WS2013/14

Exercises within "Advanced Solid State Physics",

No. 5

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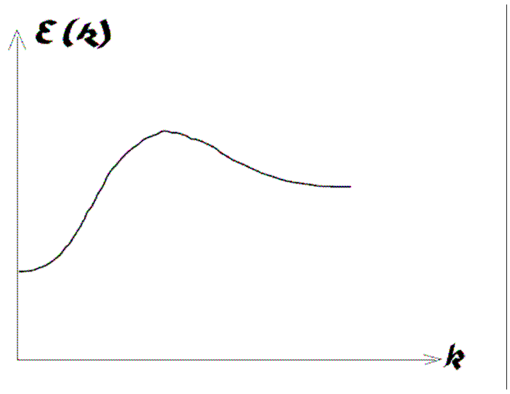
1. The fundamental bandgap energies of the elements of the fourth group of the periodic table are
   at $T = 0$ K:
   - C (diamond): 5.4 eV
   - Si: 1.17 eV
   - Ge: 0.75 eV
   - Sn: < 0.1 eV

   Explain this by using the results from the Kronig-Penney model.

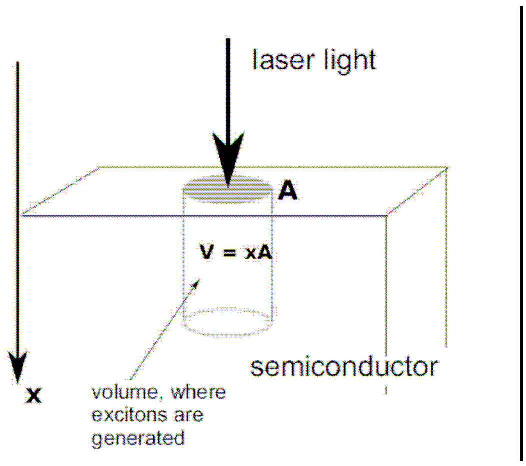
2. Sketch the effective mass corresponding to the dispersion relation shown in the figure below
   (incl. all intermediate steps)



   Write down the (explicit) dispersion relation for electrons near the conduction band minimum in GaAs and near one of the conduction band minima in Si.

3. A frequency-doubled YAG laser generates excitons in a GaAs crystal with a power of 1mW. Let the illuminated area be $A = 1\text{mm}^2$ and the average exciton lifetime be $\tau = 1$ ns. Calculate the equilibrium spatial exciton density $n_X(x)$.
   Please use α_{GaAs} at thewavelength of the YAG laser. Further, assume that each absorbed photon creates an exciton, so that there is a relation between generation and absorption rate.

Hint: Neglect diffusion processes (the illuminated area is large compared to the exciton diffusion length) and make use of the *Lambert-Beer* law for the photon flux.



4. Consider the absorption edge (for *k*-conserving optical transition between valence and conduction band) as a function of doping at low temperature and degeneracy. Show, that the absorptions edge shifts with the electron density *n* according to:

$$\Delta E = n^{2/3}\frac{h^2}{8m_e}\left(\frac{3}{\pi}\right)^{2/3}\left(1+\frac{m_e}{m_h}\right)$$

(Burstein-Moss-Shift). *Hint: Start from the k-value corresponding to the highest occupied state, and then calculate n up to this filling level.*

5. Given is an arsenic-doped silicon crystal. The arsenic concentration is $N_{As} = 10^{16}\,cm^{-3}$. Determine the concentration of electrons. How large is the concentration of electrons and holes at 300K, respectively ?
Hint: Arsenic is an effecive-mass impurity with a binding energy of 54 meV and degeneracy factor $\hat{g} = 2$.