STOCKHOLMS UNIVERSITET
FYSIKUM

Examination in Condensed Matter Physics I, FK7042, 7.5 hp
Tuesday, March 29, 2016, 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 and define any introduced variables.

Good luck! / A.R.

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1. Explain the following concepts through clear examples, including small sketches, simple calculations etc. as needed:
a) Bravais lattice and coordination number (1p)
b) Wigner-Seitz cell and Brillouin zone (1p)
c) Close packing and packing density (1p)
d) Geometric structure factor (1p)

2. Use the information of Figure 1 below to answer the following questions:
a) What does the figure describe in general terms? (0.5p)
b) What is the crystal structure of the material? (1p)
c) Is it a metal, an insulator, or a semimetal? Motivate! (0.5p)
d) Making suitable assumptions and approximations, what further information could you get from the figure? Do not perform any calculations, just motivate what could be done. (2.0p)

3. a) Show that the volume v_g of the reciprocal lattice primitive cell is $v_g = (2\pi)^3/v_c$, where v_c is the volume of the direct lattice primitive cell. (1.5p)
b) In an x-ray diffraction experiment on iron powder, the first observed diffraction peak was located at $2\theta = 44.60°$. Determine the maximum number of diffraction peaks that could possibly be observed in this experiment and give their expected locations. (2.0p)
c) If the wavelength λ could be increased, at what λ would it no longer be possible to see any diffraction peaks? (0.5p)

4. a.) Explain briefly the following concepts related to lattice vibrations: Phonon, dispersion relation, optical branch, Debye model, Umklapp process. (2p)
b.) Copper has a sound velocity $v_s = 3560$ m/s and a lattice parameter $a = 3.61$ Å. Estimate the highest vibration frequency of phonons in Cu and discuss the probability that a mode of this frequency is excited at room temperature. (2p)

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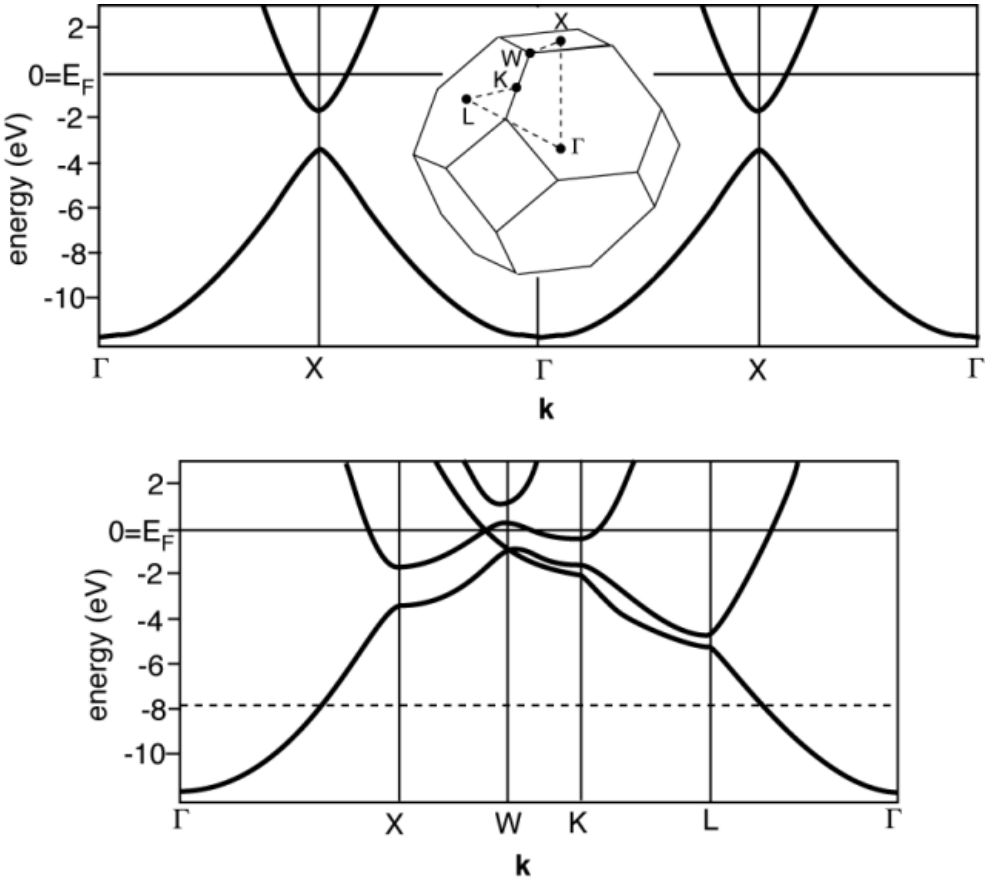

Figure 1: Figure for Problem 2. Top panel and bottom panel belong together.

5. a) Discuss the experimental observation and interpretation of the de Haas – van Alphen effect. (2p)
b) Suppose that you are studying an unknown material. You are carrying out the following measurements:

A. Resistivity as a function of temperature.

B. Hall effect.

C. Optical absorption.

D. X-ray diffraction.

Explain how you would use the results of each of these measurements to improve your understanding of what kind of material you have. (2p)

6. a) Pauli paramagnetism is a weak form of paramagnetism, involving itinerant (as opposed to localized) electrons. Make suitable assumptions and deduce an expression for the susceptibility of a Pauli paramagnet. (2p)
b) Discuss the concept of low-angle grain boundaries and how they can be studied. (2p)