P510/1
PHYSICS.
Paper 1 (Theory).
6th/July/2026.
2 $\frac{1}{2}$ HOURS.

GANGU SECONDARY SCHOOL

UGANDA ADVANCED CERTIFICATE OF EDUCATION
S.5 END OF TERM TWO ASSESSMENT 2026.
PHYSICS
Paper 1
(Theory).
Duration: 2 Hours 30 Minutes.

INSTRUCTIONS TO CANDIDATES:

- This paper consists of **six items** with three sections: **A**, **B** and **C.**
- Attempt **four items** in total.
- Section A is **compulsory.**
- Attempt **any two items** from section B and **any one item** of your choice from section C.
- All items carry equal marks.
- You are advised to spend **no more than 35 minutes** on each item..

SECTION A: WAVES.
(*This item is compulsory*)

ITEM 1.

An Acoustics research team in Kampala is setting up a precision sound laboratory to study how waves behave when they meet in enclosed spaces. During an initial calibration test, two signals, **Wave A** and **Wave B.** are transmitted into a testing chamber from opposite walls. The laboratory monitoring equipment tracks the two wave and models their displacements using the following mathematical models:

$$\textbf{Wave A: } y = a\sin\left(100\pi t - \frac{10}{9}\pi x\right)$$

$$\textbf{Wave B: } y = a\sin\left(100\pi t + \frac{10}{9}\pi x\right)$$

Later that afternoon, a technician walks in a straight line at a constant speed between two identical stationary loudspeakers outside the laboratory. Both speakers are emitting a steady tone of **600Hz**. As the technician moves directly from one speaker toward the other through the air (where the speed of sound is $\mathbf{300 ms^{-1}}$), they notice that the sound rhythmically rises and falls in loudness, creating distinct acoustic beats at a steady rate of $\mathbf{5\ s^{-1}}$.

Tasks:

As the assistant physicist on this project, write a technical assessment report for the engineering team. In your report:

1. **Explain the physical phenomenon** that occurs inside the testing chamber when Wave A and Wave B overlap, clearly identifying the specific type of interference produced.
2. **Define the fundamental wave parameters** (amplitude, frequency, and wavelength) that characterize these signals, and apply the principle of superposition to **derive the single mathematical equation** that represents the resultant wave formed inside the chamber.
3. Analyze the technician's experience outside the laboratory. Use the principles of the Doppler effect and acoustic wave interference to calculate the exact velocity at which the technician is moving between the two stationary sound sources.

SECTION B: MECHANICS.
(*Choose any two of your choice*)

ITEM 2.

The Ministry of Water and Environment is reviewing a project proposal for a new gravity-flow irrigation scheme in Kapchorwa district. To model the streamline flow of water through a non-viscous, incompressible pipe network, the design engineers have introduced a modified version of Bernoulli's equation:

$$(\boldsymbol{P-a}) \;=\; \boldsymbol{\rho g(h-b)} + \frac{\mathbf{1}}{\mathbf{2}}\,\boldsymbol{\rho(v^2-d)}$$

During the project appraisal, the district engineering board discovers that the calibration parameters $a, b,$ and d are missing their operational unit profiles. To ensure that the automated pressure valves function correctly under gravity, you have been brought in to map out the exact fundamental physical properties of these parameters using dimensional validation.

Support Material:

- P = Fluid pressure at a specific node
- h = Height/elevation of the pipe section
- v = Flow velocity of the fluid
- ρ = Fluid density
- g = Acceleration due to gravity
- ***Principle of Homogeneity*** states that physical quantities can only be added, subtracted, or equated if they share identical dimensions.

Tasks:

As the principal structural modeling engineer, prepare a comprehensive **Dimensional Audit Summary** for the district engineering board. In your summary:

a) **Explain the theoretical framework** by defining the concept of "dimensions of a physical quantity" and explaining the mathematical rule governing the relationships of terms grouped inside parentheses, such as $(P-a)$ and $(h-b)$.
b) **Deduce the fundamental base dimensions** of the elevation correction constant ***b*** and the velocity threshold constant ***d*** based on the flow dynamics of the Kapchorwa pipeline.
c) **Analyze the pressure-side configuration** of the model to determine the exact base dimensions and appropriate SI units for the parameter ***a*****,** proving whether the overall modified equation maintains dimensional consistency.

ITEM 3

During a community-led renovation of Nakasero Market in Kampala, a technical supervisor sets up a uniform timber ladder against a tall, newly painted, friction-less tiled vertical wall. The ladder has a total length of 10m and a weight of 200N. To ensure structural safety before anyone climbs, the supervisor positions the base of the ladder on the concrete ground such that the ladder makes an angle of 60° with the horizontal.

A young apprentice weighing 500N carries a heavy tin of paint and climbs exactly a quarter of the way up from the lower end of the ladder before pausing to begin painting. The site health and safety officer halts the work, expressing concern that the ladder might suddenly slip at the base and crash, causing a severe accident.

Tasks:

As a structural safety consultant, write a comprehensive safety evaluation report for the market renovation committee to determine whether the current setup is sale for the apprentice. In your report:

a) **Conduct a conceptual risk evaluation** by explaining how the concepts of centre of gravity and the moment of a force apply directly to this ladder system. Detail the physical conditions that must be fulfilled for this extended rigid to remain in a state of absolute static equilibrium while the apprentice is standing on it.

b) **Develop a free-body force model** to analyze the active load distribution. Calculate the exact **normal reaction force** exerted by the smooth wall on the top of the ladder, and explain how the concept of torque governs the balance of rotational tendencies around the ladder's base.

c) **Determine the structural binding requirements** at the ground contact point. Calculate the **magnitude** and **direction of the resultant force** acting on the lower end of the ladder and explain the critical role that ground friction plays in preventing a catastrophic slip. Advise the committee on how changing the angle of inclination would affect these reactive forces.

ITEM 4

An agricultural mechanics workshop in Mityana is manufacturing lightweight timber ladders to help farmers safely harvest coffee beans from mature, tall trees. To keep production costs affordable for smallholder farmers, the workshop does not install expensive synthetic rubber grips at the tips. The ladder must rely entirely on the natural surface friction at bits contact points to remain upright.

During field tests on a local plantation, an upright uniform ladder is placed against a rough vertical tree trunk where the coefficient of friction is defined as $\boldsymbol{\mu_x}$. The base of the ladder sits on a rough, dry compacted soil where the coefficient of friction is measured as $\boldsymbol{\mu_y}$. The filed team notices that if the ladder is angled incorrectly, it slips immediately, endangering the harvester. To print an accurate safety warning sign on the side of each ladder, the workshop needs to establish the absolute minimum limiting angle, $\boldsymbol{\Theta}$, relative to the ground, where the system is just on the brink of sliding down at both ends simultaneously

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Tasks:
As a visiting safety specialist from the Ministry of Agriculture, draft an operational safety memo for the manufacturing workshop. In your memo:

a) **Map out the vector landscape** by detailing a complete structural layout of all acting forces. Explicitly describe why the normal reactions and the static friction forces point in their respective directions at both the trunk and the soil interface when downward slippage is imminent.
b) **Formulate the mathematical proof** using the principles of static balance for the extended rigid bodies. Balance the horizontal and vertical forces to construct expressions for the contact reactions, and take rotational moments about a strategic pivot point to demonstrate that the lowest stable operational angle **Θ** must satisfy the equation:

$$\boldsymbol{\theta = tan^{-1}\left(\frac{1-\mu_x\mu_y}{2\mu_y}\right)}$$

c) **Appraise the environmental operational risks** for the farmers in that show how the requi2red angle changes if a heavy downpour makes the tree trunk perfectly slick ($\boldsymbol{\mu_x = 0}$). Conclude by explaining how increasing the roughness of the ground surface ($\boldsymbol{\mu_y}$) modifies the required ground space needed behind the base of the ladder to prevent accidents.

SECTION C: LIGHT, & ELECTRICITY.

ITEM 5
A marine researcher named Nakintu stands on the flat deck of a research ship. She needs to calculate the height of an island lighthouse ahead and calibrate her optical gear using basic laws of reflection. Before hitting the open sea, Nakintu sets a vertical plane mirror inside the cabin to check her safety gear placement. Nakintu is exactly **1.80m** tall, and her eyes are **10cm** below the top of her head.

As Nakintu continues calibrating her optical equipment, she notices that a thick plane mirror used in one of the instruments produces several images of a nearby calibration lamp. Later that night, she uses a sextant to measure the angle of elevation of a bright star to verify the ship's navigation system.

Tasks
a) Help Nakintu determine the minimum length of the vertical plane mirror she needs to see her full-length reflection from head to toe.
b) Guide her on how high above the cabin floor the bottom edge of the mirror must be positioned to achieve this.
c) With the aid of a ray diagram, explain how the thick plane mirror produces multiple images of the calibration lamp.
d) Describe how Nakintu would use the sextant to determine the angle of elevation of the star.

ITEM 6

A biomedical technician at a remote health center in Kanungu district is tasked with assembling a backup sterilization heating unit. The unit must maintain a constant high temperature to sterilize surgical instruments using a 240V d.c. solar-battery bank. The technician has three identical 24Ω nichrome heating elements and high-conductivity copper connecting wires.

Before assembling the sterilization unit, the technician sets up a test bench to calibrate the components. He conducts an experiment to verify the electrical behavior of one nichrome element. To compare its performance, he repeats the same experiment using a 240V indicator filament lamp and notices a stark contrast in how they respond to voltage variations.

The technician needs to decide whether to wire the three heating elements in a series or parallel circuit configuration to maximize heat generation.

Tasks

i. Determine the equivalent resistance and current drawn from the supply when the heating elements are connected in series and in parallel. Hence state which arrangement the technician should adopt to maximize heat generation.
ii. Describe how the technician would verify Ohm's law using one nichrome heating element, stating the necessary precautions and the limitations of the experiment.
iii. Explain why the nichrome heating element and the filament lamp respond differently to changes in potential difference, making reference to **Ohm's law**, **Ohmic** and **non-ohmic conductors**.
iv. Explain why copper is used for the connecting wires and nichrome for the heating elements, making reference to electrical conductivity and the mechansim of electrical conduction in metals.

END.

"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less." **~ Marie Curie.**