JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

4TH YEAR 2ND SEMESTER 2017/18

MAIN REGULAR

COURSE CODE: SCH 408

COURSE TITLE: Statistical Thermodynamics

EXAM VENUE: **STREAM: (BED SCI)**

DATE: **EXAM SESSION:**

TIME: 2:00 HRS

Instructions:

1. **Answer question 1 (Compulsory) in Section A and ANY other 2 questions in Section B.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room**

QUESTION ONE (30 MARKS) COMPULSORY

1. a) Define the following terms in relation to statistical thermodynamics [4 marks]
   - i) Energy level
   - i) Quantum states
   - ii) Microstates
   - iii) Degeneracy

b) Distinguish between statistical thermodynamics and classical thermodynamics [2marks]

c) Write a general expression for determining the number of microstates where there is degeneracy explaining the various quantities [5marks]

d) What determines the most probable distribution of particles? [1mark]

e) State the laws of phenomenology [4 marks]

f) In order to find and evaluate degeneracy, different models are used to represent the system of interest. Explain four such models [8marks]

g) i) By illustration determine the Stirling's approximation of N! where N is the number of particles [3marks]

ii) Explain the importance of Stirling's approximation [3marks]

QUESTION TWO (20 MARKS)

a) Consider a system of 4 coins and 2 states available for each (head and tail). The coins are identical but distinguishable.
   - i) Use an illustration to show the possible distributions [5marks]
   - ii) How many distinct outcomes are there? [1mark]
   - iii) How many distributions are? [1mark]
   - iv) What is the most probable distribution [2marks]

b) i) Use the Lagrange multiplier method to show that population of particles in an energy level can be given as: [10 marks]

$$n_i = g_i \, e^{-\alpha} \, e^{-\beta\varepsilon_i}$$

ii) State the importance of Lagrangian method of undetermined multiplier [1mark]

QUESTION THREE (20 MARKS)

a) i) State the assumptions of the Maxwell-Boltzmann statistics [5marks]

ii) Explain the significance of the Maxwell-Boltzmann distribution law [2marks]

b) Calculate the vibrational partition function for I_2 at 25 $^{\circ}$C [3 marks]

c) Evaluate the translational partition function for Ar confined to a volume of 1000 cm^3 at 298 K. Take mass of Ar = 6.64 x 10^{-26} kg; Planck's constant = 6.626 x 10^{-34} Js; Maxwel-Boltzmann constant = 1.38 x 10^{-23} J/K [4 marks]

d) Given that $\beta = \frac{1}{KT}$; $E = -N \left(\frac{\partial ln ʒ}{\partial \beta}\right)_V$ and $Nk = R$ show that [6 marks]

$$E = RT^2 \left(\frac{\partial ln ʒ}{\partial \beta}\right)_V$$

QUESTION FOUR (20 MARKS)

e) Show that Helmotz-free energy is given by the equation [4 marks]

A = - TNK ln ʒ

f) Consider three particles a,b,c to be distributed among 4 energy levels, with total energy E = 3 quanta.

i) Use an illustration to show how many ways the particles can be distributed [10 marks]

ii) Determine the total number of microstates in each distribution [3marks]

g) Write the general schrödinger wave equation explaining the various terms in the equation [3 marks]

QUESTION FIVE (20 MARKS)

h) Show that the translational partition function is given as [7marks]

$$ʒ_{trans} = \frac{(2\pi mkT)^{3/2} V}{h^3}$$

i) Determine the translational partition function for argon gas confined to a volume of 2.24 x 10^{-2} m^3 and at temperature of 273K. Take mass of Ar = 6.64 x 10^{-26} kg; Plank's constant = 6.626 x

10^{-34} Js; Maxwel-Boltzmann constant = 1.38 x 10 $^{-23}$ J/K [4 marks]

j) Calculate the vibrational partition function of iodine at 300K given that the vibrational frequency of iodine is 214.57 cm^{-1}. Take Plank's constant = 6.626 x 10^{-34} Js; Maxwel-Boltzmann constant = 1.38 x 10 $^{-23}$ J/K; speed of light = 3.0 x 10^{8} m/s [4 marks]

k) Show that the internal energy, E relates with partition function at constant volume as shown below [5 marks]

$$E = -N \left(\frac{\partial ln \mathfrak{z}}{\partial \beta} \right)_V$$