tr joelPCM Academic Council

UGANDA ADVANCED CERTIFICATE OF EDUCATION (UACE)
END OF FIRST TERM EXAMINATIONS 2026

S.6 P510/1 PHYSICS (Paper 1)

Time Allowed: **3 HOURS**

STUDENT NAME:
....
....
....

PERSONAL NUMBER: .... **SIGNATURE:** ....

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO BY THE INVIGILATOR

INSTRUCTIONS TO CANDIDATES:

1. Do not write anything in this paper; any rough work should be written in the response booklet(s) provided and crossed out.
2. The time allowed for this paper is strictly **3 Hours** and no additional time shall be granted.
3. This paper consists of **four** sections; **A, B, C** and **D** with a total of **8 items**.
4. Section A (*Particles – AO4*) has 2 items; attempt **any ONE** item.
5. Section B (*Force and Motion – AO1*) has 2 items; attempt **any ONE** item.
6. Section C (*Energy – AO2*) has 2 items; attempt **any ONE** item.
7. Section D (*Charges and Fields – AO3*) has 2 items; attempt **any ONE** item.
8. **FOUR ITEMS** should be attempted in total (one per section). Any additional item(s) attempted will not be marked.
9. Begin each item on a fresh page and clearly indicate the item number in the response booklet.
10. Show all working clearly, include appropriate units, and present well-labelled diagrams where required.
11. Silent non-programmable calculators and mathematical/logarithmic tables may be used.

FOR SCORER'S USE ONLY

SECTION	A		B		C		D		TOTAL
ITEM	1	2	3	4	5	6	7	8	
SCORE									
INITIAL									

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SECTION A: PARTICLES

AO4 — Investigate atomic, quantum, and nuclear phenomena | Attempt ANY ONE item from this section.

Item 1 **(20 marks)**

The Uganda Cancer Institute (UCI) at Mulago Hospital, Kampala, is a leading centre for the diagnosis and treatment of cancer using nuclear medicine. A medical physicist, Dr. Nakimera, supervises the preparation and administration of radioactive isotopes used in patient care. Iodine-131, which emits beta particles and destroys cancerous thyroid tissue, is among the most commonly used. A newly recruited radiographer, Tendo, observed that the count rate reading on the Geiger-Müller detector placed near a freshly prepared tracer sample had been dropping steadily over time. Puzzled as to whether the detector was faulty or the phenomenon was natural, Tendo recorded the corrected count rate every two hours under Dr. Nakimera's guidance. In an adjacent preparation room, a technician was reminding student interns that Uranium-238 — used as a sealed source for physics demonstrations — undergoes a chain of nuclear transformations beginning with alpha emission, releasing energy that can only be explained through the concept of nuclear binding energy.

Time (hours)	0	2	4	6	8
Count rate (min^{-1})	640	452	320	226	160

Support Material Provided:

- Mass of proton = 1.00728 u, mass of neutron = 1.00867 u, mass of ${}^4_2He$ nucleus = 4.00150 u
- 1 u = 931.5 MeV/c^2
- Atomic number of Uranium = 92

Tasks:

(a) Using the data Tendo collected, determine the half-life and decay constant of the radioactive tracer, and present the result graphically in a way that Dr. Nakimera could use to verify the finding. **(05)**

(b) Construct the nuclear equations for the decay chain described by the technician — one alpha decay followed by two successive beta-minus decays of Uranium-238 — and identify the symbol, proton number, and mass number of the final nuclide produced. **(05)**

(c) Calculate the nuclear binding energy per nucleon of helium-4 using the data provided, and use the shape of the binding energy per nucleon curve to explain why both nuclear fission and nuclear fusion are viable sources of energy. **(06)**

(d) Drawing from the work of Dr. Nakimera's department, discuss TWO applications of nuclear radiation in medicine or industry, identifying for each one associated risk and how it is managed in practice. **(04)**

OR

Item 2 **(20 marks)**

At St. Mary's College Kisubi, the school nurse, Nurse Akello, began noticing a rising number of students reporting to the sick bay with complaints of eye strain, headaches, and disrupted sleep. She linked the problem to the school's newly installed LED computer monitors, which emit bright blue light at approximately 450 nm — a wavelength associated with photon energies that may interact with biological tissue in the eye. She raised her concern with the Head of Science, Mr. Wasswa, a Physics teacher. Mr. Wasswa organised a classroom investigation to explore the quantum nature of light, specifically the photoelectric effect, using a sodium metal surface and the LED blue light as the source. He challenged the students to determine whether the photon energy of the blue light exceeds the known biological damage threshold for the human retina, to investigate whether the light could cause electron emission from sodium, and to explain to Nurse Akello why the classical wave theory of light fails entirely to account for what is observed in the experiment.

Support Material Provided:

- Wavelength of blue light $\lambda = 450$ nm, Planck's constant $h = 6.63 \times 10^{-34}$ Js
- Speed of light in vacuum $c = 3.0 \times 10^{8}$ m s^{-1}
- Damage threshold for the human eye = 3.1 eV, Work function of sodium $\varphi = 2.28$ eV
- 1 eV = 1.6×10^{-19} J

Tasks:

(a) Use the information provided to calculate the energy of a single blue light photon in eV, and use this result to advise whether Mr. Wasswa should reassure students that the LED monitors pose no risk of permanent damage to their retinas. **(04)**

(b) Investigate whether photoelectric emission will occur when blue light from the school monitors falls on the sodium metal surface, and if so, determine the maximum kinetic energy of the emitted photoelectrons in joules and the stopping potential required to arrest the fastest electrons. **(06)**

(c) Explain to Nurse Akello and the students, in the context of Mr. Wasswa's experiment, the TWO key observations of the photoelectric effect that the classical wave theory of light completely fails to account for. **(04)**

(d) Advise the school administration on the symptoms students may develop from prolonged exposure to blue light beyond the damage threshold, and suggest specific, physically justified protective measures that could be implemented in the computer laboratory without disrupting learning. **(06)**

SECTION B: FORCE AND MOTION

AO1 — Evaluate how forces affect static and moving bodies | Attempt ANY ONE item from this section.

Item 3 **(20 marks)**

On the morning of 15 January 2026, a serious accident occurred on the Kampala–Jinja Highway near Namanve Industrial Park. A Toyota Premio saloon car of mass 1 200 kg was travelling at 30 m s^{-1} when the driver, Mr. Ssemanda, applied the brakes hard to avoid a stalled heavy goods vehicle, bringing the car to rest in 5.0 seconds on a dry, level road surface and leaving clear skid marks on the tarmac. Traffic investigator Constable Nabirye arrived at the scene to determine whether Mr. Ssemanda had exceeded the highway speed limit of 100 km h^{-1}. A group of Senior Six students from a nearby school happened to be on a field trip to the industrial park. Their Physics teacher, Mr. Opio, transformed the accident scene into a practical lesson, additionally challenging students to analyse the motion of a ball projected horizontally from the roof of a building overlooking the road, and to determine how engine power governs a car's performance both on the level highway and on the hilly terrain that is common on Ugandan roads.

Support Material Provided:

- Mass of car m = 1 200 kg, initial speed u = 30 m s^{-1}, braking time = 5.0 s
- Building height = 80 m, horizontal projection speed = 20 m s^{-1}
- Engine power = 60 kW, gradient of incline: $\sin\theta = 0.05$
- g = 10 m s^{-2}

<u>Tasks:</u>

(a) Help Constable Nabirye reconstruct the accident by determining the deceleration of Mr. Ssemanda's car during braking, the length of skid marks she should have found on the road, and the average braking force exerted on the vehicle. **(06)**

(b) Analyse the motion of the ball that Mr. Opio projected horizontally from the roof of the 80 m building, determining the time of flight, the horizontal distance from the building where it lands, and the magnitude and direction of its velocity at the moment of impact with the road. **(07)**

(c) Determine the total resistive force acting on Mr. Ssemanda's car as it travels at a constant 30 m s^{-1} on the level highway, and recalculate the resistive force when the same car climbs the incline at the same speed with the same engine power. **(05)**

(d) Using the impulse-momentum theorem, explain why modern vehicles are equipped with crumple zones and air bags, relating the physics principles to the protection they provided — or would have provided — to Mr. Ssemanda during the collision. **(02)**

OR

Item 4 **(20 marks)**

At a construction site in Nakasero, Kampala, a worker named Godfrey was assigned to paint the outer wall of the third floor of a new office block. He placed a uniform aluminium ladder of mass 25 kg and length 8.0 m against the smooth vertical concrete wall, with the base resting on the rough horizontal ground at an angle of 60° to the floor. Godfrey, whose mass is 75 kg, climbed to a point three-quarters of the way up the ladder and began working. The site engineer, Engineer Birungi, stopped to assess whether the ground friction was sufficient to prevent the ladder from sliding — a life-safety concern she had to resolve before allowing Godfrey to continue. The same construction company was also managing a satellite-linked ground monitoring project, in which a 500 kg satellite had been placed into a circular orbit 400 km above the Earth's surface to monitor landslides on the hills surrounding Kampala in real time. The junior engineer needed to compute the satellite's orbital speed, period, and gravitational potential energy to plan daily communication windows with the ground station.

Support Material Provided:

- $g = 10 \text{ m s}^{-2}$, mass of Earth $M_E = 6.0 \times 10^{24}$ kg, radius of Earth $R_E = 6.4 \times 10^6$ m
- $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$, satellite mass = 500 kg, orbital altitude = 400 km

Tasks:

(a) Draw a clearly labelled free-body diagram of Godfrey's ladder and analyse the equilibrium of forces acting on it to determine the reaction force exerted by the smooth wall and the minimum coefficient of static friction required at the base of the ladder to prevent it from slipping. **(08)**

(b) Assist the junior engineer by calculating the orbital speed and orbital period (in minutes) of the satellite at its operating altitude of 400 km, and determine its gravitational potential energy in that orbit, taking the zero of gravitational potential energy at infinity. **(07)**

(c) State Archimedes' principle and use it to explain why the large steel barges used to transport construction materials across Lake Victoria from Kampala Port are able to float, even though solid steel is denser than water. **(03)**

(d) Define terminal velocity and explain, with reference to the forces acting on a body, the physical conditions under which an object falling through a viscous fluid reaches terminal velocity. **(02)**

SECTION C: ENERGY

AO2 — Investigate how energy is transferred and transformed | Attempt ANY ONE item from this section.

Item 5 **(20 marks)**

The Ndere Cultural Centre in Ntinda, Kampala, hosts weekly live performances showcasing Uganda's traditional music. One evening, master performer Kizza played the endingidi — a one-stringed fiddle — before a large audience. The Centre's sound engineer, Ms. Tendo Akullo, used a digital oscilloscope to analyse the waveforms produced by the instruments to calibrate the public address system. She observed that when Kizza bowed his endingidi string of length 0.80 m, fixed at both ends, it vibrated in its third harmonic at a wave speed of 120 m s^{-1}. Before the show, a visiting musician, Sergeant Ocen, drove his car at 15 m s^{-1} towards a stationary outdoor speaker emitting a continuous test tone of 850 Hz. Both Ms. Akullo and bystanders clearly noticed that the pitch Ocen heard differed from what they heard — a phenomenon she used to explain Doppler-based medical ultrasound to an intern. Backstage, a technician also set up a mechanical demonstration for visiting Senior Six students: a 0.50 kg mass attached to a spring of spring constant 200 N m^{-1} was set oscillating with an amplitude of 0.10 m, illustrating simple harmonic motion.

Support Material Provided:

- Endingidi string: length = 0.80 m, wave speed = 120 m s^{-1}, third harmonic mode
- Speed of sound in air = 340 m s^{-1}
- Spring constant k = 200 N m^{-1}, oscillating mass m = 0.50 kg, amplitude A = 0.10 m

Tasks:

(a) Help Ms. Akullo analyse the standing wave on Kizza's endingidi string by sketching the third harmonic pattern with all nodes and antinodes clearly marked, and calculating the wavelength, frequency of vibration in that mode, and the frequency of the fundamental mode of the same string. **(07)**

(b) Calculate the frequency of sound that Sergeant Ocen hears as his car approaches the outdoor speaker at 15 m s^{-1}, and describe clearly how the same Doppler principle is applied in hospital ultrasound equipment to measure the speed of blood flow in a patient's artery. **(06)**

(c) Analyse the simple harmonic motion of the spring-mass system backstage, calculating the angular frequency, maximum speed of the mass, and the total mechanical energy stored in the system. **(05)**

(d) Using examples drawn from the musical and physical events at the Ndere Cultural Centre described above, state TWO differences between a progressive (travelling) wave and a stationary (standing) wave. **(02)**

OR

Item 6 **(20 marks)**

FiberLink Uganda Limited recently won a licence to lay fibre optic cables connecting Kampala to Gulu, Mbarara, and Fort Portal. Project engineer Dr. Ssali briefed his technical team that the cables work by trapping light inside a glass core of refractive index 1.52 through total internal reflection. To demonstrate the principle, he directed a laser ray in air onto a flat glass surface at an angle of incidence of 40° and challenged the team to calculate the refraction and critical angles and to explain, using a diagram, how data pulses travel thousands of kilometres without escaping through the sides of the fibre. In Tororo, the Tororo Cement factory's thermodynamicist, Mr. Muwanga, was modelling the factory kiln's heat cycle using an ideal gas undergoing four steps: isothermal expansion at 500 K from 2.0 L to 6.0 L at initial pressure 3.0×10^5 Pa; constant-volume cooling to 300 K; isothermal compression back to 2.0 L; and constant-volume heating back to 500 K. In the factory canteen, a kitchen assistant placed 50 g of ice at 0 °C into a copper calorimeter of mass 100 g already holding 200 g of water at 20 °C, and a physics intern was asked to predict the final temperature of the mixture.

Support Material Provided:

- Refractive index of glass n = 1.52
- Specific heat capacity: copper = 400 J kg^{-1} K^{-1}, water = 4 200 J kg^{-1} K^{-1}
- Specific latent heat of fusion of ice = 3.36×10^5 J kg^{-1}
- ln 3 = 1.099

Tasks:

(a) Support Dr. Ssali's team demonstration by calculating the angle of refraction and the critical angle for the glass used in the fibre, and drawing a labelled cross-sectional diagram of an optical fibre to explain how total internal reflection enables a light pulse to travel from Kampala to Gulu without escaping through the walls of the fibre. **(08)**

(b) Assist Mr. Muwanga by sketching a fully labelled P-V diagram for the kiln's four-step thermodynamic cycle, calculating the work done by the gas during the isothermal expansion at 500 K, and applying the first law of thermodynamics to determine the heat exchanged during each constant-volume process, clearly indicating whether heat is absorbed or released in each case. **(08)**

(c) Analyse the canteen calorimetry problem: show by calculation whether all 50 g of ice will melt when placed in the calorimeter, and determine the final equilibrium temperature of the mixture. **(04)**

SECTION D: CHARGES AND FIELDS

AO3 — Explore how electric and magnetic fields interact in systems and devices | Attempt ANY ONE item from this section.

Item 7 **(20 marks)**

Raymond, a newly recruited electrical engineering intern, was posted to the UETCL Namanve substation outside Kampala for his first field attachment. At the substation he observed a large step-down transformer that reduces the local grid supply from 240 V (rms) to 12 V (rms) for distribution to nearby residential estates. The primary coil has 2 000 turns and the secondary delivers a current of 1.5 A to the load. His supervisor, Engineer Mukalazi, explained the physical causes of energy loss in real-world transformers and demonstrated how the substation's design minimises them. Raymond also observed a technician testing a single-phase AC generator consisting of a rectangular coil of 50 turns and cross-sectional area 0.020 m^2 rotating at an angular velocity of 100π rad s^{-1} in a uniform magnetic field of flux density 0.30 T and connected to an external load resistance of 40 Ω. A straight conductor of effective length 0.50 m carrying a current of 4.0 A was simultaneously placed perpendicular to the same field. Later, Engineer Mukalazi showed Raymond a moving-coil galvanometer from the instrumentation cabinet and challenged him to explain its operating principle and how it is adapted for use as an ammeter and as a voltmeter.

Support Material Provided:

- Transformer: $V_p = 240$ V (rms), $V_s = 12$ V (rms), $N_p = 2\,000$ turns, $I_s = 1.5$ A
- Generator: N = 50 turns, A = 0.020 m^2, $\omega = 100\pi$ rad s^{-1}, B = 0.30 T, R = 40 Ω
- Conductor: length l = 0.50 m, current I = 4.0 A, B = 0.30 T

Tasks:

(a) Assist Raymond in analysing the substation transformer by calculating the number of secondary turns and the primary current at 100% efficiency, and explain to him the TWO main causes of energy loss in the real transformer and how each is minimised in the substation's design. **(08)**

(b) Analyse the AC generator being tested, deriving an expression for the instantaneous EMF and calculating the peak EMF, the rms EMF, and the rms current delivered to the 40 Ω external load. **(06)**

(c) Calculate the magnetic force on the straight conductor placed in the field, and describe the operating principle of the moving-coil galvanometer, using labelled circuit diagrams to show how it is adapted to function as an ammeter and as a voltmeter. **(06)**

OR

Item 8 **(20 marks)**

Brenda, a Senior Six Physics student, spent her mid-term holiday as an intern at Kawempe Electronics Workshop in Kampala under the supervision of Mr. Opolot, an experienced electronics technician. On her first day Brenda was shown a capacitor bank salvaged from a faulty uninterruptible power supply (UPS), containing three capacitors of capacitances 4 μF, 6 μF, and 12 μF. Mr. Opolot asked her to compare how the total capacitance and energy stored differ when the capacitors are connected in series versus in parallel across a 24 V supply, and to identify at least one practical circuit application. He then handed her a resistor network extracted from a faulty television set: a 6 Ω and 12 Ω resistor connected in parallel, and this combination connected in series with a 4 Ω resistor and a 12 V battery of internal resistance 1 Ω, challenging her to fully analyse the circuit. In the afternoon a customer brought in a device damaged by electrostatic discharge. To explain the underlying physics, Mr. Opolot placed two small charged spheres — $Q_1 = +6$ μC and $Q_2 = -4$ μC — 0.30 m apart on a non-conducting bench and asked Brenda to determine the electrostatic force between them, the position where the net electric field is zero, and the electric potential at the midpoint between the charges.

Support Material Provided:

- Coulomb's constant $k = 9.0 \times 10^9$ N m^2 C^{-2}
- $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}
- $Q_1 = +6$ μC, $Q_2 = -4$ μC, separation $d = 0.30$ m, supply voltage $V = 24$ V

Tasks:

(a) Help Brenda complete the electrostatics investigation: calculate the magnitude of the electrostatic force between Q_1 and Q_2 stating whether it is attractive or repulsive, find the exact position along the line joining the charges where the resultant electric field is zero, and calculate the electric potential at the midpoint between the charges. **(08)**

(b) Analyse the capacitor bank for both series and parallel configurations connected to the 24 V supply, calculating the total capacitance and the total electrical energy stored in each case, and explain ONE specific application of capacitors relevant to the electronic devices found in Kawempe Electronics Workshop. **(06)**

(c) Draw a clearly labelled circuit diagram of the resistor network described in the scenario and fully analyse it to determine the total external resistance, the battery current, the terminal voltage of the battery, and the power dissipated in the 4 Ω series resistor. **(06)**

END OF PAPER
