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

MASAKA DIOCESAN EXAMINATIONS BOARD
JOINT MOCK EXAMINATIONS 2026
Uganda Advanced Certificate of Education
PHYSICS
Paper 1
(Theory)
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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.

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SECTION A

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

Item 1

While at the airport, a pilot conducts a final check on whether his aircraft with a total wing area of 40 m^2 can ably create sufficient lift to takeoff. Takeoff occurs when the lift exceed it's the total weight of the aircraft. Flight instruments indicate that air speed above the wings is 100 ms^{-1} while that below is 120 ms^{-1}. He does not know how to interpret the measurements in relation to the shape of the aircraft wings to create a lift force. He also wants to know whether these speeds are sufficient to cause lift.

During the flight, the aircraft's communication and navigation system fails, and the pilot carries out an emergency evacuation of the passengers using a parachute. Just 2 m above the ground Musa's parachute developed a puncture and felt weightless as he descended. Upon reaching the ground, he flexed his knees while the other passengers reported of normal weight and did not flex their knees. Musa and those passengers narrated to situation to the rescue team who were waiting. The team did not understand this.

Dr. Sarah is tasked with deploying a 2000 kg emergency communication satellite to locate the wreckage of the aircraft and restore regional links. She aims for a stable orbit at a height of 800 km above the earth's surface. She has been advised that the mission will succeed only if the launch energy needed stays within their rocket's capacity of 6.5×10^{10} J. She needs TO evaluate the success of the mission, be guided on the launching procedures, understand what is likely to happen in case the propulsion system fails when it has just reached this altitude in order to be able to estimate when it likely to return to the earth's surface.

Hint: Density of air $\rho_a = 1.29\ gm^{-3}$

Mass of Musa, 70 kg

Total weight of the aircraft = 15,000 kg

Acceleration due to gravity at the earth's surface, $g = 9.81 ms^{-2}$.

Radius of the earth, $M_e = 6.4 \times 10^6$ m.

Gravitational constant, $G = 6.67 \times 10^{-11} Nm^2 kg^{-1}$

Tasks

(a) Respond to the concerns of the pilot and the rescue team.

(b) Help Dr. Sarah to accomplish her launching mission.

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Item 2

An industrial manufacturing plant utilizes a modern diagnostic X-ray tube operating at 40 kV to maintain standard thickness gauge of aluminium sheets produced by a certain factory. The automated gauge uses a radioactive source that emits beta particles. The existing hydroelectric power grid faces a daily deficit of 7.5×10^{13} J to run the factory. Therefore, a small-scale nuclear fission reactor has been set up to cater for the deficit.

The workers in the factory do not know how nuclear fission releases energy, how such systems are regulated to maintain safety and why a neutron is used not any other particle such as alpha or a proton. In an effort to educate the workers, the engineer has provided a standard nuclear equation for the nuclear process:

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$$

Due to limited availability of uranium, the workers want to know whether 1 kg of pure uranium is enough to produce the daily deficit energy.

While meeting a group of physics learners on study trip at the factory, the quality assurance team rely on the atomic structure of aluminium which is known to possess an interplaner atomic spacing of 2.3×10^{-10} m. The students are further informed that the aluminium is flaw free diffracting angle for X-rays does not fall below 7° for the second order diffraction if the team assigns the students with verifying the standards of produced aluminium sample sheets, provide detailed procedure of how the factory maintains uniform thickness of a given aluminium sheet and how the detector identifies the radiations involved.

The team is left with the task of advising the factory workers why a beta emitting source is preferred to any other radiation.

Hint:

Mass of $^{235}_{92}U = 235.0439u$, Mass of $^{1}_{0}n = 1.0087u$, Mass of $^{141}_{56}Ba = 140.9144u$, Mass of $^{92}_{36}Kr = 91.9262u$, $1u = 931MeV$

Speed of electromagnetic radiation in vacuum, $c = 3.0 \times 10^{8} ms^{-1}$

Plunk constant, $h = 6.6 \times 10^{-34} Js$.

Electronic charge, $e = 1.6 \times 10^{-19} C$.

Tasks:

(a) Analyse the information and educate the factory workers about their concerns.

(b) Help the students and the quality assurance team to carry out its obligations.

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SECTION B
PART I

Item 3

A newly established agricultural research center in your community is developing solar-powered crop dryers to minimize post-harvest losses. The main components of the solar system are triangular prism of refracting angle, 60° to isolate infrared rays from harmful ultraviolet rays that degrade nutrients. An array of six identical rectangular solar plates measuring 2.0 m by 1.5 m as a perfect black body to absorb the solar energy that run the crop dryers. The team sets up the system in a way that sunlight strikes the first face of the glass prism at an angle of incidence 45° and infrared passes symmetrically through the glass prism. A triangular glass prism can effectively isolate these rays if their angular separation exceeds 0.46°. The team is interested in evaluating how the incoming sunlight behaves upon entering the glass prism to isolate heating rays from the harmful ones and whether it can serve the intended purpose.

It has come to the notice of the station manager that the six solar plates absorb energy from the sun at a standard solar constant of1350Wm^{-2}. The manager wants to monitor these extreme temperatures generated at the focal spot of the dryer without melting standard contact sensors. The team has proposed to the manager to choose between bolometer strip and an optical pyrometer. However, the manager doesn't know the basis of selection of the suitable measuring device. He also doesn't know how the selected device can be used to monitor the temperatures.

Hint: Refractive index of glass prism for ultraviolet rays, $n_{uv} = 1.525$.
Stefan's constant, $\sigma = 5.67 \times 10^{-8}\text{Wm}^{-2}\text{K}^{-4}$.

Tasks:

(a) Analyse the information and address the concerns of the engineering team.

(b) With justification, help the manager to monitor the operating temperatures.

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Item 4

A community resource center is preparing to host an interactive physics seminar for high schools in the area. The seminar relies on diesel generator managed by a technician to power both public address and a digital projector setup by the facilitator.

During a test run of the generator engine, the technician observes that 1 mole of oxygen at s.t.p behaves ideally inside the engine cylinder when undergoing an extreme rapid stroke. The gas is swiftly compressed to a volume 0.0166 m^3 before any heat can escape to the surroundings. This sudden compression requires the piston to perform 350 J of mechanical work on the gas, rising its temperature to 290 K. The technician does not know why the rising and is worried that the resulting internal pressure might exceed the engine block's structural safety limit of 1.64×10^5 Pa, causing an explosion that may disrupt the seminar's power supply. He needs to examine the thermodynamic behavior.

Meanwhile the facilitator sets up the projector using a single standard convex lens of focal length 12 cm, positioning the slide exactly 10 m from the projection screen. When she projects the first sample slide which displays an experimental data plot a plane progressive wave for the student's seminar assignment, the text and equations appear completely unreadable. The learners complain that the image is badly blurred, lacks sharp focus at the edges, and suffers from distracting rainbow- coloured fringes around the text characters. The facilitator needs to analyze the optical specifications needed to modify the lens setup for a perfect focus of the image. The progressive wave equation on the blurry slide is intended to show: $y = 0.1 \sin\left(200\pi t - \frac{20\pi}{17}x\right)$, where y is in mm, t is in seconds and x is the distance from a fixed origin in metres.

Without correcting these optical defects, the seminar cannot proceed, and the learners will be unable to analyze the wave's speed or deduce the modified equation for a secondary wave that has twice the amplitude, double the frequency and travels in the exact opposite direction. Finally as part of the seminar, the learners want to understand how the modified projector works to produce a clear display.

Hint:

Standard atmospheric pressure $= 1.01 \times 10^5$ Pa.
Density of oxygen at s.t.p $= 1.43$ kgm^{-3}
Molar mass of oxygen $= 32g$

Tasks

(a) Analyze the thermodynamics process to address technician's safety concerns to evaluate if the engine is at risk of an explosion.

(b) Help the facilitator with an illustration to diagnose and fix the optical defects causing the poor display, and provide the solutions to the assignment for the students once the display is clear.

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PART II

Item 5

A smart car garage in a certain city is hosting a group of mechanic trainees. One day, they have received a customer complaining of his car's cabin bulb and electric motor which were not responding properly. The mechanic trainees suspected that the fault lay within the wiring system displayed in figure 1. M is a device that runs a cooling fan.

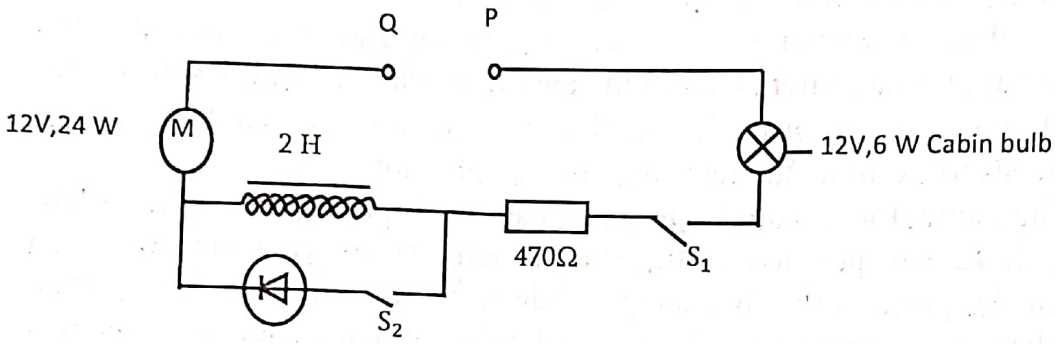


Fig. 1

As part of their tests they connected terminals P and Q across an a.c generator operating at 100 V (r.m.s), 50 Hz. When they closed switch, S_1, both the cabin bulb and the cooling fan could not respond. When all the switches, were closed only the cabin bulb responded while the cooling fan completely failed to run. One of the mechanic trainees, Tom claimed the response failure was due to blow off of the coil since the potential difference across it had exceeded 8.0 V. They need to verify whether Tom's claim is valid and analyse the behavior of the circuit components under these conditions. Another member, Sarah suggested that replacing the a.c supply with a d.c battery supply with the same rating while keeping terminal P positive with respect to maintaining switch S_2 open could be a better option for all the components to respond properly. However, she has feared that the cabin bulb may blow, she wants to know the value of a shunt which could be connected across the bulb to prevent from the blow.

Tasks:

(a) Analyse the information and address the concerns of the mechanic trainees to evaluate the performance of the first power source.

(b) Use the details provided to address the requirements of Sarah's second power source, and describe the operation of the device that runs the cooling fan.

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Item 6

Testing facilities use sensitive meters to measure electricity which are very delicate to handle. A technician is assigned to evaluate the sensitivity of a moving coil galvanometer with an internal resistance 2 Ω. The instrument consists of a rectangular coil with 500 turns each of area $4.0 \times 10^{-4}\text{m}^2$ suspended in a radial magnetic field of flux density 0.25 T by hairsprings with torsional constant, $3.0 \times 10^{-5}\text{Nmrad}^{-1}$.

To examine its response limits, the galvanometer is connected in series with a 0.5 m bare copper wire as a protective resistor. The technician repeatedly charges an air capacitor to 30 V and then discharges it through the galvanometer using a vibrating switch working at 50 times per second. When the circuit is activated, the galvanometer deflects steadily through 0.4 radians. The technician is interested in knowing the energy changes that account for deflection of the galvanometer. He does not know how the wire will eventually heat up under operation. He worries that if the heat generated in the constantan wire reaches 1.62×10^{-5} J, in in a span of half a minute after the switch has been activated, the delicate hairsprings may burn out.

Following the initial test, the technician attempts to re-use the components to assemble a radio receiver tuning circuit designed to receive incoming radio signals at exactly 2.516 MHz. He disconnects the wire from the previous circuit and uses the wire to wind a compact solenoid of length 22.7 cm with 600 turns and a cross-sectional radius 1.42 cm. He connects this new inductor in series with the capacitor and the galvanometer across a 12 V(r.m.s), 40 Hz a.c source.

He wants to measure the current through the circuit, but when he switches on the source, the galvanometer needle seemed not to deflect. He is unable to take readings and does not know why. He wants assistance to understand how the tuning circuit can be modified so that the galvanometer can register a readable current.

Hint:

Cross sectional area of copper wire, $A = 4.25 \times 10^{-10}\text{m}^2$

Electrical resistivity of constantan wire, $\rho = 1.7 \times 10^{-8}\Omega\text{m}$

Permeability of free space, $\mu_o = 4\pi \times 10^{-7}\text{Hm}^{-1}$

Tasks:

(a) Address the concerns of the technician to protect the galvanometer.

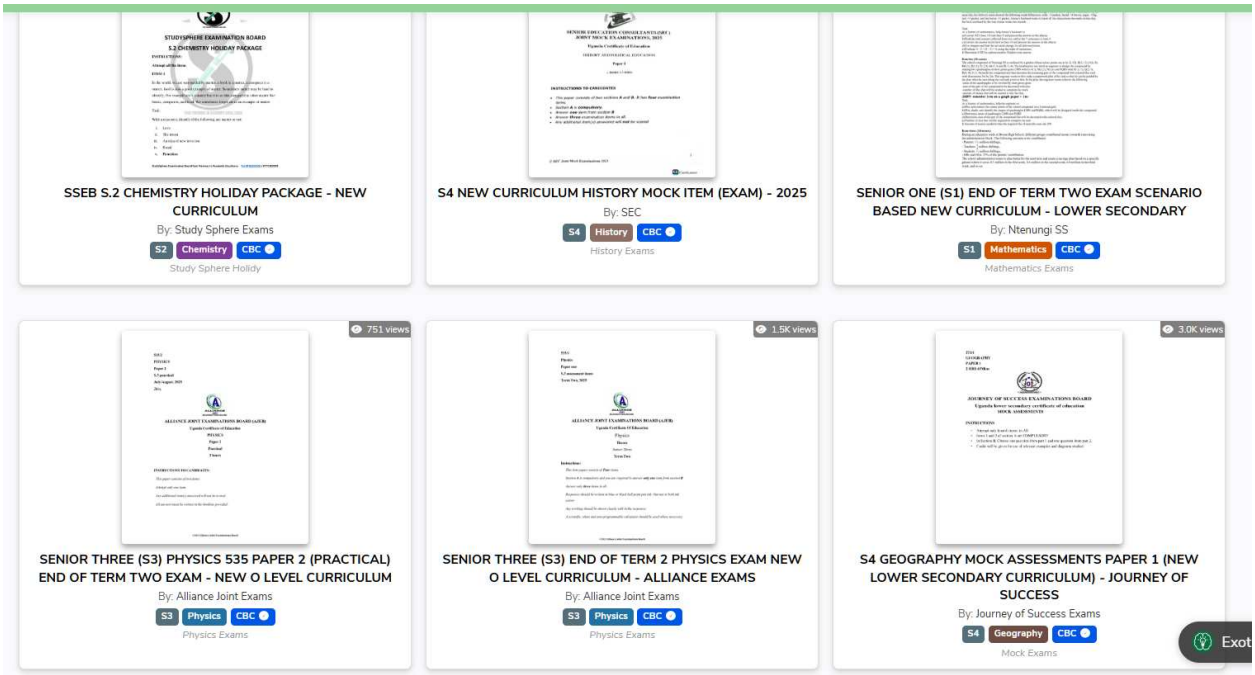
(b) Help the technician to use the galvanometer record current through the designed circuit, estimate the reading and verify whether it will be able to detect the incoming radio signals.

END

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