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# M. Sc. (PHYSICS)

# (MSCPH)

# Term-End Examination

# June, 2026

## MPH-011 : STATISTICAL MECHANICS

*Time : 2 Hours* *Maximum Marks : 50*

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***Note :*** *(i) Attempt any **five** questions.*

*(ii) Marks are indicated against each question.*

*(iii) Symbols have their usual meanings.*

*(iv) You may use calculator.*

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1. (a) Calculate the number of ways of distributing four distinguishable weakly interacting particles in two non-

degenerate energy levels according to classical Maxwell-Boltzmann statistics. 4

(b) Starting with the entropy formula $S = -k_B \sum_{i=1}^{k} P_i \ln P_i$ for probability distribution $\{P_i\}$ where $i$ is 1 to N are the distinct microstates available for the system, show that under the constraints $\sum_{i=1}^{k} P_i = 1$ and $\bar{\in} = \sum_{i=1}^{k} \in_i \; P_p$, the probability of getting the energy $\in_i$ using maximum entropy principle is

$$P_j = \frac{e^{-\beta \in_j}}{\sum_{j=1}^{N} e^{-\beta \in_j}}$$ 6

2. (a) Show that the variance of a Bionomial distribution is given by

$$\sigma^2 = \mathrm{N}\, pq$$

where N is the total size of the sample, $p$ is the probability of an event happening and $q = 1 - p$ defines the probability of not happening. 5

(b) 9 distinguishable particles are distributed over 3 non-degenerate energy levels 0, $\in$, $2\in$.

(i) What is the most probable microstate ?

(ii) Find the total energy of the distribution.

(iii) Find the entropy for the distribution. 5

3. What is Gibbs' Paradox ? Obtain the Sackur-Tetrode equation for a classical, ideal gas. How was the Gibbs' paradox resolved ?

2+6+2

4. (a) Obtain partition function for a classical ideal gas (non-interacting and non-relativistic gas) in canonical ensemble at fixed temperature T having fixed number of particles N in volume V. Also write this expression in terms of thermal wavelength ($\lambda$). 6

   (b) Obtain the equipartition theorems. 4

5. (a) The time evolution of the quantum (dynamical) state, $\psi(q, t)$, is described by the Schrödinger wave equation :

   $i\hbar \dfrac{\partial \psi}{\partial t} = \mathrm{H}\psi$ where H is the Hamiltonian operator. Using this equation, obtain the time evolution of the wave function, when the energy eigenvalues is E. 5

(b) Consider a free particle of mass $m$ in a cubical box of side L. The Hamiltonian of the particle is given by :

$$H = -\frac{\hbar^2}{2m}\nabla^2 = -\frac{\hbar^2}{2m}\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right]$$

while the eigenfunctions of the Hamiltonian satisfy the boundary conditions

$$\phi(x + L, y, z) = \phi(x, y + L, z) = \phi(x, y, z + L) = \phi(x, y, z)$$

Prove that $\phi_E(r) = \frac{1}{L^{3/2}} \exp(i\vec{k} \cdot \vec{r})$. 5

6. Write the basic postulates of BE statistics. Use the idea of most probable distribution to obtain an expression of the Bose-Einstein Distribution Function. 4+6

7. (a) Take one conduction electron per atom for silver at room temperature (30 °C) and $N/v = 5.86 \times 10^{28}\ m^{-3}$. Show that the electron gas is strongly degenerate.

   Given $h = 6.62 \times 10^{-34}$ Js,

   $k_B = 1.38 \times 10^{-23}\ JK^{-1}$

   and $m_e = 9.11 \times 10^{-31}$ kg. 5

   (b) Obtain Richardson-Dushmann equation using Fermi distribution. 5

8. (a) Make an assessment of the variation of the second viral coefficient of "Lennard-Jones" gas using the plot of $B_2(T)$ *vs*. T. 5

(b) What are cluster diagrams ? Explain with suitable examples the Topologically Equivalent diagrams. 5

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