Solid State Physics I 2012

Examination 4th April 2012

This is a closed book exam. You are not allowed to bring books, notes etc. You can use a basic or scientific calculator, but no other electronic equipment having capabilities to display or pronounce the course content.
Do not forget to indicate your full name and student number on **each** sheet.

Please write in a clear way!

1) Short questions (10 points, each question 2 points)

Briefly answer the following questions. No calculations are needed!

a. Explain why band theory of solids suggests that elements in group 4 are poor electrical conductors!
b. Heat capacity of solids can be described with different theories. Discuss what the peculiarities of Dulong-Petit, Einstein and Debye theories are!
c. Do these three theories describe in a satisfactory way experimental results on heat capacities in metals? Why?
d. What is the physical meaning of the fact that the effective mass inside a semiconductor is different than the one of a free electron?
e. What are extrinsic and intrinsic semiconductors? What are direct and indirect semiconductors?

2) Crystal structure (12 points)

The primitive translation vectors of the hexagonal space lattice may be taken as

$$\vec{a}_1 = \frac{a\sqrt{3}}{2}\hat{x} + \frac{a}{2}\hat{y};$$

$$\vec{a}_2 = -\frac{a\sqrt{3}}{2}\hat{x} + \frac{a}{2}\hat{y};$$

$$\vec{a}_3 = c\hat{z}$$

a. Calculate the volume of the primitive cell! **(2 points)**
b. Calculate the primitive translation vectors of the reciprocal lattice! **(3 points)**
c. Calculate which diffraction peaks will be visible in the experiment! **(4 points)**
d. Demonstrate the equivalence between the Bragg ($2d\sin\theta = m\lambda$) and the vectorial expression $\Delta\vec{k} = \vec{G}$! **(3 points)**

3) Phonons and band structure (15 points)

a. For acoustic phonons, the dispersion relation is given by:

$$\omega^2 = (4C/M)\sin^2(Ka/2)$$

Calculate the group velocity and show that it is constant in the long wavelength limit! **(3 points)** 3

b. Calculate the energy gap of a solid in the case the potential energy has an expression $V(x) = V\cos(2\pi x/a)$! **(4 points)** 0

c. Let us dope the material with donor atoms. Assuming that the relative dielectric constant is ε = 10 and the effective electron mass is 0.17m, where m is the mass of the free electron, calculate the donor ionization energy! **(3 points)** 0

d. Make a sketch of the electronic density of states for a semiconductor doped with donors, assuming parabolic band edges! At zero temperature, where does the Fermi energy lie? Where is the Fermi level at very high temperatures for low donor concentration? **(5 points)** 1