STOCKHOLMS UNIVERSITET
FYSIKUM

Examination in Condensed Matter Physics FY3600, part I, 5p (exam 3p, lab 2p)
Friday, March 30, 2007, 09.00-15.00.

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

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.

Good luck! / A.R.

---

1. The diamond structure can be seen as an *fcc* lattice with a 2-point basis of $\mathbf{0}$ and $(a/4)(\hat{\mathbf{x}} + \hat{\mathbf{y}} + \hat{\mathbf{z}})$.
a) Suppose that we could force lead (Pb), which has *fcc* structure, to assume diamond structure without any change in density. How much would the nearest neighbor distance then change? (3p)
b) Can the diamond structure be described as a Bravais lattice? Motivate! (1p)

2. Copper (Cu) has lattice parameter $a = 3.61$ Å and resistivity $\rho_{Cu} = 1.56\ \mu\Omega$cm at room temperature.
a) Show that the Fermi energy for Cu is $\varepsilon_F = 7.04$ eV. Make suitable assumptions. (1p)
b) Estimate the mean free path for conduction electrons in Cu. (2p)
c) What is the k-volume of the first Brillouin zone for Cu? (1p)

3. a) For a monoatomic *fcc* lattice, the Miller indices (hkl) should be all even or all odd for diffraction to occur. Verify this by calculating the structure factor for all (hkl) up to $h^2 + k^2 + l^2 = 12$. (1.5p)
b) The sodium chloride structure can be described as an *fcc* lattice with a basis consisting of one type of ion at $\mathbf{0}$ and another at $(a/2)(\hat{\mathbf{x}} + \hat{\mathbf{y}} + \hat{\mathbf{z}})$. Give a simple motivation why this structure, in general, should follow the same rule for diffraction as the *fcc* lattice does. (0.5p)
c) Potassium chloride (KCl) has the sodium chloride stucture. However, some of the Bragg reflections expected for the *fcc* lattice are missing. Give a possible explanation and show that only the all-even reflections (with an even sum $h^2 + k^2 + l^2$) remain. (2p)

4. a) Describe the Debye model and its basic assumptions. (1p)
b) Assume that we have a monoatomic, electrically insulating, 1-dimensional crystal of length L with N atoms ($L = Na$, where a is the lattice parameter). Use the Debye model to obtain an expression for its specific heat. (2p)
c) Show that the expression can be simplified to $C_v \propto T/\theta_D$ at low temperatures and $C_v = Nk_B$ at high temperatures, where θ_D is the Debye temperature. (1p)

continues on backside. . .

5. a) Describe the motion in k-space of Bloch electrons in magnetic field. Discuss the difference between electron orbits, hole orbits, and open orbits. (2p)
b) The energy gap ε_g of an intrinsic semiconductor can be determined by measuring the temperature dependence of the conductivity (or resistivity). What would you expect to see, and how would you analyze the data to determine ε_g? (2p)

6. a) Show how to obtain the Curie law, i.e., that the magnetic susceptibility $\chi \propto 1/T$, for a free spin paramagnet with $J = 1/2$. (2.5p)
b) Describe the Meissner effect. (1.5p)