

M. SC. (PHYSICS)

(MSCPH)

Term-End Examination

December, 2025

MPH-011 : STATISTICAL MECHANICS

Time : 2 Hours

Maximum Marks : 50

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

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

(iii) *Symbols have their usual meanings.*

(iv) *You may use a calculator.*

1. (a) Calculate the number of ways of distributing three distinguishable particles in two distinct energy states according to the classical Maxwell-Boltzmann statistics. 4

(b) Using the relation :

$$p(V) = \sqrt{\frac{m}{2\pi k_B T}} e^{-\frac{mV^2}{2k_B T}}$$

calculate the mean velocity and variance of the velocity of the Maxwell-Boltzmann distribution for a 1-D system. 6

2. (a) Calculate the mean and variance of Poisson's distribution. 5

(b) What is meant by Ergodic hypothesis in statistical mechanics ? How does the time average of a physical quantity relates with the ensemble average ? 5

3. Consider a system of N impurity atoms trapped in a solid, occupying one of the two

non-degenerate single particle energy state corresponding to 0 or ϵ . Calculate the number of microstates for this two-level system where the total energy of the system is fixed. Also, obtain (i) an expression of entropy in the large N ($N \gg 1$) limits, and (ii) an expression of energy. Plot E vs. T curve for the two-level system when $T \rightarrow 0$.

2+3+3+2

4. (a) Explain with suitable examples the meanings of micro-canonical, canonical and grand canonical ensembles. 5
- (b) Calculate the relative fluctuations in the energy of a system about the mean value $\left(\frac{\sigma_E}{\langle E \rangle} \right)$ in a canonical ensemble. 5

5. Suppose that an ideal classical, non-interacting, non-relativistic gas consisting of N identical monoatomic free particles each of mass ' m ' is contained in a fixed volume ' V ' and has fixed energy :

$$E \left(\text{or } E - \frac{\Delta E}{2} \text{ and } E + \frac{\Delta E}{2}, \Delta E \ll E \right).$$

If the number of microstates is given by

$$\Omega = \frac{V^N (2\pi m E)^{3N/2}}{h^{3N} \left(\frac{3N}{2} \right)!} \left(\frac{\Delta E}{E} \right) \left(\frac{3N}{2} \right),$$

obtain expression for entropy. 10

6. (a) Write any *five* postulates of quantum statistical mechanics. 5

(b) A particle is confined in a two-dimensional (2-D) phase space with parameters $x = 0$ to $x = x_0$ and $p = 0$ to $p = p_0$. What is the total number of quantum states available ? Estimate the number of quantum states available to a proton inside a nucleus (radius = 10^{-14} m), whose momentum cannot exceed 10^{-19} kg ms⁻¹. 5

7. (a) Derive Quantum Liouville's equation for steady state. 5

(b) Use the idea of most probable distribution to obtain an expression of the Fermi-Dirac distribution function. 5

8. (a) Derive first latent heat equation (Clausius-Clapeyron equation). Prove that the boiling point of a liquid increases with increase of pressure. 4+1
- (b) Explain briefly with suitable examples the meaning of (i) Order Parameter and (ii) Critical Exponents. 5

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