Name of the Department: Physics
Name of the Course: B.Sc. (Hons.) Physics - CBCS_Core
Name of the Paper: Thermal Physics
Semester: III
Unique Paper Code: 32221302

Question paper Set number: A

Duration: 3 Hours **Maximum Marks: 75**

<u>Instructions for Candidates</u>

Answer any **four** questions.
All Questions carry equal marks.

Q1. (a) Explain the concepts of temperature and thermal Equilibrium on the basis of Zeroth Law. (4)

(b) Show that the heat transferred during an infinitesimal quasistatic process of an ideal gas can be written as

$$\delta Q = \frac{C_v}{nR} VdP + \frac{C_p}{nR} PdV$$

where n denotes the number of moles and R is the Gas Constant. Apply the above equation to an adiabatic process to show that $PV^{\gamma} = constant.$ (8.75)

(c) The temperature of an ideal gas at initial pressure P_1 and volume V_1 is increased isochorically until the pressure is doubled. The gas is then expanded isothermally until the pressure drops to original value. Then it is compressed isobarically until volume returns to initial value. Sketch this process in the P-V and P-T plane. Calculate the total work done if n = 2 kilomoles, $P_1 = 10^5$ Pascal, $V_1 = 2m^3$. (6)

Q2. (a) Describe construction and working of Carnot's heat engine. Derive expression for its efficiency in terms of temperatures of its heat reservoirs. (6)

(b) The efficiency of a Carnot's engine is 40% when the temperature of the sink is 27 °C. What is the temperature of the source? In order to raise its efficiency to 50%, what do you think, out of the following two, is more effective way:
(i) Decreasing the temperature of the sink (while the temperature of the source remains the same)
(ii) Increasing the temperature of the source (while the temperature of the sink remains the same)?
Justify your answer. (6.75)

(c) A heat engine employing Carnot's cycle with an efficiency η=20% is used as a refrigerating machine, the thermal reservoirs being the same. Find the coefficient of performance of the machine. (6)

Q3. (a) Establish the concept of entropy and explain the second law of thermodynamics on the basis of the entropy. (5)

(b) Consider that an ideal gas initially confined in a volume at any given temperature is allowed to expand and the whole arrangement is thermally insulated. Is it possible not to have any thermodynamic work even though there is expansion in its volume? Justify your answer and give an example. Find the entropy change of an ideal gas undergoing such a process. (8.75)

(c) Calculate the entropy change when 3 g of ice is converted into steam and is then heated to 140 °C under constant pressure. Given that specific heat of water = 4180 J kg^{-1} K^{-1}
Latent heat of ice = 3.35 x 10^5 J kg^{-1}
Latent heat of steam = 2.26 x 10^6 J kg^{-1}
Specific heat of steam = 2 x 10^3 J $kg^{-1}K^{-1}$ (5)

Q4. (a) Describe how the process of Adiabatic demagnetisation leads to cooling in paramagnetic salt. (5)

(b) From the equation of state of paramagnetic material M = k B/T show that the partial derivatives $\left(\frac{\partial M}{\partial B}\right)_T, \left(\frac{\partial B}{\partial T}\right)_M, \left(\frac{\partial T}{\partial M}\right)_B$ satisfy the cyclic relation. (7.75)

(c) Show that

$$(i)\ dH = C_P dT + V(1 - \alpha T)dP$$
$$(ii)\ dF = -(P\alpha V + S)dT + P\beta V dP$$

α denotes volume expansivity and β denotes compressibility. (6)

Q5. (a) Describe how the distribution of molecular velocities would be like for an ideal gas confined in a volume at a constant temperature and pressure. Consequently, derive the law which explains the molecular velocities on the basis of the kinetic theory of gases. (7.75)

(b) Given that the molar mass of a gas is 44 g mol^{-1}, calculate the temperature at which most molecules in a given volume attain velocity equal to 355 m s^{-1}. (4)

(c) Discuss what possible phenomena occurs when molecules of a gas at any temperature, are moving with a range of velocities in a given volume under non equilibrium conditions. Discuss briefly about Brownian motion and its significance. (7)

Q6. (a) Define critical temperature (T_C), critical pressure (P_C) and critical volume (V_C). Using van der Waal's equation of state, find their expressions in terms of van der Waal's constants 'a' and 'b'. Hence prove that for real gases, $\frac{RT_C}{P_C V_C} = \frac{8}{3}$; where R is universal gas constant. (8.75)

(b) The volume occupied by a gas at 300 K is 1.0 lit/mole. Compare the corresponding pressures considering the gas to be

i) An ideal gas
ii) A van der Waal's gas (given $a = 1.32\ atm\ lit^2 mole^{-2}$ and $b = 0.312\ lit/mole$) (6)

(c) Express van der Waal's equation of state for 1 mole of a real gas in Virial form. Hence obtain the expressions for the second Virial coefficient and Boyle's temperature of the gas. (4)