U.G. 6th Semester Examination - 2021

PHYSICS

[HONOURS]

Course Code : PHY-H-CC-T-14

(Statistical Mechanics)

Full Marks : 40 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

1. Answer any **five** questions: 2×5=10

   a) What do microstates and macrostates mean for a statistical system of N particles moving in three dimensions?

   b) Suppose 1,000 particles are distributed along a line of length 1m with a distribution function $f(x) = Bx(1-x)$. Calculate the number of particles that lie between $0.5m \le x \le 0.50lm$. (Particle number may be fractional)

   c) The description of the microcanonical ensemble is given in terms of *N, V* and the energy between E and $E+\Delta E, \Delta E << E$. Why do we need the spread ΔE in energy?

   d) Define entropy in the microcanonical ensemble.

   e) What is Bose – Einstein condensation?

   f) Show that for a photon gas, the density of states is proportional to $E^{\frac{1}{2}}$ where E corresponds to the energy.

   g) Find the number of ways in which three identical spin $\frac{1}{2}$ fermions can be distributed in two nondegenerate distinct energy levels.

   h) Distinguish between canonical and grand canonical ensembles.

2. Answer any **two** questions : 5×2=10

   a) What are the characteristic features of liquid Helium at low temperature? What is λ transition? Why is it named so? 2+2+1

   b) What is phase space? Draw the phase space for a linear harmonic oscillator of energy E and angular frequency ω. What is the area of the phase space? 1+2+2

   c) What does it mean by "Degeneracy"? Differentiate between Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics. 2+3

d) State the applicability of Saha's ionization formula. Write down its expression explaining each term. 2+3

3. Answer any **two** questions : 10×2=20

i) a) Write down the expressions for average number of particles in the i_{th} energy level, having energy ε_i and degeneracy g_i for Bose and Fermi distributions.

b) What is the value of the chemical potential for a photon gas in equilibrium and why?

c) Draw the temperature dependence of Fermi distribution function for T = 0 K and T > 0 K. Locate the Fermi energy in the diagram.

d) The density of free electrons in Na is $2.5\times10^{28}m^{-3}$. Calculate the Fermi energy of the free electron gas and compare it with k_BT for T 300 K. 3+2+2+3

ii) a) Give Planck's quantum postulates.

b) Derive Stefan's law and Wien's displacement law from Planck's law of black body radiation.

c) What is the wavelength of maximum intensity of radiation radiated from a source at temperature 3000°C? Wien's constant = 2.898×10^{-3} mK. 2+6+2

iii) If the partition function of a system of N indistinguishable particles is given by –

$$Z(\beta)=\frac{V^N}{N!}\left(\frac{2\pi mk_BT}{h^2}\right)^{3N/2}$$

Calculate the Helmholtz free energy (F) for the same. Hence calculate the average energy U for the system. Using the thermodynamic relation F = U – TS, derive the Sackur-Tedrode equation. How does this equation solve Gibbs paradox? 3+2½+2½+2

iv) a) Discuss experimental verification of Maxwell's velocity distribution law.

b) What do you understand by Brownian motion?

c) Derive Einstein's formula for the mean square displacement of a Brownian particle. 3+2+5

———————