LOYOLA COLLEGE (AUTONOMOUS), CHENNAI – 600 034

M.Sc. DEGREE EXAMINATION – **PHYSICS**

THIRD SEMESTER – **NOVEMBER 2022**

PPH 3501 – STATISTICAL MECHANICS

Date: 23-11-2022 Dept. No. Max. : 100 Marks

Time: 09:00 AM - 12:00 NOON

PART A

Q. No Answer ALL questions (10 x 2 = 20 Marks)

1 Point out the reason for the coarse-graining of the phase space. What does the volume occupied by a phase point in phase space depend upon?

2 State the equal –e-priori-probability theorem.

3 Write down the canonical partition function of a three level system with energies $-\frac{\varepsilon}{2}, 0, \frac{\varepsilon}{2}$.

4 State Nernst theorem.

5 Express the average number of particles $\bar{N}$ and energy $\bar{E}$ in terms of grand canonical partition function.

6 Show that parity operator $\hat{P}$ can have only two eigenvalues.

7 Calculate the number of microstates of a two level Bose system with 5 particles in a 3-fold level and 3 particles in a 4-fold level.

8 Explain why the chemical potential of a system of photons or phonons must be zero.

9 Why does a Fermi gas exert a pressure even at absolute zero?

10 Express the wave function of a 3-particle Fermi system as a Slater determinant.

PART – B

Answer any FOUR questions (4 x 7.5 = 30 Marks)

11 Show that the phase trajectory of a linear harmonic oscillator is an ellipse. Determine the phase space volume, entropy and pressure of a system of N non-interacting one dimensional classical harmonic oscillators using canonical ensemble formalism.

12 Consider a magnetic system of N non-interacting dipoles in an external magnetic field. Derive an expression for the scalar quantity $\frac{S}{Nk}$ where S is the entropy and k, Boltzmann constant.

13 Construct the density matrix of two systems: one represented by the wave function $|\Psi\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$ and the other a homogeneous mix of $|0\rangle$ and $|1\rangle$ where $|n\rangle, \{n = 0,1\}$ are the Fock states. Establish that the first one is made of pure states while the second one is mixed states.

14 What is meant by BE condensation? Why does a Bose gas condense while Fermi gas does not? Bring out how the population of the ground state changes when a Bose gas is cooled below its transition temperature.

15 Applying FD statistics to the free electron gas of a white dwarf in the non-relativistic limit, show that the larger the mass of the star, the smaller the radius of the white dwarf.

16 Apply Liouville's theorem to set up the equation of motion of the density function. Establish that the physical quantities of the system remain time invariant when the density function has no explicit time dependence.

PART – C

Answer any FOUR questions **(4 x 12.5 = 50 Marks)**

17 Derive the ideal gas law (EOS) for an isolated system using statistical principles.

18 Consider a system of N ideal gas molecules contained in a volume V. Obtain the Helmholtz free energy of the system and from that determine the thermodynamical variables of the system.

19 Derive the grand canonical partition function. Express the entropy of a system in the grand canonical ensemble in terms of the probabilities for the system to exist in the energy level E with N particles in the system.

20 Point out the failure of Einstein's theory of specific heat capacity. List out the modified assumptions of Debye's theory and derive the T^3 law for specific heat capacity of a monoatomic crystalline solid.

21 Obtain an expression for the variation of chemical potential of a degenerate Fermi gas and demonstrate the result using a graph.

22 Using FD statistics establish that the electron gas in a metal exhibits a temperature independent paramagnetic susceptibility.

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