UACE 2022 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	= 1.8×10^{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) Define the following

(i) Brittleness (01 mark)

(ii) Elasticity (01mark)

(b) Stat Hooke's law (01mark)

(c) Figure 1 chows graphs of stress against strain for two metals X and Y.

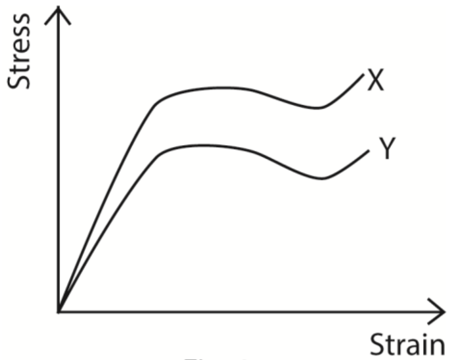


Fig. 1

State and explain which metal;

(i) has a greater Young's modulus, (02marks)

(ii) is more ductile, (02 marks)

(iii) is stronger than the other. (02marks)

(d) Two wires P and Q of the same material have equal length but the radius of P is twice that of Q. Which wire;

(i) can withstand the greater load before breaking? (02marks)

(ii) has the greater strain for a given load? (02 marks)

(e) A copper wire of length 4m and cross sectional area $1.0 \times 10^{-3}mm^2$ is fixed between two rigid supports A and B, 4m apart. What mass, when suspended at the middle of the wire will produce sag of 1.5m at that point?

(*Young's modulus of copper = 1.2×10^{11} Pa*) (04marks)

(f) Explain why water flowing out of a small hole at the bottom of a wide tank results in a backward force on the tank. (03marks)

2. (a) (i) What is meant by dimension of a physical quantity? (01 mark)

(ii) The velocity, v of a wave of wavelength, λ, on the surface of a liquid of surface tension, γ and density, ρ, is given by $x^2 = \frac{\lambda g}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$, where g is the acceleration due to gravity.

Show that the equation is dimensionally consistent. (03marks)

(b) Figure 2 shows acceleration-time graph for a body of mass 10kg which starts from rest and moves in a straight line.

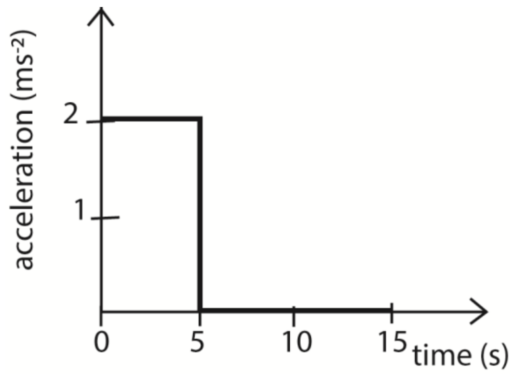


Fig. 2

Use the graph to find the;

(i) Distance travelled in 15s (04marks)

(ii) Average force acting on the body over the 15s. (03 marks)

(c) With examples, explain any two of Newton's laws of motion. (04marks)

(d) (i) State the principle of conservation of linear momentum. (01 mark)

(ii) A particle of mass M_1 moving with a velocity, U_1 collides with a stationary particle of mass, M_2. The collision is elastic and velocities of M_1 and M_2 after impact are v1 and v_2 respectively. If the particles move in the same direction and $\alpha = \frac{M_1}{M_2}$, show that $U_1 = v_1\frac{(1+\alpha)}{(1-\alpha)}$. (04 marks)

3. (a) (i) State **Bernoulli's principle**. (02 marks)

(ii) Explain with the aid of a diagram, why air flows over the wings of an aircraft causes a lift. (02 marks)

(b) Air flows over the upper surface of an aircraft's wings ate a speed of $135ms^{-1}$ and passed the lower surfaces of the wing at a speed of $120ms^{-1}$.

(i) Calculate the pressure difference due to the flow. (02marks)

(ii) Determine the lift force on the aircraft if the total wing area is $28m^2$. (*Assume the density of air is 1.2kgm*$^{-3}$) (02marks)

(c) (i) What is meant by **streamline flow**? (02marks)

(ii) With the aid of a labelled diagram, describe how the velocity of a fluid can be measured. (05 marks)

(d) The depth of water in a tank of a large cross-sectional area is maintained at 2.0m. If the water emerges out of the tank continuously through a hole of diameter 5mm drilled at a height of 10cm above the base of the tank, calculate the;

(i) speed at which water emerges out from the hole. (03marks)

(ii) rate of mass flow of water from the hole. (02marks)

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

(ii) Explain why a body moving with constant speed along a circular path has an acceleration. (03 marks)

(iii) Derive an expression for the acceleration of a body moving in a circular path of radius r with a constant speed V. (04marks)

(b) Define the following:

(i) Projectile motion (01mark)

(ii) Angular projection (01 mark)

(c) An object P is projected vertically upwards from the ground with a speed of $36ms^{-1}$. If object Q is dropped vertically above P from height of 90m above the ground after 2s, find the;

(i) time when P and Q collide, from the time P was thrown upwards.(07 marks)

(ii) height above the ground where P and Q collide. (03marks)

SECTION B

5. (a) Define the following:

    (i) specific heat capacity (01 mark)

    (ii) specific latent heat of vaporization. (01mark)

   (b) With the aid of a labelled diagram, describe an experiment to determine the specific latent heat of vaporization of a liquid. (07 marks)

   (c) The inlet and outlet temperatures of water flowing in a continuous flow method are 15.2^0C and 17.4^0C respectively. A flow rate of 20 g min^{-1} is obtained when a current of 2.3A flows and a p.d of 3.3V is applied. When oil, which flows in and out at the same temperatures as water is used, the flow rate obtained is 70.0 g min^{-1}. Calculate the specific heat capacity of the oil, if a p.d 3.9V is applied and a current of 2.7A flows. (05 marks)

   (d) Explain the effect of pressure on:

    (i) boiling point of a liquid. (03marks)

    (ii) Melting point of ice. (03 marks)

6. (a) Define the following:

    (i) Molar heat capacity of a gas at constant pressure. (01mark)

    (ii) Molar heat capacity of a gas at constant volume. (01mark)

   (b) Derive the expression Cp –Cv = R, where Cp is the molar heat capacity of a gas at constant pressure and Cv is the molar heat capacity of a gas at constant volume and R is the gas constant. (05marks)

   (c) (i) Differentiate between **adiabatic** and **isothermal** expansions. (02marks)

    (ii) State **two** examples of adiabatic changes. (01marks)

   (d) A fixed mass of an ideal gas of volume $400cm^3$ at 15^0C expands adiabatically and its temperature falls to 0^0C. It is then compressed isothermally until the pressure returns to its original value. If the molar heat capacity at constant pressure is 28.6 J $mol^{-1}K^{-1}$, calculate the final volume after isothermal compression. (05marks)

   (e) (i) What is **saturated vapour pressure** of a liquid? (01mark)

    (ii) Describe an experiment to show that a liquid boils when its saturated vapour pressure equals to the atmospheric pressure. (04marks)

7. (a) Define the following:
   (i) Temperature gradient (01 mark)
   (ii) Thermal conductivity. (01 marks)

   (b) Explain why a poor conductor whose thermal conductivity is to be determined, must be thin and fairly of large surface area. (03marks)

   (c) With the aid of a labelled diagram, describe how the presence of radiation is detected by a bolometer connected to Wheatstone bridge. (06marks)

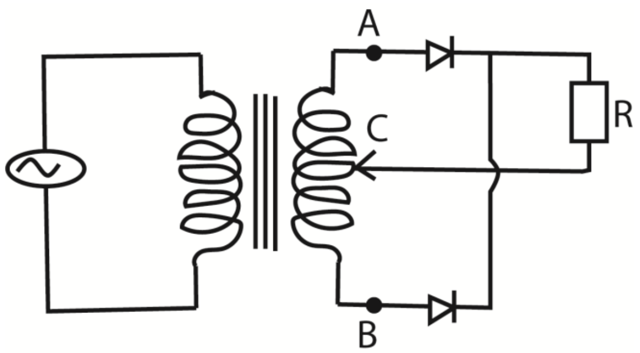
   (d) A metal sphere whose surface acts as a black body is placed at the principal focus of a concave mirror of diameter 60cm, which is directed towards the sun. If the solar radiation falling normally on the earth is $1400Wm^{-2}$, and the mean temperature of the surrounding is 30^0C, find the diameter of the sphere when the maximum temperature it attains is 1870^0C. (06marks)

   (e) State **three** properties of radiant energy. (03marks)

SECTION C

8. (a) State any four properties of cathode rays. (02marks)
   (b) Show that the path of an electron projected at right angles to a uniform electric field is a parabola. (05 marks)
   (c) Two metal plates each 5.0cm long are held horizontally 4.0cm apart in a vacuum, one being vertically above the other. The upper plate is at a potential of 400V while the lower one is earthed. Electrons having a velocity of $1.0 \times 10^7 ms^{-1}$ enter horizontally mid-way between the plates and in a direction parallel to the 5.0cm edge. Calculate the vertical deflection of the electron as it emerges from the plates. (04marks)
   (d) (i) With the aid of a labelled diagram, describe how the specific charge of positive rays may be determined. (06marks)
   (ii) Explain how the set up in (d)(i) can be used to determine the abundance of isotopes. (03 marks)

9. (a) What is meant by **thermionic emission**? (01 mark)
   (b) (i) Sketch the anode current versus anode voltage characteristics of thermionic diode. (02 marks)
   (ii) Explain the main features of the curves. (05marks)
   (c) (i) With the aid of a diagram, describe the operation of a Cathode ray oscilloscope (C.R.O) (06marks)
   (ii) Describe the use of a time base in a C.R.O. (02marks)
   (d) Explain the wave form obtained on a C.R. O connected across the resistor R in the circuit shown in Figure 3.



10. (a) State two characteristics of a photoelectric emission. (02 marks)

(b) (i) State three advantages of nuclear fusion over nuclear fission as a potential source of energy

(ii) Why does nuclear fusion take place only at high temperatures? (01mark)

(c) Given that;

Mass of a proton	= 1.0073U
Mass of an electron	= 0.0005U
Mass of a neutron	= 1.0087U and
Mass of $^{227}_{87}Fr$	= 223.0198U

(i) Calculate the difference in the mass between $^{227}_{87}Fr$ nucleus and the sum of the masses of its nucleons.

(ii) How is the difference in the masses in (c)(i)accounted for? (02marks)

(d) (i) State **three** uses of X-rays. (03marks)

(ii) Explain how quantum theory provides an explanation for the photoelectric effect. (04marks)

Suggested answers

SECTION A

1. (a) Define the following

(i) Brittleness (01 mark)

A brittle material is a substance that breaks easily when a force is exerted on it e.g. glass

Or

Brittleness describes the property of a material that fractures when subjected to stress but has little tendency to deform before rupture.

(ii) Elasticity (01mark)

Elasticity is **ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed**.

(b) Stat Hooke's law (01mark)

Hooke's law states that the extension of a material is proportional to the stretching force provided the elastic limit is not exceeded.

(c) Figure 1 chows graphs of stress against strain for two metals X and Y.

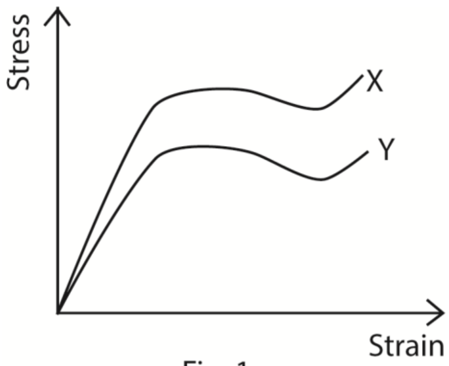


Fig. 1

State and explain which metal;

(i) has a greater Young's modulus, (02marks)
X has high stress per unit of strain

(ii) is more ductile, (02 marks)
Y Stretches more per given stress leading to low Youngers modulus

(iii) is stronger than the other. (02marks)
X resists deformation

(d) Two wires P and Q of the same material have equal length but the radius of P is twice that of Q. Which wire;

(iii) can withstand the greater load before breaking? (02marks)
P because it produces lower strain for the same load

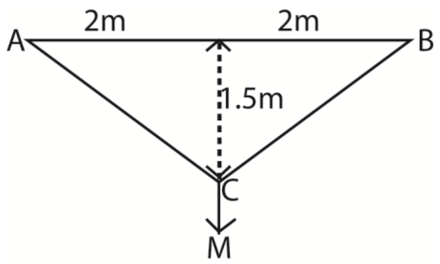
(iv) has the greater strain for a given load? (02 marks)

Q because it experienced larger increase in length

(e) A copper wire of length 4m and cross sectional area 1.0 x $10^{-3}mm^2$ is fixed between two rigid supports A and B, 4m apart. What mass, when suspended at the middle of the wire will produce sag of 1.5m at that point?

(*Young's modulus of copper = 1.2 x 10^{11}Pa*) (04marks)

Let the mass be M kg



Length of the of the stretched wire = $2\sqrt{2^2 + (1.5)^2}$ = 5m

Extension = 5 – 4 = 1m

$$\text{E} = \frac{Tensile\ stress}{Tensile\ strain} = \frac{F}{A} \div \frac{e}{L} = \frac{FL}{eA}$$

$$1.2\ x\ 10^{11} = \frac{M\ x\ 9.81\ x\ 4}{1\ x\ 1x10^{-3}x10^{-6}}$$

$$M = 3.0581kg$$

(f) Explain why water flowing out of a small hole at the bottom of a wide tank results in a backward force on the tank. (03marks)

When a **fluid** is **flowing out of** a **small hole** in a vessel, it acquires a large velocity and hence possesses large momentum. Since, no external **force** is acting on the system, a **backward** velocity must be attained by the vessel (according to law of conservation of momentum) is experienced by the vessel.

2. (a) (i) What is meant by dimension of a physical quantity? (01 mark)

Dimensions of a physical quantity is the way it is related to fundamental quantities; mass, length and time

(ii) The velocity, v of a wave of wavelength, λ, on the surface of a liquid of surface tension, γ and density, ρ, is given by $v^2 = \frac{\lambda g}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$, where g is the acceleration due to gravity.

Show that the equation is dimensionally consistent. (03marks)

Dimensions of $v^2 = (LT^{-1})^2 = L^2T^{-2}$

Dimensions of λ = L

Dimensions of $= \frac{\lambda g}{2\pi} = \frac{L(LT^{-2})}{1} = L^2T^{-2}$

Dimensions of γ = $Nm^{-1} = MT^{-2}$

Dimension of ρ = ML^{-3}

Dimensions of $\frac{2\pi\gamma}{\lambda\rho} = (MT^{-2})(L^{-1})(M^{-1}L^{3})$ = L^2T^{-2}

Since the dimensions of $v^2, \frac{\lambda g}{2\pi}, \frac{2\pi\gamma}{\lambda\rho}$ are the same, the equation is dimensionally consistent.

(b) Figure 2 shows acceleration-time graph for a body of mass 10kg which starts from rest and moves in a straight line.

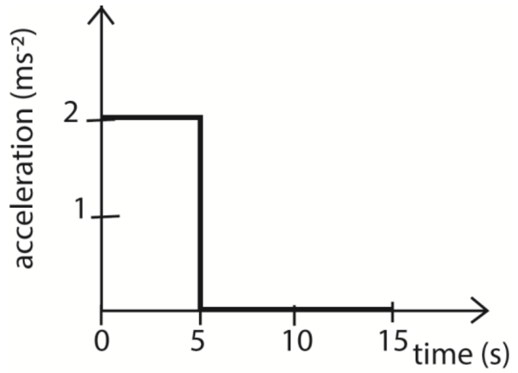


Fig. 2

Use the graph to find the;

(i) Distance travelled in 15s (04marks)

Final velocity, V, after 5 second = at = $10ms^{-1}$

Distance travelled =$\frac{1}{2}at^2 + Vt\,\frac{1}{2}x2x5^2 + 10\ x\ 10$ = 125

(ii) Average force acting on the body over the 15s. (03 marks)

Force = ma =10 x 2 = 20N

(c) With examples, explain any two of Newton's laws of motion. (04marks)

- A body continues in its state of rest or uniform motion in a straight line unless acted upon by an external force.
  For example a book remains stationed on a table until an external force is applied or a moving ball on flat smooth surface will keep rolling indefinitely at the same speed and in the same direction unless friction from the ground or an obstacle (like a player's foot) acts on it to change its state of motion.
- The rate of change of momentum of a body is directly proportional to applied force and takes place in the direction of the force.
  Examples:
  Pushing a Cart: If you push an empty shopping cart, it accelerates more quickly compared to when it is full of groceries. This is because the mass of the empty cart is less, so a given force results in greater acceleration. Conversely, the same force applied to the heavier cart results in less acceleration.
  Car Acceleration: When you press the gas pedal in a car, the engine generates a force that accelerates the car. The heavier the car (more mass), the more force is needed to achieve the same acceleration.

- For every action, there is an equal and opposite reaction

(a). Rocket Propulsion:

- **Action**: The rocket expels exhaust gases out of its engines at high speed.
- **Reaction**: The rocket itself is pushed in the opposite direction, propelling it forward. This is how spacecraft and rockets are launched into space.

(b). Walking:

- **Action**: When you walk, your foot pushes backward against the ground.
- **Reaction**: The ground pushes your foot forward with an equal and opposite force, propelling you ahead.

(c). Swimming:

- **Action**: When a swimmer pushes the water backward with their hands and feet.
- **Reaction**: The **water** pushes the swimmer forward, allowing them to move through the water.

(d). Bird Flight:

- **Action**: Birds **push** down and backward with their wings.
- **Reaction**: The air pushes the bird up and forward, enabling flight.

(e). Recoil of a Gun:

- **Action**: When a bullet is fired, the gun exerts a force on the bullet to propel it forward.
- **Reaction**: The bullet exerts an equal and opposite force on the gun, causing it to recoil backward.

(d) (i) State the principle of conservation of linear momentum. (01 mark)

If the resultant force on a system of interacting bodies is zero; total linear momentum is conserved.

(ii) A particle of mass M_1 moving with a velocity, U_1 collides with a stationary particle of mass, M_2. The collision is elastic and velocities of M_1 and M_2 after impact are v_1 and v_2 respectively. If the particles move in the same direction and $\alpha = \frac{M_1}{M_2}$, show that $U_1 = v_1\frac{(1+\alpha)}{(1-\alpha)}$. (04 marks)

From principle of conservation of momentum

$M_1U_1 + M_2U_2 = m_1v_1 + M_2v_2$ but $U_2 = 0$

⇨ $M_1U_1 = M_1v_1 + M_2v_2$

$v_2 = \frac{M_1U_1 - mM_1v_1}{M_2}$ =αU1 – αv₁ = α(U₁ – v₁) …………….. (i)

For an elastic collision, total kinetic energy is conserved.

Hence: $\frac{1}{2}M_1U_1^2 = \frac{1}{2}M_1v_1^2 + \frac{1}{2}M_2v_2^2$

$$M_1U_1^2 = M_1v_1^2 + M_2u_2^2 \text{.........................} \quad (ii)$$

Substituting Eqn. (i) in eqn. (ii)

$$M_1u_1^2 = M_1v_1^2 + m_2\big(\alpha(U_1 - v_1)\big)^2$$

Divide both sides by m_2

$$\alpha u_1^2 = \alpha v_1^2 + \big(\alpha(U_1 - v_1)\big)^2$$

$$\Rightarrow \alpha(U_1^2 - v_1^2) = \alpha^2 (U_1 - v_1)^2$$

$$(U_1 + v_1)(U_1 - v_1) = \alpha(U_1 - v_1)^2$$

$$(U_1 + v_1) = \alpha(U_1 - v_1)$$

Collecting like terms

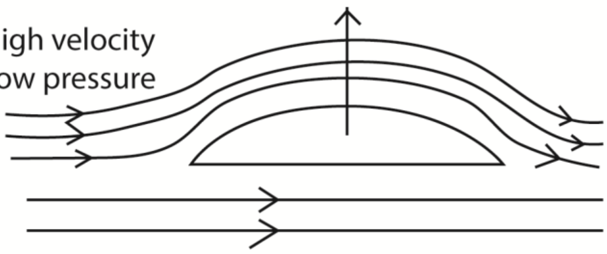
$v_1(\alpha +1) = u_1(\alpha-1)$

$$U_1 = v_1 \left(\frac{X+1}{X-1}\right)$$

3. (a) (i) State **Bernoulli's principle**. (02 marks)

For non- viscous incompressible fluid, flowing steadily, the sum of the pressure, kinetic energy and potential energy per unit volume is constant.

(ii) Explain with the aid of a diagram, why air flows over the wings of an aircraft causes a lift. (02 marks)



- Air flows above the wing of a plane at high velocity hence low pressure.
- Below the wings, air flows at low velocity and hence high pressure.
- The difference in pressure causes a lift force, therefore net upward force.

(b) Air flows over the upper surface of an aircraft's wings at a speed of $135ms^{-1}$ and passed the lower surfaces of the wing at a speed of $120ms^{-1}$.

(i) Calculate the pressure difference due to the flow. (02marks)

From P + $\frac{1}{2}\rho v^2 + \rho gh$

Assuming the difference in height is negligible;

Difference in pressure = $\frac{1}{2}x1.2(135^2 - 120^2)$ = 2,295Pa

(iii) Determine the lift force on the aircraft if the total wing area is $28m^2$. (*Assume the density of air is $1.2kgm^{-3}$*) (02marks)

F = pressure x area

= 2.295 x 28

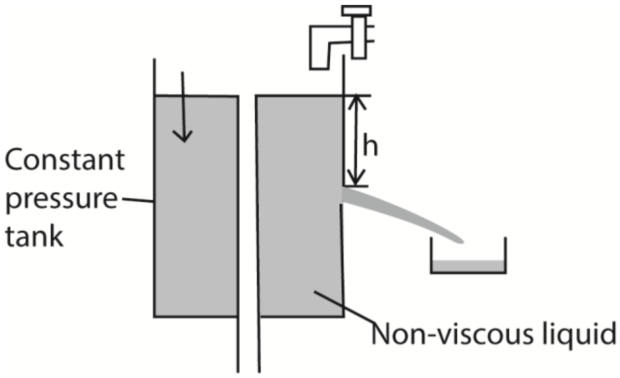
= 64, 260N

(c) (i) What is meant by **streamline flow**? (02marks)

Laminar/streamline flow occurs when the fluid flows in tiny parallel layers with no disruption between them. The successive particles passing a given point have the same velocity.

(ii) With the aid of a labelled diagram, describe how the velocity of a fluid can be measured. (05 marks)

Experiment to determine the velocity of fluid



1. A hole of diameter, r, is known is made through constant pressure apparatus
2. Volume of liquid V flowing out of the hole in time t is measured.
3. Velocity of the fluid $=\frac{V}{t}\,(cm^3s^{-1})$

(d) The depth of water in a tank of a large cross-sectional area is maintained at 2.0m. If the water emerges out of the tank continuously through a hole of diameter 5mm drilled at a height of 10cm above the base of the tank, calculate the;

(i) speed at which water emerges out from the hole. (03marks)

Height of water above the hole = 2 – 0.1 = 1.9m

Pressure of water at the hole = hρg= 1.9 x 1000 x 9.81 = $\frac{1}{2}\rho v^2$=$\frac{1}{2}x1000v^2$

v = 61.1ms^{-1}

(ii) rate of mass flow of water from the hole. (02marks)

Volume per second = Area of hole x speed of water

$$= \pi\left(\frac{5\,x\,10^{-3}}{2}\right)^2 x61.1$$

= 1.2 x$10^{-3}m^3s^{-1}$

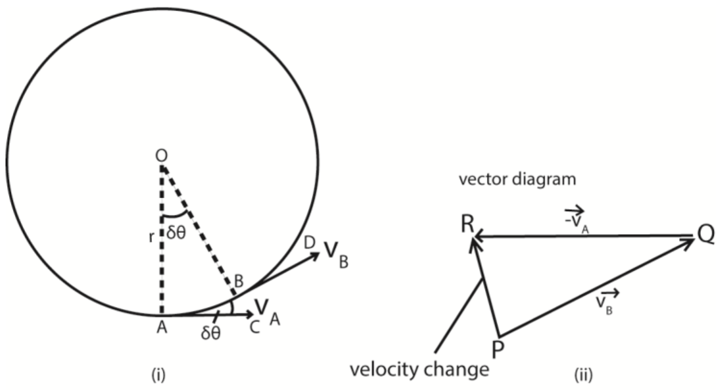
4. (a) (i) Define angular velocity. (01mark)

Angular velocity is the rate of change of angular displacement.

(ii) Explain why a body moving with constant speed along a circular path has an acceleration. (03 marks)

Acceleration is a rate of change of velocity with respect to time. In the **circular motion**, the **speed** of the **body** is **constant** but velocity changes continuously due to changes of its direction. Hence it is an **accelerated** motion

(iii) Derive an expression for the acceleration of a body moving in a circular path of radius r with a constant speed V. (04marks)



Acceleration in cycle

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 = $r\omega^2$ but ω = $\frac{V}{r}$

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

(b) Define the following:

(i) Projectile motion (01mark)

Projectile motion is motion of the body which after being given an initial velocity moves under the influence of gravity.

(ii) Angular projection (01 mark)

Is the motion of a body thrown at an angle to the horizontal

(c) An object P is projected vertically upwards from the ground with a speed of $36ms^{-1}$. If object Q is dropped vertically above P from height of 90m above the ground after 2s, find the;

(i) time when P and Q collide, from the time P was thrown upwards.(07 marks)

Let the time taken by P before collision; then that of Q = (t -2)

Distance moved by P = $36t - ½ \times 9.81t^2$

Distance moved by Q = $½ \times 9.81(t-2)^2$

Total distance = 90 = $36t - ½ \times 9.81t^2 + ½ \times 9.81(t-2)^2$

90= $36t - 4.905t^2 + 4.905(t^2 - 4t + 4)$

90 = 36t -19.62t + 19.62

16.38t = 70.38

t = 4.3s

(ii) height above the ground where P and Q collide. (03marks)

distance = 36t – ½ x 9.81t^2

=36 x 4.3 -½ x 9.81$(4.3)^2$

= 64.1

SECTION B

5. (a) Define the following:

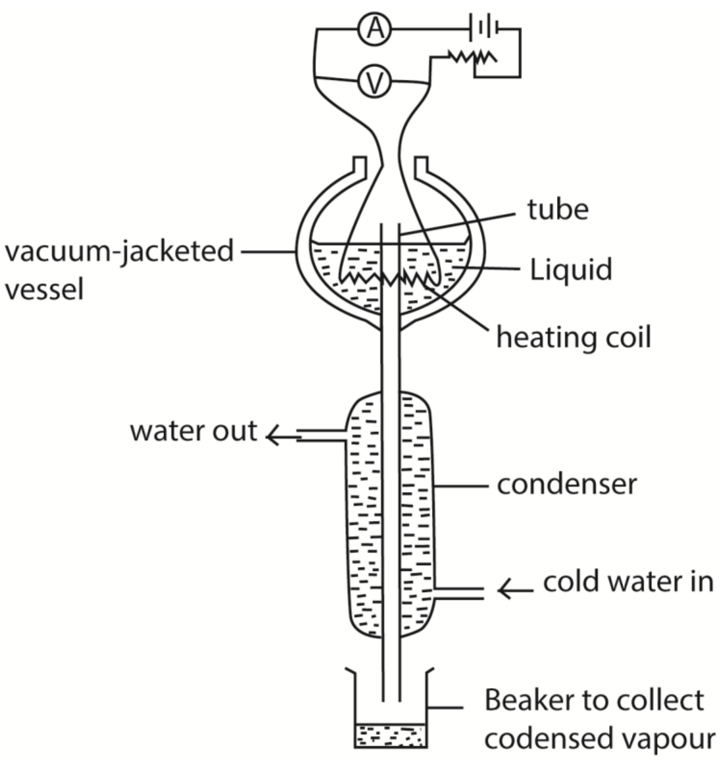
(i) specific heat capacity (01 mark)

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) specific latent heat of vaporization. (01mark)

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

(b) With the aid of a labelled diagram, describe an experiment to determine the specific latent heat of vaporization of a liquid. (07 marks)



- Put the liquid whose specific latent heat of vaporization is required in a vacuum jacketed vessel as shown above.
- The liquid is heated to boiling point.
- The current, I, and voltage, V are recorded.
- The mass of liquid, m, condensed in time, t, is determined.
- Then IV = $\frac{m}{t}L + h$, where h is the rate of heat loss to the surroundings

- To eliminate, h, the experiment is repeated for different values of I' and V' and the mass of the liquid, m' condensed in tie t is determined.
- Again I'V' = $\frac{m\prime}{t}L + h$

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

(c) The inlet and outlet temperatures of water flowing in a continuous flow method are 15.2^{0}C and 17.4^{0}C respectively. A flow rate of 20 g min^{-1} is obtained when a current of 2.3A flows and a p.d of 3.3V is applied. When oil, which flows in and out at the same temperatures as water is used, the flow rate obtained is 70.0 g min^{-1}. Calculate the specific heat capacity of the oil, if a p.d 3.9V is applied and a current of 2.7A flows. (05 marks)

VIt = mcθ+ h where h is the rate of heat loss

3.3 x 2.3 = $\frac{20}{1000\,x60}x4200x(17.4 - 15.2) + h$ ………………. (i)

3.9 x 2.7 = $\frac{70}{1000\,x60}xcx(17.4 - 15.2) + h$……………………….(ii)

Subtracting (i) from (ii)

2.94 = 2.5667x 10^{-3}c – 3.08

c = 2345Jkg^{-1}K^{-1}

hence specific heat capacity of the liquid = 2,345 Jkg^{-1}K^{-1}

(d) Explain the effect of pressure on:

(i) boiling point of a liquid. (03marks)

When the liquid boils its saturated vapour pressure = external pressure and saturated vapour pressure increases with increasing temperature. When external pressure is raised, a liquid will boil at higher saturated pressure which occurs at high temperature.

(ii) Melting point of ice. (03 marks)

Increase in pressure lowers the melting point of ice because melting of ices is followed by a decrease in volume.

6. (a) Define the following:

(i) Molar heat capacity of a gas at constant pressure. (01mark)

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

(ii) Molar heat capacity of a gas at constant volume. (01mark)

(iii) Define molar heat capacity of a gas at constant volume. (01mark)

Molar heat capacity of a gas at constant volume is the amount of heat required to raise 1 mole of the gas through1K at constant volume.

(b) Derive the expression Cp –Cv = R, where Cp is the molar heat capacity of a gas at constant pressure and Cv is the molar heat capacity of a gas at constant volume and R is the gas constant. (05marks)

From dQ = dU + dW……………. (i)
But $dQ = C_pdT$, $dU = C_vdT$ and dW= PdV = RdT
Substituting in (i)
$C_pdT = C_vdT + RdT$
$\therefore C_p - C_v = R$

(c) (i) Differentiate between **adiabatic** and **isothermal** expansions. (02marks)

Isothermal expansion occurs at constant temperature.

Adiabatic expansion occurs at no heat input or output in the system.

(ii) State **two** examples of adiabatic changes. (01marks)

Expansion of a gas in an insulated cylinder.

release of air from a pneumatic tire.

rapidly pumping air into a bicycle tire.

(d) A fixed mass of an ideal gas of volume 400cm^3 at 15^{0}C expands adiabatically and its temperature falls to 0^{0}C. It is then compressed isothermally until the pressure returns to its original value. If the molar heat capacity at constant pressure is 28.6 J mol^{-1}K^{-1}, calculate the final volume after isothermal compression. (05marks)

Solution

<u>Under adiabatic expansion</u>
Initial temperature = 273 +15 = 288K
Final temperature = 273 + 0 = 273K
Cp = Cv + R = 28.6 + 8.31 = 36.91J
$\gamma = \frac{c_p}{c_v} = \frac{36.91}{28.6}$ = 1.29
Finial volume (V) under adiabatic condition
$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$
⇨ $288(4000)^{1.29-1} = 273(v)^{1.29-1}$
V = $\sqrt[0.29]{\frac{288(4000)^{0.29}}{273}}$ = 4810.2 cm^3
Final pressures(P_2) under adiabatic condition
$P_1V_1^{\gamma} = P_2V_2^{\gamma}$
P x $(4000)^{1.29}$ = P_2 x $(4810.2)^{1.29}$
$P_2 = \frac{P\ x\ (4000)^{1.29}}{4810.2^{1.29}}$ = 0.7883P
Final volume under isothermal conditions
PV = constant
⇨ 0.7883P x 4810.2 = P x v
V = 3,792cm^3

Hence final volume = 3.792cm^3

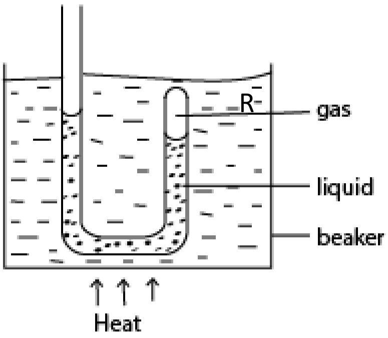
(e) (i) What is **saturated vapour pressure** of a liquid? (01mark)

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

(ii) Describe an experiment to show that a liquid boils when its saturated vapour pressure equals to the atmospheric pressure. (04marks)

The setup is shown below

Experiment to show that a liquid boils off when its saturated vapour pressure equals the external pressure



- Air is trapped in the closed limb of the tube by water column.
- The tube is heated in water bath.
- When the water bath begins to boil, the water in the tube comes to the same level in each limb.
- This shows that the vapor pressure in closed limb is equal to external pressure

Hence water boils when its saturated vapour pressure is equal to atmospheric pressure.

7. (a) Define the following:
   (i) Temperature gradient (01 mark)
   A **temperature gradient** refers to the rate of change in temperature with respect to distance.
   (ii) Thermal conductivity. (01 marks)
   Thermal conductivity is the rate of heat flow per unit cross section area per unit temperature gradient.

(b) Explain why a poor conductor whose thermal conductivity is to be determined, must be thin and fairly of large surface area. (03marks)

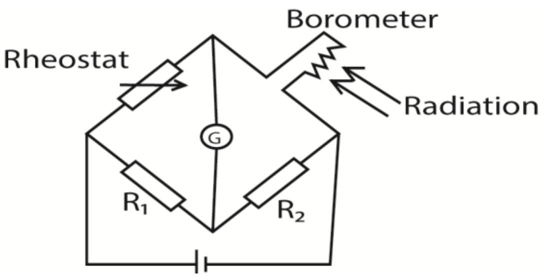
Thin Sample:

- **Reduced Heat Flow Path**: A thinner sample ensures that the heat travels a shorter distance from the hot side to the cold side. This allows for a more accurate measurement of the temperature gradient and, consequently, the thermal conductivity.
- **Minimized Thermal Resistance**: A thin sample minimizes the internal thermal resistance, which helps in obtaining more precise results.

Large Surface Area:

- **Enhanced Heat Transfer**: A larger surface area increases the amount of heat transferred across the sample, making it easier to detect and measure the temperature change.
- **Reduced Edge Effects**: A larger surface area ensures that the heat flow is predominantly one-dimensional and minimizes the impact of edge effects, which can distort the measurement.

(c) With the aid of a labelled diagram, describe how the presence of radiation is detected by a bolometer connected to Wheatstone bridge. (06marks)



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.

(d) A metal sphere whose surface acts as a black body is placed at the principal focus of a concave mirror of diameter 60cm, which is directed towards the sun. If the solar radiation falling normally on the earth is 1400Wm^{-2}, and the mean temperature of the surrounding is 30^{0}C, find the diameter of the sphere when the maximum temperature it attains is 1870^{0}C. (06marks)

Area of the mirror = $\pi r^2 = \pi(0.3)^2 = 0.2827m^2$

Power reflected by the mirror per second = 0.2827 x 1400= 396W

P = $A\sigma(T_1^4 - T_2^4)$

T_1 = 1870 + 273 =2,143K

T_2 = 30 + 273 =303K

Let the diameter of the sphere be d

$396 = \pi d^2 \times 5.67 \times 10^{-8}(2{,}143^4 - 303^4)$

d = 0.01m

(e) State **three** properties of radiant energy. (03marks)

- produce ionization and florescence
- affect photographic plates
- produces photoelectric effect
- promotes chemical reaction
- can be reflected and refracted.

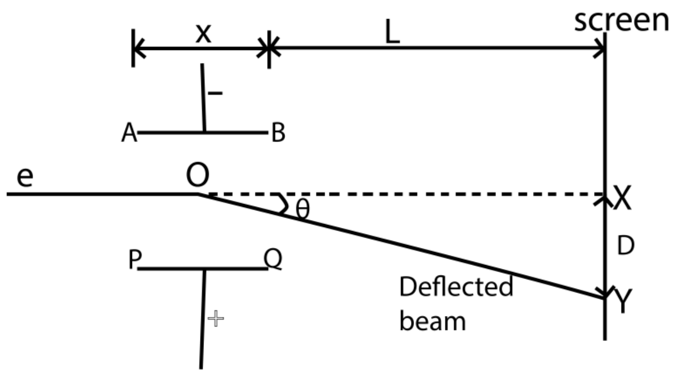
SECTION C

8. (a) State any four properties of cathode rays. (02marks)

- They are negatively charged
- Travel in straight lines
- Travel with the same speed
- Affect photographic plates

(b) Show that the path of an electron projected at right angles to a uniform electric field is a parabola. (05 marks)

Consider two parallel plates AB and PQ such that AB is vertically above PQ and at a distance d apart. Let x be the length of the plates and V the p.d between the plates.



This electric force is directed towards the positive plate causing the deflection of the beam as shown above.

But for parallel plates $E = \frac{V}{d}$

Thus $F_E = \frac{eV}{d}$

Since the electric field intensity is vertical, there is no horizontal force acting on the electron. Hence the horizontal component of the velocity of the electron does not change.

Let u be the horizontal component of the velocity of the electron entering the electric field.

Motion in the X-direction

$s = ut + \frac{1}{2}at^2$, but s = x and a =0

⇨ $t = \frac{x}{u}$………………………………. (i)

Motion in y-direction

$s = u_yt + ½ at^2$, but $u_y = 0$, s = y and $a = \frac{eE}{m}$ from ma = eE

$y = \frac{1}{2}\left(\frac{eE}{m}\right)\left(\frac{x}{u}\right)^2$

$= \left(\frac{eE}{2mu^2}\right)x^2$

⇨ $y \propto x^2$ or $y = kx^2$ which is an equation for parabola

Thus the motion of an electron in electric field is parabolic

(c) Two metal plates each 5.0cm long are held horizontally 4.0cm apart in a vacuum, one being vertically above the other. The upper plate is at a potential of 400V while the lower one is earthed. Electrons having a velocity of $1.0 \times 10^7 ms^{-1}$ enter horizontally mid-way between the plates and in a direction parallel to the 5.0cm edge. Calculate the vertical deflection of the electron as it emerges from the plates. (04marks)

Solution

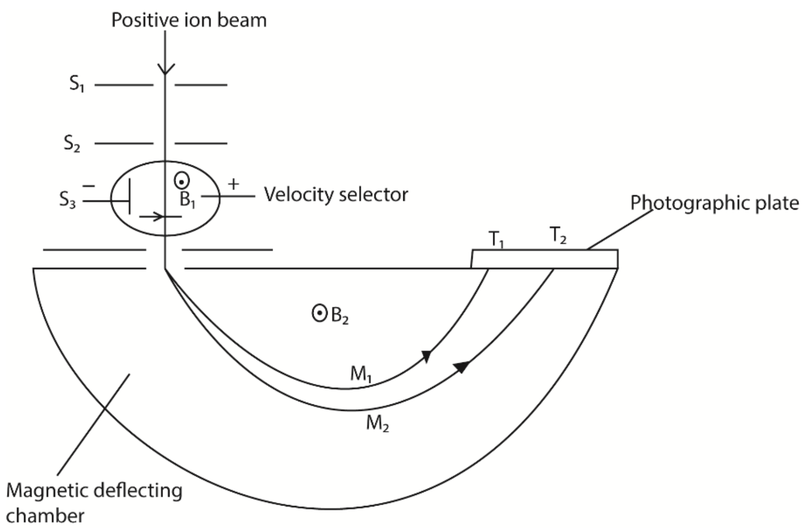
$E = \frac{400}{0.04} = 10{,}000Vm^{-1}$

Vertical displacement $y = \left(\frac{eE}{2mu^2}\right)x^2$

$= \left(\frac{1.6 \,x 10^{-19} \,x\, 10{,}000}{2 \,x\, 9.11 \,x\, 10^{-31} x\, (1x10^7)^2}\right)(0.05)^2$

$= 2.2 \times 10^{-2}m$

(d) (i) With the aid of a labelled diagram, describe how the specific charge of positive rays may be determined. (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
  $\frac{mv^2}{r} = B_2ev$
  $\therefore \frac{m}{e} = \frac{rB_2}{v}$

  But for the ions selected v = $\frac{E}{B_1}$ from above
  Specific charge, $\frac{e}{m} = \frac{E}{rB_2B_1}$

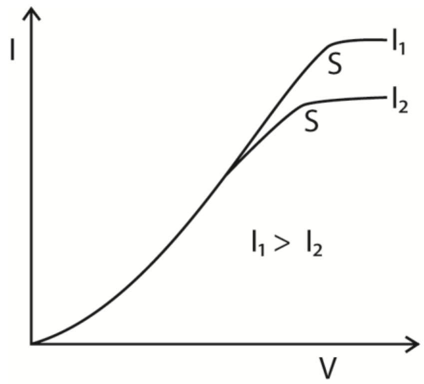
(iii) Explain how the set up in (d)(i) can be used to determine the abundance of isotopes. (03 marks)

Isotopes are characterised by the radius of the deflection while relative abundance of each isotope is proportional to the intensity of the signal received by the detector.

9. (a) What is meant by **thermionic emission**? (01 mark)

Thermionic emission is the ejection of electrons from metal surface when heated

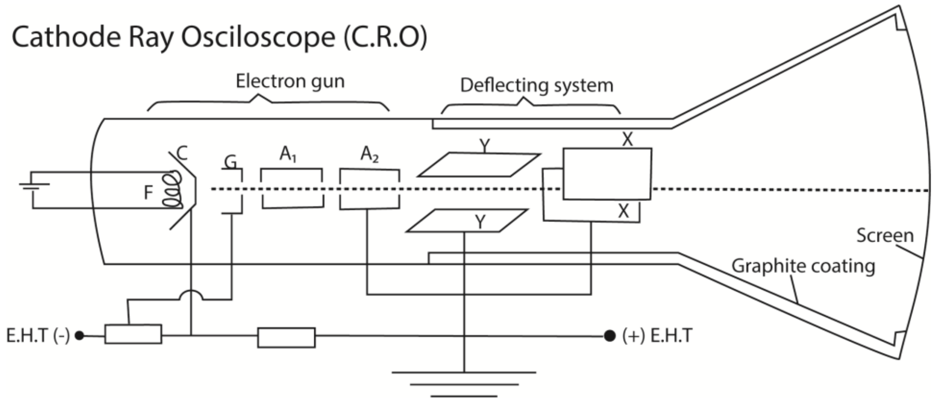
(b) (i) Sketch the anode current versus anode voltage characteristics of thermionic diode. (02 marks)



(ii) Explain the main features of the curves. (05marks)

- At low anode voltages, the anode current increases rapidly due rapid increase in the number electrons collected from cathode with increase in voltage. In this region, the anode current is limited by the thermionic emission from the cathode.
- In the space charge limited region, 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, the anode current saturates and becomes nearly constant. In this region, the anode current is primarily limited by the thermionic emission rate of electrons from the cathode.

(c) (i) With the aid of a diagram, describe the operation of a Cathode ray oscilloscope (C.R.O) (06marks)



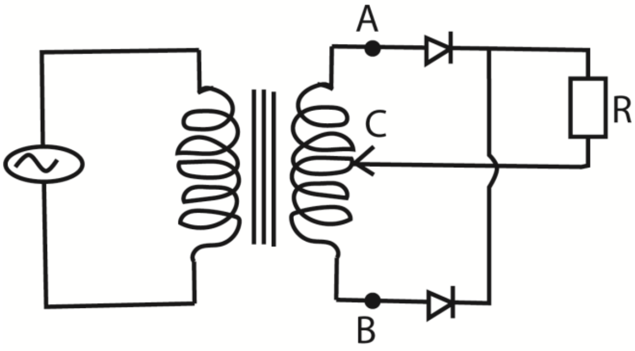
The cathode ray oscilloscope consists of

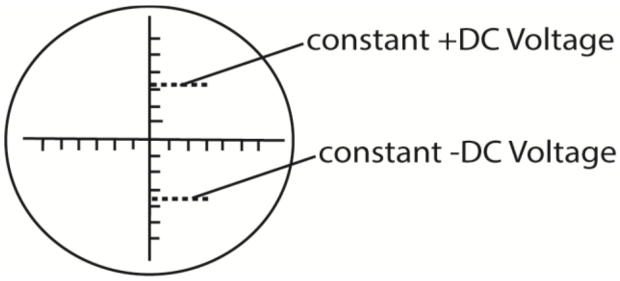
- cathode C (Electron gun) produces electron by thermionic emission
- Grid G controls number of electrons reaching the screen
- Anodes, A accelerate electrons
- Y and X- plates deflect electrons vertically and horizontally respectively
- The screen is coated with zinc sulphide to glow when hit by electron
- Time base is connected to X- plates and provides a saw tooth p.d that sweep the electron spot from left to right of the screen at steady speed

(ii) Describe the use of a time base in a C.R.O. (02marks)

- Horizontal **Deflection**: The time base generates a sawtooth voltage waveform that is applied to the horizontal deflection plates of the C.R.O. This voltage causes the electron beam to sweep horizontally across the screen from left to right at a constant speed.
- **Time Measurement**: By controlling the speed of the horizontal sweep, the time base allows you to measure the time intervals between different points on the waveform. The horizontal axis of the C.R.O. screen represents time, and the time base ensures that this axis is calibrated accurately.

(d) Explain the wave form obtained on a C.R. O connected across the resistor R in the circuit shown in Figure 3.





- **Horizontal Line**: The waveform is a straight horizontal line, indicating that the voltage is constant over time because it was rectified.
- **Vertical Position**: The vertical position of the line represents the magnitude of the DC voltage. A higher DC voltage will shift the line upward (positive voltage) or downward (negative voltage) on the screen.

10. (a) State two characteristics of a photoelectric emission. (02 marks)

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

(b) (i) State three advantages of nuclear fusion over nuclear fission as a potential source of energy

- Nuclear fusion produces more energy than nuclear fission
- Nuclear fusion produces short lived dangerous wastes
- Nuclear fusion is safer
-

(ii) Why does nuclear fusion take place only at high temperatures? (01mark)

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

(c) Given that;

Mass of a proton	= 1.0073U
Mass of an electron	= 0.0005U
Mass of a neutron	= 1.0087U and
Mass of $^{227}_{87}Fr$	= 223.0198U

(iii) Calculate the difference in the mass between $^{227}_{87}Fr$ nucleus and the sum of the masses of its nucleons.

Sum of the masses of nucleons =(87 x 1.0073 + 87 x 0.0005 + (227-87) x 1.0087)

= 228.8966U

Difference in mass = 228.8966 – 223.0198

= 5.8768U

(iv) How is the difference in the masses in (c)(i)accounted for? (02marks)

The difference is equivalent to the binding energy of $^{227}_{87}Fr$ nuclide

(d) (i) State **three** uses of X-rays. (03marks)

1. Structural analysis, stresses, fractures in solids, castings and welded joints can be analyzed by examining X-ray photograph.
2. Crystallography; Orientation and identification of minerals by analysis of diffraction patterns using Bragg's law.
3. Medical uses;
   i) Analytical uses. These include location of fractures, cancer and tumor/defective tissue absorbs x-rays differently from normal tissue.
   ii) Therapeutics use for destroying cancerous cells and tumors. 4. Detection of fire arms at international airports

(iii) Explain how quantum theory provides an explanation for the photoelectric effect. (04marks)

Explanation of the laws of photoelectric emission using quantum theory

The quantum theory states that "light is emitted and absorbed in discrete packets of energy called photons" i.e. **E = hf**

When light is incident on a metal surface, each photon interacts with a single electrons giving it all its energy. The photon is absorbed if its energy is greater than the work function and if it is less, the photon is rejected.

Increasing the intensity of light increases the number of photons striking the metal surface per second. Therefore more electrons are emitted per second and the photocurrent increases with intensity.

Increasing the frequency of incident radiation increases the energy of each photon and therefore the maximum kinetic energy of the liberated electrons increases with the frequency of radiation.

Increasing the intensity of light only increases the number of photons but not the energy in each photon. Hence kinetic energy of the emitted electrons is independent of the intensity of the incident radiation

i.e K.E = hf + w_0 where **K.E** = kinetic energy of emitted electron, **h** = Plank's constant, **f** = frequency of the radiation, **w_0** = work function (minimum energy required to dislodge an electron from a material)