P510/2
PHYSICS
Paper 2
(Theory)
Nov./Dec. 2023
2½ hours

UGANDA NATIONAL EXAMINATIONS BOARD

Uganda Advanced Certificate of Education

PHYSICS
Paper 2
(Theory)
2 hours 30 minutes

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INSTRUCTIONS TO CANDIDATES:

Answer **five** *questions, taking at least* **one** *from each of the sections;* **A**, **B**, **C** *and* **D**, *but* **not** *more than* **one** *question should be chosen from either section* **A** *or* **B**.

Any additional question(s) answered will **not** *be marked.*

Mathematical tables and graph paper are provided.

Silent, non-programmable scientific calculators may be used.

Assume where necessary:

Acceleration due to gravity, g	=	$9.81\ ms^{-2}$
Electron charge, e	=	$1.6 \times 10^{-19}\ C$
Electron mass	=	$9.11 \times 10^{-31}\ kg$
Plank's constant, h	=	$6.6 \times 10^{-34}\ Js$
Speed of light in a vacuum, C	=	$3.0 \times 10^{8}\ ms^{-1}$
Avogadro's number, N_A	=	$6.02 \times 10^{23}\ mol^{-1}$
Gas constant, R	=	$8.31\ Jmol^{-1}K^{-1}$
Charge to mass ratio, e/m	=	$1.8 \times 10^{11}\ Ckg^{-1}$
The constant $\frac{1}{4\pi\varepsilon_0}$	=	$9.0 \times 10^{9}\ F^{-1}m$
Permeability of free space, μ_0	=	$4.0\ \pi \times 10^{-7}\ Hm^{-1}$
Permittivity of free space, ε_0	=	$8.85 \times 10^{-12}\ Fm^{-1}$

SECTION A

1. (a) State the **laws of reflection of light**. (*02 marks*)

(b) (i) With the aid of ray diagrams distinguish between virtual and real images formed by a concave mirror. (*04 marks*)

(ii) Using any of the diagrams in (b) (i), derive the mirror formula. (*04 marks*)

(c) Find the position of a finite object placed on the axis of a concave mirror of radius of curvature 30 cm, if the mirror forms a virtual image three times the height of the object. (*03 marks*)

(d) With the aid of a ray diagram, describe the working of a projection lantern. (*04 marks*)

(e) A projector consists of a slide 5 cm by 5 cm which produces an image 3 m by 3 m on a screen placed 24 m from the projection lens. Calculate the focal length of the projection lens. (*03 marks*)

2. (a) (i) State the **laws of refraction of light**. (*02 marks*)

(ii) Define **refractive index** of a medium. (*01 mark*)

(b) Show that when a ray of light passes through different media separated by plane boundaries,

$$n \sin i = \text{constant},$$

where n is the absolute refractive index of a medium and i is the angle made by the ray with the normal in the medium. (*04 marks*)

(c) A glass block separates water and liquid ***A*** in a trough as shown in Figure **1**.

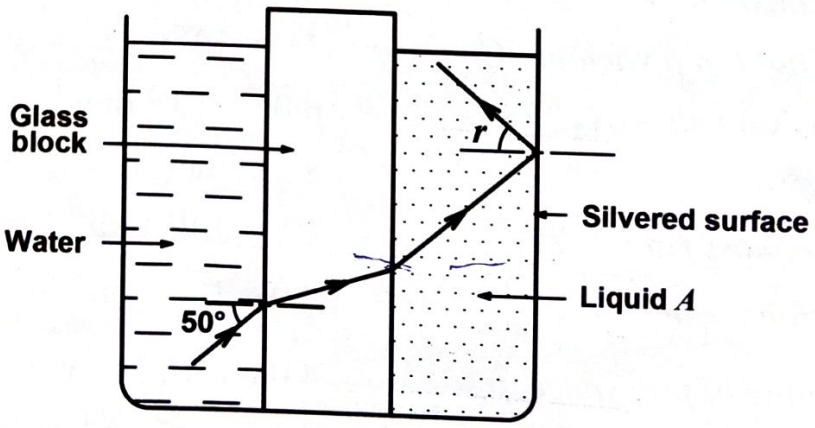

Fig. 1

Monochromatic light from water is incident on the glass block at an angle of 50^0. The opposite side of the trough is silvered.

Determine the value of angle, r, if the refractive indices of water, glass and liquid **A** are 1.33, 1.50 and 1.25 respectively. *(05 marks)*

(d) Show that the refractive index, n_g, of a glass block is given by

$$n_g = \frac{\text{Real depth}}{\text{Apparent depth}}.$$ *(04 marks)*

(e) With the aid of a ray diagram explain the observation made on a small object at the bottom of a pool of water as the observer above the surface successively shifts position from the vertical to oblique positions. *(04 marks)*

SECTION B

3. (a) (i) Explain how **stationary waves** are formed. *(04 marks)*

(ii) Describe an experiment to determine the speed of sound in air using a speaker, a microphone and a smooth wooden board. *(05 marks)*

(b) Describe **one** application of Doppler effect. *(03 marks)*

(c) A train approaching a high wall with a velocity of 25 ms^{-1} makes a sound of frequency 980 Hz.

(i) Derive an expression for the apparent frequency of the echo a passenger in the train receives. *(04 marks)*

(ii) Find the apparent frequency of the sound, the passenger receives as the train passes the wall. *(04 marks)*

4. (a) State **three** characteristics of coherent sources of light. *(03 marks)*

(b) With the aid of sketch diagrams, explain the following:

(i) Division of wavefront. *(02 marks)*

(ii) Division of amplitude. *(02 marks)*

(c) An air wedge is formed by placing two glass slides of length 10.0 cm in contact at one end and a wire between them at the other end. Viewing from vertically above, 20 dark fringes are observed to occupy a distance of 5.0 mm when the slides are illuminated with light of wavelength 500 nm.

(i) Explain how the fringes are formed. *(05 marks)*

(ii) Determine the diameter of the wire. *(03 marks)*

(d) (i) What is meant by **constructive interference** and **destructive interference** as applied to light waves. (*02 marks*)

(ii) Describe how interference of light can be used to test for the flatness of a surface. (*03 marks*)

SECTION C

5. (a) (i) Define **magnetic field line**. (*01 mark*)

(ii) A wire carrying current out of the paper is placed between two opposite poles of a permanent magnet. Sketch the resultant magnetic field pattern and explain what is observed. (*04 marks*)

(b) A conductor of length, l, carrying current, I, perpendicular to a magnetic field of flux density, B, is moved in the field. Using the principle of conservation of energy, show that the force, F, acting on the conductor is given by;

$$F = Bil.$$ (*04 marks*)

(c) (i) Write down the expression for the magnetic flux density at a perpendicular distance, a, from a straight conductor carrying current, I, in air. (*01 mark*)

(ii) Two straight parallel wires A and B carry currents of 3 A and 5 A respectively in opposite directions. Given that the wires are 0.2 m apart in air, find the distance from wire A where the resultant magnetic flux density is zero. (*03 marks*)

(d) (i) With the aid of a labelled diagram, describe how a moving coil galvanometer works. (*05 marks*)

(ii) How can the moving coil galvanometer be converted to measure charge instead of current? (*02 marks*)

6. (a) (i) State the **laws of electromagnetic induction**. (*02 marks*)

(ii) Show that the induced charge Q is given by;

$$Q = \frac{N}{R}(\phi_1 - \phi_2),$$

when the magnetic flux threading a coil of N turns and resistance R changes from ϕ_1 to ϕ_2. (*04 marks*)

(b) Explain **two** essential features of a ballistic galvanometer. (*04 marks*)

(c) A long air-closed coil of wire has 500 turns of wire per metre and cross-sectional area of 6.0 cm^2. A secondary coil of 2000 turns is wound around its centre and connected to a ballistic galvanometer. The total resistance of the coil and the galvanometer is 10 Ω and the sensitivity of the galvanometer is 4.0 divisions per micro coulomb. If a current of 5.0 A in the long coil of wire is switched off, find the deflection of the galvanometer. (*04 marks*)

(d) Describe an experiment to determine the horizontal component of the earth's magnetic field intensity using a deflection magnetometer. (*06 marks*)

7. (a) Define the following as applied to an alternating current circuit:

(i) Reactance. (*01 mark*)

(ii) Frequency. (*01 mark*)

(b) A sinusoidal voltage is applied across a resistor of resistance, R, in which an alternating current $I = I_0 \sin \omega t$ flows. Derive an expression for the root mean square value of the alternating current. (*04 marks*)

(c) A sinusoidal alternating potential difference of peak value 20 V and frequency 50 Hz is connected across an inductor of inductance 0.5 H. Calculate the root mean square value of the current which flows through the inductor. (*03 marks*)

(d) An alternating current source is connected across a capacitor which is connected in series with a bulb as shown in Figure **2**.

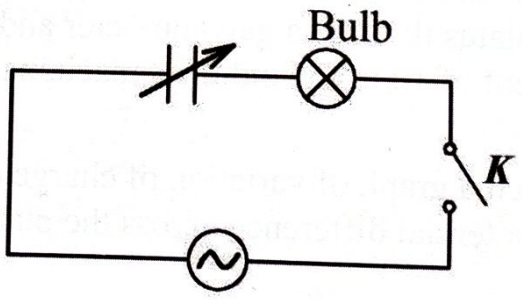

Fig. 2

Explain what is observed when;

(i) switch, ***K***, is closed. (*02 marks*)

(ii) the capacitance of the capacitor is increased while switch ***K***, is still closed. (*02 marks*)

(iii) the frequency of the source is decreased while switch ***K***, is still closed. (*02 marks*)

(e) With the aid of a labelled diagram, describe how the hot wire ammeter is used to measure alternating current. *(05 marks)*

SECTION D

8. (a) (i) State **Coulomb's law of electrostatics**. *(01 mark)*

(ii) Charges of +2 μC, −3 μC and −3 μC are placed at the corners *A*, *B* and *C* of an equilateral triangle of side 4.0 cm as shown in Figure **3**.

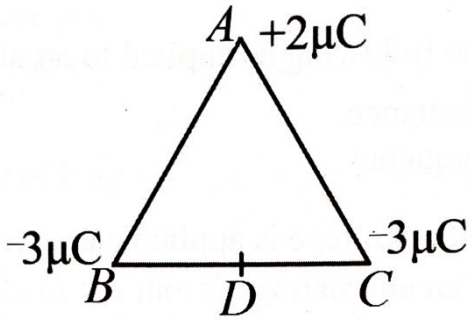

Fig. 3

Find the charge that should be placed at *D*, the mid-point of *BC* so that the net force on the charge at *A* is zero. *(05 marks)*

(b) (i) Define **capacitance** of a capacitor. *(01 mark)*

(ii) A vibrating reed switch charges and discharges a capacitor 50 times per second. The d.c supply is 25 V and the discharge circulates through a galvanometer and produces an average current of 10 μA. Find the capacitance of the capacitor. *(03 marks)*

(c) (i) Sketch a graph of variation of charge on a capacitor with the potential difference across the plates of the capacitor. *(01 mark)*

(ii) Use the graph in (c)(i) to show that the energy per unit volume in a parallel plate capacitor is given by $\frac{1}{2}\varepsilon_0 E^2$ where ε_0 is the permittivity of free space and *E* is the electric field intensity. *(04 marks)*

(d) (i) What is meant by a **dielectric** material? *(01 mark)*

(ii) Explain why the capacitance of a charged capacitor increases when a dielectric material is placed between its plates. *(04 marks)*

9. (a) (i) Describe an experiment to determine whether a given charged material is a conductor or an insulator. *(03 marks)*

(ii) Explain what is meant by **corona discharge** in electrostatics. *(03 marks)*

(b) A neutral conducting rod **BC**, earthed at **C** is placed near a positively charged sphere **A** as shown in Figure **4**.

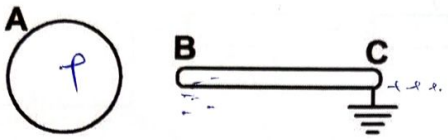

Fig. 4

Explain how the potential of **A** changes due to the presence of the rod **BC** near it. *(04 marks)*

(c) With reference to Figure **4**, on the same axes, show the variation of potential with position;

(i) along **ABC**. *(02 marks)*

(ii) when both **A** and the earthing are removed. *(02 marks)*

(d) (i) Derive the relationship between electric field intensity and electrical potential in an electric field. *(03 marks)*

(ii) Two parallel conducting plates 12 mm apart are held horizontally with one above the other in air. When the upper plate is maintained at a positive potential of 1800 V, and the lower one is earthed, a charged smoke particle of mass 4.8×10^{-15} kg is held stationary between the plates. Find the charge of the particle. *(03 marks)*

10. (a) Define **e.m.f** of a cell. *(01 mark)*

(b) Show that the drift velocity, v, of electrons in a conductor of cross sectional area, A, having, n, charge carriers per unit volume is given by;

$$v = \frac{I}{nAe}.$$

where, I, is the current through the conductor and, e, is the charge of each charge carrier. *(04 marks)*

(c) Explain the circumstances under which a galvanometer connected to a potentiometer may fail to give a two-way deflection when the sliding contact is made to touch the terminals of the slide wire of a potentiometer. *(04 marks)*

(d) Figure **5** shows a resistance box, P, a coil Q of resistance 40 Ω and an accumulator X connected to the slide wire potentiometer AB.

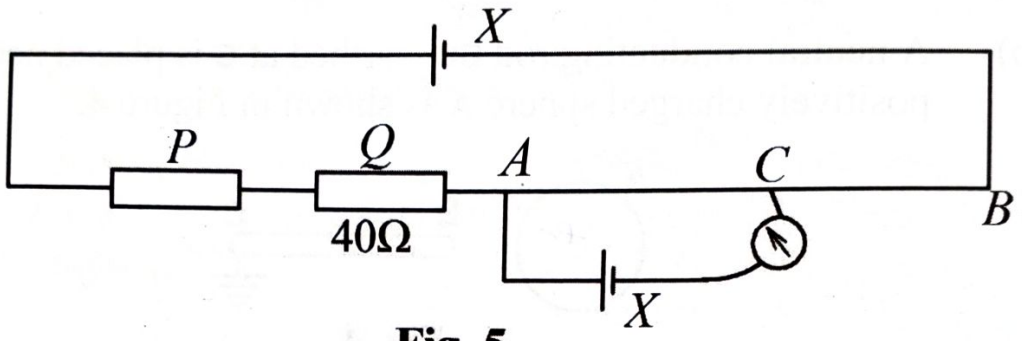

Fig. 5

The slide wire is 1.0 m long and has a resistance of 4.0 Ω. For a certain value of P, the potential drop across Q plus 32.0 cm of the slide wire is enough to balance an e.m.f of 1.018 V. For the same value of P, a potential drop across 68.5 cm of the slide wire is required to balance the e.m.f of cell X. Calculate the e.m.f of cell X.

(*06 marks*)

(e) With the aid of a diagram, describe an experiment to measure the e.m.f of a cell using a potentiometer.

(*05 marks*)