[This question paper contains 8 printed pages.]

Your Roll No..............

Sr. No. of Question Paper : 1411 C

Unique Paper Code : 32221302

Name of the Paper : Thermal Physics

Name of the Course : B.Sc. (Hons.) Physics – CBCS_Core

Semester : III

Duration : 3 Hours Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** Questions in all
3. Question No. **1** is compulsory.
4. Answer any **four** of the remaining **six**.

1. Attempt any **five** :

(a) Show that heat and work are path functions but their differences are point functions.

(b) Classify the following processes into reversible or irreversible processes and give their reasons

(i) isothermal expansion of gas

(ii) diffusion of gases

(c) A gas has the following equation of state :

$$P\left(V - \frac{a^4}{V}\right) = nRT$$

What is the work done by the gas when it is expanded isothermally?

(d) Two moles of an ideal gas expand isothermally to four times its initial volume. Calculate the entropy change in terms of R, the universal gas constant.

(e) The radius of argon atom is 0.128 nm. Calculate their mean free path at temperature 25°C and pressure 1 atmosphere. Given $K_B = 1.38 \times 10^{-23}$ JK.

(f) Calculate the deviation of van der Waals gas law from ideal gas law at the critical point.

(g) On the basis of third law of thermodynamics prove the unattainability of absolute zero temperature. (3×5=15)

2. (a) Give the mathematical form of the first law of thermodynamics and explain its significance. For an ideal gas, derive the relations

(i) $C_P - C_V = R/J$ for an isobaric process

(ii) $PV^\gamma = \text{Constant}$ for an adiabatic process

(b) A process for an ideal gas is defined by the relation $P = AT^b$. Calculate the isobaric coefficient of volume expansion (α) and isothermal compressibility (K).

(c) The volume of 1g mole of a gas filled in a container at standard pressure (1×10^5 N/m^2) and temperature (0° C) is 22.4×10^{-3} m^3. The volume of the gas is reduced to half its original value by increasing the pressure. (i) isothermally (ii) adiabatically. In each case calculate the final pressure of the gas and amount of work done [γ=1.40 and R=8.3 J mol^{-1} K^{-1}]. (6,6,3)

3. (a) Show that the efficiency of all reversible heat engines operating between the same two temperatures is same.

(b) Give Kelvin Planck and Clausius statements of the second law of thermodynamics and hence discuss their equivalence.

(c) A reversible heat engine converts one fifth of the input heat into work. On reducing the temperature of the sink by 50°C, its efficiency is doubled. Find the temperatures of the source and the sink. (6,6,3)

4. (a) With the help of an example for each process, show that there is always an increase in entropy during an irreversible process while it remains constant during a reversible process. Hence, discuss Clausius inequality.

(b) Obtain an expression for change in entropy of an ideal gas having n moles in terms of pressure and temperature when it's thermodynamic state changes from (P_i, V_i, T_i) to (P_f, V_f, T_f).

(c) Calculate the change in entropy when 0.01 kg of water at 288 K is mixed with 0.02 kg of water at 313 K. Take specific heat of water as 4200 J kg^{-1} K^{-1}. (6,6,3)

5. (a) Define four thermodynamic potentials and hence derive Maxwell's thermodynamic relations from them.

(b) Using Maxwell's relations prove

$$(\partial Cv/\partial V)_T = T(\partial^2 P/\partial T^2)_V$$

Hence show that it is equal to zero for both ideal and van der Waals gases.

(c) Calculate the change in melting point of ice at STP, when it is subjected to a pressure of 90 atmosphere. For ice, density = 0.92 g/cm^3 and latent heat of fusion = 80 cal/g. (6,6,3)

6. (a) Derive the Maxwell's law of distribution of velocity. Discuss briefly its graphical representation.

(b) State and explain the law of equipartition of energy and hence show that the value of $\gamma = C_p/C_V$ for monoatomic, diatomic and triatomic gases are 1.66, 1.4, 1.33, respectively.

(c) Calculate the root mean square speed and most probable speed of a gas whose density is 1.4 g/litre at a pressure of 10^5 N/m^2. (6,6,3)

7. (a) Describe Joule-Thomson's porous-plug experiment. Derive an expression for Joule-Thomson's coefficient (μ) and inversion temperature for a real gas obeying van der Waals equation. Explain the significance of inversion temperature.

(b) Obtain the relation between the critical temperature, Boyles temperature and the temperature of inversion for a van der Waals gas. Also write law of corresponding state.

(c) The critical Temperature of CO_2 is 31°C and its critical pressure is 73 atmospheres. Assuming that CO_2 obeys van der Waals equation, compute the critical volume of CO_2. (6,6,3)