U.G. 3rd Semester Examination - 2023

PHYSICS

[HONOURS]

Course Code : PHY-H-CC-T-06

(Thermal Physics)

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: 2×5=10

   a) What do you mean by phase transition?

   b) What is Carnot's theorem?

   c) What are isothermal elasticity and adiabatic elasticity of gas?

   d) State the law of equipartition of energy.

   e) Define Helmoltz's free energy of a thermodynamic system.

   f) How the entropy is related to the disorder, according to Boltzmann?

   g) Explain-why the 'reversibility' is an ideal concept.

   h) Define the mean free path of the gas molecule.

GROUP-B

Answer any **two** questions: 5×2=10

2. a) State Kelvin-Plank statement and Clausius statement of the second law of thermodynamics. Show that these two statements are equivalent. 2+3

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) A certain system has Gibbs free energy given by

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

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

ii) 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. 2+3

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

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

ii) Under what conditions is the equilibrium of a system determined by the minimum of the Helmholtz free energy? 3+2

GROUP-C

Answer any **two** questions: 10×2=20

3. 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

4. a) Assuming linear combination, find the degrees of freedom of a H_2O molecule. A Carnot's engine operates between the temperatures T_1 and T_2, where $(T_1 > T_2)$. Calculate its efficiency.

b) What is Curie's temperature? What is the order of ferromagnetic to paramagnetic phase transition? Establish the relation $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$, where the symbols have their usual meanings. (2+3)+(1+1+3)

5. 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)

6. a) Using Maxwell-Boltzmann distribution law for the speed of molecules in a gas, find average speed, r.m.s speed and most probable speed.

b) Two gram-molecules of hydrogen perform a free expansion from a volume of 10 litres to a volume of 30 litres, the temperature being 25°C. What is the entropy change of the universe? (2+2+2)+4
