LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	F7035T
Examination date	2012-09-01
Time	09.00 - 14.00

Examination in: STATISTICAL PHYSICS AND THERMODYNAMICS
Total number of problems: 5
Teacher on duty: Hans Weber Tel: (49)2088, Room E304
Examiner: Hans Weber Tel: (49)2088, Room E304

Allowed aids: Fysikalia, Physics Handbook, Beta, calculator, COLLECTION OF FORMULAE

Define notations and motivate assumptions and approximations. Present the solutions so that they are easy to follow. Maximum number of point is 15 p. 7.0 points is required to pass the examination. Grades 3: 7.0, 4: 9.5, 5: 12.0

1. **Harmonic oscillator**

   A two dimensional harmonic oscillator has energy levels according to

   $$\epsilon_{n_1,n_2} = (n_1 + n_2 + 1)\, \hbar\omega$$

   where n_1, n_2 are integers $n_i = 0, 1, 2, 3, ...\infty$. The oscillator is coupled to a heatbath of temperature τ with which the oscillator can exchange energy.

   (a) Calculate the partition function of the oscillator for any temperature.

   (b) At what temperature equals the probability to find the oscillator in a state of energy $\hbar\omega$ to find it in a state of energy $2\hbar\omega$?

   (c) How large is this probability ?

   (3p)

2. **Helium ^3He**

   Helium ^3He has spin $= \frac{1}{2}$ and may at low temperatures to a good approximation be described as an ideal Fermi gas. At these low temperatures ^3He is in the liquid phase with a density of $\rho = 83$ kg m^{-3}.

   a) Determine the Fermi temperature T_F and also the specific heat C_v of ^3He at T=0.2 K.

   b) Can you still use the approximations you did in a) if the temperature where say 2-3 K? If not why? If yes why?

   (3p)

TURN PAGE!

3. **Binding of O_2 to hemoglobin**

   A hemoglobin molecule can bind four O_2 molecules. Assume ϵ is the energy of each bound O_2, relative to O_2 at rest at infinite distance. Let λ denote the absolute activity $e^{\mu/\tau}$ of free O_2 (in solution).

   (a) What is the probability that one and only one O_2 is adsorbed on a hemoglobin molecule?

   (b) What is the probability that four O_2 are adsorbed on a hemoglobin molecule?

   (c) Make a sketch of these probabilities as a function of λ.

   (3p)

4. **Quantum mechanical rotor**

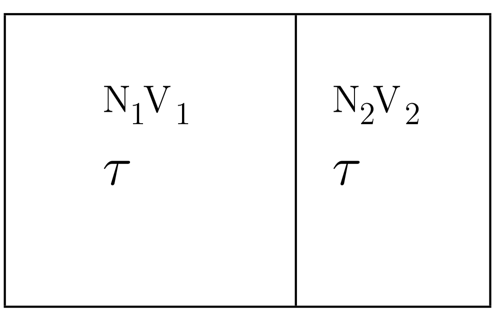
   A quantum mechanical rotor (molecule) has energy levels $\epsilon_j = j(j+1)\hbar^2/2I$ where I is the moment of inertia, each level has degeneration $g(j) = 2j+1$ where $j = 0, 1, 2, \ldots$. Calculate the for the rotational degrees of freedom the contribution to the heat capacity for low temperatures ($\tau << \hbar^2/I$). Is the behaviour of exponential or algebraic character at low temperatures? (3p)

5. **Ideal mono atomic gas**

   An ideal mon atomic gas confined in a box. The box is devided into two sub parts (compartment 1 and 2) according to the figure below. For compartment one 1 we have volume $V_1 = 2V$, number of particles $N_1 = N$ and temperature τ. For compartment two 2 we have volume $V_2 = V$, number of particles $N_2 = N$ and temperature τ.

   Calculate the change of entropy as the wall between compartment 1 and 2 is removed.

   The temperature τ is kept constant.



(3p)

GOOD LUCK !