2024
B.A./B.Sc.
Sixth Semester
CORE – 14
PHYSICS
Course Code: PHC 6.21
(Statistical Mechanics)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five questions, taking one from each unit.

UNIT–I

1. (a) State and prove Boltzmann's theorem connecting entropy and probability. 5
   (b) Fourteen particles are to be distributed in two boxes with weightages in the ratio 5:2. Determine the probabilities of distributions for (10,4), (8,6) and (7,7). 5
   (c) Prove that the internal energy U of a system is given by

$$U = NkT^2 \frac{\partial}{\partial T}(\log Z)$$ 4

2. (a) Show that if the partition function is given by Z, the mean energy is given by $\bar{\varepsilon} = -\frac{\partial(\log Z)}{\partial \beta}$, where $\beta = \frac{1}{KT}$. 4
   (b) A system can have three energy levels 0, ε, 2ε. The energy level ε and 2ε are doubly degenerate; while the energy level 0 is non-degenerate. Find the partition function and also find entropy and average energy of the system. 4
   (c) Write short notes on the following: 3×2=6
   (i) Postulates of equal a priori probability
   (ii) Law of equipartition of energy

UNIT–II

3. (a) What is thermal radiation? Explain why thermal radiation is also called as an infrared radiation. 5
   (b) State Stefan-Boltzmann law and prove it thermodynamically. 6
   (c) A black body is placed in an evacuated enclosure whose walls are blackened and kept at 300 K. Compare the net amount of heat gained or lost by the body
   (i) when its temperature is 600 K and
   (ii) when its temperature is 100 K. 3

4. (a) What is Wien's displacement law? Show how thermodynamics considerations alone lead to Wien's displacement law for the distribution of energy in the spectrum of a black body. 7
   (b) A black body at 500° C has a surface area of 0.5 m^2 and radiates heat at the rate of 1.02×10^4 J/s. Calculate Stefan's constant. 2
   (c) State and prove Saha's ionization formula. 5

UNIT–III

5. (a) Show that the Stefan's constant (σ) is related to Planck's constant (h) by the formula $\sigma = \frac{2}{15}\frac{\pi^5 K^4}{C^2 h^3}$. 4
   (b) What is quantum theory of radiation? Derive Planck's formula for the distribution of energy in the spectrum of a black body. Deduce Wien's distribution law and Rayleigh-Jeans law from it. 1+6+3=10

6. (a) Use Planck's formula to obtain expression for
   (i) Stefan's constant and
   (ii) Wien's constant 8
   (b) Discuss the ultraviolet catastrophe. 6

UNIT–IV

7. (a) Deduce Bose-Einstein distribution formula and discuss its application to liquid helium II. 8
   (b) Write a short note on radiation as a photon gas. Derive the expression for entropy and find the average number of a photon gas in a cavity. 6

8. (a) Distinguish between Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. 6

(b) Obtain the thermodynamics functions of a photon gas using Planck's formula. 8

UNIT–V

9. (a) Show that for strongly degenerate Fermi-Dirac gas, it possesses some energy $\frac{3}{5}nE_f$ and exerts pressure $\frac{1}{5}\frac{nh^2}{mV}\left(\frac{3n}{8\pi V}\right)^{2/3}$ at absolute zero temperature. 5

(b) State Dulong and Petit's law. Explain how this law fails to account for the experimental results. Show that for high temperatures, both Einstein and Debye's formula for specific heat of solid reduces to Dulong and Petit's law. 9

10. (a) What is Fermi level? Deduce an expression for Fermi energy ε_f. 6

(b) What are white dwarf stars? Obtain the Chandrasekhar mass limit for white dwarf stars. 8