MASENO UNIVERSITY

UNIVERSITY EXAMINATIONS 2015/2016

FIRST YEAR FIRST SEMESTER EXAMINATIONS FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

MAIN CAMPUS

SPH 805: STATISTICAL MECHANICS

Date: 17th December, 2015 Time: 9.00 - 12.00pm

INSTRUCTIONS:

- Answer any THREE Questions.

Constants

Boltzmann constant $k = 1.38 \times 10^{-23}$; density of Sodium is $0.97\ gm^{-3}$;
Mass of Hydrogen atom is $1.66 \times 10^{-24}\ g$; Mass of the electron is $9.05 \times 10^{-28} g$;
Planck's constant is $6.62 \times 10^{-34} Jsec$, Avagadro's number is 6.025×10^{23} per gram molecule
Atomic weight of Sodium metal is 23.

Answer any **three** questions

Q1. Derive the number of states $W(E)$ for a given total energy from the partition function $Z_N(\beta)$ of a system of N oscillators having a characteristic angular frequency ω. Calculate the entropy $S(E)$ by asymptotic calculation for large N. **(10**

Q2. The average kinetic energy of the hydrogen atoms in a certain stellar atmosphere (assumed to be in thermal equilibrium) is 1.0 eV. **(20**

i) What is the temperature of the atmosphere in Kelvins?

ii) What is the ratio of the number of atoms in the second excited state (n=3) to the number in the ground state?

iii) Discuss qualitatively the number of ionized atoms. Is it likely to be much greater than or much less than the number in $n = 3$? why?

Q3. The energy level of an oscillator with frequency ν is given by

$$\varepsilon = \frac{1}{2}h\nu, \quad \frac{3}{2}h\nu, \quad . \quad . \quad . \quad . \quad . \quad . \left(n+\frac{1}{2}\right)h\nu, \quad . \quad .$$

When a system consisting of N almost independent oscillators has the total energy

$$E = \tfrac{1}{2}Nh\nu + Mh\nu \qquad (M \text{ is an integer})$$

i) find the thermodynamic weight W_M, and

ii) determine the relation between the temperature of this system and E.

Q4. Apply the canonical and $T-p$ distribution in classical statistical mechanics to an ideal gas consisting of N monatomic molecules and derive the respective thermodynamic function.

Q5. A cubically shaped vessel 20 cm on a side contains diatomic H_2 gas at a temperature of 300 K. Each H_2 molecule consists of two hydrogen atoms, separated by $\sim 10^{-8}\ cm$. Assume that the gas behaves like an ideal gas. Ignore the vibrational degree of freedom. (20Mk

i) What is the average velocity of the molecules?

ii) What is the average velocity of rotation of the molecules around an axis which is the perpendicular bisector of the line joining the two atoms (consider each atom as a point mass)?

iii) Derive the value expected for the molar heat capacities C_p and C_v for such a gas.

END