



UNIVERSITY EXAMINATIONS

FIRST SEMESTER 2025/2026 ACADEMIC YEAR

**FIRST YEAR EXAMINATION FOR THE DEGREES OF
BACHELOR OF EDUCATION (SCIENCE) AND BACHELOR
OF SCIENCE (GENERAL)**

PHYS 113: HEAT AND THERMODYNAMICS

STREAMS: REGULAR

TIME: 2 HRS

DAY: MONDAY [8.30 – 10.30 A.M]

DATE: 02/02/2026

THIS QUESTION PAPER CONSISTS OF FIVE (5) PAGES

PLEASE DO NOT OPEN UNTIL THE INVIGILATOR SAYS SO.

INSTRUCTIONS

Read the questions carefully then answer question **ONE (30 MARKS –COMPULSORY)** and any other **TWO** questions **(20 MARKS each)**.

QUESTION ONE (30 MARKS)

- (a) Define the following terms
- i) Isothermal (1 Mark)
 - ii) Adiabatic (1 Mark)
 - iii) Zeroth law (1 Mark)
- (b) Mention any **two** advantages of mercury as a thermometric fluid. (2 Marks)
- (c) The normal boiling point of nitrogen is -195.75°C .
- (i) What is this temperature in Kelvin and in Fahrenheit? (2 Marks)
 - (ii) If the temperature changes from -195.75°C to -100°C , find the change in the temperature on the Fahrenheit scale. (2 Marks)
- (d) A steel rod has a length $L = 8\text{m}$ and radius $r = 1.5\text{ cm}$ when the temperature is 20°C . Take $\alpha = 11 \times 10^{-6} (\text{C}^{\circ})^{-1}$ and Young's modulus of the rod to be $Y = 200 \times 10^9 \text{ N/m}^2$
- (i) What is its length on a hot day when the temperature is 50°C ? (3 Marks)
 - (ii) If the rod's ends were originally fixed, then find the compression force on the rod? (3 Marks)
- (e) State any four types of thermometers and their temperature ranges. (4 Marks)
- (f) The main constituents of air are nitrogen molecules of molar mass $M(\text{N}_2) = 28 \text{ kg/kmol}$ and oxygen molecules of molar mass $M(\text{O}_2) = 32 \text{ kg/kmol}$ with approximate proportions of 80% and 20%, respectively. Using the ideal gas law, find the mass of air in a volume of 50 cm^3 at a pressure of 700 torr and temperature of 20°C . (4 Marks)
- (g) An internal energy of a solid increased when the heat is transferred to it from its surroundings. A 1kg bar of copper is heated at atmospheric pressure. If its temperature is increased from 20°C to 50°C , and Coefficient of linear expansion of copper $= 17 \times 10^{-6}/^{\circ}\text{C}$
- i) Find the work done by copper (2 Marks)
 - ii) What quantity of heat is transferred to the copper? (2 Marks)
 - iii) What is the increase in internal energy of the copper? (2 Marks)

QUESTION TWO (20 MARKS)

- (a) Draw a Carnot engine driven backwards, absorbs heat at the cold reservoir and rejects heat at a hotter reservoir. **(4 Marks)**
- (b) Show the efficiency or figure of merit of a Carnot engine in terms of the amount of heat extracted for a given expenditure of mechanical work. **(3 Marks)**
- (c) A Carnot engine uses an ideal gas as a working substance. It is driven in reverse by a 0.5KW electric motor of efficiency 60% in order to freeze water at 0°C. Assume the working temperature of the engine is 15°C and 0°C and no heat losses in the refrigerator unit. Find the time taken to freeze 10kg of water. **(5 Marks)**
- (d) A glass window measures 1 m × 1.5m × 0.5 cm and has a thermal conductivity of 0.8W/m.C°. The temperature of the inner surface of the glass is $T_H = 20^\circ\text{C}$, while the temperature for the outer surface is $T_C = -15^\circ\text{C}$.
- (i) Calculate the rate of heat flow by conduction through the window. **(3 Marks)**
- (ii) If the inner face of the window is taken to be at $x = 0$, see the figure, then find the temperature of the glass as a function of x . **(5 Marks)**

QUESTION THREE (20 MARKS)

- (a) (i) How many molecules are there in 1 cm³ of air at room temperature (27°C)? **(2 Marks)**
- (ii) How many kilomoles of air are in that volume? **(4 Marks)**
- (iii) The best vacuum that can be produced corresponds to a pressure of about 10^{-16} atm. How many molecules remain in 1 cm³? **(3 Marks)**
- (b) What is the amount of heat Q absorbed to raise the temperature of 100grammes of water from 20°C to 100°C (shouldn't evaporate) **(3 Marks)**
- (c) The Eiffel tower is built from iron, and it is about 324 m high. Its coefficient of linear expansion is approximately $12 \times 10^{-6} (\text{C}^\circ)^{-1}$ and assumed constant. What is the increase in the tower's length when the temperature changes from 0 °C in winter to 30 °C? **(4 Marks)**
- (d) The initial volume, pressure, and temperature of helium gas trapped in a container with a movable piston are $2 \times 10^{-3} \text{ m}^3$, 150 kPa, and 300 K, respectively. If the volume is decreased to $1.5 \times 10^{-3} \text{ m}^3$ and

the pressure increases to 300 kPa find the final temperature of the gas, assuming it behaves like an ideal gas. (4 Marks)

QUESTION FOUR (20 MARKS)

- (a) State the **first** law of thermodynamics (1 Mark)
- (b) Find the quantity of heat required to convert ice of mass 500 g at -10°C into water at 20°C . The specific heat of ice is $c_i = 2,220 \text{ J/kg}\cdot^{\circ}\text{C}$, the latent heat of fusion is $L_F = 3.33 \times 10^5 \text{ J/kg}$, and the specific heat of water is $c_w = 4,186 \text{ J/kg}\cdot^{\circ}\text{C}$. (4 Marks)
- (c) Distinguish between a reversible and irreversible process, illustrate your answer by use of one example (3 Marks)
- (d) At a constant pressure of 1 atm, a movable piston encloses 1 kg of water with a volume of 10^{-3} m^3 and a temperature of 100°C . Heat is added from a reservoir until the liquid water changes completely into steam of volume 1.671 m^3 .
- (i) How much work is done by the system (water + steam) during the boiling process? (3 Marks)
- (ii) How much heat energy is added to the system? (3 Marks)
- (iii) What is the change in the internal energy of the system? (3 Marks)
- (e) State **three** common energy-transfer mechanisms that are responsible for changing the internal energy state of a system (3 Marks)

QUESTION FIVE (20 MARKS)

- (a) Distinguish the following terms as used in heat and thermodynamics
- (i) Latent heat of vaporization and latent heat of fusion (2 Marks)
- (ii) Condensation and boiling (2 Marks)
- (iii) Freezing and melting (2 Marks)

- (b) A 3.00gm Lead bullet at 30°C is fired at a speed of 240m/s into a large block of ice at 0°C , in which it embeds itself. what quantity of ice melts. (Specific heat of lead = 128 J/kg°) **(4 Marks)**
- (c) A 5.00 gm lead bullet traveling at 300m/s is stopped by a large tree. If half the kinetic energy of the bullet is transformed into internal energy and remains with the bullet while the other half is transmitted to the tree, what is the increase in temperature of the bullet? **(5 Marks)**
- (d) The length of a certain block of steel is 25m and cross sectional area 20cm^2 . The steel is heated so that its temperature changes from 10°C to 45°C . Take Coefficient of linear expansion for steel is $\alpha = 11 \times 10^{-6} \text{ C}^{-1}$. Calculate;
- i) The change in length and **(2 Marks)**
 - ii) Change in area. **(2 Marks)**
 - iii) Change in volume. **(1 Mark)**