EE 735 Assignment 2

Due Date: 25st August 2023, 11:59 PM

Useful information:

- One-dimensional Poisson's equation for PN junction with depletion approximation is

$$\nabla^2 V(x) = -\frac{\rho(x)}{\varepsilon_s}$$

Where, $\rho(x) = q\ (N_D{}^+ - N_A{}^-),\ -x_p \leq x \leq x_n$ for **abrupt junction**

$$\rho(x) = \ qax\ , \text{ where } \textbf{Junction slope } a = \frac{(N_D^+(x=x_n) - N_A^-(x=x_p))}{W},$$

$$w = x_n + x_p,\ -x_p \leq x \leq x_n \quad \text{for } \textbf{linearly graded junction}$$

- Gauss Law for the electric field in PN junction diode:

$$E(x) = \int \frac{\rho(x)}{\varepsilon_s} dx \quad ,-x_p \leq x \leq x_n$$

- Charge neutrality equation: $N_D{}^+ - N_A{}^- = p - n$

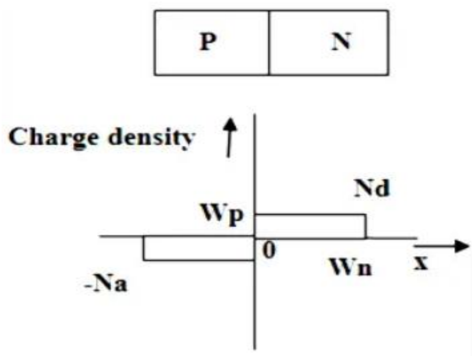
Where $N_D{}^+$ and $N_A{}^-$ are the partially ionized donor and acceptor concentrations.

Question 1:

Solve the following for PN junction diode shown in the figure by considering both abrupt and linearly graded junction.

*(**Parameters**: Length of P region= Length of N region = 2e-6 meters, N region doping (Nd) = 1e15 cm^{-3}, built-in potential V_{bi} = 0.6V, ε_{Si} = 11.8 ,ε_0 =8.85e-14 F/cm, n_i (constant) =10^{10} /cm^3 , q=1.6e-19 C)*

Threshold voltage (V_t) = KT/q**= 0.02600 V** @ 300 K (**for V_t consider upto 5 digits after decimal**), Where **T=300+1.5*X Kelvin, where X last digit of your roll number.**



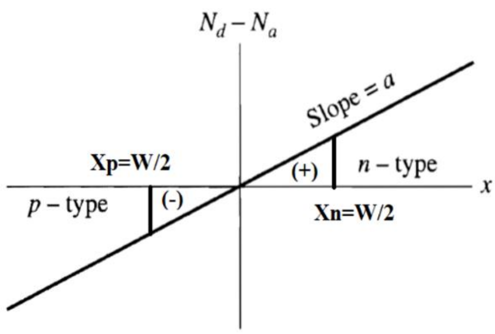


Figure 1 : i) abrupt/step graded junction profile *ii) linearly graded junction profile*

A. Plot the **Charge profile, Electric field and Voltage profile** by solving the Gauss Law for the given PN junction diode using numerical integration techniques such as Trapezoidal/Simpson's methods. Compare the result with the inbuilt MATLAB functions for integration. You can check the accuracy of numerically integrated results by varying the grid spacing.

B. Replace the continuous partial derivatives by finite-difference Eq as $\nabla^2 V_{(i)} = (V_{(i-1)} - 2V_{(i)} + V_{(i+1)})/h^2$. solve the Poisson equation with **depletion approximation**. For this calculation first compute the L and U matrices numerically. Use these matrices to solve the system of linear equations $[A]_{n\times n}\,[V]_{n\times 1} = [b]_{n\times 1}$ using LU decomposition method (**Do not use inbuilt LU command**) and compare graphically the result with inbuilt MATLAB operator $A\backslash b$.

C. Use Gauss-Seidel method to solve the linear equations $[A]_{n\times n}\,[V]_{n\times 1} = [b]_{n\times 1}$ and compare the result graphically with result got from part B.

Question 2:

Consider a compensated semiconductor (**Si**) bar with doping concentrations $N_D = 1e15\ cm^{-3}$ *and* $N_A = 1e17\ cm^{-3}$. Use **Newton Raphson** method to solve the charge neutrality equation for finding the fermi energy $\boldsymbol{E_F}$. Plot Energy band diagram depicting conduction band minimum (EC), valence band maximum (EV), mid gap energy level (Emid), fermi energy level EF. **Mention all the assumptions made.**

Reference:

1. Robert Pierret book, Semiconductor Device Fundamentals, Chapter 5, Section 5.2.2 (Step junction), Section 5.2.5 (Linearly graded junction)
2. Robert Pierret book, Advanced Semiconductor Fundamentals, Chapter 4, Section 4.4.3, and Section 4.4.4

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