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Your Roll No. ....

Sr. No. of Question Paper : 7484A **J**

Unique Paper Code : 32221302

Name of the Paper : Thermal Physics

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

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**, attempting any **two** parts from each question.

1. Attempt **all** parts.

   (a) Which of the two, an isothermal or an adiabatic, has greater slope? Prove mathematically. (2)

(b) A Carnot's engine whose sink is at 27°C has an efficiency of 50%. By how much the temperature of the source be changed to decrease its efficiency to 40%? (2)

(c) One kilogram of water is heated from 0°C to 100°C and converted into steam at the same temperature. Calculate the increase in entropy. Given that specific heat of water is $4.18 \times 10^3\ Jkg^{-1}K^{-1}$ and latent heat of vaporisation is $2.24 \times 10^6\ Jkg^{-1}$. (3)

(d) Using Carnot's cycle derive Clausius-Clapeyron latent heat equation. (4)

(e) A substance has volume expansivity = 2bT/V and isothermal compressibility = a/V, where 'a' and 'b' are constants. Find the equation of state. (3)

(f) Define Boyle Temperature. Give relation between Boyle temperature, Temperature of inversion and Critical temperature. (2)

(g) What is Brownian motion? Give its characteristics. (3)

2. (a) (i) State first law of thermodynamics. What are its physical significance and limitations? Write first law of thermodynamics for an adiabatic, isobaric and isochoric processes. (4)

(ii) Derive the work done by an ideal gas in expanding adiabatically from initial state (P_i, V_i, T_i) to the final state (P_f, V_f, T_f}). (3)

(b) Using first law of thermodynamics, prove that

(i) $$\left(\frac{\partial U}{\partial P}\right)_V = \frac{C_V K_T}{\beta}$$

(ii) $$\left(\frac{\partial U}{\partial V}\right)_P = \frac{C_P}{\beta V} - P$$

Where β and K_T are volume expansion coefficient and isothermal compressibility respectively. (3.5,3.5)

(c) Find ΔW and ΔU for an iron cube of side 6 cm as it is heated from 20°C to 300°C. For iron $C = 0.11$ cal/g°C and volume coefficient of expansion is $\beta = 3.6 \times 10^{-5}$°C^{-1}. Given, Mass of the cube is 1700 gm. (7)

3. (a) What are reversible and irreversible processes? Give one example of each. Prove that if Kelvin-Planck statement of second law is violated then Clausius statement is also violated. (7)

(b) If, two Carnot engines R and S are operated in series such as engine R absorbs heat at temperature T_1 and rejects heat to the sink at temperature T_2, while Engine S absorbs half of the heat rejected by engine R and rejects heat to the sink at temperature T_3. If the work done in both the cases is equal, show that $T_2 = (T_3 + 2T_1)/3$. (7)

(c) (i) A refrigerator freezes 6 kg of water at 0°C into ice in a time interval of 20 min. Assume that room temp, is 25°C, calculate the power needed to accomplish it.

(ii) If coefficient of performance of a refrigerator is 5 and operates at the room temperature 27°C, find the temperature inside the refrigerator. (3.5,3.5)

4. (a) Define entropy. What is principle of increase of entropy? Find increase in entropy for reversible and irreversible processes. (7)

(b) If two bodies have equal mass *m* and heat capacity c, are kept at different temperatures T_1 and T_2 respectively, taking $T_1 > T_2$ and the first body as source of heat for reversible engine and the second as sink, find out the maximum work done. (7)

(c) (i) The temperature variation of C_P is given by the relation $C_P = 0.4\ T - 0.05\ T^2 - 0.25$, in the temperature range 50 K to 100 K in cal/K. If 4 moles of the substance is heated from 50 K to 100 K, calculate the change in entropy.

(ii) An ideal gas is confined to a cylinder by a piston. The piston is slowly pushed such that the gas temperature remains at 20°C. During compression, 730 J of work is done on the gas. Find the entropy change of the gas.

(3.5,3.5)

. (a) What are thermodynamic potentials? Why are they so called? Give relations for them. Write physical significance of Gibb's free energy. (7)

(b) Apply Maxwell's relation to prove that the difference of isothermal compressibility and adiabatic compressibility is equal to $TV\beta^2/C_P$.

(c) Minute droplets of water are slowly pushed out of an atomizer into air. The average radius of the droplets is 10^{-4} cm. If 1 kg of water is atomized isothermally at 25°C, calculate the amount of heat transferred. The specific volume of water at 25°C is 1.00187×10^{-3} $m^3kg^{-}1$ and the rate of change of surface tension of water with temperature is $-0.152 \times 10^{-3}\ Nm^{-1}K^{-1}$. (7)

6. (a) Define mean free path (λ) of molecules of a gas.

Derive the expression $\lambda = \frac{3}{4\pi\sigma^2 n}$. Where σ is the diameter of the gas molecules and n is the no. of molecules per unit volume. (Assuming that all molecules move with the same velocity i.e. the average velocity of the gas. (7)

(b) (i) Plot Maxwell distribution function for molecular speeds at temperatures T_1, T_2 and T_3 such as $T_1 < T_2 < T_3$. Write the necessary inference from these curves.

(ii) Calculate the value of v_x for which the probability of a molecule having x-velocity falls to half of its maximum value. (3,4)

(c) (i) Calculate the probability that the speed of oxygen molecule lies between 109.5 and 110.5 metre/sec at 300 K.

(ii) Hydrogen and Nitrogen are maintained under identical conditions of temperature and pressure. Calculate the ratio of their coefficients of viscosity if the diameters of these molecules are 2.5×10^{-10} m and 3.5×10^{-10} m respectively. (4,3)

7. (a) Discuss Joule-Thomson porous plug experiment. Obtain equation for Joule-Thomson co-efficient. (7)

(b) What are the limitations of Van der waal's equation of state. Draw and discuss similarities and dis-similarities of theoretical and experimental curves for CO_2 gas. (7)

(c) The Van der Waal's constant for Hydrogen are $a = 0.247$ *atm.* litre^{2}mol^{-2} and b = 2.65×10^{-2} *litre/mol*. Calculate

(i) The temperature of inversion

(ii) Joule Thomson coefficient for 2 atm fall c
pressure, initial temp, being 100 K. Give
$R = {}^{224}/_{273}$ atoms litre/mol/K. (7