P510/1
PHYSICS
Paper 1
(Theory)
July/August 2026
3 hours

WAKISSHA JOINT MOCK EXAMINATIONS

Uganda Advanced Certificate of Education

PHYSICS

Paper 1

3 hours

INSTRUCTIONS TO CANDIDATES:

- *This examination paper consists of two sections* **A** *and* **B.** *It has* **six** *items.*
- *Section* **A** *has* **two** *compulsory items.*
- *Section* **B** *has two parts;* **I** *and* **II.** *Respond to only* **one** *item from each part.*
- *Respond to* **four** *items in all.*
- *Any additional item(s) responded to, will* **not** *be scored.*
- *Responses to* **each** *item should start on a fresh page.*
- *Silent non-programmable scientific calculators may be used.*

Turn Over

SECTION A

Respond to **all** *the items in this section.*

Item 1

As part of preparations for the PAMOJA AFCON Tournament, the Uganda Cranes conducted a series of training sessions involving football skills, physical conditioning and transportation to their hill top training camp.

During a free-kick practice session, a striker places the ball 20.0 m directly in front of the centre of the goal. A defensive wall stands 9.0 m from the ball and is 2.0 m high, while the crossbar is 2.44 m above the ground. The sticker intends to kick the ball so that it just clears the wall before entering the goal. Air resistance during the kick is neglected.

In another training drill, the same football of mass 0.43 kg is released from rest from a height of 30.0 m above the ground. As it falls, the ball experiences air resistance and eventually reaches terminal velocity before striking the ground. The ball has a circumference of 68 cm and an internal pressure of 1.2 x 105 p_a.

The team's training camp is located at the top of a hill inclined at 30^0 to the horizontal. A team bus of mass 2500 kg starts from rest and accelerates uniformly at 5.0 ms^{-2} for 10 s while travelling up the slope, neglecting friction at the tyres.

The players appreciated the training activities and transportation but were unable to explain the physics involved in the different situations.

Task

(a) Analyse the information provided to explain the mechanics involved in football training activities and the team's journey to the training camp.

(b) Evaluate the performance of the football and the team bus using appropriate principles of mechanics and recommend suitable measures to improve their performance.

Item 2

At a national research and energy innovation center, a group of students visits laboratories studying nuclear energy, radiation detection and electron behavior in electric and magnetic fields. The visit aims to expose students to how atomic and electronic principles are applied in modern science.

In the nuclear research section, scientists explain how the stability of nuclei depends on binding energy per nucleon and how energy is released in nuclear processes.

The students observe a graphics relationship between binding energy per nucleon and mass number.

In the radiation laboratory, a Geiger-Muller tube is used to detect radiation from a thorium sample. The scientists note that counts are still recorded even when no radioactive source is present. The thorium-230 of mass 1g and half-life 75,400 years was detected by the machine.

In another experiment, students study the emission of electrons from metal surfaces when illuminated by light and observe how X-rays are produced in a vacuum tube.

Finally in the electron dynamics laboratory, they observe the motion of electrons in an electric fields and how their specific charge can be determined experimentally.

Task

(a) Analyse the information provided to explain the observation made in the nuclear radiation, photoelectric X-ray and electron dynamics experiments using appropriate principles and carrying out relevant calculations.

(b) Describe the motion of electrons in electric and magnetic fields and explain how their specific charge is determined experimentally, highlighting its significance in modern applications.

SECTION B

Part 1

Respond to **one** *item from this part.*

Item 3

A biconvex silica lens (n = 1.45 at 1064 nm) is used to focus a 100W continuous - wave laser. Because the laser power is high, the lens absorbs heat, changing its refractive index and shape (thermal lensing). The lens is placed in a custom continuous flow calorimeter to determine the exact focal length under operation by monitoring its heat absorption.

Support material:

- The lens is manufactured as biconvex, with radius of curvature $R_1 = +50$ mm
- and $R_2 = -50$ mm.
- The lens is submerged in the flow chamber surrounded by a specialized cooling oil of refractive index $n_{oil} = 1.30$.
- The cooling oil flows around the lens at a constant rate $m = 0.05\ kgs^{-1}$.
- The inlet temperature $T_1 = 20.0^0C$ and outlet temperature $T_2 = 22.5^0C$ are measured.
- The specific heat capacity of oil is $C_{oil} = 2100\ Jkg^{-1}k^{-1}$.
- Heat loss to the environment is negligible.
- The refractive index of the lens material increases to $n = 1.48$ due to thermal heating.

Task:

(a) Analyse the information provided to determine the focal length of the lens and the energy absorbed by it under operation.

(b) Explain the operation of the continuous flows calorimeter and how it is used to measure heat absorbed by the lens.

$$C = \frac{I_2V_2 - I_1V_1}{\left(\frac{m_2}{t} - \frac{m_1}{t}\right)(Q_2 - Q_1)}$$

$$I_2V_2 - I_1V_1 = C\left(\frac{m_2}{t} - \frac{m_1}{t}\right)(Q_2 - Q_1)$$

$$= \frac{m_2}{t} C (Q_2 - Q_1)$$

Item 4

A company is planning to start a project of wave power around Lake Victoria. The company project manager approached an engineer. The engineer explained that the available wave power device can only generate electricity if the wave amplitude is at least 0.155 m. The manager therefore needed to determine whether the lake waves are suitable for the project.

The lake wave is modelled by the equation $y = A \sin (\frac{2\pi t}{T} - kx)$, where T is the period of the wave and k is the wave number, y is the displacement of one wave in meters from undisturbed surface and x is the distance moved by the wave. For future research purposes the manager would like to have a record of the wave equation of the water waves.

Because the direct measurement of the moving wave is difficult, the manger decided to use a screen method based on reflection of light to determine amplitude.

A narrow laser beam is directed onto the water surface. The reflected beam falls on a vertical screen placed 100 m way. When light is reflected from the crest of the wave it reaches the mean position O on the screen. When light is reflected from the wave surface at it's greatest positive slope, the reflected sports shifts 0.8 m above the mean position O. The students need to use knowledge of light reflection on rotated reflecting surface to determine the inclination of greatest slope of the wave.

To check the accuracy of the manager's results, engineer used as second method. A converging lens is placed in the path of the reflected beam so that the light is focused into an optical fiber. The optical fiber carries the light to a photo detector and the electronically recorded signal is compared with the manager's screen measurements. The manager does not know how the optical fiber transmits the light and why a convex lens was used in this option by the engineers.

Support material

- The angle of inclination of greatest slope of the wave is equal to the maximum slope of the wave.
- Wave length $\lambda = 25.0$ m and period $T = 10.0$ S

Task:

(a) Analyse the information provided to help the manager determine whether the lake waves can support power generation and establish the wave equation.

(b) Discuss the accuracy of the optical measurement method and explain how the second method using a lens and optical fiber improves reliability.

PART II

Respond to **one** *item from this part.*

Item 5

At an electronics and material testing laboratory, technicians are designing capacitors for use in power supplies, radio circuits and energy storage units.

To ensure safe and efficient operation, they must understand how charge, voltage, geometry and insulating materials affect capacitor or behaviour.

In one test a metallic spherical of radius 7.5 cm is connected to a high voltage source of 9.0 V to study how much electric charge it can safely hold.

In another experiment, two large metal spheres are mounted facing each other and their separation is varied while the resulting electrical properties are observed.

Engineers also investigate how inserting different materials between capacitor plates affects charge storage and how a ballistic galvanometer can be used to determine electrical properties of insulating materials with high precision.

In the same laboratory, a technician of physics sets up several test circuits supplied by a stable D.C power source.

The aim is to verify fundamental electrical laws, calibrate measuring instruments and evaluate the performance of power sources used in students experiments.

In the first set up, a uniform metallic conductor is connected in series with a variable resistor, an ammeter and a switch. A voltmeter is also connected across a uniform conductor. The technician varies the current through the conductor while carefully monitoring the potential difference across it, ensuring that the temperature of the conductor remains nearly constant throughout the test.

The technician also evaluates the efficiency of a practical power circuit consisting of a battery of emf 20 V and internal resistance 4 Ω supplying a load resistor of resistance 10 Ω.

The analysis helps to determine how much of the chemical energy in the battery is usefully converted into electrical energy in the external circuit.

Finally engineers investigate why delicate electronic equipments are frequently destroyed during operation especially when they are near highly charged machinery.

Support material.

Area of capacitor plates = 5.0 cm^2

Separation of the plates = 2.0 mm

P.d across the plates = 6.0 V

Permittivity of free space = 8.85 x 10^{-12} Fm^{-1}

$E = I(R+r)$

$V = IR$

Task

(a) Analyse the information provided to determine the charge stored on the capacitor system, evaluate the efficiency of the battery using appropriate electrical principles and relevant calculations.

(b) Explain how capacitance depends on geometry and dielectric materials, use of a ballistic galvanometer in material testing and account for equipment damage near highly charged systems, including prevention measures.

Item 6

A large agricultural irrigation farm operates an electrically driven water pump used to distribute water across different sections of land.

The pump is powered by a steady alternating current supply generated on site using a rotating – coil generator driven by a diesel engine. The generator has 500 turns in its coil, rotating in a uniform magnetic field of strength 0.30T.

Each coil has an area of 0.020 m^2 and the generator rotates at a steady frequency of 50 Hz. One farmer wonders how a magnet and wire coiled together give electricity.

To improve stability and protect the motor of the pump, the pump circuit includes;

- A series inductor of inductance 0.60 H
- A capacitor of capacitance 60 μF
- A motor resistor of resistance 20 Ω.

They want to add a logic base control system that ensures the pump operates only when water demand is required and the electrical conditions are safe.

However, the farmers report that the pump operates less efficiently than expected with reduced useful mechanical output compared to electrical energy supplied. Engineers suspect that there is an unknown resistance affecting how the motor draw current from the source.

Task:

(a) Analyse the information provided to determine the performance of the pump system and advise the engineer how to improve its efficiency.

(b) Explain how electrical energy is generated by the rotating coil generator and propose a suitable logical control strategy for safe operation of the pump.

END