UNIVERSITY OF EMBU

2018/2019 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

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

SPH 404: STATISTICAL PHYSICS

DATE: APRIL 8, 2019 **TIME: 8:30 AM – 10:30 AM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

QUESTION ONE (30 MARKS)

a) Bosons are quantum particles with symmetric wave functions. Explain. (1 mark)

b) In a black body the number of photons is not conserved. Explain (2 marks)

c) A system consists of two particles of which can be in any one of the three quantum states of respective energies 0, ϵ, and 3ϵ in thermal equillibrium at a temperature T. write an expression for its partition function of the system if the particles obey Bose Einstein statistics

(3 marks)

d) Briefly describe the partition function (1 marks)

i) Distinguish between fermions and bosons (2 marks)

j) Consider a one level system having energy E = -NKT $\ln\left(\frac{v}{v_0}\right)$. v_0 is a constant. Write down Z (the partion function) (3 marks)

k) 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)

l) Distinguish between Fermi-Dirac and Maxwel-Boltzman statistics (3 marks)

m) Demonstrate that entropy as given by the Boltzman expression $S=k\ln\Omega$ is an extensive quantity (3 marks)

n) Briefly describe a black body (3 marks)

o) Explain the principle of 'a priori assumption' (2 marks)

p) For a simple one dimensional harmonic oscillator in equilibrium at a temperature T, with $H = \frac{p^2}{2m} + \frac{1}{2}k_0x^2$,

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

Show that the partition function $Z = \frac{e^{\frac{-\beta\hbar}{2\omega}}}{1-e^{\frac{-\beta\hbar\omega}{}}}$ (3 marks)

QUESTION TWO (20 MARKS)

a) In Bose – Einstein statistics the total number of ways of distributing N particles is given by $\omega = \left(\frac{(n_i+g_i-1)!}{n_i!(g_i-1)!}\right)$. Obtain an expression for the set of occupation numbers $\{n_i\}$ that maximizes $\omega(n_i)$ subject to the conditions $E = \sum_i \epsilon_i n_i$ and $N = \sum_i n_i$ (10 marks)

b) In CO, spacing between excited rotational states is 0.0025KJ/Mol. If the degeneracy of the first excited state is 3, calculate the fraction of molecules in the first excited state at room temperature. (5 marks)

c) Consider a one level system having energy E = -NKT ln $\left(\frac{v}{v_0}\right)$. v_0 is a constant. Write down Z (the partition function) and hence find the average pressure of the system (5 marks)

QUESTION THREE (20 MARKS)

a) Consider a system with 6 distinguishable particles, 2 energy levels (one with degeneracy of 2 and the other degeneracy of 5).

i) For such a system there is no equilibrium macro state. Explain. (5 marks)

ii) Obtain all the macro states for the system (5 marks)

iii) Calculate the microstates associated with all the macro states in (b ii) above. (10 marks)

QUESTION FOUR (20 MARKS)

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

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

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

$$U(S,V)=\left(\frac{3h^2}{4\pi m}\right)\frac{N}{V}\text{Exp}\left(\frac{2S}{3NK} - 1\right)$$ (5 marks)

b) Obtain expressions for

i) The absolute temperature (5 marks)

ii) Heat capacity at constant volume (5 marks)

iii) The equation of state (5 marks)

QUESTION FIVE (20 MARKS)

a) In CO, spacing between excited rotational states is 0.025Kj/mol. If the degeneracy of the first excited state is 3, calculate the fraction of the molecules in the 1st excited state at room temperature (5 marks)

b) Find the number of molecules of oxygen molecules in 0.1 kg whose speed lie between 195 and 205m/s at o ^0c (5 marks)

c) Calculate the mean speed, mean square speed and mean kinetic energy for helium at 100 ^0c

(10 marks)

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