लक्ष्यं विधमानम्

WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 6th Semester Examination, 2023

PHSACOR14T-PHYSICS (CC14)

STATISTICAL MECHANICS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: $2\times10=20$

(a) Define equilibrium state of a system.

(b) State the principle of equipartition of energy.

(c) Obtain the canonical partition function of a two level system having energies ε and 2ε. Also find the probability that the system is in the higher energy (2ε) state.

(d) Define microstates and macrostates with examples.

(e) Distinguish between canonical and grand canonical ensemble.

(f) What do you mean by stationary ensemble?

(g) Write down the expression for the thermal wavelength of a particle of mass m at temperature T and show that it has the dimension of length.

(h) Why the elementary volume of a cell in phase space for quantum particle cannot be zero?

(i) Show that the average energy of a system of particles $\langle E\rangle=\dfrac{k_B T^2}{Z}\left(\dfrac{\partial Z}{\partial T}\right)_V$.

(j) Determine the wavelength corresponding to the maximum emissivity of a blackbody at a temperature equal to 300 K. Take $b=2898\,\mu\text{m.K}$

(k) Prove that total pressure of diffused radiation is $P_{\text{rad}}=\frac{1}{3}u$, u being the energy density of radiation.

(l) Draw the Fermi-Dirac distribution function at $T=0\,\text{K}$ and $T>0\,\text{K}$. Locate the Fermi energy in the diagram.

(m) Find out the number of ways in which n identical bosons may be distributed among g energy levels.

(n) Helium has two isotopes, viz, He^3 and He^4. Classify these as fermions and bosons. Justify your conclusion.

(o) What do you mean by Bose-Einstein condensation?

2. (a) Consider a classical ideal gas consisting of N particles. The energy ε of a particle is given by $\varepsilon = cp$, where c is a constant and p is the magnitude of the momentum. Calculate (i) the partition function of the system, (ii) internal energy and (iii) specific heat C_V. 3+2+2

(b) What is Gibbs paradox? How this is solved? 3

3. (a) What do you mean by partition function? 2

(b) Consider a system consisting of two particles each of which can be in any one of three quantum states of energies 0, $\varepsilon, 3\varepsilon$ respectively. The system is in contact with a heat reservoir at temperature $T = (k_B\beta)^{-1}$. Calculate partition for particles obeying 2+2+2

(i) MB statistics

(ii) BE statistics

(iii) FD statistics

(c) State Wiedemann-Franz law. 2

4. (a) Derive the Saha ionization equation in stellar atmosphere. 3

(b) State and explain the law of chemical equilibrium. 2

(c) Derive Stefan Boltzmann law from Planck's law of blackbody radiation and find the value of Stefan constant. In this case, what will be the heat capacity C_V? 3+1+1

5. (a) State the symmetry requirement for a collection of identical particles under quantum regime. How does it lead to Pauli exclusion principle for fermions? 2+1

(b) Define Fermi energy and Fermi temperature. Explain the significance of Fermi energy at absolute zero and at any other temperature. 2+1

(c) Show that at $T = 0$, the average energy of an electron in a metal is $\frac{3}{5}E_F(0)$, where $E_F(0)$ denotes the Fermi energy at absolute zero temperature. 4

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