Problems for Physics 3 in Solid State Physics

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Name:	

Point(s): *Leave this field empty!*	

1 Theoretical questions

1. Define the following terms:
   a. conventional unit cell
   b. primitive unit cell
   c. Wigner-Seitz cell

   (1 point)

2. What symmetry or symmetries must an ideal crystal have? (1 point)

3. Describe the following crystal defects:
   a) vacancy
   b) dislocation (1 point)

4. Draw a picture of the unit cell of the Bravais lattice of a **bcc** crystal, together with the (100), (110) and (111) crystallographic planes! (You may make separate drawings for each.) (1 point)

5. What is the coordination number of the first neighbours for an **fcc** lattice? (1 point)

6. Define the Fermi-level and the Fermi-energy for an electron gas at temperatures above 0 K! (1 point)

7. What is the definition of the effective mass? Can the effective mass be negative? Explain! (1 point)

8. How many branches does the phonon dispersion relation have in 1 and 3 dimensions? (1 point)

9. Draw a picture of the velocity and acceleration of an electron in the 1st Brillouin zone under a constant external force! How can an electron be transferred into the 2nd Brillouin zone? (1 point)

10. Give the value of the $n \cdot p$ product for Boron doped Si! The dopant concentration is $10^{15}\ atom/cm^3$, and the $n \cdot p$ product for intrinsic Si is $1.44 \cdot 10^{19}\ 1/cm^3$. Explain the result! (1 point)

2 Problems

1. For the carbon monoxide molecule the spacing of the vibrational energy levels is found to be $\Delta E = 0.2690\ eV$. Find the force constant for the interatomic force! (1 point)

2. Consider a semiconductor material with an energy gap of 0.200 eV! Find the probability that a state on the bottom of the conduction band is occupied at a temperature of
   a) 300 K and
   b) 310 K!
   Calculate these probabilities for an other semiconductor with a band gap of 1.00 eV! (2 points)

3. The base vectors of a hexagonal lettice may be the following:

$$\mathsf{a}_1 = \frac{\sqrt{3}}{2} a \cdot \mathsf{e}_x + \frac{1}{2} a \cdot \mathsf{e}_y$$

$$\mathsf{a}_2 = -\frac{\sqrt{3}}{2} a \cdot \mathsf{e}_x + \frac{1}{2} a \cdot \mathsf{e}_y$$

$$\mathsf{a}_3 = c \cdot \mathsf{e}_z$$

   where $\mathsf{e}_x, \mathsf{e}_x$ and e_x are the unit vectors in directions x,y and z. Determine the base reciprocal vectors of this lattice!
   What kind of lattice is the reciprocal lattice? (3 points)

4. If for some reason our Sun became a white dwarf of radius $2 \cdot 10^7$ m then all of the $9.7 \cdot 10^{56}$ electrons it contains would be set free. Find the Fermi energy for this electron system! (3 points)
   (This is only a theoretical problem as our Sun will become a red giant and not a white dwarf at the end of its "life" in about 5 billion years from now.)