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M. SC. (PHYSICS) (MSCPH)

Term-End Examination

June, 2025

MPH-011 : STATISTICAL MECHANICS

Time : 2 Hours *Maximum Marks : 50*

Note : *Attempt any* ***five*** *questions. Marks are indicated against each question. Symbols have their usual meanings. You may use calculator.*

1. (a) (i) Suppose that N-diatomic molecules of hydrogen gas are free to move in 2D plane. These molecules have two rotational degrees of freedom also. What will be the dimension of free space ? 2

(ii) Consider a toss of 5 fair coins. Obtain the probability of getting : (1) 3 heads, (2) 5 heads. 3

(b) Show that for a Binomial distribution, the mean value of $x < x >$ is given by :

$$(x) = N_p$$

where N is the total size of the sample and p is the probability of an event happening. 5

2. Obtain an expression for probability of finding the system in microstate k corresponding to energy E_k in canonical ensemble. Hence, obtain the expression of canonical partition function. 10

3. (a) State and derive the classical Liouville's theorem. 5

(b) Obtain an expression of fluctuations in the number of particles of the system in grand canonical ensemble. 5

4. (a) Calculate the number of quantum states available to a particle confined to a length of 1·2 Å, and having its linear momentum lying between -10^{-20} kg ms^{-1} and $+10^{-20}$ kg ms^{-1}. 2

(b) Show that the density operator of a canonical ensemble in energy representation can be written as :

$$\rho = \frac{1}{Q_N(\beta)} e^{-\beta \hat{H}} \sum_n | \phi_n > < \phi_n |$$

and hence show that $\rho = \dfrac{e^{-\beta \hat{H}}}{\mathrm{Tr}(e^{-\beta \hat{H}})}$ 8

5. Derive Planck's radiation law starting from Bose-Einstein distribution function. 10

6. For an ideal classical, non-interacting, non-relativistic gas of N identical, monoatomic free particles contained in a fixed volume V having fixed energy E (or $E - \frac{\Delta E}{2}$ and $E + \frac{\Delta E}{2}$, $\Delta E << E$), obtain an expression for number of microstates. 10

7. (a) In the context of a particle moving in a straight line, explain the meaning of the following : 3+2

   (i) Phase point

   (ii) Phase path

   (iii) Phase space

   Also, determine the phase trajectory for a body falling freely from rest.

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

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

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

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