

Course code	<b>F7006T</b>
Examination date	2014-08-28
Time	9.00 - 14.00 (5 hours)

Examination in: FASTA TILLSTÅNDETS FYSIK / SOLID STATE PHYSICS

Total number of problems: 5

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Allowed aids: Fysikalia, Physics Handbook, Beta, calculator, COLLECTION OF FORMULAE for Solid state physics and COLLECTION OF FORMULAE for Quantum Physics.

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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. Crystal structure

Aluminum, Chrome and Germanium are chemical elements with different crystal structures.

- (a) How many atoms does the primitive unit cell contain in these elements?
- (b) How many atoms does the conventional unit cell contain in these elements?
- (c) Calculate the nearest and next nearest neighbour distance, in Ångström, for Germanium.

(3p)

### 2. Conduction of a semi conductor

A crystal of Silicon is doped according so that one atom out of a million Silicon atoms is exchanged to an Arsenic atom.

Assume that all impurity atoms are ionized. By how large a factor will the electrical conductivity (At  $T=300\text{K}$ ) of the doped semi conductor increase due to the impurity atoms compared to pure silicon?

Let  $m_e = m_h = m$  (= rest mass),  $\mu_e = 1300\text{cm}^2/\text{Vs}$  and  $\mu_h = 500\text{cm}^2/\text{Vs}$ .

(3p)

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### 3. Band structure

The band structure of a semi conductor is given by

$$\begin{aligned} E_v(k) &= -1.5 \cdot 10^{-38} k^2 \\ E_c(k) &= 1.7 \cdot 10^{-19} + 0.4 \cdot 10^{-37} k^2, \end{aligned}$$

where the energies are given in Joule.

- How large is the band gap of the semi conductor in eV?
- Calculate the effective masses of the holes and electrons in units of the free electron mass  $m_0$ .
- What energy does a photon need to have to excite an electron with momentum  $k = 5.0 \cdot 10^8 \text{ m}^{-1}$  from the valence band to the conduction band? Express the energy in eV.

(3p)

### 4. Diamagnetism

In benzene the carbon atoms form a regular hexagon of side  $1.4 \text{ \AA}$ . One outer electron from each atom has a wavefunction that extends round the whole ring of atoms (the other three outer electrons from each atom are in  $sp^2$  atomic orbitals). Estimate roughly the contribution of these electrons to the diamagnetic susceptibility of liquid benzene

(density =  $880 \text{ kg m}^{-3}$ , molecular weight = 78 ( $\text{C}_6\text{H}_6$ )).

(3p)

### 5. Heat capacity

Sodium metal displays free-electron-like behaviour. The thermal effective electron mass is equal to the electron mass and the Debye temperature is 160 K. What fraction of the total heat capacity at 300 K is contributed by the electrons.

(3p)

Good Luck !