UNIVERSITY OF EMBU

2017/2018 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

FOURTH YEAR MAIN EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION SCIENCE.

SPH 404: STATISTICAL PHYSICS

DATE: APRIL 4, 2018 **TIME: 8:30-10:30AM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

QUESTION ONE (30 MARKS)

a) Differentiate between micro and macro states (2 marks)

b) Distinguish between Fermi-Dirac and Bose-Einstein statistics (4 marks)

c) An ideal gas that obeys Maxwell Boltzman statistics has N particles at a temperature T. find the internal energy (2 marks)

d) Explain the principle of a priori assumption (2 marks)

e) Demonstrate that entropy as given by the Boltzmann expression, S=klnΩ, is an extensive quantity (3 marks)

f) Briefly explain the partion function (2 marks)

g) The partion function of a system is given by Ln Z= aT^4V, where a is a constant, T is absolute temperature and V is the volume. Calculate the internal energy of the system (3 marks)

i) Distinguish between fermions and bosons (2 marks)

j) Explain briefly Pauli's exclusion principle (2 marks)

k) A system consists of three independent particles localized in space. Each particle has states of energy 0 and ε. When this system is in thermal equilibrium with a heat bath at temperature, T, calculate its partition function. (the respective degeneracies are 1,3,3,1) (3 marks)

l) Explain the features of a system of a small black body placed inside a chamber with perfect insulating walls (3 marks)

m) Bosons are quantum particles with symmetric wavefunctions. Explain. (2 marks)

QUESTION TWO (20MARKS)

a) For a simple one dimensional harmonic oscillator in equilibrium at a temperature T, with H $= \frac{p^2}{2m} + \frac{1}{2}k_0 x^2$,

$$\epsilon_j = (j + \tfrac{1}{2})\hbar\omega.\ j = 0,\ 1,\ 2\ldots.$$

i) Show that the partion function $Z = \frac{e^{\frac{-\beta\hbar}{2\omega}}}{1 - e^{\frac{-\beta\hbar\omega}{}}}$ (5 marks)

ii) Obtain an expression for the average energy of the oscillator. (5 marks)

b) For a system in thermal equilibrium with a larger system(canonical ensemble), the fundamental relation for the Helmholts free energy, is given by

$$A(V, T) = -KTLn\ Q_N$$

where $Q_N = \frac{1}{N!}\left(\frac{N}{V}(2\pi mkT)^{\frac{3}{2}}\right)^N$

i) Show that $A = \left[NKT[Ln \frac{N}{V}\left(\frac{h^2}{2\pi mkT}\right)^{\frac{3}{2}} - 1\right]$ (3 marks)

ii) Obtain expressions for the pressure, entropy and internal energy of the system. (7 marks)

QUESTION THREE (20MARKS)

a) Consider a one level system having energy $E = -NKT\ \ln\left(\frac{v}{v_0}\right)$. v_0 is a constant.

i) Write down Z (the partion function) (5 marks)

ii) Find the average pressure of the system (5 marks)

b) In a sample of hydrogen gas at 25 ^0c ,

i) what proportion of the atoms are in the first exited electronic state if it lies 1000Kj/mole above the ground state (5 marks)

ii) The proportion of the atoms in the excited state if T= 10^7K. (5 marks)

QUESTION FOUR (20MARKS)

a) For a non-interructing system of gas molecules, the measure of disorder can be expressed as,

$$S(E,v) = NK \ln[V(\frac{4\pi mE}{3Nh^2})]^{\frac{3}{2}} + \frac{3}{2}NK.$$ *[the symbols have the usual meanings]*

i) Show that the internal energy U(S,V) can be written as

$$U(s,v)=\left(\frac{3h^2}{4\pi m}\right)\frac{N}{V}\mathrm{Exp}\left(\frac{2S}{3NK} - 1\right)$$ (7 marks)

b) Obtain expressions for

i) The absolute temperature (5 marks)

ii) Heat capacity at constant volume (5 marks)

iii) The equation of state (3 marks)

QUESTION FIVE (20 MARKS)

A system of four particles each of which can exist among the four energy levels $\varepsilon, 2\varepsilon, 3\varepsilon$ and 4ε . The respective degeneracies are 1, 1, 2, 2. The total energy for the system is 10ε.

i) List the number of macro states for Bose- Einstein statistics (5 marks)

ii) List the number of microstates associated with the macro states above (15 marks)

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