m = 3.0 \times 10^{-2} \times 1 \times 10^4 = 30$

From A =$\frac{V_0}{V_i} = \frac{\mu V_i}{R_a + R_L}$

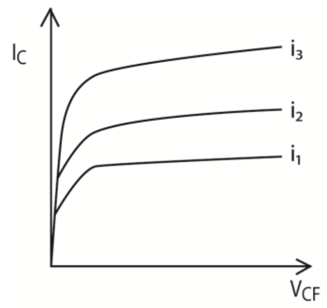
$= \frac{30 \, x \, 3 \, x \, 10^4}{1 \, x \, 10^4 + 3 \, x \, 10^4}$

= 22.5

(c) (i) Describe the structure of a junction transistor. (02marks)

A transistor consist of 3 layers of P- and n- semiconductors called respectively emitter, base and collector. The base is thinner. It can be PnP type or nPn transistor.

(ii) Sketch and describe the collector-current against collector-emitter voltage characteristic of a junction transistor. (03marks)



For small values of V, Ic increases linearly with V but strongly dependent on i.

Compiled by Dr. Bbosa Science