Tfy-3.4311 Materials Physics II Examination 9.1.2009

READ CAREFULLY THE FOLLOWING INSTRUCTIONS!
State clearly on your answer paper which of the following exam options you have chosen:

- Full course exam, no exercise points taken into account: A2, A4, B5, C1, C2 (total 30 p)
- Mid-term exam 1, points from exercises taken into account: A1–A5
- Mid-term exam 2, points from exercises taken into account: B1–B6

You can answer in Finnish if you like. Explain the concepts that you use in your answers. All the figures are in the next pages, after the problems. **Return also this exam sheet!**

A1 Charge carrier densities in homogeneous semiconductors (5 p).

A2 Scottky model for a pn-junction. Explain the assumptions, quantities, and physical priciples (laws) used! (5 p).

A3 a) How does the mobility behave in doped semiconductors as a function of temperature? Why? (3 p)
b) Explain the experimental results depicted in Fig. 1! (2 p)

A4 a) Atomic diamagnetism. Explain the main principles! (3 p)
b) Pauli paramagnetism for the free electron gas. Explain the main principles! (3 p)
c) Explain the origin of the exchange interaction and the structure of the Heisenberg exchange Hamiltonian! (3 p)

A5 a) Fig. 2 compares the mean-field model with magnetization values measured for Ni. Where are theory and experiment in disagreement and why? (2 p)
b) Spin waves. Explain their physical idea! Wht type of phenomana they explain? What are their most important properties? (4 p)

B1 Derive OR explain how you would derive the equation for the number of Frenkel pairs in thermal equilibrium. (5 p)

B2 a) Defects in ionic crystals. What types of defects there exist? What one should take into account in their theoretical modeling? (3 p)
b) Explain how defects can affect the mechanical properties of a metal! (3 p)

B3 Describe the laws and quantities needed to model atomic diffusion in solids (4 p)

B4 a) Describe the atomic polarizability and the ionic displacement polarizability in terms of simple models! (4 p)
b) Clausius-Mossotti relation for dielectric properties (2 p)

B5 How does the dispersion relation for transversal electromagnetic oscillations in insulators behave? What kind of regions can you recognize? (3 p)

B6 a) Interpret the results shown in Fig. 3. (2 p)
b) Fig. 4 shows the reflectivity of of different n-doped InSb samples. Interpret the results. (2 p)
c) Explain the features of the absorption spectrum of Cu_2O shown in Fig. 5. (2 p)

C1 Derive the equation for the number of Frenkel pairs in thermal equilibrium. (5 p)

C2 a) Derive the expression

$$\epsilon(\omega) = \epsilon_\infty + \frac{\omega_0^2(\epsilon_0 - \epsilon_\infty)}{\omega_0^2 - \omega^2 - i\gamma\omega}$$

for the complex dielectric constant $\epsilon(\omega)$ for the model of a damped dipolar oscillator having the equation of motion

$$\mu\ddot{\mathbf{u}} + \mu\gamma\dot{\mathbf{u}} = -k\mathbf{u} + e^*\mathbf{E}_{loc},$$

where the damping constant, $\gamma > 0$, accounts for the optical absorption in the medium. (5 p.)
b) Obtain expressions for the real (ϵ_1) and imaginary (ϵ_2) parts of ϵ and show that ϵ_2 peaks at a frequency $\omega_0 = \omega_T$, and ϵ_1 has zeros at frequencies ω_0 and ω_L (in the limit of small damping). (3 p.)

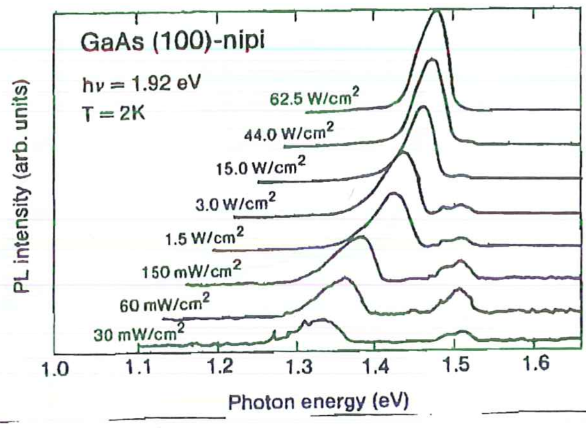

Figure 1: PL = photoluminescence

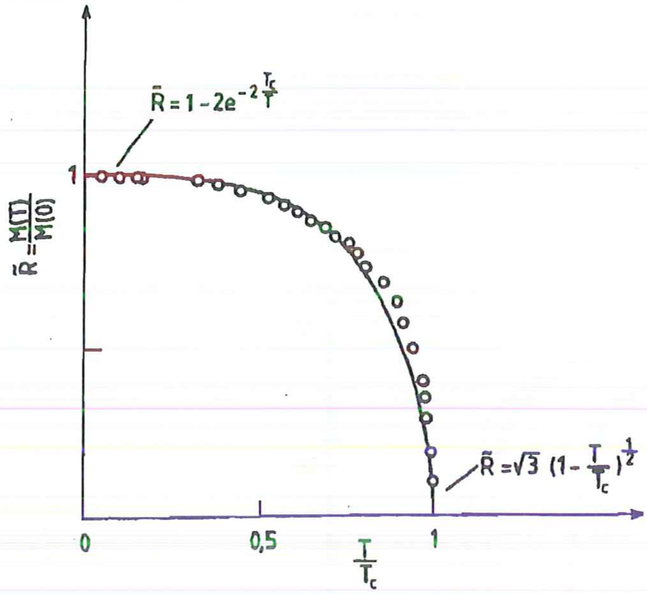

Figure 2: Dotted curve is the experimental result.

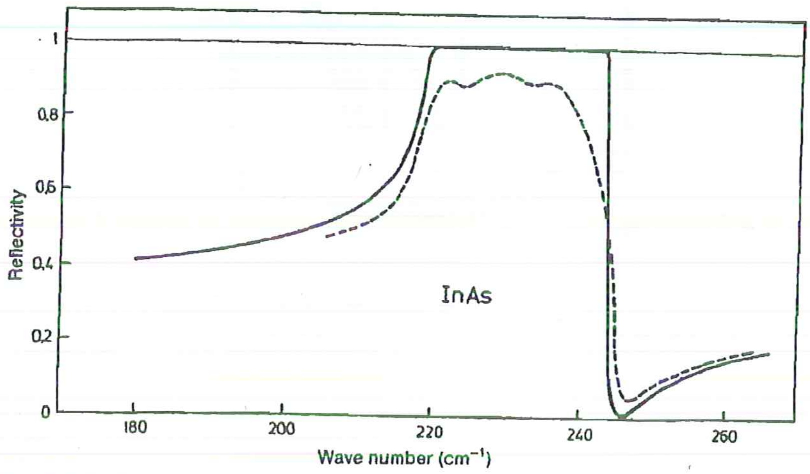

Fig. 11.8. Reflectivity for the undamped case (theoretical). The dashed line is the experimentally measured curve for a real ionic crystal (InAs). (After [11.4])

Figure 3:

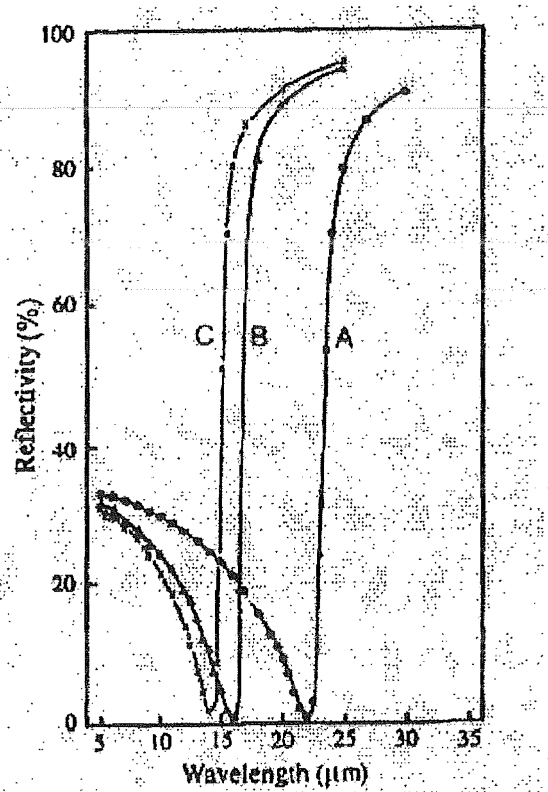

Figure 4:

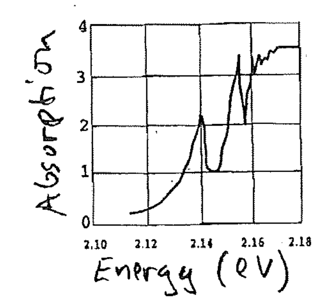

FIG. 5