EE 735: ASSIGNMENT 3

Deep Kumar Pal, 23M1135

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PROBLEM 1

(i) Abrupt Junction

SIMULATION APPROACH

Given,

Length of p-type region $= 1.5 \times 10^{-4}$ cm, Length of n-type region $= 1.5 \times 10^{-4}$ cm

N-type region doping concentration $(N_d) = 6 \times 10^{15}$ /cm^3

P-type region doping concentration $(N_a) = 4 \times 10^{15}$ /cm^3

$\epsilon_{Si} = 11.8$, $\varepsilon_0 = 8.85 \times 10^{-14}$ F/cm, $n_i = 1.5 \times 10^{10}$ /cm^3, q $= 1.6 \times 10^{-19}$ C

Temperature $(T) = 300$ K and Thermal voltage $(V_t) = 0.026\ V$, E$_g = 1.12$ eV

The following profiles are simulated with depletion approximation and without depletion approximation:
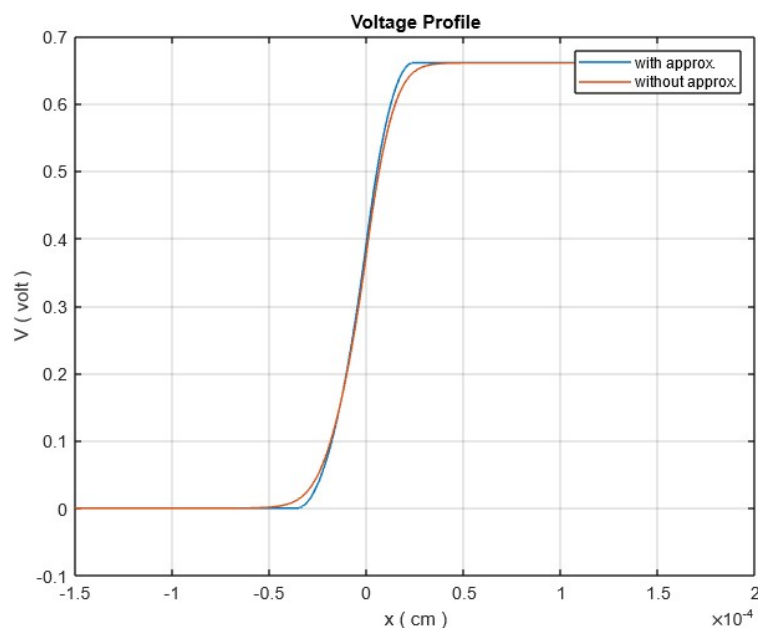
1. Potential (V)

2. Electric Field (E)

3. Charge concentration (ρ/q) (where q is electron charge)

The following plots are simulated without depletion approximation:

1. Electron (n) and Hole (p) concentrations

2. Energy band diagram depicting conduction band minimum (E$_C$), Valence band maximum (E$_V$), mid gap energy level (E$_{mid}$) and Fermi energy level (E$_F$) .

RESULT

The plots of the various profiles are given below,

Electric Field Profile

Charge Concentration Profile

Electron and Hole Concentration

Energy Band Diagram
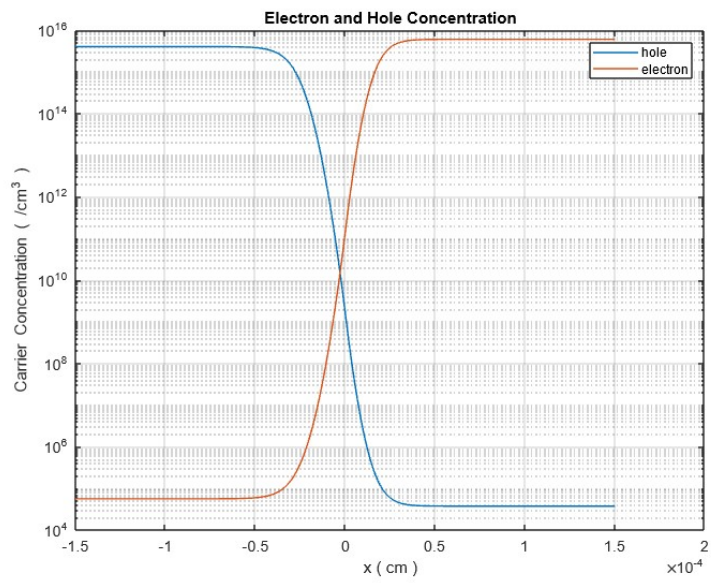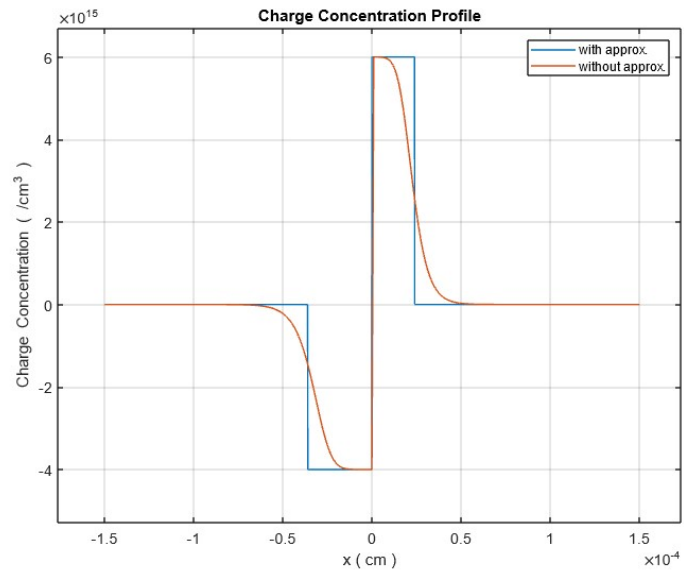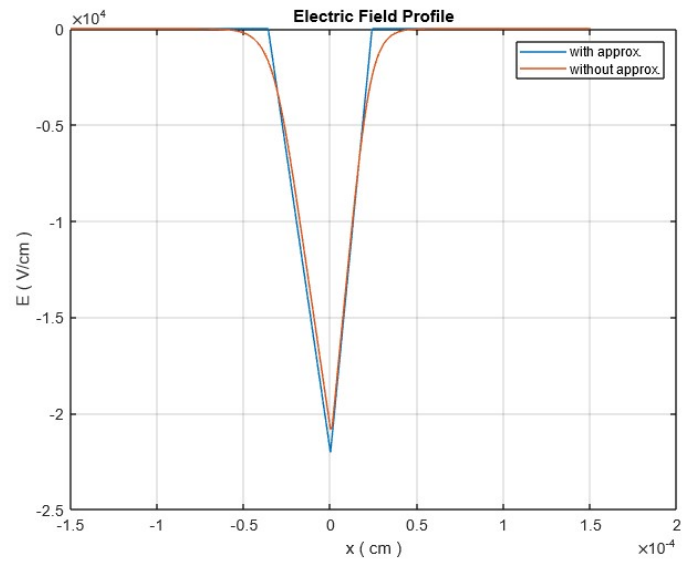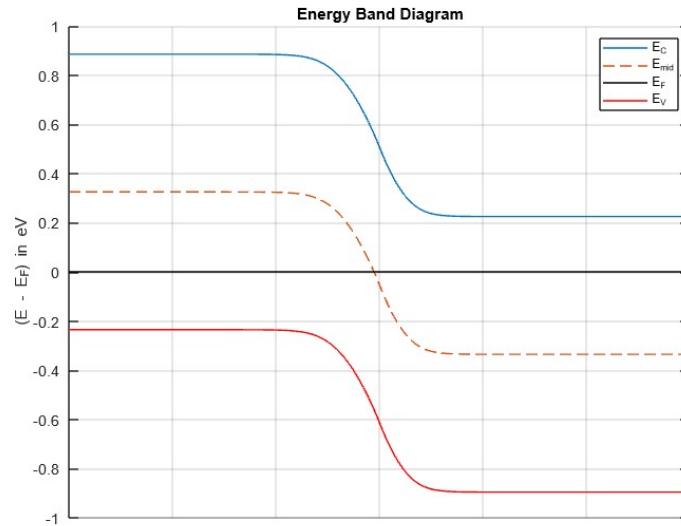
CONCLUSION

The built-in potential obtained for both cases are almost same as given below,

Built-in potential (with depletion approximation) = 0.660795 V

Built-in potential (without depletion approximation) = 0.660217 V

The charge distribution profile and electric field profile without depletion approximation maintains smoother transitions at the depletion edges from their approximated counterpart.
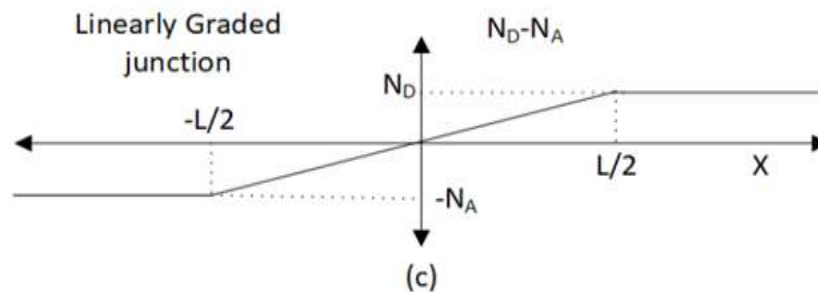
(ii) Linear Junction

SIMULATION APPROACH

Length of p-type region, $L = 1.5 \times 10^{-4}\ cm$, Length of n-type region, $L = 1.5 \times 10^{-4}\ cm$

$\epsilon_{Si} = 11.8$, $\varepsilon_0 = 8.85 \times 10^{-14}$ F/cm, $n_i = 1.5 \times 10^{10}$ /cm^3, q $= 1.6 \times 10^{-1}$ C

Temperature $(T) = 300$ K and Thermal voltage $(V_t) = 0.026\ V$, E$_g = 1.12$ eV

The doping profile is given as,

(c)

N-type region doping concentration $(N_d) = 6 \times 10^{15}$ /cm^3

P-type region doping concentration $(N_a) = 6 \times 10^{15}$ /cm^3

Impurity gradient close to the junction region, $m = \frac{N_d + N_a}{L} = \frac{6 \times 10^{15} + 6 \times 10^{15}}{1.5 \times 10^{-4}} = 8 \times 10^{19} \ /cm^4$

The following profiles are simulated with depletion approximation and without depletion approximation:

4. Potential (V)

5. Electric Field (E)

6. Charge concentration (ρ/q) (where q is electron charge)

The following plots are simulated without depletion approximation:

3. Electron (n) and Hole (p) concentrations

4. Energy band diagram depicting conduction band minimum (E_C), Valence band maximum (E_V), mid gap energy level (E_{mid}) and Fermi energy level (E_F) .

RESULT

The plots of the various profiles are given below,

Charge Concentration Profile

Electron and Hole Concentration

Energy Band Diagram
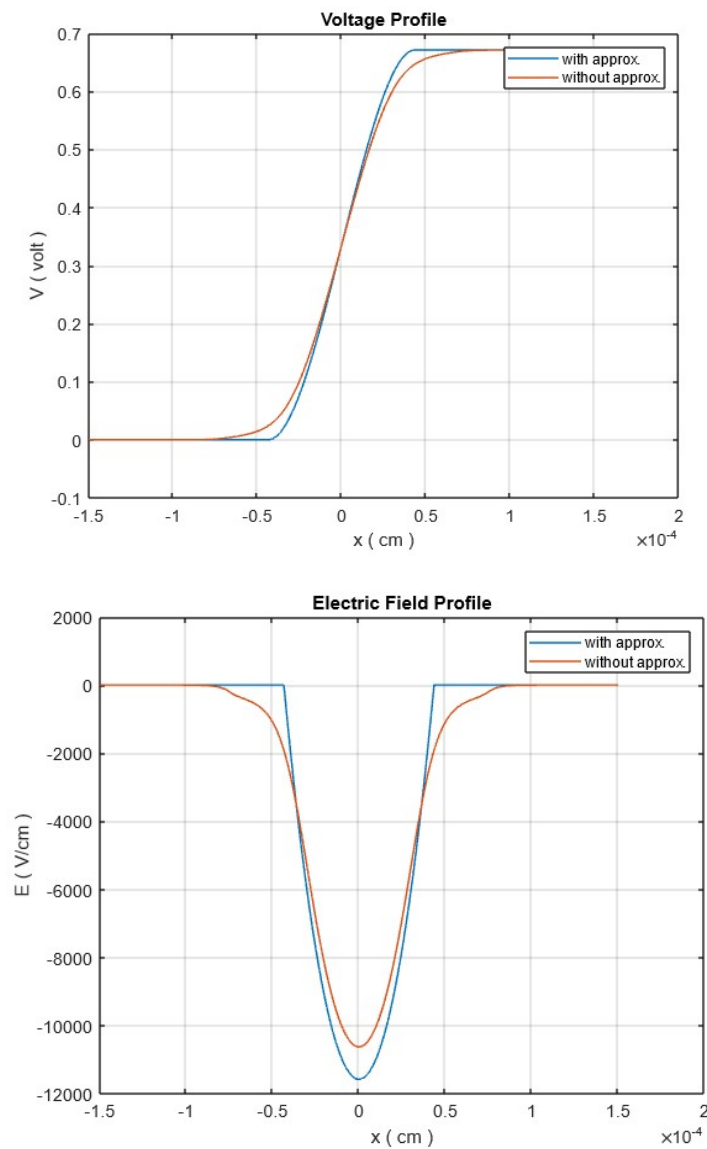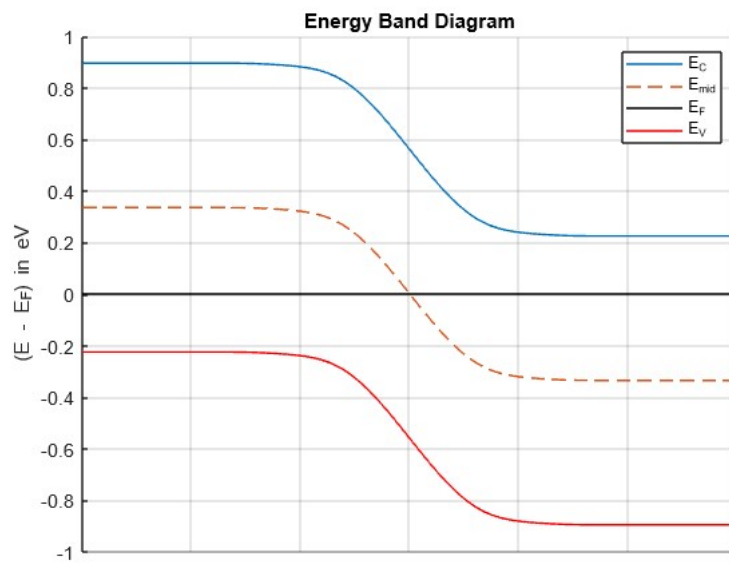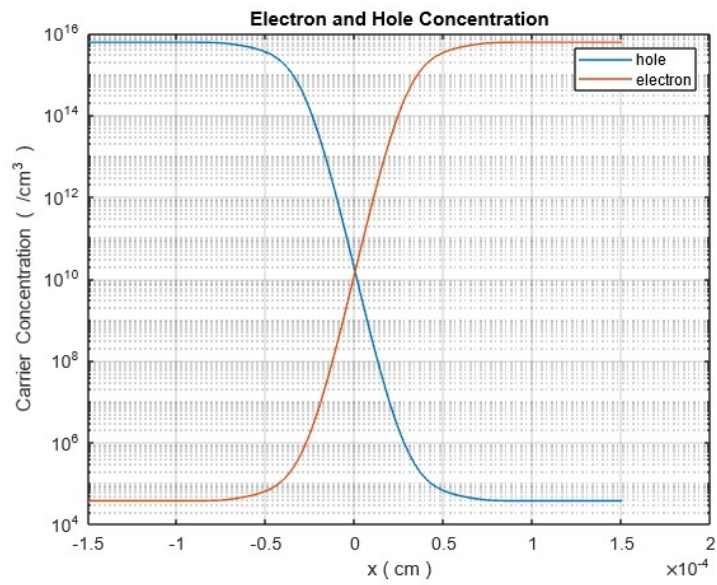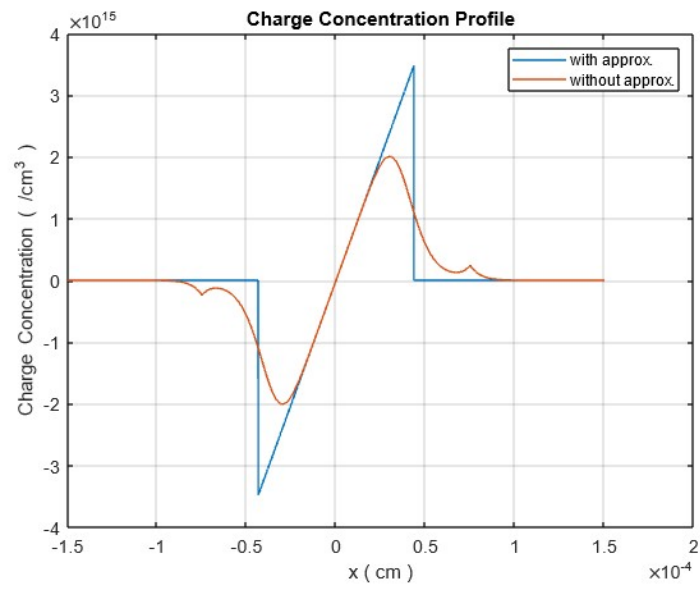
CONCLUSION

The built-in potential obtained for both cases are almost same as given below,

Built-in potential (with depletion approximation) = 0.670984 V

Built-in potential (without depletion approximation) = 0.670759 V

The charge distribution profile and electric field profile without depletion approximation maintains smoother transitions at the depletion edges from their approximated counterpart.

PROBLEM 2

SIMULATION APPROACH

Given,

Length of p-plus region $= 0.5 \times 10^{-4}\ cm$

Length of n-plus region $= 0.5 \times 10^{-4}\ cm$

P-plus type region doping concentration $(N_{a1}) = 10^{17}\ /cm^3$

N type region doping concentration $(N_d) = 10^{15}\ /cm^3$

N-plus type region doping concentration $(N_{d1}) = 10^{17}\ /cm^3$

$\epsilon_{Si} = 11.8$, $\varepsilon_0 = 8.85 \times 10^{-14}$ F/cm, $n_i = 1.5 \times 10^{10}\ /cm^3$, q $= 1.6 \times 10^{-19}$ C

Temperature $(T) = 300$ K and Thermal voltage $(V_t) = 0.026\ V$

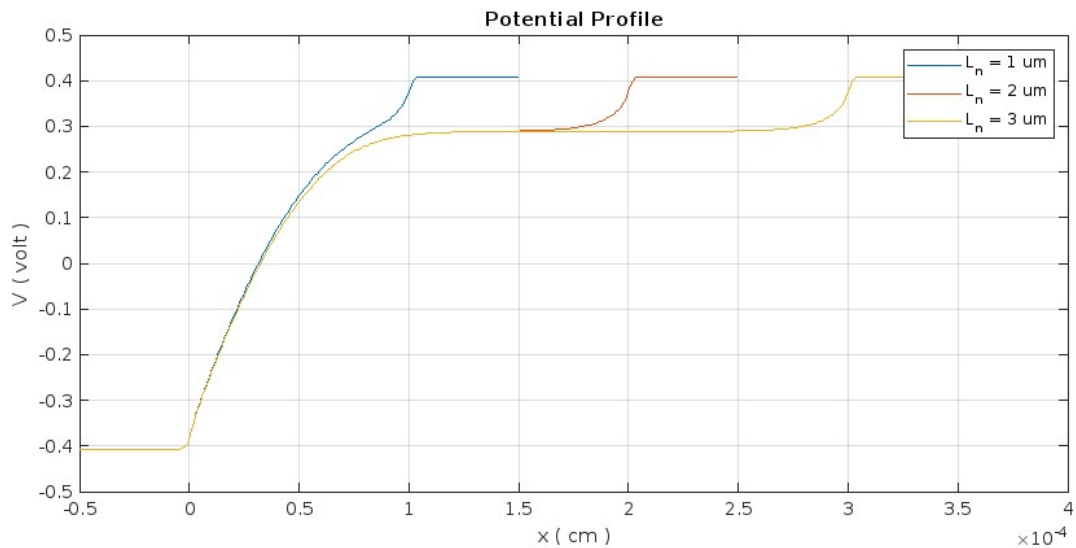The Potential profile for length of n region $1\ \mu m$, $2\ \mu m$ and $3\ \mu m$ are plotted in same plot.

The following profiles are simulated for by taking length of n region $2\ \mu m$

1. Potential (V)
2. Electric Field (E)
3. Charge concentration (ρ/q) (where q is electron charge)
4. Electron (n) and Hole (p) concentration.
5. Energy band diagram depicting conduction band minimum (E_C), Valence band maximum (E_V), mid gap energy level (E_{mid}) and Fermi energy level (E_F).
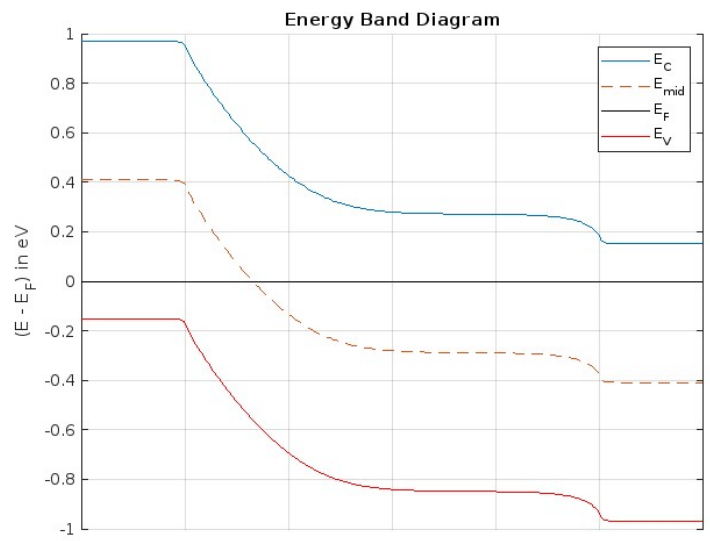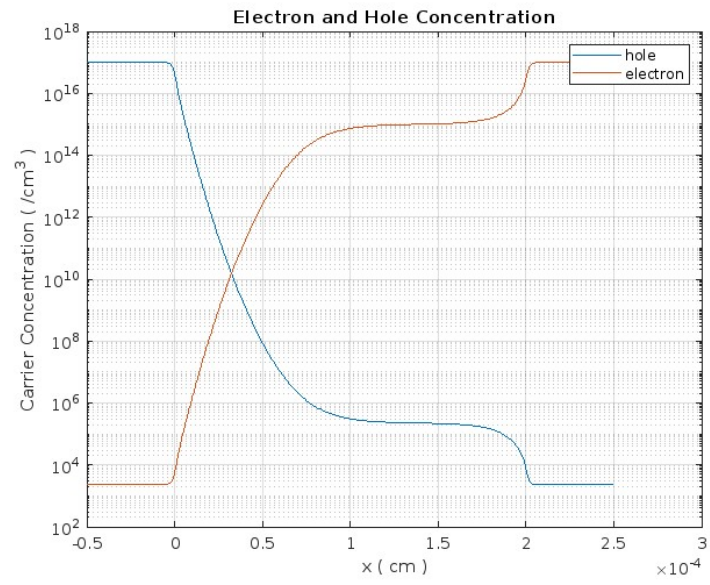
RESULT AND CONCLUSION

The plots of the various potential profiles are given below,

The plots of the various profiles are given below,

Voltage Profile

Electric Field Profile

Charge Concentration Profile

Electron and Hole Concentration

Energy Band Diagram
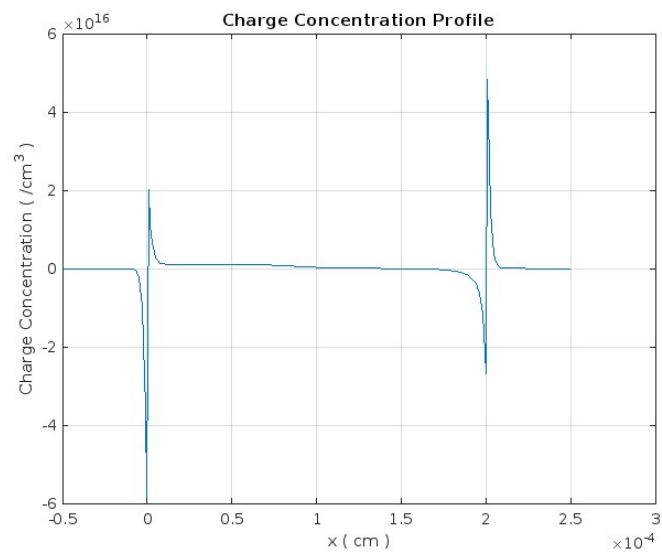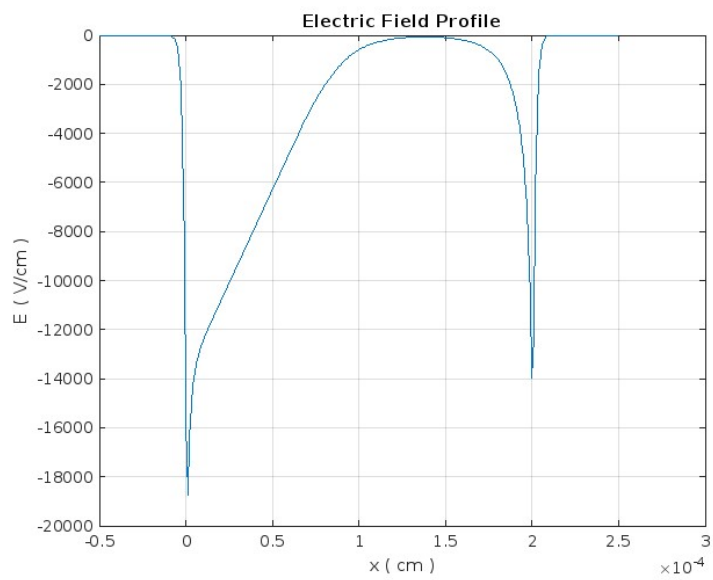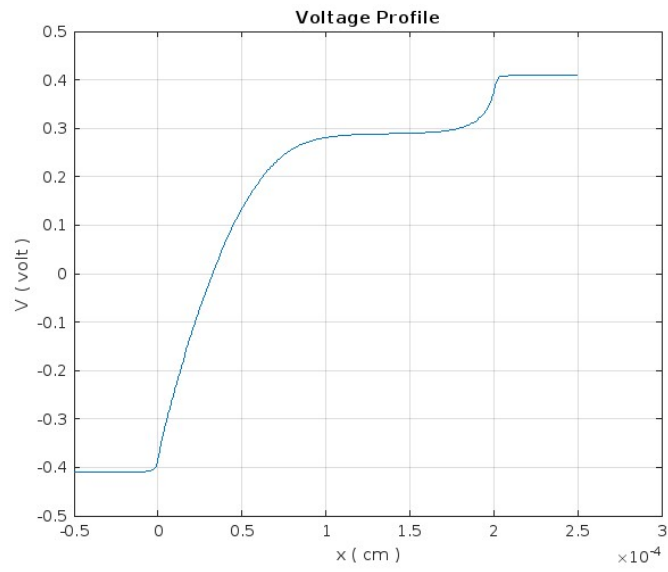
PROBLEM 3

SIMULATION APPROACH

Given,

$\epsilon_{Si} = 11.8$, $\varepsilon_0 = 8.85 \times 10^{-1}$ F/cm, $n_i = 1.5 \times 10^{10}$ /cm^3, q $= 1.6 \times 10^{-19}$ C

Temperature $(T) = 300$ K and Thermal voltage $(V_t) = 0.026\ V$, $E_g = 1.12$ eV

Built-in potential, $V_{bi} = 0.06 + \frac{3 \times 5}{300} = 0.11$ V

Length of both N-plus and N region, $L = 1.4\ \mu$m
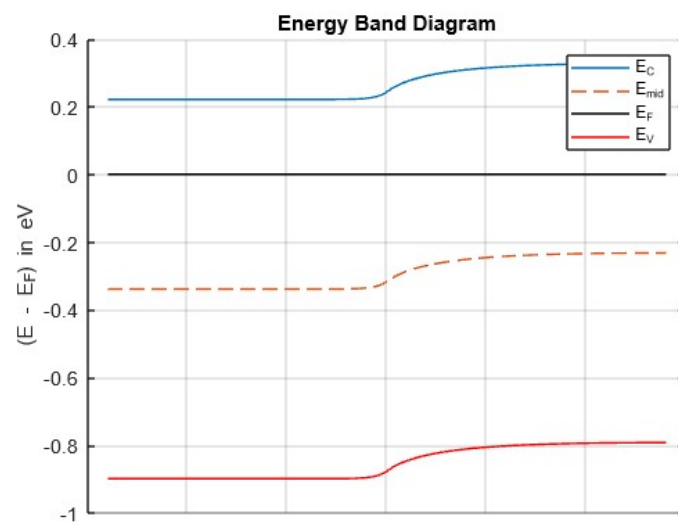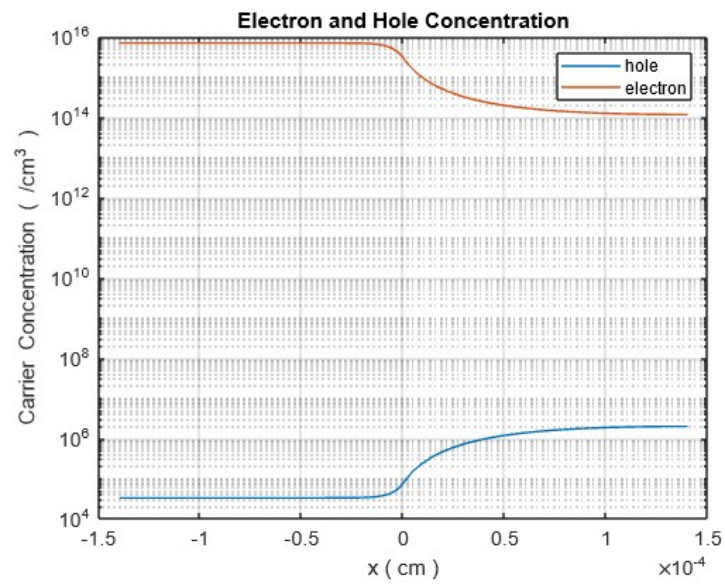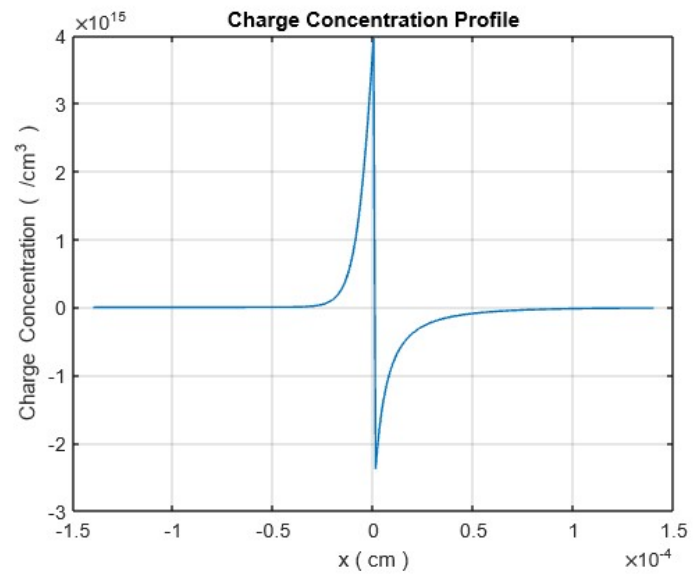
N-plus type region doping concentration $(N_{d2}) = 6.877 \times 10^{15}$ /cm^3

N type region doping concentration $(N_{d1}) = 10^{14}$ /cm^3

RESULT AND DISCUSSION

The profiles obtained are shown below,

Charge Concentration Profile

Electron and Hole Concentration

Energy Band Diagram
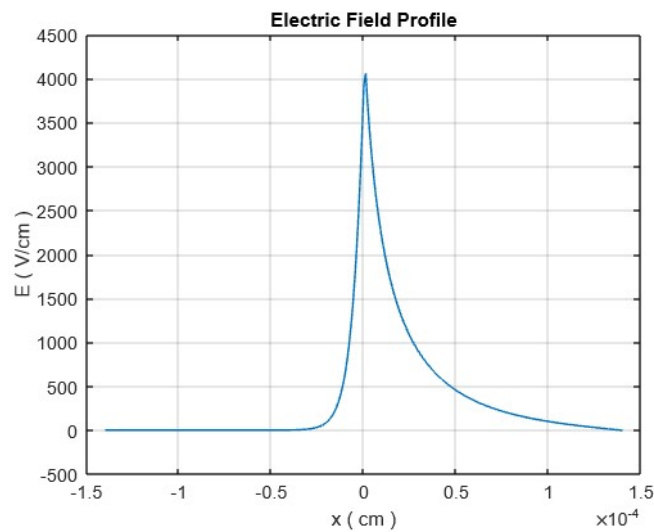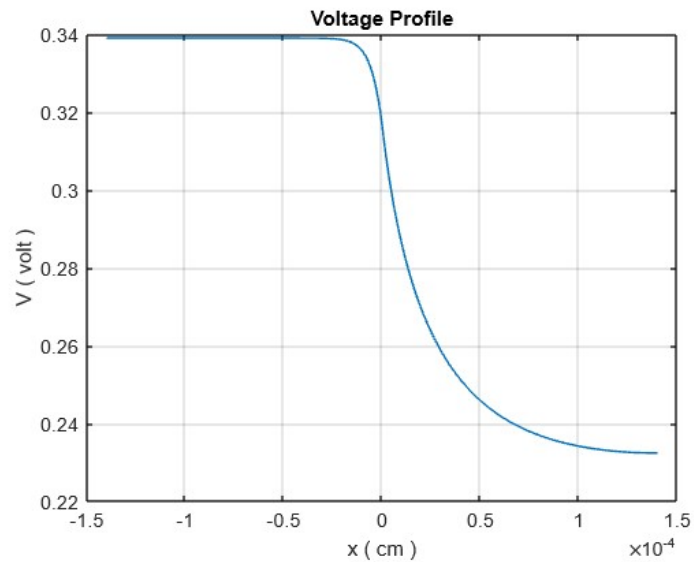
The voltage profile for T = 300 K and T = 304.5 K is given below,