RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. SIXTH SEMESTER EXAMINATION, MAY 2023

THIRD YEAR [BATCH 2020-23]

Date : 12/05/2023 **PHYSICS (HONOURS)**

Time : 11 am – 1 pm **Paper : CC13** Full Marks : 50

Answer **any five** questions: [5×10]

1. a) Define microstates and macrostates. For a one-dimensional harmonic oscillator with energy between E to $E + \delta E$ draw the phase space diagram. Indicate the difference between microstates and macrostates in the context of this diagram.

   b) For a microcanonical ensemble obtain the expressions of temperature (T), pressure (P) and chemical potential (μ) in terms of number of accessible states (Ω).

   c) A system of 4 particles has energy levels with energies 0, 1, 2, and 3 units. The total energy of the system is 3 units. List the accessible microstates if the particles are (i) distinguishable, (ii) indistinguishable. [(2+1+1)+3+3]

2. a) Derive the Sackur-Tetrode equation for the entropy of an ideal monatomic gas. How does it resolve the Gibbs paradox?

   b) Show that for an ideal gas the grand partition function, $\mathcal{Z}_G(\mu, V, T) = e^{\bar{N}}$, where $\bar{N}$ is the average number of particles. [7+3]

3. a) A system consisting of N one-dimensional classical harmonic oscillators is in thermal equilibrium with a bath at absolute temperature T. Calculate the partition function of the system. Hence, obtain the Helmholtz free energy and the entropy of the system.

   b) Energy of a particle in one dimension has the form $E = ap^2 + b|q|^5$, where p and q are the generalised momentum and coordinate, respectively, and a and b are constants. Calculate the specific heat. [(1+2+2)+5]

4. a) What are the characteristic feature of boson and fermion? Give a few examples of both type.

   b) In the domain of quantum statistics, derive the validity criterion of the classical approximation.

   c) Draw the Fermi – Dirac distribution function at T = 0K and at T>0 K. Prove that for a system at T > 0 K obeying F-D statistics, the probability that a level lying $\Delta\in$ below the Fermi level is unoccupied is the same as the probability of occupation of a level lying $\Delta\in$ above the Fermi level. [(2+1)+3+(2+2)]

5. a) Show that one dimensional random walk problem can be treated as a diffusion phenomena. Find its diffusion coefficient.

   b) Set up Langevin's equation for one dimensional Brownian motion. Solve the equation with the help of reasonable approximations. Find the mean square displacement of the Brownian particle. [4+6]

6. a) Consider a black body radiation contained in a volume V and maintained at temperature T. What is the chemical potential of photon? Justify your answer. Find the total number of photons per unit volume of the radiation field.

   b) Discuss the origin of the Cosmic Microwave Background Radiation [CMBR]. Estimate the average number of the photons per unit volume in the interstellar space, at the temperature of the CMBR. [$h = 6.626\times10^{-34}\,Js, k_B = 1.38\times10^{23}\,J.K$] [(2+4)+(2+2)]

7. a) What do you know about White dwarf star? Why is it a very faint star? What is the Chandrasekhar limit?

   b) Consider N extremly – relativistic electron gas in three dimension at 0 K. For the above system find (i) Fermi energy, (ii) average energy per electron and (iii) degeneracy pressure.[(2+1+1)+(2+2+2)]

8. a) Distinguish between ordinary vapour-liquid condensation and Bose- Einstein condensation.

   b) Find out an expression of B-E condensation temperature (Tc).

   c) Below 2.18 K, He^4 exhibits a remarkable phase termed as the superfluid phase. What are the important properties of the superfluid? [(2+2)+4+2]

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