PHYS4450 Solid State Physics

SAMPLE QUESTIONS FOR DISCUSSION in Week 13 EXERCISE CLASS (17 April 2013)
You may want to think about them before attending exercise class.

SQ25 and SQ26 are about semiconductors, with SQ26 on the Hall effect when both electrons and holes are charge carriers. SQ27 studies the effective mass of the states on the Fermi surface in a half-filled 2D tight-binding band.

SQ25 **(Semiconductor statistics.)** Two semiconductors have the same crystal structure and the same unit cell size. Each has a single parabolic valence band. Semiconductor A has a hole effective mass $m_h^{(A)}$ and semiconductor B has a hole effective mass $m_h^{(B)}$. It happens that $m_h^{(A)} = 3m_h^{(B)}$. Each semiconductor also has a single parabolic conduction band, characterized by the same effective mass m_e. It also happens that they have the same value of the energy gap. Assume that $|\epsilon - \mu| \gg kT$ for all states.

Compare: (a) their band structure (sketch pictures); (b) their Fermi energies, each measured from the top of the VB; (c) changes in their chemical potentials as the temperature is raised from 0 to 300 K; and (d) the numbers of conduction band electrons at 300 K. If the answers in (c) and (d) are different for semiconductor A and semiconductor B, discuss the reason why they are different.

SQ26 **(This is Kittel's Problem 3 in Chapter 8.)** One can follow the Drude model and study the effects of both an electric and magnetic field on free electrons (some equations in Kittel's Chapter 6 will be useful). For the Hall coefficient obtained based on free electron theory with negatively charged electron as charge carrier, it takes on a negative value. However, from the Table in Kittel (Chapter 6), there are positive values observed in experiments. With band theory, these values can be explained.

In semiconductors, it is also possible that both negatively charged electrons and positively charged holes contribute to the Hall coefficient. Following Problem 3 in Chapter 8 of Kittel, derive an expression for the Hall efficient in terms of the carrier concentrations n and p, and the carrier mobilities.

SQ27 **(Effective Mass – Half-filled 2D Tight-Binding Band.)** This SQ may be hard. TA: Sketch the Fermi surface of a 2D tight-binding band half-filled by electrons (it was done before). Now, find the effective mass along one side of the Fermi surface.