Avinashilingam Institute for Home Science and Higher Education for Women

Deemed to be University Estd. u/s 3 of UGC Act 1956, Category A by MHRD (now MoE)
Re-accredited with A++ Grade by NAAC. CGPA 3.65/4, Category I by UGC
Coimbatore - 641 043, Tamil Nadu, India

Master's Degree Examination – May 2025
II Semester

Class : I P.G. **Time: 3 Hours**
Major : Physics **Max. Marks: 100**

23MPHC08 Statistical Mechanics

Course Outcomes:

CO1: Establish the connection between statistics and thermodynamics
CO2: Distinguish between three types of ensembles and derive their partition functions to explain the behaviour of classical and quantum systems
CO3: Analyze the classical and quantum statistics
CO4: Compare the statistical behavior of ideal Bose gas and Fermi gas
CO5: Discuss on heat capacities for gas, solids and understand phase transitions

Part A **10 x 1 = 10**
Choose the Correct Answer

1. What is a microstate in statistical thermodynamics? CO1K1
   a. A specific configuration of a system's particles that corresponds to a given macro state
   b. The temperature of a system at equilibrium
   c. The average kinetic energy of a system
   d. The overall entropy of the system

2. What is the Gibbs paradox primarily concerned with? CO1K1
   a. The behaviour of heat transfer in closed systems
   b. The change in entropy when two similar or different gases are mixed
   c. The calculation of free energy in thermodynamic processes
   d. The temperature dependence of specific heat capacity

3. Liouville's equation ensures the conservation of CO2K3
   a. Energy b. Volume in phase space c. Entropy d. Momentum

4. What does the microcanonical ensemble describe? CO2K1
   a. A system with fixed energy, volume, and number of particles
   b. A system with fixed temperature, volume, and number of particles
   c. A system with fixed pressure, temperature, and volume
   d. A system with variable energy and volume

5. The canonical ensemble assumes that CO3K4
   a. The system is in thermal equilibrium with a reservoir at a fixed temperature
   b. The system has no interaction with its surroundings
   c. The energy and particle number fluctuate significantly
   d. The system contains only one particle

6. What does a grand canonical ensemble allow for? CO3K1
   a. Exchange of energy and particles with the surroundings
   b. Exchange of energy but no particles with the surroundings
   c. Exchange of particles but no energy with the surroundings
   d. Neither energy nor particle exchange with the surroundings

7. Which of the following is an example of a system that follows Bose-Einstein statistics? CO4K1
   a. Electrons in an atom b. Photons in blackbody radiation
   c. Neutrons in a nucleus d. Gas molecules at room temperature

8. What is the key feature of Fermi-Dirac statistics? CO4K1
   a. Particles can occupy the same quantum state
   b. Only one particle can occupy a given quantum state
   c. The particles do not obey quantum mechanics
   d. It applies only to photons and bosons

9. What does each site in the Ising model represent? CO5K1
   a. A particle's velocity b. A spin variable with two possible states
   c. The temperature of the system d. The pressure at a specific point

10. In Landau theory, the phase transition occurs when: CO5K2
   a. The system reaches a maximum in entropy
   b. The order parameter changes continuously at the critical temperature
   c. The order parameter becomes zero at the critical temperature
   d. The system reaches thermal equilibrium

Part B 5 x 6 = 30

Answer ALL questions

Each answer should not exceed 400 words or two pages

11.a. Explain the concept of thermodynamic potentials. CO1K2

(or)

11.b. How does the ideal gas law relate to other thermodynamic properties? CO1K2

12.a. Explain Liouville's theorem and its implications for phase space. CO2K3

(or)

12.b. Explain the connection between entropy and probability in the Boltzmann relation. CO2K3

13.a. Derive the expression for Helmholtz free energy and explain its components. CO3K4

(or)

13.b. Discuss the physical significance of the Grand Canonical Ensemble. CO3K4

14.a. How is the density operator defined for a pure state, and what does it represent? CO4K2

(or)

14.b. How does the quantum Liouville equation relate to the concept of quantum statistical mechanics? CO4K2

15.a. Write a note on ferromagnetic phases. CO5K3

(or)

15.b. Classify the phase transitions by order and symmetry. CO5K2

Part C 5 x 12 = 60

Answer ALL questions

Each answer should not exceed 800 words or four pages

16.a. Explain the concept of free energy in thermodynamics. CO1K4

(or)

16.b. How does the Gibbs' Paradox relate to the concept of entropy in statistical mechanics? CO1K4

17.a. How is the microcanonical ensemble used to derive thermodynamic quantities such as temperature and pressure? CO2K4

(or)

17.b. Derive the Sackur-Tetrode equation for the entropy of an ideal gas. CO2K4

18.a. Derive the partition function for a system in the canonical ensemble. CO3K5

(or)

18.b. Calculate the average number of particles in a system described by the grand Canonical ensemble. CO3K3

19.a. Express the practical conditions required for observing Bose-Einstein condensation in an ideal Bose gas. CO4K4

(or)

19.b. What are the fundamental principles behind Fermi-Dirac statistics, and how do they apply to fermions? CO4K4

20.a. Discuss the exact solution of Ising model in one dimension. CO5K3

(or)

20.b. Describe the concept of an order parameter fit into Landau's theory of phase transitions. CO5K3

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