LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F7006T**
Examination date	2014-06-05
Time	9.00 - 14.00 (5 hours)

Examination in: FASTA TILLSTÅNDETS FYSIK / SOLID STATE PHYSICS
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 for Solid state physics and COLLECTION OF FORMULAE for Quantum Physics.

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 are required to pass the examination. Grades 3: 7.5, 4: 9.5, 5: 12.0

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1. **Crystal structure and the reciprocal lattice**

   Three two-dimensional structures (A, B and C) are shown in Figure 1 (you may assume that in each case the pattern is repeated to in- finity).

   (a) For each structure write down a set of primitive lattice vectors, and briefly describe the primitive basis.

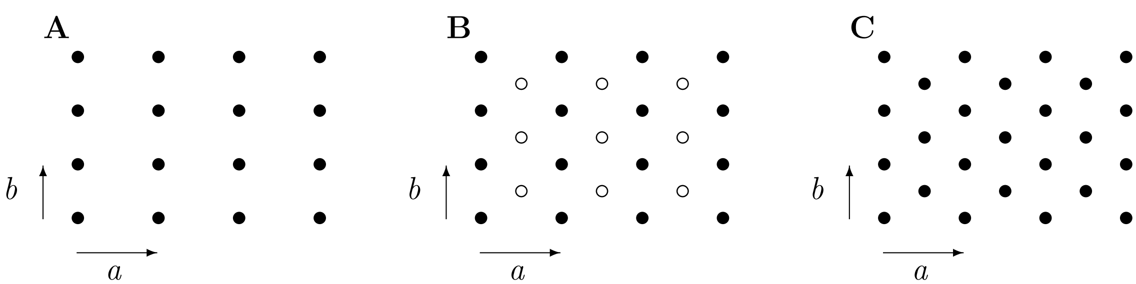

Figure 1: Three structures A, B and C. The markings • and ∘ represent different kinds of atoms.

   (b) Write down the reciprocal lattice vectors for structure A.

   (c) For structure A show that Bragg reflection can occur when $k - k' = n(2\pi/a)\hat{\imath} + m(2\pi/b)\hat{\jmath}$, where n and m are integers. The wavevectors of the incoming and outgoing beams are k and k'. (3p)

2. **Debye temperature**

   The table below shows measurements of the heat capacity of Zn. Use the data to calculate the Debye temperature.

T (K)	1.0	2.0	3.0	4.0	5.0
C_v (J/kmol K)	0.72	1.83	3.80	7.19	12.0

(3p)

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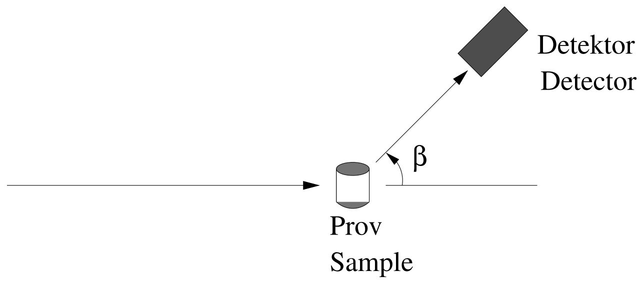

Figure 2: Principal drawing of the scattering settup

3. **X-ray diffraction**

Below you find data from a measurement of the x-ray diffraction pattern from a powder sample. The table shows the angles β where the diffraction peaks are found. Identify the cubic crystal structure. In Figure 2 the setup is shown.

β	30.3°	43.4°	53.9°	63.1°	71.6°	79.7°	87.6°

(3p)

4. **Semiconductor**

The electrical conductivity of semiconductors can be changed if impurities are introduced in the crystal. Find out how the electrical conductivity of silicon (Si) is changed if we introduce a small amount of antimony (Sb) in the crystal. The silicon crystal is doped in such a way that there is one Sb atom per 10^6 Si atoms. Is it true that the conductivity at 300 K of the doped silicon is 1000 times higher than the conductivity of a pure silicon crystal? (3p)

5. **Gouy balance**

A friend of yours has made a laboratory work where the Gouy method was used to measure the magnetic susceptibility. Your friend wants your help to analyse the measurements on the salt $Ce(NO_3)_3 \cdot 6\ H_2O$, which gave the results in the table below.

B_1 (T)	0.158	0.316	0.386	0.455	0.512	0.539
$\Delta m(g)$	0.006	0.029	0.044	0.061	0.078	0.086

The measurements where made on a glass tube filled with salt. The inner diameter of the tube is 7.7 mm and the salt has a density of $1.40 \cdot 10^3$ kg/m^3. The contribution from the glass tube is small and may be neglected.

(a) Calculate a theoretical value for the effective number of Bohr magnetons of the Ce^{3+} ions. The configuration is $4f^1$.

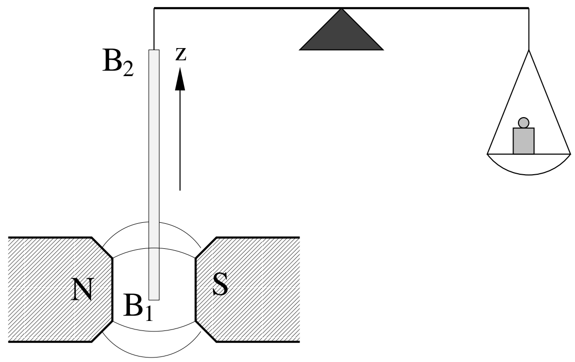

Figure 3: Principal drawing of the settup for Gouys method

(b) Use the experimental data to calculate the magnetic susceptibility of the salt.

(c) Use the experimental data to find the effective number of Bohr magnetons and compare it with a theoretical calculation on the Ce^{3+} ions.

Hint: From your own laboratory work you remember that the force on the sample is given by

$$F = \frac{A\chi B_1^2}{2\mu_0} \tag{1}$$

(3p)

Good Luck !