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M.Sc. Physics 3rd Semester

1128

STATISTICAL MECHANICS

Paper–PHY-7002

Time Allowed : 3 Hours] **[Maximum Marks : 60**

Note :– Attempt **five** questions in all selecting **one** question from each of the Units I–IV and the compulsory question from Unit–V. All questions carry equal marks.

UNIT–I

1. (a) For an ideal gas canonical ensemble, show that

$$\frac{S}{Nk} = \ln\left(\frac{Q_1}{N}\right) + T\left(\frac{\partial \ln Q_1}{\partial T}\right)p$$ where the symbols have appropriate meaning.

(b) What is entropy of mixing ? Discuss how the entropy of mixing of samples of two dissimilar gases is different from zero and lead to Gibb's Paradox. 6,6

2. (a) Define the phase space of a classical system. Describe how microstate of a system is represented in phase space.

(b) For a canonical ensemble, the probability density around the value $E \approx U$ is given by

$$P(E) \propto e^{-\beta E} g(E) \approx e^{-\beta(U-TS)} \exp\left\{-\frac{(E-U)^2}{2kT^2C_v}\right\}$$

which represents a Gaussian distribution. If the same distribution is measured in the variable $\frac{E}{U}$ instead of E, what is the :

(i) Shape of the distribution

(ii) Mean value of the distribution

(iii) Dispersion of the distribution

(iv) How does the shape of the distribution change in the limit $N \to \infty$?

(c) Using the method of most probable values, derive an expression for energy density of a system in a canonical ensemble. 4,4,4

UNIT–II

3. (a) Discuss the energy fluctuations in a Grand Canonical ensemble and show that is is more than its corresponding value in a canonical ensemble.

(b) Write an expression for the mean occupation number of a single-particle state with energy ε for Fermi Dirac, Bose Einstein and Maxwell-Boltzman cases. Derive an expression for probability showing that bosons exhibit a special tendency of bunching together. 6,6

4. (a) A mole of argon and a mole of helium are contained in two separate vessels of equal volume. If argon is at 300K, what should the temperature of helium be so that the two have same entropy ?

(b) Discuss the problem of a solid-vapor equilibrium as a system of independent localized particles, set up the necessary condition for the formation of the solid phase. 6,6

UNIT–III

5. (a) An important application of Bose-Einstein statistics is to investigate the thermodynamic properties of a black body radiation. Write the Grand partition function for the photon gas coming out of a cavity in a black body and show that C_p/C_v of the photon gas is infinite.

(b) Derive an expression for the fugacity of an ideal Bose gas and show that it decreases asymptotically as a function of temperature. 6,6

6. (a) Set up the equation of state for an ideal Fermi gas. Hence determine its various properties in terms of particle density and the temperature. Establish the conditions leading to the complete degeneracy of the system.

(b) Define Fermi energy. Calculate zero point energy of Fermi gas and show that it is purely due to a quantum effect. 8,4

UNIT–IV

7. (a) Describe what are first order and second order phase transistions ? Compare by giving at least one example of each.

(b) Discuss the Einstein-Smoluchowski theory of the Brownian motion and show that the ensemble of Brownian particles, initially concentrated at the origin diffuses out as the time progresses. 6,6

8. (a) Describe the Heisenberg model of Ferromagnetism. What is its importance ?

(b) Write a note on non-equilibrium processes. 6,6

UNIT–V

9. (a) What is isothermal compressibility ? Under what conditions accompanying phase transistions, it becomes excessively large?

(b) Calculate the number of different arrangements of 4 indistinguishable particles among six cells of equal a priori probability, there being no restriction on the arangement of particles within the cells.

(c) Define degeneracy discriminant. Calculate its value for hydrogen gas.

(d) At the same temperature, will a gas of classical molecules, a gas of bosons or a gas of fermions exert the greatest pressure ? Explain by using appropriate formulae.

(e) A mole of hydrogen and a mole of helium are contained in two separate vessels of equal volume. If the hydrogen is at 300 K, what should the temperature of helium be so that the two have same entropy ? 2,2,3,2,3