STOCKHOLMS UNIVERSITET
FYSIKUM

Examination in Condensed Matter Physics I, FK7042/FK3004, 7.5 hp
Thursday, March 15, 2012, 09.00-14.00.

Allowed help:
- periodic table and fundamental constants (distributed)
- formula sheet (distributed)
- pocket calculator, BETA / mathematics handbook or similar

Instructions:
All solutions should be easy to read and have enough details to be followed. The use of nontrivial formulas from the formula sheet should be explained. *Summarize each problem* before its solution, so that the solution becomes self-explained. State any assumptions or interpretation of a problem formulation.

Good luck! / A.R.

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1. Metallic Zinc has a molar mass $M = 65.38\,\mathrm{g/mol}$ and density $7.14\,\mathrm{g/cm^3}$. The crystal structure is *hcp* (hexagonal close-packed).
a) Describe the *hcp* structure in terms of a Bravais lattice and specify the basis. (1.5p)
b) According to the periodic table, the *hcp* structure of Zn is not ideal. Instead $c/a \approx 1.856 > \sqrt{8/3}$, where a and c are the conventional lattice parameters. Use this information to determine a and c. (2.5p)

2. The Drude model is a simple model of the metallic state that treats electrons as independent, classical particles.
a) Define and interpret the relaxation time τ in the Drude model, and find the probability for an electron not to collide during a time t. (2p)
b) Show how the introduction of τ together with the Drude assumption of scattering in random directions leads to Ohm's law. (2p)

3. Aluminium (Al) has *fcc* structure with a lattice parameter $a = 4.05$ Å.
a) Express the k-volume of the 1:st Brillouin zone for Al in terms of a. (1.5p)
b) From de Haas – van Alphen data one can conclude that there are no fourth-zone electron pockets in Al. From a table of high-field Hall measurements one can find that $-1/(R_\mathrm{H} ne) = -0.3$ for Al. According to theory, one should expect the high-field Hall coefficient to be $R_\mathrm{H} = -1/(n_e - n_h)e$. Assume that Al has 3 valence electrons per atom. Discuss how well the experimental Hall data agrees with theory. (2.5p)

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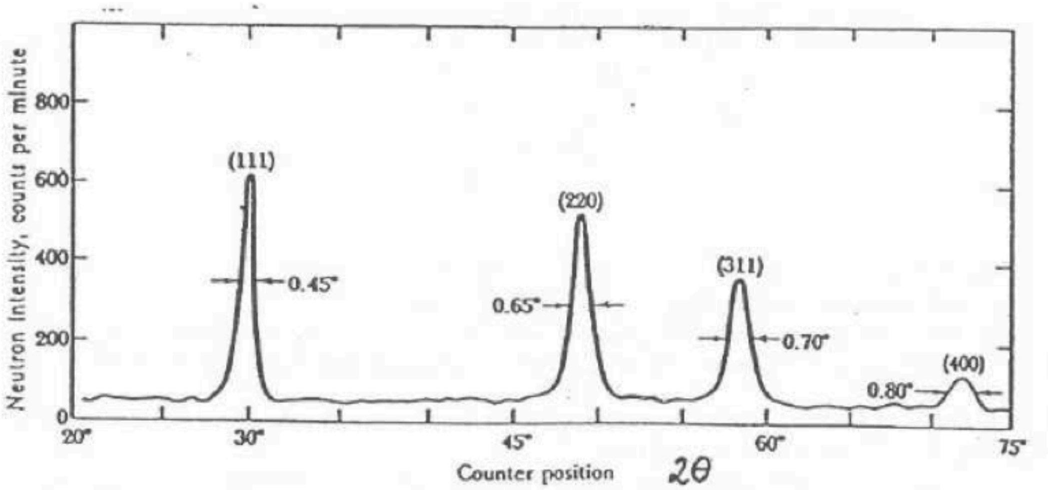
4. The figure shows a diffraction pattern obtained from a neutron beam scattered against powdered diamond.
a) It is seen that the Miller indices (h k l) are all even or all odd. However, some peaks, such as (2 2 2), are missing. Motivate why this is expected. (1p)
b) Calculate the wavelength and kinetic energy of the neutrons. Hint: Use the de Broglie relation $p = h/\lambda$. (3p)



Neutron diffraction pattern for powdered diamond. (After C. Bacon.)

5. a) An intrinsic semiconductor has a temperature independent energy gap $\varepsilon_G = 0.8\,\text{eV}$. Assume that the mean free path for electrons and holes are the same at 250 K and 300 K. Estimate the resistivity ratio $\rho(300\,\text{K})/\rho(250\,\text{K})$. State your assumptions. (2p)
b) Explain the following concepts: Bloch function, localized states. (2p)

6. a) Find an expression for the Pauli paramagnetic susceptibility due to conduction electrons. A strict derivation is not needed, but motivate and explain how you obtain the expression. (2p)
b) Sketch the magnetic susceptibility as a function of applied magnetic field for type-I and type-II superconductors. (1p)
c) For conventional superconductors that are described by the BCS theory the critical temperature is proportional to the Debye temperature. Discuss how this gives rise to the isotope effect.(1p)