UNIVERSITY OF GUJRAT
A WORLD CLASS UNIVERSITY

(M.A/M.Sc Part-II) **Roll No:** ________

(Physics) Statistical Physics

Time Allowed : 3 hrs
Max. Marks : 50

Attempt **FOUR** Questions, selecting at least **ONE** from each section.

SECTION I

1- a) How many degrees of freedom are associated with a Diatomic Molecule? Write down the total classical heat capacity of a diatomic molecule. 3

b) The quantum energy levels of a rigid linear rotator is $E_j = \frac{h^2}{8\pi^2 I} j(j+1)$ where j = 0, 1, 2, …. And '*I*' is the moment of inertia about a line perpendicular to the axis and through the centre of mass. Consider only the rotational motion of a diatomic molecule:

i) Derive the general expression of the rotational partition function and find its values at high temperatures,

ii) Also evaluate the values of Free Energy F, energy *U* and specific heat. 6, 3.5

2- a) Distinguish between Canonical and Grand Canonical ensembles. 4

b) The classical partition function consisting of N independent identical spinless particles, is

$$Z = \frac{1}{N!h^{3N}} \int e^{-E/\tau}\, d\Gamma.$$

Using the above expression of partition function, derive the following expression of entropy called as Sackur-Tetrode equation.

$$\sigma = N \log\left(\frac{V e}{N \lambda^3}\right) + \frac{3}{2} N \qquad \text{where } \lambda = \frac{h}{(2\pi M\tau)^{1/2}}$$ is the thermal de Broglie wavelength. 8.5

3- a) Describe briefly what are (i) Systems, ii) Assemblies and iii) Phase Space 3.5

b) Derive the expression of the probability distribution $\omega(M)$ of a system of *N* independent particles having total magnetic moment *M* in the absence of magnetic field. 6

c) If the volume of a perfect gas of *N* atoms is doubled, the energy being the constant, what will be the change in entropy? 3

4- a) Derive the following Bose-Einstein distribution: 6, 2, 4.5

$$n(\epsilon) = \frac{1}{e^{-\mu/\tau}\, e^{\epsilon/\tau} - 1}$$

Show that at high temperatures ($e^{\mu/\tau} << 1$), the above expression

i) reduces to the classical Boltzmann distribution, and

ii) We obtain the classical results for energy as $U \cong \frac{3}{2} N\tau$.

SECTION II

5- a) Derive the following Fermi-Dirac distribution and state clearly the physical reasoning used:

$$f(\epsilon) = \frac{1}{e^{(\epsilon - \epsilon_F)/\tau} + 1}$$

Sketch the graphs for the Fermi-Dirac distribution when T = 0 and then T ≠ 0 and give an explanation how you obtain these sketches. 9, 3.5

6- a) Derive the following expression of Plank Radiation Law for the spectral distribution of radiation inside a constant temperature enclosure: $u(v, T)d\lambda = \frac{8\pi h}{c^3} \frac{v^3}{(e^{hv/kT} - 1)}$

Show that the above expression can be reduced to Stefan-Boltzmann law. 6, 3

b) What will be the Fermi temperature of an electron gas in potassium if its Fermi energy is 2.1 eV. (Boltzmann constant is $k = 1.3807 \times 10^{-23}$ JK^{-1}, 1 eV = 1.6022×10^{-19} J) 3.5

7- Write notes on the following: 6, 6.5

a) Bose-Einstein condensation

b) Gibb's Paradox