1. Consider a two-level system at thermal equilibrium. The concentration of particles \( N = 10^{18} \) cm\(^{-3}\). There are \( 10^{19} \) cm\(^{-3}\) states at each energy level.

(a) Assuming \( E_2 = 1.1 \) eV, \( E_1 = 1.0 \) eV, \( T = 300 \) K, find \( N_1 \) and \( N_2 \) if the system obeys Boltzmann statistics. \( (k_B T = 0.026 \) eV). \( N_1 \) and \( N_2 \) are the carrier concentrations at each level.

\[
\begin{align*}
N_2 & \quad E_2 \\
N_1 & \quad E_1
\end{align*}
\]

(b) Find the Fermi level and \( N_1 \) and \( N_2 \) if the particles are Fermions. (Hint: You may need to do approximations as needed to simplify the mathematics in finding \( E_F \).)
230B problem:

2. Consider an n-channel MOSFET with n\(^+\) polysilicon gate (neglect poly depletion effect). The gate oxide is 3 nm thick, and the p-type body (or substrate) has the retrograde doping shown below. 

(a) What is the maximum depletion width when the band bending reaches \(2\psi_B\) (take \(2\psi_B = 1\) V), i.e., strong inversion condition?

(b) What is the body effect coefficient, \(m\), and the inverse slope of log sub-threshold current versus gate voltage (long-channel device)?

(c) What is the scale length, \(\lambda\)? How short a channel length can the device be scaled to before short-channel effect becomes severe?

(d) What is the threshold voltage and how much does it change (increase or decrease) when a reverse bias of \(-1.0\) V is applied to the substrate?

\[N_a\]

\[10^{18} \text{ cm}^{-3}\]

\[0 \quad 20 \text{ nm} \quad x\]