LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	**F7045T / F7006T (old)**
Examination date	2017-10-20
Time	9.00 - 14.00 (5 hours)

Examination in: FASTA TILLSTÅNDETS FYSIK / SOLID STATE PHYSICS
Total number of problems: 5
Teacher on duty: Nils Almqvist Tel: (49)2291, Room E303
Examiner: Hans Weber Tel: (49)2088, Room E163

Allowed aids: Fysika(lia), 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. **Reciprocal space.**

   (a) For sodium (natrium) calculate the shortest distance in reciprocal space from the origin to the surface of the Brillouin zone.

   (b) Is the Fermi sphere larger or smaller than the Brillouin zone and by how much?

   (3p)

2. **Heat capacity**

   A measurement of the heat capcity of Potasium (Kalium) at low tempertures the following results where reached: (Potasium has one valence electron, $E_F = k_B T_F$.)

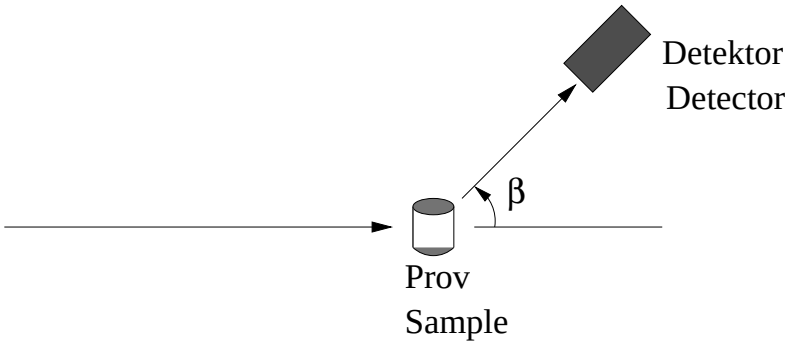
T (K)	0.5	1.0	1.5	2.0	2.5	3.0	3.5
C_v (mJ/mol K)	1.38	5.00	13.1	28.0	52.09	87.0	136

   (a) Using these data determine the Debye temperture θ_D and the Fermi energy E_F of potassium.

   (b) Using crystal data and the experimental results for (E_F) determine the effective mass of the electrons in terms of the free electron mass m_0.

   (3p)

TURN PAGE!



3. **Bragg scattering.**

   The diffraction pattern of a polycrystalline mono atomic powder is shown in the figure below (next page). The X-rays used is the $K_{\alpha 1}$ line from copper (Cu). The angle β can be controlled between 0° and 90°. The outcome of the experiment is presented in the figure below, where the intensity (I) of the deflected beam is presented as a function of β.

   From the data in the figure determine the structure (sc, fcc, bcc or diamond) of the sample.

   (3p)

4. **Semi conductor conductivity**

   A crystal of Silicon is doped with Antimony (Sb) of concentration 10^{21} m^{-3}. The impurity level is 39 meV from the nearest band edge. At the temperature 450 K the following applies: the band gap is $E_g = 1.14$ eV, the mobilities are $\mu_e = 1350$ cm^2/Vs and $\mu_h = 480$ cm^2/Vs. The effective masses can be appropriated to $m_e = m_h = 0.50 m_0$. As the impurity level is close the a band edge you may assume that all impurity atoms are ionised.

   Calculate the electrical conductivity of the crystal at T=450 K. (3p)

5. **Semi conductor**

   The relative dielectric constant for reflection of Indium Antimonide (InSb) is $\epsilon_r = 17$. The effective mass of the electrons is $m_\mathrm{e} = 0.014 m_0$. Calculate:

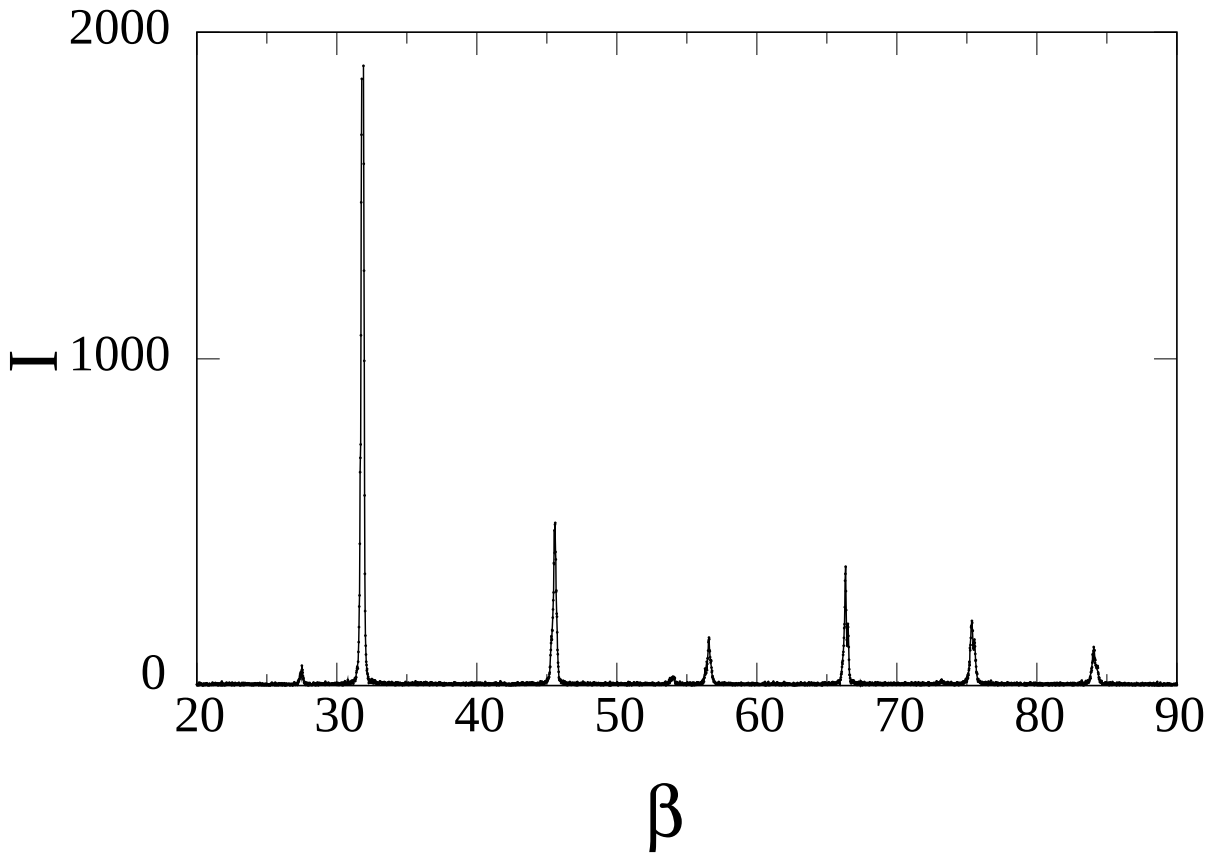
   (a) The donor ionisation energy.

   (b) Estimate the radius of the electronic ground state orbit around a donor.

   (c) At approximately how large concentration of donors will the ground state orbits start to overlap.

   (d) What happens to the ground state of the donors if the concentration exceeds the result calculated in c). (3p)

Good Luck !


2000
1000
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β