DEPARTMENT OF ELECTRONIC ENGINEERING

N.E.D. UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOLID STATE DEVICE

BATCH 2017-18

LAB SESSION # 11, 12,13

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ROLL # EL-17062 SECTION: C

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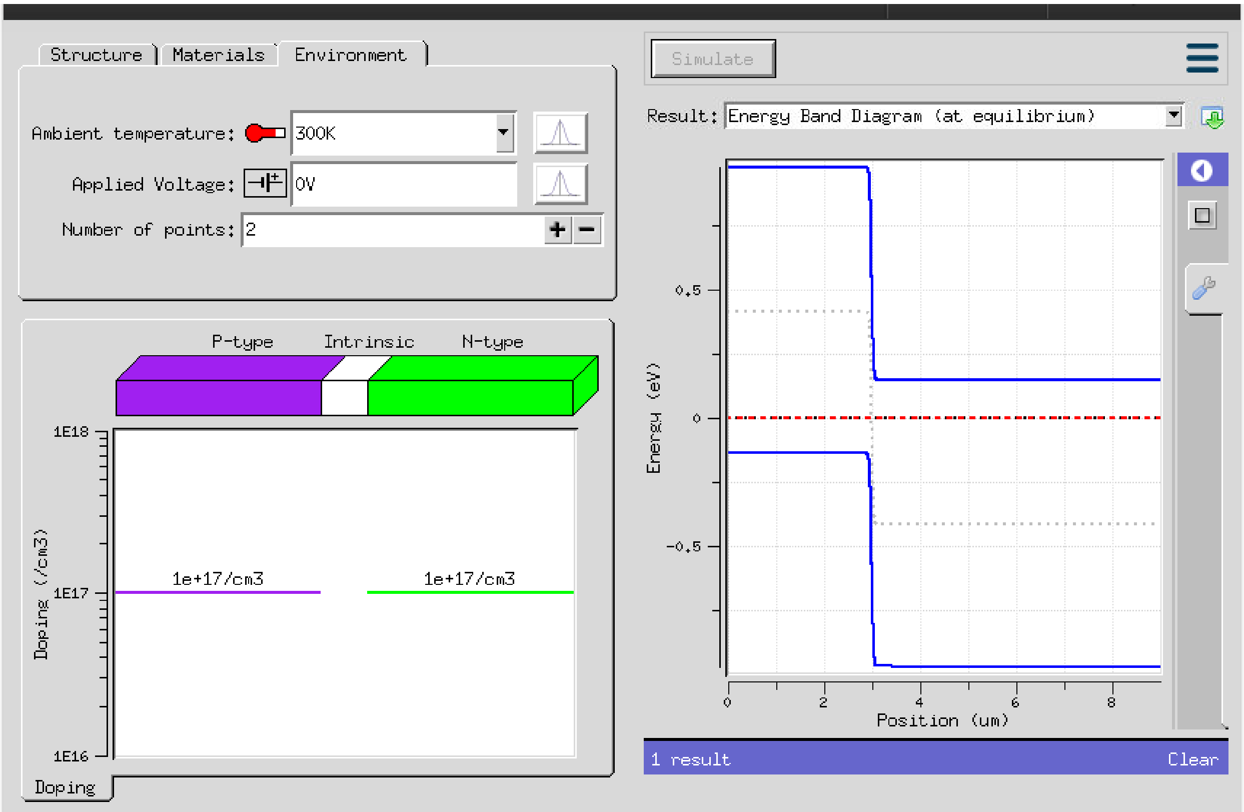
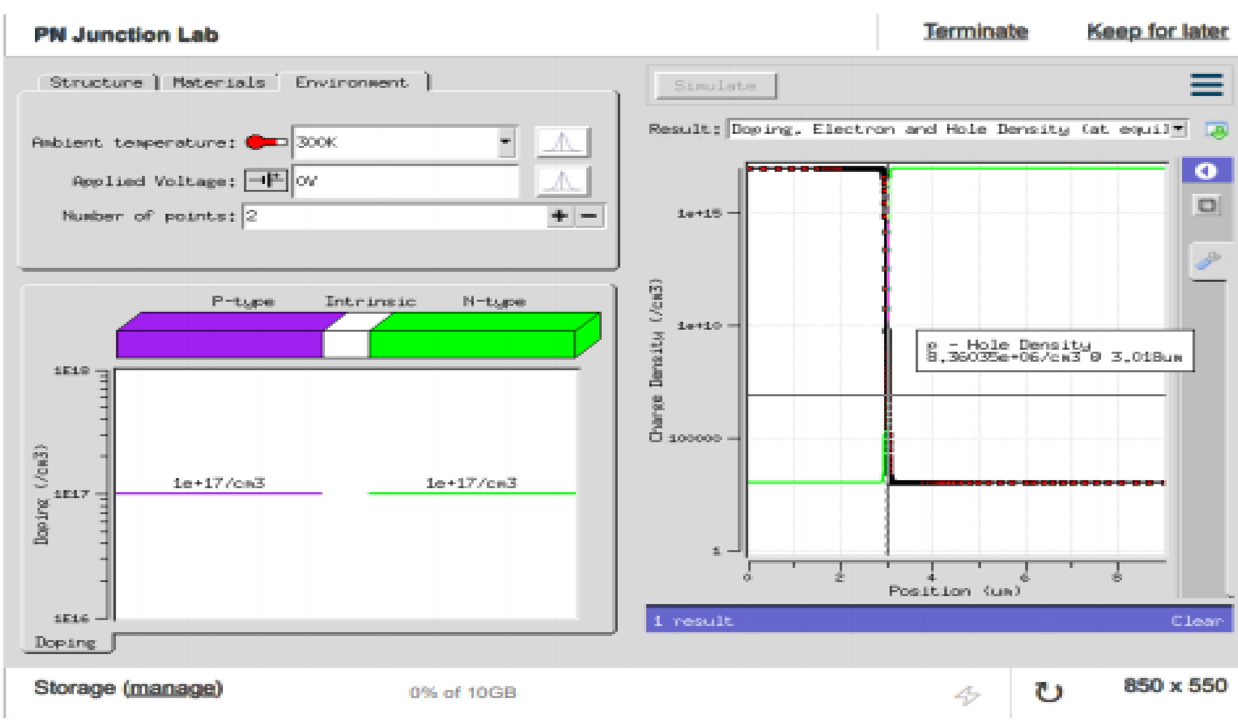
LAB 11

Task No.01 : - Consider an equally doped PN junction diode under equilibrium

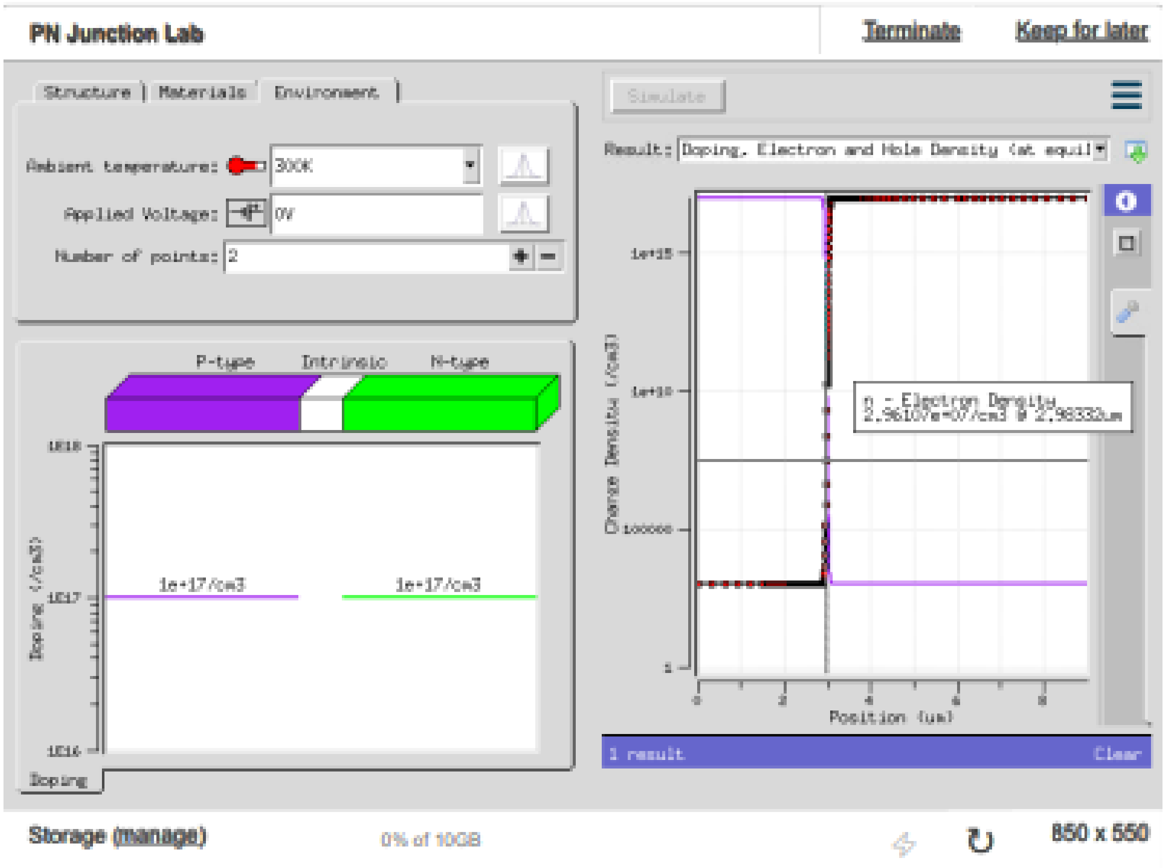
Q.1: - Observe the energy band diagram.



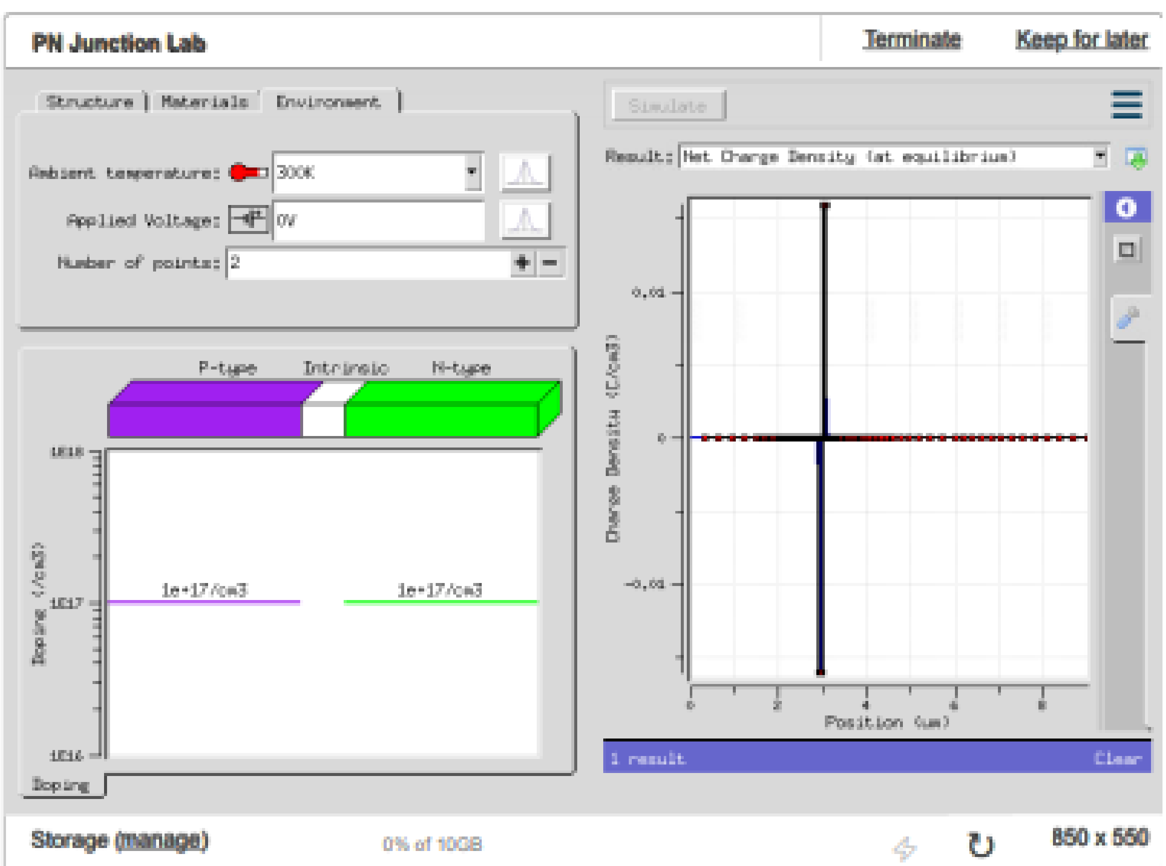
Q.2: -Observe doping, electron and hole density



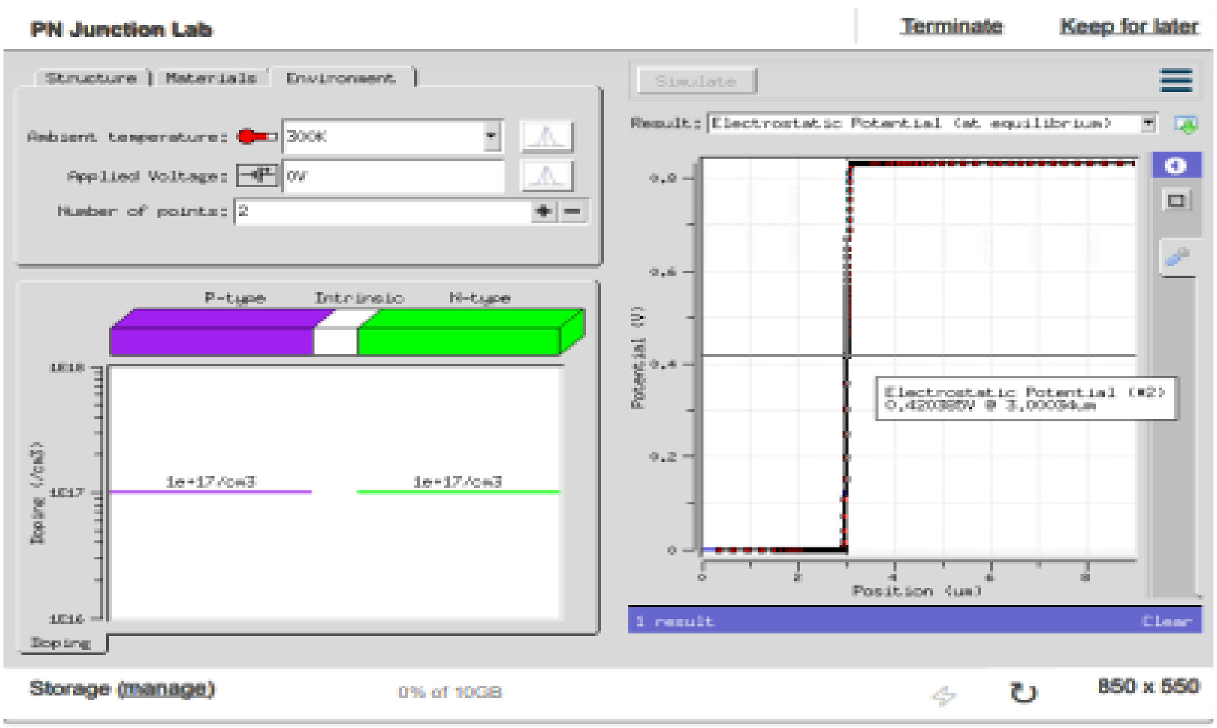
Q.3: - Write down the values of pp, pn, np, n�



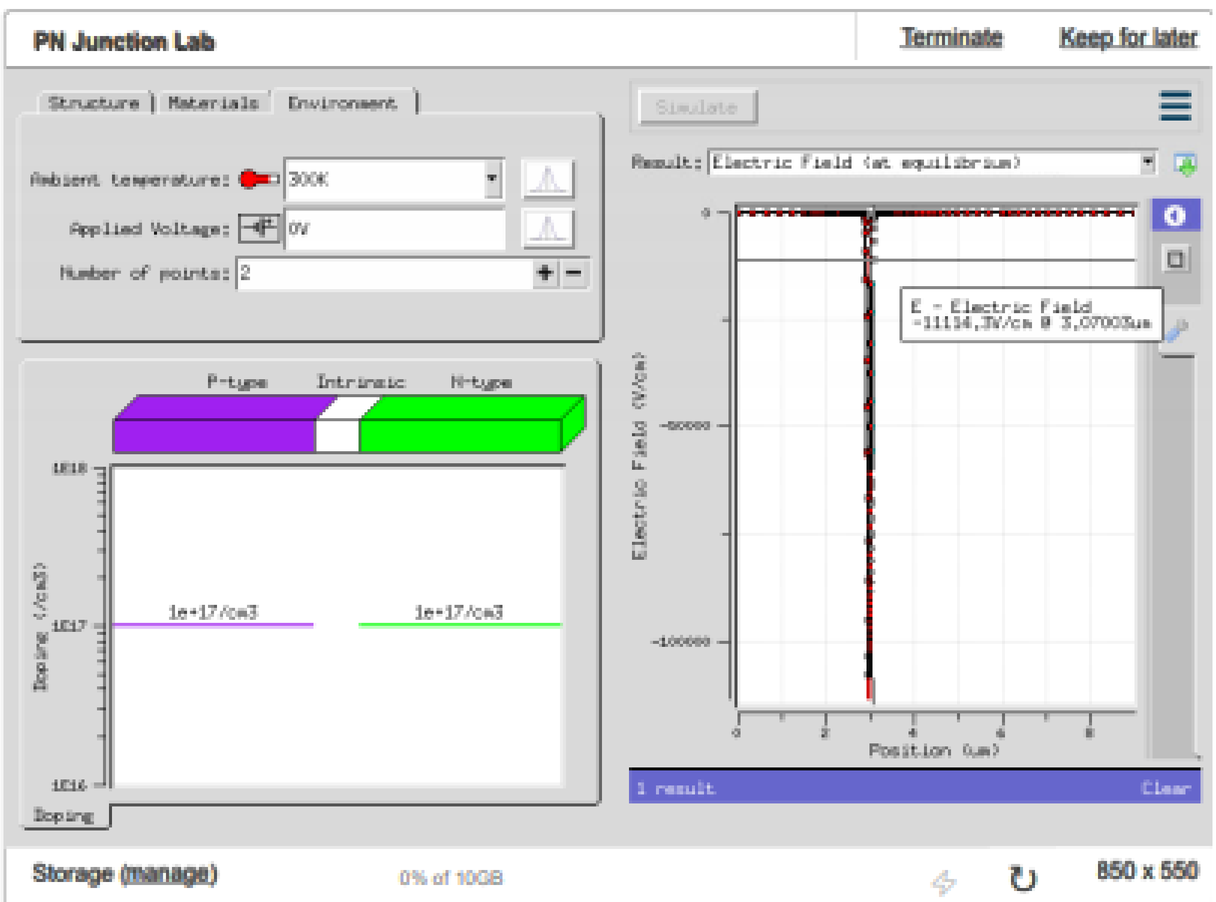
Q.4: - Observe the charge density.



Q.5:- Observe the electrostatic potential.



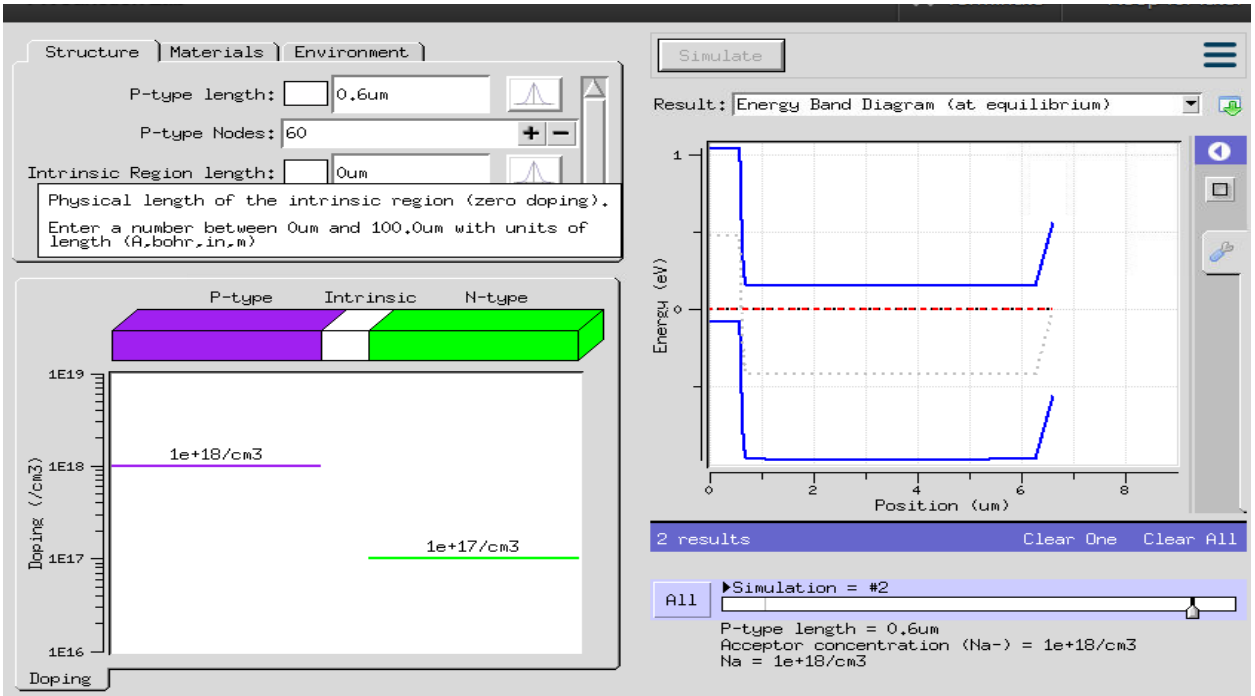
Q.7:- Observe the electric field



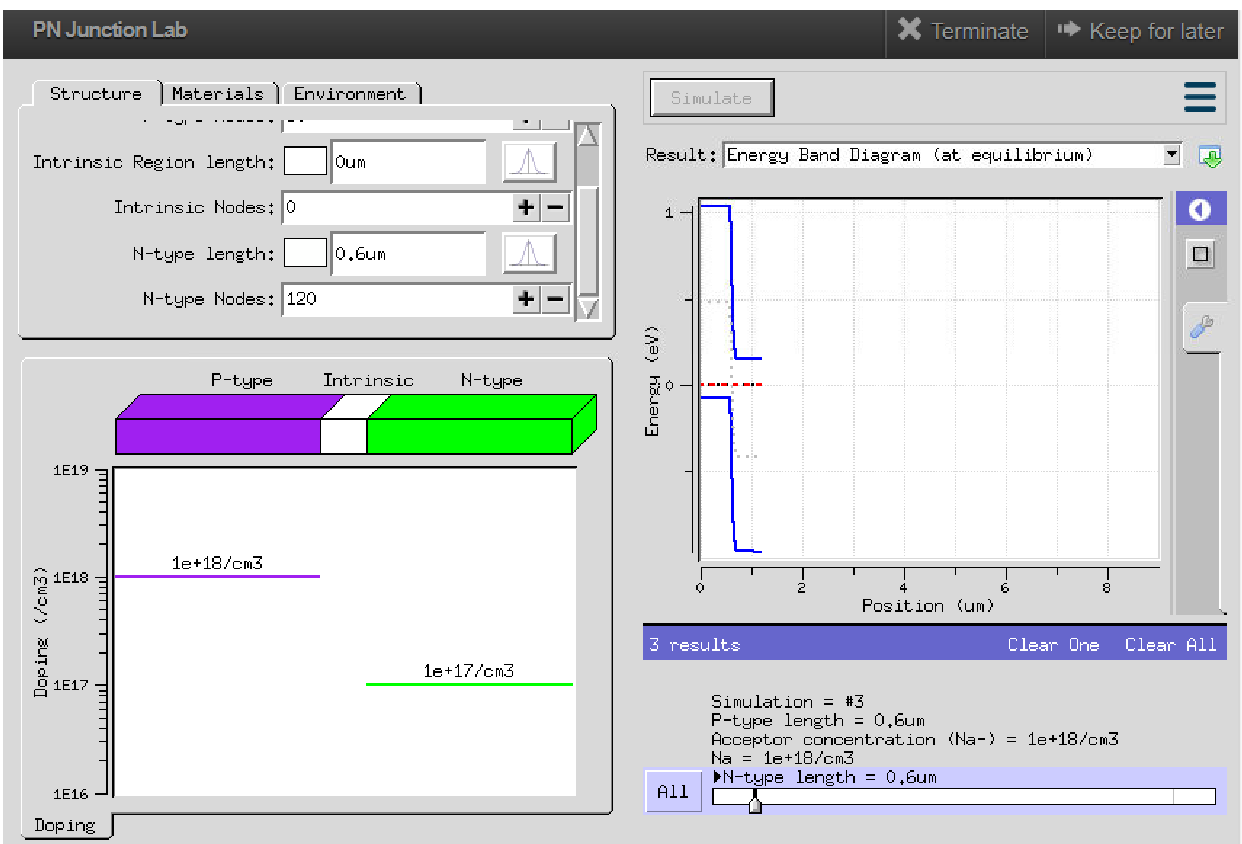
Task No.02:- Observe 3 PN junction diodes. First assume $Nd > Na$, then assume $Nd = Na$ and lastly $Nd < Na$

Q.1: - Compare the energy band diagrams of the above mentioned junctions.

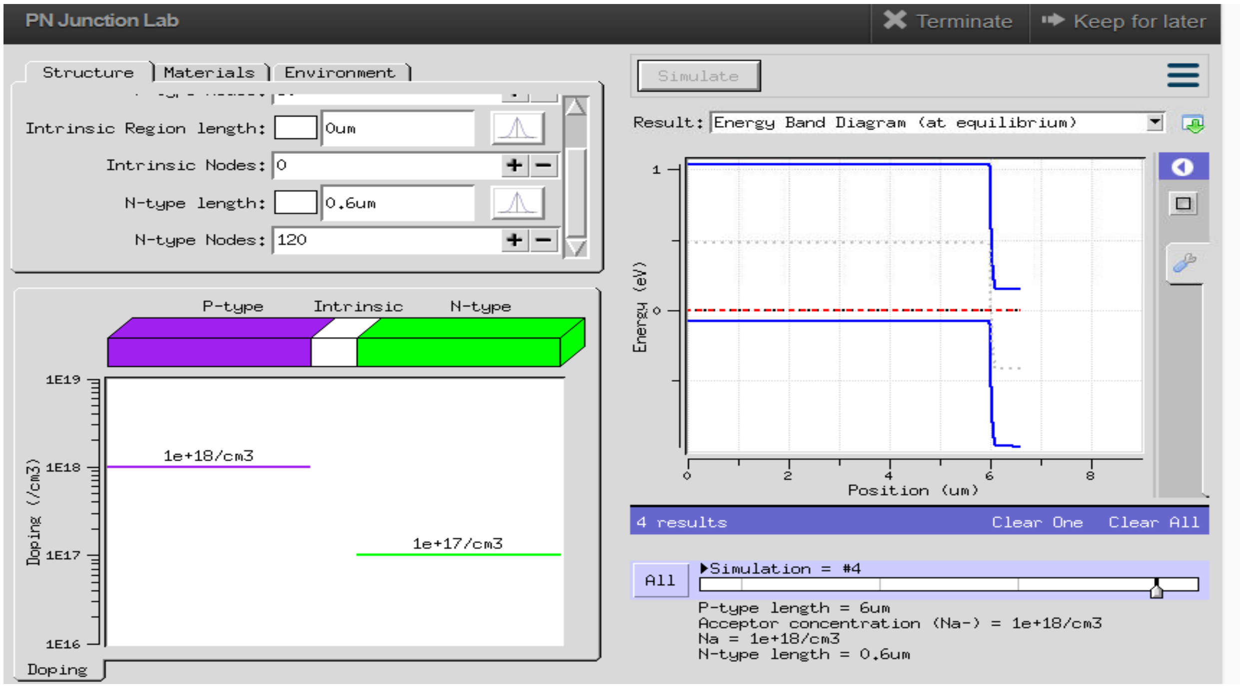
For $Nd > Na$



For $Nd = Na$



For $Nd < Na$

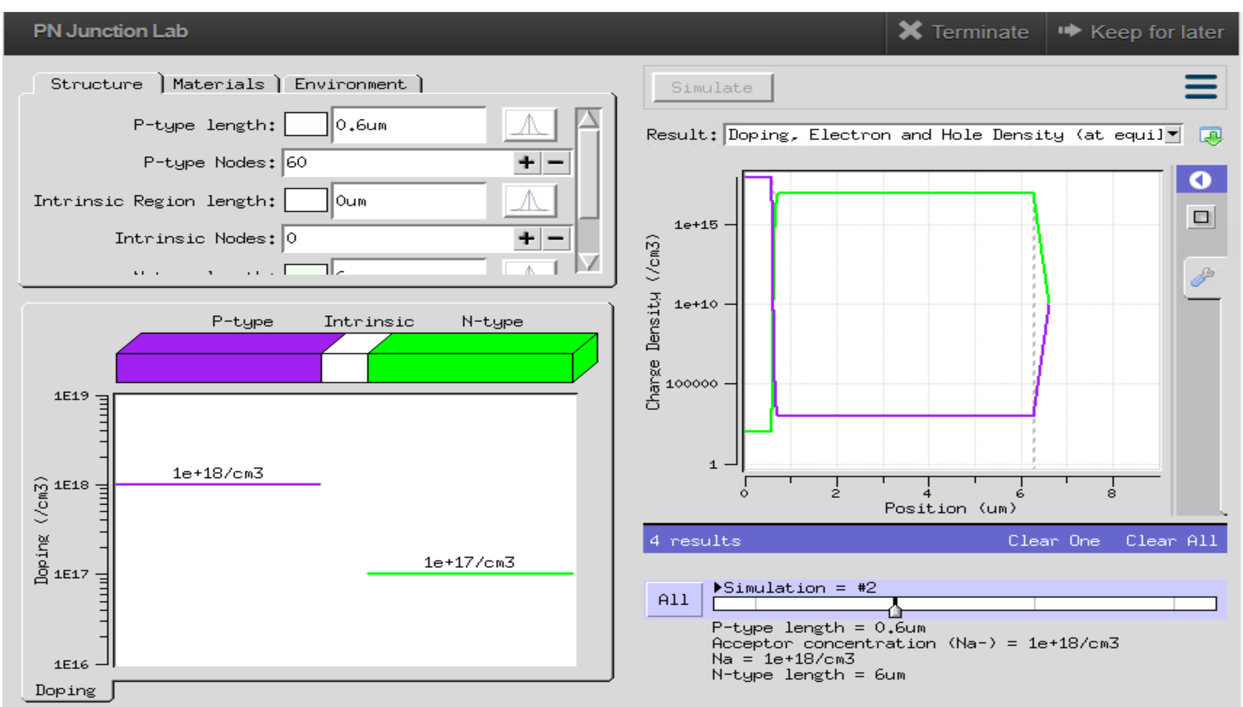


Q.2: - What is the effect of doing on depletion region width?

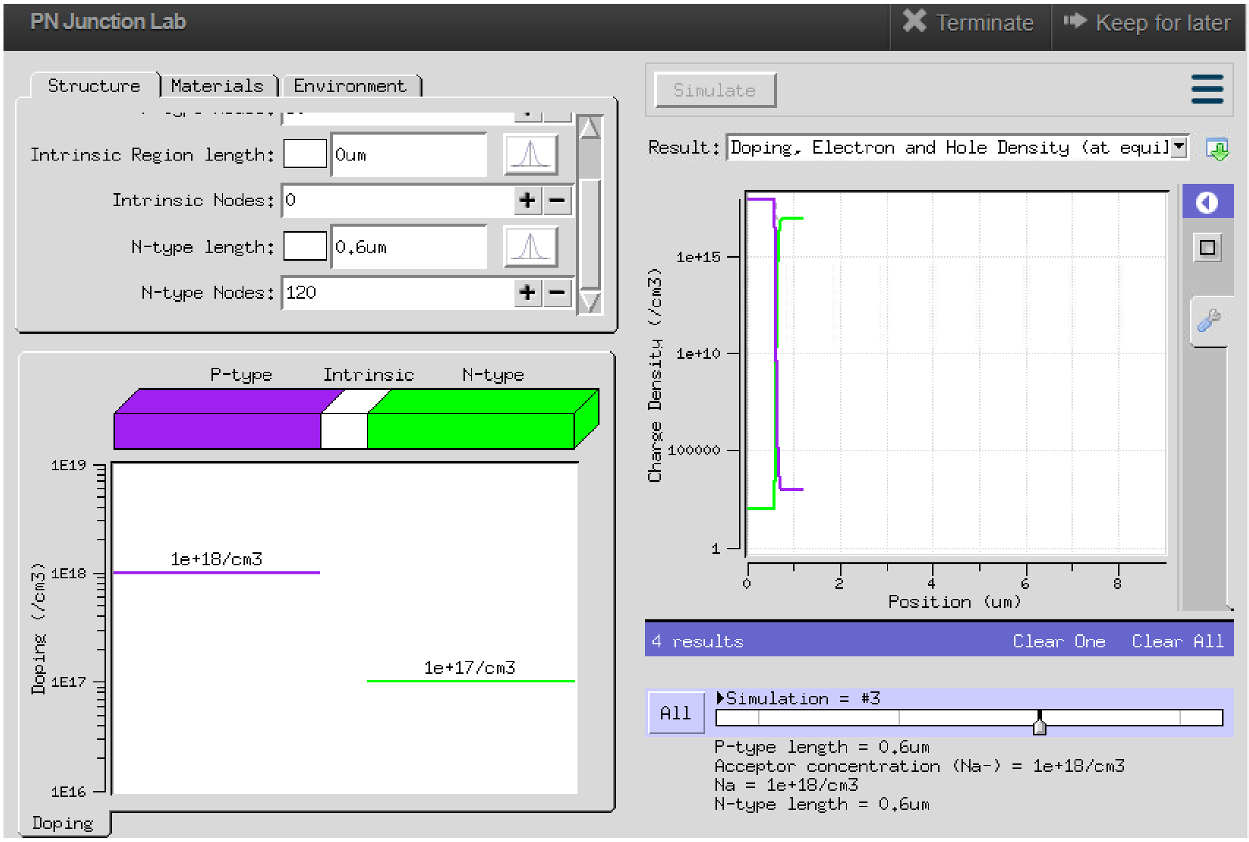
We can say depletion width decreases with increase in doping because it does but only relative to the doping on the other side of the pn junction. If each side of the junction has equal numbers of majority carriers then the same depletion region width is needed to uncover the same amount of space charge.

Q.3: - Compare doping, electron density and hole density of the 3 PN junction diodes.

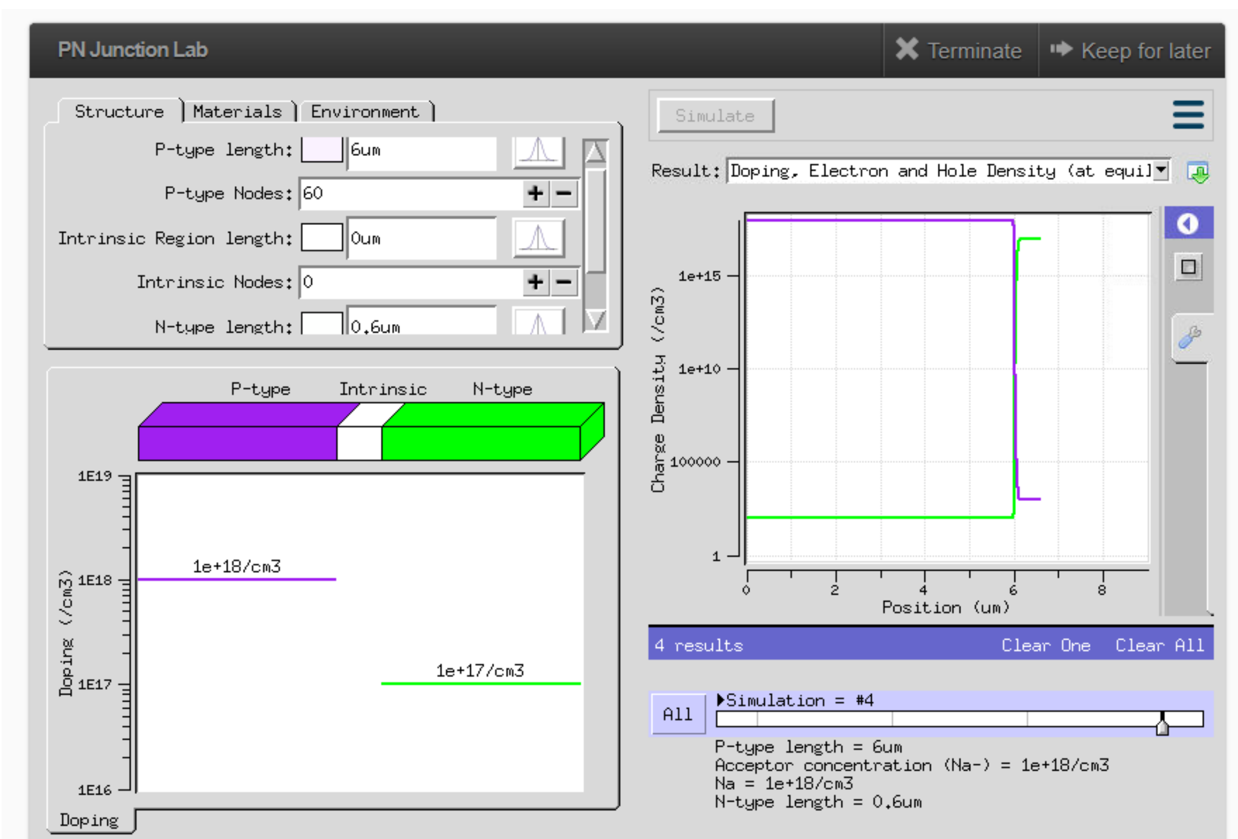
For $Nd > Na$



For $Nd = Na$

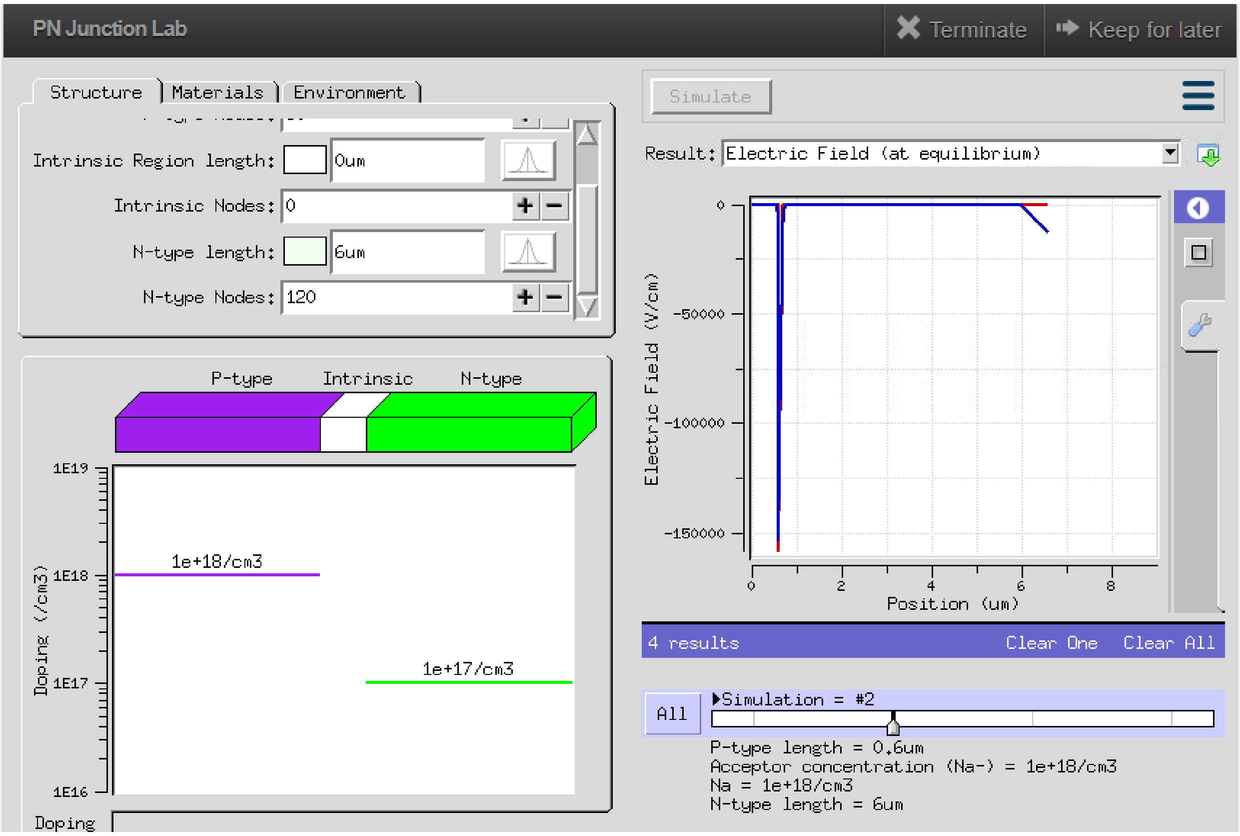


For $Nd < Na$

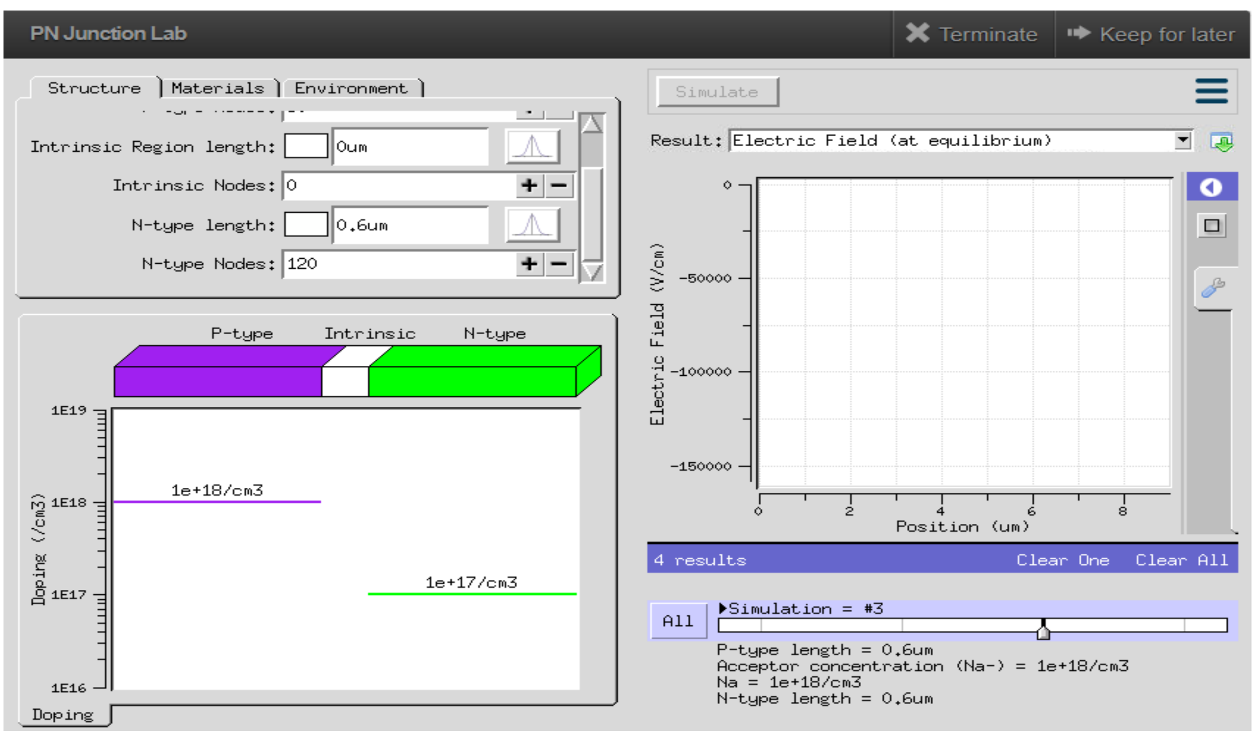


Q.5: - Compare the electric field of these 3 diodes under equilibrium

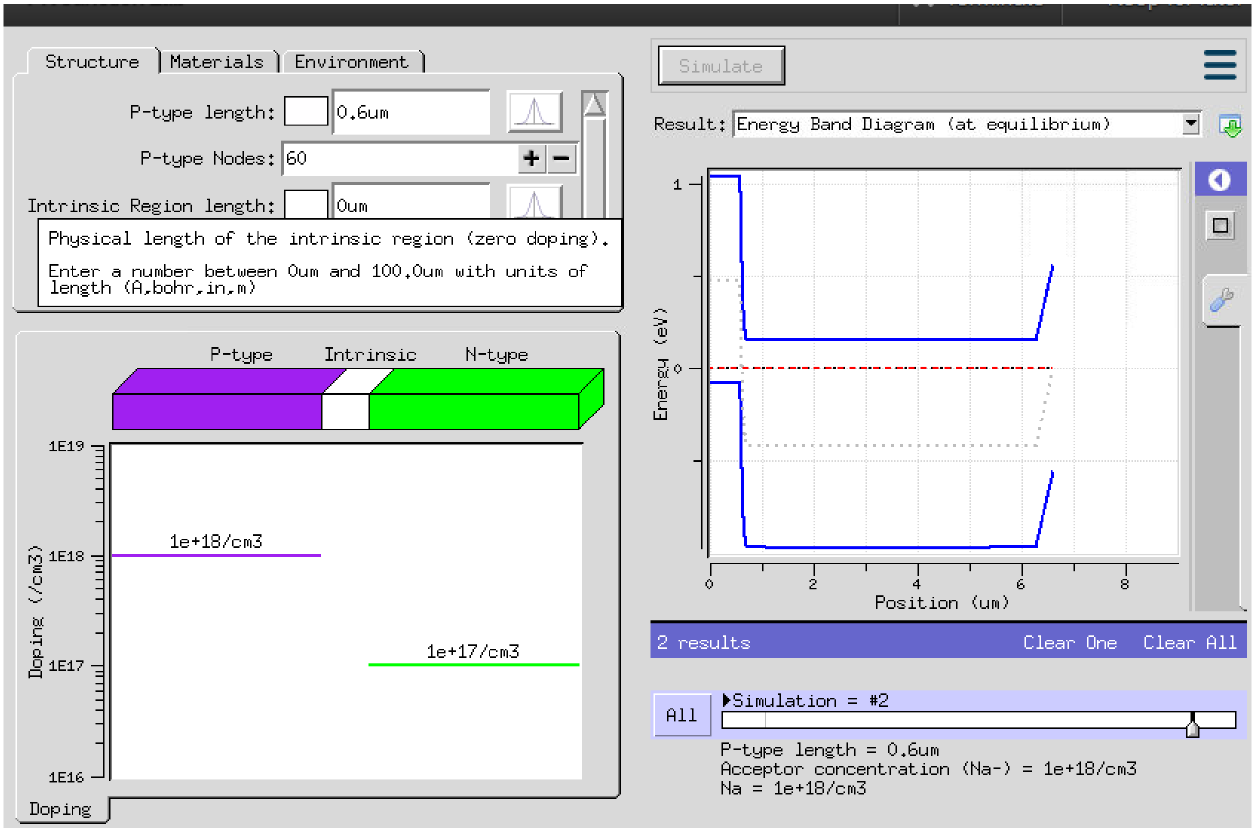
For $Nd > Na$



For $Nd = Na$



For $Nd < Na$



Structure
Materials
Environment
P-type length:
0.6um
P-type Nodes:
60
Intrinsic Region length:
0um
Physical length of the intrinsic region (zero doping).
Enter a number between 0um and 100.0um with units of length (A,bohr,in,m)
P-type
Intrinsic
N-type
1E19
1E18
1E17
1E16
Doping (/cm3)
1e+18/cm3
1e+17/cm3
Doping
Simulate
Result:
Energy Band Diagram (at equilibrium)
Energy (eV)
Position (um)
2 results
Clear One
Clear All
All
Simulation = #2
P-type length = 0.6um
Acceptor concentration (Na-) = 1e+18/cm3
Na = 1e+18/cm3

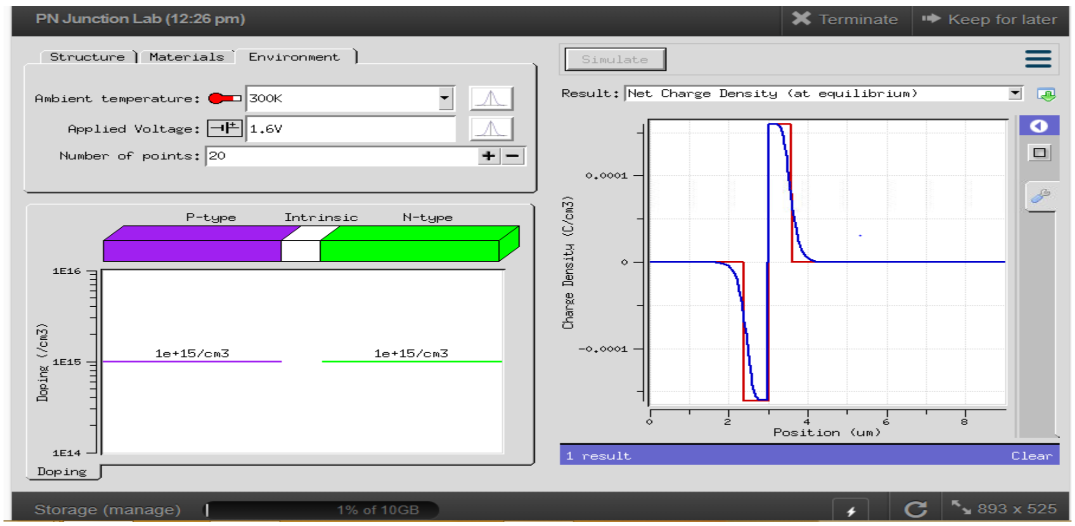
Lab 12

Task 1: Observe a PN junction diode under forward bias

Q.1: - Compare the charge density of forward biased diode with an unbiased diode

Charge density is becoming negative, from 0 to -0.0006 and then at position 3um it is 0.0001602 C/cm^3 and then it is decreasing to 0.

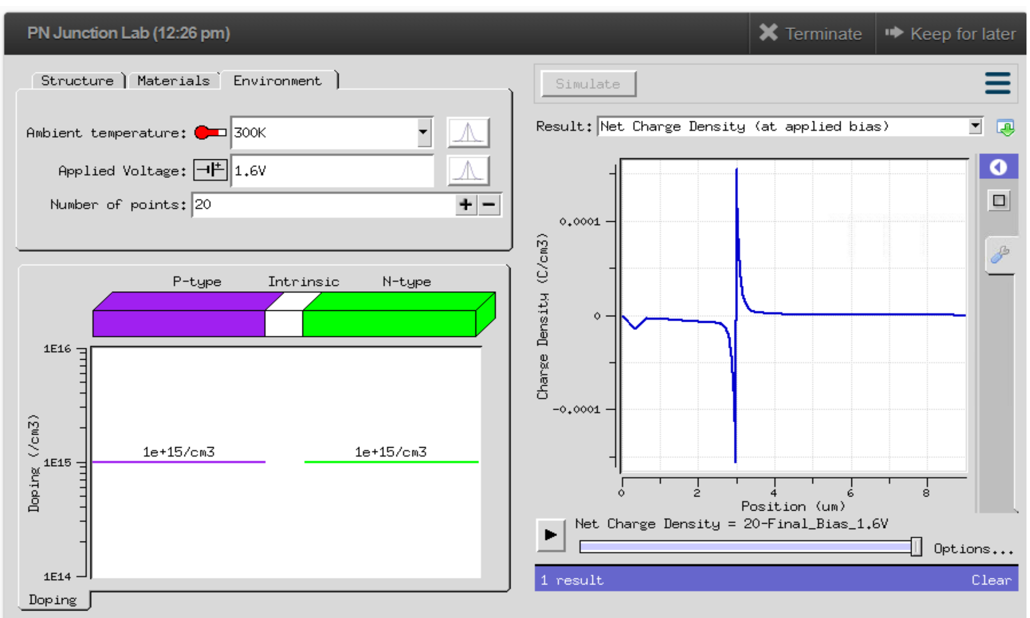
Net charge is 0.0001602C/cm^3 at position 3um



Biased net charge density

Here at position 3um there is a sharp change in charge density which peaks at 0.0001549C/cm3. And then sharply falls close to 0.

Initially it falls sharpy from 0 to -0.00015C/cm3 at 2.99um, and at 3.00 it is 0.00015C/cm3 and then sharply falls close to zero.

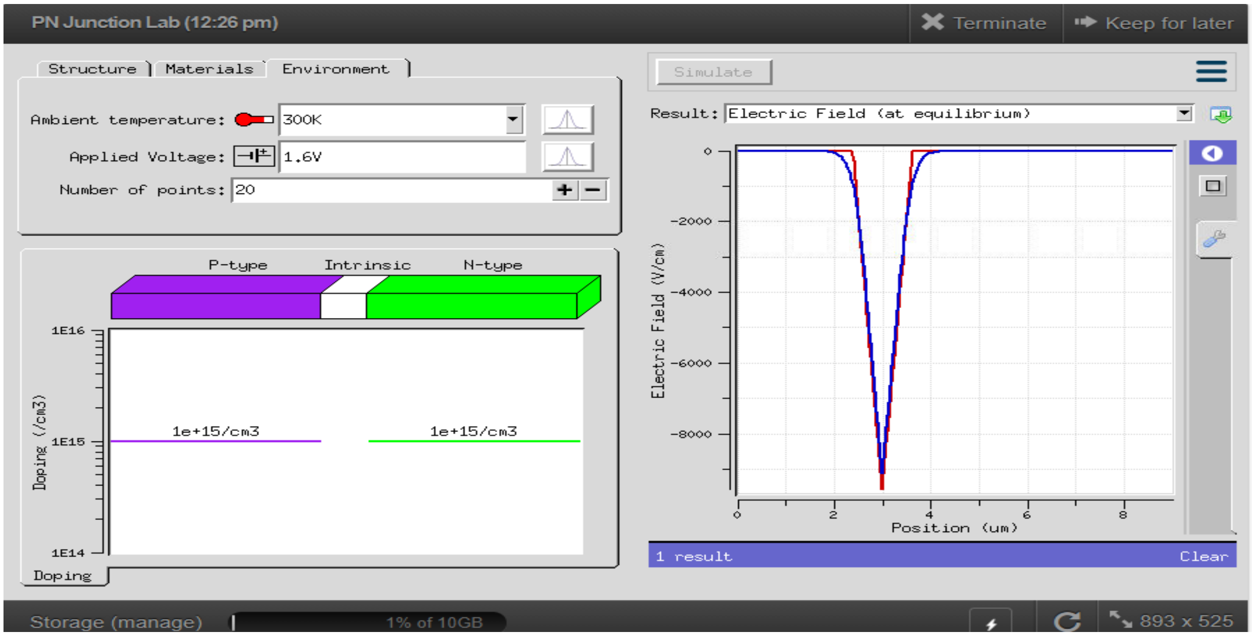


Q.2: - Is there any change in charge density and width of the depletion region by forward biasing the diode. Yes/No? Justify

Yes there is a difference in the width of the depletion region with forward biasing the diode because when an external voltage V is applied across the semiconductor **diode** such that p-side is positive and n-side is negative , the direction of applied voltage (V) is opposite to the barrier potential (V0). As a result the **depletion layer width** decreases and the barrier height is reduced.

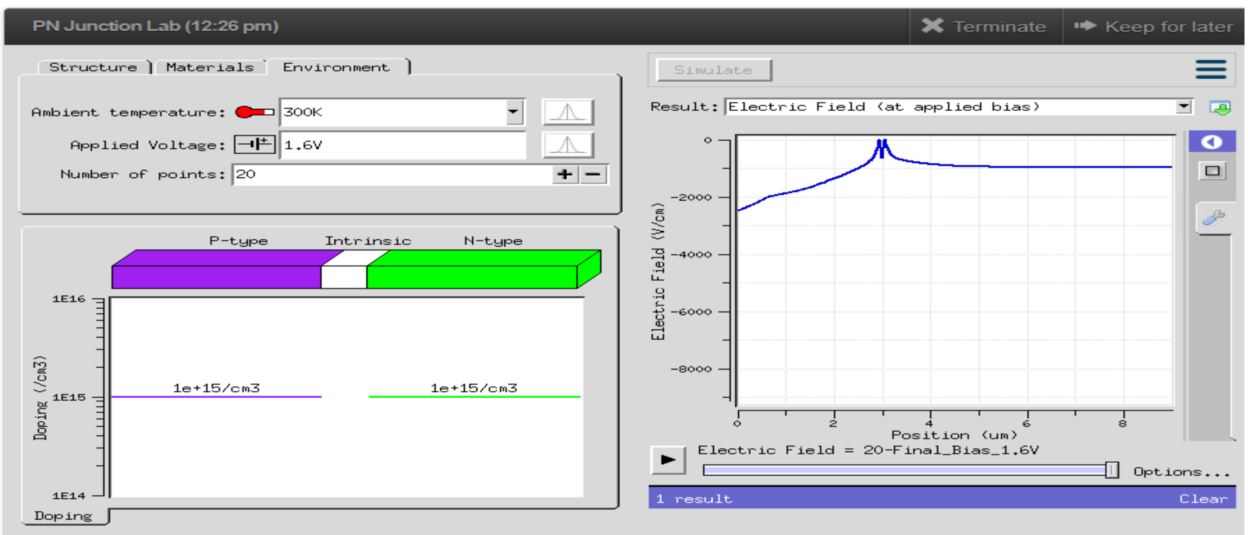
Q.3:- Compare the electric field of a forward biased diode with an unbiased

Electric field is -9114.08V/cm at position 3um



Electric field biased

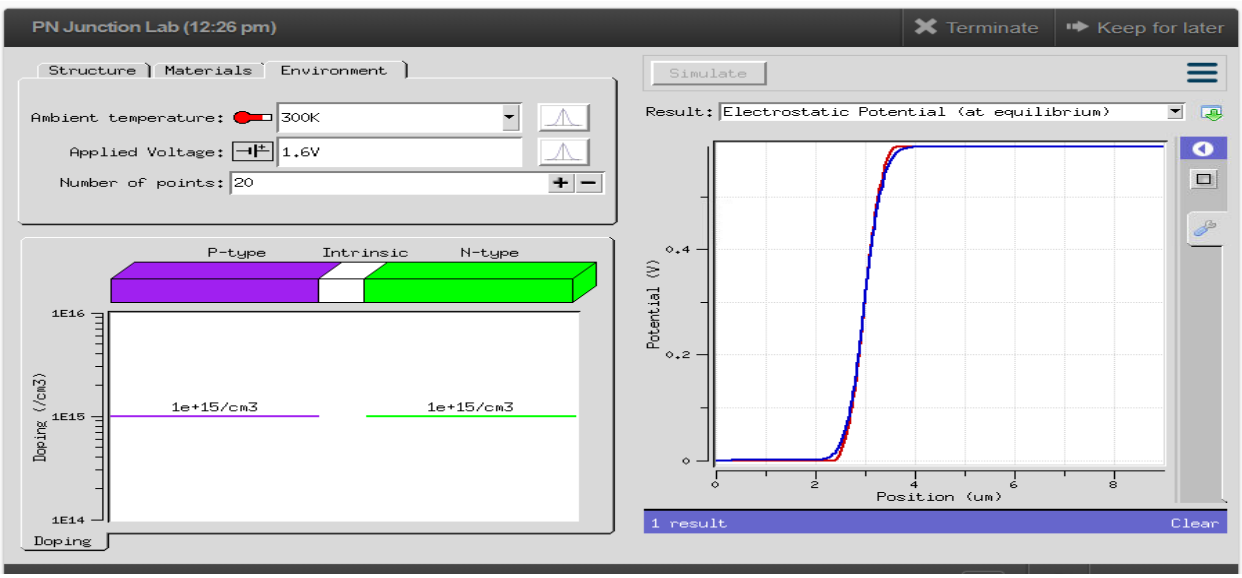
Electric field is -638.84 V/cm at 3um. There is a dip at this position. And then electric field is 0



Q.4:- Compare the electrostatic potential of a forward biased diode with an unbiased diode

The electric fields are different. Electric field is not zero at any position. It does come close to zero but is a non zero value at other positions. It starts from -2476.68V/cm and then starts decreasing to almost zero, then increases to -638.84V/cm then it becomes steady to – 962.326V/cm.

Unbiased electrostatic potential

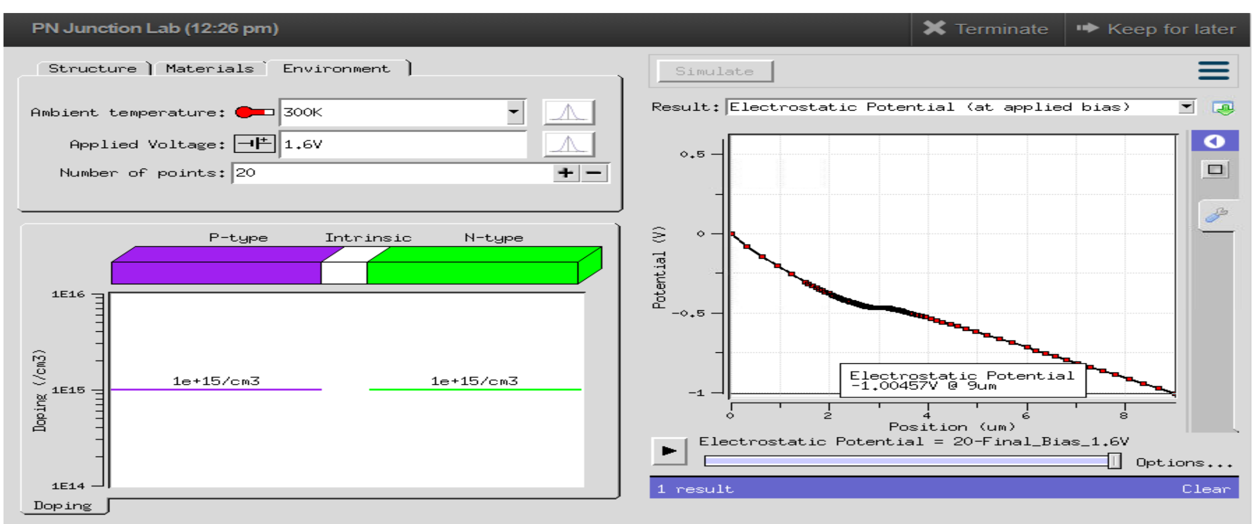


0.594349V at 3.95um

0.5905 at 9um

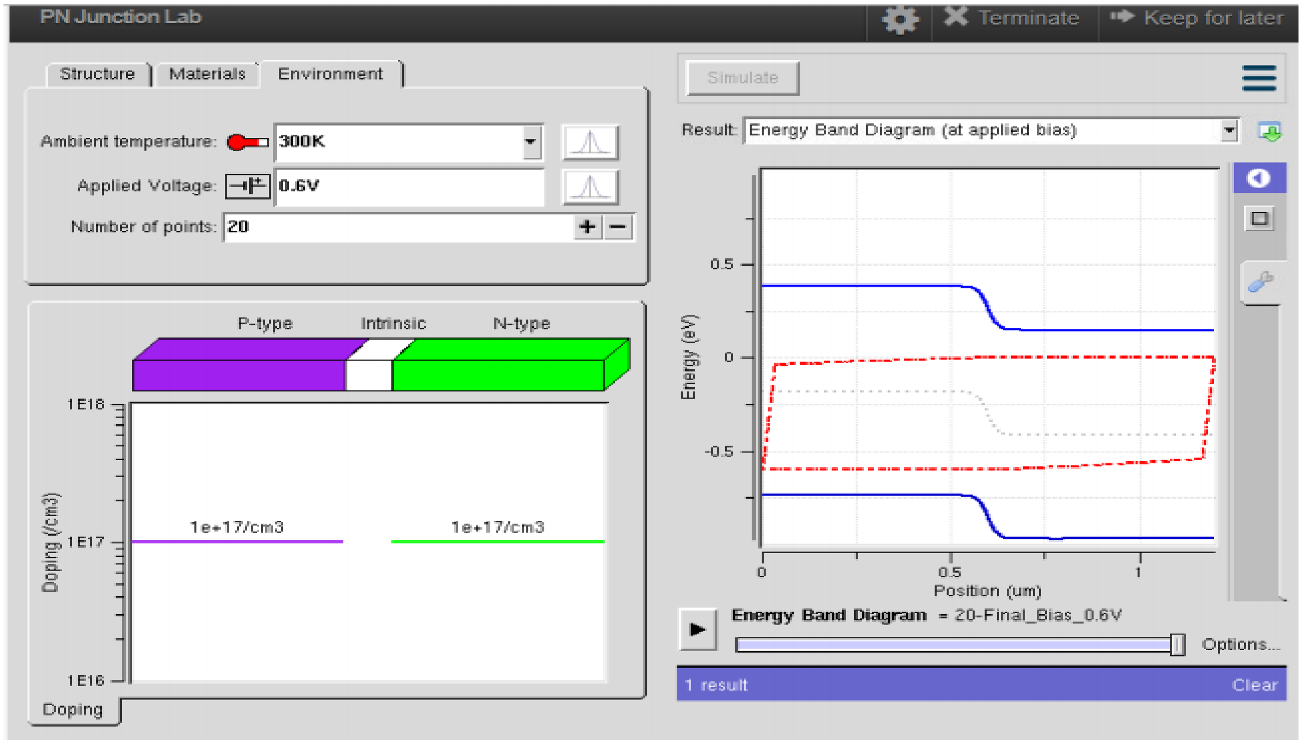
Electrostatic potential unbiased

From 0 the electrostatic potential is increasing and increases to -1.00 at position 9um

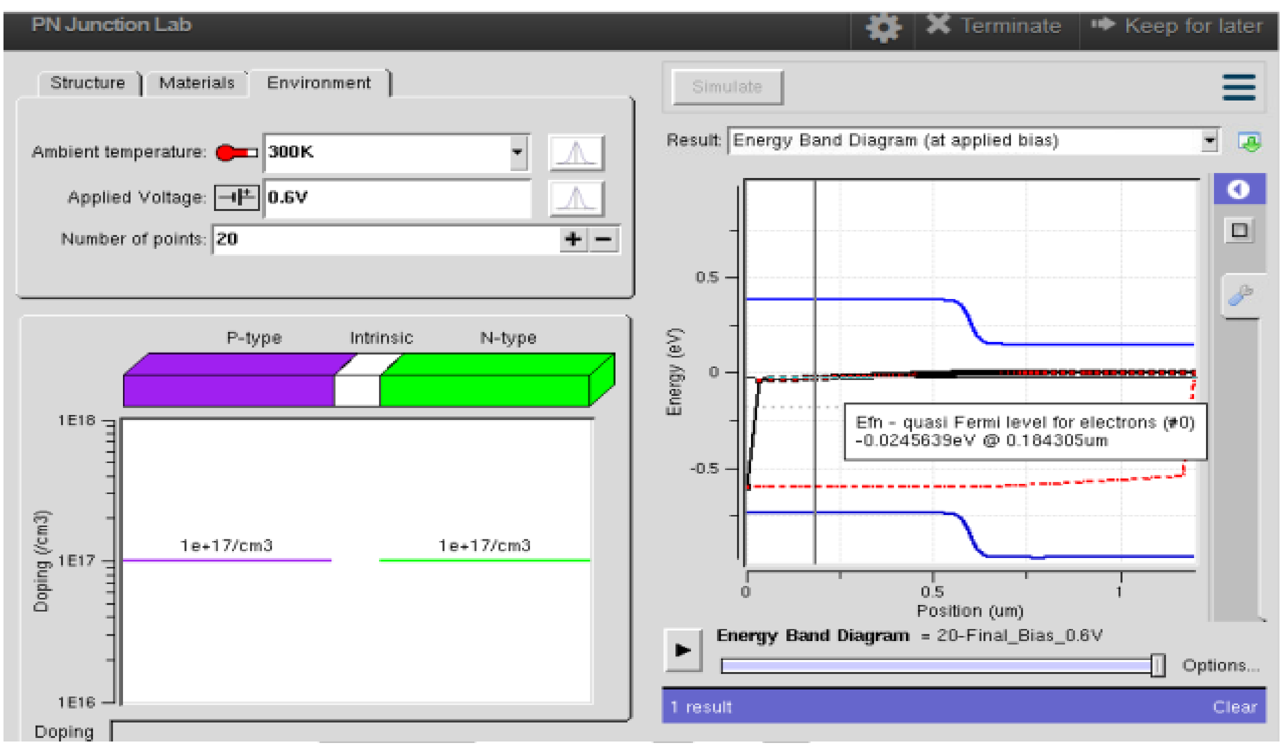


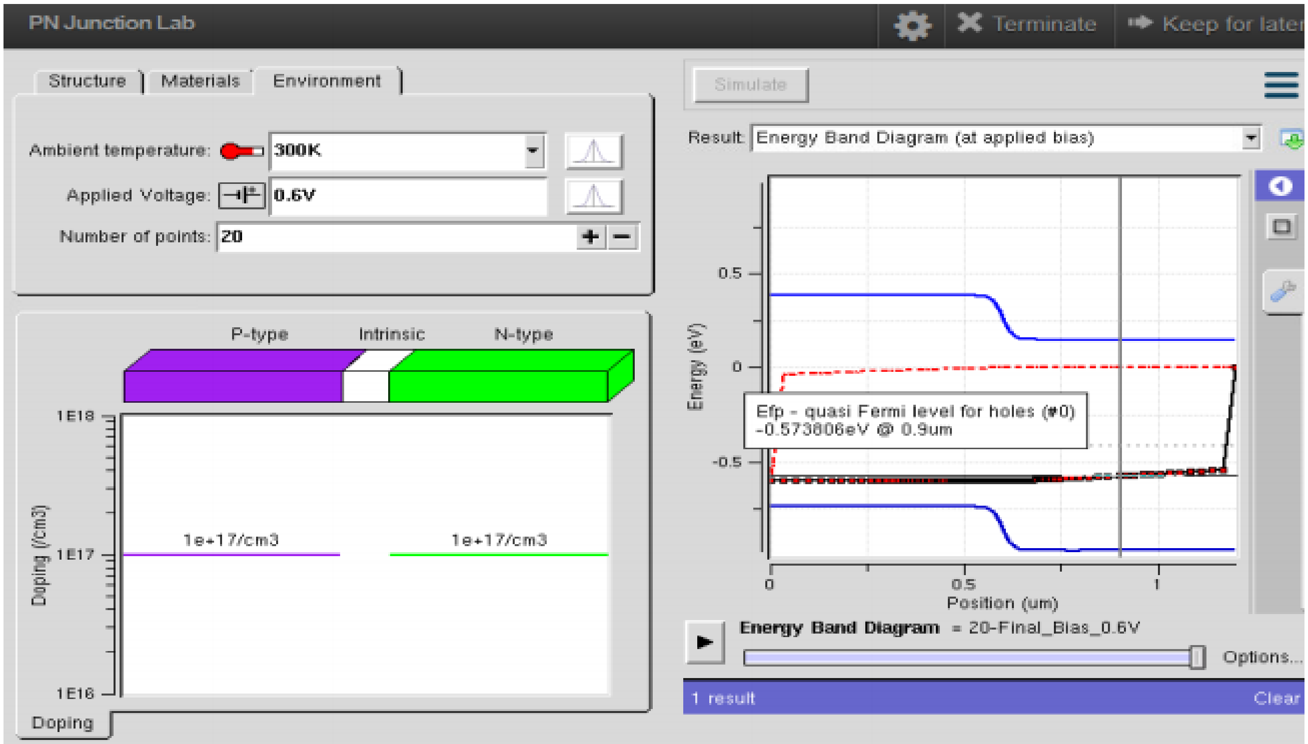
Task No.02: - Now forward bias the PN junction by applying a potential equals to $Vbb - 0.2V$ (Take the value of Vbb from task 1 of last lab)

Q.1:- Observe the energy band diagram under applied bias



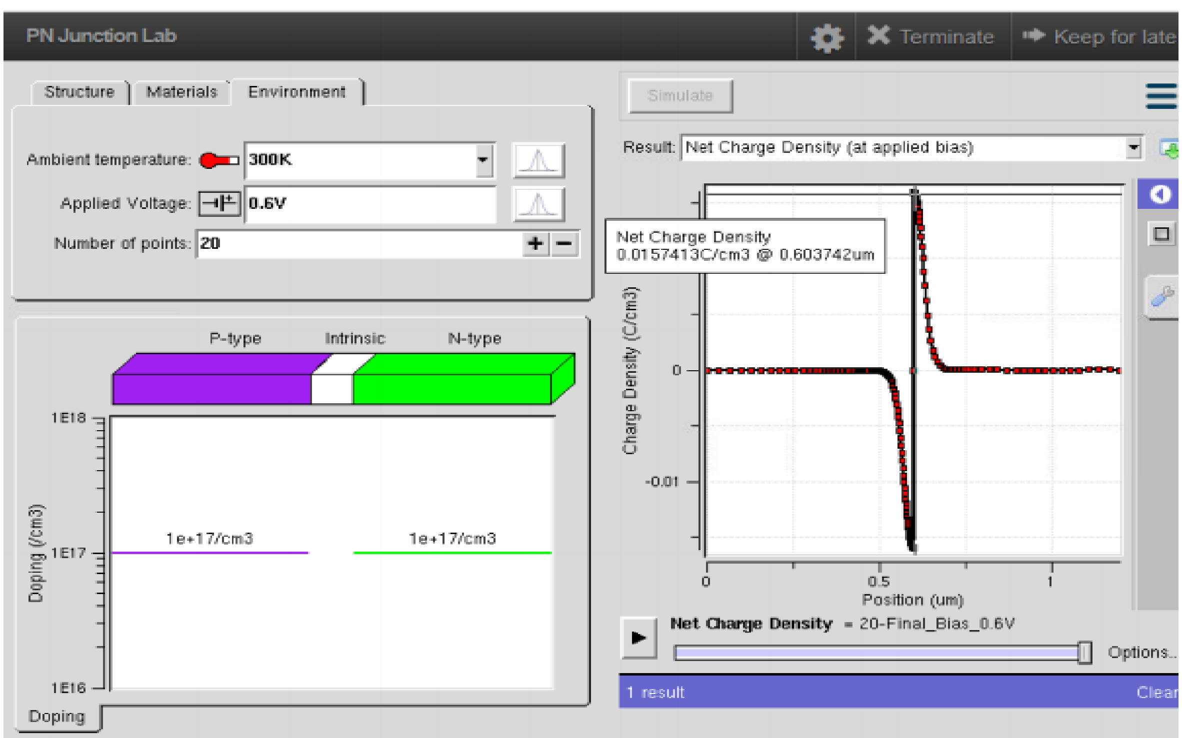
Q.2: -What information do you get about carrier concentration by looking quasi Fermi level in the energy band diagram?



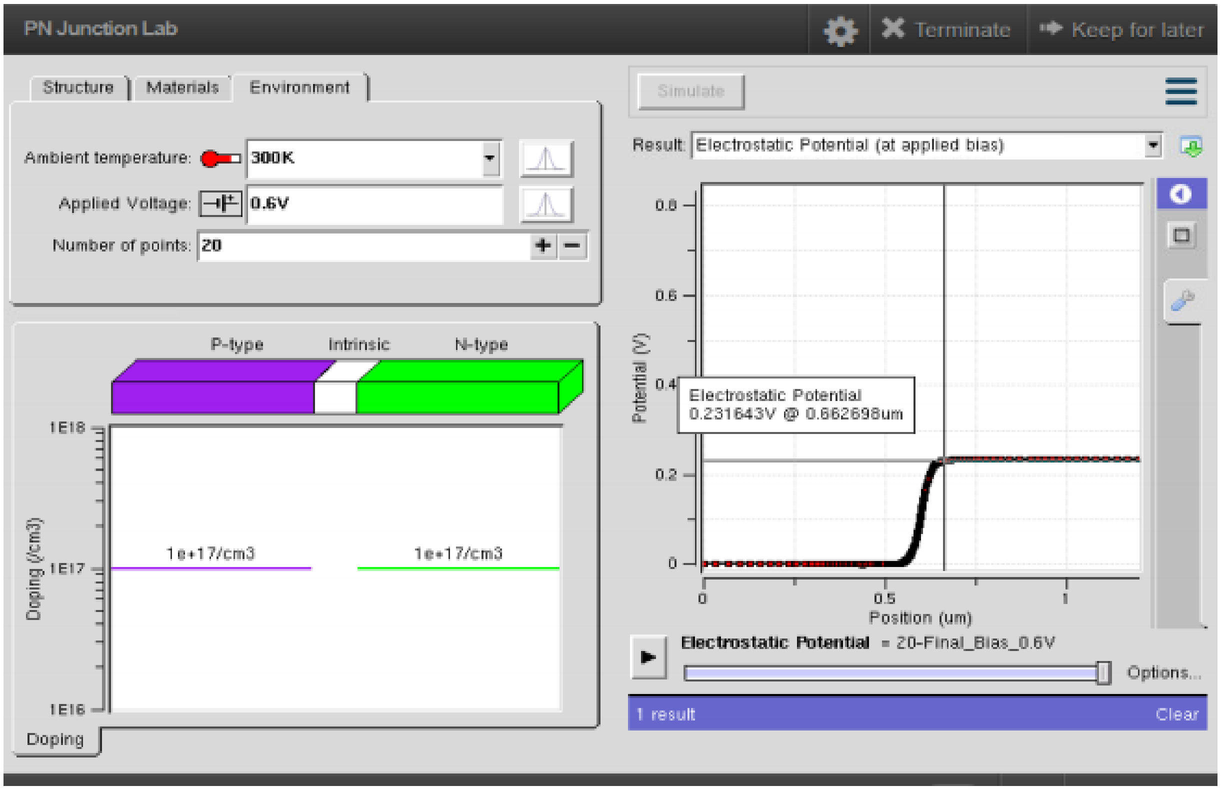


If we look at the energy band diagram we will find that electron will diffuse from n side to p side so quasi Fermi level for electron is present near to Ec. There is very little change in fermi level because a few electron will recombine with holes and most of them will reach to the boundary of p-n junction diode without recombination

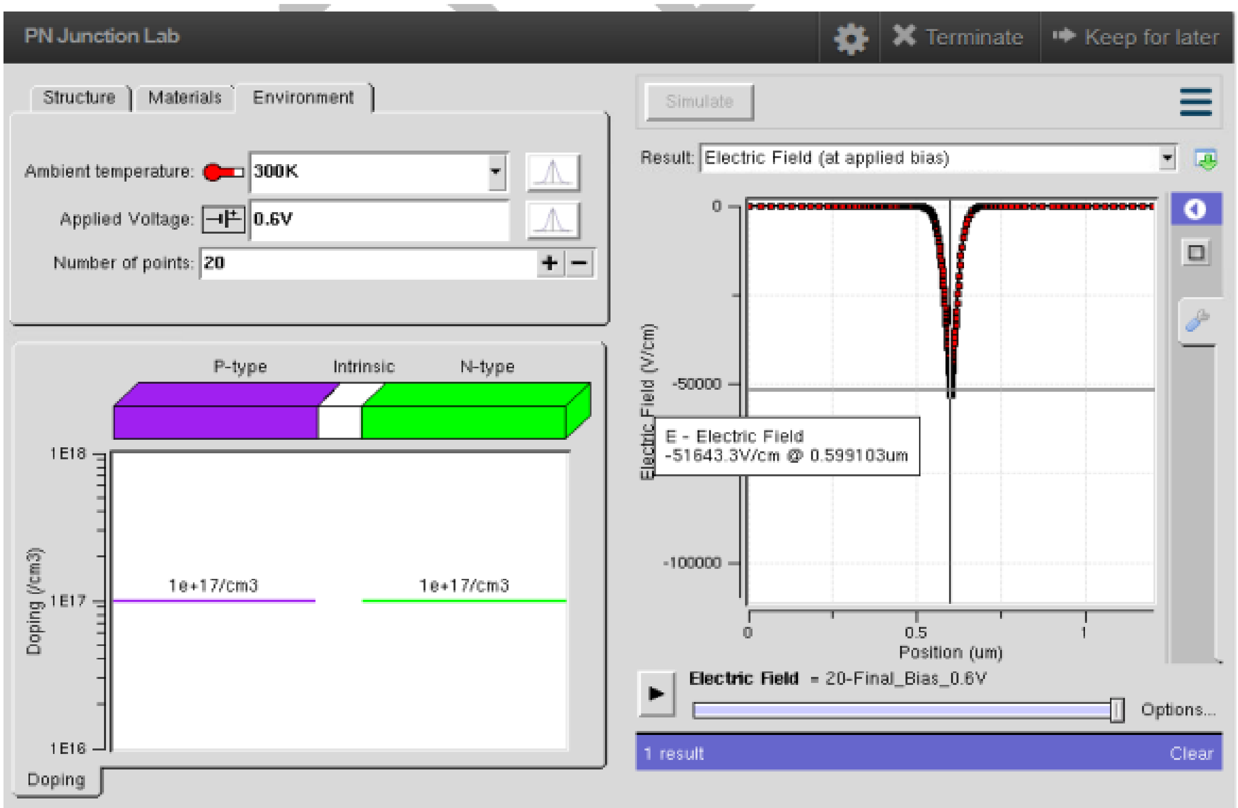
Q.3:- Observe charge density at applied bias



Q.4:- Observe electrostatic potential at applied bias

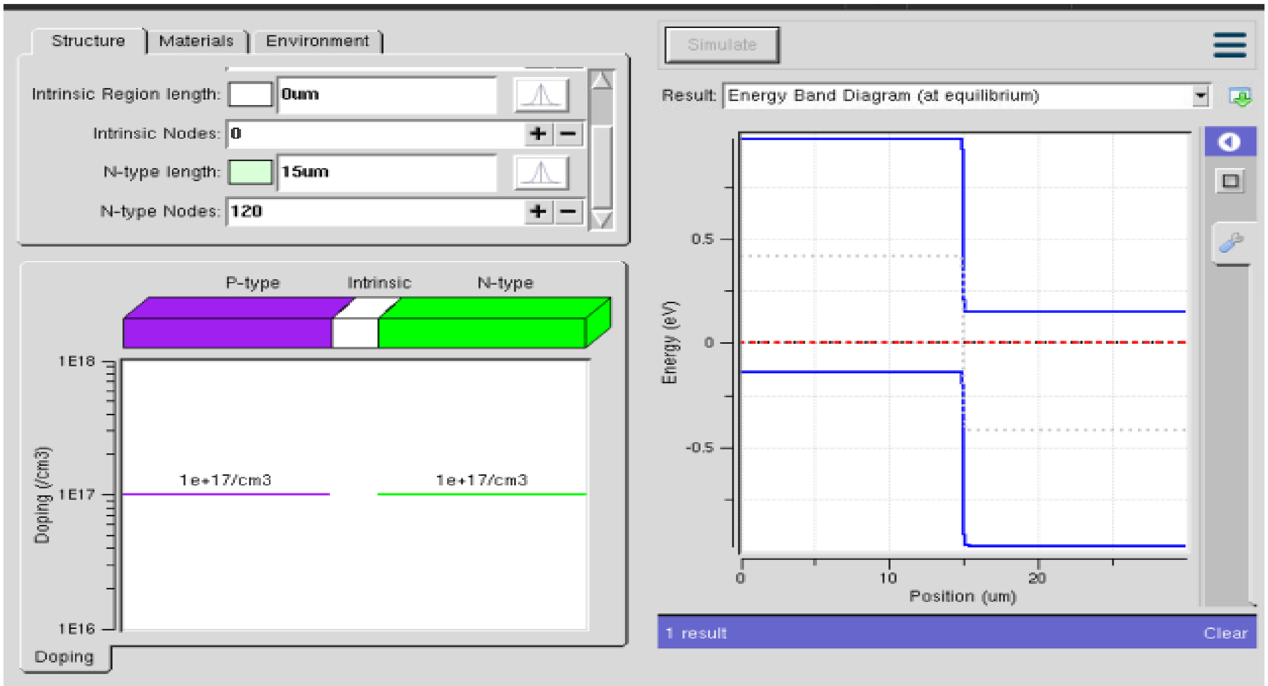


Q.5: - Observe electric field at applied bias



Task No.03: - Repeat task No.02 but this time increase the length of P and N regions.

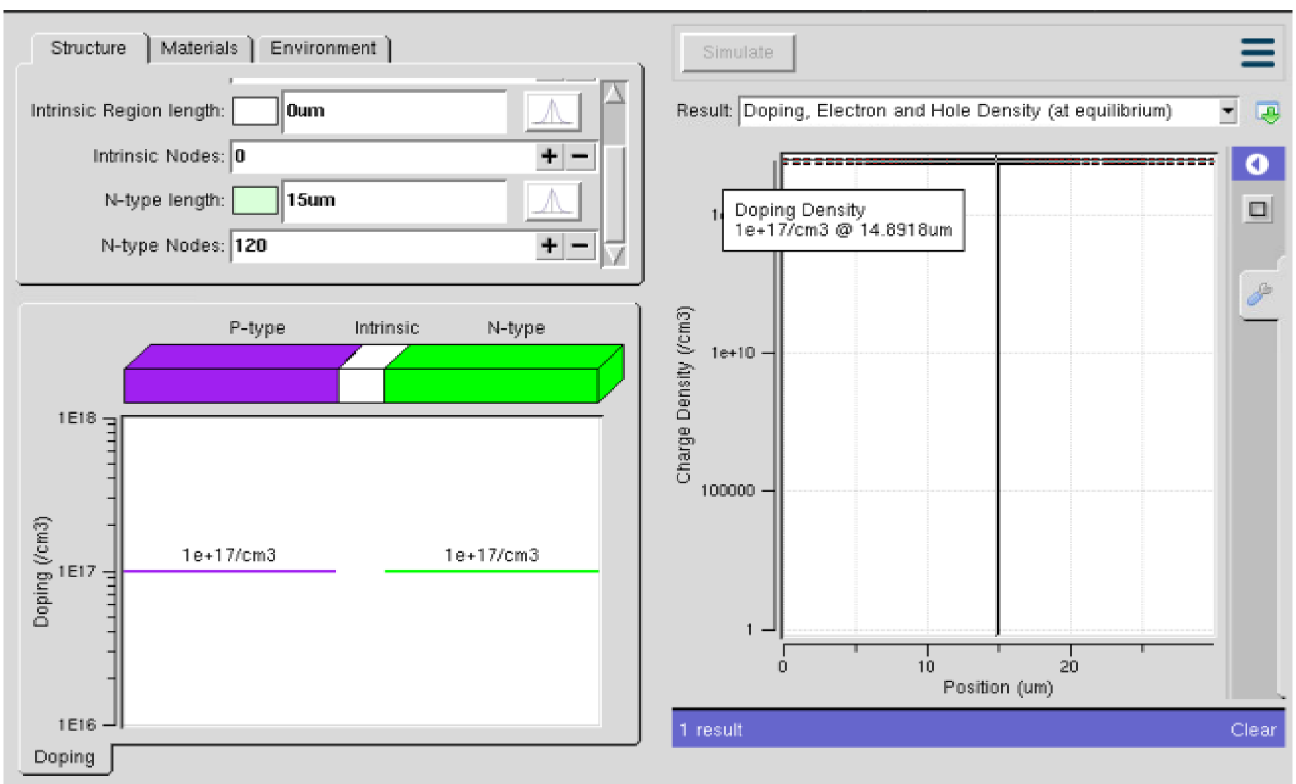
Q.1:- Observe the energy band diagram under equilibrium.

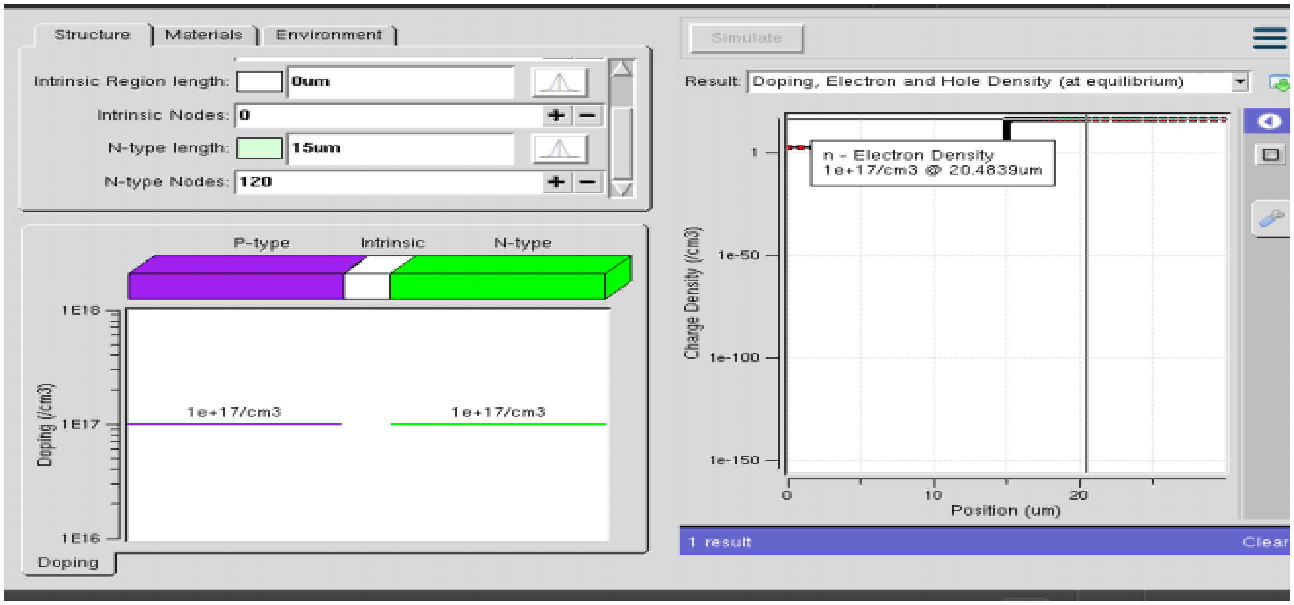


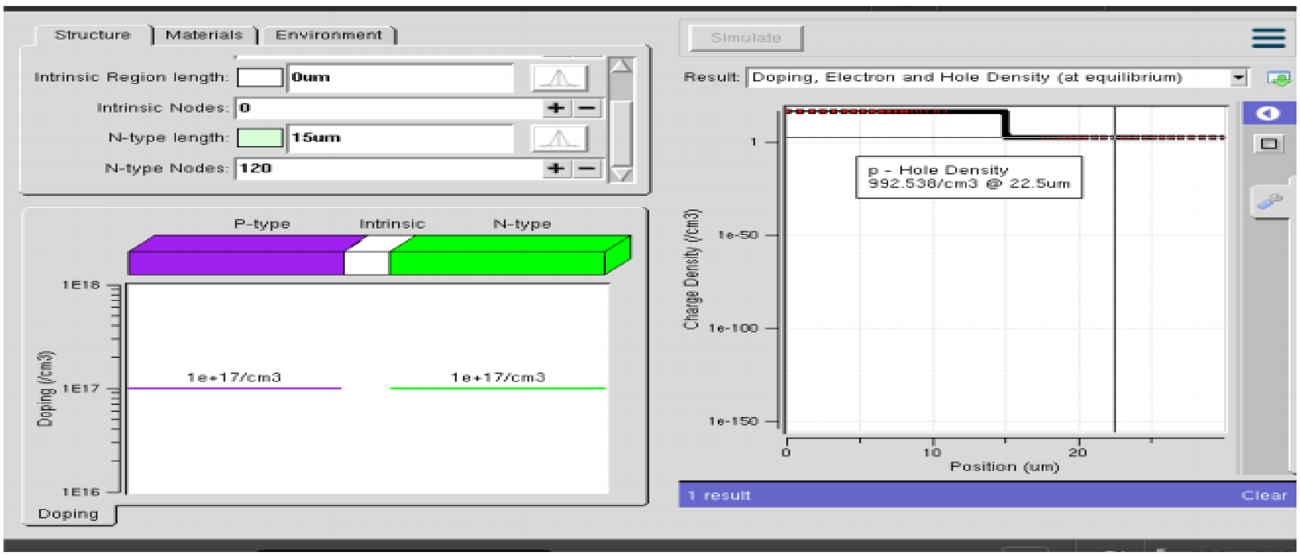
Q.2: - What difference do you observe by increasing the length of P and N regions?

Answer :Although width of the depletion region is same as of the last case but depletion region width is almost negligible as compare to the length of p and n regions (p region length is 15um and n region length is also 15um).

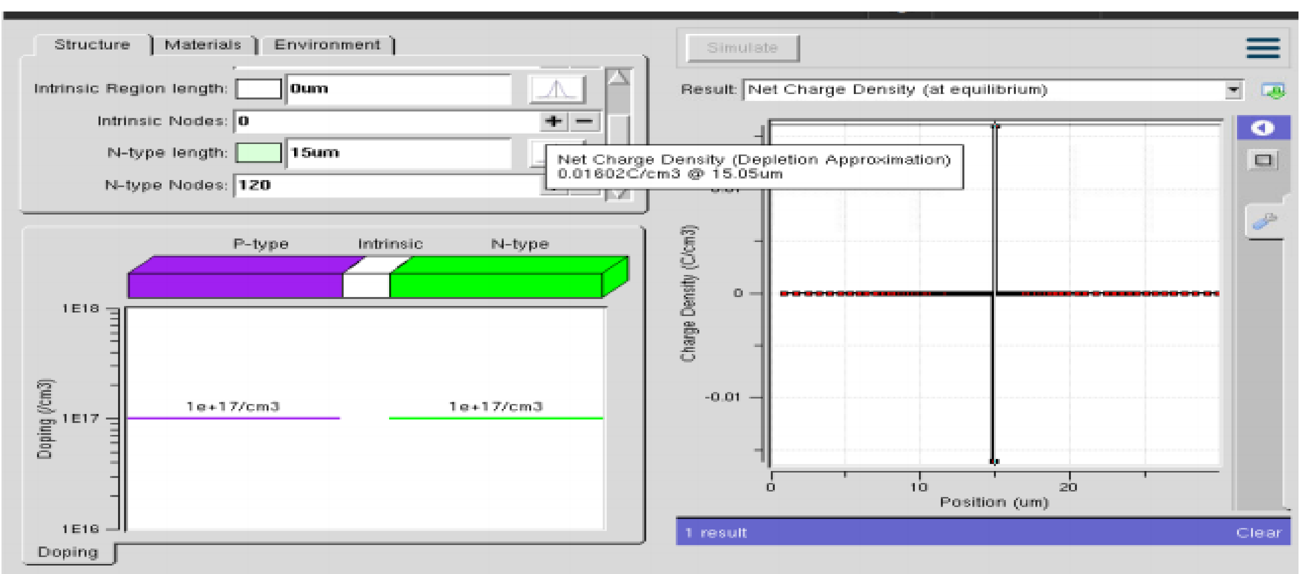
Q.3: Observe doping, electron and hole density at equilibrium



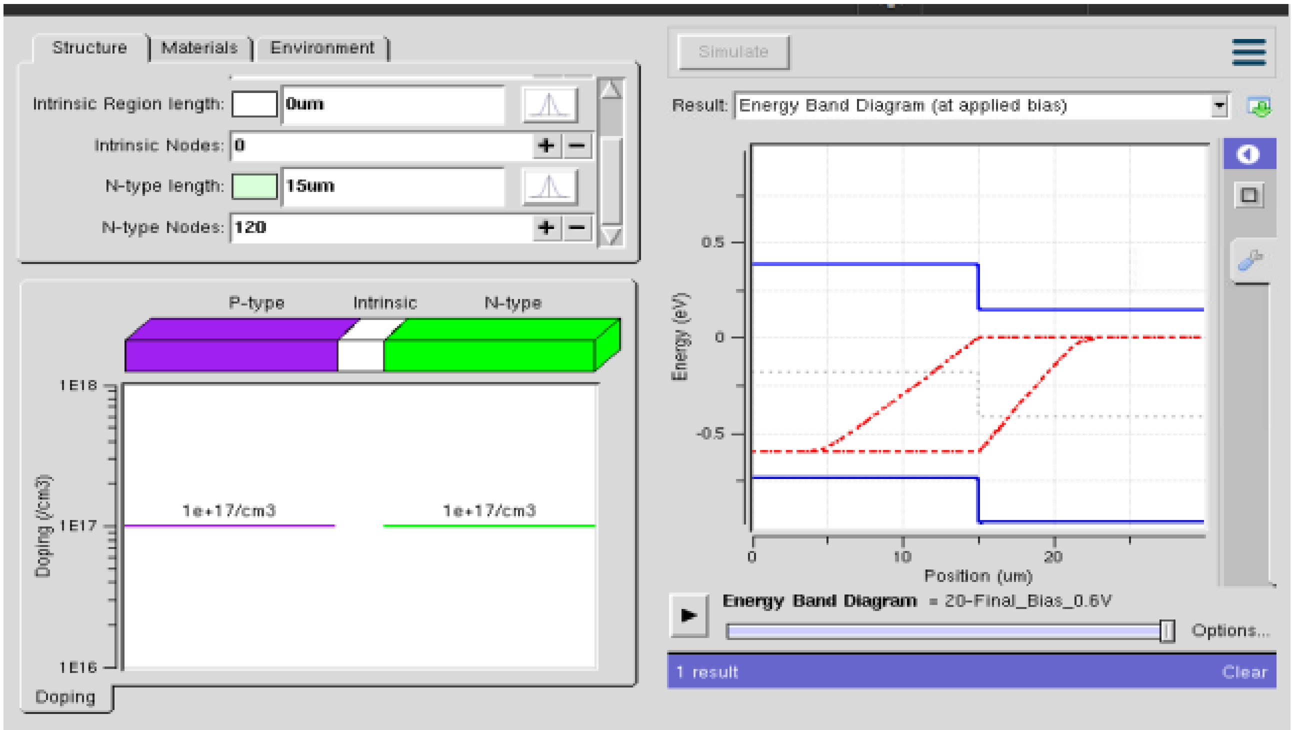




Q.4: - Observe the charge density at equilibrium

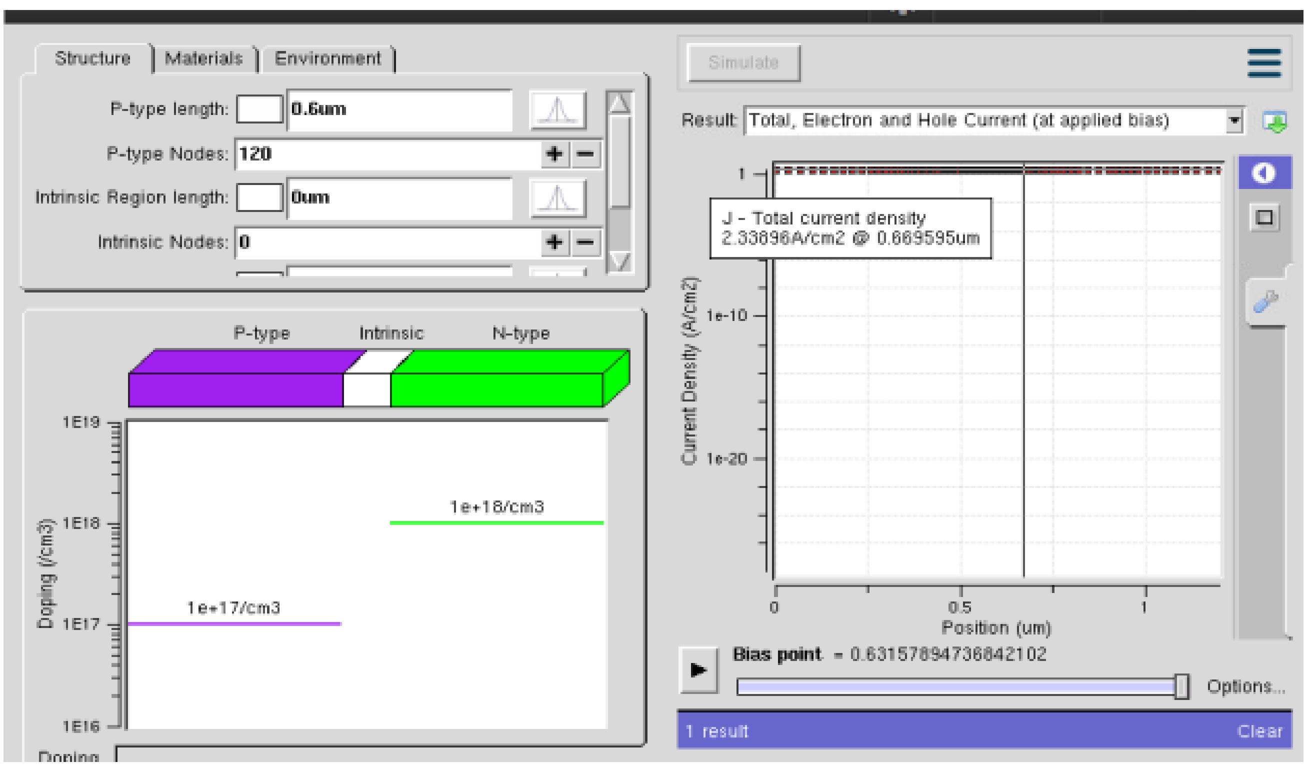


Q.5: - Observe the energy band diagram under non-equilibrium

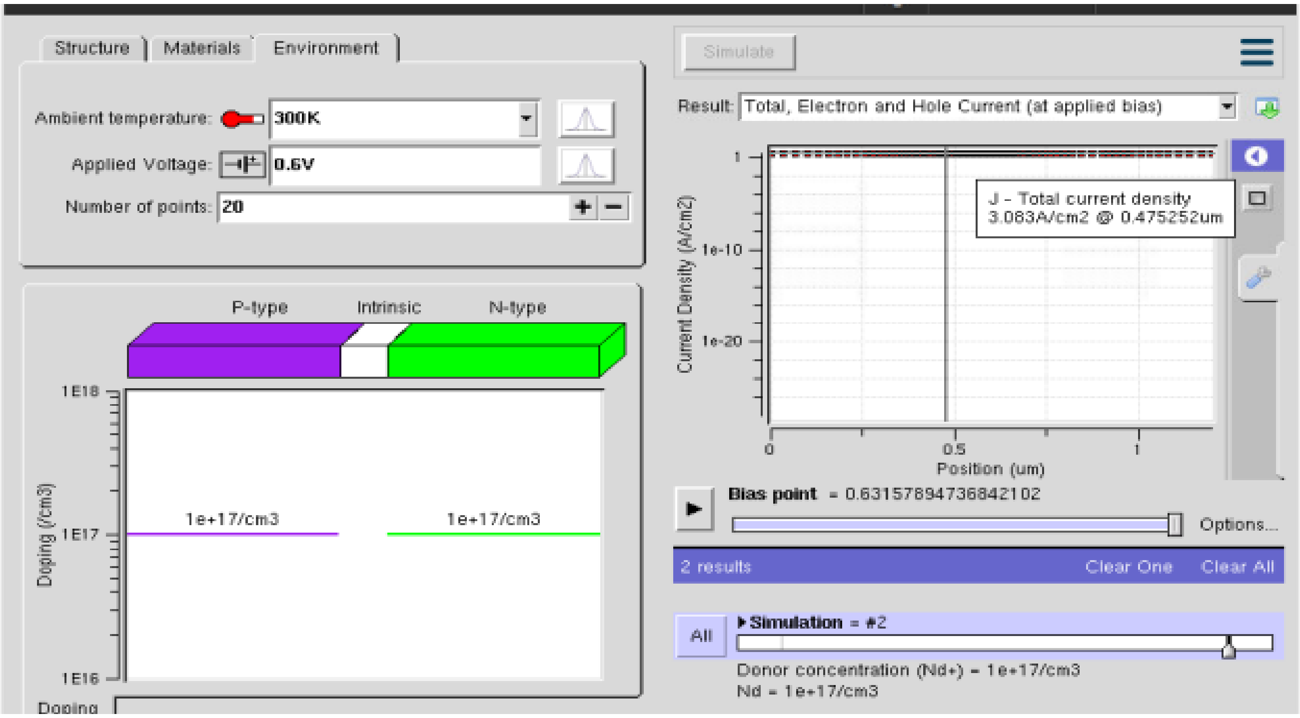


Task No.04:- Observe 3 PN junction diodes. First assume $Nd > Na$, then assume $Nd = Na$ and lastly $Nd < Na$. Forward bias these diodes by applying VA=0.6V

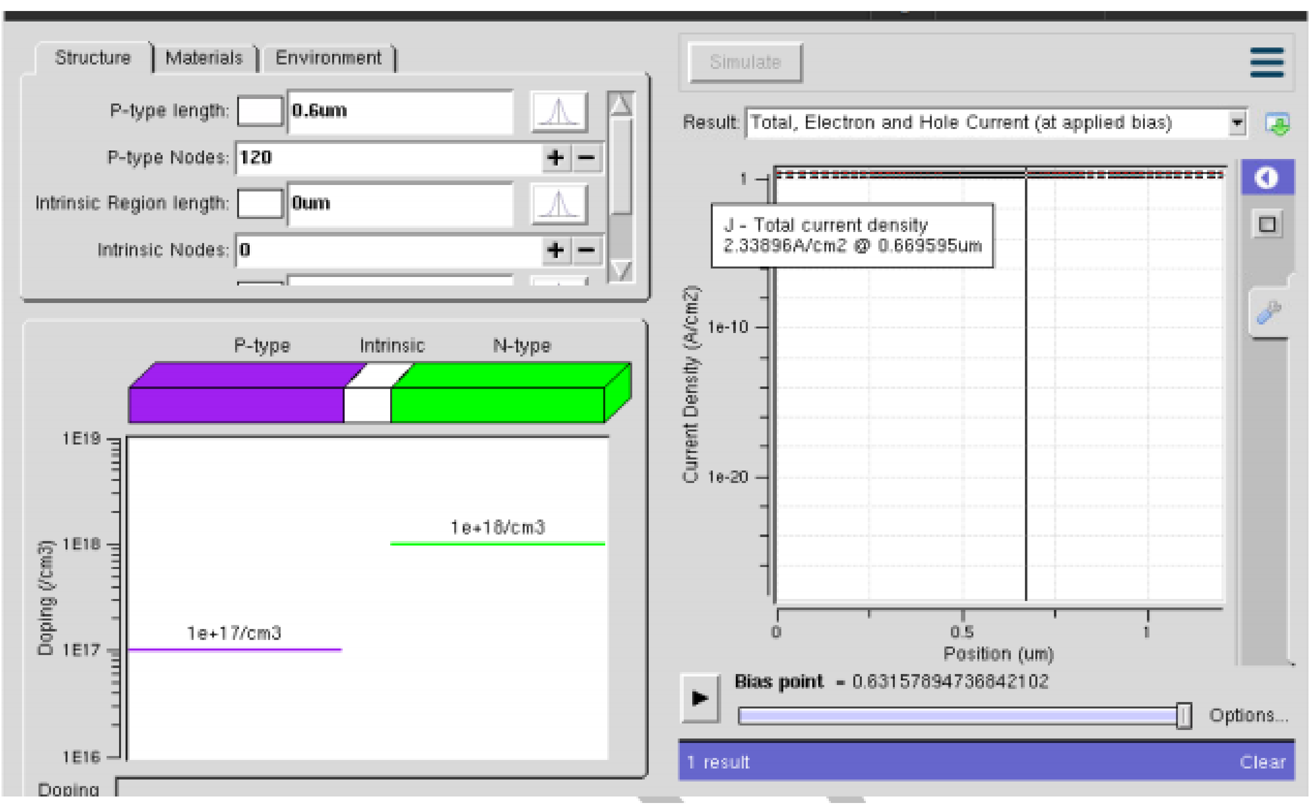
Q.1: - Observe the total current that flows through the diode when $Nd < Na$. Also mention its value.



Q.2: - Observe the total current that flows through the diode when $Nd = Na$. Also mention its value.



Q.3: - Observe the total current that flows through the diode when $Nd > Na$. Also mention its value.



Q.4:- Maximum current flows when Na=____________ and Nd=___________________.

Ans: Maximum current flows when Na=1e17/cm^3 ,Nd=1e17/cm^3

Task No.05: - Suppose you have a biased PN junction diode, with Na= 1017/cc3and Nd= 1016/cc3. Now you want to increases the hole current at fixed applied voltage (forward bias). Can we achieve this by increasing the acceptor doping. Yes/no? Justify your point of view by simulation results and mathematical equation(s). Don't forget to specify donor and acceptor doping for increased hole current.

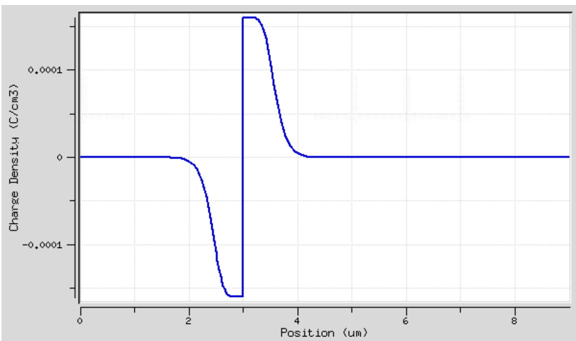
Answer: As it is clear from diode equation that current flows due to P-n (the minority carrier on N side) and Np (that is electrons on P side) so if we want to increase the hole current we have to increase the value of Pn this can only be done by reducing the donor concentration that is if Nd get reduce electron on the Nn will reduce (Nn) and holes Pn will increase.

LAB SESSION13

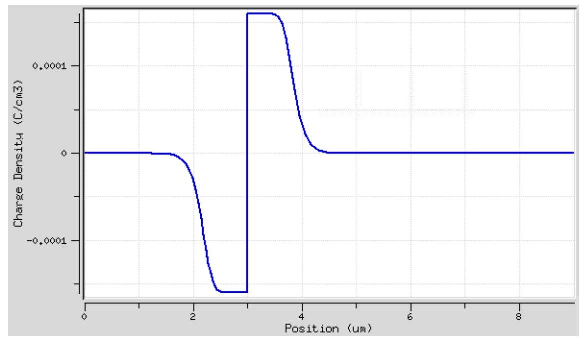
Understand and analyze the effect of forward biasing on Energy band diagram, Depletion region, Electric field, Electrostatic Potential. Also observe the phenomenon of Carrier Injection and Current Density under the influence of forward biasing.

TASK # 1: Observe a PN junction diode under reverse bias

Q.1:- Compare the charge density of reverse biased diode with an unbiased diode.



Unbiased

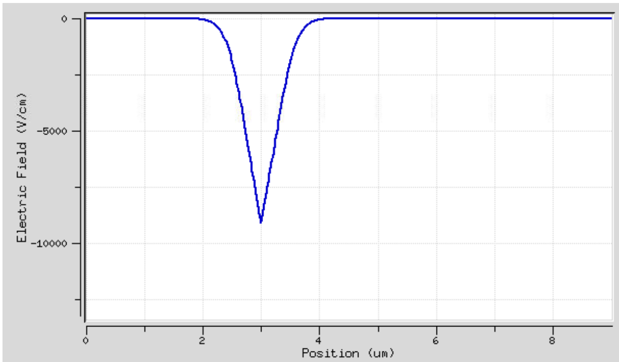


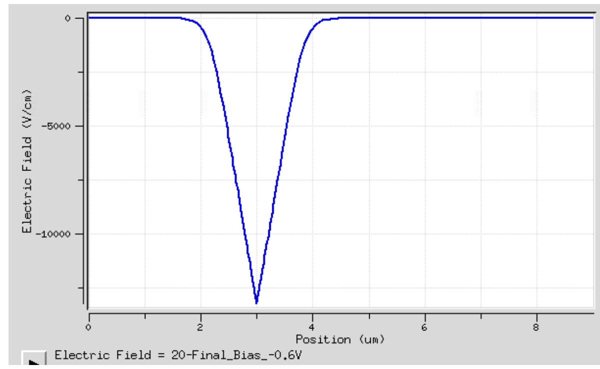
Reversed Biased

Q.2: - Is there any change in charge density and width of the depletion region by reverse biasing the diode. Yes/No? Justify

Yes, the charge densities and width of depletion region increases with increases in reveres voltage.

Q.3:- Compare the electric field of a reverse biased diode with an unbiased diode





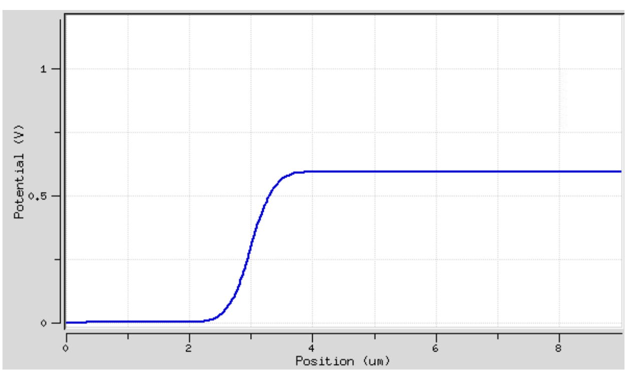
Unbiased

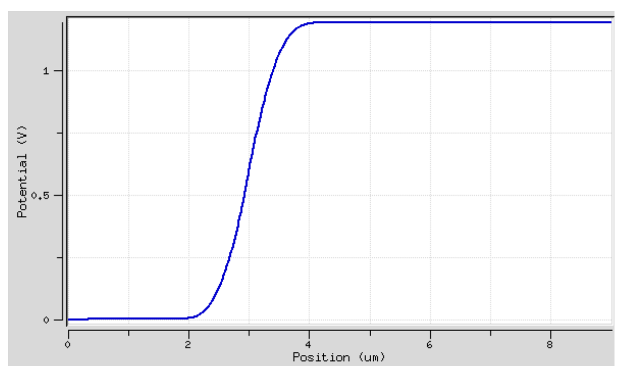
Reversed Biased

Q.4: - What is the effect of reverse biasing on electric field?

Due to reveres biasing of the junction the electric filed decreases to more negative.

Q.5:- Compare the electrostatic potential of a reverse biased diode with an unbiased diode.



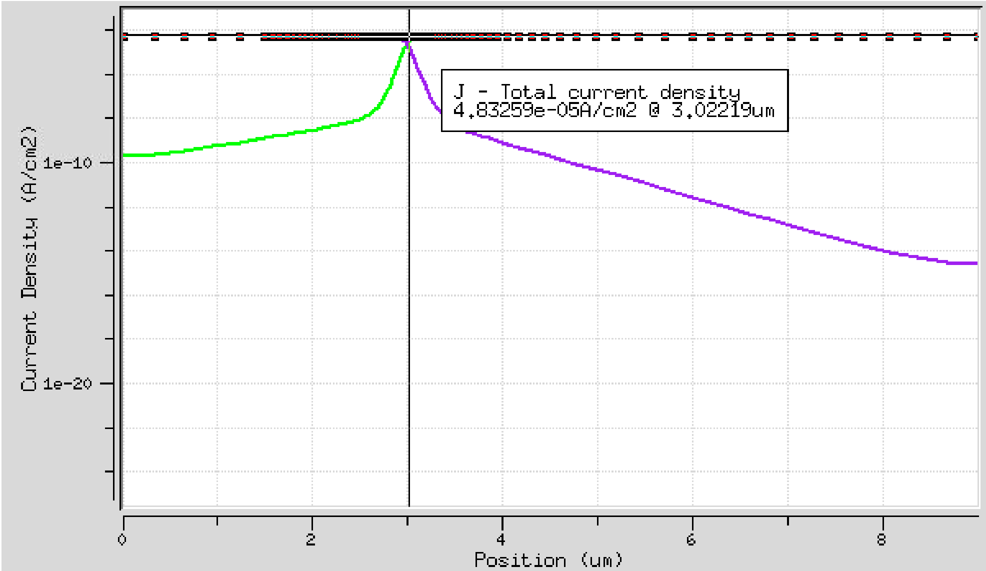


Unbiased

Reversed Biased

Electrostatic potential increase with reverse biasing

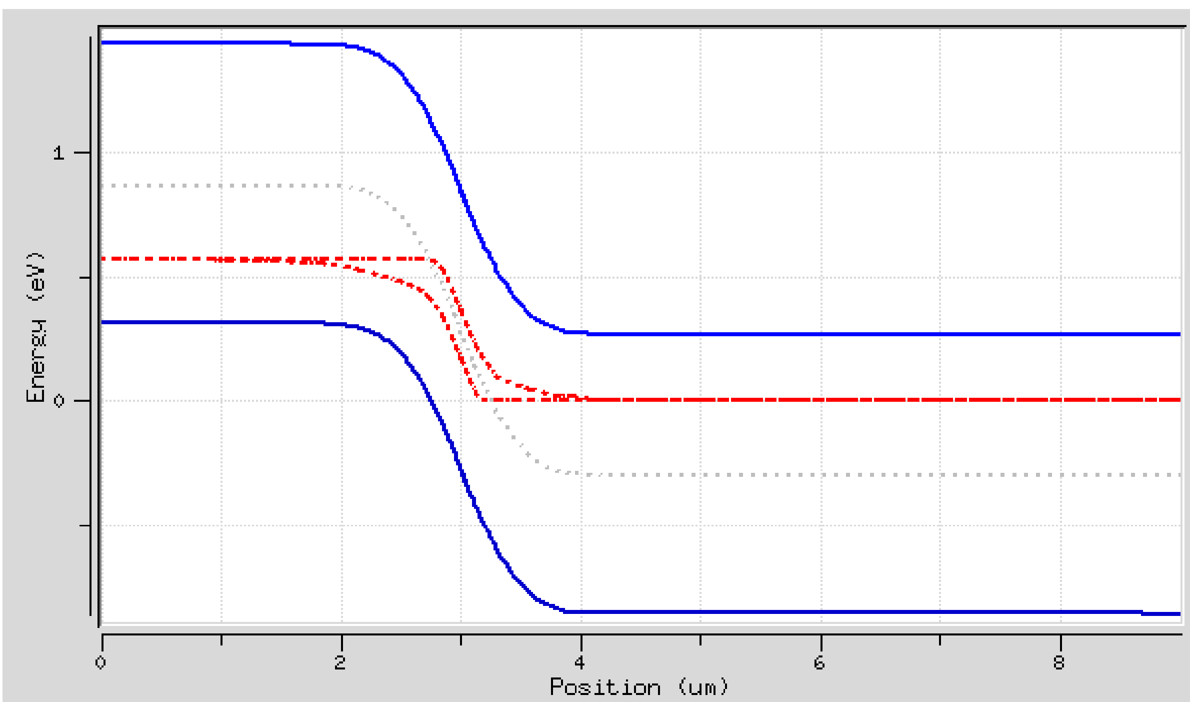
Q.6: Observe the reverse current and write down its value.



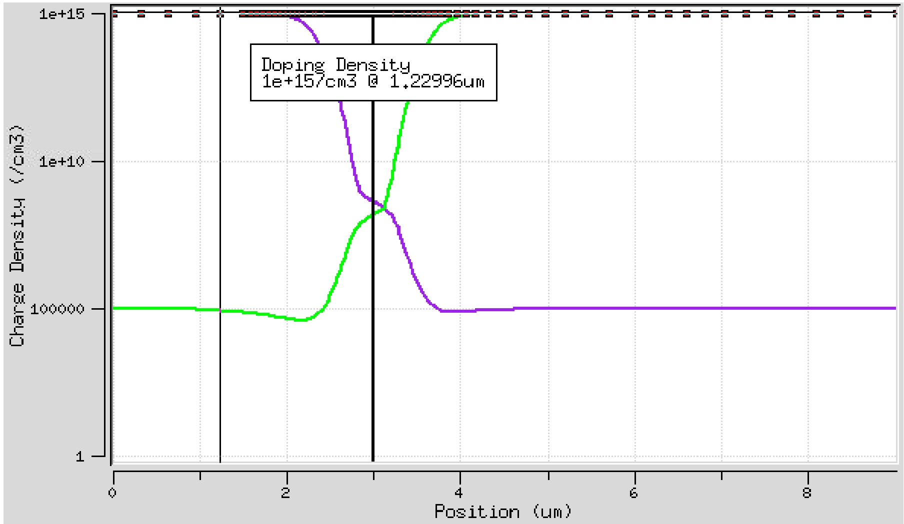
$J_{TOTAL} = 4.83e\text{-}5\ A/cm^2$

Task No.02: -Reverse bias a PN junction diode

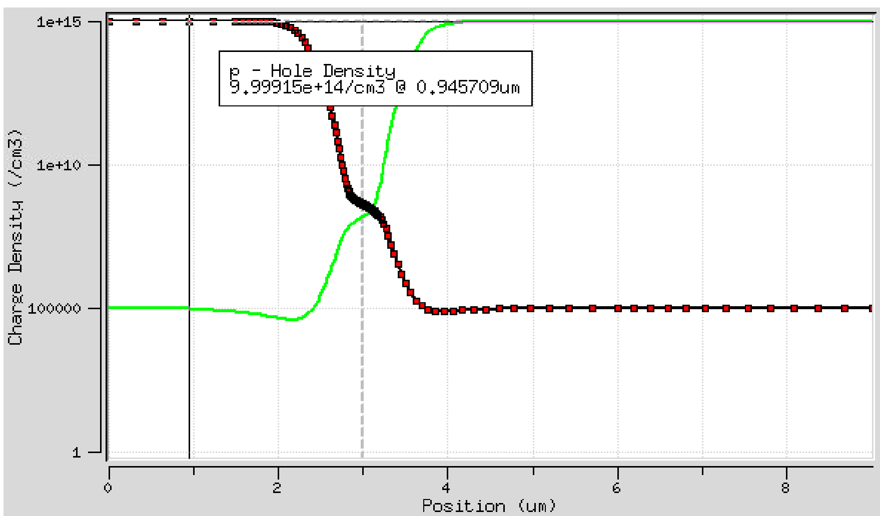
Q.1: - Observe the energy band diagram at applied bias.



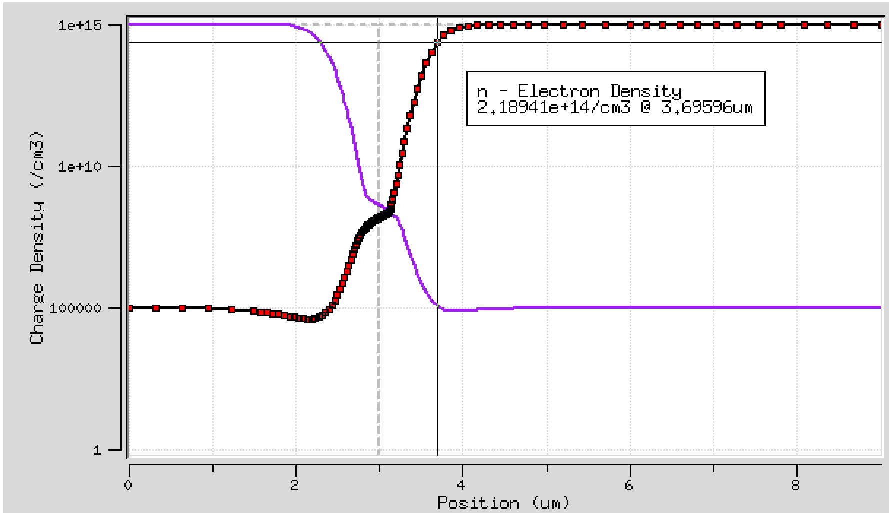
Q.2: - Observe doping, electron and hole density at applied bias.



Doping Density



Hole Density



Electron Density

Q.3: - What is the effect of biasing on minority carrier concentration near depletion region. Will it increase or decrease? Specify the reason.

The minorit**y** carrier concentrati**on near depletion region increases** Essentially, majority carriers are pushed away from the junction, leaving behind more charged ions. Thus,

the **depletion** region **is** widened and its field becomes stronger, which increases the drift component of current (through the junction interface) and decreases the diffusion componen