JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

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

4RD YEAR SECOND SEMESTER 2020/2021 ACADEMIC YEAR

RESIT

COURSE CODE: SCH 408

COURSE TITLE: STATISTICAL THERMODYNAMICS

EXAM VENUE: **DATE:**

TIME: **EXAM SESSION:**

STREAM:

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.**

SECTION A (30 MARKS)

Question 1.

a) Explain the difference between classical and statistical thermodynamics (4 marks)
b) Explain what is meant by;
   i) Population of a state (2 marks)
   ii) Thermodynamic system (2 marks)
   iii) Property of a system (2 marks)
   iv) Weight of a configuration (2 marks)
c) i) Write an expression for the weight of a configuration (2 marks)
   ii) Calculate the number of ways of distributing 20 identical objects with the arrangement 1, 0, 3, 5, 10, 1. (2 marks)
d) The Boltzmann distribution is given by the equation;

$$\frac{N_i}{N} = \frac{e^{-\beta\varepsilon_i}}{\sum_i e^{-\beta\varepsilon_i}}$$

Where

$$\beta = \frac{1}{kT}$$

   i) Explain the significance of T. (3 marks)
   ii) State the importance of the Boltzmann distribution (2 marks).
e) Define the term Internal Energy (2 marks)
f) How is the internal energy related to the derivative of the partition function (3 marks)
g) What is the significance of the molecular partition function (4 marks)

SECTION B

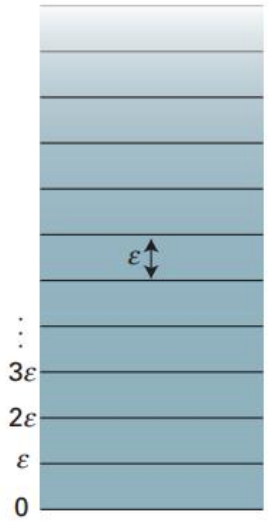
Question 2 (20 marks)

a) What is meant by, 'a canonical ensemble' (2 marks)
b) State the first and second laws of thermodynamics (2 marks)
c) Describe the usefulness of statistical thermodynamics (4 Marks)
d) what is a thermodynamic system (2 marks)
e) The molecular partition function is given by;

$$q = \sum_{\text{levels } i} g_i e^{-\beta\varepsilon_i}$$

Explain what happens to q at low and high temperatures (5 marks).

f) Evaluate the partition function for a molecule with an infinite number of equally spaced nondegenerate energy levels (figure below). These levels can be thought of as the vibrational energy levels of a diatomic molecule in the harmonic approximation (5 marks)



Question 3 (20 marks)

a) Write an expression for the partition function of a linear molecule (such as HCl) treated as a rigid rotor. (10 marks)
b) Derive an expression for the relation between internal energy (*U)* and the partition function (q). (10 marks)

Question 4 (20 marks).

a) Write the partition function for a particle in a one-dimensional box (10 marks)
b) Derive an expression for the pressure of a gas of independent particles (10 marks)

Question 5 (20 marks).

a) The Boltzmann formula for the entropy is given by the equation;

$$S = k \ln W$$

Explain what happens to W and hence S as the temperature is lowered. (5 marks)

b) The **Sackur–Tetrode equation** for the entropy of a monatomic gas is given by;

$$S(T) = nR \ln\left(\frac{e^{5/2}V}{nN_A\Lambda^3}\right) \qquad \Lambda = \frac{h}{(2\pi mkT)^{1/2}}$$

i) What does it imply (5 marks)

ii) Because the gas is perfect, use the relation $V = nRT/p$ to express the entropy in terms of the pressure (5 marks)

c) The energy of a molecule is the sum of contributions from its different modes of motion. Explain (5 marks)