2023

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 the fundamental assumption of statistical mechanics regarding an assembly of particles. 3

(b) What is Gibb's paradox? How has it been resolved? 5

(c) Consider N identical quantum oscillator which can occupy the energy levels with $E_n = \left(n + \frac{1}{2}\right)h\omega$, where $n = 0,1,2,\ldots$. Find the partition function and also find the average energy and entropy. 6

2. (a) Derive Maxwell's law of distribution of velocities of a gas molecule. 7

(b) Consider two cells (1 & 2) and four molecules a, b, c, d. Write down explicitly the different microstates which may be observed and macrostates into which the molecules may be distributed. Also, find the thermodynamic probability of the most probable and least probable macrostates. 4

(c) Explain the concept of negative temperature. 3

UNIT–II

3. (a) Write short explanatory notes on the following: 6

(i) Pressure of radiation

(ii) Wien's displacement law

(iii) Impact of Planck's law on the development of physics

(b) State and prove Kirchhoff's law of radiation and discuss its importance. 6

(c) Deduce the temperature at which a black body loses thermal energy at the rate of 1 watt/cm^2. Given $\sigma = 5.6\times10^{-8}$ watt/m^{2}K^4. 2

4. (a) Show that the radiation in an isothermal enclosure depends only on the temperature and not on the nature of the walls of the enclosure or on the bodies present inside it. 7

(b) Calculate the energy radiated per minute from the filament of an incandescent lamp at 3000 K, if the surface area is 1.0 cm^2 and its emissivity is 0.425. Given $\sigma = 5.6\times10^{-8}$ Joule/m^2-sec-K^4. 2

(c) State and prove Rayleigh-Jeans law. 5

UNIT–III

5. (a) State briefly the importance of theoretical and experimental investigation of black body radiation. How far did the efforts of Jeans and Wien succeed in explaining the experimental results? 6

(b) Show that Wien's law and Rayleigh-Jeans law are special cases of Planck's law. 8

6. (a) Show that the number of photons in black body radiation at a temperature T is equal to $N = \frac{V}{\pi^2}\left(\frac{KT}{\hbar C}\right)^3 \int_0^\infty \frac{x^2}{e^x - 1} dx$ 7

(b) Obtain the expression for the wavelength corresponding to maximum energy of emission using Planck's law. 7

UNIT–IV

7. (a) What is the difference between Bosons and Fermions? 2

(b) Apply Bose-Einstein statistics to photon gas and hence derive Planck's law for the spectral distribution of energy in black body radiation. 7

(c) Write short notes on Bose-Einstein statistics and Bose-Einstein condensation. 5

8. (a) Four identical particles can be in any six states. What are the number of possible ways of distributing them in various states according to MD, BE, and FD statistics? 3

(b) What is degenerate gas? How do the Bose and Fermi distributions tend to classical distribution? 4

(c) Derive the relation between total particles and energy for Bose-Einstein gas. 7

UNIT–V

9. (a) What is Fermi energy? Derive the Fermi-Dirac distribution formula. 8

(b) The density of zinc is 7.13 g/cm^3 and its atomic weight is 65.4. Calculate its Fermi energy. Given that the effective mass of a free electron in zinc crystal is 7.7×10^{-31} kg and N is 6.02×10^{23} atoms/gram-atom. 6

10. (a) What is the fundamental difference between the assumptions of Einstein and Debye's theory of specific heat of solids? Derive Debye T^3 law and interpret the result. 10

(b) Write a note on white dwarf stars. 4