P510/1
PHYSICS
Paper 1
AUGUST
2023

MASAKA DIOCESE EXAMINATIONS BOARD

Uganda Advanced Certificate of Education

PHYSICS

PAPER 1

2 Hours, 30 minutes

INSTRUCTIONS TO CANDIDATES:

Attempt **five** *questions, including* **one** *but not more than* **two** *from each of the sections,* **A**, **B** *and* **C**. ***Any additional question(s) attempted will not be marked.***
Non-programmable scientific electronic calculators may be used.
Assume where necessary:

Acceleration due to gravity, g	=	$9.81\ m\ s^{-2}$
Electron charge, e	=	$1.6 \times 10^{-19}\ C.$
Electron mass	=	$9.11 \times 10^{-31}\ kg$
Mass of earth	=	$5.97 \times 10^{24}\ kg.$
Planck's constant, h	=	$6.6 \times 10^{-34}\ J\ s.$
Stefan's – Boltzmann's constant, σ	=	$5.7 \times 10^{-8}\ Wm^{-2}\ K^{-4}$
Radius of Earth	=	$6.4 \times 10^{6}\ m.$
Radius of the sun	=	$7.0 \times 10^{8}\ m.$
Radius of earth's orbit about the sun	=	$1.5 \times 10^{11}\ m$
Speed of light in a vacuum, c	=	$3.0 \times 10^{8}\ m\ s^{-1}$
Thermal conductivity of copper	=	$390\ W\ m^{-1}\ K^{-1}$
Thermal conductivity of aluminium	=	$210\ W\ m^{-1}\ K^{-1}$
Specific heat capacity of water	=	$4200\ J\ kg^{-1}\ K^{-1}$
Universal Gravitational constant, G	=	$6.67 \times 10^{-11}\ N\ m^{2}\ kg^{-2}$
Avogadro's number N_A	=	$6.02 \times 10^{23}\ mol^{-1}.$
Density of water	=	$1000\ kg\ m^{-3}$
Gas constant, R	=	$8.31\ J\ mol^{-1}\ K^{-1}$
Charge to mass ratio, e/m	=	$1.8 \times 10^{11}\ C\ kg^{-1}$
The constant $\frac{1}{4\pi\varepsilon_o}$	=	$9.0 \times 10^{9}\ F^{-1}\ m$
Faradays constant, F	=	$9.65 \times 10^{4}\ C\ mol^{-1}$

SECTION A

Turn Over

1. (a) State the condition under which the law of conservation of linear momentum will be conserved. (1 mark)

(b) Two balls A and B of mass m_1 and m_2 respectively lie on a smooth surface in a straight line. If the balls are projected with velocities u_1 and u_2 respectively in the same direction. Show that on colliding elastically ball A will move with a velocity

$$v = \frac{(m_1 - m_2)u_1 + 2m_2u_2}{(m_1 + m_2)}$$

(7 marks)

(c) Two pendula of equal length l have each a bob A and B of masses $3M$ and M respectively. The pendula are hung with bobs in contact, as shown in Figure 1.

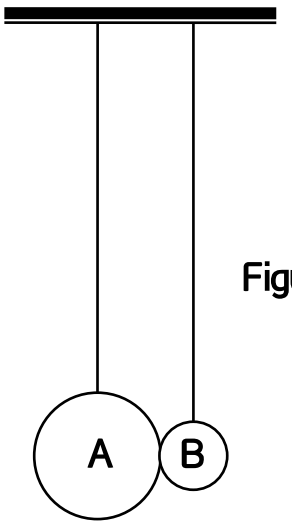

Figure 1

The bob A is displaced such that the string makes an angle θ with the vertical and released. If A makes a perfectly inelastic collision with B, show that the height, h, to which B rises is given by

$$h = \frac{9l(1 - \cos\theta)}{16}$$ (6 marks)

(d) (i) What is meant by the terms **centre of gravity** and a **uniform body**. (2 marks)

(ii) Describe an experiment to locate the centre of gravity of an irregular object. (4 marks)

2. (a) Define the following terms.
(i) **Angular velocity**. (1 mark)
(ii) **Centripetal acceleration**. (1 mark)

(b) Derive the expression for the acceleration of a body moving with angular velocity, ω, through a circular path of radius, r. (4 marks)

(c) (i) What is meant by **banking** of a road in circular motion? (1 mark)
(ii) Draw a sketch diagram to show forces acting on a car moving round a banked track. (2 marks)
(iii) A car moves along a circular track of radius 100 m, banked at an angle of 10^{o}. If the coefficient of friction between the tyres of the car and the ground is 0.3, find the maximum speed at which the car can move without overturning. (4 marks)

(d) A conical pendulum has a string of length 1.2 m and describes a horizontal circular path of radius 0.6 m. If the tension in the string is 22.66 N, find the
(i) mass of the body attached to the string. (3 marks)
(ii) angular speed of the mass. (2 marks)

(e) Explain why a motor cyclist leans towards the centre of a circular path. (2 marks)

3. (a) State **Newton's law of gravitation** and deduce the dimensions of the universal gravitational constant, G. (4 marks)

(b) Describe an experiment to determine the universal gravitational constant, G. (6 marks)

(c) Explain and sketch the variation of acceleration due to gravity with distance from the centre of the earth. (6 marks)

(d) Given that the density of the Earth is ρ and its radius is R_e, show that the expression for the acceleration due to gravity, g at a distance **X** below the surface of the Earth is given by

$$g = \frac{4}{3}\pi G(R_e - X)\rho$$

where G is universal gravitational constant. (4 marks)

4. (a) Define the following
   (i) **Brittleness.** (1 mark)
   (ii) **Young's modulus**. (1 mark)

Turn Over

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

(c) A uniform metal bar of length 1.0 m and diameter 2.0 cm is fired between two rigid supports at 25 °C. If the temperature of the rod is raised to 75 °C. Find the
   (i) Force exerted on the supports. (3 marks)
   (ii) Energy stored in the rod at 75 °C. (3 marks)

(Young's modulus for a metal bar = 2×10^{11} Pa, coefficient of linear expansion = $1.0 \times 10^{-5}\ K^{-1}$)

(d) (i) Define **terminal velocity**. (1 mark)
   (ii) Sketch a velocity- time graph for a ball bearing dropped in a tall glass jar with a viscous fluid such as oil. (1 mark)
   (ii) Derive an expression for the terminal velocity of a ball – bearing of radius r and density ρ, falling through a liquid of density σ and coefficient of viscosity η. (4 marks)

SECTION B

5. (a) What is meant by the **Kinetic theory of gases**? (3 marks)

(b) The pressure, P, of an ideal gas is given by $P = \frac{1}{3}\rho\overline{C^2}$ where ρ is the density of the gas and $\overline{C^2}$ its mean square speed.
   (i) Show clearly the steps taken to derive this expression. (6 marks)
   (ii) State the assumptions made in deriving this expression. (2marks)

(c) (i) State **Stephan's law** of black body radiation. (1 mark)
   (ii) State four properties of radiant energy. (2 marks)

(d) A metal sphere whose surface acts as a black body, is placed at the principal focus of a concave mirror of diameter 60 cm, which is directed towards the sun. If the solar radiation falling normally on the earth is 1400 Wm^{-2}, and the mean temperature of the surroundings is 30 ^{o}C, find the diameter of the sphere when the maximum temperature it attains is 1870 ^{o}C. (6 marks)

6. (a) (i) Define a **thermometric property**. (1mark)
(ii) Explain why different thermometers given different values for temperature of a body. (2marks)

(b) With the aid of a labelled diagram, describe how a constant volume gas thermometer is used to determine absolute temperature of a body. (6 marks)

(c) (i) Define specific latent heat of vaporization and state its units. (2marks)
(ii) Explain why specific latent heat of vaporization of a substance is bigger than its specific latent heat of fusion. (3 marks)

(d) (i) State **Newton's law of cooling**. (1 mark)
(ii) A metal sphere when suspended in a constant temperature enclosure cools from 80 ^{o}C to 70 ^{o}C in 5 minutes. Calculate the temperature of the enclosure. (5 marks)

7. (a) (i) Define **thermal conductivity**. (1 marks)
(ii) Explain the mechanism of heat conduction through solids. (4 marks)

(b) With the use of a well labelled diagram, describe an experiment to determine the coefficient of thermal conductivity of a plastic material. (6 marks)

(c) Water of mass 2.5 kg in an aluminium container of mass 1.0 kg of uniform thickness 3.0 mm and a base area 0.1 m^2 is heated by an electric fire and its temperature rises from 20 ^{o}C to 100 in 7 ^{o}C minutes and 16 seconds. Assuming no heat is lost to the surroundings, find the
(i) power of the electric fire. (3 marks)
(ii) rate at which water boils away. (2 marks)
(iii) temperature of the underside of the aluminium container. (2 marks)

(d) Explain why a metal surface feels cooler to touch than a wooden one. (2marks)

SECTION C

8. (a) (i) Define **cathode rays**. (1 mark)
(ii) State and justify any two properties of cathode rays. (2 marks)

(b) (i) Describe with the aid of a labelled diagram the structure and mode of operation of a C.R.O. (6 marks)
(ii) State the advantages of a C.R.O over a moving coil voltmeter. (2 marks)

Turn Over

(c)

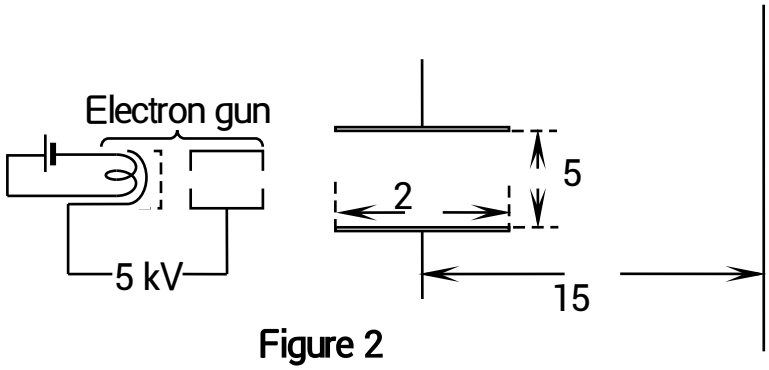

Figure 2

In Figure 2, calculate the deflection of the spot in mm per volt potential difference of a cathode ray tube given that the electrons are accelerated by a potential difference of 5.0 kV between the cathode and the anode given that the length of the deflector plates is 2.0 cm, separation of the deflector plates is 5.0 mm and the distance from the midpoint of the deflector plates from the screen is 15.0 cm. (6 marks)

(d) A beam of electrons having a common velocity enters a uniform magnetic field in a direction normal to the field. Describe and explain the subsequent path of the electrons. (3 marks)

9. (a) What is meant by the following.
(i) A **photon**. (1 mark)
(ii) **Photoelectric effect**. (1 mark)

(b) With the aid of a labelled diagram describe an experiment to determine Planck's constant. (6 marks)

(c) (i) Violet light of wavelength 0.4 μm is incident on a metal surface of threshold wavelength 0.65 μm. Find the maximum speed of the emitted electrons. (4 marks)

(ii) Explain why light whose frequency is less than the threshold frequency cannot cause photo electric emission. (2 marks)

(d) State the observations and conclusions made from Rutherford's alpha particle scattering experiment. (3 marks)

(e) Figure 3 shows some of the energy levels of the hydrogen atom.

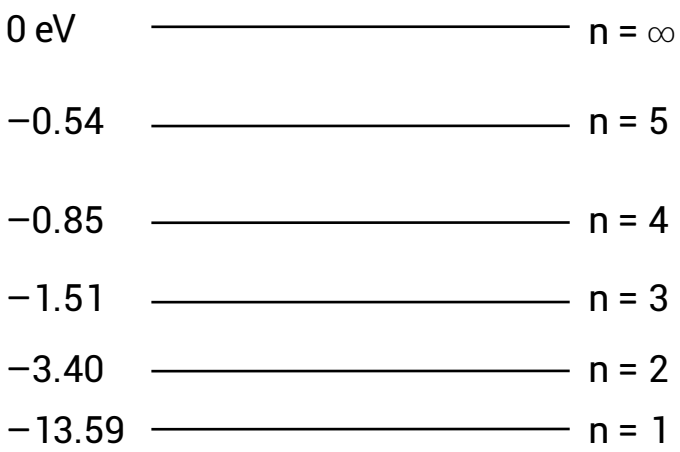

Figure 3

(i) Calculate the ionization energy for the hydrogen atom. (1 mark)

(ii) Calculate the wavelength of the radiation emitted by the electron transition from the 4^{th} to the 2^{nd} energy level. (2 marks)

10. (a) Define the following terms as used in the study of radioactivity.

(i) **Activity**. (1 mark)
(ii) **Decay constant**. (1 mark)
(iii) **Atomic mass unit**. (1 mark)

(b) (i) Sketch a graph showing how binding energy per nucleon varies with mass number. (1 mark)
(ii) Describe the main features of the graph in (b)(i) above. (3 marks)

(c) A fresh sample of radioactive $^{54}_{26}Fe$ weighs 15 g and its activity is 8.5×10^{14} disintegrations per second. Find the
(i) half-life of $^{54}_{26}Fe$. (4 marks)
(ii) activity of 15 g sample after two years. (3 marks)

(d) With the aid of a labelled diagram describe the structure and action of a **cloud chamber**. (6 marks)

END