November 2025
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) Differentiate between microstate and macrostate. How does probability depend upon the number of microstates? 4
   (b) Describe how an expression for entropy is set up in statistical mechanics. Show how it has the same properties as the thermodynamical entropy. 6
   (c) Find the values of v_x for which the probability falls to $\frac{1}{e}$ times and $\frac{1}{10}$ times, the maximum value. 4

2. (a) 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. 6
   (b) If the energy in a magnetic field is $E = -n\mu B$, then show that for $n \ll N$, the Helmholtz free energy $F(n)$ is given by:
   $F(n) = -n\mu B + \frac{n^2 kT}{2N}$, and $\left[F(n)\right]_{\min} = -\frac{n\mu B}{2}$ 5
   (c) What do you understand by thermodynamical probability of distribution? 3

UNIT–II

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

   (b) Derive the expressions for the density matrix in microcanonical, canonical, and grand canonical ensembles. 10

4. (a) Deduce the Fermi-Dirac distribution law. 7

   (b) Show that the partition function for the grand canonical ensemble is given by:

   $Z\left(\text{grand canonical}\right) = \text{Trace } e^{-(n\mu - H)/kT}$, where symbols have their usual meanings. 7

UNIT–III

5. (a) Where did Einstein go wrong in deriving specific heat formula for solids? What was Debye's approach in this matter? Derive Debye's formula for specific heat of solids. 8

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

6. (a) (i) Calculate Einstein's frequency for copper for which $\theta_E = 230$ K. (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) 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. 8

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 and discuss the Langevin's theory of translational Brownian motion. 8

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

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

UNIT–V

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

(b) Derive the van der Waals equation of state and find the thermodynamic coordinates of critical point. 6

(c) Give four characteristics of matter at critical point. 4

10. (a) Explain Ising model. Show that one-dimensional Ising model cannot be ferromagnetic. 6

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