UACE 2024 Physics paper 1 Guide

2hours 30 minutes

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

- Assume where necessary:

Acceleration due to gravity, g	= $9.81ms^{-2}$
Electronic charge, e	= 1.6×10^{-19} C
Electronic mass	= 9.11×10^{-31} kg
Mass of the earth	= 5.97×10^{24} kg
Planck's constant, h	= 6.6×10^{-34} JS
Stefan's Boltzmann's constant, σ	= 5.67×10^{-8} Wm^{-2} K^{-4}
Radius of the earth	= 6.4×10^{6} m
Radius of the sun	= 7×10^{8}m
Radius of the earth's orbit about the sun	= 1.5×10^{11}m
Speed of light in free space, c	= $3.0 \times 10^{8}ms^{-1}$
Specific heat capacity of water	= 4200 J Kg^{-1} K^{-1}
Thermal conductivity of copper	= $390Wm^{-1}K^{-1}$
Thermal conductivity of aluminium	= 210 $Wm^{-1}K^{-1}$
Universal gravitational constant, G	= 6.67×10^{-11} Nm^{2} kg^{-2}
Avogradro's number N_A	= 6.02×10^{23} mol^{-1}
Surface tension of water	= $7.0 \times 10^{-2}Nm^{-1}$
Density of water	= $1000kgm^{-3}$
Gas constant R	= 8.31 $Jmol^{-1}kg^{-1}$

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 constant, F = $9.65 \times 10^{4} Cmol^{-1}$.

SECTION A

1. (a) What is meant by the following
   (i) Momentum (01mark)
   (ii) Force (01mark)
   (iii) Elastic collision
   (b) State Newton's laws of motion (03 marks)
   (c) A car travelling at 108kmh-1 collides head on with a massive wall and stops virtually instantly. A passage of mass 80kg, seated in the car and wearing a seat belt is brought to rest in I,1s.
   Find
   (i) Force exerted by the seat belt on the passenger. (03marks)
   (ii) Energy absorbed in the seat belt system as a result. (03marks)

   (d) (i) What is a dimensionless quantity? Give one example. (02 marks)
   (ii) Define impulse and derive its dimensions (03marks)
   (iii) Derive the relation between power, force and velocity. (03marks)

2. (a) Define the following:
   (i) Gravitation field strength (01 mark)
   (ii) Parking orbit (01mark)
   (b) A rocket of mass, m, is fired from the earth's surface so that it just escapes from the gravitational influence of the earth. If the radius of the earth is r, show that the velocity of escape V, is given by $V = \sqrt{2gr}$. (03marks)
   (c) State three differences between free oscillation and damped Oscillations. (03marks)
   (d) Describe an experiment to determine the oscillation due to gravity, g, using a helical spring, slotted mass, stop clock and meter rule. (06 marks)
   (e) A communication satellite of ass 100kg moves in a circular orbit round the earth at a distance of 3.2×10^{6}m from the earth's surface.
   Calculate the;
   (i) period of revolution of the satellite(03 marks)
   (ii) kinetic energy of the satellite (03marks)

3. (a) (i) Define the term static pressure and dynamic pressure as applied to fluid flow
   (02marks)
   (ii) Describe how the speed of flowing water can be obtained using Pitot-Static tubes. (05marks)
   (iii) State the assumption made in (a)(ii) (01mark)

(b) (i) State Bernoulli's principle. (01mark)

(ii) Explain why gas in a Bunsen burner does not escape from the base of the burner but continues burning at the top. (03marks)

(iii) A large tank contains water to depth of 1.0m. if a small hole is drilled in the tank at a depth of 20c below the top surface of the water, calculate the speed at which the water emerges from the hole. (03marks)

(c)(i) State Archimedes' principle (01 marks)

(ii) An alloy of mass 588g and volume 100cm3 is made of iron of relative density 8.0 and alumimium of relative density 2.7.
Find the proportion by volume of the alloy. (04marks)

4. (a) (i) What is an elastic material? (01mark)

(ii) Show that the energy,E, stored in a stretched elastic aterial of elastic,k, is given by $E = \frac{1}{2}k(e_2{}^2 - e_{12}{}^2)$, where e_2 and e_1 are extensions produced (04marks)

(iii) Explain the energy transforation which occur during elastic deformation. (03marks)

(b)(i) State the easurements taken in an experieent to determine Young's Modulus of a mateiralof a material in form of a wire. (02marks)

(ii) Explain why in the experient in (b)(i), two identical wires are used. (02marks)

(c) Two wires 2.0 m long, one of steel and the other of brass are suspended vertically from two points 0.10m apart in the same horizontal plane. Their lower ends ae fixed to a light horizontal bar at points 0.10m apart. When a force of 100N is applied vertically downwards to the centre of the bar, the bar tilts by 2^0 to the horizontal due to the brass wire of the brass wire stretching more than the steel.
Assuming tht the wires are vertical and the diameter of each wire is 0.80mm, calculate the;

(i) Difference between the extensions in the wires. (02marks)

(ii) Extension produced in the brass wire
[Young Modulus for steel = $2.0 \times 10^{11}$$nm^{-2}$] (06arks)

SECTION B

5. (a) Define the following:

(i) Specific heat capacity (01mark)

(ii) Latent heat. (01marks)

(b) (i) Describe an experiment to determine the specific heat capacity of a solid using the method of mixtures. (06marks)

(ii) State two precautions taken in (b)(i). (02marks)

(c) An electric heater of 2.2kW was used to heat 2kg of water, initially at 25^0C, in a kettle of heat capacity $400JK^{-1}$ until the water boiled at 100^0C. the heating was continued for 3 more minutes and it was found that the mass of water in the kettle was 1.802kg.
Calculate;

(i) how long it took the water to boil

(ii) the specific latent heat of vaporization (05mark)

(d) Explain why the specific latent heat of vaporization in much higher than the specific lantent heat of fusion for the same substance. (05marks)

6. (a) Define the following;
    (i) Saturted vapour. (01mark)
    (ii) Partial pressure of a gas. (01 marks)

   (b) (i) Explain the effect of increase in temperature on the saturated vapour pressure of a liquid. (04marks)
    (ii) Describe an experiment to deterine the saturated vapour pressure and boiling point of water

   (c) (i) Define an idea gas (01ark)
    (ii) What assumptions of the kinetic theory of an ideal gas need to be modified to account for the behaviour of a real gas

   (d) A sealed flask of volue 80cm^3 contains argon at a pressure of 10kPa and a temperature of 27^{0}C. Calculate;
    (i) number of molecules of argon in the flask (03marks)
    (ii) rootmean square speed of the molecules in the flask
    (Molar mass of argon is 0.018kg) (03 mark)

7. (a) State
    (i) Stafan's law of thermal radiation (01mark)
    (ii) Wien's displacement law. (01 ark)

   (b) Describe an experiment to show the rate of heat loss from a body depends on the nature of the surface. (04marks)

   (c) (i) Describe an experiment to detect thermal radiation. (03 marks)
    (ii) Explain the echanisn of heat transfer in fluids. (03 marks)

   (d) Explain;
    (i) what is meant by a perfect black body. (01 mark)
    (ii) what is meant by quality of radiation. (01 mark)
    (iii) Why a black body at 1000K is red hot whereas it is white hot at 2000K. (02 mark)

   (e) The element of an electric fire with an output of 0.5kW, is a cylinder 20cm long.The element hehaves as a black body and when in use its temperature is 693.5^{0}C. Calculate the diameter of the element. (04marks)

SECTIONC

8. (a) What is meant by the following as applied to photoelectric effect:
    (i) Threshold frequency (01 mark)
    (ii) Work function? (01 mark)

   (b) Explain how the classical wave theory fails to account for observation that photoelectric emission is an intantaneous process. (03 marks)

   (c) In a laboratory demonstration of photoelectric effect, a freshlycleaned zinc plate is connected to a cup of a gold-leaf electroscope.
    Explain what is observed when;
    (i) the electroscope is given a negative charge and the zinc plate is illuminated by ultraviolet light. (03 marks)
    (ii) the electroscoscope is given negative charge and the zinc plate is illuminatedby infrared radiation. (03 marks)

(d) A narrow and parallel beam of monochroatic light of wavelength 546nm of the photon incident on the metal plate and power of 0.080W is incident on a metal plate. Assuming 2.0% of photons incident on the metal platecaus electron emission from the metal, find the photo current produced. (05 marks)

(e) (i) State how the intensity and quality of X-rays produced in an X-ray tube can be controlled. (02marks)

(ii) Calculate the sallest glancing angle at which X-rays of wavelength 7.0 x 10^{-11}m will be reflected from a crystal whose atomic plane spacing is 2.0×10^{-10}m. (03 marks)

9. (a) Define the following:

(i) Avogadro's constant (01mark)

(ii) Specifific charge. (01mark)

(b) With the aid of a labelled diagram, describe Thermson's experient for determining specific charge. (06marks)

(c) In Milikan's experiment, an oildrop falls with a stead velocity of 2.5 x 10^{-4}ms^{-1} when the p.d across the plates is zero. When the p.d between the plates is 2387V, with the upper plate being positive, the oil drop just remains stationary. Given that the density of oil is 900kgm^{-3}, vescosity of air is 1.8 x 10^{-5} Nsm^{-2} and the separation of the plates is 1.5cm apart, calculate

(i) the number of electronic charges on the drop. (05marks)

(ii) the velocity with which the drop will move when it has collected twomore electrons if the p.d between the plates remain uncharged. (04marks)

(d) Explain how a cathode ray oscillocicope can be used to measure a.c voltage. (03marks)

10. (a) Define the following:

(i) Mass number. (01mark)

(ii) Half-life (01mark)

(b) State the laws of radioactivity and use it to derive the decay law expression, $N = N_0e^{-\lambda t}$ (05marks)

(c) State two

(i) uses of radi0isotopes. (02arks)

(ii) hazards due to radiations emmitted by radioisopes (01mark)

(d) (i) With the aid of a labelled diagram, describe how a diffusion cloud chamber works (07marks)

(iii) Sketch the nature of path formed by each of the ionising radiation in the cloud chamber. (03marks)

Suggested answers

1. (a) What is meant by the following
   (i) Momentum (01mark)
   Linear momentum is the product of mass and its velocity

   (ii) Force (01mark)
   Force: A push or pull upon an object resulting from the object's interaction with another object.

   (iii) Elastic collision
   During an elastic collision, the interacting bodies separate after interaction and there is conservation of total kinetic energy.

   (b) State Newton's laws of motion (03 marks)
   - 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.

   (c) A car travelling at 108kmh^{-1} collides head on with a massive wall and stops virtually instantly. A passage of mass 80kg, seated in the car and wearing a seat belt is brought to rest in 0.1s.
   Find
   (i) Force exerted by the seat belt on the passenger. (03marks)
   $F = ma = m\frac{\Delta V}{\Delta t}$
   $\frac{108km}{h} = \frac{108x1000}{3600} = 30m/s$

   $a = \frac{\Delta V}{\Delta t} = \frac{0-30}{0.1} = -300$ms^{-2} (negative sign indicate the direction of force)
   Force = 80 x 300 = 24000N
   (ii) Energy absorbed in the seat belt system as a result. (03marks)
   Let the distance moved by the passenger before stopped by the belt
   $v^2 = u^2 - 2as$
   s = $\frac{30^2}{2x300}$ = 1.5m
   energy = F x d = 1.5 x 24000 =36,000J

   Or
   Energy = $\frac{1}{2}mv^2 = \frac{1}{2}x80x30^2$ =36,000J

   (d) (i) What is a dimensionless quantity? Give one example. (02 marks)

   A **dimensionless quantity** is a quantity that does not have any physical dimensions and is expressed as a pure number without any units.

Examples of Dimensionless Quantities:

- **Pi (π)**: The ratio of the circumference of a circle to its diameter.
- **Reynolds Number (Re)**: A measure of the relative importance of inertial forces to viscous forces in fluid flow.
- **Strain**: The ratio of the change in length to the original length of a material.
- **Coefficient of Friction**: The ratio of the force of friction between two bodies to the normal force pressing them together.
- **Relative Density (Specific Gravity)**: The ratio of the density of a substance to the density of a reference substance (typically water).

(ii) Define impulse and derive its dimensions (03marks)

Impulse is the product of force and the time for which it acts.

I.e. Impulse = F .t

= ma.t

= MLT^{-2} . T

= MLT^{-1}

Hence the units of impulse are MLT^{-1}

(iii) Derive the relation between power, force and velocity. (03marks)

Power (P) is defined as the rate at which work is done.

I.e. P = $\frac{\Delta W}{\Delta t}$ where W is work and t is time.

= $\frac{\Delta(F.s)}{\Delta t}$ where F is the force applied and s is the distance moved

= $F\left(\frac{\Delta s}{\Delta t}\right)$ = F.v (where v is the velocity)

2. (a) Define the following:

(i) Gravitation field strength (01 mark)

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.

Or

It is defined as the force per unit mass experienced by a small test mass placed in the gravitational field.

(ii) Parking orbit (01mark)

A parking orbit is the path in space followed by a satellite whose period of revolution is equal to the period of rotation of the earth.

Or

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

(b) A rocket of mass, m, is fired from the earth's surface so that it just escapes from the gravitational influence of the earth. If the radius of the earth is r, show that the velocity of escape V, is given by $V = \sqrt{2gr}$. (03marks)

Derivation

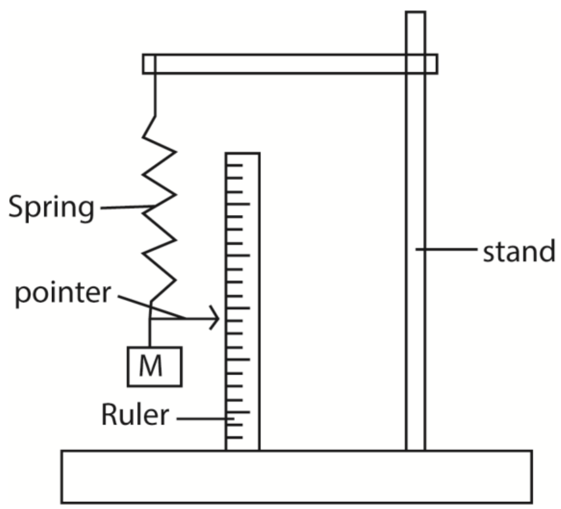
- **Ecape velocity,** v, is the minium velocity required for an object to escape the gravitation infuence of a celestial body without any further propoulsion.
- **Grvitation Potential energy,** U, of an of mass m at a distance r from the centre of the Earth (where r is the radius of the Earth) is given by
  $U = \frac{GMm}{r}$ where G = gravitationaconstant and M is the mass of the Earth.
- Kinetic Energy (K.E) of the body is given by
  $K.E = \frac{1}{2}mv^2$
- Energy conservation conservation
  $\frac{1}{2}mv^2 = \frac{GMm}{r}$

  $v^2 = \frac{2GM}{r}$ ....(i)
  But $g = \frac{GM}{r^2}$ or $\frac{GM}{r} = gr$
- Substituting for $\frac{GM}{r}$ in equation (i)
  $v^2 = 2gr$
  $v = \sqrt{2gr}$ as required

(c) State three differences between free oscillation and damped Oscillations. (03marks)

- **Energy loss:** In free oscillations there is no loss of energy while in damped oscillations there is gradual loss of energy.
- **Amplitude:** In free oscillations the amplitude remains constant while in damped oscillations amplitude gradually decreases.
- **Frequency and period:** in free oscillation there is constant frequency and period while in damped oscillation the frequency and period may change

(d) Describe an experiment to determine the oscillation due to gravity, g, using a helical spring, slotted mass, stop clock and meter rule. (06 marks)



- 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 $g = \frac{4\pi^2}{S}$

(e) A communication satellite of ass 100kg moves in a circular orbit round the earth's at a distance of 3.2×10^6m from the earth's surface.
Calculate the;

(i) period of revolution of the satellite(03 marks)

Distance r of the orbit from the centre of the earth

$= R + r$

$= 6.4 \times 10^6 + 3.2 \times 10^6$

$= 9.6 \times 10^6$m

Using Kepler's Third law and substituting

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

$$= \left(\frac{4\pi^2}{6.67 \times 10^{-11} x\, 5.97 \times 10^{24}}\right)\left(9.6 \times 10^6\right)^3$$

T = 9,365.6 s = 2.6hours

(ii) kinetic energy of the satellite (03marks)

$$K.E = \frac{1}{2}mv^2$$

But $v^2 = \frac{2GM}{r}$

$$K.E = \frac{GMm}{2r}$$

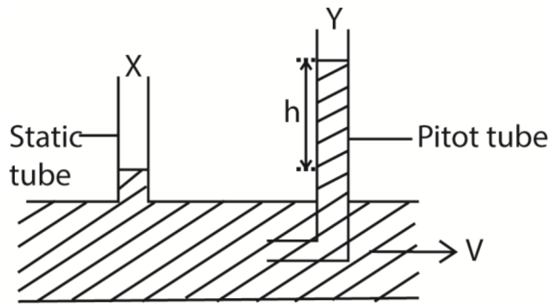
$$= \frac{6.67 \times 10^{-11} x\, 5.97 \times 10^{24} x 100}{2\, x\, 9.6 \times 10^6}$$

$= 2.080125 \times 10^9$ J

3. (a) (i) Define the term static pressure and dynamic pressure as applied to fluid Flow. (02marks)

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

(ii) Describe how the speed of flowing water can be obtained using Pitot-Static tubes. (05marks)



Pilot-static tube consists of a static tube which measures the static pressure and the pilot tube that measures the total pressure. Total pressure is the sum of static and dynamic pressure.

From P + $\frac{1}{2}\rho v^2 + \rho gh = constant$
Static pressure = P + ρgh (where P is atmospheric pressure)
Dynamic pressure = $\frac{1}{2}\rho v^2$
Total pressure, P_y = static pressure (P_x) + dynamic pressure
= P + $\frac{1}{2}\rho v^2 + \rho gh$
For horizontal tube, h is constant
But, Total pressure, P_y = static pressure (P_x) + dynamic pressure

$$P_y = P_X + \frac{1}{2}\rho v^2$$

$$(P_y - P_x) = \frac{1}{2}\rho v^2$$

$$V = \sqrt{\left(\frac{2(P_y - P_x)}{\rho}\right)}$$

(iii) State the assumption made in (a)(ii) (01mark)
- The fluid is non-compressible
- The pitot tube is place in the center of the fluid because velocity is highest in the middle of lamina flow
- velocity is low and pressure difference is small.

(b) (i) State Bernoulli's principle. (01mark)
Bernoulli's Principle states that for a streamline motion of an incompressible non viscous fluid, the sum of pressure at any point and kinetic energy per unit volume is always constant.

(ii) Explain why gas in a Bunsen burner does not escape from the base of the burner but continues burning at the top. (03marks)

- **Upward Flow**: The gas is forced to flow upward through the burner tube due to the pressure from the gas supply. This upward flow ensures that the gas does not escape from the base.
- **Venturi Effect**: The design of the burner creates a Venturi effect, where the gas velocity increases as it passes through a narrow section, drawing in air through the side holes and mixing with the gas.

(iii) A large tank contains water to depth of 1.0m. If a small hole is drilled in the tank at a depth of 20cm below the top surface of the water, calculate the speed at which the water emerges from the hole. (03marks)

Using Torricelli's theorem

It statesthat thespeed v ofinflux of a fluid under gravity through an orificeat a depth h below the surface of the fluid is given by

$v = \sqrt{2gh}$

Where g is the acceleration due to gravity (9.81ms-2)

h is the depth of the hole below the surface of the water = 20cm =0.2m

substitions

$v = \sqrt{2x9.81 \; x \; 0.2}$

$= 1.98ms^{-1}$

(c)(i) State Archimedes' principle (01 marks)

When a body is partially or fully immersed in a fluid, it experiences an up thrust which is equal to the weight of a fluid displaced.

(ii) An alloy of mass 588g and volume $100cm^3$ is made of iron of relative density 8.0 and alumimium of relative density 2.7.

Find the proportion by volume of the alloy. (04marks)

Data given

- Total mass of the alloy (m) = 588g
- Totalvolume of the alloy (V): 100cm3
- Relativedensity of iron (ρ_1) =8.0
- Relative density of aluminium (ρ_2) =2.7

Converting relative density to actual density (since relative density is the ratio of the density of of substance to density of water, which is 1g/cm)

- Density of iron (ρ_1) =8.0 g/cm^3
- Density of aluminium (ρ_2) =2.7g/cm^3

Let the volume of iron be Vi and the volume of aluminium be Va

$V = V_i + V_a$

Expressing the mass of iron and aluminium in terms of their densities and volumes

Mass of iron (mi) = $\rho_i.V_i$

Mass ofaluminium (ma) = $\rho_a.V_a$

The total mass of the alloy is the sum of the masses iron and aluminum

m = mi + ma

$588 = 8.0 \, xV_i + 2.7 \, x \, V_a$ …………………………. (i)

Total volume = volume of iron + volume of aluminium

$V = V_i + V_a$

$100 = V_i$ and V_a ……………………………………(ii)

Solving equations (i) and (ii)

Vi = $60cm^3$

Va = $40cm^3$

Hence the volume of Iron in the alloy is $60cm^3$ and that of aluminium is $40cm^3$

4. (a) (i) What is an elastic material? (01mark)

An **elastic material** is a type of material that can undergo significant deformation when subjected to an external force but will return to its original shape and size once the force is removed.

(ii) Show that the energy,E, stored in a stretched elastic aterial of elastic,k, is given by $E = \frac{1}{2}k({e_2}^2 - {e_1}^2)$, where e_2 and e_1 are extensions produced. (04marks)

- Elastic Potential Energy: The elastic potential energy stored in a materialwhen it is stretched or compressed by an extension e is given by
  $E = \frac{1}{2}ke^2$ (where k is the elastic constant of the material)
- Energydifference,E: If the material is stretched from an initial e1to a final extension e2, the energy difference is given by
  $E = E_2 - E_1$
  $= \frac{1}{2}k{e_2}^2 - \frac{1}{2}k{e_1}^2$
  $= \frac{1}{2}k({e_2}^2 - {e_1}^2)$ as required

(iii) Explain the energy transforation which occur during elastic deformation. (03marks)

- When external force is applied to an elastic material, it deforms and the work done is stored as elastic potential energy or on molecular level; the atoms and molecules within the material are displaced from their equilibrium positions. The potential energy is stored in the form of elastic bonds between these molecules when external force is applied.
- For small deformations, the relationship between the force and the deformation follows Hooke's Law, where the force is proportional to the displacement.
- As long as the deformation is within the elastic limit of the material, the energy is stored without causing permanent changes to the material's structure.
- When external force is released, the stored elastic potential energy is released and the material returns to its initial state/shape.

(b)(i) State the easurements taken in an experieent to determine Young's Modulus of a mateiralof a material in form of a wire. (02marks)

- Initil length
- Diameter of the wire
- Final length
- Applied force/load

(ii) Explain why in the experient in (b)(i), two identical wires are used. (02marks)

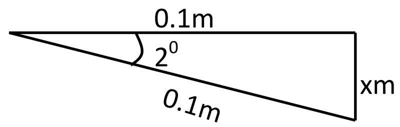
To eliminate errors due to:

(i) the yielding of the support when loads are added to the test wire,

(ii) changes of temperature.

(c) Two wires 2.0 m long, one of steel and the other of brass are suspended vertically from two points 0.10m apart in the same horizontal plane. Their lower ends ae fixed to a light horizontal bar at points 0.10m apart. When a force of 100N is applied vertically downwards to the centre of the bar, the bar tilts by 2^0 to the horizontal due to the brass wire of the brass wire stretching more than the steel.
Assuming tht the wires are vertical and the diameter of each wire is 0.80mm, calculate the;

(i) Difference between the extensions in the wires. (02marks)
Let the difference in extension be x



Using cosine rule
$x^2 = 0.1^2 + 0.1^2 - 2 \times 0.1 \times 0.1\cos 2$
x = 0.0035m

(ii) Extension produced in the brass wire
[Young Modulus for steel = 2.0 x 10^{11}nm^{-2}] (06marks)

Force on the steel wire = $\frac{100}{2} = 50N$

Crossection areaof steel wire , A = $\pi\left(\frac{d}{2}\right)^2$

$= \pi\left(\frac{0.8x10^{-3}}{2}\right)^2$

$= 5.0x10^{-7}m^2$

Extension = $\frac{F.L}{A.E}$

$= \frac{50\ x\ 2}{5.0x10^{-7}.2\ x\ 10^{11}}$

= 0.001m

Hence extension of brass = 0.001+0.0035 = 0.0045m

SECTION B

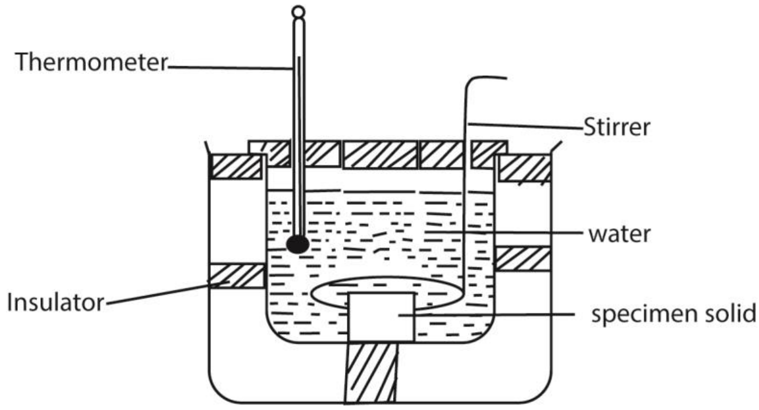
5. (a) Define the following:

(i) Specific heat capacity (01mark)
Specific heat capacity is the amount of heat requires to raise the temperature of 1kg mass of a substance by 1K or 1^0C

(ii) Latent heat. (01marks)
Latent heat is energy absorbed or released by a substance during a change in its physical state (phase) without changing its temperature.

(b) (i) Describe an experiment to determine the specific heat capacity of a solid using the method of mixtures. (06marks)

Measurement of specific heat capacity of a solid by the method of mixtures



- A solid on mass m_s kg and specific heat capacity, c_s, is heated in boiling water at temperature at temperature θ_1 ^{0}C and quickly transferred to a calorimeter of heat capacity, C, containing water of mass, m_1 and , at the temperature θ_2.
- The final constant temperature θ_3 of the mixture is determined.
  Assuming there is no heat loss

Heat lost by the solid = heat gained by calorimeter + heat gained by water

$m_s \times c_s \times (\theta_1 - \theta_3) = (C + c_w m_1)(\theta_3 - \theta_2)$

$c_s = \frac{(C + c_w m_1)(\theta_3 - \theta_2)}{m_s c_s}$ where c_w is specific heat capacity of water

(iii) State two precautions taken in (b)(i). (02marks)
- The calorimeter must be heavily lagged to minimize heat loss from the mixture.
- Transfer the solid fast to minimize heat loss from it during the transfer.
- Stir the mixture gently to ensure uniform temperature distribution without causing splashing or heat loss.
- Carry out the experiment several times to minimize errors
- Make correction for heat loss.

(c) An electric heater of 2.2kW was used to heat 2kg of water, initially at 25^{0}C, in a kettle of heat capacity 400JK^{-1} until the water boiled at 100^{0}C. The heating was continued for 3 more minutes and it was found that the mass of water in the kettle was 1.802kg.
Calculate;

(i) how long it took the water to boil

Heat given out by the heater = heat gained by the kettle and water

$VIt = C\theta + mc\theta$

$2.2 \times 10^3 t = 400(100 - 25) + 2 \times 4200 (100 - 25)$

$t = 300s = 5$minutes

(ii) the specific latent heat of vaporization (05mark)

Mass of water vaporized = 2 – 1.802 =0.198

Let specific latent heat be L

$VIt = mL$

$2.2 \times 10^3 \times 3 \times 60 = 0.198L$

$L = 2 \times 10^6 Jkg^{-1}$

(d) Explain why the specific latent heat of vaporization in much higher than the specific lantent heat of fusion for the same substance. (05marks)

Latent heat of fusion only supply energy to breaks down the forces that keep ordered pattern of molecules is solid crystalline structure to form a liquid. The potential energy of the molecules increase but the average kinetic energy and temperature of the molecules remain unchanged.

While,

Latent heat of vaporization is always greater that latent heat of fusion because energy is supplied to break down stronger molecular bonds in liquids and to provide energy to liquid molecules in order to expand into gas molecules against atmospheric pressure.

6. (a) Define the following;

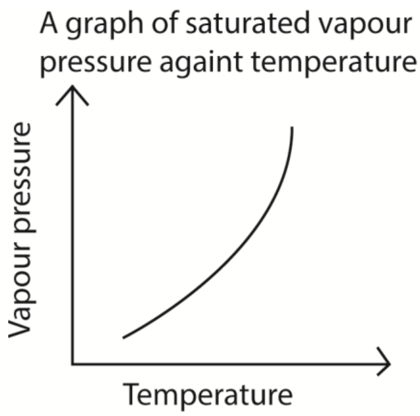
- Saturted vapour. (01mark)

  A saturated vapour is one that is a dynamic equilibrium with its own liquid

- Partial pressure of a gas. (01 marks)

  Partial pressure is the pressure that would be exerted by a gas if it alone occupied the volume of the mixture.

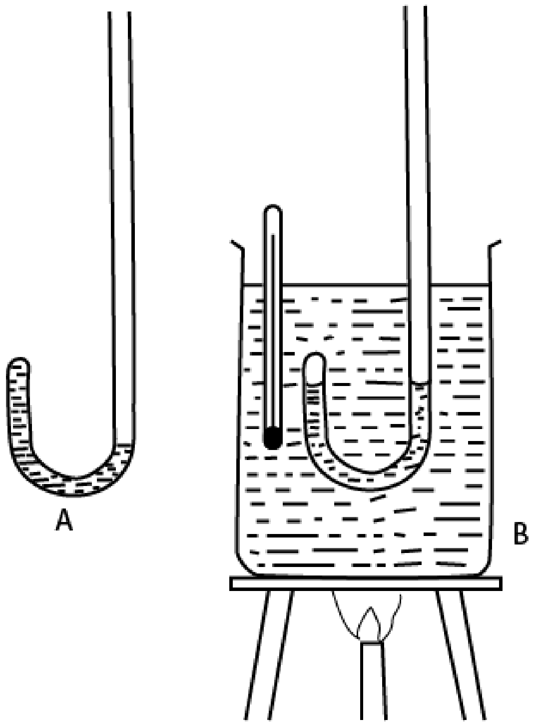
(b) (i) Explain the effect of increase in temperature on the saturated vapour pressure of a liquid. (04marks)



Saturated vapour pressure increases with temperature due to the increase in kinetic energy and the probability of molecules overcoming the intermolecular forces holding them in the liquid phase, allowing them to escape into the vapour phase

(ii) Describe an experiment to deterine the saturated vapour pressure and boiling point of water

The setup is shown below



- Atmospheric pressure, H. is deterined using a mercury barometer
- Water is trapped in a J tube as shown in A
- The J-tube in and its content is transferred into a beaker of water B and a thermometer is inserted as shown in B.
- Water in the beaker is heated until it boils and the boiling point is obtained from the constant reading of the thermometer.
- It also noted that water in the closed and open tube of the J-tube are at the same level indicating that water boils when its saturated vapor pressure is equal to the atmospheric pressure H.

(c) (i) Define an idea gas (01ark)

An Ideal gas s one that obeys Boyle's law under all conditions

(ii) What assumptions of the kinetic theory of an ideal gas need to be modified to account for the behaviour of a real gas

The kinetic theory of an ideal gas makes several simplifying assumptions that don't hold true for real gases, especially under conditions of high pressure and low temperature. Here are the key assumptions that need to be modified to better describe the behavior of real gases:

- **Negligible Volume of Gas Molecules**: The kinetic theory assumes that the volume of individual gas molecules is negligible compared to the volume of the container. In reality, gas molecules do occupy space, and their finite size becomes significant at high pressures, where the volume of the container is reduced.
- **No Intermolecular Forces**: The theory assumes that there are no attractive or repulsive forces between gas molecules. However, real gases experience intermolecular forces (Van der Waals forces), which affect their behavior. Attractive forces become significant at low temperatures, leading to deviations from ideal gas behavior.

- **Perfectly Elastic Collisions**: The theory assumes that collisions between gas molecules and with the walls of the container are perfectly elastic, meaning there is no loss of kinetic energy. In reality, some energy is lost in collisions, although it is often small enough to be negligible in many situations.
- **Random Motion**: While gas molecules do move randomly, the theory assumes complete randomness without considering the influence of intermolecular forces. In real gases, these forces can lead to non-random behavior, particularly under certain conditions.

To account for these deviations, the Van der Waals equation is often used as an improvement over the ideal gas law:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

Where

- P is the pressure of the gas.
- V_m is the molar volume of the gas.
- T is the temperature of the gas.
- R is the universal gas constant.
- a and b are empirical constants specific to each gas, accounting for intermolecular forces and the finite volume of gas molecules, respectively.

(d) A sealed flask of volue $80cm^3$ contains argon at a pressure of 10kPa and a temperature of 27^0C. Calculate;

(i) number of molecules of argon in the flask (03marks)

From PV = nRT

$$n = \frac{10 \times 10^3 \times 80 \times 10^{-6}}{8.31 \times 300} = 3.2 \times 10^{-4} \text{ moles}$$

Number of molecules = $3.2 \times 10^{-4} \times 6.02 \times 10^{23} = 1.9264 \times 10^{20}$.

(ii) root mean square speed of the molecules in the flask (Molar mass of argon is 0.018kg) (03 mark)

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

Mass ofArgon = $3.2 \times 10^{-4} \times 0.018 = 5.76 \times 10^{-6}$kg

$$\rho = \frac{M}{V} = \frac{5.76\times10^{-6}}{80\times10^{-6}} = 7.2 \times 10^{-2}\,kgm^{-3}$$

$$\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 1 \times 10^4}{7.2\times10^{-2}}} = 645.5\ ms^{-1}$$

7. (a) State

(i) Stefan's law of thermal radiation (01mark)

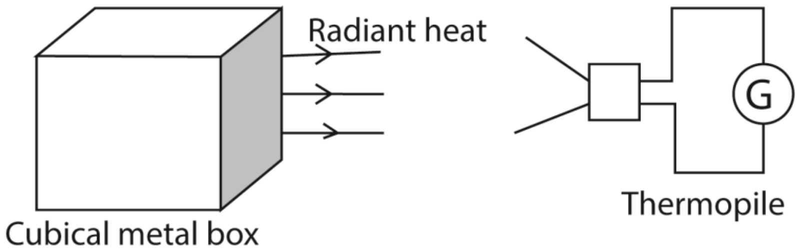
Stefan's law states that the total power radiated by a black body per unit surface area is proportional to the fourth power of its absolute temperature. i.e. $\frac{P}{A} \propto T^4$

(ii) Wien's displacement law. (01 ark)

The wavelength λ_m at which maximum energy is radiated for temperature, T is such that $\lambda_m T$ = constant.

(b) Describe an experiment to show the rate of heat loss from a body depends on the nature of the surface. (04marks)

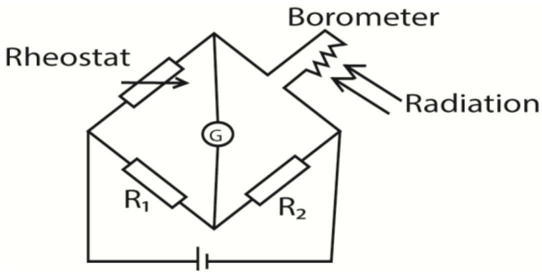
A cubical metal tank whose sides are painted; dull black, dull white and highly polished is filled with hot water and radiations from each surface are detected by a thermopile as shown below.



The galvanometer deflection is greatest when the thermopile is facing the dull black surface and least when facing a highly polished silver surface. Therefore, a polished surface is the least radiator and a black surface is the best radiator. Hence, rate of heat loss from a body depends on the nature of the surface.

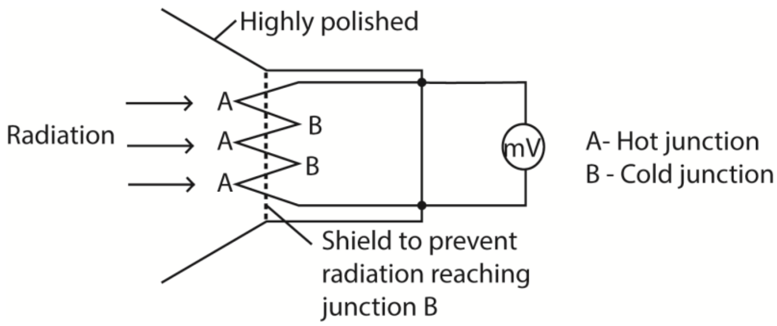
(c) (i) Describe an experiment to detect thermal radiation. (03 marks)

Using **Barometer**



The bolometer strip is connected to Wheatstone bridge circuit above. The rheostat is adjusted until the galvanometer shows no deflection. When the radiations fall on the strip, they are absorbed and its temperature rises leading to an increase in resistance. The galvanometer deflects showing the presence of radiations.

Or Using **a thermopile**

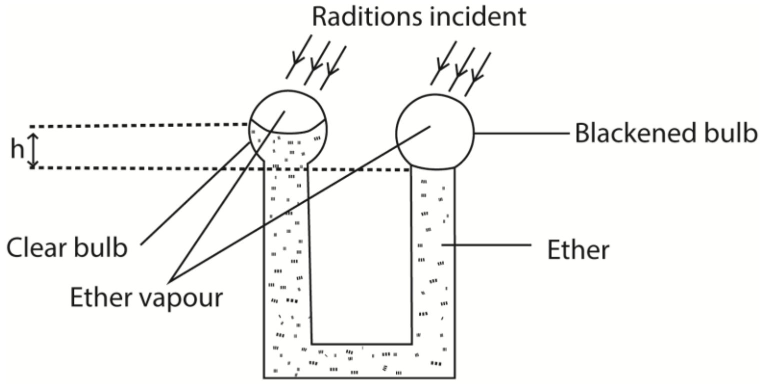


Radiation falling on junction A is absorbed and temperature rises above that of junction B. An e.m.f is generated and is measured by millivolt meter which deflects as a result.

Or

Using the ether-thermo scope.

A blackened and clear bulbs are connected to a tube partly filled with ether i.e. each bulb contains mixture of air and ether vapour. When the arrangement is exposed to infrared radiations, more radiations are absorbed by the blackened bulb than those absorbed by the clear bulb. This raises the pressure inside the blackened bulb causing the ether liquid to be raised in the unblackened bulb as shown below.



The rise h is proportional to incident radiation

(iii) Explain the echanisn of heat transfer in fluids. (03 marks)

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

(d) Explain;

(i) what is meant by a perfect black body. (01 mark)

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

(ii) what is meant by quality of radiation. (01 mark)

The **quality of radiation** refers to the characteristics (such as frequency, intensity) or properties of radiation that determine its effects and interactions with matter.

(iii) Why a black body at 1000K is red hot whereas it is white hot at 2000K.

(02 mark)

Red hot: 1000K, the peak wavelength emitted by a black body falls in visible red range making the black body appear red hot.

White Hot: At 2000K, the black body produces a mixture of peak wavelengths with colors in the visible spectrum including red, yellow, green, and blue, which combine to produce white light. Thus, the black body appears white hot.

(e) The element of an electric fire with an output of 0.5kW, is a cylinder 20cm long.The element behaves as a black body and when in use its temperature is 693.5^{0}C. Calculate the diameter of the element. (04marks)

From $P = \sigma A T^4$

$= \sigma(\pi d L)T^4$

⇨ $d = \frac{P}{\sigma \pi L T^4}$

Substitution

$$d = \frac{0.5\ x\ 10^3}{(5.67x10^{-8})\pi(20x\ 10^{-2})(693.5+273)^4}$$

$= 0.016m$

SECTIONC

8. (a) What is meant by the following as applied to photoelectric effect:

(i) Threshold frequency (01 mark)

It is the frequency of incident radiation below which no electron emission takes place from a metal surface.

(ii) Work function? (01 mark)

Work function is the minimum energy required to liberate an electron from a metal surface.

(b) Explain how the classical wave theory fails to account for observation that photoelectric emission is an intantaneous process. (03 marks)

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

(c) In a laboratory demonstration of photoelectric effect, a freshlycleaned zinc plate is connected to a cup of a gold-leaf electroscope.

Explain what is observed when;

(i) the electroscope is given a negative charge and the zinc plate is illuminated by ultraviolet light. (03 marks)

Divergence decreases because the zinc plate loses electrons by photoelectric effect since ultraviolet radiation has ferequency higher than threshold frequence of zinc.

(ii) the electroscoscope is given negative charge and the zinc plate is illuminatedby infrared radiation. (03 marks)

No changein divergence because no electrons are lost by photoelectric effect since infrared radiation has ferequency below threshold frequence of zinc.

(d) A narrow and parallel beam of monochroatic light of wavelength 546nm of the photon incident on the metal plate and power of 0.080W is incident on a metal plate. Assuming 2.0% of photons incident on the metal plate cause electron emission from the metal, find the photo current produced. (05 marks)

$E = \frac{hc}{\lambda} = \frac{6.6\,x10^{-34}x\;3x10^{8}}{546\;x\;10^{-9}} = 3.63\;x10^{-19}J$

Number of photos incident per second, N $= \frac{P}{E} = \frac{0.08}{3.63x10^{-19}}$

$= 2.2x10^{17}$photons per second

Number of photons emitted, $N_e = \frac{2}{100}x2.2x10^{17}$

$= 4.4 \times 10^{15}$ photons per second

Current $I = N_e \times e$

$= 4.4 \times 10^{15} \times 1.6 \times 10^{-19}$

$= 7.04 \times 10^{-4}$A

(e) (i) State how the intensity and quality of X-rays produced in an X-ray tube can be controlled. (02marks)

The intensity of X-rays are controlled by filament current i.e.the greater the filament current, the greater the number of electrons striking the anode per second and the greater the intensity.

The quality or penetrating power of X-ray is controlled by p.d between the filament and the anode which determines the kinetic energy with which electrons strike the anode.

(ii) Calculate the sallest glancing angle at which X-rays of wavelength 7.0×10^{-11}m will be reflected from a crystal whose atomic plane spacing is $2.0x10^{-10}$m. (03 marks)

$2dsin\;\theta = n\lambda$

For smallest glancing angle n = 1

$sin\;\theta = \frac{n\lambda}{2d} = \frac{1\;x\;7.0x10^{-11}}{2x2\;x\;10^{-10}} = 0.175$

$\theta = \sin^{-1} 0.175 = 10.1^{0}$

9. (a) Define the following:

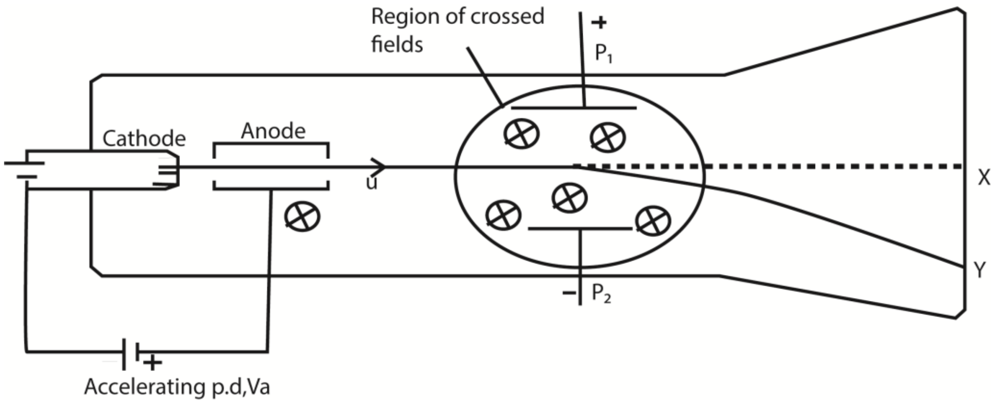
(i) Avogadro's constant (01mark)

Avogadro's constant is the number of atoms in one mole of substance.

(ii) Specifific charge. (01mark)

Specific charge is the ratio of charge to mass of a particle

(b) With the aid of a labelled diagram, describe Thomson's experient for determining specific charge. (06marks)



- The electrons are produced thermionically by a hot filament cathode and are accelerated towards a cylindrical anode and pass through it.
- The small hole on the anode confines the electrons to a narrow beam.
- When both the electric field and the magnetic field are off, the electrons reach the screen at X and cause fluorescence.
- If the velocity of the electrons on emerging from the anode is u then

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

⇨ $\frac{e}{m} = \frac{u^2}{2Va}$ .... (i)

Where Va is the accelerating voltage between the cathode and anode.

- The magnetic field is switched on and the beam is deflected to position Y.
- In order to bring the beam back to the original position X, the electric field is switched on and adjusted until the beam is at X again.
- This implies that The magnetic force = the electric force

  Beu = eE

  ∴u = $\frac{E}{B}$ ....(ii)

- Substituting eqn. (ii) in (i)

  $\frac{e}{m} = \frac{E^2}{2B^2Va}$ but E = $\frac{V}{d}$

∴ $\frac{e}{m} = \frac{V^2}{2B^2d^2Va}$ where, V is the p.d between the plates at separation of d apart

(c) In Milikan's experiment, an oildrop falls with a stead velocity of 2.5 x $10^{-4}ms^{-1}$ when the p.d across the plates is zero. When the p.d between the plates is 2387V, with the upper plate being positive, the oil drop just remains stationary. Given that the density of oil is 900kgm^{-3}, vescosity of air is

1.8×10^{-5} Nsm^{-2} and the separation of the plates is 1.5cm apart, calculate

(i) the number of electronic charges on the drop. (05marks)

$$q = \frac{6\pi\eta d v_0}{V}\left[\frac{9\eta v_0}{2g(\rho-\sigma)}\right]^{\frac{1}{2}}$$

Assuming the density of air is negligible

$$= \frac{6\pi x 1.8x10^{-5} \text{ x } 0.015 \text{ x } 2.5 \text{ x } 10^{-4}}{2387}\left[\frac{9 \, x \, 1.8x10^{-5}x2.5 \, x \, 10^{-4}}{2x9.81 \, x \, 900}\right]^{\frac{1}{2}}$$

$= 8.07 \times 10^{-19}$C

Number of electron = $\frac{q}{e} = \frac{8.07x10^{-19}}{1.6x10^{-19}}$ = 5

(iii) the velocity with which the drop will move when it has collected twomore electrons if the p.d between the plates remain uncharged. (04marks)

$$q = \frac{6\pi\eta d v_0}{V}\left[\frac{9\eta v_0}{2g(\rho)}\right]^{\frac{1}{2}}$$

$$q^2 = \frac{324\pi^2\eta^3 d^2 v_0^{\ 3}}{2V^2 g\rho}$$

$$v_0 = \left(\frac{2V^2 g\rho q^2}{324\pi^2\eta^3 d^2}\right)^{\frac{1}{3}}$$

$$= \left(\frac{2(2387)^2 x9.81 \, x900 \, x\left(7x1.610^{-19}\right)^2}{324\pi^2(1.8x10^{-5})^3(0.015)^2}\right)^{\frac{1}{3}}$$

$$= 3.12x10^{-4} m/s$$

(d) Explain how a cathode ray oscillocicope can be used to measure a.c voltage. (03marks)

An unknown a.c. voltage, whose peak value is required, is connected to the Y-plates. With the time-base switched off, the vertical line on the screen is centered and its length then measured as shown in figure (i) below. This is proportional to twice the amplitude or peak voltage, V_0. By measuring the length corresponding to a known a.c. voltage V, then V_0 can be found by proportion.

10. (a) Define the following:

(i) Mass number. (01mark)

It is the sum of protons and neutrons in an atom

(ii) Half-life (01mark)

Half-life ($t_{½}$) is the time taken for the number of atoms in a radioactive element to reduce to half the original value.

(b) State the laws of radioactivity and use it to derive the decay law expression, $N = N_0e^{-\lambda t}$ (05marks)

This law states that the rate at which a radioactive substance decays is directly proportional to the number of undecayed nuclei present at that time.

i.e. $\frac{dN}{dt} = -kN$ where N is the number of undecayed atoms at time, t, k is a constant

collecting like terms

$$\frac{dN}{N} = -kdt$$

Integrating both sides

$\int \frac{dN}{N} = -k \int dt$

InN = -kt + c

t = 0, c = $\ln N_0$

substituting for c

InN = -kt + $\ln N_0$

Or N = $N_0 e^{-kt}$

(c) State two

(i) uses of radioisotopes. (02arks)

In industry

- Sterilization of food
- Detecting leakages in pipes
- Determining thickness of paper
- Determining the rate of wear
- Carbon dating

In medicine

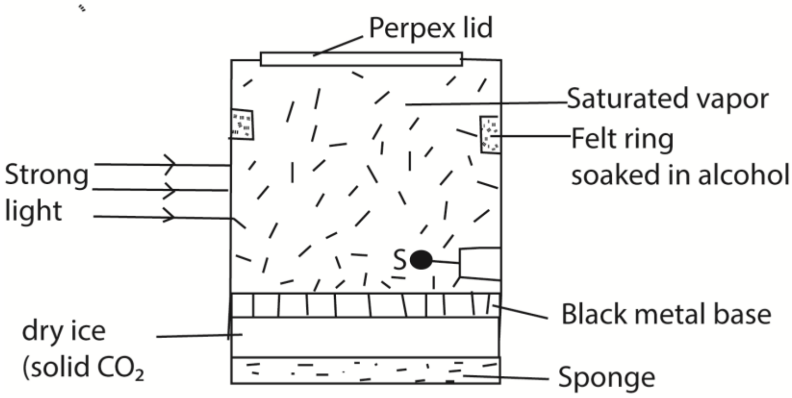
- Treatment of cancer
- Tracer of disease
- Sterilizing medical equipment

(iii) hazards due to radiations emmitted by radioisopes (01mark)

- May cause cancers
- Eye damage
- Cause sterility
- Cause mutation

(d) (i) With the aid of a labelled diagram, describe how a diffusion cloud chamber works (07marks)

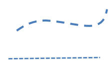
The diffusion cloud chamber

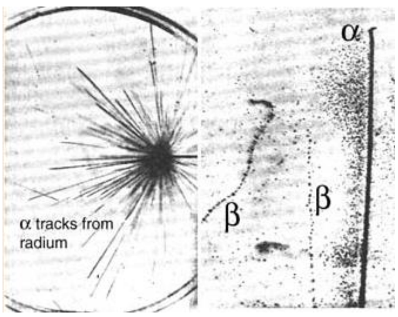


- The base of the chamber is maintained at low temperature, about -800c by the solid carbon dioxide while the top of the chamber is at room temperature, and so there is a temperature gradient between the top and the bottom of the chamber.
- The air at the top of the chamber is saturated with alcohol 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 different types of radiation can be identified based on the characteristics of the tracks they leave in the cloud chamber

(iv) Sketch the nature of path formed by each of the ionising radiation in the cloud chamber. (03marks)

- Alpha track
- Beta track
- Gamma track





Gamma paths are very faint

END