Roll No. .... Total Pages : 4

MD/M-20 **407**

STATISTICAL PHYSICS

Paper–EP 801

Time : Three Hours] [Maximum Marks : 40

Note : Attempt *five* questions in all. Question No. 1 is compulsory. Attempt the remaining *four* questions by taking *one* question from each unit.

Compulsory Question

1. (a) Define the terms 'ensemble' and 'phase space'. Represent micro-canonical ensemble in phase space. 2

(b) Explain in brief the microscopic origin of Gibbs paradox. 2

(c) Deduce a general expression for the quantum-mechanical ensemble average. 2

(d) Bring out essential difference between first-order and second-order phase transitions. Give at least *one* example for each type. 2

UNIT–I

2. (a) Establish the fundamental link between statistics and thermodynamics by considering the problem of energy exchange between two physical systems A_1 and A_2 in thermal contact. Show specifically that : $S = k_B \ln \Omega$. 5

(b) What do you understand by 'Quantization of phase space' ? Deduce the basic quantum of phase space. 3

3. (a) An ensemble can be characterized in terms of density function $\rho(q, p, t)$. Obtain equation governing the time evolution of ρ. 5

(b) State symmetry conditions on the *physically acceptable* wave function of a system of identical particles, and the link between symmetry and the law of distribution of particles among accessible single-particle states. 3

UNIT–II

4. (a) Derive an explicit expression for the canonical partition function for a classical monoatomic ideal gas and use it to obtain its entropy and equation of state. 5

(b) Gibbs removed the so-called 'Gibbs paradox' by dividing the classical result of the number of microstates by a number N!. Can we say Gibbs took proper care of quantum nature of particles? Elaborate your answer. 3

5. (a) Introduce grand canonical ensemble. How is this ensemble advantageous over other ensembles? Obtain the probability that a system in grand canonical ensemble at any time t is found to be in one of the states characterized by the energy E_s and number of particles N_r. 6

(b) What do you understand by entropy? Explain whether it is an intensive or extensive quantity. 2

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UNIT–III

6. (a) Consider an ideal quantum gas of N point-like particles and energy E in a container of volume V. Use the framework of grand-canonical ensemble to work out the law governing the equilibrium occupation of single-particle quantum states. Explain whether such a law depends on the spin of the constituent particles. 6

(b) Illustrate graphically the Fermi-Dirac distribution function at zero, room and extremely high temperatures. 2

7. (a) Determine the internal energy and equation of state for an ideal Fermi gas. Find the limit in which the equation reduces to the classical equation of state. 6

(b) Why can not a system of fermions exhibit the Bose-Einstein condensation? 2

UNIT–IV

8. (a) Find the first two virial coefficients (viz. a_1 and a_2) for a gas interacting by the Lennard-Jones potential :

$$u(r) = 4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right].$$

(b) Find out the exact solution of Ising model in one dimension. Show explicitly that the ground state of such a model cannot be ferromagnetic. 5

9. (a) Explain the term 'Brownian motion'. Discuss its origin and comment on the impact the discovery of this motion had on the atomic theory of matter. 2

(b) Describe in detail the cluster expansion method for a classical gas to obtain the virial equation of state. 6