I. PROBLEM SESSION 12

A. Problem 12.1

- Describe how energy bands are filled with electrons? What is the difference between metal, semi-metal, semiconductor and insulator in terms of band structure and electron filling?
-Describe the meaning of the effective mass concept. Why the effective mass is different from that of the electron rest mass? Can the effective mass be negative? What does it mean?
-Recall the concept of holes in a semiconductor. Compare the properties of holes and electrons.
-Describe the concept of impurity doping of a semiconductor. How do different forms of doping alter the electronic properties of semiconductors? What is the role of temperature?
-How might phonon interactions affect the conduction properties of semiconductors?

B. Problem 12.2

Impurity orbits. Indium antimonide has $E_g = 0.23$ eV; dielectric constant $\epsilon = 18$; electron effective mass $m_e = 0.015$m. Calculate (a) the donor ionization energy; (b) the radius of the ground state orbit. (c) At what minimum donor concentration will appreciable overlap effects between the orbits of adjacent impurity atoms occur? This overlap tends to produce an impurity band - a band of energy levels which permit conductivity presumably by a hopping mechanism in which electrons move from one impurity site to a neighboring ionized impurity site.
(Kittel problem 1 p.218)

C. Problem 12.3

Silicon is the most commonly used semiconductur in industry today. The property of semiconductors that makes them most useful for constructing electronic devices is that their conductivity may easily be modified by introducing impurities into their crystal lattice. The concept of adding impurities to a semiconductor in a controlled way is known as doping and even a very low concentration of impurities can alter the conduction properties of the crystal by orders of magnitude.
Consider a silicon crystal is doped with $1 * 10^{15}$ donors per cm^3 having ionization energy of 45 meV. Estimate the concentration of free electrons in the conduction band (n) at 4, 77, 300, 600 K. Assume the effective density of states in the conduction band $N_c = 3 * 10^{19} cm^3$ and th band gap $E_g = 1.12$ eV are independent of temperature (to be more precise these are actually room temperature values, please make an argument that assuming no temperature dependence in N_c/E_g we still may do a reasonable approximation of n(T)). Calculate free electrons concentrations in undoped Si at the same temperatures/conditions. Compare electron concentrations in undoped and doped materials and illustrate similarities/differences using n versus $1/T$ plot.