This question paper contains 4+2 printed pages]

Roll No. | | | | | | | | | | | |

S. No. of Question Paper : 873

Unique Paper Code : 222602 G

Name of the Paper : Statistical Physics [PHHT-620]

Name of the Course : B.Sc. (Hons.) Physics

Semester : VI

Duration : 3 Hours Maximum Marks : 75

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt *five* questions in all.

Question No. 1 is compulsory.

All questions carry equal marks.

Symbols have their usual meanings.

1. Answer any *five* of the following : 5×3=15

(*a*) Explain the significance of partition function in statistical thermodynamics.

(*b*) Calculate the wavelength corresponding to maximum emission from the Sun's surface at a temperature of 6000 K. ($b = 2898\ \mu m\ K$)

(*c*) Discuss the limitations of law of equipartition of energy.

(*d*) Under what conditions do the Bose-Einstein and Fermi-Dirac distribution approach the Maxwell-Boltzmann distribution.

(*e*) Give the equilibrium temperatures of two systems at temperature +300 K and –300 K in thermal contact.

(*f*) Write *two* properties of photons which make them different from other bosons.

(*g*) The Fermi energy for metal A is 3.15 eV. Find its value for metal B given that the free electron density in metal B is nine times that in metal A.

(*h*) What are the basic assumptions of Planck's theory of Black body radiation ?

2. (*a*) Explain the meaning of thermodynamic probability. How does thermodynamic probability differ from conventional definition of probability ? 3

(*b*) Establish the relation between entropy and thermodynamic probability and show that the constant occurring in the relation is the Boltzmann's constant. 7.5

3. (*a*) Prove that the single particle partition function for an ideal monoatomic gas enclosed in a cube (volume V, maintained at temperature T) is given by :

$$Z_S = \left(\frac{2\pi m k_B T}{h^2}\right)^{3/2} V$$

where, m is the mass of each particle of gas and h is the Planck's constant. 4

(*b*) Assuming that this gas consists of N identical and indistinguishable particles, prove that the expression for the entropy (S) of this gas is given by :

$$S = N k_B \left(\frac{5}{2} + \ln\frac{Z_S}{N}\right)$$

and hence show that this expression resolves Gibbs' paradox. 7.4

4. (*a*) State and prove Kirchhoff's law for Black body radiation. Discuss one of its applications. 1,3,1

(*b*) Derive the expression for pressure exerted by diffuse radiation. 5

(*c*) Show thermodynamically that when the radiations enclosed in an enclosure are adiabatically expanded, $TV^{1/3}$ is a constant. 5

5. (*a*) Show that the number of modes of vibrations per unit volume of an enclosure in the frequency range ν and ν + *d*ν is given by :

$$N_\nu d\nu = \frac{8\pi\nu^2}{c^3} d\nu.$$

Using this expression, deduce the Rayleigh-Jean's law of energy distribution. 8,2

(*b*) Prove that the energy emitted per unit area per second from a black body is proportional to the fourth power of its absolute temperature. 5

6. (*a*) Show that number of microstates associated with a given macrostate for B-E statistics is given by :

$$W = \prod_i \frac{(n_i + g_i - 1)!}{n_i!(g_i - 1)!}$$

where, n_i represents the number of particles in the energy level ε_i having degeneracy g_i. 4

(*b*) Using Stirling's approximation and maximizing $S = k_B \ln(W)$, subject to the constraints that total energy E and total number of particles N are constant, show that B-E distribution function is given by :

$$n_i = \frac{g_i}{e^{\alpha + \beta\varepsilon_i} - 1}$$

where, α and β are Lagrange multipliers. 8

(*c*) Show that chemical potential of a boson gas is negative. 3

7. (*a*) Obtain the expressions for E_{F_0}, the Fermi energy at T = 0 K and P_0, the zero-point pressure of electron gas. 5,2

(*b*) Prove that the average kinetic energy per particle of Fermi gas at T = 0 K is given by :

$$\langle E \rangle = \frac{3}{5} E_{F_0}.$$ 6

(*c*) Why $\langle E \rangle$ in part (*b*) is not zero ? 2

8\. (*a*) Show that the matter in white dwarf stars behave like a strongly degenerate relativistic electron gas. 5

(*b*) What is Bose-Einstein condensation ? Derive an expression for the temperature at which this phenomenon occurs. 2,8

 2,000