

ECE 221A Winter 2009
Homework 1
Due: Thursday January 22, 2009

I. Fermi Levels and Occupation of States

- a. 2.8
- b. 2.9
- c. 2.10

II. PN Junctions

- a. 4.5
- b. 4.6
- c. 4.7

Problem 2.8 Consider a donor an energy E_D from the conduction band as shown in figure 2.40. If the density of the donor device is $N_D(\text{cm}^{-3})$ derive a relationship for the position of the fermi level as a function of temperature in terms of N_C and N_V . Plot the fermi level as a function of temperature for the case $N_D = N_A = N_V$. Physically explain your result. Repeat for the case of a donor and an acceptor of densities N_D and N_A respectively. What will be the dependence of the fermi level on temperature if (i) $N_D = N_A$, (ii) $N_D > N_A$, and (iii) $N_D < N_A$. Explain.

Problem 2.9 Consider a slab of GaAs that is doped n-type with 10^{17}cm^{-3} .

1. Consider the case where there is a surface donor state 0.5 eV from the conduction band. What is the fermi level at the surface as the density of this level is increased from 10^{10}cm^{-2} to 10^{14}cm^{-2} ?

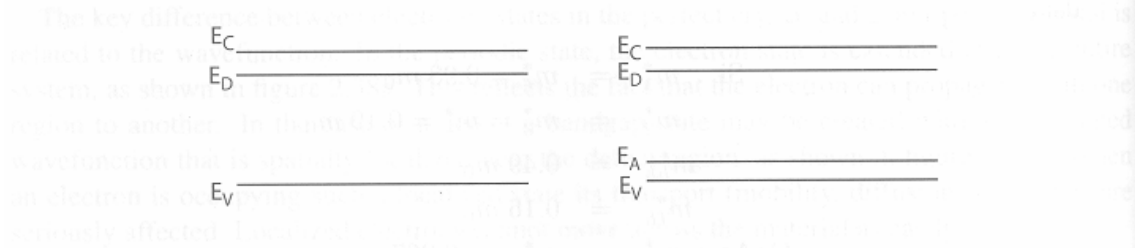


Figure 2.40: Figure for problem 2.8.

2. Solve the previous part for the case with only an acceptor state 0.5 eV from the conduction band.
3. Assume now that there are two defect levels of equal density, one donor-like and the other acceptor-like, at the surface. The acceptor state is 0.3 eV from the conduction band edge and the donor state is 0.5 eV from the conduction band edge. How does the fermi level pinning at the surface change as the areal density of each of these states is kept equal and increased from 10^{10} cm^{-2} to 10^{14} cm^{-2} ?
4. Now the positions of the defect levels are changed. The acceptor state is 0.5 eV from the conduction band edge and the donor state is 0.3 eV from the conduction band edge. How does the fermi level pinning at the surface change as the density of each of these states is kept equal and increased from 10^{10} cm^{-2} to 10^{14} cm^{-2} ?
5. Metals X and Y are now evaporated on the surface with 10^{13} cm^{-2} donor states at 0.5 eV from the conduction band. Find the position of the fermi level at the surface for metal X ($\Phi_{ms} = 0.3 \text{ eV}$) and metal Y ($\Phi_{ms} = 0.7 \text{ eV}$).
6. Repeat part 5 but with acceptor states this time, assuming they have the same energy level and areal density.

Draw band diagrams to explain your solutions.

Problem 2.10 Assume a pn junction with an acceptor close to the valence band edge, so that the acceptors are fully ionized at 300K. Assume $N_A = N_D = 10^{18} \text{ cm}^{-3}$. What is the built-in voltage of the junction? Now, the choice of acceptor is changed such that only 1/10th of the acceptors are ionized.

1. What is the acceptor level relative to the valence band?
2. What is the new built-in voltage of the diode. Make reasonable approximations which *should* be justified.
3. Draw a band diagram of the system showing the acceptor level and the Fermi level.

Problem 4.5 An abrupt silicon p - n diode at 300 K has a doping of $N_a = 10^{18} \text{ cm}^{-3}$, $N_d = 10^{15} \text{ cm}^{-3}$. Calculate the built-in potential and the depletion widths in the n and p regions.

Problem 4.6 A Ge p - n diode has $N_a = 5 \times 10^{17} \text{ cm}^{-3}$ and $N_d = 10^{17} \text{ cm}^{-3}$. Calculate the built-in voltage at 300 K. At what temperature does the built-in voltage decrease by 1%?

Problem 4.7 Consider a p - n junction with $N_A = N_D = 10^{17} \text{ cm}^{-3}$. When the capacitance is measured to be twice the value expected. The reason is an unintentional interfacial dipole between the p and n layers.

1. What is the magnitude of the dipole moment?
2. Draw the band diagrams of the ideal p - n junction and the non-ideal one. Include the electric field profiles and depletion region widths.

Assume that the dipole is supported by negative and positive charges separated by a very small distance, δ .