MWALIMU EXAMINATIONS BUREAU

UACE RESOURCE MOCK EXAMINATIONS – 2022

S.6 PHYSICS
Paper 1 Draft Marking Guide

SECTION A

1. (a) Define

(i) **Work** (1mark)

Work is the product of force and distance moved in the direction of the force.

(ii) **Friction** (1mark)

Friction is a force that opposes the relative motion between two surfaces in contact.

(b) (i) Distinguish between a **conservative force** and a **non-conservative force**. (2marks)

Conservative force	**Non-conservative force**
Is a force for which the work done to move a body round a closed path is zero	Is a force for which the work done to move a body round a closed path is not zero
Work done to move a body from one point to another is independent of the path taken	Work done to move a body from one point to another depends on the path taken
Mechanical energy is conserved	Mechanical energy is not conserved

Any 1x2 = 2marks

(ii) Give one example of each type of force. (1mark)

Examples of conservative forces

- Gravitational force
- Magnetic force

- Electric force
- Examples of non-conservative forces
- Friction
- Air resistance
- Viscous drag

Any 1x1 = 1mark

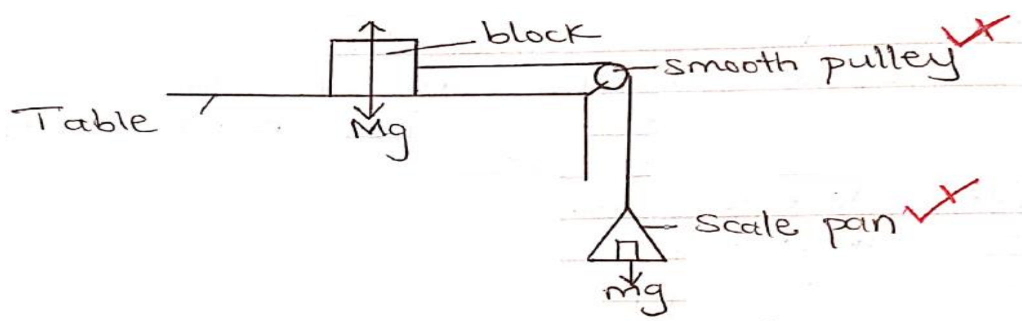
(c) (i) State the laws of **static friction**. (3marks)

- Friction opposes the relative motion between two surfaces in contact.
- Limiting frictional force is proportional to the normal reaction.
- Friction is independent of area of contact provided the normal reaction remains constant.

(ii) Using the **molecular theory** explain the laws of solid friction. (4 marks)

- Surfaces have projections of small area. When in contact the surfaces rest on each other's projections and exert high pressure. The molecules are pushed into close proximity and bonds are formed. For motion to take place these bonds have to be broken hence an opposing force. This explains friction opposes motion.
- Increase in weight of top surface increases the pressure at the points of contact and stronger bonds are formed. This increases the actual area of contact until the new weight is fully supported thus increase in force to break the stronger bonds. when area of contact is stronger the actual contact area remains the same. Thus no change in the frictional force. This explains friction is independent of the area of contact for the same normal reaction.

(iii) Describe an experiment to determine the coefficient of kinetic friction between two solid surfaces. (4marks)

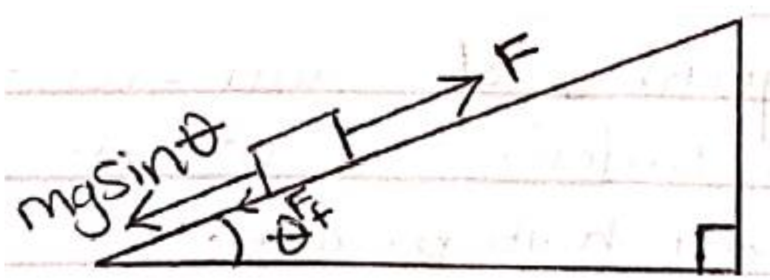


A black of known mass, M is placed on a flat table and connected to a scale pan using a high string. A mass is placed on the scale pan block given a slight push.

More masses are added in bits and block given a slight push until it moves with uniform velocity. Total weight Mg of scale pan and contents is obtained. Experiment is repeated with more masses placed on the block to vary the weight Mg.

A graph of Mg against Mg is plotted.
The shape, S, of the graph is calculated coefficient of kinetic friction = slope S

(d) A car of mass 1.2 x 10^3kg increases its speed from 10ms^{-1} to 20ms^{-1} while moving up an incline of inclination 1 in 20. The car moves through 500m against a constant resistance to motion of 300N. Calculate the driving force exerted by the engine and a maximum speed the car can possibly attain with its engine working at a constant rate. (3 marks)



$$F - (mg\sin\theta + F_f) = ma$$

$$\text{but } V^2 = u^2 + 2as \Rightarrow 20^2 = 10^2 + 2(a)(500)a = 0.3\text{ms}^{-2}$$

$$F = (1.2 \times 10^3) \times 0.3 + (1.2 \times 10^3) \times 9.81 \times \frac{1}{20} + 300$$

$$F = 1.2486 \times 10^3\text{N}$$

2. (a) What is meant by the following terms?

(i) **Velocity gradient**. (1mark)

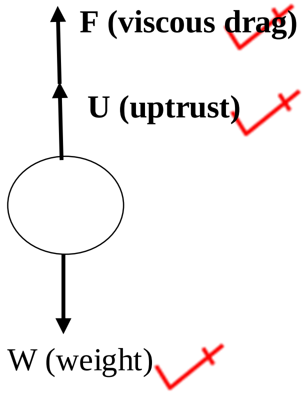
Velocity gradient is the change of velocity between two points per unit length of separation of the pits.

OR Is the rate of change of velocity with change in distance of separation.

(ii) **Coefficient of viscosity**. (1mark)

Coefficient of viscosity is the tangential force per unit areas of fluid which resists the motion of one layer over another when the velocity gradient between the layer in unity.

(b) Derive an expression for the terminal velocity of steel ball bearing of radius r, and density ρ, falling through a liquid of density σ and coefficient of viscosity η. (5marks)



At terminal velocity; W = U + F

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

$$\Rightarrow v_o = 2r^2(\rho - \sigma)\,{}^{g}/_{9\eta}$$

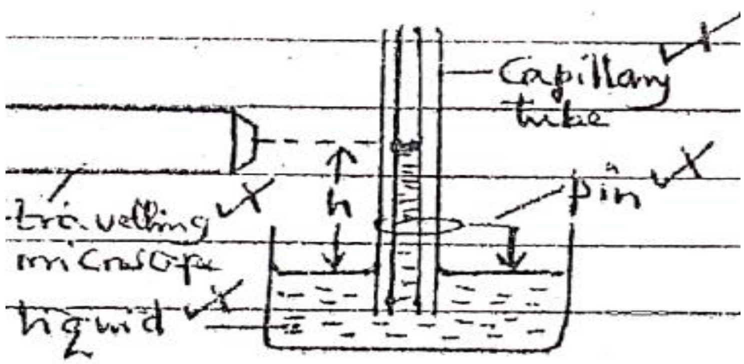
(c) (i) Define **surface tension**. (1mark)

Surface tension is the force per unit length acting in the surface per period to one side of a line in the surface.

(ii) Explain the origin of surface tension. (3marks)

Moles in the surface are more widely spaced than those in the bulk.
The surface moles experience not attractive forces downwards. This puts the moles in a state of tension.

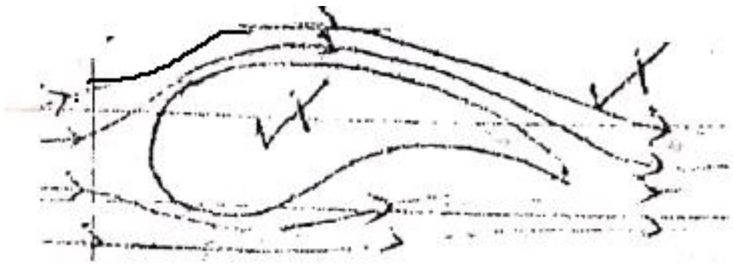
(iii) Describe an experiment to measure the surface tension of a liquid by the capillarity method. (6marks)



- A clean capillary-tube is supported vertically with its lower end dipping in the liquid.

- The travelling microscope is first focused on the bottom of the meniscus in the tube, and then on the tip of the pin when the beaker is removed.
- Column length h is obtained.
- If the radius r of the capillary tube and angle of contact θ of the liquid are known, then the surface tension is given by
  $\varphi = hr\rho g/2\cos\theta$, where ρ = density of liquid.

(d) Explain, with the aid of a diagram why air-flow over the wings of an aircraft at take-off causes a lift. (3marks)



- Air flows faster over the top than at the bottom.
- By Bernoulli's principle, the pressure under which increased and that above reduced. The pressure difference creates an upward resultant force. Perpendicular to flow which provides most of the lift.

3. (a) (i) What is meant by a **conservative force**, and give two examples? (2marks)

- A conservative force is a force for which the work done to move a body from one point to another is independent of the path taken.
- Work done to move around a closed path is zero.
- Mechanical energy is conserved

Examples of conservative force include:

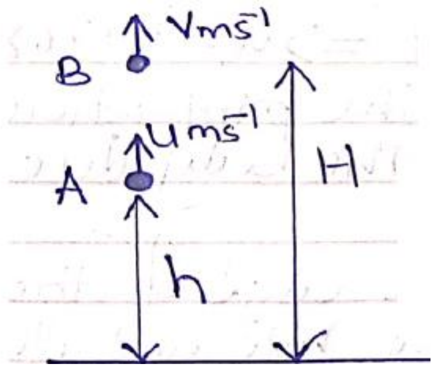
- Gravitational force field
- Magnetic force
- Electrostatic force field

Any 2x½ = 1mark

(b) (i) State the law of **conservation of mechanical energy**. (1mark)

The law of conservation of mechanical energy state that in any mechanical system the total energy remains constant provided that there are no dissipative forces.

(ii) A body of mass **M**, is projected vertically upwards with a speed**, u**. Show that the law of conservation of mechanical energy is obeyed throughout its motion. (5marks)



- The sum of k.e and p.e is constant in the absence of dissipative forces.
- $m.\mathrm{e} = \mathrm{p.e} + \mathrm{k.e}$

$\mathrm{At\ A,} (\mathrm{m.e})\mathrm{A} = \mathrm{mgh} + \frac{1}{2}\mathrm{mv}^2$

$\mathrm{At\ B,} (\mathrm{m.e})\mathrm{B} = \mathrm{mgH} + \frac{1}{2}\mathrm{mv}^2$

$\mathrm{but\ v}^2 = \mathrm{u}^2 - 2\mathrm{g}(\mathrm{H} - \mathrm{h})$

$\mathrm{v}^2 = \mathrm{u}^2 - 2\mathrm{gH} + 2\mathrm{gh}$

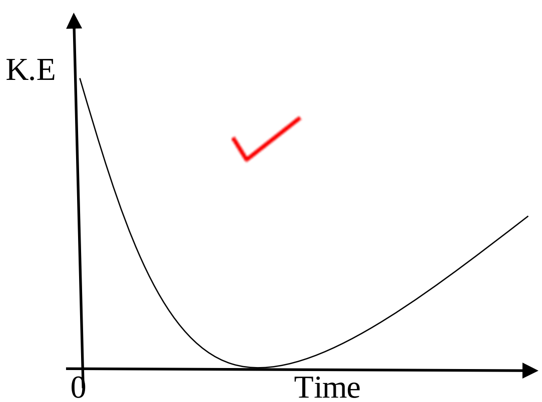
$\Rightarrow (\mathrm{m.e})\mathrm{B} = \mathrm{mgH} + + \frac{1}{2}\mathrm{mv}^2 - \mathrm{mgH} + \mathrm{mgh}$

$(\mathrm{m.e})\mathrm{B} = \mathrm{mgh} + + \frac{1}{2}\mathrm{mv}^2$

$\therefore (\mathrm{m.e})\mathrm{A} = (\mathrm{m.e})\mathrm{B}$

Hence the law of conservation of mechanical energy is obeyed throughout its motion.

(iii) Sketch a graph showing variation of kinetic energy of the body with time. (1mark)



(c) A bullet of mass 20g moving horizontally strikes and gets embedded in a wooden block of mass 500g resting on a horizontal table. The block slides through a distance of 2.3m before coming to rest. If the coefficient of kinetic friction between the block and the table is 0.3, calculate the

(i) Friction force between the block and the table. (2marks)

$F = \mu R \Rightarrow F = \mu(mg)$

$F = 0.3 \times 0.52 \times 9.81$

$\Rightarrow F = 1.53N$

(ii) Velocity of the bullet just before it strikes the block. (4marks)

$$F = ma$$

$$-1.53 = 0.52a \Rightarrow a = -2.94ms^{-2}$$

$$v^2 = u^2 + 2as \Rightarrow 0 = v_1^2 - 2 \times 2.94 \times 2.3$$

$$V_1 = 3.68ms^{-1}$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)V_1$$

$$0.02u_1 = 0.52 \times 3.68$$

$$u_1 = 95.68ms^{-1}$$

ALTERNATIVE

- Using the work energy theorem

$$\frac{1}{2}(m_1 + m_2)V_1^2 = \mu(m_1 + m_2)gs$$

$$V_1^2 = 2\mu gs \Rightarrow \sqrt{(2 \times 0.3 \times 9.81 \times 2.3)}$$

$$V_1 = 3.68ms^{-1}$$

$$m_1u_1 = (m_1 + m_2)V_1 \quad 0.02u_1 = 0.52 \times 3.68$$

$$\Rightarrow u_1 = 95.68ms^{-1}$$

(d) (i) Define **centre of gravity**. (1mark)

Centre of gravity is the point where the resultant force on the body due to gravity acts.

(ii) Describe an experiment to determine the **centre of gravity** of an irregular lamina. (4marks)

- Make three holes near the edge of the sheet suspend the sheet from one hole and allow it to swing freely.
- Hang pendulum bob attached to a string from the same point of suspension.
- Mark the outline of the pendulum on the sheet.
- Repeat the procedure above using the other holes.
- The intersection of the outlines is the centre of gravity of the sheet.

4. (a) Define the terms;

(i) **Stress** (1mark)

Stress is the ratio of force to the cross sectional area.

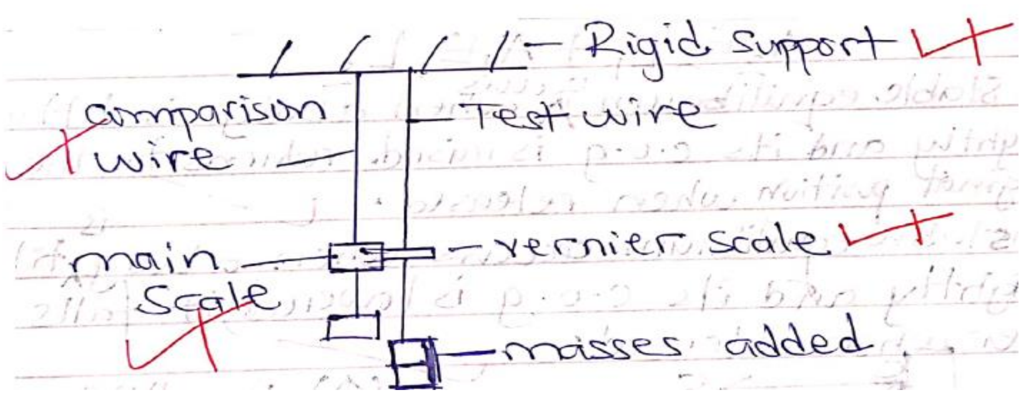
(ii) **Work hardening** (1mark)

Work hardening is a process in which an applied force strengthens a material by repeatedly deforming it and occurs when plane dislocations increase with no more slippage of the atomic planes.

(b) (i) Distinguish between **elastic deformation** and **plastic deformation**. (2marks)

- Elastic deformation is when a material is deformed and it regains its original shape and size when deforming force is removed.
- Plastic deformation is when a force is applied and the material gets permanently deformed. And doesn't regain its original shape and size when the deforming force is removed.

(ii) Describe an experiment to determine **Young's modulus of steel wire**. (6marks)



- Two steel wires of the same length and diameter are fixed on the same rigid support as above. Small weights are fixed at the free ends of the wires to keep them taut (kink free). Length, L of test wire is measured and recorded. Diameter, is measured three times and the average diameter, d obtained. Cross sectional area $A = \pi d^2/_4$ is calculated. Various loads are added onto the test wire in turns and corresponding extensions obtained. For each load used, the wire must be able to go back to its original length. A graph of load, against extension is plotted. Slopes, S of the graph is obtained Young's modulus E is obtained from E = SL/A

(c) Two wires of lengths **L_1** and **L_2** cross sectional areas **A_1** and **A_2** and Young's moduli **E_1** and **E_2** respectively are joined in series. Show that the force, **F** exerted on the wire to produce total extension, e is given by,

$$F = \frac{(E_2E_1A_2A_1)}{(L_2E_1A_1)+(L_1E_2A_2)}(e)$$ (4marks)

$$\mathrm{E} = \frac{\mathrm{Fl_o}}{\mathrm{eA}}$$

$$\Rightarrow \mathrm{e} = \frac{\mathrm{Fl_o}}{\mathrm{EA}}$$

$$\text{For wire 1}, \mathrm{e_1} = \frac{\mathrm{FL_1}}{\mathrm{E_1A_1}}$$

$$\text{For wire 2}, \ \mathrm{e_2} = \frac{\mathrm{FL_2}}{\mathrm{E_2A_2}}$$

$$\text{Total extension}, \mathrm{e} = \mathrm{e_1} + \mathrm{e_2} \ \Rightarrow \mathrm{e} = \frac{\mathrm{FL_1}}{\mathrm{EA_1}} + \frac{\mathrm{FL_2}}{\mathrm{E_2A_2}}$$

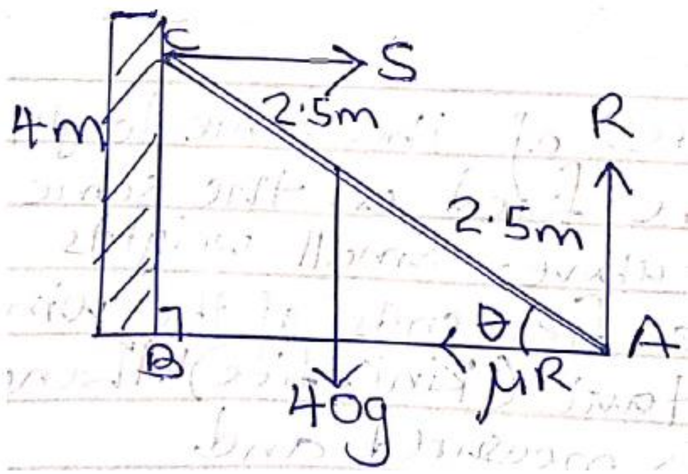
$$\mathrm{e} = \frac{\mathrm{F(A_2E_2L_1+A_1E_1L_2)}}{\mathrm{E_1A_1E_2A_2}}$$

$$\Rightarrow \mathrm{F} = \frac{\mathrm{A_1A_2E_1E_2} \quad \mathrm{e}}{\mathrm{A_2E_2L_1+A_1E_1L_2}}$$

(d) (i) Distinguish between **stable equilibrium** and **unstable equilibrium.** (2marks)

- Stable equilibrium occurs when a body is tilted slightly and its center of gravity (c.o.g) is raised returns to the original position when released.
- Unstable equilibrium occurs when a body is tilted slightly and its c.o.g is lowered, it falls over when released.

(ii) A uniform ladder 5.0m long and of mass 40kg rests with its upper end against a smooth vertical wall and its lower end 3.0m from the wall on a rough ground. Calculate the force at the foot of the ladder. (4marks)



$$(\uparrow) R = 40g = 392.4$$

$$(\rightarrow)\ S = \mu R$$

$$S = \mu(392.4)$$

$$\cos\theta = \frac{3}{5}\ \theta = 53.13^{\circ}$$

- Take moments about A $40 \times 9.81 \times 2.5 \cos 53.13^0$

$S = 147.15\text{N}$

$F = \sqrt{x^2 + y^2} = \sqrt{(147.15^2) + (392.4)^2}$

$F = 419.1\text{N}$

$\theta = \tan^{-1}\left(\frac{y}{x}\right) \Rightarrow \theta = \tan^{-1}\left(\frac{392.4}{419.1}\right)$

$\theta = 69.2^{\circ}$

SECTION B

5. (a) Define the following

(i) **Isothermal change**. (1mark)

- Isothermal change is the change in volume and pressure of a gas at constant temperature.

(ii) **Critical temperature.** (1mark)

- Critical temperature is the temperature above which gas cannot be liquefied by only compression.

(b) The equation of state for one mole of real gas of volume, V and pressure P at a temperature T is given by $\left(P+\frac{a}{V^2}\right)(V-b)=RT$ where a and b are constants.

Explain the significance of the terms $\frac{a}{V^2}$ *and* b. (2marks)

- $\frac{a}{V^2}$ is the pressure defect which accounts for the existence of intermolecular forces of attraction.
- b is a constant that accounts for the finite volume of the molecules themselves.

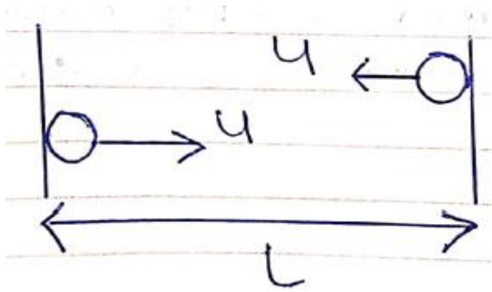
(c) (i) State the **kinetic theory of matter**. (1mark)

- Kinetic theory of matter states that all motion and the motion increases when temperature increases.

(ii) Describe briefly an experiment to demonstrate the kinetic theory of matter. (3marks)

- Smoke is confined in a smoke cell using illuminated using a lamp. Smoke particles are seen moving randomly and haphazardly within the cell. The continuous random motion of the smoke particles is because of unequal force of collision with invisible air molecules.

(iii) A gas of density ℓ, with molecules moving at a mean speed, $\overline{C^2}$, is contained in a cube of side, l. Show that the pressure exerted by the gas is $P=\frac{1}{3}\ell\overline{C^2}$ (4marks)



- For a molecule of mass, M, moving at speed u between walls of a cube

change in momentum $\Delta m = 2mu$

Force on each wall $F = \frac{2mu}{2l/u}$

Pressure on wall, $P = \frac{mu^2}{l} \times \frac{1}{l_2} = \frac{mu^2}{l_3}$

For N molecules moving at $u_1, u_2, \ldots\ldots 4N$

(d) (i) Distinguish between **saturated vapour** pressure and **partial pressure**. (2marks)

Saturated vapour pressure is the pressure exerted by a vapour that is in a dynamic equilibrium with its own liquid **whereas** partial pressure is pressure exerted by a gas in a mixture of gases if that gas alone was to occupy the container.

(ii) Explain the effect of increase in temperature on the saturated vapour pressure of a liquid. (3marks)

When temp of a liquid in dynamic equilibrium with its vapour increases, the mean k.e of molecules of a liquid increases. This increases the rate of evaporation, the density of vapour increases; the rate of condensation increases until the vapor and liquid are again in dynamic equilibrium. The number of vapor molecules entering the liquid per sec is now greater than before hence increase in saturation vapour pressure

(e) An ideal gas at a pressure of 1.0×10^5 Pa and temperature of 27^oC is compressed isothermally to half its volume. The gas then expands adiabatically to its original volume. Taking $\gamma = 1.4$, calculate the final temperature of the gas. (3marks)

Given, $P_1 = 1.0 \times 10^5$ and $T_1 = 273 + 27^oC = 300K$

Let $V_1 = x$; then $V_2 = ½ x$; $V_3 = x$

$T_2=T_1=300K$ (change is isothermal)

Using TV^{y-1} = Constant

$\therefore T_2V_2^{y-1} = T_3V_3^{y-1}$

$T_3 = T_2(V_2/V_3)^{y-1}$

.. $= 300(x/2x)^{1.4-1}$

$= 227.358K$

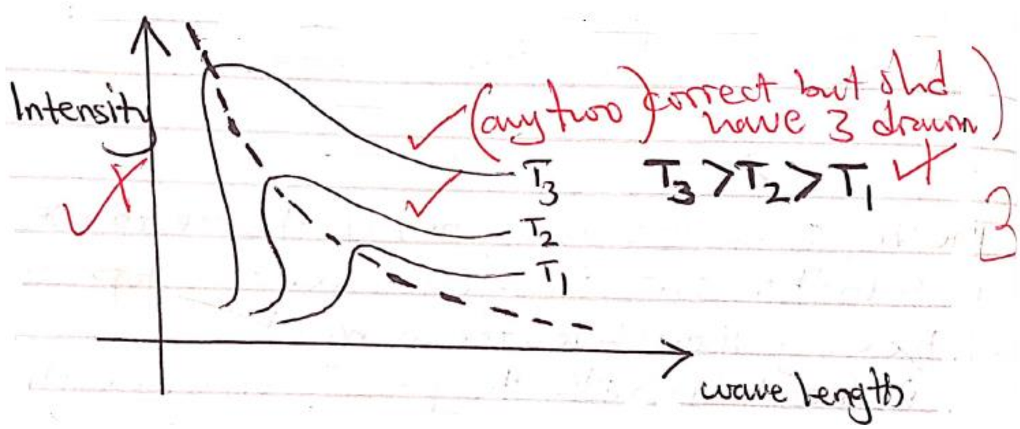
6. (a) (i) State the laws of **black body radiation**. (2marks)

- Wien's displacement law states that the wavelength at which intensity of radiation emitted is a maximum is inversely proportional to its absolute temperature. $\left(\lambda_{max} \infty \frac{1}{T}\right)$
- Stefan's law states that the total energy radiated per second per unit area of surface of a black body is proportional to the fourth power of the absolute temperature of the body.

(ii) Why is black body radiation referred to as temperature radiation? (1mark)

- Black body is called temperature radiation because the quality or the intensity of radiation emitted depends on the temperature of the body emitting the radiation.

(iii) Sketch the variation of intensity of radiation emitted with wavelength for a black body at three different temperatures. (3marks)



(b) (i) If the equilibrium temperature of the earth's surface is T and the total rate of emission by the sun is E, show that $\boldsymbol{T} = \frac{\boldsymbol{E}}{\boldsymbol{16\sigma\pi R^2}}$, where σ = Stefan's constant and R is the radius of the earth's orbit around the sun. (4marks)

Solar intensity, $I = \frac{E}{4\pi R^2}$ = power of radiation falling on m^2 on earth

Power falling on earth = $I \times \pi r_e^2$, where r_e = radius of earth

$$= \frac{E}{4\pi R^2} \times \pi r_e^2 = \frac{E r_e^2}{4R^2}$$

Power radiated by earth $= 4\pi r_e^2 \sigma T^4$

At thermal equilibrium = $4\pi r_e^2 \sigma T^4 = \frac{E r_e^2}{4R^2}$

$$T^4 = \frac{E}{16\sigma\pi R^2}$$

(ii) State the assumption made in b (i) above. (1mark)

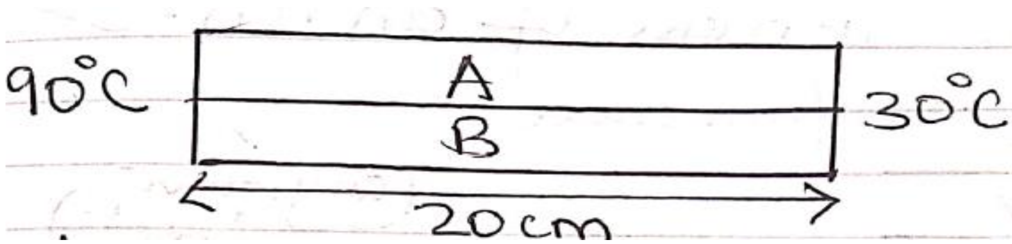
- Assumption is that none of the radiation from the sun is absorbed by the atmosphere
- The earth radiates as a black body
- The sun is a black body

Any one correct

(c) (i) What is meant by **temperature gradient** as applied to a thermal conductor? (1mark)

- Temperature gradient of a conductor is the ratio of the difference in temperature between the ends of the conductor to the length of the conductor.

(ii) Two perfectly lagged metal bars A and B, each of length 20cm, are arranged in parallel, with their hot ends maintained at 90^{o}C and their cold ends at 30^{o}C. If the cross sectional area of each bar is $2.5cm^2$, find the net rate of heat flow through the parallel bars. Take thermal conductivity of A = $400Wm^{-1}K^{-1}$ and that of B = $200Wm^{-1}K^{-1}$. (4marks)



$$L_A = L_B = 0.2m, A = 2.5cm^2 = 2.5 \times 10^{-4}m^2$$

$$\frac{Q}{t} = \frac{K_A A(90-30)}{L_A} + \frac{K_B A(90-30)}{L_B}$$

$$\frac{Q}{t} = \frac{400 \times 2.5 \times 10^{-4} \times 60}{0.2} + \frac{200 \times 2.5 \times 10^{-4} \times 60}{0.2}$$

$$\frac{Q}{t} = 45JS^{-1}$$

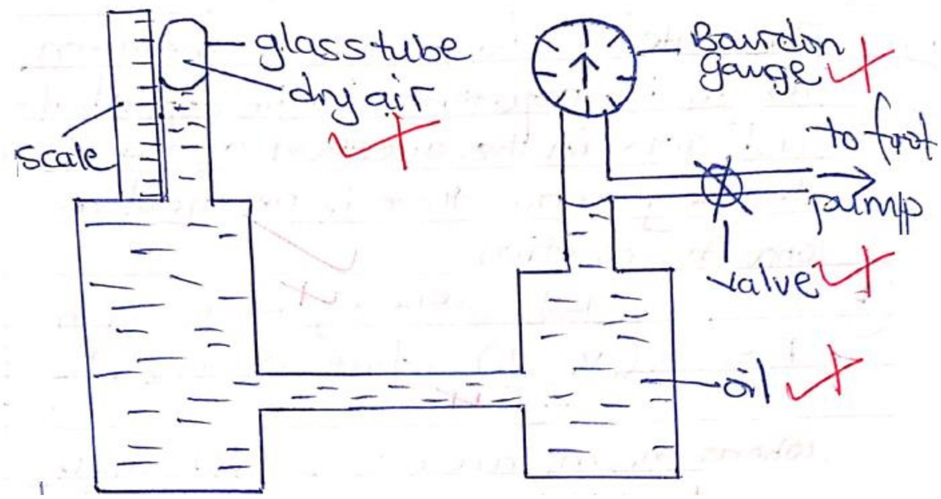
(d) Explain how **Greenhouse effect** leads to **global warming**. (4marks)

- Short wave length radiation incident on the atmosphere is partly absorbed by the atmosphere partly reflected by land and partly absorbed by the earth.
- The radiation absorbed by the earth heats up the earth and the earth re-radiates it into space.
- Owing to the lower temperature of the earth the longer wavelength radiation from the earth is trapped by the greenhouse gases CFCs, CO_2.
- this leads to increased temperature of the earth's atmosphere thus leading to global warming.

7. (a) (i) State **Boyle's law**. (1mark)

- Boyle's law states that for a fixed mass of a gas at constant temperature the pressure is inversely proportional to its volume.

(ii) Describe an experiment to verify Boyle's law. (6marks)



- Gas under investigation is trapped above oil in a glass tube. Volume V of air trapped is read from the scale.
- It is compressed by using the foot pump to increase the pressure above the oil in the reservoir. Pressure P of air trapped is read from the bourdon gauge. Pressure is increased in stages and different pairs of P and V are recorded values of $\frac{1}{P}$ are calculated .
- A graph of V versus $\frac{1}{P}$ is plotted .
- The graph is a straight line through the origin. This verifies Boyle's law.

(iii) Explain why the pressure of a fixed mass of gas rises if its temperature is increased. (2marks)

- When temperature of a fixed mass of gas is increased at constant volume.
- The molecules move faster and gain k.e .
- They bombard the walls more frequently and with increased force since force α pressure ⇒ pressure of gas increases.

(b) (i) Define the term **thermometric property** and give four examples.(3marks)

- Is a physical property of a substance whose value varies uniformly and continuously with change in temperature of a fixed mass of gas at constant volume.

Examples

- Length of liquid in capillary tube
- Pressure of a fixed mass of gas at constant volume
- Volume of fixed mass of gas at constant pressure
- Resistance of platinum wire
- emf of a thermocouple.

Any 4x ½ = 2marks

(ii) State two qualities of a good thermometric property. (1mark)

- Should vary linearly and continuously
- Should be sensitive to temperature changes
- Should vary over a wide range of temperature

Any 2x ½ = 1 mark

(c) (i) With reference to a liquid in glass thermometer, describe the steps involved in setting up a **Kelvin scale of temperature**. (3marks)

- Length L_{tr} of liquid column is measured at the triple point of water, length L_T of liquid column is measured at an unknown temperature T

$$T = \frac{L_T}{L_{tr}} \times 273.16K$$

(ii) State one advantage and one disadvantage of the resistance thermometer. (1mark)

Advantage

- It us accurate
- Measures a wide range temperature
- It is Portable

Disadvantage

Does not give direct reading

(d) A resistance thermometer has a resistance of 21.42Ω at the ice point, 29.10Ω at steam point and 28.11Ω at some unknown temperature ϴ. Calculate ϴ on the scale of this thermometer. (3marks)

$$\theta = \frac{R_\theta - R_o}{R_{100} - R_o} \times 100℃$$

$$\theta = \frac{28.11 - 21.42}{29.10 - 21.42} \times 100℃$$

$$\theta = 87.1℃$$

SECTION C

8. (a) Define the terms

(i) **Mass number**. (1mark)

- Mass number is the total number of protons and neutrons in the nucleus.

(ii) **Decay constant**. (1mark)

- Decay constant is the fraction of number of atoms that decay per second.

(b) Derive the relation between **half-life**, $T_{\frac{1}{2}}$ and the **decay constant** λ. (3marks)

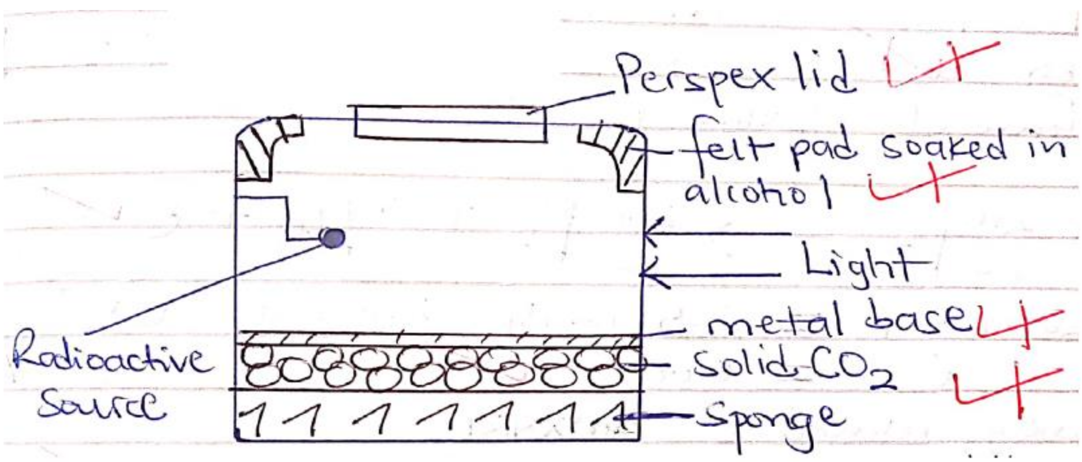
- $N = \mathrm{Noe}^{-\lambda t}$ At half life $t = T_{1/2}$, $N = N_0/_2$

$$\frac{\mathrm{No}}{2} = \mathrm{Noe}^{-xt_1/_2} \Rightarrow \frac{1}{2} = e^{\lambda T_1/_2}$$

$$e^{\lambda T_1/_2} = 2 \Rightarrow \lambda T_{1/_2} \mathrm{Log}_e^2 = \mathrm{Log}_e^2$$

$$T_{1/_2} = \frac{\mathrm{In}2}{\lambda}$$

(c) With the aid of a labelled diagram describe the operation of a **diffusion cloud chamber** in detecting radiation. (6marks)



- Top of chamber is at room temperature and the bottom is maintained at very low temperature by the solid CO_2. A temperature gradient is established between the top and bottom of the chamber. Air at the top is saturated with alcohol vapour from the felt pad which diffuses downwards into the cooler region. The air in the cooler region becomes super saturated. When an ionizing radiation passes through the air, the excess vapour condenses on the ions formed drops. When the inside of the chamber is illuminated tracks are seen as a series of droplets. Thickness and length of path show the extent to which ionization has occurred.

(d) (i) What is meant by **binding energy of a nucleus**? (1mark)

- Binding energy is the energy required to split the nucleus into its protons and neutrons. ✓

(ii) Distinguish between **nuclear fusion** and **nuclear fission**. (2marks)

- Nuclear fusion is a process where two small nuclei combine to form a heavier nucleus accompanied by the release of energy. ✓
- Nuclear fission is a process where a heavy nucleus splits to form two lighter nuclei accompanied by the release of energy. ✓

(iii) State the significance of each of the process in (ii) above. (1mark)

- Fusion is used in the release of energy.
- Energy or production of the hydrogen bomb.
- Fission is used in production of the atomic bombs or generation of nuclear energy in form of electricity.
  Any 2x ½ = 1 mark

(e) The radioactive nuclei $^{210}_{84}Po$ emits alpha particles and the product nuclei are of $^{206}_{82}Pb$, taking the mass of $^{210}_{84}Pb = 209.937\text{u}$, $^{206}_{82}Pb = 205.929u$, $^{4}_{2}He = 4.002u$ and 1 u = 931 MeV.

(i) Calculate the energy released in the disintegration. (4marks)

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

$209.937u = 205.929u + 4.002u + E$ ✓

$E = 0.006u$ ✓

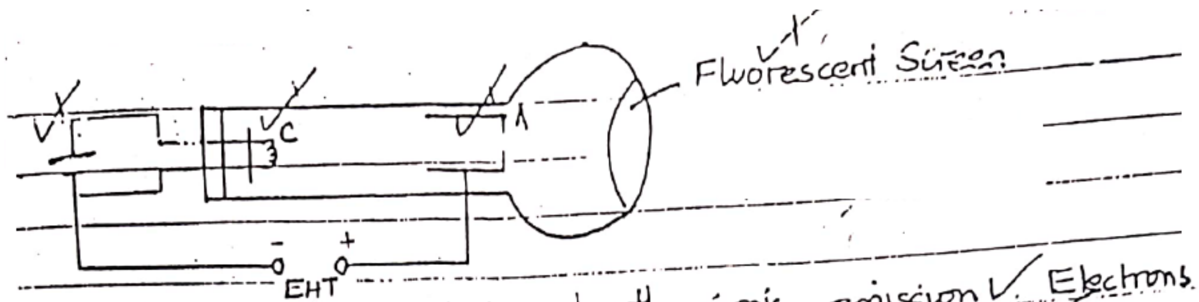
Energy released $E = \Delta m \times 931$

$E = 0.006 \times 931 = 5.59\text{ MeV}$ ✓

(ii) Explain why not all the energy does not appear as the kinetic energy of the alpha particle. (1mark)

Part of the energy is taken by the Pb nucleus as it recoils with smaller velocity hence smaller energy.

9. (a) (i) Describe with aid of a diagram, the production of **cathode rays**. (4marks)



Cathode C produces electrons by thermionic emission. Electrons are accelerated by P.d between Cathode and anode A.

(ii) State and justify two properties of cathode rays. (2marks)

Cathode rays travel in a straight line because they cast a sharp shadow a maltese cross on the fluorescent screen

OR

Cathode rays carry a negative charge, they are deflected by electric and magnetic fields

(b) Explain each of the following terms as applied to photo-electric emission:

(i) **Stopping potential**. (1mark)

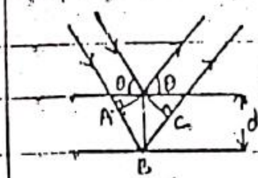
Minimum potential which reduces the photo-current to zero

(ii) **Threshold frequency**. (1mark)

Frequency of incident radiation below which no electron emission takes palce from a metal

(c) Explain X-ray diffraction by crystals and derive **Bragg's law**. (6marks)

When X-rays fall on a single plane of atoms in a crystal, each atom scatters a fraction of the incident beam. The X-rays scattered from various planes interfere constructively in those directions for which the scattered rays are parallel, otherwise destructive interference occurs.



Path difference $= \overline{AB} + \overline{BC}$

$= d\sin\theta + d\sin\theta = 2d\sin\theta$

For constructive interference, Path difference $= n\lambda$ (n = integer)

$\Rightarrow n\lambda = 2d\sin\theta$ (6)

(d) The potential difference between the cathode and the anode of an X-ray tube is 5.0 x 10^{-4} V. If only 0.4% of the kinetic energy of the electrons is converted into X-rays and the rest is dissipated as heat in the target at a rate of 600W, find the

(i) Current that flows. (3marks)

99.6% of energy is converted into heat ∴ Power converted into heat

$= 0.996\,IV = 600W$

$\frac{99.6}{100} \times 5.0\times10^{-4} \times I = 600 \Rightarrow I = 1.21\times10^{6}A$

(ii) Speed of the electrons striking the target. (3marks)

$eV = \frac{1}{2}mu^2$, $u^2 = \frac{2eV}{m} \Rightarrow u = \sqrt{\frac{2eV}{m}}$

$u = \sqrt{\frac{2\times1.6\times10^{-19}\times5.0\times10^{-4}}{9.11\times10^{-31}}} = 1.33\times10^{4}ms^{-1}$

10. (a) What is meant by the following.

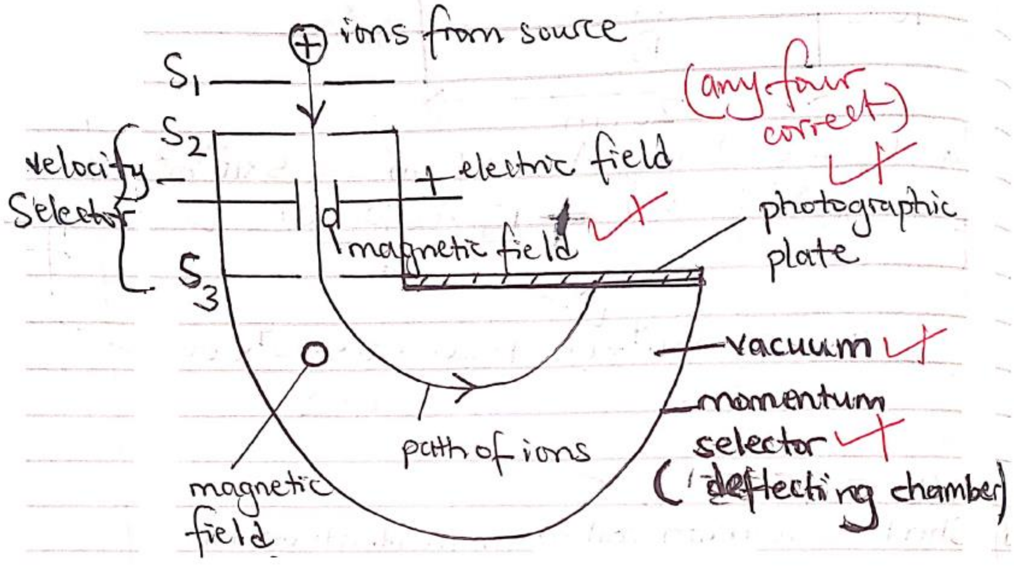
(i) **Isotopes**. (1mark)

Isotopes are atoms of same element with the same atomic number but difference mass numbers

(ii) **Specific charge of an ion**? (1mark)

Specific charge of an ion is the charge per unit mass of an ion

(b) With the help of a diagram, describe how specific charge of an ion can be determined using the **Bainbridge mass spectrometer**. (6marks)



Ions from source are directed into a velocity selector with crossed electric and magnetic fields applied at the same time. Ions of the same charge Q pass through the velocity selector undeflected with velocity V given by $QE = B_1QV \Rightarrow V = E/B_1$. The selected ions enter a deflection chamber having only magnetic field of flux density B_2. The ions move along circular paths and strike a photographic plate. Centripetal force on ions is provided by B_2

$B_2QV = \frac{mV^2}{r}$. The radius r of the circle described is measured. The charge to mass ratio is given by $Q/m = E/B_1B_2r$ where m is the mass of the ions, E the electric field intensity and B_1, B_2 are the magnetic flux densities.

(c) In a Bainbridge mass spectrometer, the magnesium ions ${}^{24}Mg^{+}$ and ${}^{26}Mg^{2+}$ are deflected in circular paths by a uniform magnetic field. Calculate;

(i) The ratio of the specific charges of the two ions. (3marks)

For ${}^{24}Mg^{+}$ ion, $Q/m = Q/24$

For ${}^{26}Mg^{2+}$ ion, $Q/m = 2Q/26$

Ratio of Specific charges $= \frac{Q}{24} : \frac{2Q}{26} = \frac{Q}{24} \times \frac{26}{2Q}$

$= 13 : 24$

or 0.54

(ii) The radius of the path of the heavier ion if that of the lighter ion is 0.36m. (2 marks)

$\left(\frac{Q}{m}\right)_1 \propto \frac{1}{r_1}$

$\left(\frac{Q}{m}\right)_2 \propto \frac{1}{r_2}$ $\Rightarrow \frac{\left(\frac{Q}{m}\right)_1}{\left(\frac{Q}{m}\right)_2} = \frac{r_2}{r_1} = \frac{13}{24}$

but $r_1 = 0.36m$

$\frac{r_2}{0.36} = \frac{13}{24} \Rightarrow r_2 = 0.195m$

(d) In a simple model of the hydrogen atom, an electron of mass m and charge –e, moves in a circular orbit about the nucleus.

(i) Show that the kinetic energy of the electron is given by $\frac{e^2}{8\pi\varepsilon r}$, where r is the radius of the electron's orbit, ε is the permittivity of free space. (2marks)

Electric force on electron, $F_e = \frac{e^2}{4\pi\epsilon_0 r^2}$

Centripetal force on electron, $F_c = \frac{mv^2}{r}$

At equilibrium, $F_e = F_c$

$\frac{e^2}{4\pi\epsilon_0 r^2} = \frac{mv^2}{r}$

$\Rightarrow \frac{1}{2}mv^2 = \frac{e^2}{8\pi\epsilon_0 r}$

$K.e = \frac{e^2}{8\pi\epsilon_0 r}$

(ii) Given that the angular momentum of the electron is $\frac{nh}{2\pi}$, where n is an integer and h is Planck's constant, show that the total energy of the electron is $E_n = -\frac{me^4}{8n^2h^2\varepsilon^2}$. (3marks)

$$\delta W = F\delta r \Rightarrow dW = F\,dr \Rightarrow W = \int_{\infty}^{r} F\,dr$$

$$W = \int_{\infty}^{r} \frac{e}{4\pi\varepsilon_0 r^2}\,dr = -\frac{e^2}{4\pi\varepsilon_0 r}$$

$$P.e = \frac{-e^2}{4\pi\varepsilon_0 r}$$

Total energy E_n $= K.e + P.e = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$

$$E_n = \frac{-e^2}{8\pi\varepsilon_0 r}$$

Angular momentum $= \frac{nh}{2\pi} = mvr$

$$m^2v^2r^2 = \frac{n^2h^2}{4\pi^2}$$

$$mv^2 = \frac{n^2h^2}{4\pi^2 m r^2}$$

$$K.e = \frac{1}{2}mv^2 = \frac{n^2h^2}{8\pi^2 m r^2}$$

Equate expressions for K.e

$$\frac{e^2}{8\pi\varepsilon_0 r} = \frac{n^2h^2}{8\pi^2 m r^2}$$

$$r = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$$

$$E_n = \frac{-me^4}{8\varepsilon_0^2 h^2 n^2}$$

(iii) Explain the significance of the minus sign in the expression for E_n in (d)(ii) above. (2marks)

The total energy of the electrons is negative because electrons are bound to the nucleus of the atom. Work must therefore be done to remove electrons from the atom. This work is done against the nuclear attraction binding the electrons in the atom.

END