Physics 3313, Homework #8 (due 4/5)

P1 The built-in potential barrier in a semiconductor is found to be 0.697 V at \(T = 300\) K and 0.279 V at \(T = 500\) K. What is the relative change in the intrinsic carrier concentration from 300 K to 500 K?

P2 Determine the total depletion width for a GaAs pn junction at \(T = 300\) K with doping concentrations \(N_d = 2 \times 10^{16} \text{ cm}^{-3}\), \(N_a = 2 \times 10^{15} \text{ cm}^{-3}\). The intrinsic carrier concentration for GaAs is \(1.8 \times 10^6 \text{ cm}^{-3}\), and relative permittivity \(\varepsilon_r = 13\).

P3 We are assuming an abrupt depletion approximation for the space charge region. That is, no free carriers exist within the depletion region and the semiconductor abruptly changes to a neutral region outside the space charge region. This approximation is adequate for most applications, but the abrupt transition does not exist. The space charge region changes over a distance of a few Debye lengths, where the Debye length in the n region is given by

\[
L_D = \sqrt{\frac{\varepsilon kT}{e^2 N_d}}.
\]

Calculate \(L_D\) and find the ratio of \(L_D/x_n\) if the p-type doping concentration is \(N_a = 4 \times 10^{17} \text{ cm}^{-3}\) and the n-type doping concentration is (a) \(N_d = 4 \times 10^{14} \text{ cm}^{-3}\), (b) \(N_d = 4 \times 10^{17} \text{ cm}^{-3}\).

P4 In a series of measurements of a p+n junction capacitance as a function of applied reverse-bias voltage, the following results were obtained:

<table>
<thead>
<tr>
<th>(V_R, \text{ V})</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C, \text{ pF})</td>
<td>2.02</td>
<td>1.63</td>
<td>1.40</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Determine the built-in potential barrier for the junction. Explain in detail how you arrived at the answer. Hint: since you have more than two measurements, you will need to apply a linear regression to obtain the result. You can use any software you prefer, or you can calculate it by hand: for a linear dependence \(y = b_0 + b_1 x\) coefficients \(b_0\) and \(b_1\) can be calculated as

\[
b_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}, \quad b_0 = \bar{y} - b_1 \bar{x}, \quad \text{where} \quad \bar{x} = \frac{\sum x_i}{N}, \quad \bar{y} = \frac{\sum y_i}{N}.
\]