EE2: Physics for Electrical Engineers

Midterm Spring 2016

April 27th 2016, 2 to 4 pm, 1102 Perloff Hall

Instructors: Prof. Chee Wei Wong, Jinghui Yang and Yi-Ping Lai
Closed book, but with 1-sheet (2-sides of 8.5" × 11" paper) of notes.
Please use calculator.

Question 1. (35 points) Chapter 1 and 2: The Crystal Structure of Solids & Introduction to Quantum Mechanics

1.A. (10 points). What are the fourteen Bravias lattice of crystal solids found in Nature?

1.B. (10 points). The de Broglie wavelength of an electron is 85 Å. Determine the electron energy (in eV), momentum and velocity.

1.C. (15 points). Write down the one-dimensional non-relativistic form of the time-dependent Schrödinger equation. For the one-electron atom wavefunction (hydrogen atom), draw the radial probability density function $\Psi_{nlm} \cdot \Psi^*_{nlm}$ for the principal quantum number n =1 and n = 2 states.

Question 2. (30 points) Chapter 3: Introduction to the Quantum Theory of Solids

2.A. (15 points). Extending from the discretized energy levels in hydrogen, we taught the Kronig-Penny model. Describe briefly the key points in the Kronig-Penny model in the formation of the allowed and forbidden bands. Include notes on the Bloch function and the *k*-space description.

2.B. (15 points). With the formation of the conduction-valence bands, density of states, and the Fermi-Dirac distribution function, determine the probability that an energy level is occupied by an electron if the state is $5kT$ above the Fermi level.

Question 3. (35 points) Chapter 4: The Semiconductor in Equilibrium

3.A. (15 points). For a particular semiconductor, E_g = 1.50 eV, $m_p^* = 10\, m_n^*$, T = 300K and n_i = 10^5 cm^{-3}. Determine the position of the intrinsic Fermi level E_{fi} with respect to the center of the band gap.

3.B. (20 points). Impurity atoms are added so that the Fermi energy level is 0.45 eV below the center of the band gap. (i) Are acceptors or donor atoms added? (ii) What is the concentration of impurity atoms added?

Helpful constants:
Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K
Planck's constant $h = 6.625 \times 10^{-34}$ J-s
Electronic charge $e = 1.60 \times 10^{-19}$ C