1. (35 %) Please sketch the thermal equilibrium energy band diagrams of
   (a) metal - n semiconductor junction (when $\phi_m > \phi_s$). (5 %)
   (b) metal - p semiconductor junction (when $\phi_m < \phi_s$). (5 %)
   (c) n semiconductor – p semiconductor junction (straddling case, E_g: n-type < p-type). (8 %)
   (d) n semiconductor – p semiconductor junction (staggered case, E_g: n-type > p-type). (8 %)

   and show the ϕ_{Bn}, ϕ_{Bp} (Schottky barrier for n or p- semiconductor), V_{bin}, V_{bip} (built-in potential barrier for n or p- semiconductor), E_F (Fermi level), X_n, X_p (space charge region in n or p- semiconductor), ΔE_V (the difference between two valance band energies), and ΔE_C (the difference between two conductor band energies) on the diagrams.

   (e) in the case of question (c), when χ_n= 4.13 eV, χ_p= 4.07 eV, E_{gn}= 0.67 eV, E_{gp}= 1.43 eV, please calculate the ΔE_V and ΔE_C. (9 %)

   [Note: ϕ_m (metal work function), ϕ_s (semiconductor work function), χ_n, χ_p (electron affinity of n or p- semiconductor cases), E_{gn}, E_{gp} (energy gap of n or p- semiconductor) and the doped concentration of n-semiconductor is larger than p-semiconductor in all cases.]

2. (15 %) In a semiconductor crystal, electrons traveling in the [120] and [011] directions encounter different potential barriers. If the maximum in the valence band energy occurs at k = 0 along the [120] and [011] directions, and the minimum in the conduction band energy occurs at k = $\pi/2a$ along the [011] directions, please sketch the E versus k-space direction diagram of this semiconductor with three-dimensional concepts, and show the E_g on the diagram

3. (20%) Explain the following items:
   (a) Annealing.
   (b) Quasi-Fermi energy level.
   (c) Population inversion.
   (d) Tunnel diode.

4. (30%) (a) Plot the relation for electron mobility in silicon versus temperature, and explain why that ?
   (b) Describe detailedly for the Haynes-Shockley experiment setup, and explain how it works?