2023
M.Sc.
First Semester
CORE – 04
PHYSICS
Course Code: MPHC 1.41
(Statistical Mechanics)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five questions, taking one from each unit.

UNIT–I

1. (a) What do you mean by phase space? How will you divide the phase space into cells? 1+2=3
   (b) Differentiate between microstate and macrostate. How does probability depend upon the number of microstates? 5
   (c) Find the values of v_x for which the probability falls to 6
   (i) $\frac{1}{e}$ times
   (ii) $\frac{1}{10}$ times, the maximum value
2. (a) Show that the probability function is given by
   $$P(v) = 4\pi\left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e m^{-mv^2/kT}.$$
   Hence derive expressions for most probable speed, average speed and root mean square speed. 7
   (b) How does canonical ensemble differ from a microcanonical ensemble? 2
   (c) Derive an expression for the partition function of a canonical ensemble made up of ideal gas molecules. Use it to calculate the thermodynamical parameters like entropy, free energy, pressure and chemical potential of the ensemble. 5

UNIT –II

3. (a) Derive the Fermi-Dirac distribution formula and show that the specific heat of a strongly degenerate Fermi-Dirac gas is directly proportional to its absolute temperature. Discuss the importance of this result. 10

   (b) Explain the quantum statistics of identical particles and the postulate of equal a priori probability in quantum statistics. 4

4. (a) Show that the mean energy of free-electron at absolute zero is $\frac{3}{5}$ times that of Fermi energy at absolute zero. 6

   (b) Calculate on the basis of Fermi-Dirac statistics the electronic contribution to the specific heat of a metal like silver. How has the specific heat been verified experimentally? 8

UNIT–III

5. (a) Discuss the drawbacks in deriving the Einstein specific heat formula for solids. What was Debye's approach in this matter? Derive Debye's formula for specific heat of solids. 3+2+3=8

   (b) Calculate the critical temperature at which Bose-Einstein condensation will start. 6

6. (a) (i) Calculate Einstein's frequency for copper for which $\Theta_E = 230K$. Given $h = 6.6\times10^{-34}$ joule-sec; Boltzmann's constant $k = 1.37\times10^{-23}$ joule/K.

   (ii) Use result (i) to show that the classical theory result $C_V = 3R$ should be valid for copper if $T > 230^{\circ}$ C. 6

   (b) What is black body radiation? Show that Planck's law reduces to Wein's law for shorter wavelengths and Rayleigh-Jean's law for longer wavelengths. 1+4=5

   (c) Give Einstein's assumptions to explain the variation of the specific heat of solids with temperature. 3

UNIT–IV

7. (a) What do you mean by electrical noise? Derive the relation for the spectral density $G(\omega)$ in the frequency range ω and $\omega+\Delta\omega$ of the fluctuating voltage with resistance (R) of a metal at a given temperature. 1+5=6

   (b) Explain Brownian motion. Discuss Langevin's theory of translational Brownian motion. 8

8. (a) Explain the Fokker Planck equation representing the motion due to a fluctuating force. 8

   (b) Derive Einstein's expression for the diffusion coefficient $D = \frac{RT}{N}.\frac{1}{6\pi\eta r}$. How will you determine N with the help of Brownian movement in gases. 6

UNIT–V

9. (a) What are the two factors taken into account to derive the Van der Waals equation? 2

   (b) Derive Van der Waals equation of state and find the thermodynamic coordinates of critical point. 8

   (c) What do you mean by first order and second order phase transitions? Give a clear distinction between them. 4

10. (a) Explain Ising model. Give a brief account of one-dimensional Ising model. 6

    (b) Discuss the Landau theory of phase transitions. 8
