STOCKHOLMS UNIVERSITET
FYSIKUM

Examination in Condensed Matter Physics I, FK7042/FK3004, 7.5 hp
Thursday, March 21, 2013, 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. Consider two different ionic crystals, sodium chloride (NaCl) and caesium chloride (CsCl). Their lattice parameters are $a_{\mathrm{NaCl}} = 5.65\,\text{Å}$ and $a_{\mathrm{CsCl}} = 4.12\,\text{Å}$, respectively. In the structures, the Na^+ ions arrange in an *fcc* lattice, while the Cs^+ ions arrange in a simple cubic (*sc*) lattice. The Cs^+ ion is about 60% larger than the Na^+ ion.
a) Use this information to make a crude estimate of the ionic radii for Na^+, Cs^+, and Cl^-. (2p)
b) Find how much the density of NaCl would change if NaCl had the CsCl structure. (2p)

2. Silver (Ag) is a monovalent metal with a Fermi surface that can be approximated with a sphere. The resistivity of Ag is $3.8\,\text{n}\Omega\text{cm}$ at $20\,\text{K}$, its density is $10.5\,\text{g/cm}^3$, and its molar mass is $107.9\,\text{g/mol}$.
a) Calculate the Fermi energy ε_{F} (in eV), the Fermi velocity v_{F} (in m/s) and Fermi temperature T_{F} (in K) for Ag. (1.5p)
b) Calculate the electron density n (in cm^{-3}), the electronic relaxation time τ at low temperatures (20 K), and the corresponding mean free path l for Ag. (1.5p)
c) Discuss the feasibility of performing de Haas–van Alphen experiments on Ag in moderate magnetic fields ($B = 1\,\text{T}$) by studying the product $\omega_{\mathrm{c}}\tau$, where ω_{c} is the cyclotron frequency. (1p)

3. A given metal has *fcc* structure with lattice parameter a and can be described by the free electron model. Let the number of valence electrons per atom x (not necessarily an integer number) be such that the Fermi surface barely touches the surface of the 1:st Brillouin zone.
a) Find the Fermi k-vector at which the Brillouin zone is touched. (1.5p)
b) Determine x. (2.5p)

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4. a) Explain briefly the following concepts related to lattice vibrations: Phonon, dispersion relation, optical branch, Debye model, Umklapp process. (2.5p)
b) Copper has a sound velocity $v_s = 3560$ m/s and a lattice parameter $a = 3.61$ Å. Estimate the Debye temperature of Cu. (1.5p)

5. Suppose that you have two differently doped semiconductors that you want to investigate. You plan to study Hall effect and Seebeck effect at room temperature, and the temperature dependence of resistivity, thermal conductivity, and specific heat. Discuss what you would expect to see in the measurements by sketching graphs (with labels on the axes) of anticipated behavior. Motivate and explain the graphs! (4p)

6. a) Derive an expression for the Curie temperature in the mean field approximation. Assume an exchange field $B_E = \mu_0 \lambda M$. Describe your starting point. (1.5p)
b) Discuss how magnetic ions interact. (1p)
c) Discuss the concentration of vacancies in materials. (1.5p)