Physics 3313, Midterm I

(1) The microcrystalline structure of a steel wire changes from body-centered-cubic to face-centered-cubic as it is heated to red hot \((T = 1180 \text{ K})\). The transition from BCC to FCC results in an 8% increase in density, causing the iron sample to shrink in size as it is heated above the transition temperature. Calculate the ratio of the lattice constants of the two structures.

(2) Consider a system of non-interacting particles in an infinite potential well of width \(a = 5 \text{ Å}\). If the longest wavelength of photons that can be absorbed by the system is 300 nm, calculate the effective mass of particles in terms of electron mass \(m_e\).

(3) The conduction and valence bands in a certain semiconductor can be described as \(E_c(k) = E_1 - E_2 \cos ka\) and \(E_v(k) = E_3 + E_4 \cos 2ka\), respectively, where \(E_1 = 6 \text{ eV}, \ E_2 = 1 \text{ eV}, \ E_3 = 3.4 \text{ eV}, \ E_4 = 0.5 \text{ eV}\). (a) Is it a direct or indirect bandgap material? (b) What is its bandgap energy? (c) Find the hole to electron effective mass ratio.

(4) Consider a system with two energy levels \(E_1\) and \(E_2\) separated by 0.1 eV. The distribution of electrons in the system is described by the Fermi-Dirac probability function. At \(T = 300 \text{ K}\), the probability to find an electron at level \(E_1\) is ten times larger than the probability to find an electron at level \(E_2\). Determine the position of the levels with respect to the Fermi level \(E_F\).