Tfy-3.4311 Materials Physics II Examination 9.1.2014 (1st midterm)

Try to answer shortly by listing the essential arguments (phenomena, materials properties, other quantities, relations, ...) in a proper order. Short equations and figures with explanations are also a good way to clarify dependencies and trends. The exact forms of different equations are not important but the quantities and their relations needed to describe a phenomenon or property.

1. *Charge carrier densities and mobilities in semiconductors.*

   (a) In which applications direct-band-gap semiconductors can be used, but the indirect-band-gap semiconductors cannot? Why? (1 p)

   (b) Consider a semiconductor doped by donor impurities. What is the magnitude of the impurity concentration in typical doping? How do the charge carrier densities and the chemical potential behave as a function of the temperature? (2 p)

   (c) How does the conductivity behave as a function of temperature? What are the temperature dependent quantities and processes affecting the conductivity? (3 p)

   (d) Effective mass theory. What are the basic assumptions and what kind of trends the model explains? (2 p)

2. *pn and hetero junctions.*

   (a) Which are the currents flowing in equilibrium in a pn junction (Explain their origins)? (1 p)

   (b) What are band offsets and band bendings for hetero junctions? On which materials properties they depend on? How the band offsets can be determined for different junctions? (3 p)

   (c) Explain the non-equilibrium model for the electronic structure of a pn junction under an external bias voltage over the junction? What is the meaning of quasi-Fermi levels? (2 p)

   (d) Which are the current components flowing in the case of a pn junction under an external bias voltage over the junction (explain their origins and magnitudes) and the form of the total current? Which are the materials parameters affecting on the total current? (2 p)

3. *Response of materials to an external magnetic field*

   (a) Magnetism is a quantum-mechanical phenomenon. How the response of a material to the external magnetic field $\mathbf{B_0}$ is described in the quantum-mechanical formalism? (3 p)

   (b) Describe the response of atoms to $\mathbf{B_0}$ also in terms of magnetic moments, quantized energy levels, and their filling at a finite temperature. How the resulting susceptibility depends on the temperature (4 p)

4. *Spontaneous magnetism*

   (a) Which are the competing effects in the Stoner model determining whether or not a metal is ferromagnetic? (1 p)

   (b) What type of theories there exists to describe the temperature behaviour of ferromagnets? Are the theoretical models in agreement with experiments? What is the role of spin waves? (4 p)

   (c) Which effects cause the existence of domains and the details of the domain structure in ferromagnets? (2 p)