6.730 PHYSICS FOR SOLID STATE APPLICATIONS

Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

PROBLEM SET 10

Issued: 4-24-96 Due: 5-1-96, at the beginning of class.

Problem 10.0 Students in 6.972: Please send your email address to Bin Xu at “binx@mit.edu”.

Problem 10.1 Total Effective Mass Tensor for Si.

The 6 constant energy surfaces for energies just above the conduction band edge in silicon are shown below.

These surfaces are ellipsoidal and are described by two effective masses; m_t for the transverse mass and m_ℓ for the longitudinal mass. For example, for the ellipsoid along the z-axis, the surface of constant energy is

$$E(\mathbf{k}) = E_c + \frac{\hbar^2}{2}\left(\frac{(k_x - k_{x,0})^2}{m_t} + \frac{(k_y - k_{y,0})^2}{m_t} + \frac{(k_z - k_{z,0})^2}{m_\ell}\right) .$$

(a) The acceleration $\mathbf{a}$ response to an external driving force $\mathbf{F}$ is given in terms of the the inverse of the effective mass tensor $\mathbf{M}_j^{-1}$ for each pocket j;

namely, $\mathbf{a}_j = \mathbf{M}_j^{-1}\mathbf{F}$. Show that the total acceleration responds isotropically to the force; that is, $\mathbf{a}_{\text{total}} = M^{-1}\mathbf{F}$, where M is a scalar. Be sure to calculate the contributions from all six ellipsoids and find M explicitly.

(b) What is the numerical value of this effective mass ratio M/m_e for for Si.

Problem 10.2 Acceptor Levels.
(a) Let an acceptor atom (with 3 valence electrons per atom) is placed on a Si site. Assume that the acceptor levels are near the valence band energy E_v. Us the effective mass theorem to find these energy levels. Be careful with your signs, and be explicit if you are talking about electrons, "electrons", or "holes."

(b) In Si there are two valence bands (the third one is split-off and does not enter the problem). Find the probability that an acceptor is ionized, assuming that it can not be doubly ionized.

Problem 10.3 Do problem 4 in Chapter 28 of Ashcroft and Mermin. (See attached sheets for relevant plots; you do not need to plot these results.)

Final is Thursday, May 23, 1996 from 1:30 pm to 4:30 pm in room 16-310.