1. Consider an abrupt P-N Junction with the net impurity concentration of \(6 \times 10^{16} \text{ cm}^{-3}\) on the n side and \(7 \times 10^{17} \text{ cm}^{-3}\) on the p side. Determine the built in potential. (20 pts)

2. Assume a Si step junction operated at 300K with \(N_A = 10^{17} / \text{cm}^3\) and \(N_D = 10^{14} / \text{cm}^3\). Find the size of \(W\) and \(\phi_{\text{max}}\) under equilibrium conditions. (30 pts)

3. Consider a P-I-N junction (Si, 300K, equilibrium, \(\varepsilon_s = 11.7 \varepsilon_0\) where \(\varepsilon_0 = 8.854 \times 10^{-14} \text{ F cm}^{-1}\)) as shown in the problem below: (50 pts)

This is completely similar to a pn junction except that we have two junctions now, a p-i junction at \(x=0\) and an i-n junction at \(x=x_i\). So, we would have the usual depletion regions and built-in potentials at the two junctions. (Note that if \(x_i = 0\), then this is the normal pn junction). Remember that in the intrinsic region, the number of carriers is very low compared to \(n_{i0}\) in the n-region or \(p_{i0}\) in the p-region. Therefore, under the depletion approximation, in addition to the small depletion regions on the p- and n-sides, the entire intrinsic region is depleted of free carriers and has zero space charge density.

a. Draw the energy band diagram. Clearly label an x-axis and show \(E_c(x)\), \(E_v(x)\), \(E_i(x)\) and \(E_F\) for all points of interest in the device.

b. Find \(E_c - E_F\) in the p-region and the n-region. Hence, find the built-in potential, \(V_{0, \text{pin}}\).

c. Sketch \(V(x)\) for all \(x\) from \(-W_p\) to \(+W_n\).

d. Sketch \(E(x)\) for all \(x\) from \(-W_p\) to \(+W_n\).

e. Find the depletion capacitance of the pn junction.