KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF BSC (PHYSICS)

COURSE CODE: SPC 422

COURSE TITLE: STATISTICAL MECHANICS

DURATION: 2 HOURS

DATE: 30/08/2022 **TIME:** 2:00PM-4:00PM

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- Indicate **answered questions** on the front cover.

Start every question on a new page and make sure question's number is written on each page
This paper consists of **4** printed pages. Please Turn Over

QUESTION ONE [30 Marks]

a) Differentiate between statistical mechanics and quantum mechanics. [2 Marks]

b) What do you understand by the term statistical ensemble? [3 Marks]

c) State the three laws of thermodynamics [3 Marks]

d) Define the following terms: (i) phase path (ii) phase-space (iii) phase point as used in statistical mechanics. [3 Marks]

e) Differentiate between macroscopic and microscopic systems. Give examples [3 Marks]

f) Define the term density matrix [2 Marks]

g) Define entropy as used in classical micro-canonical ensemble and demonstrate that it is an extensive property. [4 Marks]

h) A substance weighing 10 kg at temperature -50° C melts at 0°. Compute its change in entropy. Comment with reasons weather there is an increase in entropy or not. [4 Marks]

i) Explain why no phase path representing a dynamical state can never cross itself. [3 Marks]

j) Discuss Heisenberg's uncertainty principle and show that it is impossible to have sharp phase paths in quantum theory. [3 Marks]

QUESTION TWO [20 Marks]

a) Write brief notes on the following based on classical statistical mechanics stating the equation of density matrix or partition function in each case:

i) Uniform ensemble [4 Marks]

ii) Isobaric ensemble [4 Marks]

iii) Micro-canonical ensemble [4 Marks]

iv) Canonical ensemble [4 Marks]

v) Grand Canonical ensemble [4 Marks]

QUESTION THREE [20 Marks]

a) If entropy, S is defined as $S = KlogC_{Class}$ where C_{Class} stands for classical count; the most probable distribution is given by $n_i = \omega_i e^{-(\alpha+\beta\epsilon_i)}$, where $\beta = \frac{1}{KT}$ and $e^{\alpha} = \frac{V}{Nh^3}(2m\pi KT)^{\frac{3}{2}}$, derive an expression for the ideal gas equation, i.e show that $PV = NKT$ [12 Marks]

b) Derive expressions for the internal energy, E and enthalpy, H in terms of the partition function, Q [8 Marks]

QUESTION FOUR [20 Marks]

a) Write down the equations of motion of a phase point considering the motion of an oscillator in phase space. [3 Marks]

b) Show that the orbit in phase space of a simple linear harmonic oscillator is an ellipse and that its period, T in phase space is equal to the area of the phase ellipse divided by the energy, E of the oscillator. [10 Marks]

c) Using Hamilton's equations show that the path of the body falling under gravity is a parabola. [7 Marks]

QUESTION FIVE [20 Marks]

a) Derive the expression for $C_{B\text{-}E}$. [8 Marks]

b) Show that if the basic vectors are a set of energy eigen functions, then the probability that a system chosen at random from the canonical ensemble will be found in the energy state E_n is:

$$\rho_n = \frac{1}{Q} e^{-\beta E_n}$$ [8 Marks]

c) Show that Q is invariant under a change of basic vectors. [4 Marks]

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