Bago University
Department of Physics
First Semester Examination, March 2019

Second Year (BSc)
(Physics Specialization)

Phys 2107
Statistical Mechanics
Time Allowed: (3) Hours

Answer any Six questions.

1 (a) Define macrostates and microstates of the assembly. What is thermodynamic probability? Write down the Maxwell-Boltzmann distribution function and explain the symbols used.

(b) If the most probable speed of a hydrogen gas molecule is 100 ms^{-1} at temperature T K. Find the most probable speed of an oxygen gas molecule at temperature 2T K.

2 (a) Explain the energy levels, energy states, degeneracy of a level and occupation number of a level by means of boxes and shelves. Draw a schematic representation of a set of energy levels, their degeneracies and their occupation numbers.

(b) At what temperature would one in a thousand of the atoms in a gas of atomic hydrogen be in the n = 2 energy level?

3 (a) Derive the kinetic energy of a free particle of the j^{th} level in a cubical box of side length L and volume V.

(b) A container at 0°C contains about 3 x 10^{25} hydrogen atoms. Find the number of these atoms in their first excited states at 10000°C.

4 (a) Compute on the basis of the Bose-Einstein statistics, for 5 particles and 2 levels with four energy states in each level, the thermodynamic probabilities of the six macrostates.

(b) Construct a diagram to show the possible macrostates of a system of six fermions with a total energy of $7\in$. The levels are equally spaced and have a degeneracy of 3 each. Calculate the thermodynamic probabilities of the first five macrostates.

5 (a) Write down the Bose-Einstein distribution function and Fermi-Dirac distribution function. Which particles are applied to describe Bose-Einstein statistics and Fermi-Dirac statistics?

(b) Five particles of total energy $12\in$ are distributed among the states of four energy levels. Level 1 has energy $\in$ and is nondegenerate; level 2 has energy $2\in$ and degeneracy 3; level 3 has energy $3\in$ and degeneracy 4; level 4 has energy $4\in$ and degeneracy 5. Calculate the thermodynamic probabilities of the first four macrostates if the particles obey Fermi-Dirac statistics.

6 (a) Define the Fermi energy. Write down the Fermi-Dirac distribution function in terms of Fermi energy and show that the probability of a fermion occupies a state of energy $\in_F$ is $\frac{1}{2}$.

(b) What is the probability that the quantum state whose energy is 0.10 eV above the Fermi energy will be occupied at 800 K?

7 (a) What are white dwarfs and neutron stars? What is the Schwarzschild radius?

(b) Assume that in Tungsten having atomic mass, 183.8u and density, 19.3 gcm^{-3} there are two free electrons per atom. Calculate the Fermi energy.

8 (a) By using Einstein postulates related to specific heat of solids, derive the Dulong-Petit law $c_V = 3R$.

(b) The density of zinc is 7.13 g cm^{-3} and its atomic mass is 65.4u. The effective mass of an electron is 0.85 m_e. Calculate the Fermi energy in zinc.

Use if necessary: $k_B = 1.38 \times 10^{-23}$ JK^{-1}, $N_A = 6.022 \times 10^{26}$ molecule/k-mole, k = 8.617 x 10^{-5} eVK^{-1}, h = 6.625 x 10^{-34} Js Mass of an electron = 9.1 x 10^{-31} kg, 1u = 1.66 $\times 10^{-27}$ kg

$$[\int_0^{\infty} \frac{x^2\,dx}{e^x - 1} = 2.404]$$