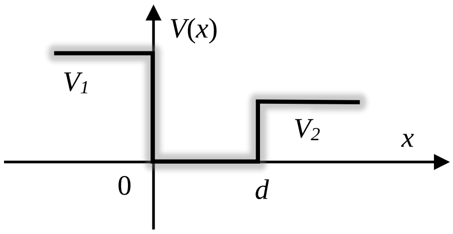
ECE 594A – Introduction to Nanoelectronics – Assignment 1

Deadline: **5/24/2013 Friday by 5 PM**. Hand in to Jiahao Kang in HFH 2152C.

Part I – Quantum Mechanics

1. 1D Schrödinger Equation

a. Find the energy levels and the wave functions of a particle in a non-symmetric potential well as below.



b. Investigate the case $V_1 = V_2$ in part a.

c. Given $V_1 = 5$ eV, $V_2 = 3$ eV and $d = 5$ nm, with the help of any computer software (for example, MATLAB), solve for the energy level values of all the bound states. Is it possible to have exactly 10 bound states just by varying d?

2. Uncertainty Relation

a. Expand the function $F(\hat{p})$ in the form of a Taylor series.

b. Find the uncertainty relation for the operators $\hat{q}$ and $F(\hat{p})$, if $\hat{q}$ and $\hat{p}$ satisfy the commutation relation $\hat{q}\hat{p} - \hat{p}\hat{q} = i\hbar$.

3. Hydrogen Atoms

a. Prove that in the ground state of the hydrogen atom, the most probable value of r is $a = \hbar/me^2$.

b. *contd.* The mean value of $\overline{1/r}$ is $1/a$.

Part II – Solid State and Semiconductor Physics

4. Lattice and Reciprocal Lattice

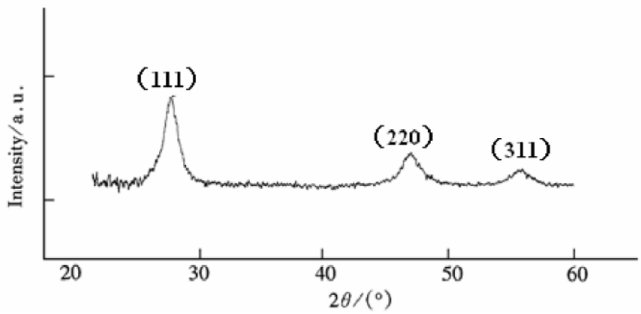
a. Assume that each atom is a hard sphere with the surface of each atom in contact with the surface of its nearest neighbor. Determine the percentage of total unit cell volume that is occupied in a simple cubic lattice, a fcc lattice, a bcc lattice and a diamond lattice.

b. Show that in cubic crystals the direction [hkl] is perpendicular to plane (hkl).

c. Show that the reciprocal lattice of 2D hexagonal lattice is also hexagonal.

d. Given the lattice constant a for fcc lattice, find the distance between (100) planes. Repeat for (111) and (200).

e. Given the x-ray diffraction pattern for polysilicon as below, find the diffraction angles for the three peaks. (λ = 1.54 Å)



5. Semiconductor Carrier Statistics

a. If 2×10^{15} gold atoms per cm^3 are added to intrinsic silicon as a substitutional impurity and are distributed uniformly throughout the semiconductor, determine the distance between gold atoms in terms of the silicon lattice constant a. (Assume the gold atoms are distributed in a rectangular or cubic array.)

b. Calculate E_{Fi} with respect to the center of the bandgap in silicon for T = 200, 400 and 600 K. $m_{dn} = 1.08\ m_0$, $m_{dp} = 0.56\ m_0$.

c. Silicon at T = 300 K is doped with acceptor atoms at a concentration of $N_a = 7 \times 10^{15}$ cm^{-3}. Determine $E_F - E_v$. Then calculate the concentration of additional acceptor atoms that must be added to move the Fermi level a distance kT closer to the valence-band edge. $N_v = 2.5 \times 10^{19}$ cm^{-3}.

6. Mobility, Conductivity and Ohm's Law

a. A GaAs semiconductor resistor is doped with donor impurities at a concentration of $N_d = 10^{15}$ cm^{-3}. The cross-sectional area is 50×10^{-6} cm^2. The current in the resistor is to be I = 10 mA with 5 V applied. Determine the required length of the device. μ_{GaAs} = 8500 cm^2/V-s.

b. First calculate the resistivity at T = 300 K of intrinsic silicon. If rectangular semiconductor bars are fabricated using this silicon, determine the resistance if its cross-sectional area is 85 μm^2 and length is 200 μm. μ_n = 1350 cm^2/V-s, μ_p = 480 cm^2/V-s. $n_i = 1.5 \times 10^{10}$ cm^{-3}.