Assignment 5: Introduction to Solid State Physics

1) Explain qualitatively the nearly free-electron model and the tight binding model.

2) Start with equations (5.27) and (5.29) and arrive at Eq. (5.32). Explain both terms in Eq. (5.32), in particular which one is associated with delocalization and why.

3) Start with equations (5.32) and (5.33) and derive Eq. (5.42). What are the minimum and maximum energies, and the bandwidth?

4) Using Eq. (5.42) or (5.43), find the effective mass at the bottom and at the top of the band. Is it intuitively expected that the effective mass should be inversely proportional to the overlap integral? Why? What does it mean to have a negative effective mass (sketch a figure like Fig. 5.37 to explain it)?

5) In the case of the nearly free-electron model, use perturbation theory and derive Eq. (5.18). Explain all the steps.

6) Considering the first and the second bands, which point in k-space requires the use of degenerate perturbation theory? Why? What is the origin of the gap between the two bands?

7) At $k = \pi/a$, what are the two "good" linear combinations for the wavefunction? In terms of the probability density, what can you say about the probability of finding the electrons in each case?