REV-01
MSP/01/05

2023/06

SET A

M.Sc. PHYSICS
FOURTH SEMESTER
STATISTICAL PHYSICS
MSP – 401 [SPECIAL REPEAT]
[USE OMR FOR OBJECTIVE PART]

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

(Objective)

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

Choose the correct answer from the following: ***1X20=20***

1. Which among the following is not an expression for Chemical potential?

a. $\mu_i = \left\{\frac{\partial G}{\partial N_i}\right\}_{T,P,N_j}$

b. $\mu_i = \left\{\frac{\partial Z}{\partial N_i}\right\}_{S,V,N_j}$

c. $\mu_i = \left\{\frac{\partial F}{\partial N_i}\right\}_{T,V,N_j}$

d. $\mu_i = \left\{\frac{\partial U}{\partial N_i}\right\}_{S,V,N_j}$

2. The instantaneous position of a particle in the phase-space is represented by a point known as,
   a. phase point
   b. representative point
   c. both (i) & (ii)
   d. none of these

3. The instantaneous state of any system of n degrees of freedom can be completely specified by the position of a suitable point in the
   a. 6n- dimensional phase- space
   b. n- dimensional phase- space
   c. 2n- dimensional phase- space
   d. none of these

4. According to Gibb's, which of the following expression represents the principle of conservation of density in phase-space.

a. $\frac{\partial \rho}{\partial t} = 0$

b. $\partial\left(\frac{\partial \Gamma}{\partial t}\right) = 0$

c. $\partial\left(\frac{\delta N}{\partial t}\right) = 0$

d. $\rho \frac{d}{dt}(\delta \Gamma) = 0$

5. Many different microstates may correspond to ---------- .
   a. the same macrostate
   b. different macrostate
   c. indefinite macrostate
   d. no macrostate

6. Which among the following obey Maxwell-Boltzmann statistics?
   a. photon
   b. neutron
   c. oxygen molecule
   d. hydrogen-molecule

7. The particles obeying Maxwell-Boltzmann statistics are
   a. only identical
   b. identical and indistinguishable
   c. only distinguishable
   d. none of these

8. The Helmholtz free energy in terms of partition function can be expressed as

   a. $F = kTlogZ$
   b. $F = klogZ$
   c. $F = \sigma TlogZ$
   d. $F = \sigma logZ$

9. In a grand canonical ensemble, the grand potential can be expressed as ---------- .

   a. $\Omega = Ts - U - \mu N$
   b. $\Omega = U - TS - \mu N$
   c. $\Omega = U + TS - \mu N$
   d. $\Omega = U - TS + \mu N$

10. An ensemble of system where each sub-system can exchange energy but not particles is known as -------- ensemble.
   a. microcanonical
   b. canonical
   c. grand canonical
   d. Gibb's canonical

11. The density matrix is
   a. unitary
   b. Hermitian
   c. Non-Hermitian
   d. None of above

12. The spin of bosons is
   a. Full integral
   b. $\frac{3}{2}$
   c. Half integral
   d. None of the above

13. The chemical potential of photons is
   a. Finite but non zero
   b. zero
   c. infinity
   d. Not defined

14. Anti-Symmetric wave functions are shown by
    a. fermions
    b. Classical particles
    c. bosons
    d. electrons

15. Conditions under which quantum statistics can be applied are
    a. Low density and low temperature
    b. High density and low temperature
    c. Any density and any temperature
    d. Low density and high temperature

16. In thermal equilibrium, the probability distribution function is
    a. Dependent on time
    b. Independent of time
    c. Dependent on temperature
    d. None of the above

17. The critical exponent of volume is
    a. 3
    b. 1
    c. 2
    d. 1.5

18. If the 2nd derivative of free energy diverges then the transition is known as
    a. 2nd order transition
    b. 1st order transition
    c. 0th order transition
    d. None of the above

19. The chemical potential of fermions can be
    a. Only positive
    b. Only negative
    c. Both positive and negative
    d. Only zero

20. In thermal equilibrium, the probability density is a function of
    a. Hamiltonian
    b. momentum
    c. position
    d. time

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Descriptive

Time : 2 hrs. 30 mins. Marks : 50

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

1. a. What is Gibb's paradox? How can it be resolved? 5+5=10

   b. Calculate entropy at absolute zero and hence find the expression which represents the statistical mechanical formulation of *third law of Thermodynamics*.

2. Starting from grand canonical partition function, derive the occupation states for both Fermions and Bosons. 10

3. For a highly degenerate Fermi gas, find an expression for chemical potential up to 2nd order correction. 10

4. Show that for a Brownian motion, the velocities are exponentially correlated. 6+4 =10

5. Show that the magnetic transition is analogous to transition at critical point by comparing the critical exponents. 10

6. a. Define clearly the grand canonical ensemble. 2+3+5 =10

   b. Show that for a perfect gas represented by a grand canonical ensemble, the probability of finding the sub-system with n atoms is given by Poisson's distribution,

$$\omega(n) = \frac{1}{n!}(\bar{n})\exp(-\bar{n})$$

   c. Obtain the relations which can be used to evaluate thermodynamic quantities for grand canonical ensemble.

Or

Deduce the expressions for density fluctuations in agrand canonical ensemble.

7. a. What do you mean by partition function? **2+5+3 =10**

b. Express entropy in terms of partition function.

c. Show that the entropy in the canonical ensemble can be expressed as,

$$\sigma = -\sum \rho_r \log \rho_r$$

8. a. State and prove the second part of Liouville's theorem. **3+4+3 =10**

b. For a perfect gas in microcanonical ensemble, find the expression for volume in phase-space.

c. Show that the internal energy of harmonic oscillator of frequency

γ are

$$E = h\gamma\left(\frac{1}{2} + \frac{1}{e^{\theta} - 1}\right), where\ \theta = \frac{h\gamma}{kT}$$

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