UACE 2023 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 x 10 $^{-19}$ C
Electronic mass	= 9.11 x 10 $^{-31}$ kg
Mass of the earth	= 5.97 x 10 ^{24} kg
Planck's constant, h	= 6.6 x 10 $^{-34}$ JS
Stefan's Boltzmann's constant, σ	= 5.67 x 10 $^{-8}$ Wm $^{-2}$ K $^{-4}$
Radius of the earth	= 6.4 x 10^{6} m
Radius of the sun	= 7 x 10^{8}m
Radius of the earth's orbit about the sun	= 1.5 x 10^{11}m
Speed of light in free space, c	= 3.0 x 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 x 10 $^{-11}$ Nm^{2} kg $^{-2}$
Avogradro's number N_A	= 6.02 x 10^{23} mol $^{-1}$
Surface tension of water	= 7.0 x 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 x 10^{11}Ckg-1
The constant $\frac{1}{4\pi\varepsilon_0}$	= 9.0x 10^{9}F^{-1}m
Faraday constant, F	= 9.65 x 10^{4}Cmol^{-1}.

SECTION A

1. (a) Define the following
   (i) Vector and Scalar quantities (02mark)
   (ii) The Newton (01mark)

   (b) Use the method of dimensions to show NKg^{-1} and ms^{-2} are equivalent (02marks)

   (c) Figure 1 shows forces of 3.0N, 3.5N. 4.5N and 5.0N acting on a body P of mass 500g. If P was initially at rest, calculate the distance P moves in 5s.

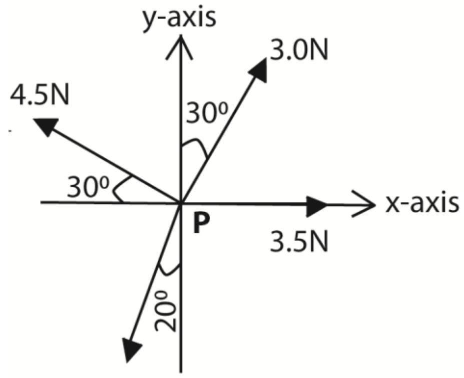


Fig. 1

   (d) (i) Explain why the tension in a cable of a lift when it is ascending is different from when it is descending. (03marks)

   (ii) Explain the circumstances under which a person in a lit feels weightless. (02marks)

   (e) A stone is projected horizontally with a velocity of $30ms^{-1}$from a height of 60m above the ground. Find how far the stone travels horizontally.

2. (a) Define the following:
   (i) Acceleration (01mark)
   (ii) Instantaneous velocity (01 mark)

   (b) A child wishing to reach the top of a vertical pole, climbs 3m in 1s and slides downwards 2m in the next second. The child climbs another 3m in 1s and slips by 2m in the next second. The process is repeated until the top is reached in a total time of 9s.

   (i) Using a graph paper, draw a displacement time graph for the motion of the child. (04 marks)
   (ii) Find the height of the pole. (01mark)

   (c) (i) State the laws of friction. (03marks)

   (ii) A ball A and B of respective masses 5kg and 3 kg, moves in a straight line in the same direction on a horizontal surface.

When A knocks B which is moving at $15ms^{-1}$, it stops but B continues to move in the same direction and comes to rest in a distance of 81.5m. Calculate the velocity of A before collision, assuming the coefficient of friction between the balls and the surface is 0.25. (05marks)

(d) A stone tied to a string is whirled in a horizontal circle. Explain the motion of the stone when the string breaks. (05marks)

3. (a) (i) State Hooke' law. (01marks)

(ii) Use the molecular theory to explain Hooke's law. (04 marks)

(b) Describe the justification of the existence of molecules in gasses. (04 marks)

(c) (i) Explain the significance of the banked tracks. (02 marks)

(ii) Derive an expression for the speed of a bicycle rider around a circular path (03 marks)

(d) (i) Show that the speed of a satellite in an orbit close to the earth surface is given by

$$V = (gRe)^{\frac{1}{2}}$$

Where V is the speed of a satellite, g is the acceleration due to gravity and Re is the radius of the earth. (03 marks)

(ii) Calculate the period of the satellite in the orbit, at height 6.4×10^3 km above the earth and acceleration due to gravity is $9.91ms^{-2}$. (03marks)

4. (a) (i) Define the term **surface tension** and **angle constant**. (02marks)

(ii) Account for the temperature dependency of surface tension. (03marks)

(b) When a capillary tube is held in a vertical position with one end just dipping in a liquid of surface tension, **γ**, and density, **ρ**, the liquid rises to a height **h**. Derive an expression for **h** in terms of **γ**, **ρ** and radius, **r** of the tube. Assume the angle of contact is zero. (04 marks)

(c) Water enters a house through a pipe of diameter 2.4cm at a pressure of $3.6 \times 10^5 Nm^{-2}$. The pipe leading to the second floor bathroom 6.0m above is 1.2cm in diameter. If the velocity of water as it enters the house is $3.0ms^{-1}$.

(i) Calculate the velocity of water at the outlet of the pipe leading to the second floor bathroom. (03marks)

(ii) use Bernoulli's principle to find the pressure of the water through the pipe in the bathroom. (04 marks)

(d) A sphere of radius, **r**, and of material of density**, ρ**, falls vertically through a liquid of density, **σ**, and viscosity, **η**. Derive an expression for the terminal velocity in terms of the quantities given and acceleration due to gravity, **g**. (04 marks)

SECTION B

5. (a) What is meant by the following:
   (i) Super-heated water? (01 mark)
   (ii) Super cooled vapour? (01 mark)

   (b) Explain how:

   (i) a gas in a vessel exerts pressure. (03marks)
   (ii) the atmosphere surrounding the earth prevents it from becoming unbearably cold. (03marks)

   (c) A container of volume $0.2m^3$ contains hydrogen gas of molar mass $2gmol^{-1}$ at a pressure of 1.5×10^4 Pa and a temperature of 27^0C.

   Calculate the:

   (i) number of hydrogen molecules in the container. (03 marks)
   (ii) mean square speed of the molecules. (03 marks)
   (iii) root mean square speed of oxygen molecules at the same temperature. (Molar mass of oxygen – $32mol^{-1}$) (02 marks)

   (d) Sketch a graph of saturated vapour pressure of a liquid against temperature and explain the shape of the curve. (04 marks)

6. (a)Define the following as applied to heat: (03 marks)
   (i) conduction
   (ii) convection
   (iii) radiation

   (b) (i) Define thermal conductivity and state its units. (02 marks)
   (ii) Explain why the experiment to determine the thermal conductivity of a metal, the specimen is made thin and long. (02 marks)

   (c) The sun radiates as a black body at 6000K and it is 1.5×10^{11}m from the earth. Given that radius of the sun is 7×10^8m, find the;

   (i) solar flux on the earth's surface. (03marks)
   (ii) time it will take 2.5kg of ice at its melting point to melt when placed at the focal point of a concave mirror of diameter 0.8m whose axis is parallel to the sun's radiation. (03marks)
   (*Specific latent heat of fusion of ice is $3.36 \times 10^5 Jkg^{-1}$*)

   (d) (i) Explain how a balometer strip is used to detect radiation. (04marks)

   (ii) Explain why the intensity of solar radiation on top of earth's atmosphere is higher than that on the earth's surface. (03 marks)

7. (a) (i) What is meant by **isothermal** and **adiabatic** processes in a gas. (03marks)

(ii) State the conditions necessary to achieve the processes in (a)(i) (04 marks)

(iii) Explain why air coming out of a valve of a ball feels cold (02marks)

(b) A mass of air initially occupying a volume of $2000cm^3$ at a pressure of 76mmHG and a temperature of 20^0C expands adiabatically and reversibly to twice its volume. It is then compressed isothermally and reversibly to a volume of $3000cm^3$.

(i) Find the final temperature and pressure of the gas. (06marks)

(ii) *Indicate the two processes on a P-V diagram. (02 Marks)*

(The ration of the specific heat capacities of air = 1.4)

(c)Show that the work done, W, by a gas in expanding from volume V_1 to V_2 at constant pressure, P, is $W = P(V_2 – V_1)$. (04 marks)

SECTION C

8. (a) (i) What is a **nuclide**? (01mark)

(ii) Define an **isotope** and give **two** examples. (02 marks)

(iii) What is meant by irradiation? (01 mark)

(b) Describe how the radiations emitted in a cloud chamber may be identified. (03marks)

(c) Polonium, $^{210}_{84}Po$ decays to lead, $^{206}_{82}Pb$ by emitting an alpha particle.

(i) Write a nuclear equation for the reaction (01mark)

(ii) Calculate the energy of disintegration in MeV. (04 marks)

(iii) Calculate the speed of the emitted alpha particles. (04 marks)

Mass of polonium = 209.983U

Mass of lead = 205.986U

Mass of alpha particle = 4.003U

(d) (i) Explain why it is difficult to separate isotopes U-238 and U-235. (02 marks)

(ii) Give one biological use and one industrial use of radiations

9. (a) Define the following

(i) Fusion (01 mark)

(ii) Fission (01 mark)

(b) (i) Sketch the variation of binding energy per nucleon against mass number. (01mark)

(ii) Use the sketch in (b) (i) to explain the origin of fusion and fission energies. (04 marks)

(c) (i) What is meant by photoelectric emission? (01marks)

(ii) Write down Einstein's photoelectric equation and define each symbol in the equation. (02 marks)

(iii) Describe an experiment based on the Einstein's photoelectric equation to determine Plank's constant. (07marks)

(d) Show that the path followed by an electron between two charged metal plates is parabolic. (03marks)

10. (a) (i) What is meant by an intrinsic material? (01mark)

(ii) Explain how a p-n junction is made. (05 marks)

(iii) With the aid of a circuit diagram, describe how a transistor can be used as a voltage amplifier (04marks)

(b) (i) Sketch a two-input AND gate and its corresponding truth table.

(ii) Explain how a two-input AND gate may be designed such that its output is used to sound an alarm when it is dark. (03marks)

(c) State three differences between positive rays and cathode rays. (03marks)

Suggested answers

SECTION A

1. (a) Define the following

(i) Vector and Scalar quantities (02mark)

A scalar quantity is a physical quantity with magnitude but no direction

A vector quantity is a physical quantity with both magnitude and direction

(ii) The Newton (01mark)

The newton is a force which gives amass of 1kg an acceleration of $1ms^{-2}$.

(b) Use the method of dimensions to show NKg^{-1} and ms^{-2} are equivalent (02marks)

$$\frac{N}{kg} = \frac{Ma}{kg} = \frac{kgms^{-2}}{kg} = ms^{-2}$$

(c) Figure 1 shows forces of 3.0N, 3.5N. 4.5N and 5.0N acting on a body P of mass 500g. If P was initially at rest, calculate the distance P moves in 5s.

Resolving forces in the y- and x- directions

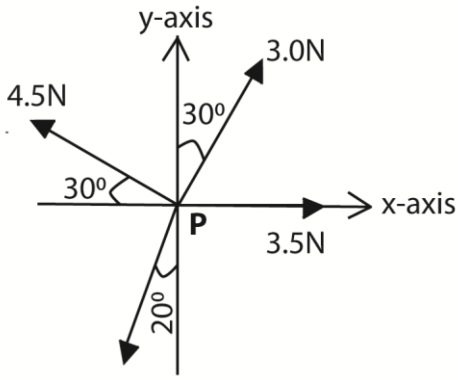


Fig. 1

$$= \binom{3.5}{0} + \binom{3sin30}{3cos30} + \binom{-4.5cos30}{4.5sin30} + \binom{-5sin20}{-5cos20}$$

$$= \binom{3.5}{0} + \binom{1.500}{2.598} + \binom{-3.897}{2.250} + \binom{-1.710}{-4.698}$$

$$= \binom{-0.607}{0.15}$$

Resultant force on P = $\sqrt{(-0.607)^2 + (0.15)^2}$ = 0.8714N

Acceleration, a, of P = $\frac{F}{m} = \frac{0.8714}{0.5}$ =$1.7428ms^{-2}$

From the second equation of motion

Distance moved = $\frac{1}{2}at^2$

= $\frac{1}{2}x1.7412\ x\ 5^2$

= 21.785m

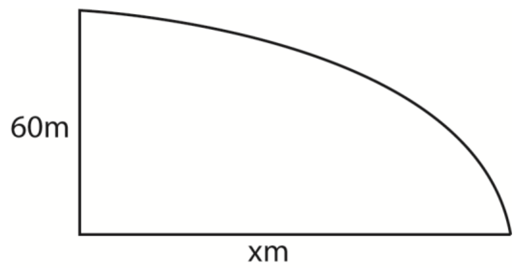
(d) (i) Explain why the tension in a cable of a lift when it is ascending is different from when it is descending. (03marks)

The tension is greater when the lift is ascending because **it has to overcome both the weight of the lift (and its occupants) and the force due to its acceleration upwards**. i.e. upwards T = m(g-a) while downwards, T = m(g-a); where m = mass of the lift and its occupants.

(ii) Explain the circumstances under which a person in a lit feels weightless. (02marks)

When acceleration is equal to the acceleration due to gravity/when a lift experiences a free fall. i.e., the person is no longer pressing against the floor, and the floor is not pushing up against the person.

(e) A stone is projected horizontally with a velocity of 30ms^{-1}from a height of 60m above the ground. Find how far the stone travels horizontally.



Let the time taken be t

From the second equation of motion, vertical distance = $60 \ = \frac{1}{2} x\ 9.81t^2$

t = 3.4975s

Horizontal distance, x = vt = 30 x 3.4975 = 104.925m

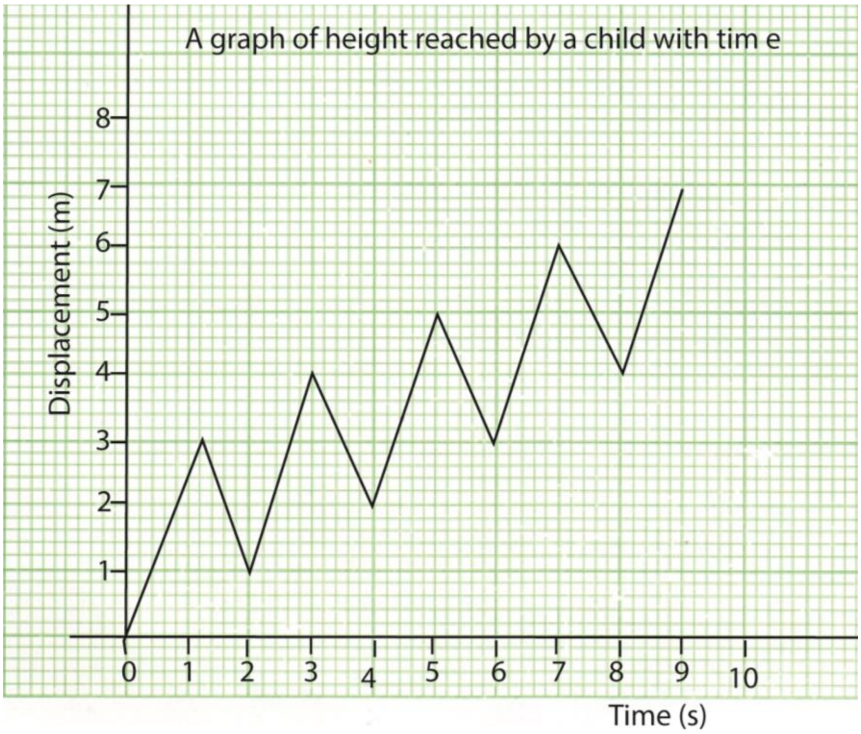
2. (a) Define the following:

(i) Acceleration (01mark)
Acceleration is the rate of change of velocity.

(ii) Instantaneous velocity (01 mark)
It is the velocity of an object at a specific instant in time

(b) A child wishing to reach the top of a vertical pole, climbs 3m in 1s and slides downwards 2m in the next second. The child climbs another 3m in 1s and slips by 2m in the next second. The process is repeated until the top is reached in a total time of 9s.

(iii) Using a graph paper, draw a displacement time graph for the motion of the child. (04 marks)



(iv) Find the height of the pole. (01mark)
7m

(c) (i) State the laws of friction. (03marks)

- 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) A ball A and B of respective masses 5kg and 3 kg, moves in a straight line in the same direction on a horizontal surface.

When A knocks B which is moving at 15ms^{-1}, it stops but B continues to move in the same direction and comes to rest in a distance of 81.5m. Calculate the velocity of A before collision, assuming the coefficient of friction between the balls and the surface is 0.25. (05marks)

<u>Solution</u>

Friction force on B = μR = 0.25 x 3 x 9.81 = 7.3575N

Deceleration= $\frac{F}{m} = \frac{7.3575}{3}$ = 2.4525ms^{-2}

Let the velocity of B after collision be u and final velocity of B = 0

From the third equation of motion

$0 = u^2 - 2 \times 2.4525 \times 81.5$

$u^2 = 399.7575$

$u = 20ms^{-1}$

Let the velocity of A before collision b V

From the conservation of momentum

$5V + 3 \times 15 = 5 \times 0 + 3 \times 20$

$5V = 15$

$V = 3$

Hence the velocity of A before collision = $3ms^{-1}$

(d) A stone tied to a string is whirled in a horizontal circle. Explain the motion of the stone when the string breaks. (05marks)

- **Before the String Breaks**:
  - The stone is kept in a circular path by the tension in the string, which provides the necessary centripetal force directed towards the center of the circle.
  - The stone continuously changes direction as it moves along the circular path, but the tension in the string ensures it stays in the circle.
- **At the Moment the String Breaks**:
  - The centripetal force disappears immediately because the tension in the string is no longer present.
  - Without this force, there is nothing to keep the stone moving in a circular path.
- **After the String Breaks**:
  - According to Newton's First Law of Motion (inertia), an object in motion will continue in motion with the same speed and in the same direction unless acted upon by an external force.
  - Therefore, the stone will move in a straight line tangent to the circle at the point where the string breaks. This path is called a tangential path.
  - The stone's velocity at the moment the string breaks determines the direction of this straight-line motion.

3. (a) (i) State Hooke' law. (01marks)

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

(ii) Use the molecular theory to explain Hooke's law. (04 marks)

Molecular Theory Explanation of Hooke's Law

- **Atomic Bonds**: In a solid material, atoms are arranged in a regular pattern and are held together by interatomic forces, often visualized as tiny springs connecting each pair of atoms.
- **Equilibrium Position**: Atoms are in an equilibrium position when the material is unstressed. The interatomic forces are balanced, and the atoms are at their natural separation distance.

- **Displacement from Equilibrium**: When an external force is applied to stretch or compress the material, the atoms are displaced from their equilibrium positions. This causes the interatomic "springs" to either stretch or compress.
- **Restorative Forces**: According to molecular theory, the interatomic forces act like springs that obey Hooke's law. The displacement of atoms from their equilibrium positions creates restorative forces that are proportional to the displacement, trying to bring the atoms back to their equilibrium state.
- **Linear Relationship**: For small displacements, the relationship between the force applied to the material and the resulting displacement is linear. This linearity results from the nature of the interatomic forces, which can be approximated as linear (like springs) for small deformations.

(b) Describe the justification of the existence of molecules in gasses. (04 marks)

This can be explained be the Kinetic Molecular Theory:

- **Particle Nature of Matter**: This theory states that all matter is composed of small particles (molecules) that are in constant motion. In gases, these particles are widely spaced and move freely.
- **Pressure and Temperature Relationship**: The behavior of gases, such as their ability to expand and fill containers, is explained by the motion of gas molecules. The pressure exerted by a gas is due to collisions of molecules with the walls of the container. As temperature increases, the kinetic energy of the molecules increases, leading to more frequent and forceful collisions.
- **Diffusion**: The process of gas molecules spreading out to evenly fill a space is evidence of their constant motion. Molecules move from areas of higher concentration to lower concentration, demonstrating their individual existence and motion.
- **Brownian Motion**: The random movement of small particles suspended in a gas (or liquid) is caused by collisions with the gas molecules. This visible motion provides indirect evidence of the existence of molecules in gases.

Experimental Evidence:

- **Gas Laws**: The behavior of gases under various conditions, described by laws such as Boyle's Law, Charles's Law, and Avogadro's Law, supports the idea that gases consist of discrete molecules. For example, Boyle's Law states that the pressure of a gas is inversely proportional to its volume at constant temperature, which can be explained by the molecular nature of gases.
- **Spectroscopy**: The analysis of light absorbed or emitted by gases shows distinct spectral lines corresponding to specific energy levels of gas molecules. This provides evidence for the existence and characteristics of gas molecules.

(c) (i) Explain the significance of the banked tracks. (02 marks)

It enables vehicles to navigate turns at higher speeds without skidding because, on banked track, a component of normal reaction supplements friction to provide the centripetal force.

(ii) Derive an expression for the speed of a bicycle rider around a circular path. (03 marks)

Assumption

v = speed of the bicycle

r = radius of the circular path

m= mass of the bicycle and the rider

g = acceleration due to gravity

θ = banking angle of the track (if applicable)

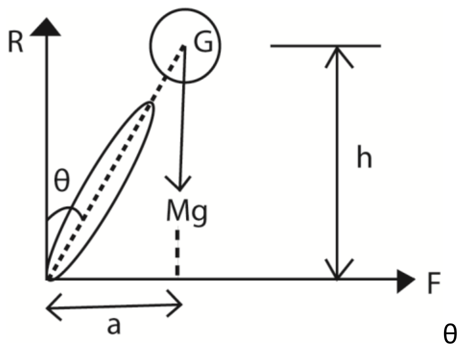
F_c = centripetal force= $\frac{mv^2}{r}$

F_r = friction = μR=μmg

For a circular motion centripetal force = friction

$$\Rightarrow \frac{mv^2}{r} = \mu mg$$
$$v = \sqrt{\mu mgr}$$

For banked track



θ

Ncosθ = mg (vertical component)

N = $\frac{mg}{cos\theta}$ ……………………………………………………………..(i)

Nsinθ =$\frac{mv^2}{r}$(horizontal component) ……………………(ii)

Substituting (i) into (ii)

$$\frac{mv^2}{r} = \frac{mg}{cos\theta} sin\theta$$

$$v = \sqrt{rgtan\theta}$$

(d) (i) Show that the speed of a satellite in an orbit close to the earth surface is given by

$$V = (gRe)^{\frac{1}{2}}$$

Where V is the speed of a satellite, g is the acceleration due to gravity and Re is the radius of the earth. (03 marks)

If m is the mass of the satellite

The centripetal force = mg = $\frac{mV^2}{Re}$

V^2 = gRe

= $(gRe)^{\frac{1}{2}}$

(ii) Calculate the period of the satellite in the orbit, at height 6.4 x 10^3 km above the earth and acceleration due to gravity is 9.91ms^{-2}. (03marks)

$$T = \frac{2\pi}{r_e}\sqrt{\frac{(r_e+h)^3}{g}}$$

$$T = \frac{2\pi}{6.4x10^6}\sqrt{\frac{(6.4x10^6+6.4\,x10^3)^3}{9.81}} = 160{,}726s$$

4. (a) (i) Define the term **surface tension** and **angle constant**. (02marks)

- Surface tension is the force per metre length acting in the surface at right angles to one side of the line drawn in the surface.
- Angle of contact is the angle between the solid surface and the tangent plane to the liquid surface measured through the liquid.

(ii) Account for the temperature dependency of surface tension. (03marks)

Increase in temperatures increases the kinetic energy of liquid molecules and thus reduces the cohesive force and/or van der Waal forces among the molecules of the liquid thereby lowering the surface tension.

(b) When a capillary tube is held in a vertical position with one end just dipping in a liquid of surface tension, **γ**, and density, **ρ**, the liquid rises to a height **h**. Derive an expression for **h** in terms of **γ**, **ρ** and radius, **r** of the tube. Assume the angle of contact is zero. (04 marks)

The liquid rises until the vertical component of the upward forces due to surface tension is equal to the weight of the liquid column.

$F\gamma\cos\theta = W$ but $\theta = 0$

⇨ $F\gamma = W$

$\gamma = \frac{F}{L}$

$F = \gamma L$

$L = 2\pi r$

But W = mg and m = Vρ (where ρ is the density of the liquid in kg/m^3)

$W = v\rho g = 2\pi r^2 h\rho g$

$F\gamma = 2\pi r^2 h\rho g$

$\gamma.2\pi r = 2\pi r^2 h\rho g$

$h = \frac{2\gamma}{r\rho g}$

γ – coefficient of surface tension
θ – angle of contact
r – radius of capillary tube
ρ – density of the liquid

(c) Water enters a house through a pipe of diameter 2.4cm at a pressure of $3.6 \times 10^5 Nm^{-2}$. The pipe leading to the second floor bathroom 6.0m above is 1.2cm in diameter. If the velocity of water as it enters the house is $3.0ms^{-1}$.

(i) Calculate the velocity of water at the outlet of the pipe leading to the second floor bathroom. (03marks)

Let the velocity of water be V

$A_1V_1 = A_2V_2$

$\pi(1.2)^2 \times 3 = \pi(0.6)^2V$

$V = \frac{(1.2)^2}{(0.6)2} = 4.0ms^{-1}$

(ii) Use Bernoulli's principle to find the pressure of the water through the pipe in the bathroom. (04 marks)

Let the required pressure be P

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

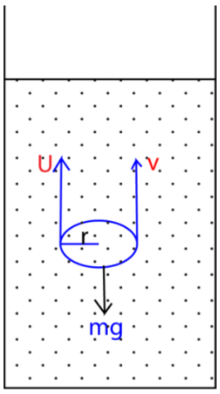
$P + \frac{1}{2} x\ 1000\ x\ 1.2^2 + 1000\ x\ 9.81\ x\ 6 = 3.6\ x\ 10^5 + \frac{1}{2}\ x\ 1000\ x\ 3^2 + 0$

P + 720 +58,860 = 360000 + 4,500

$P = 304,920Nm^{-2}$

(d) A sphere of radius, **r**, and of material of density**, ρ**, falls vertically through a liquid of density, **σ**, and viscosity, **η**. Derive an expression for the terminal velocity in terms of the quantities given and acceleration due to gravity, **g**. (04 marks)

Solution



mg = U + v

mg = $\frac{4}{3}\pi r^3\sigma g$

U = weight of fluid displaced

= $\frac{4}{3}\pi r^3\rho g$

v = drag force = $6\pi\eta v_0 r$

$\frac{4}{3}\pi r^3\rho g = \frac{4}{3}\pi r^3\sigma g + 6\pi\eta v_0 r$

$6\pi\eta v_0 r = \frac{4}{3}\pi r^3(\rho - \sigma)g$

$v_0 = \frac{2r^2(\rho-\sigma)g}{9\eta}$

SECTION B

5. (a) What is meant by the following:

(i) Super-heated water? (01 mark)

Superheated water is **liquid water under pressure at temperatures between the usual boiling point,** 100 **°C and the critical temperature,** 374 °C.

(ii) Super cooled vapour? (01 mark)

(b) Explain how:

(i) a gas in a vessel exerts pressure. (03marks)

A gas in a vessel exerts pressure due to the constant motion and collisions of its molecules with the walls of the container. Each molecule that collides with of vessel exerts a small force on the wall; and the cumulative effect of numerous collisions over a given area generates a continuous force on the wall of the vessel. This force per unit area constitutes pressure of a gas.

(ii) the atmosphere surrounding the earth prevents it from becoming unbearably cold. (03marks)

- atmosphere contain greenhouse gases and clouds that trap heat from the sun keeping the earth warm
- atmospheric gases act as insulators reducing temperature fluctuations
- circulation of atmospheric gases redistributes heat from the equator to cold paces

(c) A container of volume $0.2m^3$ contains hydrogen gas of molar mass $2gmol^{-1}$ at a pressure of 1.5×10^4 Pa and a temperature of 27^0C.

Calculate the:

(i) number of hydrogen molecules in the container. (03 marks)

From $PV = nRT$

$1.5 \times 10^4 \times 0.2 = n \times 8.31 \times (273 + 17)$

The number of moles of hydrogen gas, $n = \frac{1.5x10^4x0.2}{8.31x290} = 1.2449$

Number of hydrogen molecules = $1.2449 \times 6.02 \times 10^{23}$

$= 7.4943 \times 10^{23}$ molecules

(ii) mean square speed of the molecules. (03 marks)

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

Mass of hydrogen = 1.2449 x2 =2.4898g

$$\rho = \frac{M}{V} = \frac{2.4898}{0.2} = 12.449\text{kgm}^{-3}$$

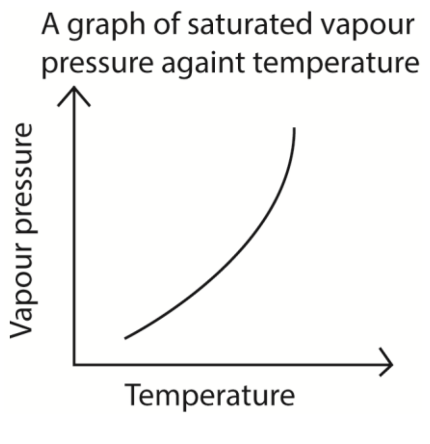
$$\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \ x \ 1.5 \ x \ 10^4}{12.449}} = 60 \text{ ms}^{-1}$$

(iii) root mean square speed of oxygen molecules at the same temperature. (Molar mass of oxygen – 32mol^{-1}) (02 marks)

$$\frac{\overline{c_O^2}}{\overline{c_H^2}} = \frac{m_H}{m_O}$$

Hence root mean square speed of oxygen $= \frac{2}{32} x \ 60 = 3.75\text{ms}^{-1}$

(d) Sketch a graph of saturated vapour pressure of a liquid against temperature and explain the shape of the curve. (04 marks)



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

6. (a)Define the following as applied to heat: (03 marks)

(i) Conduction

Conduction is the transfer of heat from a region of high temperature to that of low temperature without a resultant movement of the molecules of conducting material.

(ii) Convection

Convection is a process of heat transfer in fluids from a region of high temperature to a region of low temperature, due to movement of the medium.

(iii) Radiation

Radiation is a means of heat transfer through a vacuum or that does not involve a medium

(b) (i) Define thermal conductivity and state its units. (02 marks)

Thermal conductivity s the rate of heat flow per unit cross section area per unit temperature gradient

Units: $Wm^{-1}K^{-1}$

(ii) Explain why the experiment to determine the thermal conductivity of a metal, the specimen is made thin and long. (02 marks)

- **Gradient Establishment**: A thin and long specimen ensures a well-defined temperature gradient along its length. This is crucial because thermal conductivity is measured based on the heat flow along the temperature gradient.
- **Reduced Heat Loss**: A thinner specimen minimizes lateral (side) heat loss, ensuring that most of the heat flows along the length of the specimen. This reduces errors and improves the accuracy of the experiment.

(c) The sun radiates as a black body at 6000K and it is 1.5×10^{11}m from the earth. Given that radius of the sun is 7×10^{8}m, find the;

(i) solar flux on the earth's surface. (03marks)

Solar flux $= \frac{4\pi r_s^2 \sigma T_s^4}{4\pi R^2} = \frac{4\pi (7 x 10^8)^2 x 5.67 x 10^{-8} x 6000^4}{4\pi (1.5 x 10^{11})^2} = 1.6 \times 10^3 Wm^{-2}$.

(ii) time it will take 2.5kg of ice at its melting point to melt when placed at the focal point of a concave mirror of diameter 0.8m whose axis is parallel to the sun's radiation. (03marks)

(*Specific latent heat of fusion of ice is $3.36 \times 10^5 Jkg^{-1}$*)

Area of the mirror = $\pi r^2 = \pi(0.4)^2 = 0.5m^2$

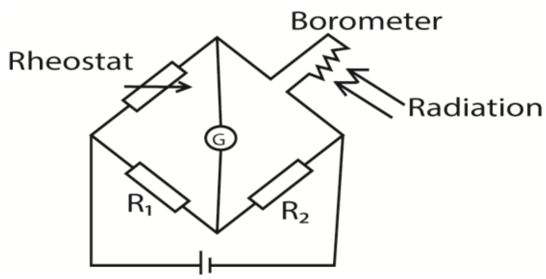
Power reflected by the mirror per second = 0.5 x 1600= 800W

Heat reflected = heat gained by ice

800t = 2.5 x 3.36 x 105

t = 1,050s or 17.5minutes

(d) (i) Explain how a balometer strip is used to detect radiation. (04marks)



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.

(ii) Explain why the intensity of solar radiation on top of earth's atmosphere is higher than that on the earth's surface. (03 marks)

- Portion of the radiation is absorbed by clouds, ozone layer and other atmospheric particle before reaching earth's surface
- Portion of the radiation is reflected by clouds, ozone layer and other atmospheric particle before reaching earth's surface
- Portion of the radiation is scatter atmospheric particle before reaching earth's surface

7. (a) (i) What is meant by **isothermal** and **adiabatic** processes in a gas. (03marks)

Isothermal expansion takes place at constant temperature.
Adiabatic expansion takes place at constant heat.

(ii) State the conditions necessary to achieve the processes in (a)(i) (04 marks)

Isothermal process occurs at constant temperature and therefore the gas must be enclosed in thin walled container of good thermal conductivity placed in a large het reservoir and occurs slowly enough to allow heat exchange with the surrounding.

Adiabatic process requires no heat input or out and therefore should occur rapidly in well insulated container like a thermos flask and gas should be ideal.

(iii) Explain why air coming out of a valve of a ball feels cold. (02marks)

This is due rapid (adiabatic) expansion accompanied with a decrease in temperature which cause a cold sensation.

(b) A mass of air initially occupying a volume of $2000cm^3$ at a pressure of 76mmHG and a temperature of 20^0C expands adiabatically and reversibly to twice its volume. It is then compressed isothermally and reversibly to a volume of $3000cm^3$.

(i) Find the final temperature and pressure of the gas. (06marks)

<u>Under adiabatic expansion</u>

Initial temperature = 273 +20 = 293

Finial temperature under adiabatic condition

$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

⇨ $293(2000)^{1.4-1} = T(4000)^{1.4-1}$

T = $\frac{293}{2^{0.4}}$ = 222.1K

Final pressures under adiabatic condition

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$76\ x(2000)^{1.4} = P(4000)^{1.4}$

$P = \frac{76\ x(2000)^{1.4}}{(4000)^{1.4}}$ = 28.8mmHG

Under isothermal conditions

PV = constant

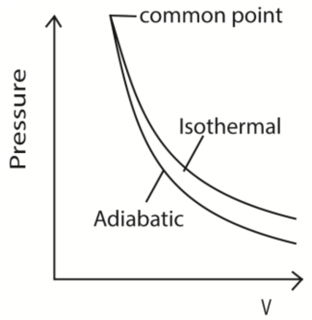
⇨ 28.8 x 4000 = P x 3000

P = $\frac{28.8\ x\ 4000}{3000}$ = 38.4mmHg

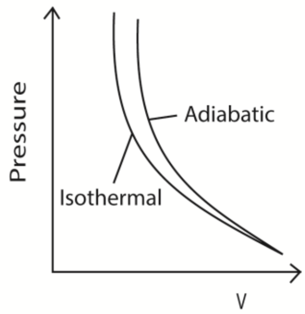
Hence final temperature and pressure are 222.1K and 38.4mmHg respectively

(ii) *Indicate the two processes on a P-V diagram. (02 Marks)*

(The ration of the specific heat capacities of air = 1.4)



Or



(c) Show that the work done, W, by a gas in expanding from volume V_1 to V_2 at constant pressure, P, is W = P($V_2 - V_1$). (04 marks)

If the piston is moved through a small distance dx, so that the pressure P is constant then

dw = Fdx

but F = PA;

=> dw = PAdx; also, Adx = dv

$\therefore dw = Pdv$

=> W = $\int_{v_1}^{v_2} Pdv$

= $[PV]_{v_1}^{v_2}$

= P($v_2 - v_1$)

SECTION C

8. (a) (i) What is a **nuclide**? (01mark)

A nuclide is an atomic nucleus characterized by its number of protons and neutrons.

(ii) Define an **isotope** and give **two** examples. (02 marks)

An isotope is one of the atom of those that contain the same number of protons but different number of neutrons e.g. ^{1}H and ^{2}H; ^{16}O and ^{18}O; ^{12}C and ^{14}C.

(iii) What is meant by irradiation? (01 mark)

Irradiation refers to the process by which an object or substance is exposed to radiation.

(b) Describe how the radiations emitted in a cloud chamber may be identified. (03marks)

- The different types of radiation can be identified based on the characteristics of the tracks they leave in the cloud chamber
- Alpha particles produce thick, short, and straight tracks.
- Beta particles produce thinner, longer, and often curved or zigzag tracks.
- **Gamma radiations** produce faint, thin tracks.

(c) Polonium, $^{210}_{84}Po$ decays to lead, $^{206}_{82}Pb$ by emitting an alpha particle.

(i) Write a nuclear equation for the reaction (01mark)

$^{210}_{84}Po \longrightarrow ^{206}_{82}Pb + ^{4}_{2}He$

(ii) Calculate the energy of disintegration in MeV. (04 marks)

Mass defect = (205.986 + 4.003)- 209.983

= 0.006U

But IU = 931MeV

∴ 0.006U = 0.006 x 931 =5.586MeV

(iii) Calculate the speed of the emitted alpha particles. (04 marks)

1eV =1.6×10^{-19}J

1MeV=1.6×10^{-13}J

Hence energy liberated = 5.586 x =1.6×10^{-13}J

Assuming all the energy is taken up by alpha particle

$\frac{1}{2}mv^2 =$ 5.586 x =1.6×10^{-13}J

$\frac{1}{2}x\ (4.003\ x\ 1.66\ x10^{-27})v^2 =$ 5.586 x 1.6 $\times10^{-13}$J

$v = 2.69x10^{14}$ms^{-1}

Mass of polonium = 209.983U

Mass of lead = 205.986U

Mass of alpha particle = 4.003U

(d) (i) Explain why it is difficult to separate isotopes U-238 and U-235. (02 marks)

Their small mass difference makes physical separation processes based on mass or weight differences, less effective and more challenging.

(ii) Give one biological use and one industrial use of radiations

- **Medical**: Irradiation is used in cancer treatment (radiotherapy) to target and kill cancer cells.
- **Food Safety**: It is used to kill bacteria and other pathogens in food, extending its shelf life.
- **Sterilization**: Irradiation is used to sterilize medical instruments and other materials.

9. (a) Define the following

(i) Fusion (01 mark)

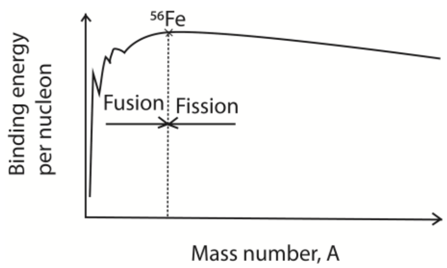
Nuclear fusion is the union of two lighter nuclei to produce heavier nucleus of higher binding energy per nucleon accompanied by release of energy, e.g.

$$ {}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n + Energy $$

(ii) Fission (01 mark)

Nuclear fission is the splitting of a heavy nucleus into two or more light nuclei accompanied by the release of energy.

(b) (i) Sketch the variation of binding energy per nucleon against mass number. (01mark)



(ii) Use the sketch in (b) (i) to explain the origin of fusion and fission energies. (04 marks)

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

(c) (i) What is meant by photoelectric emission? (01marks)

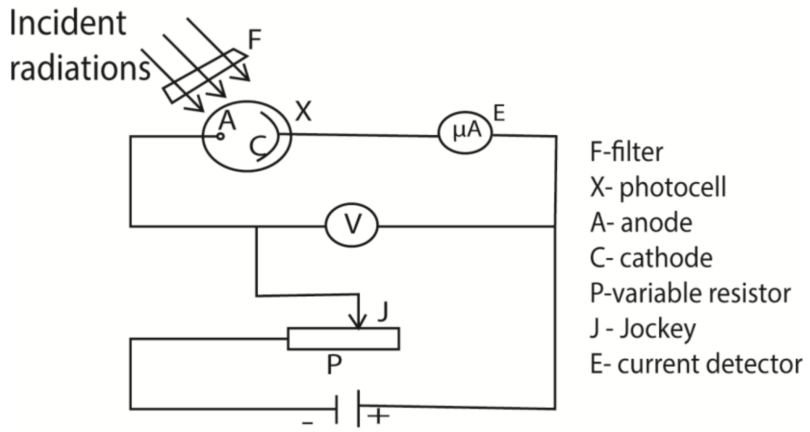
Photoelectric emission is the discharge of electrons from clean metal surface struck by electromagnetic radiations of high energy.

(ii) Write down Einstein's photoelectric equation and define each symbol in the equation. (02 marks)

$hf = w_0 + \frac{1}{2} mv^2$;

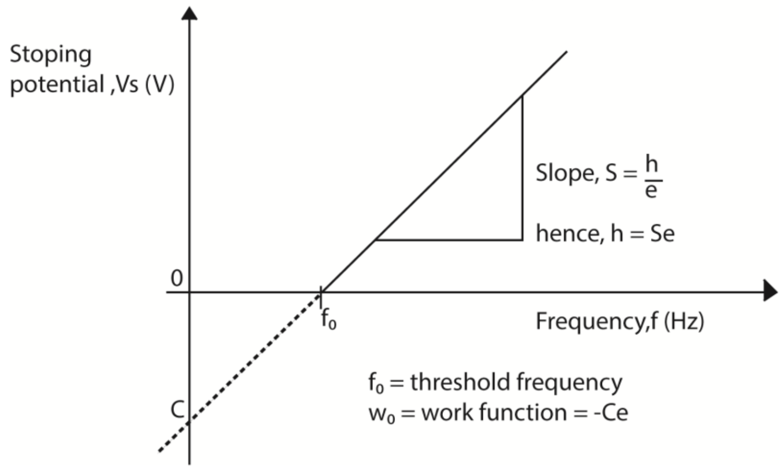
where h = Plank's constant, f = frequency of radiation, w_0 = work function, m = mass of electron, v = velocity of electron

(iii) Describe an experiment based on the Einstein's photoelectric equation to determine Plank's constant. (07marks)



- A radiation of known frequency, f, is made incident on the photocathode
- Emitted electrons travel to the anode and cause a current to flow, detected at E.
- The p.d V is adjusted until the reading of E is zero (i.e. no current flows).
- The value of this p.d is the stopping potential (Vs) and is recorded from the voltmeter, V.
- The procedure is repeated with light of different frequencies, f.
- A graph of stopping potential (Vs) against frequency (f) is plotted
- A straight line graph is obtained which verifies Einstein's equation; $V_s = \frac{h}{e}f - \frac{h}{e}f_0$

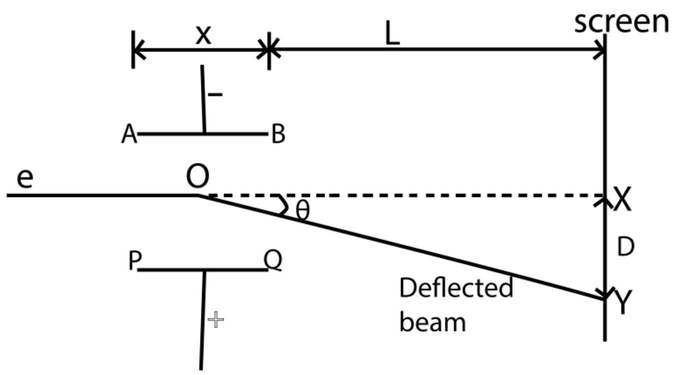
A graph of stopping potential against frequency of radiation



The slope of the graph is $\frac{h}{e}$ from which Plank's constant, h, can be obtained.

(d) Show that the path followed by an electron between two charged metal plates is parabolic. (03marks)

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

$s = u_y t + \frac{1}{2} at^2$, 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

10. (a) (i) What is meant by an intrinsic material? (01mark)

An intrinsic material refers to a pure semiconductor material that has not been intentionally doped with impurities. Common intrinsic semiconductors include silicon (Si) and germanium (Ge).

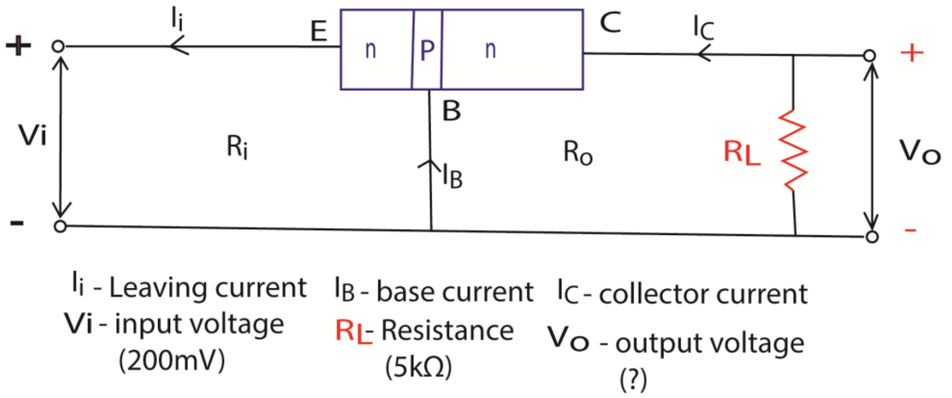
(ii) Explain how a p-n junction is made. (05 marks)

A p-n junction is created by joining p-type and n-type semiconductors together.

- **Doping**: p-type and n-type semiconductors are created by doping with specific impurities.
- **Joining**: Combine p-type and n-type materials to form a junction.

- **Depletion Region**: Charge carriers diffuse, forming a depletion region with an electric field.
- **Equilibrium**: Establish a potential barrier, preventing further diffusion of charge carriers.
- **Biasing**: Apply external voltage to manipulate current flow through the junction.

(iii) With the aid of a circuit diagram, describe how a transistor can be used as a voltage amplifier (04marks)



Since input resistance R_i is usually very small; Ii is high

But Ii ≅ Ic

But output voltage = $I_C R_L$

Since R_L is very big compare Ri, the output voltage is very high, compared to input voltage and hence amplification

If Ri = 20Ω and Ro = 1MV

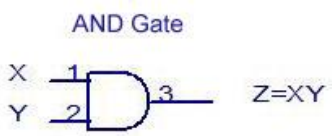
$I_E = I_C = \frac{V_i}{R_i} = \frac{200mV}{20\Omega} = 10mA$

The output voltage, $V_0 = I_C R_i = 10 \times 10^{-3} \times 5 \times 10^{3} = 50V$

Hence amplification $= \frac{50}{200x10^{-3}}$ = 250

(b) (i) Sketch a two-input AND gate and its corresponding truth table.

2 Input AND Gate



TRUTH TABLE

INPUTS		OUTPUT
X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

(ii) Explain how a two-input AND gate may be designed such that its output is used to sound an alarm when it is dark. (03marks)

A two-input AND gate can be designed to sound an alarm when it is dark by using two sensors: a light sensor (LDR) and a second condition sensor, such as a door switch. Here's a step-by-step explanation of how this can be achieved:

Components Needed:

1. **Light Dependent Resistor (LDR)**: This acts as the light sensor. Its resistance changes based on the light intensity.
2. **Door Switch**: This can be a simple mechanical switch or a magnetic reed switch that closes when the door is opened or closed.
3. **AND Gate**: A digital logic gate with two inputs and one output. The output is high (1) only when both inputs are high (1).
4. **Alarm/Buzzer**: An audible device that sounds when activated.
5. **Power Supply**: To power the circuit.

Design Steps:

1. **Set Up the LDR**:
   - **Connection**: Connect the LDR in series with a resistor to form a voltage divider. The junction of the LDR and the resistor will provide a voltage that varies with the light intensity.
   - **Comparator Circuit**: Use a comparator to compare the voltage from the LDR to a reference voltage. The output of the comparator will be high (1) when it is dark (low voltage across LDR due to high resistance) and low (0) when it is light.
2. **Set Up the Door Switch**:
   - **Connection**: Connect the door switch such that it provides a high (1) signal when the door is in the condition you want to monitor (e.g., door closed) and low (0) otherwise.
3. **Connect to AND Gate**:
   - **Input 1**: Connect the output of the comparator (indicating dark condition) to one input of the AND gate.
   - **Input 2**: Connect the output of the door switch to the other input of the AND gate.
4. **Connect the Output to the Alarm**:
   - **Output**: Connect the output of the AND gate to the alarm or buzzer.
   - **Activation**: When both inputs to the AND gate are high (1), the output will be high, triggering the alarm.

Operation:

- **Condition 1**: When it is dark, the comparator output is high (1).
- **Condition 2**: When the door switch is in the desired state (e.g., door closed), its output is high (1).
- **AND Gate Output**: The AND gate will output a high (1) signal only when both conditions are met (it is dark and the door is closed).
- **Alarm Activation**: The high output from the AND gate will activate the alarm.

(c) State three differences between positive rays and cathode rays. (03marks)

1.

Positive rays	Cathode ray
Positively charged	Negatively charged
Low penetrating power	High penetrating power
High ionizing power	Low ionizing power
Helium nucleus	An electron