**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION**

**DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION**

# PST 6374 THERMODYNAMICS 5

**NOVEMBER 2024 EXAMINATION**

**This Examination Paper consists of 4 printed pages**

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: None Internal

Examiner: Mrs. N. Moyo

External Examiner: Dr N. Zezekwa

## INSTRUCTION

1. This paper consists of **6** questions.
2. Answer **any 5** questions from this question paper.
3. Begin each full question on a new page.
4. Show all your working steps clearly in any calculation.

## MARK ALLOCATION

| QUESTION | MARKS |
|---|---|
| First question | 20 |
| Second question | 20 |
| Third question | 20 |
| Fourth question | 20 |
| Fith question | 20 |
| TOTAL | 100 |

1. Figure 1 below represents $n$ mols of an ideal monatomic gas being taken through a cycle that consists of two isothermal processes at temperatures $3T_i$ and $T_i$ and two constant-volume processes. For each cycle, determine, in terms of $n$, $R$, and $T_i$

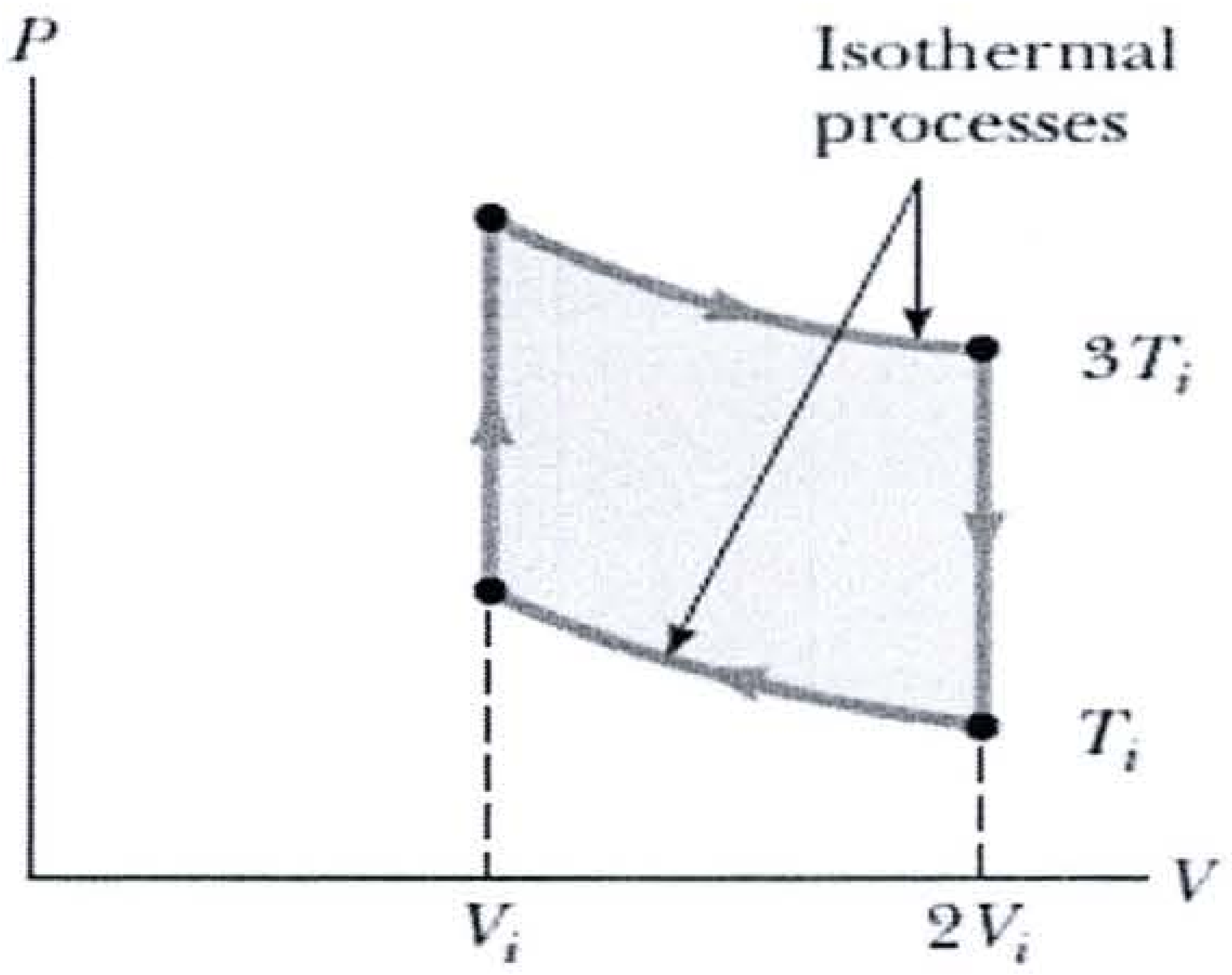



FIG 1

(a) Find out the following
   (i) The type of cycle in operation and the four transformations integrating this cycle. [5]
   (ii) The transformations where there is heat absorption by the gas and heat loss to the surrounding. [2]
   (iii) The net energy transferred by heat to the gas. [7]

(b) The efficiency of an engine operating in this cycle. [6]

2. (a) By considering a constant volume process and a constant pressure processes, show that the specific heat capacities of an ideal gas are expressed as $nC_v = \frac{\partial Q}{\partial T} = \frac{\partial U}{\partial T}$ and $nC_p = \frac{\partial U}{\partial T} + nR$ , Hence show that the specific heat capacity of an ideal gas at contant pressure is larger than at constant volume by a factor R, the gas constant. [10]

(b) A cylinder of n moles undergoes a reversible adiabatic process. Show that the work done during the process is given by $W = \frac{1}{\gamma-1}(P_iV_i - P_fV_f)$ [6]

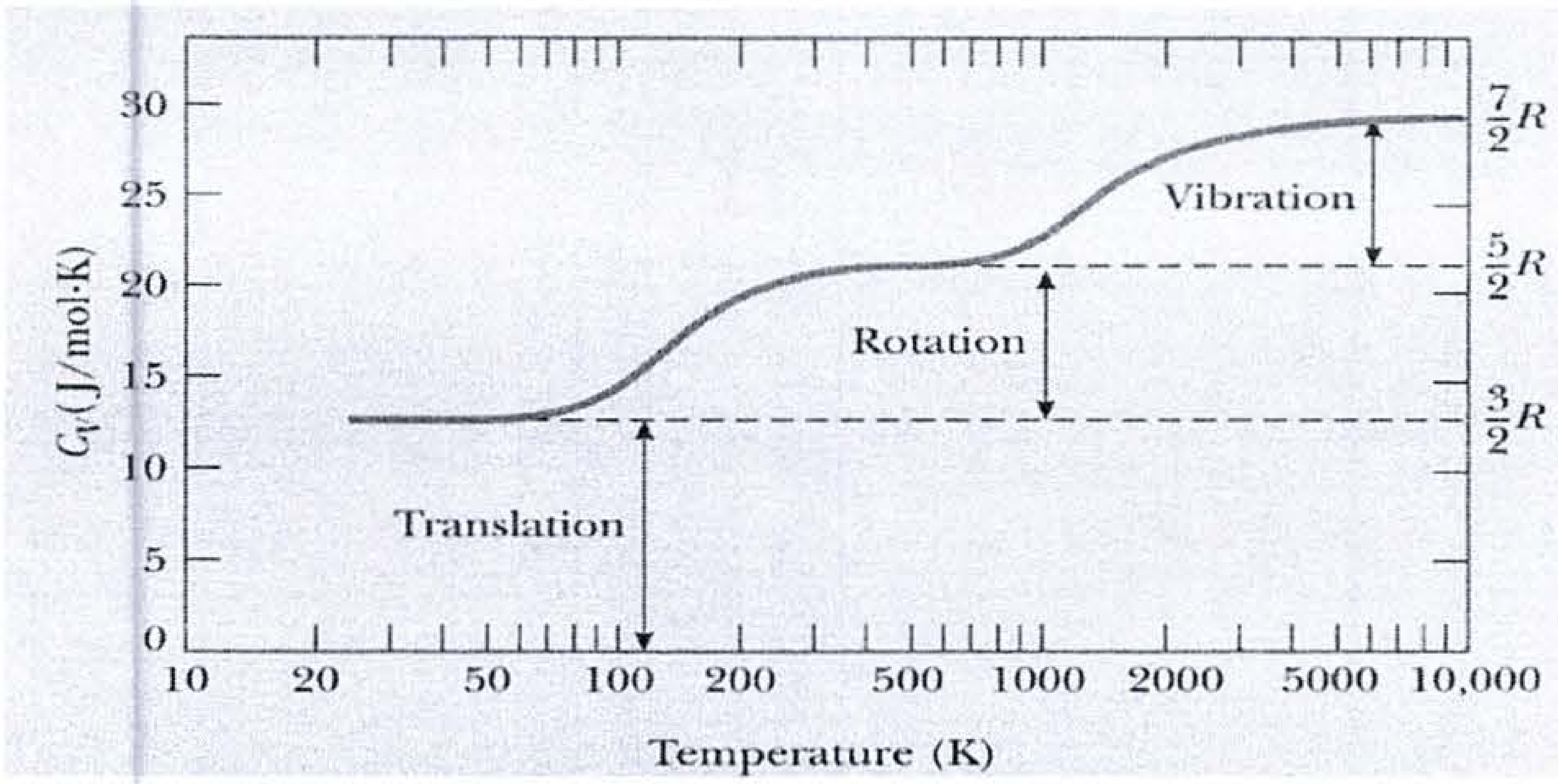
*(c)* What is the difference between isothermal and adiabatic work. Show that the work done by an ideal gas during an isothermal transformation is given by

$$W = nRT ln \frac{V_f}{V_i}$$ [4]

3. (a) Enunciate the Second Law of thermodynamics in terms of the heat engine (Kelvin statement) and in terms of a refrigerator (Claussius's statement). Prove that both statements are equivalent. [10]

(b) A refrigerator has a coefficient of performance (Cop) of 3.00. The ice tray component is a -10°C and the room temperature is 20°C, The refrigerator can convert 30.00g of water at 20°C to 20.00g of ice at -20°C each minute. The latent heat of fusion of water is 3.33 x $10^5$ J/Kg K. the specific heat capacity of water and ice are 4186 and 2090 J/Kg K Respectively. By drawing the cooling/ heating curves to show the changes taking place. what is the power of the compressor? [10]

4. (a) Explain the shown behaviour of the specific heat capacities of gases with the increasing temperature on the diagram below. Use the kinetic molecular and the equipartition of energy theory in your expalanation. [15]




(b) Show that the average kinetic energy of the particles of an ideal gas is given by $K = \frac{3}{2} KT$ [5]

5. (a) Starting from the Central equation (dU = −P dV + T dS) and this definition, derive the Maxwell relation associated with the Helmholtz potential. [5]

(b) Show that

$$C_P - C_V = \left[\left(\frac{\partial U}{\partial V}\right)_T + P\right]\left(\frac{\partial V}{\partial T}\right)_P$$

Hence using the appropriate Maxwell relation, show that

$$\left(\frac{\partial C_V}{\partial V}\right)_T = T\left(\frac{\partial^2 P}{\partial T^2}\right)_V$$ and that

$$C_P - C_V = \frac{VT\beta_P^2}{\kappa_T}$$

[15]

6. (a) What change in entropy occurs when a 27.9 g ice cube at -12 °C is transformed into steam at 115°C. The latent heat of fusion and the latent heat of vaporization of water are 3.33 x $10^5$ J/Kg and 2,26 x $10^5$ J/Kg respectively. [10]

(b) By using the second law of thermodynamics $S = \frac{\Delta Q}{T}$ and its thermodynamic form :

$\frac{1}{T} = \frac{\partial S}{\partial Q}$, show that $S = k \ln \Omega$, where S is the absolute entropy of the thermodynamic system. [6]

(d) Describe the third law of thermodynamics. [4]

**END OF PAPER**