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MPH–011

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 :

$$p(\mathrm{V}) = \sqrt{\frac{m}{2\pi k_{\mathrm{B}}\mathrm{T}}}\, e^{-\frac{m\mathrm{V}^2}{2k_{\mathrm{B}}\mathrm{T}}}$$

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 (> > 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 $\left(\frac{\sigma_E}{< E >}\right)$ 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 :

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

If the number of microstates is given by

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

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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