LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	F7035T
Examination date	2019-03-30
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 E163
Examiner: Hans Weber Tel: (49)2088, Room E163

Allowed aids: Fysikalia/Fysika, 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. 7.5 points is required to pass the examination. Grades 3: 7.5, 4: 10.0, 5: 12.0

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1. **Entropy**

   Use simple arguments concerning the specific heat C_v to answer the following questions.

   a) For a metal the temperature is changed from $200K$ to $800K$. By how large a factor will the entropy change for the conduction electrons?

   b) For the electromagnetic radiation inside a cavity the temperature is changed from $500K$ to $2000K$. By how large a factor will the entropy change for the radiation field inside the cavity?

   (3p)

2. **Astrophysics Black holes and star atmospheres**

   a) The entropy of a non–rotating non–charged black hole is given by $\sigma = \frac{c^3 A}{4G\hbar}$ where $A = 4\pi R_s^2$ is the area of the black hole, $R_s = \frac{2GM}{c^2}$ is the Schwarzschild radius, M is the mass and G is Newton's constant of gravitation. The energy is given by $E = mc^2$. Evaluate the temperature of the black hole.

   b) The energy levels of atomic hydrogen are given by: $E_n = -\frac{13.6}{n^2}$ eV, where $n = 1, 2, 3, 4, ...$ is the principal quantum number and each energy level has degeneracy $2n^2$. In the atmosphere of a star containing atomic hydrogen the average kinetic energy is 1.0 eV. Evaluate the ratio between the number of atoms in the excited levels with $n = 2$ and $n = 3$.

   (3p)

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3. **The specific heat C_v of a molecule**

At low temperatures the specific heat C_v of a certain molecule is dominated by two energy levels that are close to each other in energy. The ground state has degeneracy 1 and the excited level has degeneracy 3. The energy of the excited level may be choosen to be ϵ and the ground state as zero.

Calculate C_v for a molecule and calculate its maximum value and show that this does not depend on ϵ

(Hint you may use graphical methods to solve an equation)

(3p)

4. **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)

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5. **Gas-solid equilibrium**

In a container of volume V a substance solid phase is in equilibrium with its gas phase. The atoms have a binding energy $-\epsilon_0$ to the solid phase.

Use the following approximations. The substance is mono atomic and for the gas phase the ideal gas applies. Further the gas phase has volume V independent of the amount in the solid phase. Also the entropy of the solid phase is negligible.

Let the total number of atoms be $N = N_s + N_g$ where N_s and N_g are the number of atoms in the solid phase and gas phase.

a) Express the free energy of the system F. (Hint $F = F_s + F_g$.)

b) Minimize F with respect to N_g and derive an expression for N_g.

c) Estimate ϵ_0 for H_2O using the data in the table. Answer in electron volts ! (Assume the ideal gas applies to the gas phase of H_2O. Hint: Note that the range of temperatures is small if you need to make approximations for to the expression of p_g.)

T (^oC)	saturation pressure (kPa)
-2	0.5176
-6	0.3689
-10	0.2602
-14	0.1815
-20	0.1035
-30	0.0381
-40	0.0129

(3p)

GOOD LUCK !