Homework 7

Phys 155, Winter 2008, UCSC

Due Mar 1

For problems from H&H, please note that solutions are included in the textbook. However, use those solutions simply as a guide, if necessary. If you do, your answers should show clear evidence (your own words, logic, details, diagrams, etc.) for your own understanding.

1. [sp^3 molecular orbitals of diamond, Si, Ge, GaAs, ZnS, ZnSe, etc.; 5 points] Problem 4.5 of H&H

2. [Effective mass of semi-conductor; 7 points] We consider a nearly free electron model in one dimension. Within this model, we are interested only in the states near the zone boundary, as usual. We consider the bottom two bands, which means that near the zone boundary, we have a 2×2 matrix problem. We specifically consider $k \approx \pi/a$, near the zone boundary on the right side.

   (a) Show that the unperturbed states (that is, free electron states) can be described by linear dispersions $\varepsilon(k) \approx \varepsilon(k = \pi/a) \pm \hbar v \times (k - \pi/a)$ for $k \approx \pi/a$, where $mv = \hbar\pi/a$.

   (b) Now turn on the weak crystal potential and solve the 2×2 problem. [You can use the result of the previous home work.] Show that in this approximation the effective mass of electron and the effective mass of hole are the same, which we denote as m^*. Express m^* in terms of v and $\Delta \equiv |V(-2\pi/a)| = |V(2\pi/a)|$, where $V(G)$ is the Fourier component of the crystal potential, as before ($V(\vec{G}) \equiv \langle \vec{k} + \vec{G}|H_1|\vec{k}\rangle$ where H_1 is the crystal potential).

   (c) Evaluate the ratio of m^*/m_e using a typical value $a = 3$ and $\Delta = 0.5$ eV. Verify that $m^* \ll m_e$.

3. [Donors and acceptors; 8 points] Problems 5.3+5.4 of H&H