MPH-011

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

STATISTICAL MECHANICS

Valid from 1st January, 2026 to 31st December, 2026

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2026)

Dear Student,

Please read the section on assignments in the Programme Guide for M.Sc. (Physics). A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet. The total marks for this assignment is 100, of which 40 marks are needed to pass it.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

ENROLMENT NO.: ………………………………………………

NAME: ……………………………………………………

ADDRESS: ………………………………………………

COURSE CODE:………………………….

COURSE TITLE: …………………………

ASSIGNMENT CODE: …………………..

STUDY CENTRE: ……………………….. **DATE:** ……………………………………………

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.
3) Leave 4 cm margin on the left, top and bottom of your answer sheet.
4) Your answers should be precise.
5) **Submit the assignment answer sheets within the due date.**
6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date shall not be accepted. We strongly suggest that you retain a copy of your answer sheets.**
7) This assignment is **valid from 1st January, 2026 to 31st December, 2026**. If you have failed in this assignment or fail to submit it by December 31, 2026, then you need to get the assignment for the year 2027, and submit it as per the instructions given in the Programme Guide.
8) **You cannot fill the examination form for this course** until you have submitted this assignment. For any queries, please contact: drsgupta@ignou.ac.in and mbnewmai@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
STATISTICAL MECHANICS

Course Code: MPH-011
Assignment Code: MPH-011/TMA/2026
Max. Marks: 100

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) Show under what condition Poisson distribution tends to Normal distribution. (10)

   b) A monthly demand for commodity is a continuous random distribution with probability distribution function given as:

$$p(x) = \begin{cases} 3N(x^2 - 1) & 1 < x < 2 \\ 0 & \text{elsewhere} \end{cases}$$

   where N is normalization constant. Obtain the value of N so that the function is normalized and hence, find the mean and the variance. (10)

   c) N particles obey Maxwell-Boltzmann distribution. They are distributed among three states with energies $E_1 = 0, E_2 = k_B T$, and $E_3 = 4k_B T$. If the equilibrium energy of the system is approximately $3000 k_B T$, calculate the total number of particles. (5)

2. a) Obtain the phase space area enclosed by a classical harmonic oscillator for energies ranging from 0 to E. (5)

   b) The Hamiltonian for the non-relativistic, non-interacting, monoatomic ideal gas is given by

$$H(q,p) = \sum_{i=1}^{3N} \frac{p_i^2}{2m} + U(q_i)$$

   where m is the mass of the particle and $U(q_i)$ is the potential energy. Obtain an expression of the phase space volume of the energy shell and hence obtain an expression of number of microstates. (10)

   c) Obtain expression for average energy $U(\equiv \langle E \rangle)$ for the canonical ensemble in terms of partition function Z. (5)

   d) For the grand canonical ensemble, obtain an expression for the ensemble average energy and ensemble average particle numbers. (5)

PART B

3. a) i) A proton $\left(\text{mass} = 1.67 \times 10^{-27}\text{kg}\right)$ inside a nucleus $\left(\text{radius} = 10^{-14}\text{m}\right)$ may have speed upto $2.0 \times 10^{8}\text{ms}^{-1}$. How many quantum states are available to it? (2)

ii) The time evolution of the quantum state, $\psi(q,t)$ is given by the Schrödinger wave equation:

$$i\hbar \frac{\partial \psi}{\partial t} = \hat{H}\psi$$

where *H* is the Hamiltonian operator. Using this equation, obtain time evolution of the wave function when the energy eigenvalue is *E*. (3)

b) State and prove quantum Liouville equation. (5)

c) Using the relation of thermodynamic probability

$$W = \prod_{i=1}^{N} \frac{g_i}{N_i!\left(g_i - N_i\right)!}$$

Obtain an expression of Fermi Dirac distribution function. Show a plot of $f(\in)$ (the occupation index of a state corresponding to energy $\in_i$) versus $\in$ for different temperatures and discuss it. What is the physical interpretation of Fermi energy? (5)

d) Show that the probability that a state with energy $\delta\in$ above the Fermi level $\in_F$ filled is equal to the probability of a state with energy $\delta\in$ below the Fermi level $\in_F$ is empty. (5)

e) What is the Bose-Einstein condensation? Write an expression of number of particles in the excited state $\left(N_{ex}\right)$ in terms of Bose-Einstein condensation temperature (T_c), total number of bosons (N) in an assembly and temperature *T*. Show a plot of distribution of bosons as a function of temperature below and above the T_c. (5)

4. a) State the Virial theorem and prove Boyle's law using it. (5)

b) What is meant by Cluster Integrals ? Express B_2 and B_3 in terms of Cluster Integrals. (5)

c) Using entropy as a function of temperature and pressure, obtain the first Ehrenfest's equation. (5)

d) Discuss the concept of thermodynamic fluctuations in the canonical ensemble. Define energy fluctuations and derive an expression for the mean square fluctuation of energy. Using a classical ideal gas, show that the relative fluctuation in energy varies as $f \approx 1/\sqrt{N}$ and hence, justify why thermodynamic calculations are valid for ordinary macroscopic systems. (10)

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