

**ADVANCED LEVEL PHYSICS**

**Integrated Scenario Examination – End of Year 2025**

**Time: 3 Hours**

**Answer ALL items**

**End of year physics offer by tr. joelPCM**

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**Item 1**

On a hot afternoon in Karamoja, a surveyor uses a brass–steel composite measuring rod to align a baseline for a solar energy project. The ambient air temperature rises steadily from  $25^{\circ}\text{C}$  to  $46^{\circ}\text{C}$  as the sun intensifies. Nearby, a mirage appears on the horizon, confusing junior assistants. The rod had earlier been calibrated using a mercury thermometer at standard pressure. As measurements continue, discrepancies arise when the rod is compared with an optical laser range finder. The surveyor suspects thermal expansion effects, refractive index gradients in air, and thermometer calibration errors. The site also lies at a higher altitude than the calibration laboratory. He halts the exercise to analyze the physics behind the anomalies before proceeding.

## TASKS

- A. Explain why the composite rod may bend rather than expand uniformly under the temperature change.
- B. Analyze how the mirage formation affects the apparent position of distant objects and relate this to refractive index variation.
- C. Discuss how altitude affects the mercury thermometer reading used during calibration.
- D. Propose a physics-based method to correct the measured baseline length.

## Item 2

A physics teacher in Mbarara demonstrates thermodynamic cycles using a sealed glass cylinder containing air and a movable piston. The cylinder is placed alternately in boiling water and melting ice. A plane mirror behind the setup helps students observe piston movement more clearly. During one cycle, the piston sticks briefly, and condensation forms inside the cylinder walls. The teacher notices that light reflected from the mirror appears distorted due to temperature gradients in the surrounding air. Students are asked to relate mechanical work, heat transfer, and optical effects occurring simultaneously.

## TASKS

- A. Identify the thermodynamic processes involved in one complete cycle of piston motion.
- B. Explain the formation of condensation inside the cylinder using kinetic theory.
- C. Analyze how temperature gradients affect reflection of light near the apparatus.
- D. Discuss how mechanical work done by the gas can be estimated from observable quantities.

## Item 3

A sailor on Lake Victoria uses a sextant early in the morning to determine latitude. The air is cool near the water surface but warmer above, producing a slight mirage effect. The sextant mirrors were calibrated at room temperature the previous night. As the sun rises, the metal frame of the sextant expands unevenly. The sailor records an angle slightly larger than expected. Later comparison with GPS data shows a systematic error.

## TASKS

- A. Explain how refraction near the water surface alters the apparent altitude of the sun.
- B. Analyze how thermal expansion of the sextant frame affects angular measurement.
- C. Discuss why early morning conditions increase the likelihood of optical errors.
- D. Suggest practical corrections to improve accuracy of sextant observations.

#### Item 4

In a laboratory experiment, students investigate the relationship between pressure and temperature using a constant-volume gas thermometer. The thermometer is immersed in oil baths at different temperatures while being viewed through a thick glass window. As temperature increases, students notice slight displacement of the mercury column when viewed at an angle. Meanwhile, heat losses occur through the glass walls, and pressure readings lag behind temperature changes.

#### TASKS

- A. Explain why a constant-volume gas thermometer is preferred for defining thermodynamic temperature.
- B. Analyze the optical reason for apparent displacement of the mercury column.
- C. Discuss the effect of heat loss on pressure–temperature measurements.
- D. Propose improvements to reduce experimental uncertainty.

#### Item 5

During a desert road trip simulation, a physics model shows how mirages form due to temperature gradients above asphalt. At the same time, infrared radiation sensors measure heat flow from the ground. A convex lens is used to project an image of the shimmering road onto a screen. The image appears unstable and blurred as temperature increases.

#### TASKS

- A. Explain the formation of inferior mirages using refractive index gradients.
- B. Relate the observed optical instability to heat transfer mechanisms.
- C. Analyze how lens imaging is affected by non-uniform refractive media.
- D. Discuss why mirages disappear when the road surface cools.

#### Item 6

A student heats a metal rod at one end while the other end supports a small plane mirror used to reflect a laser beam onto a scale. As heating continues, the reflected spot shifts gradually. The surrounding air shimmers, and the student measures temperature using an alcohol thermometer nearby. The experiment aims to study both thermal conductivity and optical sensitivity.

#### TASKS

- A. Explain the cause of the gradual shift of the laser spot.
- B. Analyze the role of thermal expansion and mirror rotation.
- C. Discuss limitations of alcohol thermometers in high-temperature gradients.
- D. Evaluate how optical methods improve sensitivity in thermal experiments.

#### Item 7

A closed refrigerator is placed inside a room with mirrored walls for an energy audit experiment. When switched on, the room temperature slowly rises despite the cooling inside the fridge. Light beams passing near the refrigerator appear slightly bent due to warm air convection currents. Students debate whether the refrigerator violates the second law of thermodynamics.

#### TASKS

- A. Explain why the room temperature increases when the refrigerator operates.
- B. Relate the observation to the second law of thermodynamics.
- C. Analyze how convection currents affect light propagation.
- D. Discuss the overall energy balance of the system.

#### Item 8

At a hilltop observatory, astronomers use refracting telescopes at night. The temperature drops rapidly after sunset, causing the glass lenses and metal tube to contract differently. Star images appear slightly shifted, and thermometers show inconsistent readings. The astronomers also notice atmospheric refraction effects near the horizon.

#### TASKS

- A. Explain the effect of differential thermal contraction on image formation.
- B. Analyze why refraction is stronger near the horizon.
- C. Discuss thermometer lag in rapidly changing temperatures.
- D. Propose design features that reduce thermal and optical errors.

#### Item 9

A physics club builds a solar cooker using mirrors to concentrate sunlight onto a blackened metal container filled with water. As heating progresses, steam forms, pressure builds slightly, and reflected sunlight becomes harder to focus due to rising hot air. Temperature readings fluctuate unexpectedly.

#### TASKS

- A. Explain how reflection and absorption contribute to heating efficiency.
- B. Analyze the effect of convection currents on mirror focusing.
- C. Discuss the thermodynamic processes occurring in the water.
- D. Suggest methods to stabilize temperature measurements.

#### Item 10

On the final day of fieldwork, a physics class measures the speed of light using an optical setup involving mirrors and rotating discs, while ambient temperature varies significantly. The refractive index of air changes during the experiment, and thermal expansion affects the alignment of components. Results differ slightly from the accepted value.

#### TASKS

- A. Explain how temperature affects the refractive index of air.
- B. Analyze the impact of thermal expansion on optical alignment.
- C. Discuss why precision experiments are sensitive to environmental conditions.
- D. Evaluate methods to minimize systematic errors in such measurements.

### **UGANDA ADVANCED CERTIFICATE OF EDUCATION PHYSICS – END OF YEAR 2025**

#### ***Integrated Scenario Examination***

***Author: Joel Amanire***

***Level: Advanced (New Curriculum)***

***Time: 3 Hours***

***Instructions: Answer all items. Show all workings. Use standard constants where necessary.***

#### **Inspiring Quotes for Physics Students**

***“The important thing is not to stop questioning. Curiosity has its own reason for existing.” – Albert Einstein***

***“Physics is like sex: sure, it may give some practical results, but that’s not why we do it.” – Richard Feynman***

***“A scientist is not someone who gives the right answers, he’s one who asks the right questions.” – Claude Lévi-Strauss***

***“The universe is under no obligation to make sense to you.” – Neil deGrasse Tyson***

***“Do not worry about your difficulties in Physics. I can assure you mine are still greater.” – Albert Einstein***

***“In science, there are no shortcuts to truth.” – Karl Popper***

***“Physics is the most fundamental of all the sciences, for understanding it gives insight into everything else.” – Stephen Hawking***

***“Success in science depends on curiosity, perseverance, and imagination.” – Marie Curie***

**“The goal of education in physics is not just knowledge, but the ability to think critically and solve real-world problems.” – Joel Amanire**

**“Every great physicist starts with a question and a willingness to be wrong.” –  
Inspired by Feynman**