**In the equations n=ni*exp(V/Vt) and p=ni*exp(-V/Vt), the fermi energy level (Ef) is 0. So, use Ef = 0 while drawing the energy band diagram.**

Use Newton-Raphson method to solve the poisson's equation for the given devices under thermal equilibrium condition. Use finite central difference scheme for numerical solutions.

The poisson's equation is

$$\frac{d^2V}{dx^2} = -\frac{\rho}{\varepsilon} \quad ; \quad \text{where } \rho = q \times (N_D^+ - N_A^- + p - n);$$

Use Maxwell-Bolzmann statistics for electron ($n$) and hole ($p$) concentrations. Consider complete ionization of donor ($N_D$) and acceptor ($N_A$) dopants. Use intrinsic carrier concentration $n_i = 1.45 \times 10^{10} /cm^3$, relative permittivity $\varepsilon_r = 12$, energy band gap $E_G = 1.12 \, eV$ .Temperature is 300 kelvin.

Plot the following profiles as function of X (i.e. spatial variation) for all the questions:

a) Potential (V)
b) Electric field (E)
c) Charge concentration ($\rho/q$)
d) Electron (n) and hole (p) concentrations
e) Energy band diagram depicting conduction band minimum ($E_C$), valence band maximum ($E_V$), mid gap energy level ($E_{mid}$), fermi energy level $E_F$ .

**Q1.**

A P-N junction diode with a) abrupt junction b) linearly graded junction. $N_D = N_A = 10^{16} /cm^3$.
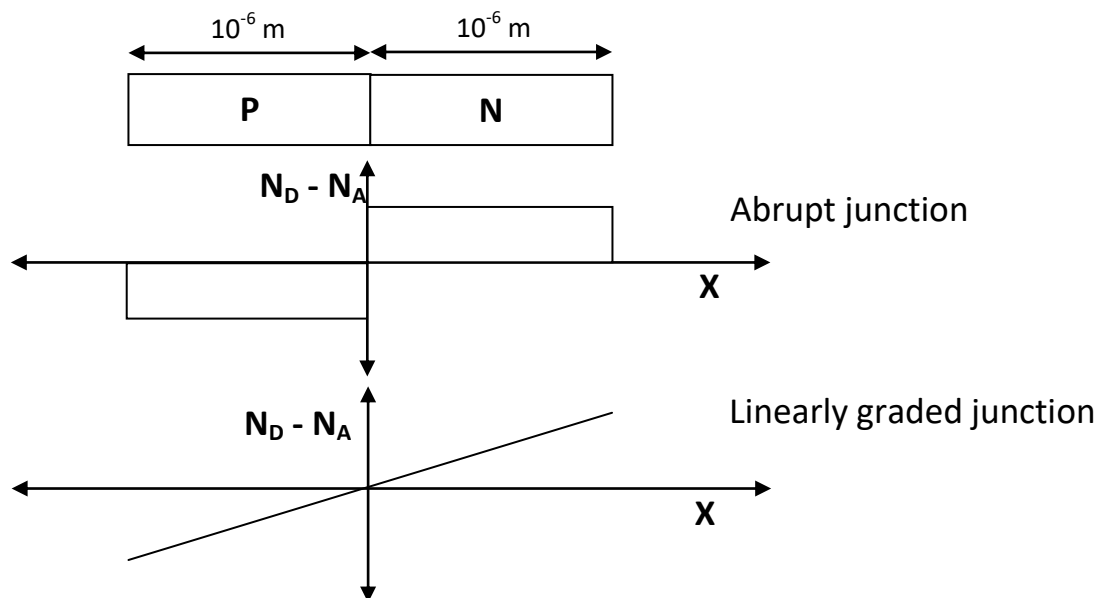


Compare the V vs X graph with the one obtained in Assignment 2 using depletion approximation. Give a qualitative description of your observation.

**Q2.**

An N$^+$-N abrupt junction with doping concentrations $10^{17}$ /cm$^3$ and $10^{16}$ /cm$^3$ on the respective sides. Dimensions are same as in Q1 with P region replaced by N$^+$ region. Compare the E vs X profile with the one in Q1. Explain your observation.

**Q3.**

An N$^+$-P-N$^+$ structure with abrupt junctions. Doping in N$^+$ regions is $N_D = 10^{17}/cm^3$ and that in P region is $N_A = 10^{16}/cm^3$. Length of N$^+$ regions is $10^{-6}$ m each and that of P region is varied over the following range: (1, 0.9, 0.8, 0.7, 0.6) x $10^{-6}$ m. Show the variation of (V vs X) as function of P region length (L$_P$). Give a qualitative description of your observation.