LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

| Course code | F7035T |
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| Examination date | 2017-05-13 |
| 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

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

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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

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1. **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 $\epsilon$ 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 $\epsilon$

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

   (3p)

2. **Atomic nuclei at low temperatures**

   A crystal consists of $N$ atoms consisting of nuclei with integer spin $S$. The energy of the nuclei depends on their spin state with respect to an applied field. The possible energy states are given by $0, \epsilon, 2\epsilon, ..., S\epsilon$, where the ground state is not degenerated and the other states all have degeneracy 2.

   The crystal is held at a low temperature. Calculate the contribution to the heat capacity from the spin degrees of freedom of the nucleus in the limit $S\epsilon/\tau >> 1$, ($\tau = k_B T$).

   (3p)

3. **Freezing of water**

   The latent heat of melting of water is 334 J/g. The density of ice at zero degrees centigrade is 0,9168 g/cm$^3$. The density of water at zero degrees centigrade is 0,9998 g/cm$^3$.

   How will the freezing point of water change if the pressure rises from 1,00 to 20,0 atmospheres?

   (3p)

TURN PAGE!

4. **Maxwell velocity distribution**

An experiment is designed to measure the Maxwell velocity distribution for a gas of Sodium (Na) atoms at $T = 300^oC$. The experimental set up is according to figure 1.

In the oven there is a gas of Sodium atoms. At the slit at A the atoms are allowed to leave the oven. The slit at A is usually closed by the rotating drum. But as the slit D in the drum and the slit A line up Sodium atoms are allowed to exit the oven into the rotating drum.

The drum has a diameter $d = 10.0$cm and rotates with an angular velocity $\omega$ around the axis C.

Determine the angular velocity $\omega$ required so that Sodium atoms in the beam travelling at the most probable velocity $v_{mp}$ in the beam will hit the slit D again as they have travelled across the drum. (ie the drum has rotated half a turn) (3p)

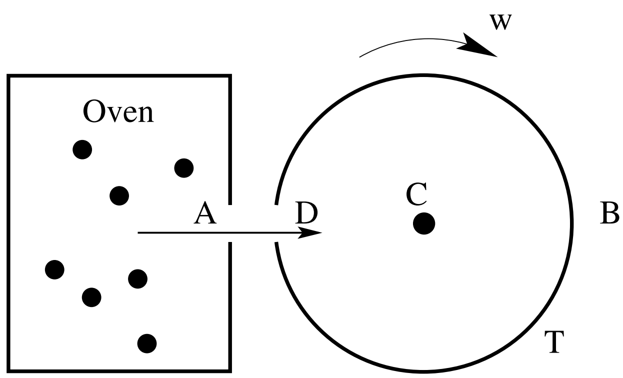


Figure 1: A principal experimental setup to determine the Maxwell velocity distribution.

5. **Paramagnetic system**

A paramagnetic system consists of particles of spin 1 and magnetic moment $m$. Each spin can point in three directions, parallel, anti–parallel and transverse to an external magnetic field. The corresponding energies are $-mB, +mB$ and 0. Determine the change of entropy for a particle as the magnetic field changes from 0 to $B_0$ at constant temperature. Show that for $1 << \frac{\tau}{mB_0}$ the decrease in entropy depends on the temperature $\tau$ as $\frac{A}{\tau^2}$, determine $A$.

(3p)

GOOD LUCK !