

U.G. 3rd Semester Examination - 2024**PHYSICS****[HONOURS]****Course Code : PHY-H-CC-T-06****(Thermal Physics)****[CBCS]**

Full Marks : 40

Time : $2\frac{1}{2}$ Hours*The figures in the right-hand margin indicate marks.**Candidates are required to give their answers in their own words as far as practicable.***GROUP-A**

1. Answer any five questions: $2 \times 5 = 10$
 - a) Define Helmholtz's free energy of a thermodynamic system.
 - b) What are isothermal elasticity and adiabatic elasticity of a gas?
 - c) How the entropy is related to the disorder, according to Boltzmann?
 - d) State the law of equipartition of energy.
 - e) Explain the concept of quasi-static process in thermal physics.
 - f) What is r.m.s speed of a gas? At what temperature will r.m.s speed of oxygen molecule be double its value at N.T.P., while pressure remaining constant?
 - g) Explain-why the 'reversibility' is an ideal concept.

[Turn over]

- h) State and explain the 1st law of thermodynamics.

GROUP-B

2. Answer any two questions: $5 \times 2 = 10$

- a) Show that the Kelvin-Planck statement and Clausius statement of the second law of thermodynamics are equivalent. 5
- b) What is r.m.s speed of a gas? Consider a gas of molecules of mass 32 units at 27°C . Calculate the probability that the speed of a molecule will lie between 100m/s to 101m/s. 5

- c) i) The Helmholtz free energy function A can be obtained from the internal energy U by a Legendre transformation. Show that it is a function of T and V .
- ii) A certain system has Gibbs free energy given by

$$G(P, T) = RT \ln \left[\frac{ap}{(RT)^{5/2}} \right]$$

where a and R are constants. Find out C_p , the specific heat at constant pressure.

- d) i) Under what conditions is the equilibrium of a system determined by the minimum of the Helmholtz free energy?

- ii) For the equation of state $V = \frac{RT}{P} - \frac{C}{T^3}$

Show that $\left[\frac{\partial C_p}{\partial p} \right]_T = \frac{12C}{T^4}$ 2+3

GROUP-C

Answer any two questions:

$10 \times 2 = 20$

3. a) Define Joule-Thomson coefficient μ_{JT} . Establish the relation for the rate of change of temperature with pressure in a Joule-Thomson process :

$$\mu_{JT} = \left(\frac{\partial T}{\partial P} \right)_H = \frac{V}{C_p} (\alpha T - 1)$$

What is the value of this coefficient for an ideal gas?

- b) Find an expression for the number of molecules $n(E)dE$ in the energy range E to $E+dE$, according the Maxwell—Boltzmann distribution law. Plot the distribution function. $(1+3+1)+(4+1)$
4. a) Show that the probability of a gas molecule, traversing a distance x in a collision-free

process, is $e^{-\frac{x}{\lambda}}$, where λ is the mean free path of the gas molecule.

- b) Assuming linear combination, find the number of the degrees of freedom of a water molecule.
- c) Using Maxwell's distribution for the speed of molecules in a gas, find the most probable speed v_p . Is the distribution symmetric about v_p ? $3+2+(3+2)=10$

5. a) Establish the relation

$$\left(\frac{\partial S}{\partial V} \right)_T = \left(\frac{\partial P}{\partial T} \right)_V$$

- b) Using the fact that dS is an exact differential, derive the following relation:

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

- c) Show that the probability of a gas molecule in a collision-free process is exponentially decaying. 4+2+4
6. a) Using the law of equipartition of energy, establish the relation between degrees of freedom and the ratio of the two specific heats of a gas.
- b) What is Carnot's theorem? A Carnot engine operates between two temperatures T_1 and T_2 , where $T_1 > T_2$. Show that the efficiency of the cycle is $\left(1 - \frac{T_2}{T_1}\right)$.
- c) Consider two distinguishable particles X and Y. If the diameter of X is thrice that of Y while molecular weight is thrice, find the ratio of the co-efficient of viscosity of the two molecules. 3+(1+4)+2=10
-