UACE 2020 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	= $5.67 \times 10^{-8} Wm^{-2} K^{-4}$
Radius of the earth	= 6.4×10^{6} m
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 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	= $6.67 \times 10^{-11} Nm^{2} kg^{-2}$
Avogradro'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	= $8.31 Jmol^{-1}kg^{-1}$
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 = $9.65 \times 10^4 C mol^{-1}$.

SECTION A

1. (a) (i) State the laws of static friction. (03 marks)
   (ii) Use the molecular theory of matter to explain the law stated in (a)(i) (06 marks)
   (b) Describe briefly how to measure the limiting friction between wooden block and a plane surface. (04marks)
   (c) A block of wood of mass 4.95kg rests on a horizontal table of height 5.0m at a distance of 6.0m from the edge of the table. A bullet of mass 50.0g moving with a horizontal velocity of $500ms^{-1}$ hits and gets embedded in the block. If the coefficient of dynamic friction between the block and the table is 0.3
   (i) find the initial velocity of the block after collision with the bullet.
   (ii) Calculate the horizontal distance from the table to the point where the block hits the ground. (05marks)
2. (a) Define the following as applied to materials
   (i) Stress (01 mark)
   (ii) Young's Modulus (01 mark)

   (b) The velocity of compressional waves travelling along a rod made of material of Young's Modulus, E, and density, ρ, is given by V = $\left(\frac{E}{\rho}\right)^{\frac{1}{2}}$. Show that the formula is dimensionally consistent. (02 marks)

   (c) Derive an expression for the energy stored in a stretched wire within the elastic limit. (03marks)

   (d) A uniform wire of length 2.49m is attached to two fixed points A and B, a horizontal distance 2m apart. When a 5kgmass is attached to mid-point C of the wired, the equilibrium position of C is 0.75m below the line AB. Neglecting the weight of the wire and taking Young's Modulus for the material to be $2 \times 10^{11} Nm^{-2}$, find the

   (i) strain in the wire (04 marks)

   (ii) stress in the wire (02 marks)

   (iii) energy stored in the wire (04 marks)

   (e) (i) Sketch the stress-strain curve for glass and explain its shape. (02 marks)

   (ii) Why does glass break easily? (01 marks)

3. (a) (i) Define **Centripetal acceleration**. (01 mark)
   (ii) Show that force F on a body of mass M moving in a circle of radius r with constant speed V is given by $F = \frac{MV^2}{r}$. (05 marks)

   (iii) Derive the condition for a car to move round a banked circular track without slipping. (04 marks)

(b) Describe how a helical spring may be used to determine the acceleration due to gravity. (05 marks)

(c) A Particle moving with simple harmonic motion has a speed of $8.0ms^{-1}$ and acceleration of $12ms^{-2}$ when it is 3.0m from equilibrium position. Find the;

(i) amplitude of motion. (03 marks)

(ii) maximum acceleration. (02marks)

4. (a) Define the following:
   (i) Pressure. (01 mark)
   (ii) Relative density (01 mark)

(b) (i) State Archimedes Principle (01 mark)

(ii) Describe an experiment to determine the relative density of a liquid. (04marks)

(c) (i) Derive the expression for Bernoulli's equation. (05marks)

(ii) Explain why a person standing by the road side may be pulled towards the road when a very fast moving bus passes by. (03marks)

(d) A water tight drum tied to a cable anchored on the sea-bed floats 500m beneath the sea surface as shown in figure 1.

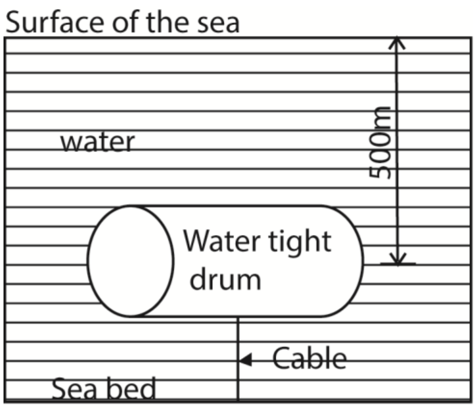


Fig. 1

If the weight of the drum is 500N and its volume 25m3, calculate the;

(i) pressure on the drum due to sea water. (02 marks)
(ii) tension in the cable assuming it is vertical. (03 mark)

SECTION B

5. (a) Define the following:
   (i) Tripple point of water (01 marks)
   (ii) Absolute zero temperature (01mark)

(b) Explain why tipp[e point of water is taken as a standard in modern thermometry instead of ice and steam points. (04 marks)

(c) (i) What is a **thermometric property**? (01 marks)

(ii) State **three** qualities of a good thermometric property? (03mark)

(d)(i) a constant volume thermometer was used to measure temperature when the atmospheric pressure was 760mmHg.

The following values were obtained.

	Length of Mercury in closed limb (mmHg)	Length of Mercury in open limb (mmHg)
Bulb in ice	140	130
Bulb in steam	140	330
Bulb at room temperature	140	170

Calculate the room temperature. (05marks)

(ii) List two advantages of the constant volume gas thermometer over the mercury in glass thermometer. (02 marks)

(e) Explain what happens when the temperature of a fixed mass of ice is raised from 0^0C to 10^0C. (03marks)

6. (a) Define specific heat capacity. (01 mark)
   (b) Describe, stating the assumptions made, an electrical method for the determination of the specific heat capacity of a metal. (08marks)
   (c) In an experiment to determine specific heat capacity of a liquid using the continuous flow calorimeter;
   (i) the reading are taken when the apparatus has attained a steady state. Explain the meaning of a steady state. (02marks)
   (ii) Explain why two sets of reading are taken. (01 mark)

   (d) When water is passed through a continuous flow calorimeter at the rate of 100 g min^{-1}, the temperature rises from 16^0C to 20^0C, when the p.d. across the heater is 20V and the current is 1.5A. When another liquid at 160C is passed through the calorimeter at the rate of 120 g min-1, the same temperature change is obtained at a p.d of 30V and current 1.2A. Calculate the specific heat capacity of the liquid. (04 marks)

   (e) (i)Define latent heat. (01 mark)

   (ii) Explain why latent heat of vaporisation is always greater than that of fusion

7. (a) (i) Explain how a thermocouple is used to measure temperature on a Celsius scale. (05marks)
   (ii) State two advantages of a thermocouple. (01mark)

(b) (i) Two cylindrical bodies A and B are made of the same material but the length of A is twice that of B and the cross sectional area of B is a third that of A. If the ends of A and B are subjected to same temperature difference, find the ratio of the rate of heat flow through A to the rate of heat flow through B. (03marks)

(ii) In the determination of thermal conductivity of copper, when water flows round the cool end of a copper rod at a rate of 600cm^3 per minute, its temperature increases by 3.3^{0}C. the temperature at two points, a distance 5.2cm apart, along the copper rod are 70^{0}C and 30^{0}C respectively. Find the thermal conductivity of copper if the radius of the rod is 1.2cm.

(c) Describe an experiment to measure thermal conductivity of cork. (07marks)

8. (a) What is meant by the following as applied to radioactivity?
   (i) Activity (01mark)
   (ii) Decay constant (01mark)

   (b) (i) Explain briefly, why radioactivity is referred to as random and spontaneous. (02marks)

   (ii) The half-life of $^{230}_{92}Th$ is 2.4 x 10^{11}s. Find the number of disintegration per second that occur in 1g of $^{230}_{92}Th$. (03marks)

   (c)(i) Describe, with the aid of a labelled diagram, how the Wilson cloud chamber can be used to detect ionization radiation. (06marks)

   (ii) Explain the difference in the patterns of the tracks seen in the chamber when α and β particles are present in the chamber. (02marks)

   (d) (i) What is **mass defect**. (01 mark)

   (ii) Calculate, in MeV, the energy released when helium nucleons are produced by fusing two neutrons and two protons. (04mark)

Mass of a proton	= 1.0075U
Mass of a neutron	=1.00898U
Mass of helium	= 4,00277U
1U	= 931MeV

9. (a) (i) What is meant by a **p-n junction** as applied to semiconductors? (01mark)
   (ii) Explain the term **doping** as applied to p-n junction diode. (03marks)

   (b) (i) Explain, with the aid of a labelled diagram, the I – V characteristic of a junction diode. (03 marks)
   (ii) Describe how full wave rectification can be achieved using a bridge rectifier. (04marks)

   (c) The input resistance of a certain n-p-n transistor in the common emitter connection is 3kΩ. The small current amplification transfer ratio is 100. The internal resistance of the emitter-base junction is negligible and the load resistor is 6kΩ. Find the voltage gain. (04marks)

(d) (i) Explain the mechanism of the thermionic emission. (03marks)

(ii) The gain control of a Cathode Ray Oscilloscope (C.R.O) is set at 0.5Vcm-1, and an alternating voltage produces a vertical line of length 2.0cm with the time base off. Find the root men square value of the potential difference. (02 marks)

10. (a) Define specific charge of a positive ion and state its units. (02mark)

(b) With the aid of a labelled diagram, describe how Bainbridge spectrometer can be used to determine the specific charge of positive ions. (06marks)

(c) A beam of positive ions accelerated through a potential difference of 2,000V enters a region of a uniform magnetic flux density **B**. The ions describe a circular path of radius 3.2cm while in the field. If the specific charge of the ions is 8.5 x 10^7Ckg^{-1}, derive an expression for the charge mass ratio of the ions and use it to calculate the value of **B**.

(d) State the use of each of the following features of Cathode Ray Oscilloscope (CRO):

(i) anode system (01mark)

(ii) Y-plates (01mark)

(iii) The grid.

(e) An electron with energy 5kV moves in the direction of an electric field of intensity 1.6 x 104Vm^{-1}. What distance will the electron move before coming to rest? (04marks)

Suggested answers

SECTION A

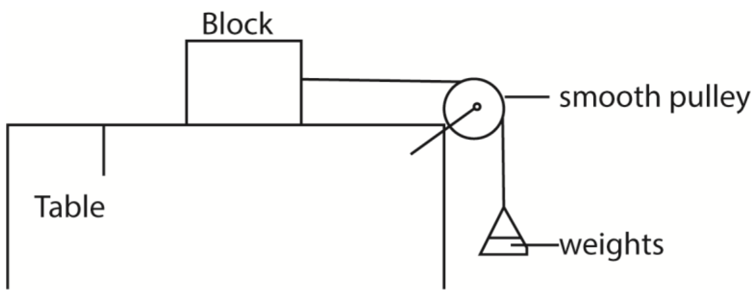
1. (a) (i) State the laws of static friction. (03 marks)

- Friction force opposes 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.

(ii) Use the molecular theory of matter to explain the law stated in (a)(i) (06 marks)

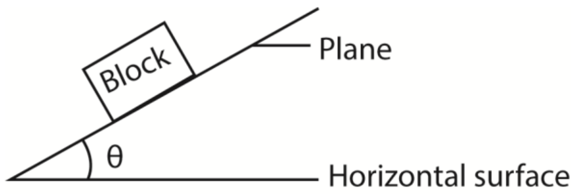
- On a microscopic level, even seemingly smooth surfaces have rough and uneven features (high and low points). When two surfaces come into contact, the high points (asperities) of one surface are welded to those of the other with strong attractions.
- Actual area of contact between solid surfaces is very small. Therefore pressure at points of contact is very high; projections emerge to produce adhesion or welding. Motion in any direction has to break the attractive force at the point of contact i.e. force which oppose motion is obtained (Law I)
- The actual area of contact is the sum of the areas of tiny projections that adhere to each other and are nearly independent of the surface areas of contact.(law II)
- Increase in weight increases the actual area of contact and hence greater limiting frictional force.(Law III)
- Also, the movement of surfaces over each other results in the conversion of kinetic energy into other forms of energy, such as heat. This energy dissipation is a fundamental aspect of friction, as it opposes the relative motion of the surfaces. (Law I)

(b) Describe briefly how to measure the limiting friction between wooden block and a plane surface. (04marks)



- A block of mass m is placed on a flat table and connected to a scale pan as shown in the diagram above.
- Small weights are added in bits on to the scale pan until the block just starts to move. The total weight of the scale pan and weights added is obtained, W_f.
- The coefficient of static friction, $\mu = \frac{W_f}{mg}$

Alternative method



- A block is placed on horizontal plane. The plane is tilted gently until the block just start to slide
- The angle of tilt θ is measured
- The coefficient of static friction, μ = tanθ

(c) A block of wood of mass 3.95kg rests on a horizontal table of height 5.0m at a distance of 6.0m from the edge of the table. A bullet of mass 50.0g moving with a horizontal velocity of 500ms^{-1} hits and gets embedded in the block. If the coefficient of dynamic friction between the block and the table is 0.3

(i) find the initial velocity of the block after collision with the bullet.

Let the initial velocity be V

By conserving momentum

0.050 x 500 = (3.95 +0.05) v

v = 6.25ms^{-1}

Hence initial velocity = 5ms^{-1}

(ii) Calculate the horizontal distance from the table to the point where the block hits the ground. (05marks)

Let the velocity of wood and bullet at the edge of the table be V

Deceleration = $\frac{0.3\ x 9.81\ x\ 4}{4}$ = 2.943

Using the third equation of motion

V^2 = (6.25)^2 – 2 x 2.943 x 6

V = 1.9356ms^{-1}

Let t = time taken for the wood to fall on the ground

Using the 2nd equation of motion

5 = $\frac{1}{2}x9.81t^2$

t = 1s

Horizontal distance moved = Vt = 1.9356 x 1 = 1.9356m

Hence the wood fell 1,9356m from the table

2. (a) Define the following as applied to materials

(i) Stress (01 mark)

Stress is force per unit area.

(ii) Young's Modulus (01 mark)

Young's modulus is the ratio of tensile stress to tensile strain

(b) The velocity of compressional waves travelling along a rod made of material of Young's Modulus, E, and density, ρ, is given by V = $\left(\frac{E}{\rho}\right)^{\frac{1}{2}}$. Show that the formula is dimensionally consistent. (02 marks)

LHS, [V] = LT^{-1} ……………………………………………… (i)

Since [E] = $ML^{-1}T^{-2}$ and [ρ] = ML^{-3}

⇨ RHS = $\left[\frac{ML^{-1}T^{-2}}{ML^{-2}}\right]^{\frac{1}{2}}$ = LT^{-1} ……………………………… (ii)

From eqn. (i) and eqn. (ii) the relation is dimensionally consistent.

(c) Derive an expression for the energy stored in a stretched wire within the elastic limit. (03marks)

Energy stored in the rod = $\frac{1}{2}Fe$

∴ Energy stored per unit volume = $\frac{\frac{1}{2}Fe}{AL}$

But F = $\frac{YAe}{L}$

Energy store per unit volume = $\frac{1}{2}\ x\ \frac{YAe.e}{AL^2} = \frac{1}{2}Y\left(\frac{e}{L}\right)^2$

Or

For a small extension, dx

Work done, dw = Fdx

From Hooke's law, F = kx

∴ $dw = kxdx$ => Total work done, w = $\int dw$

$w\ =\ \int_0^e kxdx$

Energy store = $\left|\frac{kx^2}{2}\right|_0^e$, but k = $\frac{YA}{L}$

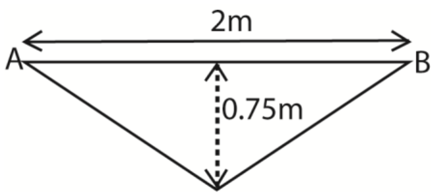
=> Energy stored = $\frac{1}{2}\ x\frac{YAe^2}{L}$

Energy stored per unit volume = $\frac{1}{2}\ x\ \frac{YAe.e}{AL^2} = \frac{1}{2}Y\left(\frac{e}{L}\right)^2$

Where is Young's modulus, e = extension, L=initial length of the rod, A = cross section 'area

(d) A uniform wire of length 2.49m is attached to two fixed points A and B, a horizontal distance 2m apart. When a 5kgmass is attached to mid-point C of the wired, the equilibrium position of C is 0.75m below the line AB. Neglecting the weight of the wire and taking Young's Modulus for the material to be 2 x $10^{11}$$Nm^{-2}$, find the

(i) strain in the wire (04 marks)



Final length of the wire = $2\sqrt{1^2 + (0.75)^2}$ =2.5m

Extension, e = 2.5 – 2.49 = 0.01m

Strain = $\frac{e}{L} = \frac{0.01}{2.49}$= 0.004

(ii) stress in the wire (02 marks)

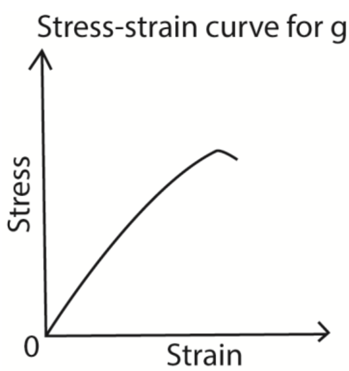
Young's modulus = $\frac{stress}{strain}$

Stress = Young's modulus x strain =$2 \times 10^{11} \times 0.25 = 8 \times 10^{8}$ Nm^{-2}

(iii) energy stored in the wire (04 marks)

Energy stored in the rod = $\frac{1}{2}Fe$ = $\frac{1}{2}x\ 5\ x\ 9.81\ x\ 0.01$ = 2.4525J

(e) (i) Sketch the stress-strain curve for glass and explain its shape. (02 marks)



Glass: has he smallest elastic region and no plastic deformation regions.

(ii) Why does glass break easily? (01 marks)

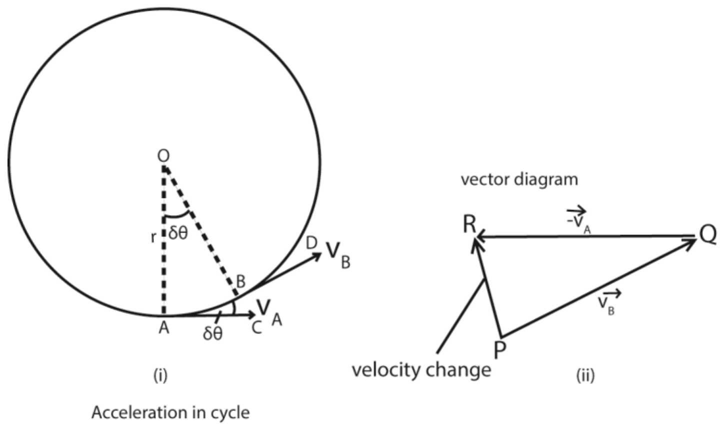
Glass is brittle due to small cracks on its surface. Any concentration of tensile stress/force on any of these cracks makes the glass break.

3. (a) (i) Define **Centripetal acceleration**. (01 mark)

This is the rate of change of velocity for a body moving in a circular path and it is directed towards the center of that circular path.

(ii) Show that force F on a body of mass M moving in a circle of radius r with constant speed V is given by $F = \frac{MV^2}{r}$. (05 marks)

Let the acceleration and velocity of a body moving in a circle of radius, r ,be a and Vrespectively



The velocity change from A to B = $v_B - v_A$ or $v_B + (-v_A)$.

In figure 2(ii) above, PQ represents v_B in magnitude (v) and direction BD; QR represents $-v_A$ in magnitude (v) and direction (CA).

Velocity change = $v_B + (-v_A)$ = PR

When δt is small, the angle AOB or δθ is small;
Also angle PQR equal to δθ is small

PR or acceleration then points toward O, the centres of the circle.

a = $\frac{velocity\ change}{time} = \frac{PR}{\delta t} = \frac{v\delta\theta}{\delta t}$

but $\frac{\delta\theta}{\delta t}$ =ω and v = rω

a = rω x ω = rω^2 but ω = $\frac{V}{r}$

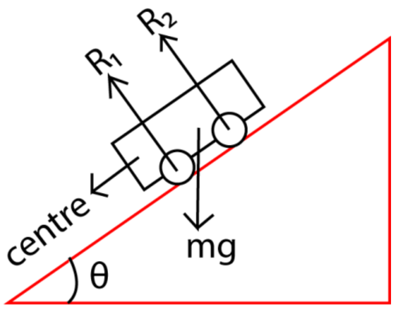
- a = $\frac{v^2}{r}$

But Force = ma

Hence $F = \frac{MV^2}{r}$.

(iv) Derive the condition for a car to move round a banked circular track without slipping. (04 marks)

Consider car negotiating a bend inclined at an angle θ to the horizontal. It is assumed that there is no tendency to slip at the wheels, therefore no frictional forces.



Resolving horizontally

$R_1\sin\theta + R_2\sin\theta = m\frac{v^2}{r}$ ……………………………(i)

Resolving vertically

$R_1\cos\theta + R_2\cos\theta = mg$ ……………………………(ii)

Eqn. (i) ÷ Eqn. (ii)

$\frac{R_1 \sin\theta + R_2 \sin\theta}{R_1 \cos\theta + R_2 \cos\theta} = {m\frac{v^2}{r}}/{mg}$

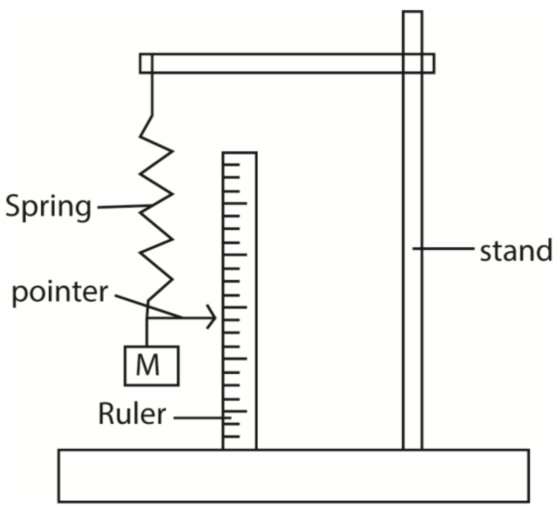
$\tan\theta = \frac{v^2}{rg}$

$v^2 = rg\tan\theta$

$v = \sqrt{rg\tan\theta}$

Hence car will not skip when $v \leq \sqrt{rg\tan\theta}$

(b) Describe how a helical spring may be used to determine the acceleration due to gravity. (05 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 = $\frac{4\pi^2}{S}$

(c) A Particle moving with simple harmonic motion has a speed of $8.0ms^{-1}$ and acceleration of $12ms^{-2}$ when it is 3.0m from equilibrium position. Find the;

(i) amplitude of motion. (03 marks)

a = $\omega^2 x$

$\omega^2 = \frac{12}{3} = 4s^{-2}$

$v^2 = \omega^2(r^2 - x^2)$

64 = 4 $(r^2 - 9)$

r = 5m

Hence amplitude = 5m

(ii) maximum acceleration. (02marks)

Maximum acceleration = r ω^2 = 5 x 4 = $20ms^{-2}$

4. (a) Define the following:

(i) Pressure. (01 mark)

Pressure is force per unit area

(ii) Relative density (01 mark)

Relative density is the ratio of density of a substance to the density of water

(b) (i) State Archimedes Principle (01 mark)

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) Describe an experiment to determine the relative density of a liquid. (04marks)

By means of a thread, determine the weight of solid in air, liquid, and water = W_1, W_2, and W_3 respectively.

R.D = $\frac{W_1 - W_2}{W_1 - W_2}$

(c) (i) Derive the expression for Bernoulli's equation. (05marks)

Derivation of Bernoulli's expression

- Considering a moving incompressible liquid, if the viscosity is negligibly small, there are no frictional forces to overcome.
- In this case the work done by the pressure difference per unit volume of a fluid flowing along a pipe steadily is equal to the gain of kinetic energy per unit volume plus the gain in potential energy per unit volume.
- Assuming the area is constant at a particular place for a short time of flow; the work done by a pressure in moving a fluid through a distance
  = force x distance moved
  = (pressure x area) x distance moved
  = pressure x volume moved,
- At the. beginning of the pipe where the pressure is P_1, the work done per unit volume on the fluid is thus P_1;
- At the other end, the work done per unit volume by the fluid is likewise P_2
- Hence the net work done on the fluid per unit volume = $P_1 - P_{21}$
- The kinetic energy per unit volume = $\frac{1}{2}$ mass per unit volume x velocity^2
  = $\frac{1}{2}\rho$ x velocity^2,
  where ρ is the density of the fluid.
  = $\frac{1}{2}\rho$ x velocity^2
- Thus if v_2 and v_1 are the final and initial velocities respectively at the end and the beginning of the pipe, the kinetic energy gained per unit volume
  = $\frac{1}{2}\rho({v_2}^2 - {v_{12}}^2)$.
- Further, if h_2 and h_1, are the respective heights measured from a fixed· level at the end and· beginning of the pipe, the potential energy gained per unit volume
  = mass per unit volume x g x (h_2 - h_1)
  = pg(h_2 - h_1).

- Thus, from the conservation of energy

$$P_1 - P_2 = \frac{1}{2}\rho({v_2}^2 - {v_{12}}^2) + \rho g(h_2 - h_1).$$

$$P_1 + \frac{1}{2}\rho {v_1}^2 + \ \rho g h_1 = P_2 + \frac{1}{2}\rho {v_2}^2 + \ \rho g h_2$$

$$\therefore P + \frac{1}{2}\rho v^2 + \ \rho g h = constant$$

Hence for streamline motion of an incompressible non-viscous fluid

"*The* sum of the pressure at any part plus the kinetic energy per unit volume pus potential energy per unit volume is always constant."

(ii) Explain why a person standing by the road side may be pulled towards the road when a very fast moving bus passes by. (03marks)

The wind close the first moving bus moves fast creating a region of lower pressure than that close to a stationary person. This creates a net force that pulls the persons toward the bus in the road.

(d) A water tight drum tied to a cable anchored on the sea-bed floats 500m beneath the sea surface as shown in figure 1.

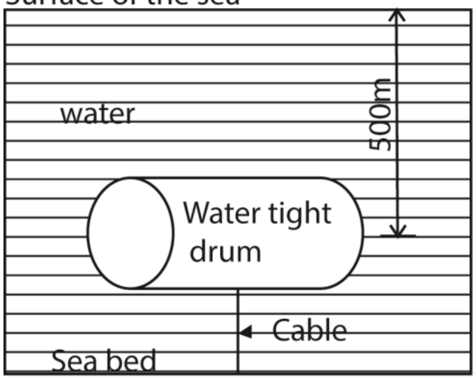


Fig. 1

If the weight of the drum is 500N and its volume 25m^3, calculate the;

(iii) pressure on the drum due to sea water. (02 marks)

pressure = hρg = 500 x 1000 x 9.81 = 4,905,000Nm^2

(iv) tension in the cable assuming it is vertical. (03 mark)

Upthrust on the drum = weight of water displaced

= vρg

= 25 x 1000 x 9.81

= 245,250N

Tension in the string =upthrust – weight of the drum

= 245,250 – 500

= 244,750N

SECTION B

5. (a) Define the following:

(i) Triple point of water (01 marks)

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

(ii) Absolute zero temperature (01mark)

It is the minimum temperature on thermodynamic scale i.e. 0K.

(b) Explain why triple point of water is taken as a standard in modern thermometry instead of ice and steam points. (04 marks)

It is constant, reproducible and not affected by pressure variations and impurities in water.

(c) (i) What is a **thermometric property**? (01 marks)

Thermometric property is a physical measurable property that varies linearly and continuously with temperature and is constant at constant temperature.

(ii) State **three** qualities of a good thermometric property? (03mark)

- should vary linearly with change in in temperature

- Should vary continuously with temperature
- Should be sensitive to temperature changes
- Should be measurable
- Should vary over a wide range of temperature.

(d)(i) a constant volume thermometer was used to measure temperature when the atmospheric pressure was 760mmHg.

The following values were obtained.

	Length of Mercury in closed limb (mmHg)	Length of Mercury in open limb (mmHg)
Bulb in ice	140	130
Bulb in steam	140	330
Bulb at room temperature	140	170

Calculate the room temperature. (05marks)

Room temperature = $\frac{170-130}{330-130}x100 = 20^0C$

(iii) List two advantages of the constant volume gas thermometer over the mercury in glass thermometer. (02 marks)

- it has a wide range
- very accurate
- very sensitive

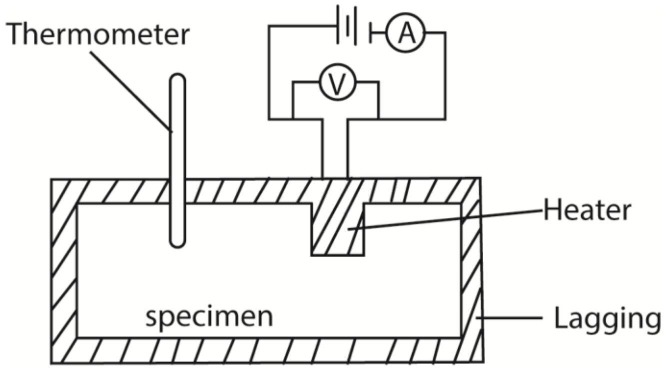
(e) Explain what happens when the temperature of a fixed mass of ice is raised from 0^0C to 10^0C. (03marks)

- Temperature remains constant until all the ice has melted and then temperature of water increases to from 0^0C to 10^0C.
- The volume decreases up to 4^0C and then increase as temperature increases to 10^0C.

6. (a) Define specific heat capacity. (01 mark)

Specific heat capacity is the amount of heat requires raising the temperature of 1kg mass of a substance by 1K or 1^0C

(b) Describe, stating the assumptions made, an electrical method for the determination of the specific heat capacity of a metal. (08marks)



- Two holes are drilled into the specimen solid of copper of mass m.
- A thermometer is inserted in one of the holes and an electric heater into the other hole. The holes are then filled with a good conducting fluid, e.g. oil to ensure thermal contact.
- The apparatus is insulated and initial temperature θ_0 is recorded.
- The heater is switched on at the same time a stop clock is started.
- The steady values of ammeter reading, I and voltmeter reading, V are recorded.
- After considerable temperature rise, the heater is switched off and stop clock stopped.
- The highest temperature θ_1 recorded and time t taken noted.
- The specific heat capacity, c, of the conducting solid is calculated from

$c = \frac{IVt}{m(\theta_1 - \theta_0)}$

Assumption

- no heat loss
- metal has good conductivity
- there is good heat transfer from the heater to the metal

(c) In an experiment to determine specific heat capacity of a liquid using the continuous flow calorimeter;

(i) the reading are taken when the apparatus has attained a steady state. Explain the meaning of a steady state. (02marks)

A steady rate occurs when the inlet and outlet thermometer readings and flow rates are constant.

(ii) Explain why two sets of reading are taken. (01 mark)

To account for heat losses.

(d) When water is passed through a continuous flow calorimeter at the rate of 100 g min^{-1}, the temperature rises from 16^{0}C to 20^{0}C, when the p.d. across the heater is 20V and the current is 1.5A. When another liquid at 16^{0}C is passed through the calorimeter at the rate of 120 g min^{-1}, the same temperature change is obtained at a p.d of 30V and current 1.2A. Calculate the specific heat capacity of the liquid. (04 marks)

Rate of dissipation heat = rate at which heat gained by water + rate of heat loss (h)

VI = mcθ + h

$20 \times 1.5 = \frac{100}{60x1000} xc\ x\ (20 - 16) + h$ ....(i)

$30 \times 1.2 = \frac{120}{60x1000} xc\ x\ (20 - 16) + h$ ....(ii)

Eqn (ii) – eqn. (i)

$6 = \frac{20}{60x1000} xc\ x4$

c = 4,500Jkg^{-1}K^{-1}

Hence specific heat capacity of the liquid is 4,500Jkg^{-1}K^{-1}.

(e) (i)Define latent heat. (01 mark)

Specific latent het of fusion is the amount of heat required to change 1kg mass of a substance from solid to liquid without change of temperature.

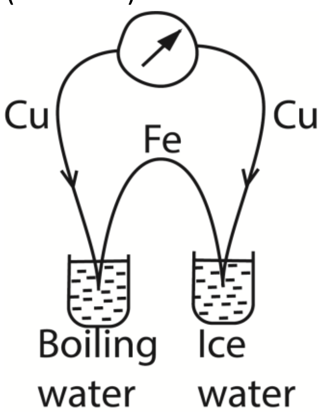
(ii) Explain why latent heat of vaporisation is always greater than that of fusion

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 it supplies both energy 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.

7. (a) (i) Explain how a thermocouple is used to measure temperature on a Celsius scale. (05marks)



The e.m.f, E_{Tr} is obtained when a hot junction is placed in water at triple point. E.m.f, E_T is obtained at unknown temperature T.

$T= \frac{E_T}{E_{Tr}}\ x\ 273.16K$

(ii) State two advantages of a thermocouple. (01mark)

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

(b) (i) Two cylindrical bodies A and B are made of the same material but the length of A is twice that of B and the cross sectional area of B is a third that of A. If the ends of A and B are subjected to same temperature difference, find the ratio of the rate of heat flow through A to the rate of heat flow through B. (03marks)

Rate of heat flow Q =$k.A.\frac{\Delta T}{L}$

Where

k = thermal conductivity of the material (which is the same for both A and B)

A = the cross-sectional area

ΔT = temperature difference

L = length of the material

$\frac{Q_A}{Q_B} = \frac{k.A.\frac{\Delta T}{2L}}{k.\frac{1}{3}A.\frac{\Delta T}{L}} = \frac{1}{2}x\frac{3}{1} = \frac{3}{2}$

Hence the ratio of the rate of heat flow through A to the rate of heat flow through B = 3:2

(ii) In the determination of thermal conductivity of copper, when water flows round the cool end of a copper rod at a rate of 600cm^3 per minute, its temperature increases by 3.3^{0}C. the temperature at two points, a distance 5.2cm apart, along the copper rod are 70^{0}C and 30^{0}C respectively. Find the thermal conductivity of copper if the radius of the rod is 1.2cm.

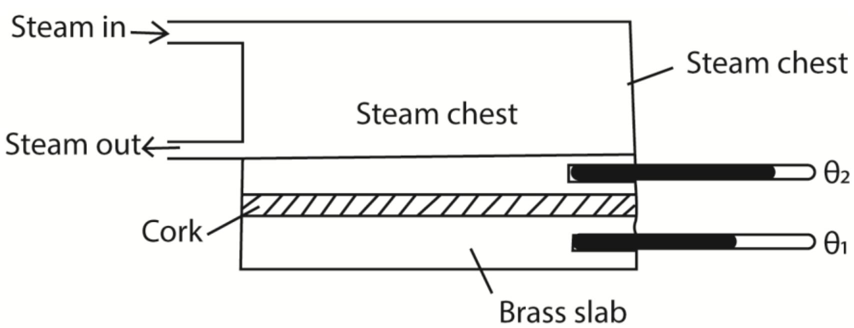
$\frac{Q}{t} = kA\left(\frac{\theta_2 - \theta_1}{L}\right) = mc_w(\theta_4 - \theta_3)$

Mass of water m kgs^{-1} =$\frac{600}{60\,x100}$= 0.01

Cross section area of copper rod = $\pi(1.2x10^{-2})^2$=$4.5239\,x\,10^{-4}$m^2

=> $kx4.5239\,x\,10^{-4}\left(\frac{70-30}{0.052}\right) = 0.01\,x\,4200\,x3.3$ =398.3Wm^{-1}K^{-1}

(c) Describe an experiment to measure thermal conductivity of cork. (07marks)



- Cork iscut 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^{0}C above θ_1.
- Steam chest is removes and the top of the glass slab is covered by the cork disc.
- The temperature of the slab is recorded at suitable time interval until its temperature is about 10^{0}C below θ_1.
- A graph of temperature against time is plotted and its slope s determined at θ_1

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

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

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

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

SECTION C

8. (a) What is meant by the following as applied to radioactivity?

(i) Activity (01mark)

Activity is the number of atoms disintegrating per second

(ii) Decay constant (01mark)

Decay constant is the fractional number of disintegrations per second.

(b) (i) Explain briefly, why radioactivity is referred to as random and spontaneous. (02marks)

Radioactivity is referred to as random because it is unpredictable; we cannot predict when a particular nucleus will decay and spontaneous because it occurs naturally and does not require any external trigger or influence

(ii) The half-life of $^{230}_{92}Th$ is 2.4 x 10^{11}s. Find the number of disintegration per second that occur in 1g of $^{230}_{92}Th$. (03marks)

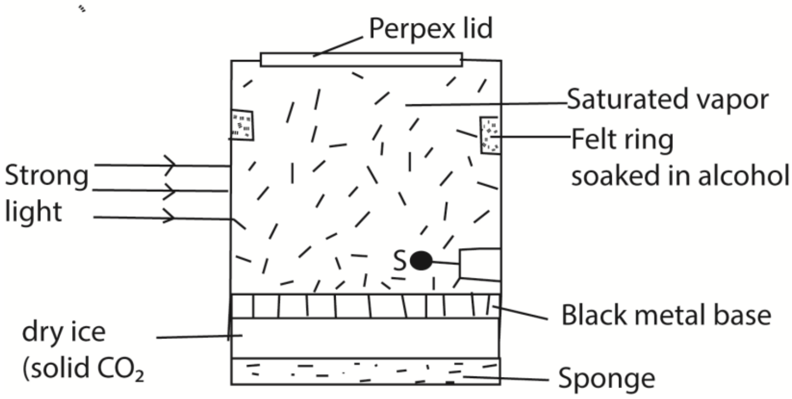
Decay constant, λ = $\frac{In2}{t_{\frac{1}{2}}} = \frac{In2}{2.4\ x 10^{11}}$ s^{-1}

Number of atoms, N, in 1g of $^{230}_{92}Th = \frac{1}{230} x\ 6.02x10^{23}$ atoms/mol

Activity, A = λN = $\frac{In2}{2.4\ x10^{11}} x \frac{1}{230} x\ 6.02x10^{23}$ = 7.56 x $10^{9}s^{-1}$

(c)(i) Describe, with the aid of a labelled diagram, how the Wilson cloud chamber can be used to detect ionization radiation. (06marks)

The diffusion cloud chamber



- 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 different types of radiation can be identified based on the characteristics of the tracks they leave in the cloud chamber

(ii) Explain the difference in the patterns of the tracks seen in the chamber when α and β particles are present in the chamber. (02marks)

- **Alpha particles** produce thick, short, and straight tracks.
- **Beta particles** produce thinner, longer, and often curved or zigzag tracks.

(d) (i) What is **mass defect**. (01 mark)

Mass defect is the difference in mass of constituent nucleons and the nucleus of an atom

(ii) Calculate, in MeV, the energy released when helium nucleons are produced by fusing two neutrons and two protons. (04mark)

Mass of a proton = 1.0075U

Mass of a neutron =1.00898U

Mass of helium = 4,00277U

1U = 931MeV

Mass of nucleons in Helium = 2 x 1.0075 + 2 x 1.00898 = 4.03296U

Mass defect = 4.03296 – 4.00277 =0.03019U

Energy released = 0.03019 x 931 = 28.10689MeV

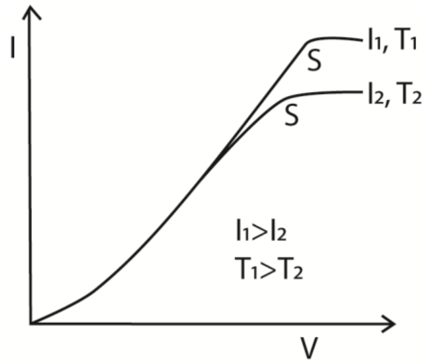
9. (a) (i) What is meant by a **p-n junction** as applied to semiconductors? (01mark)

A **p-n junction** is a joint formed when a p-type semiconductor (which has an abundance of positive charge carriers called holes) is joined with an n-type semiconductor (which has an abundance of negative charge carriers called electrons).

(ii) Explain the term **doping** as applied to p-n junction diode. (03marks)

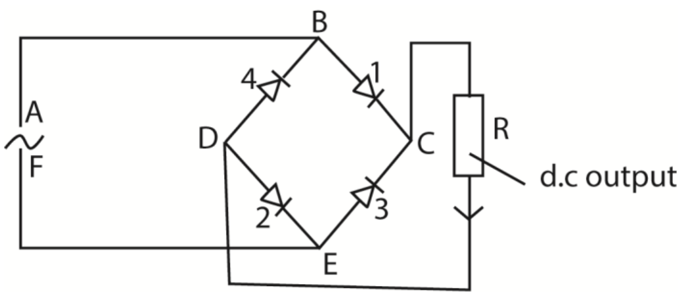
Doping is the process of intentionally introducing impurities into an intrinsic (pure) semiconductor to modify its electrical properties.

(b) (i) Explain, with the aid of a labelled diagram, the I – V characteristic of a junction diode. (03 marks)

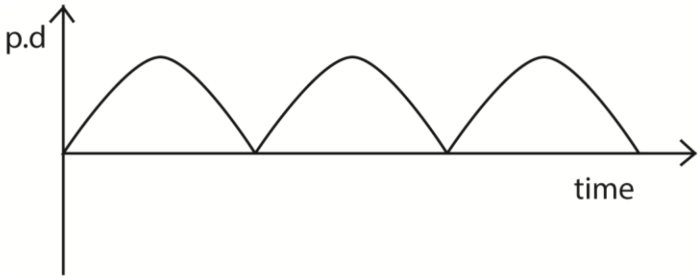


- **At low anode voltages up S**, the anode current increases rapidly due rapid increase in the number electrons collected from cathode with increase in voltage up to S. In this region, the anode current is limited by the thermionic emission from the cathode.
- **In the space charge limited region around S**, the increase in anode current slows down. In this region, the current is limited by the space charge effect, where the repulsion between electrons in the space between the cathode and anode limits the flow of current.
- **At high anode voltages beyond S**, the anode current saturates and becomes nearly constant because the anode is collecting all electrons from the cathode. In this region, the anode current is primarily limited by the thermionic emission rate of electrons from the cathode.
- **At high temperature T_1,** more electrons and hence more current $I_1$are liberated than I_2 at low temperature T_2.

(ii) Describe how full wave rectification can be achieved using a bridge rectifier. (04marks)



- Four diodes are arranged in a bridge network as shown above.
- If A s positive during the first half cycle, diode 1 and 2 conduct and current takes the path ABCRDEF
- In the next half cycle when F is positive, diode 3 and 4 conduct and current flows through the path FECRDBA
- Once again current flows through R in the same direction during both cycle of input and d.c output is obtained.



(c) The input resistance of a certain n-p-n transistor in the common emitter connection is 3kΩ. The small current amplification transfer ratio is 100. The internal resistance of the emitter-base junction is negligible and the load resistor is 6kΩ. Find the voltage gain. (04marks)

The voltage gain $A_v = -\beta\left(\frac{R_c}{R_{in}}\right)$

Where β is the current amplification factor = 100

R_c is the load resistor = 6kΩ

R_{in} is theinput resistance = 3kΩ

By substitution $A_v = -100\left(\frac{6k\Omega}{3k\Omega}\right)$ = -200

The negative sign indicates a phase inversion between the input and output signals. So, the voltage gain of the transistor is −200-200.

(d) (i) Explain the mechanism of the thermionic emission. (03marks)

- **Thermionic emission** is the phenomenon where electrons are emitted from a hot metal.
- Heat supplies kinetic energy electrons of a metal which makes them vibrate vigorously.

- If an electron gains energy above its work function it escapes from the surface with kinetic energy equal to the difference between the energy supplied and the work functions of an electron.
- In a vacuum tube or similar device, the emitted electrons can be collected by an anode, creating a flow of electric current. This flow of electrons is referred to as **thermionic current**.

(iii) The gain control of a Cathode Ray Oscilloscope (C.R.O) is set at $0.5Vcm^{-1}$, and an alternating voltage produces a vertical line of length 2.0cm with the time base off. Find the root men square value of the potential difference. (02 marks)

V_{peak}= Gain control x length of vertical line = 0.5 x 2 = 1.0V

$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{1.0}{\sqrt{2}}$= 0.707V

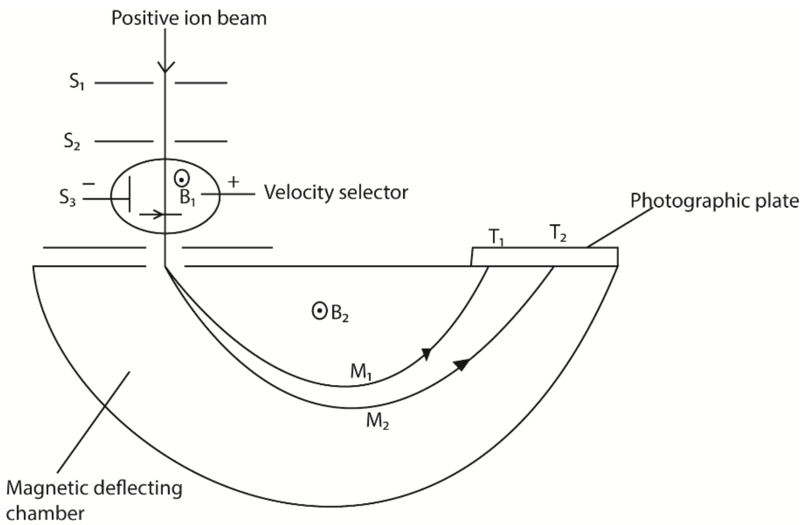
10. (a) Define specific charge of a positive ion and state its units. (02mark)

Specific charge of a positive ion is defined as the ratio of the charge Q of the ion to its mass (m)

i.e. specific charge = Q/m

Units are coulombs per kilogram (C/kg)

(b) With the aid of a labelled diagram, describe how Bainbridge spectrometer can be used to determine the specific charge of positive ions. (06marks)



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

Mode of Action

- Positive ions are produced in a discharge tube and admitted as a beam through slits S_1 and S_2.
- The beam then passes between insulated plates P, Q, connected to a battery, which create an electric field of intensity E.

- A uniform magnetic field B_1, perpendicular to E is applied over the region of the plates and all ions, charge e with the same velocity, v given by $B_1ev = Ee$ will then pass undeflected through the plates and through a slit S_3.
- The selected ions are deflected in a circular path of radius r by a uniform perpendicular magnetic field B_2 and an image is produced on a photographic plate as shown.

  In this case

  $$\frac{mv^2}{r} = B_2 ev$$

  $$\therefore \frac{m}{e} = \frac{rB_2}{v}$$

  But for the ions selected v = $\frac{E}{B_1}$ from above

  Specific charge, $\frac{e}{m} = \frac{E}{rB_2B_1}$

(c) A beam of positive ions accelerated through a potential difference of 2,000V enters a region of a uniform magnetic flux density **B**. The ions describe a circular path of radius 3.2cm while in the field. If the specific charge of the ions is 8.5 x 10^7Ckg^{-1}, derive an expression for the charge mass ratio of the ions and use it to calculate the value of **B**.

Derivingthe charge to Mass ratio (specific charge

The force on a charged particlemoving in a magnetic field is given by the Lorentz force

F = qvB

For circular motion, the centripetal force, F = $\frac{mv^2}{r}$

Equating the forces qvB = $\frac{mv^2}{r}$

$$v = \frac{qBr}{m} \text{ .... (i)}$$

-

But kinetic energy (K.E) gained by the ion when accelerated through a potential difference (V) is

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

$$v^2 = \frac{2qV}{m} \text{ .... (ii)}$$

Equating (i) and (ii)

$$\left(\frac{qBr}{m}\right)^2 = \frac{2qV}{m}$$

$$\frac{q}{m} = \frac{2V}{B^2r^2}$$

Calculating B

$$B^2 = \frac{2V}{\left(\frac{q}{m}\right)r^2} = \frac{2\,x 2{,}000}{8.5\,x\,10^7 x(0.032)^2}$$

B =0.2144T

(d) State the use of each of the following features of Cathode Ray Oscilloscope (CRO):

(i) anode system (01mark)

Anode accelerates electrons

(ii) Y-plates (01mark)

Y-plates deflect electrons vertically

(iii) The grid.

Grid G controls number of electrons reaching the screen

(e) An electron with energy 5kV moves in the direction of an electric field of intensity 1.6 x 104Vm^{-1}. What distance will the electron move before coming to rest? (04marks)

Given data

- Energy of the electron (E) = 5 x 10^3V
- Electricfield intensity = 1.6 x 10^4V/m
- Charge of the electron (q) = 1.6 x 10-19C (Note : We will use the agnitude since direction is considered in the field)

Kinetic Energy

The initial kinetic energy (KE) on the electron is

KE = qV

= (1.6 x 10^{-19}C)(5 x 10^3V)

= 8 x 10^{-16}J

Work done by Electric Field

The work done (W) by the electric Field on the electron to it rest is given by

W = qE_{field} . d

Whered is the distance moved by the electron before coming to rest

K.E = qE_{field} . d

d = $\frac{K.E}{qE_{fied}} = \frac{8x\ 10^{-16}}{1.6\ x\ 10^{-19}x\ 1.6\ x\ 10^4}$ =0.3125m (4d.p)

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