বিদ্যাসাগর বিশ্ববিদ্যালয়

VIDYASAGAR UNIVERSITY

Question Paper

B.Sc. Honours Examinations 2022

(Under CBCS Pattern)

Semester - VI

Subject : PHYSICS

Paper : C 14 - T

Full Marks : 40

Time : 2 Hours

Candidates are required to give their answers in their own words as far as practicable.
The figures in the margin indicate full marks.

[STATISTICAL MECHANICS]

Group - A

Answer any ***four*** questions : 5×4=20

1. (a) Find the relationship between entropy and thermodynamic probability or accessible microstates. 3

   (b) Write statistical definition of temperature in terms of accessible microstates. Assuming the number of accessible microstates $\Omega(E,V)\alpha\left(V^N E^{\frac{3N}{2}}\right)$, find the molar specific heat at constant volume. 2

2. (a) Explain the concept of chemical potential in micro-canonical ensemble. Show that particle equilibrium is achieved when chemical potential of two systems are equal. 1+2

(b) Show that in canonical ensemble. the average energy in terms of partition function (z) is given by $\langle E\rangle = -\frac{\partial}{\partial\beta}(\ln Z)$ 2

3. (a) Applying proper Boltzmann factor, show that average energy of a classical simple harmonic oscillator is proportional to the absolute temperature. 3

(b) A system can take only three different states $\varepsilon_1 = 0, \varepsilon_2 = 1.38\times10^{21}$ Joule, $\varepsilon_3 = 2.76\times10^{21}$ Jule. These states occur in 2,5,4 different ways respectively. Deduce the probability that at temperature 100 K the system may be (i) in one of the microstates of energy ε_3 and (ii) in ground state ε_1. Given Boltzmann constant $k = 1.38\times10^{-23}\frac{Joule}{K}$. 2

4. (a) Show that the average internal energy of a Fermi gas of electron at absolute zero of temperature is 0.6 E_{F0}. Hence find the relation between pressure P and volume V of an ideal fermion gas at T=0 K. 3

(b) Three identical spin $\frac{1}{2}$ fermions are to be distributed in two non-degenerate distinct energy levels. Find the number of ways this can be done. 2

5. (a) What is Ultraviolet Catestrophe? Explain this in the light of Rayleigh-Jeans law of black body radiation. 2

(b) How many photons are there in 1 cc of radiation at 27ºC? Also find the average value of energy of photon. Given $\int_0^\infty \frac{x^2}{e^x-1}dx = 2.405$ and $\int_0^\infty \frac{x^3}{e^x-1}dx = \frac{\pi^4}{15}$. 3

6. (a) What are white Dwarfs? Why is electron inside the white Dwarf considered as highly degenerate FD gas? 2

(b) What do you mean by Chandrasekhar limit? Explain qualitatively. 2

(c) Show that the Fermi level corresponds to the energy level for which the probability of occupation is $\frac{1}{2}$. 1

Group - B

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

7. (a) Calculate deviation of an ideal Bose gas equation from the perfect gas equation. How is it related to gas degeneracy? 4+2

(b) What is λ-*transition*? Why is it so named? 2

(c) Write four significant extraordinary properties of the liquid helium at $T < T_\lambda$? 2

8. (a) Calculate energy of highly degenerate Fermi gas at $T > 0$ *K*. Using this result, calculate temperature dependent electronic specific heat. 5+2

(b) An atom has a non-degenerate ground state with energy $\varepsilon_0 = 0$ and a doubly degenerate excited state with energy $\varepsilon_1 = \varepsilon$. Calculate the specific heat at very low temperature $(\beta\varepsilon >> 1)$. 3

9. (a) What is Gibb's paradox? How can this paradox be removed through modification of corresponding partition function? 5

(b) Prove that at $T > 0$, the fraction of occupied states in an energy level higher than Fermi level by certain value, say *kT* is equal to fraction of unoccupied states in an energy level lower than Fermi level by *kT*. 3

(c) Consider three gases of same number of molecules separately. One obeying MB statistics, one obeying BE statistics and other obeying FD statistics. At same temperature, which will exert the greatest and least pressure? Justify your answer. 2

10. (a) In a system of *N* distinguishable particles, each particle be in one of two states with energies 0 and $(-\varepsilon)$ respectively. Show that the mean energy of the system at temperature *T* is $\frac{-N\varepsilon}{1+e^{-\varepsilon/kT}}$. 3

(b) A closed system having three non-degenerate energy level with energies $\varepsilon = 0, +\varepsilon, -\varepsilon$ is at temperature T. Find the partition function for $\varepsilon = 2kT$. 2

(c) Deduce Planck's law of blackbody radiation mentioning the applicability of the statistics used. 1+4
