

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

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	=	$1.6 \times 10^{-19} \text{ C}$
Electron mass	=	$9.11 \times 10^{-31} \text{ kg}$
Plank's constant, h	=	$6.6 \times 10^{-34} \text{ Js}$
Speed of light in a vacuum, c	=	$3.0 \times 10^8 \text{ ms}^{-1}$
Avogadro's number, N_A	=	$6.02 \times 10^{23} \text{ mol}^{-1}$
Gas constant, R	=	$8.31 \text{ Jmol}^{-1}\text{K}^{-1}$
Charge to mass ratio, e/m	=	$1.8 \times 10^{11} \text{ Ckg}^{-1}$
The constant $\frac{1}{4\pi\epsilon_0}$	=	$9.0 \times 10^9 \text{ F}^{-1}\text{m}$
Permeability of free space, μ_0	=	$4.0 \pi \times 10^{-7} \text{ Hm}^{-1}$
Permittivity of free space, ϵ_0	=	$8.85 \times 10^{-12} \text{ Fm}^{-1}$

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.

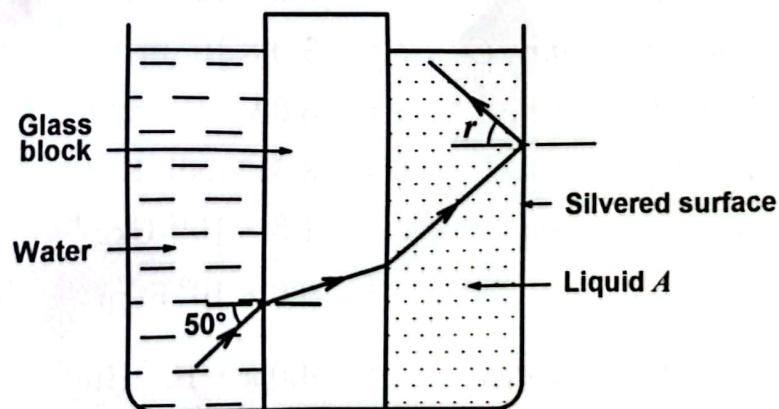


Fig. 1

Monochromatic light from water is incident on the glass block at an angle of 50° . 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

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

- (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;
- $$F = Bil. \quad (04 \text{ marks})$$
- (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 10Ω 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.

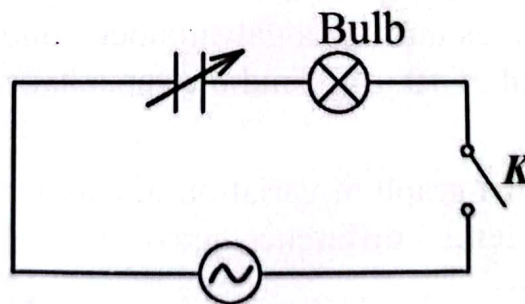


Fig. 2

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)

$T = \frac{1}{f}$

- (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 $+2 \mu\text{C}$, $-3 \mu\text{C}$ and $-3 \mu\text{C}$ are placed at the corners A , B and C of an equilateral triangle of side 4.0 cm as shown in Figure 3.

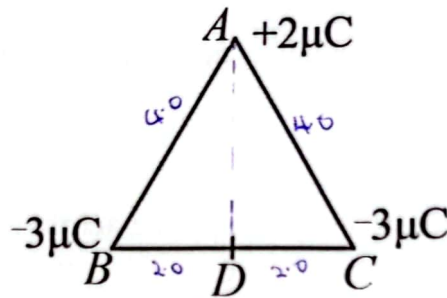


Fig. 3

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 $10 \mu\text{A}$. 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 $\frac{1}{2} \epsilon_0 E^2$ where ϵ_0 is the permittivity of free space and E is the electric field intensity. $\frac{\epsilon_0 V}{d}$ (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.

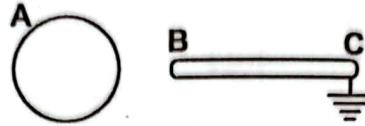


Fig. 4

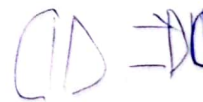
Explain how the potential of **A** changes due to the presence of the rod **BC** near it. (04 marks)

- (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 $40\ \Omega$ and an accumulator X connected to the slide wire potentiometer AB .

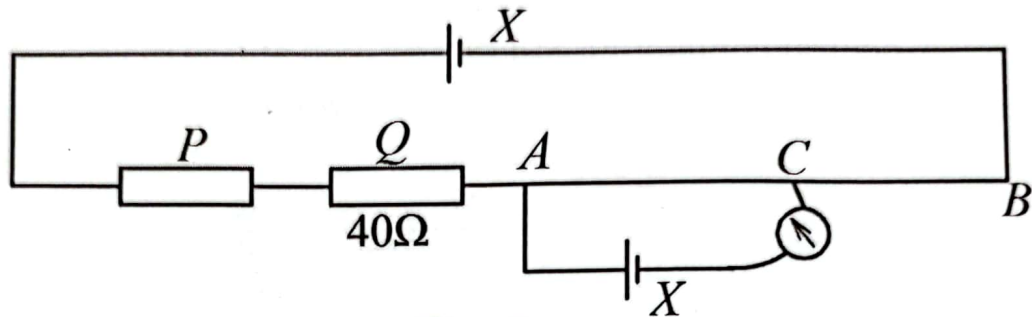


Fig. 5

The slide wire is $1.0\ \text{m}$ long and has a resistance of $4.0\ \Omega$. For a certain value of P , the potential drop across Q plus $32.0\ \text{cm}$ of the slide wire is enough to balance an e.m.f of $1.018\ \text{V}$. For the same value of P , a potential drop across $68.5\ \text{cm}$ 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)