ECE2: Physics for Electrical Engineers

Midterm Spring 2019

May 1st 2019, 2 to 3:55 pm, Franz Hall 1260

Instructors: Prof. Chee Wei Wong, Jin Ho Kang and Jiahui Huang
Closed book, but with 1-sheet (2-sides of 8.5" × 11" paper) of notes.
Please use calculator.

Question 1. (30 points) Chapter 1 and 2: The Crystal Structure of Solids & Introduction to Quantum Mechanics

1.A. (15 points). Determine the wavenumber, wavelength, and period of a wavefunction that describes an electron traveling in free space at a velocity v of 5×10^6 cm/s.

1.B. (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. (35 points) Chapter 3: Introduction to the Quantum Theory of Solids

2.A. (15 points). The Fermi energy for copper at $T = 300$ K is 7.0 eV. The electrons in copper follow the Fermi-Dirac distribution function. Find the probably of an energy level at 7.15 eV being occupied by an electron.

2.B. (20 points). Determine the total number (#/cm^3) of energy states in silicon between (E_v) and ($E_v - 3kT$) at $T = 300$ K.

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

3.A. (15 points). In class we taught that the equilibrium electron concentration distribution $n(E)$ is found from $n(E) = g(E) f_F(E)$. Please sketch superimposed plots of E versus $g_c(E)$ and E versus $f_F(E)$, and subsequently how the electron and hole concentration distribution are computed? Then please write down how the equilibrium electron concentration can be expressed as a function of the Fermi level and the effective density of states in the conduction band.

3.B. (20 points) Silicon at 300 K is doped with donor impurity atoms at a concentration of $N_d = 6 \times 10^{15}$ cm^{-3}. First, calculate ($E_c - E_F$). Second, calculate the concentration of additional donor impurity atoms that must be added to move the Fermi energy level a distance kT closer to the conduction band edge.

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
Electron mass $m = 9.11 \times 10^{-31}$ kg