2023/12

SET A

M.Sc. PHYSICS
FIRST SEMESTER
STATISTICAL PHYSICS
MSP – 102

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs. **Full Marks: 70**

(Objective)

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1×20=20***

1. In canonical ensemble, the r.m.s fluctuation in energy is
   a. $\frac{\sqrt{kT^2}}{U}$
   b. $\frac{\sqrt{kTC_v}}{U}$
   c. $\sqrt{\frac{kT^2C_v}{U}}$
   d. $\frac{\sqrt{kT^2C_v}}{U}$

2. Which of the following statement is false?
   a. In classical statistics, the particles have a certain degree of togetherness as well as separateness.
   b. Maxwell-Boltzmann statistics describes the distribution of gas molecules.
   c. Liouville's theorem gives the principle of conservation of energies of particles.
   d. In Grand canonical ensemble, the system is separated by rigid, permeable and conducting walls.

3. In case of Maxwell-Boltzmann velocity distribution curve, which one of the following is correct?
   a. As T increases, the distribution becomes narrow.
   b. As T increases, the distribution spreads out.
   c. As T increases, the distribution gets sharper.
   d. As T decreases, the distribution spreads out.

4. In case of Maxwell-Boltzmann statistics, the molecular size is
   a. Negligible
   b. Equal to the intermolecular distance
   c. Less than the intermolecular distance
   d. More than the intermolecular distance

5. The thermodynamic probability of Maxwell-Boltzmann distribution is
   a. $N!\frac{g_i}{ni!}$
   b. $N!\frac{g_i^{n_i}}{ni}$
   c. $N\frac{g_i^{n_i}}{ni!}$
   d. $N!\frac{g_i^{n_i}}{ni!}$

6. The partition function for a 3 dimensional monoatomic gas is given by?
   a. $\frac{1}{h^3}\iint e^{-E/kT}d^3q\,d^3p$
   b. $\frac{1}{h}\iint e^{-\beta E}d^3q\,d^3p$
   c. $\frac{1}{h^2}\iint e^{-\beta/kT}dq\,dp$
   d. $\frac{1}{h^2}\iint e^{-\beta/kT}d^3q\,d^3p$

7. In case of a classical ideal gas, which of the following option for N particle system is correct?

a. $Z_N = \left(\frac{V(\sqrt{2\pi mkT})^3}{h^3}\right)^N$

b. $Z_N = \left(\frac{V 2\pi mkT}{h^3}\right)^{3N}$

c. $Z_N = \left(\frac{V(2\pi mkT)^3}{h^3}\right)^N$

d. $Z_N = \left(\frac{V\sqrt{2\pi mkT}}{h^3}\right)^N$

8. Maxwell-Boltzmann distribution function is given by $n_i =$

a. $\frac{g_i}{e^{\alpha+\beta E_i}-1}$

b. $\frac{g_i}{e^{\alpha+\beta E_i}+1}$

c. $\frac{g_i}{e^{\alpha-\beta E_i}}$

d. $\frac{g_i}{e^{\alpha+\beta E_i}}$

9. In canonical ensemble, which of the following is true?

a. Energy can vary from 0 to infinity

b. Energy does not vary at all

c. Energy can vary from 0 to 1

d. Energy is restricted

10. Partition function of an equilibrium system is given by

a. $\sum_i g_i e^{\alpha-\beta E_i}$

b. $\sum_i g_i e^{-\beta E_i}$

c. $\sum_i e^{-\beta E_i}$

d. $\sum_i g_i e^{\alpha+\beta E_i}$

11. What is the partition function in quantum statistical mechanics?

a. It represents the total number of accessible microstates for a given macrostate

b. It represents the probability of a system being in a particular energy state

c. It represents the total energy of a system

d. It represents the average value of an observable in a given quantum state

12. Which of the following is a fundamental postulate of quantum statistical mechanics?

a. The wave function collapses to an eigenstate upon measurement

b. The total energy of a system is conserved

c. The probability of an event is given by the square of the absolute value of the wave function

d. The average value of an observable is given by the expected value of the corresponding operator

13. At what temperature does Bose-Einstein condensation occur?

a. Room temperature

b. Absolute zero

c. 1000 degrees Celsius

d. It can occur at any temperature

14. What are some real-world applications of Bose-Einstein statistics?

a. Superconductivity and superfluidity

b. Solar energy capture

c. Nuclear fission

d. Quantum computing

15. In quantum statistical mechanics, the average energy of a system is given by

a. The expectation value of the Hamiltonian operator.

b. The product of the partition function and the temperature

c. The sum of the energies of all possible states divided by the total number of states

d. The Gibbs free energy

16. The grand canonical density matrix can be written as (symbols have usual meaning)

a. $\rho_{nn} = e^{+\beta E_n}/z$
b. $\rho_{an} = e^{-\beta(E_i - \mu N_i)}/z$
c. $\rho_{nn} = e^{E_n}/z$
d. $\rho_{nn} = e^{\beta(E_n - n_i)}/z$

17. In Fermi-Dirac distribution function, the chemical potential represents

a. The rate of change of particle number with respect to energy.
b. The energy required to add one more particle to the system.
c. The temperature of the system.
d. The probability of finding a particle in a specific energy state.

18. In a quantum mechanical ensemble, which of the following best describes the behavior of individual particles?

a. The behavior of individual particles can be predicted with certainty.
b. The behavior of individual particles follows classical laws of physics.
c. The behavior of individual particles is probabilistic.
d. The behavior of individual particles is completely random.

19. What is the significance of Pauli exclusion principle in quantum statistical mechanics?

a. Determines the probability distribution of particles in different energy states
b. Ensures the stability of electrons in atoms and molecules
c. Describes the behavior of identical particles in quantum systems
d. Determines the average energy of a system

20. Number of microstates in a macrostate may be

a. Equal
b. $\geq$
c. $\leq$
d. greater

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Descriptive

Time : 2 hrs. 30 min. Marks : 50

[Answer question no.1 & any four (4) from the rest]

1. a. Discuss briefly the phase space of a classical system and derive the partition function of classical ideal gas for N particle system. 5+5=10

   b. Explain Bose-Einstein condensation and derive the criteria for Bose Einstein condensation to occur.

2. Find out the energy and density fluctuation in grand canonical ensemble. 4+6=10

3. Discuss the Simple Harmonic Oscillator in classical statistics along with three thermodynamic properties. 8+2=10

4. Derive Maxwell-Boltzmann velocity distribution function and draw the graph showing the dependence on temperature. 6+4=10

5. a. Explain the statistical weight of BE statistics. 2+8=10

   b. Derive the equation of state for ideal Bose gas and discuss classical limit for Bosons.

6. a. Find the expression for average occupancy of single particle energy state in the case of Bose-Einstein and Fermi-Dirac distribution assuming ideal gas conditions. 6+2+2 =10

   b. Derive Liouvilles' equation (time evolution of density matrix) in context of quantum statistical mechanic

   c. Write a brief note on quantum mechanical microcanonical ensemble.

7. a. What do you mean by ideal Fermi gas? Derive the expression for Fermi energy. 1+4=5

   b. Show graphically how the distribution functions (Maxwell-Boltzmann, Bose-Einstein and Fermi Dirac) varies with temperature($(\varepsilon - \mu)/KT$). 1

   c. What is Ising model? Provide a concise explanation of how the Ising model is used to simulate the physics of a ferromagnetic substance. 3

8. a. What is density matrix? What is the role of density matrices in quantum statistical mechanics? State the properties of density matrix. 1+1+2 =4

   b. What is phase transition? Draw the phase diagram 2+1=3

   c. State the properties of liquid Helium II. 3

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