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TM242813P

Reg. No :.....

Name :.....

MASTER'S DEGREE (C.S.S) EXAMINATION, MARCH 2024

2023 ADMISSIONS REGULAR

SEMESTER II - CORE COURSE PHYSICS

PH2C07TM20 - Thermodynamics and Statistical Mechanics

Time : 3 Hours **Maximum Weight : 30**

Part A

I. Answer any Eight questions. Each question carries 1 weight **(8x1=8)**

1. Define entropy and deduce the expression for entropy and heat capacities.
2. Examine the attributes for a function to be considered as a function of state.
3. Estimate the fluctuation in energy when two systems are brought in contact and kept in isolation from the rest of the universe.
4. Explain the term partition function and find the total partition function of a diatomic molecule.
5. Obtain the symmetrized wave functions for a two-particle system of (i) bosons (ii) fermions
6. State Wein's displacement law.
7. Calculate the root mean square speed of hydrogen molecules of mass 3.32×10^{-27} kg at 300 K.
8. Define chemical potential. Express it in terms of Gibbs free.
9. Express the entropy for a single particle state for fermions in terms of the distribution function.
10. Define symmetric breaking field and estimate the critical exponents γ and δ.

Part B

II. Answer any Six questions. Each question carries 2 weights **(6x2=12)**

11. Gasoline vapor is injected into the cylinder of an automobile engine when the piston is in its expanded position. The temperature, pressure and volume of the resulting gas-air mixture are 40^0C, 1105N/m^2 and 220cm^3 respectively. The mixture is then compressed adiabatically to a volume of 40cm^3. What are the pressure and temperature of the mixture after the compression? Given the ratio of C_p to C_v is 1.4
12. Consider that 10^{-6} J of heat is taken from a system at a temperature of 300K and is added to a system at 299K. Determine the change in entropy of the two systems and the factor by which the number of accessible states increases.
13. A system has four energy levels which are non-degenerate. The energy levels are $E_1 = 0$, $E_2 = 1.4 \times 10^{-23}$ J, $E_3 = 1.2 \times 10^{-23}$ J and $E_4 = 8.4 \times 10^{-23}$ J. Given that the system is at a temperature of 5K, find the probability that the system is in the $E_1 = 0$ level?
14. Suppose there are single-particle energy eigenvalues of 0, ε, 2ε and 3ε which are non-degenerate. A total of 6ε is to be shared between four particles. List the configuration of the particles and their degeneracies for: distinguishable particles, indistinguishable Bose particles, indistinguishable Fermi particles.
15. Calculate the partition function in three dimensions for a particle whose energy varies with wave vector $\varepsilon(k) = ak^3$.
16. Explain law of mass action with an example.
17. Deduce the expression for the Fermi vector and hence calculate the Fermi wave vector and Fermi Temperature of electrons in Magnesium with a number density of conduction electrons is 8.6 x 10^{28} m^{-3}.
18. Deduce the expression for Helmholtz free energy for phase separation in mixtures.

Part C

III. Answer any Two questions. Each question carries 5 weights **(2x5=10)**

19. Establish the second law of thermodynamics using statistical mechanics.
20. Obtain the expressions for thermodynamic quantities for a canonical system in terms of partition function. Apply these formulae for the simplest two level system with non-degenerate quantum states to obtain the expression for heat capacity at constant volume.
21. Explain the condition for chemical equilibrium in terms of chemical potential. Discuss any two methods for calculating chemical potential.
22. Discuss Ising model and hence deduce the expression for Free Energy for magnetization.