DEPARTMENT OF ELECTRONIC ENGINEERING

N.E.D. UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOLID STATE DEVICE

BATCH 2017-18

LAB SESSION # 9, 10

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ROLL # EL-17062 SECTION: C

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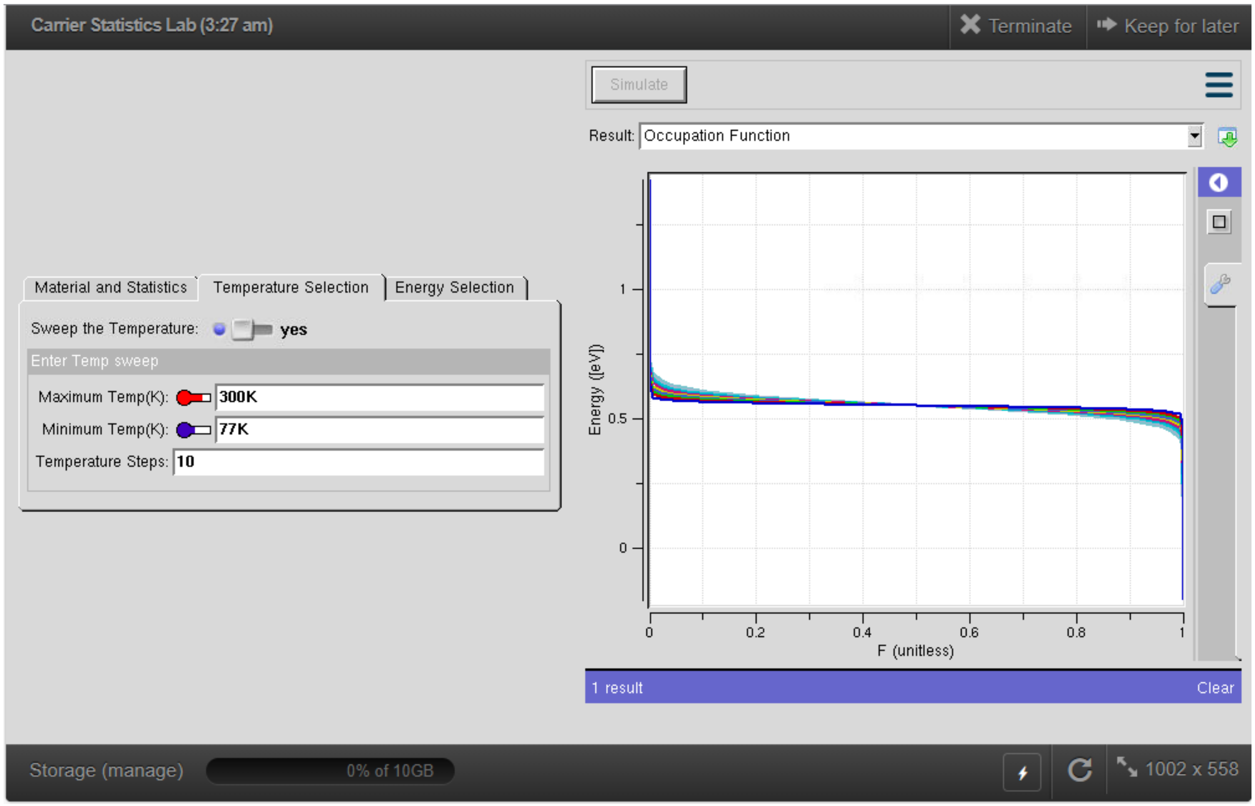
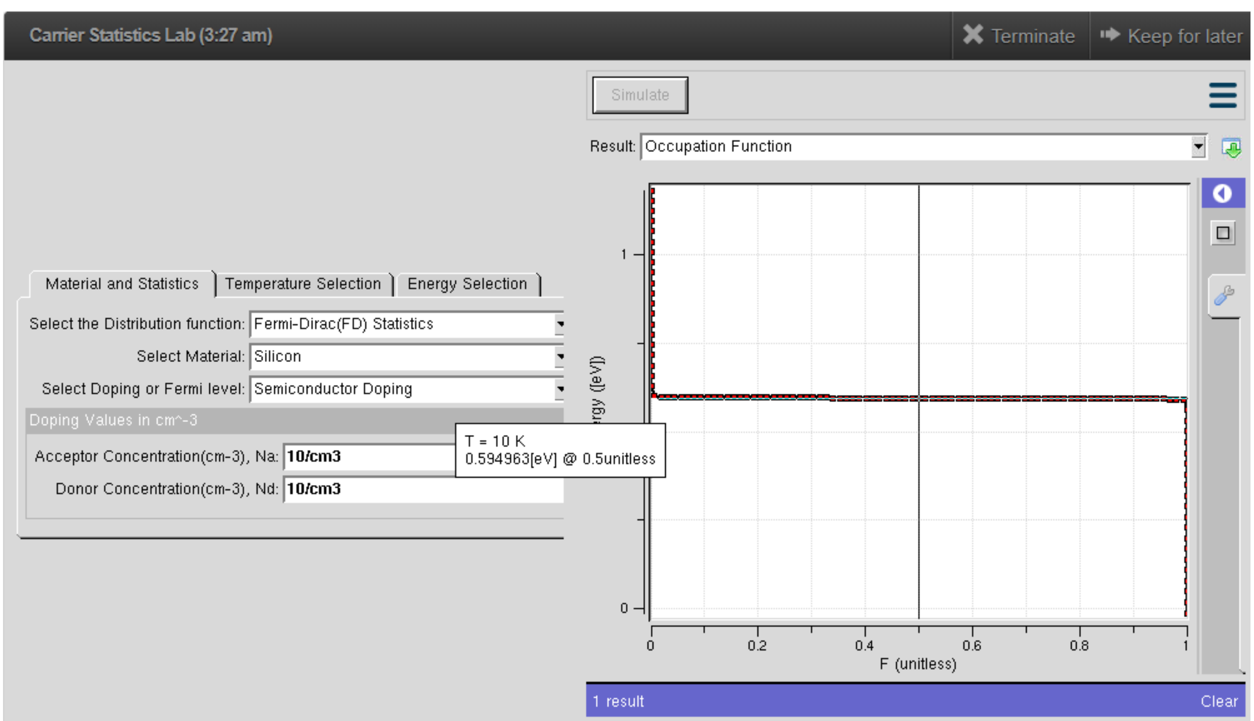
LAB NO: 3

TASK NO# 1: Set the Fermi level at 0.55eV and observe Fermi function over a range of temperature



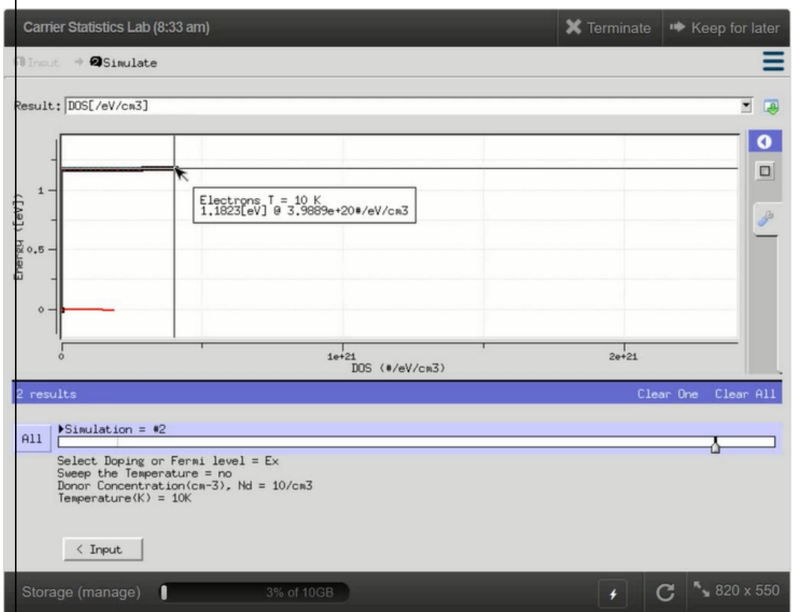
TASK#NO2: Observe the Fermi function of an intrinsic semiconductor at a very low temperature.

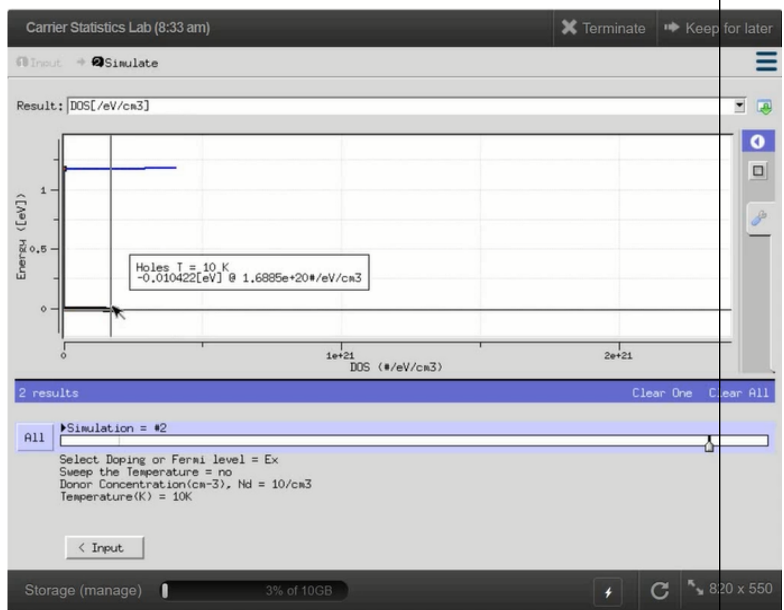


Q1) The Fermi level lies at?

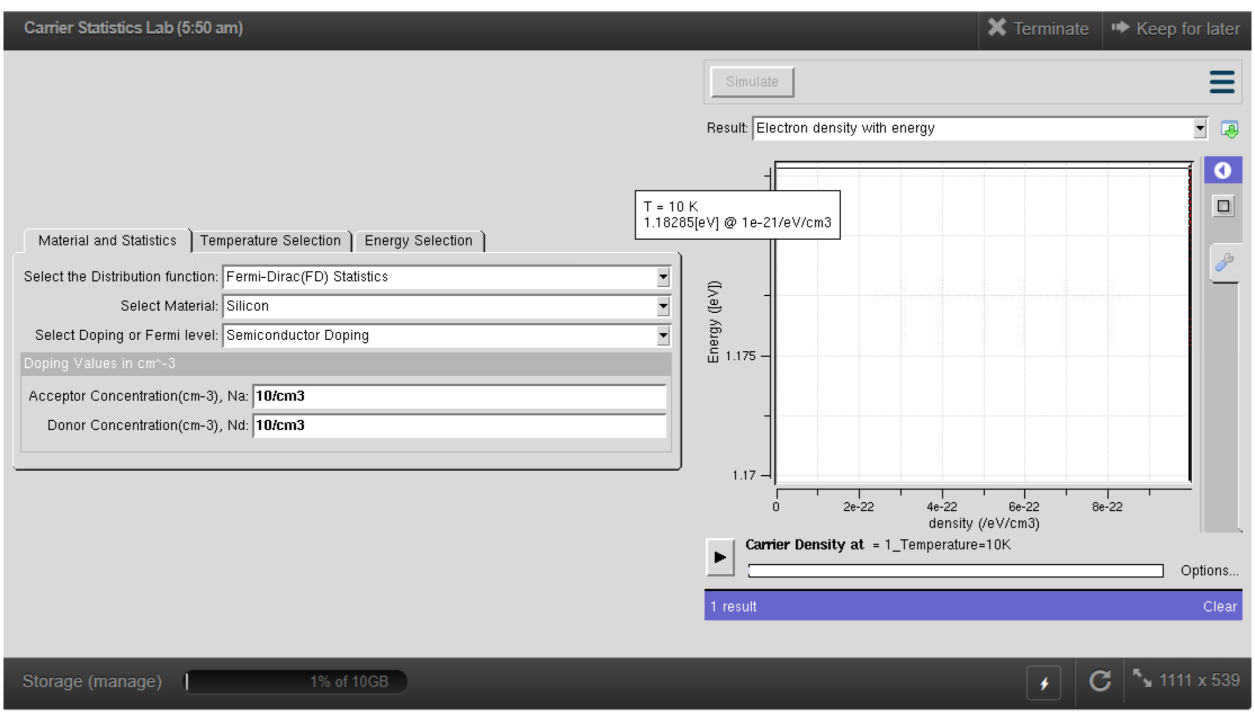
ANS: The Fermi Level lies at 0.594963eV

Q2) Observe the density of state curve





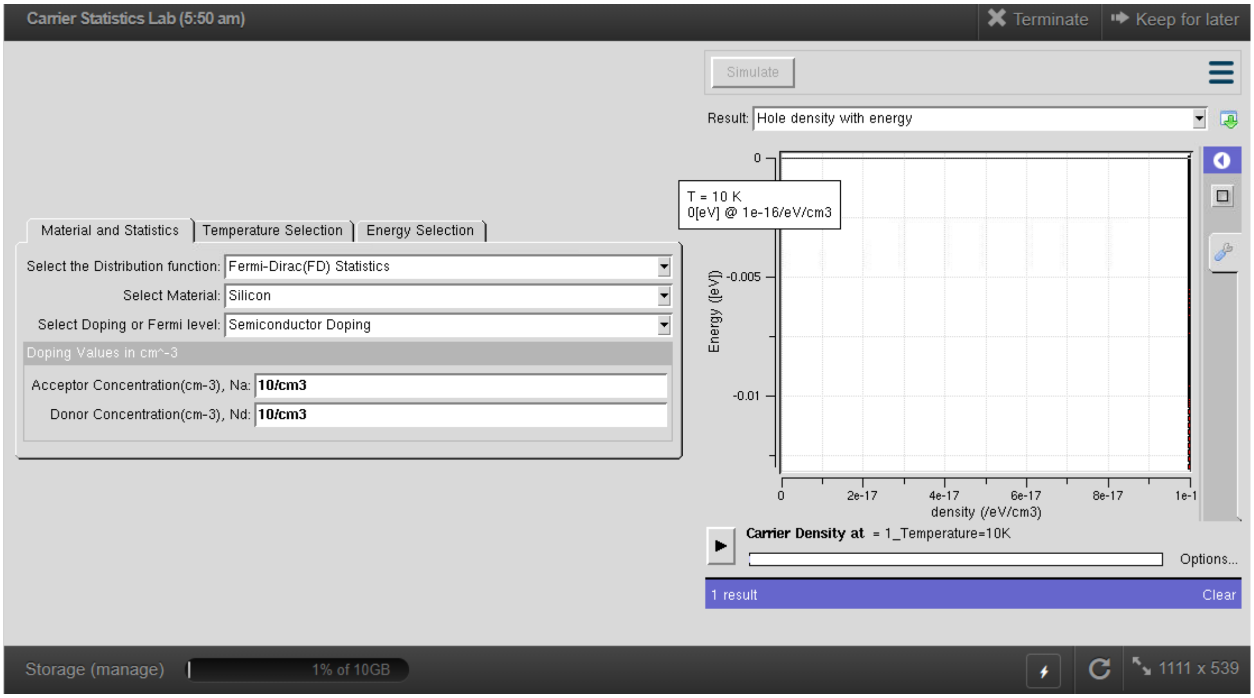
Q3) observe electron concentration with respect to energy.



Comments:

Electron density is 1e-21. This is a very small value as temperature is very low

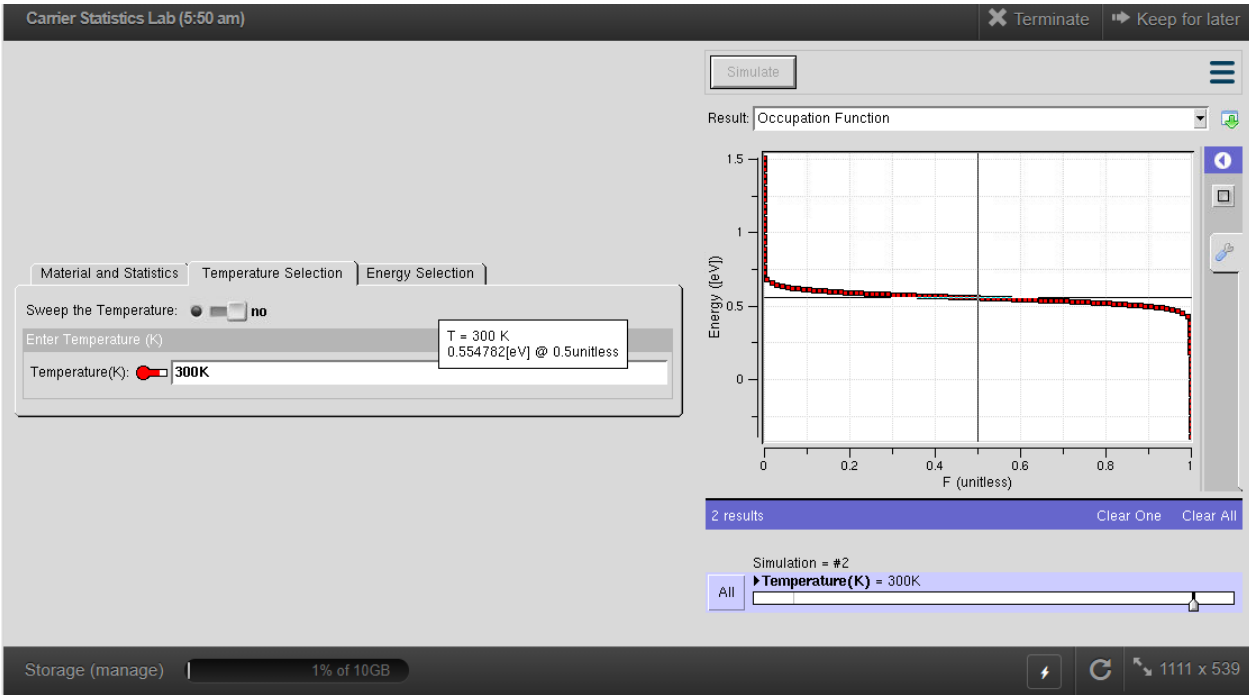
Q4) observe hole density with respect to energy



Comments:

Hole density is almost equal to zero as temperature is very low

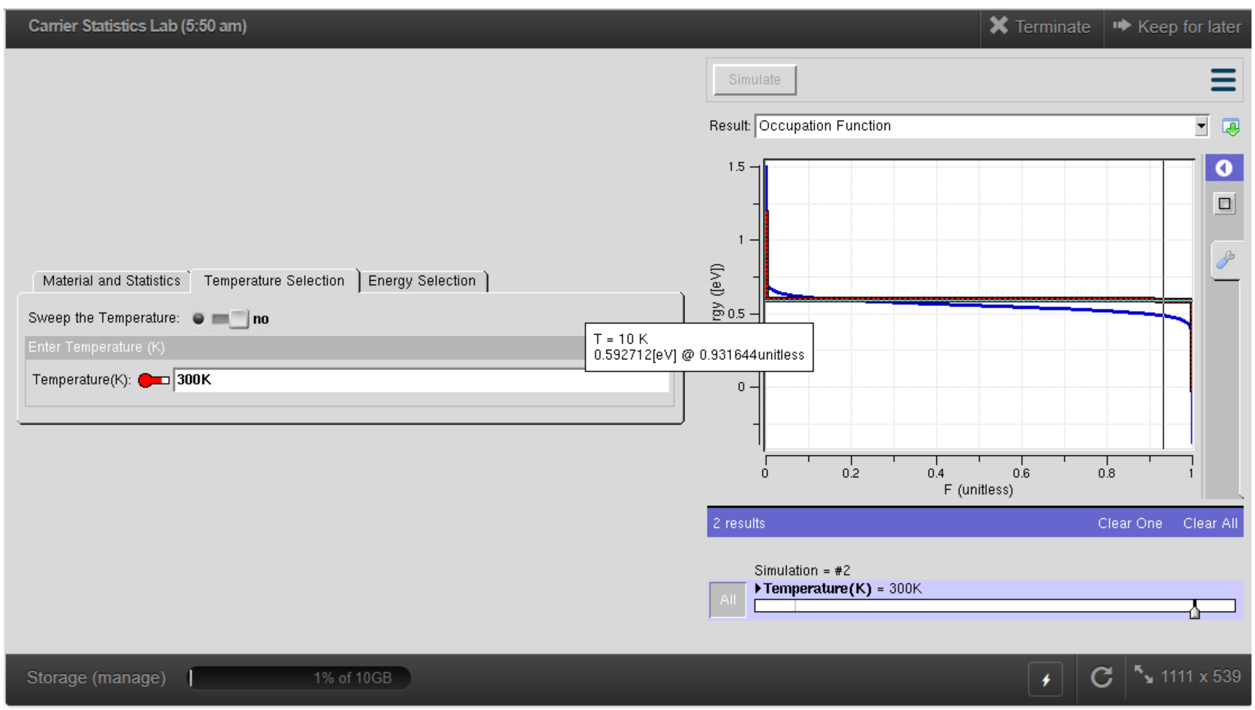
TASKNO#3: Now observe the same semiconductor at room temperature



Q1) Fermi level lies at?

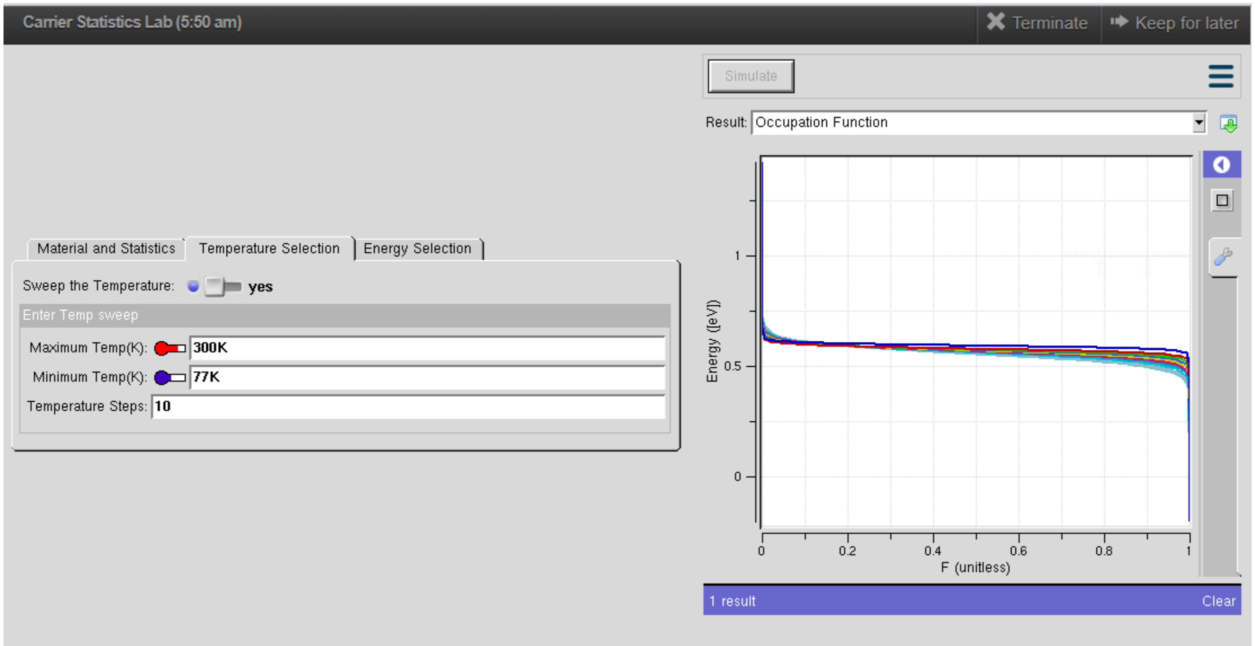
ANS: 0.554782 eV

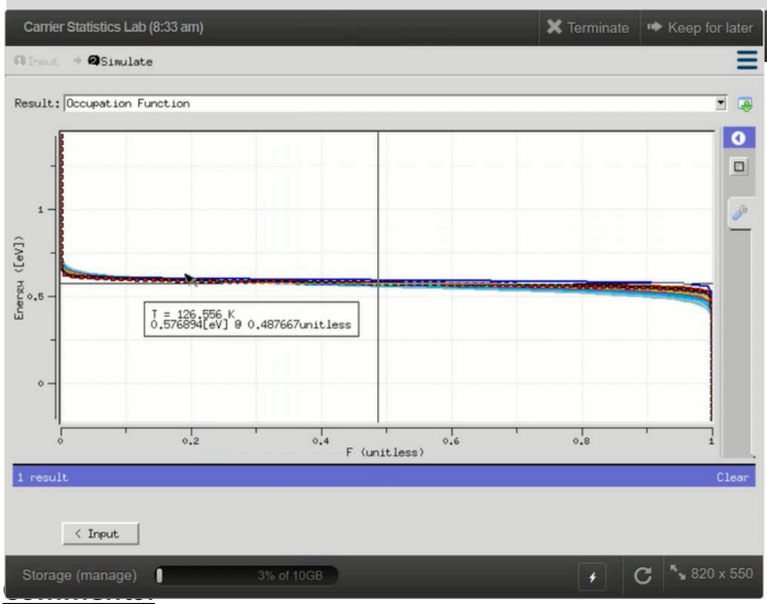
Q2) Compare Fermi functions of task 1 and task 2

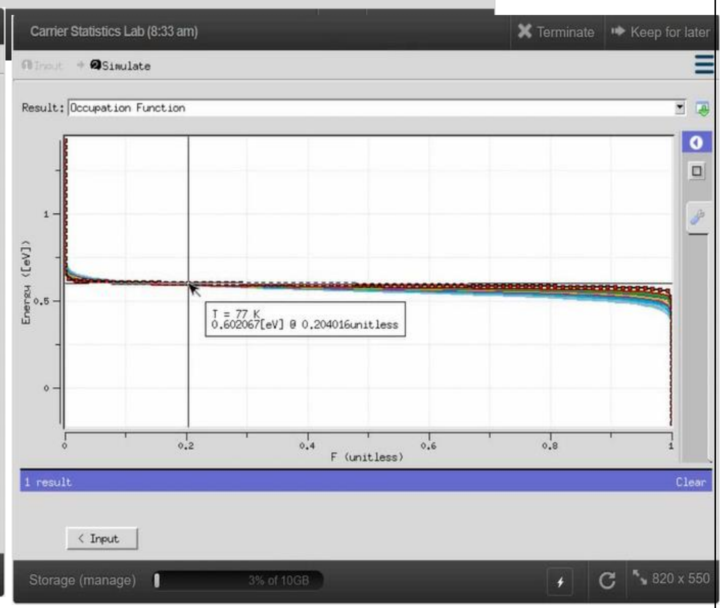


Comments: Variation in the value of Fermi function [occupation function] is observed for task 1 and task 2

<u>Q3)</u> it is usually given in the book that “if we see the curve of Fermi function of an intrinsic semiconductor at different temperature we will observe that they overlap each other at Fermi level”. Is it true as per your simulation results (Also attach simulation results)? Yes or no? Give reason.





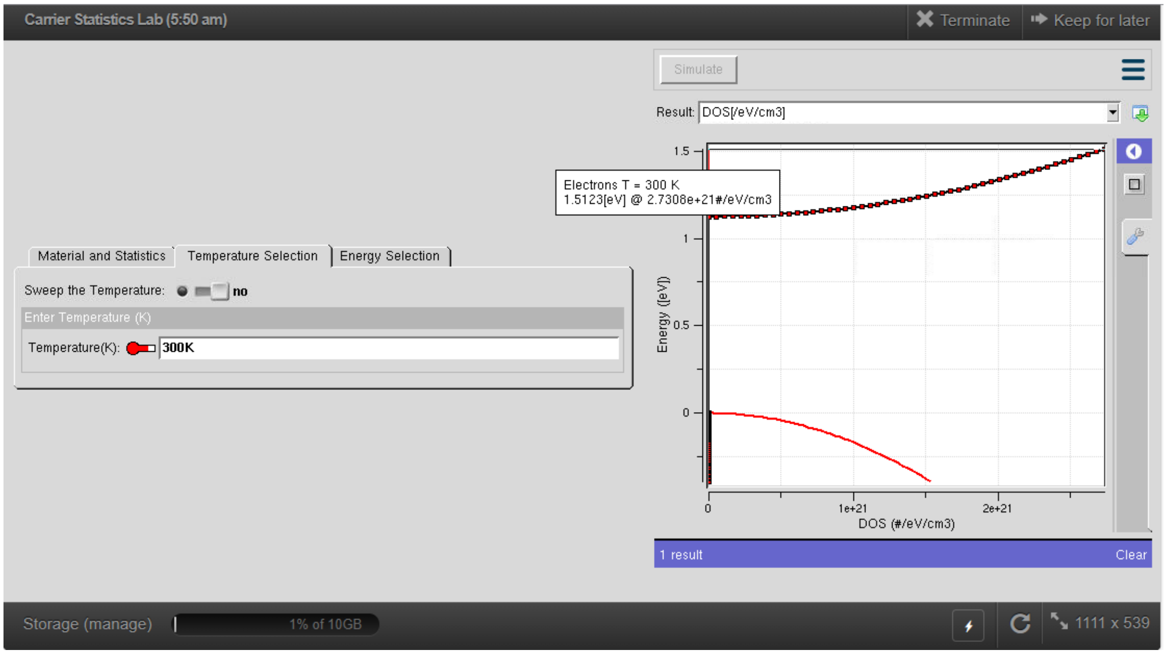


It is not true

<u>Reason:</u>

As we increase the temperature, the band gap reduces. As band gap reduces, the value also reduces from 0.5 to 0.2 (on the x-axis). The position of the Fermi level changes with temperature.

Q4) observe the density of states at the room temperature.

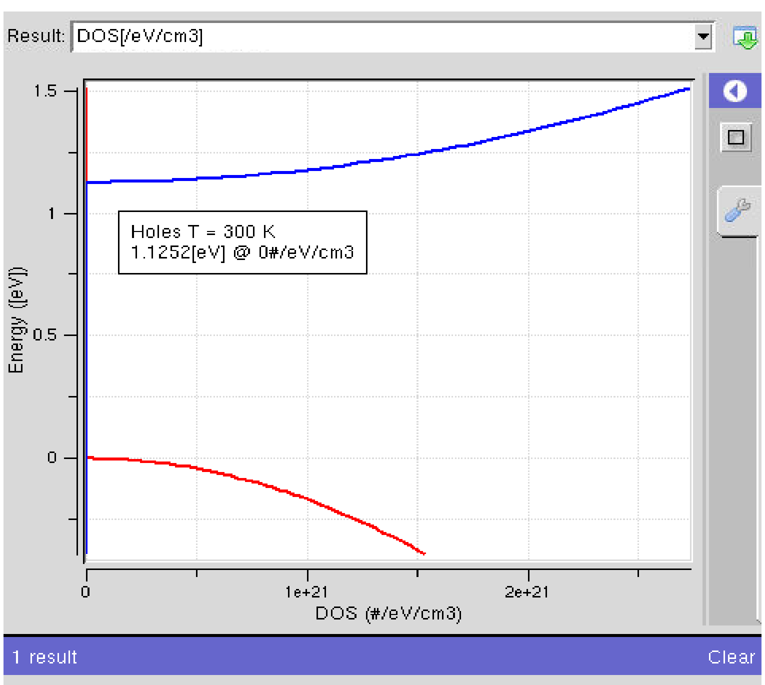


Comment:

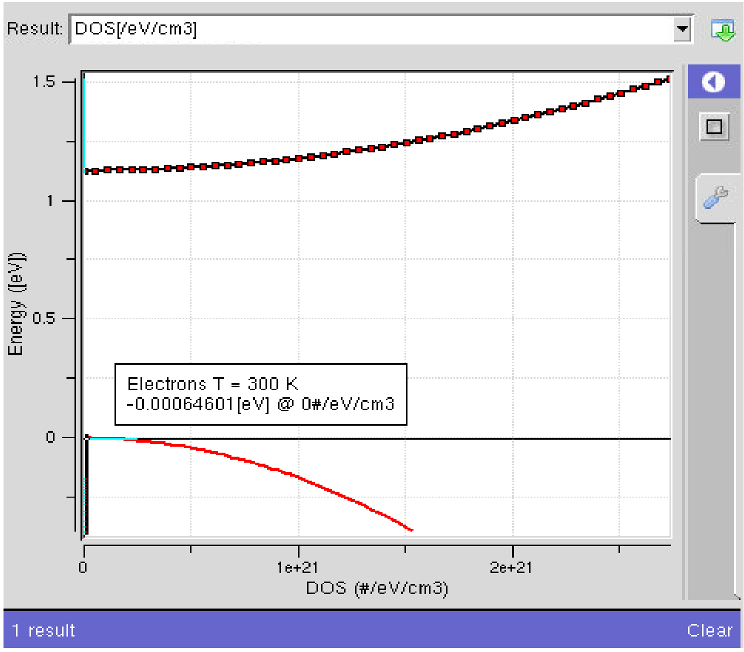
The electron and hole densities at room temperature are 2.7308e21eV/cm3 and 1.5312e21/cm3 respectively.

Q5) What is the density of states at valence band and conduction band edges.

For holes:



For Electrons



Comments:

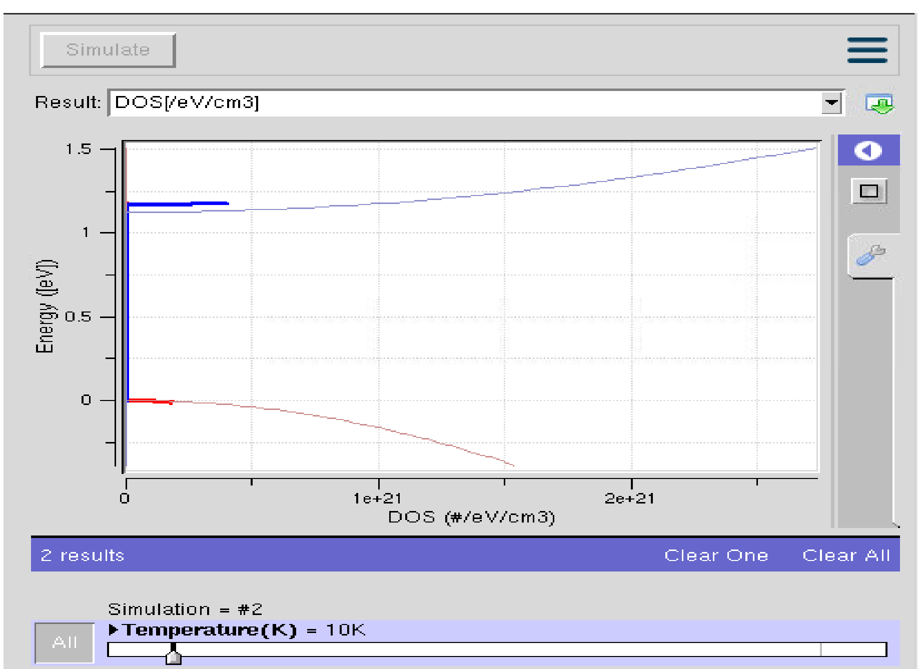
The electrons and holes densities at the edge of band gap are zero.

Q6) The density of states is different for valence band and conduction band. Why?

Comments:

The densities of states are different because of their masses. That's why densities are different.

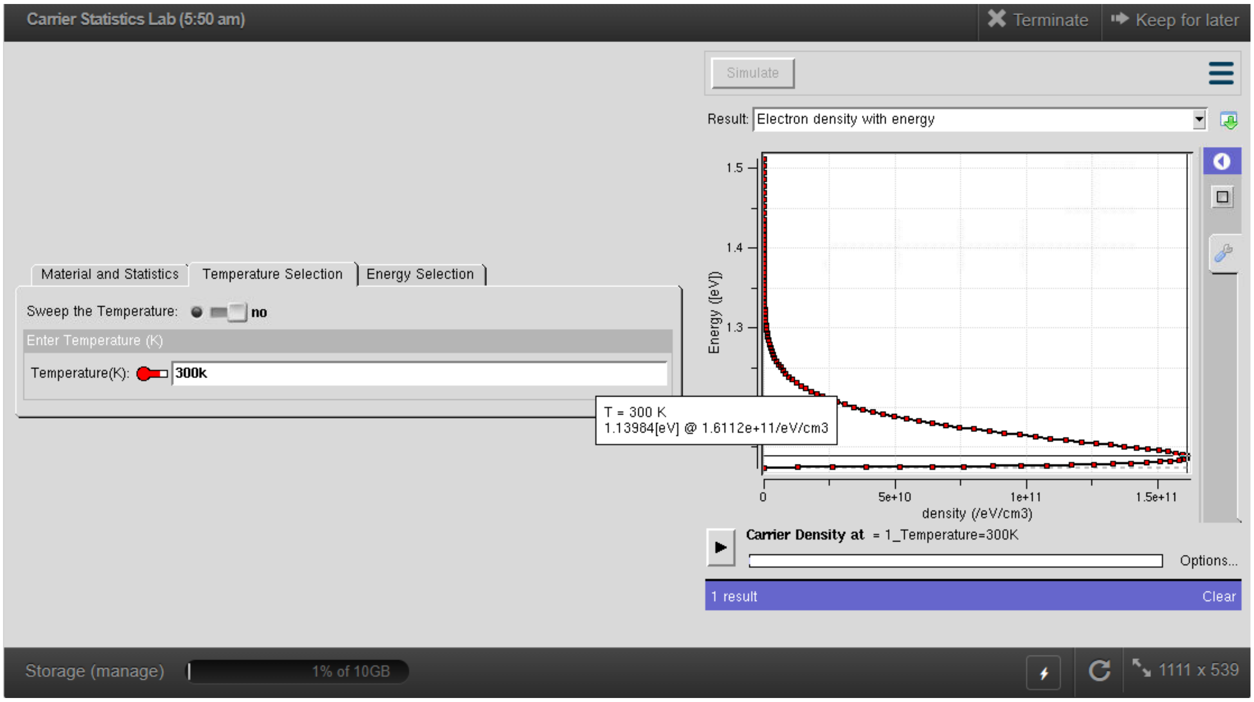
Q7) Now compare density of states at both temperatures. Is the band gap independent of temperature?



Comments:

The densities of states are different at both temperatures. The band gap is not independent of temperature. The band gap is smaller when the temperature is higher and low when the temperature is higher. The band gap is varying with temperature.

Q8) observe the electron density at 300k



Comments:

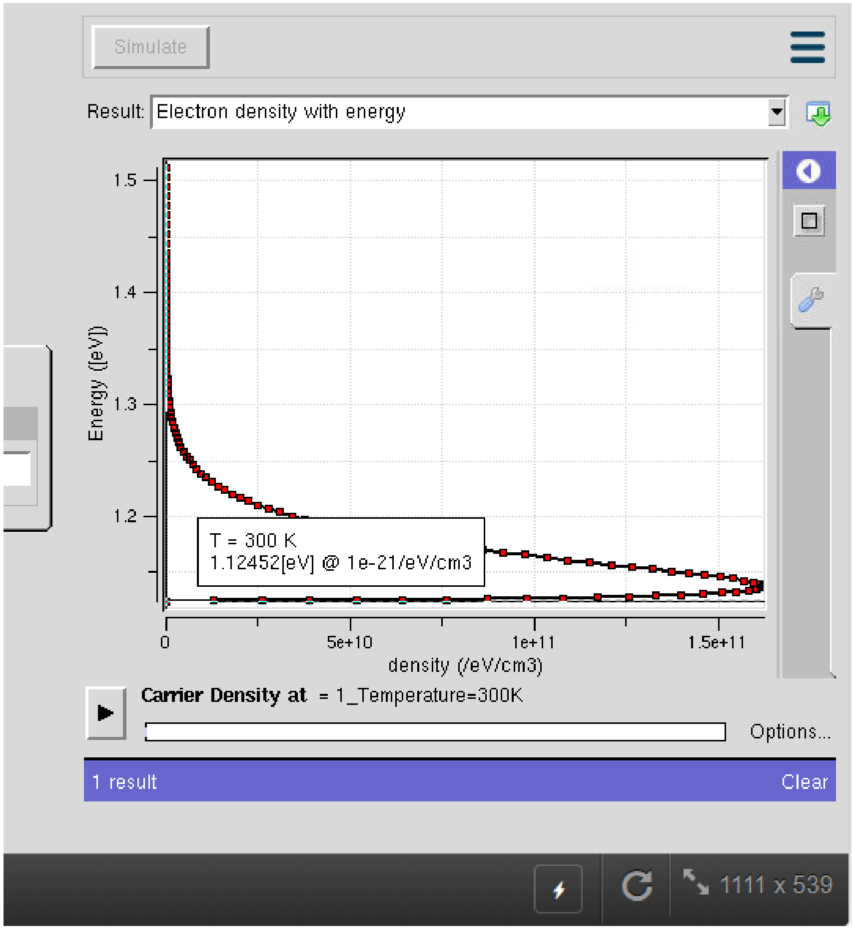
The electron density at 300k is 1.6112e+11eV/cm3

Q9) as we move towards higher energy level, carrier concentration decreases. Give reason.

Comments:

It is decreasing because as we move upward into conduction band, the probability of finding an electron decreases. That's why the carrier concentration will decrease.

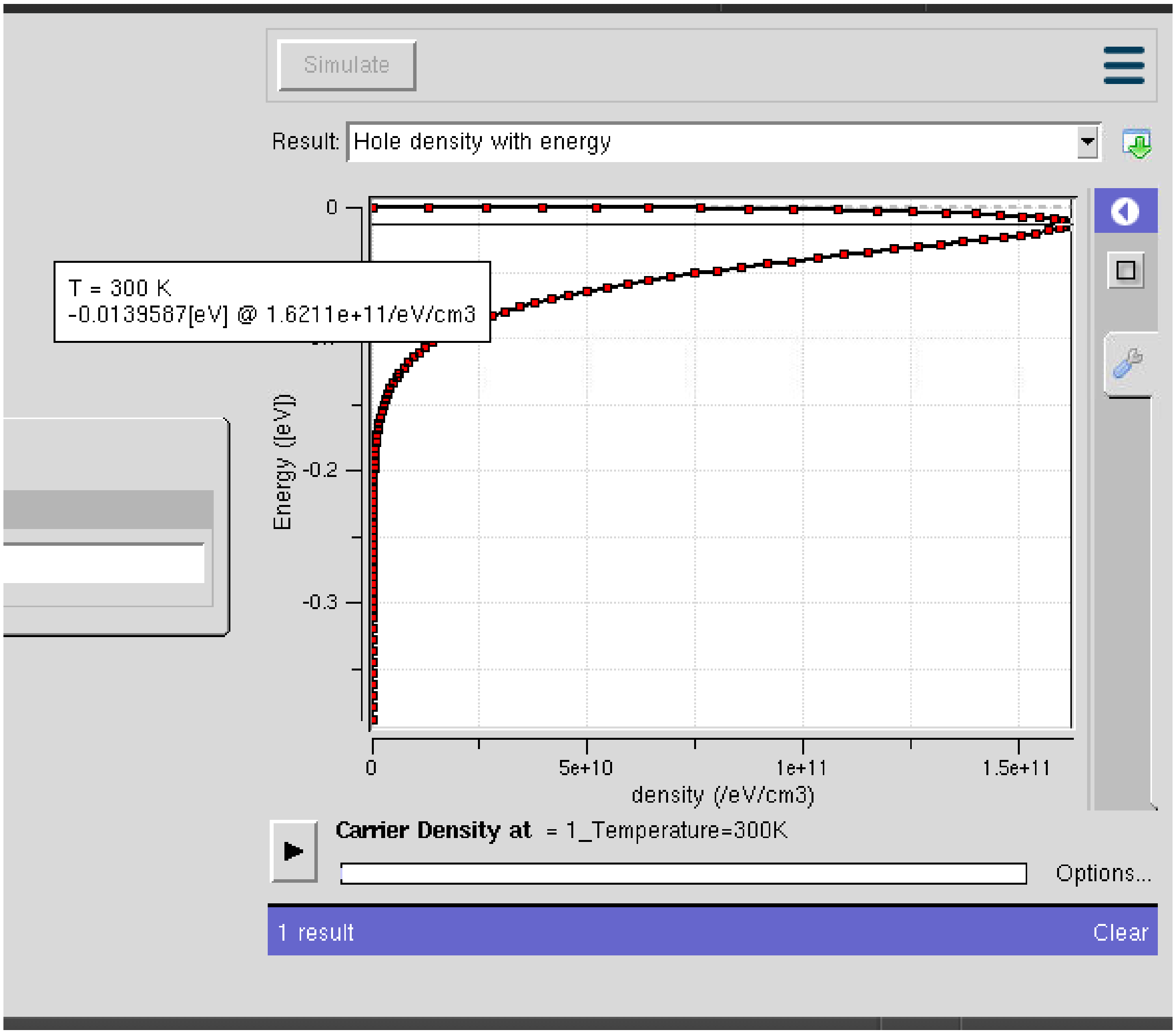
Q10) what is the electron concentration at the edge of the conduction band



Comments:

The electron concentration at the edge of the band gap is 1e-21eV/cm3. This value is almost equal to zero.

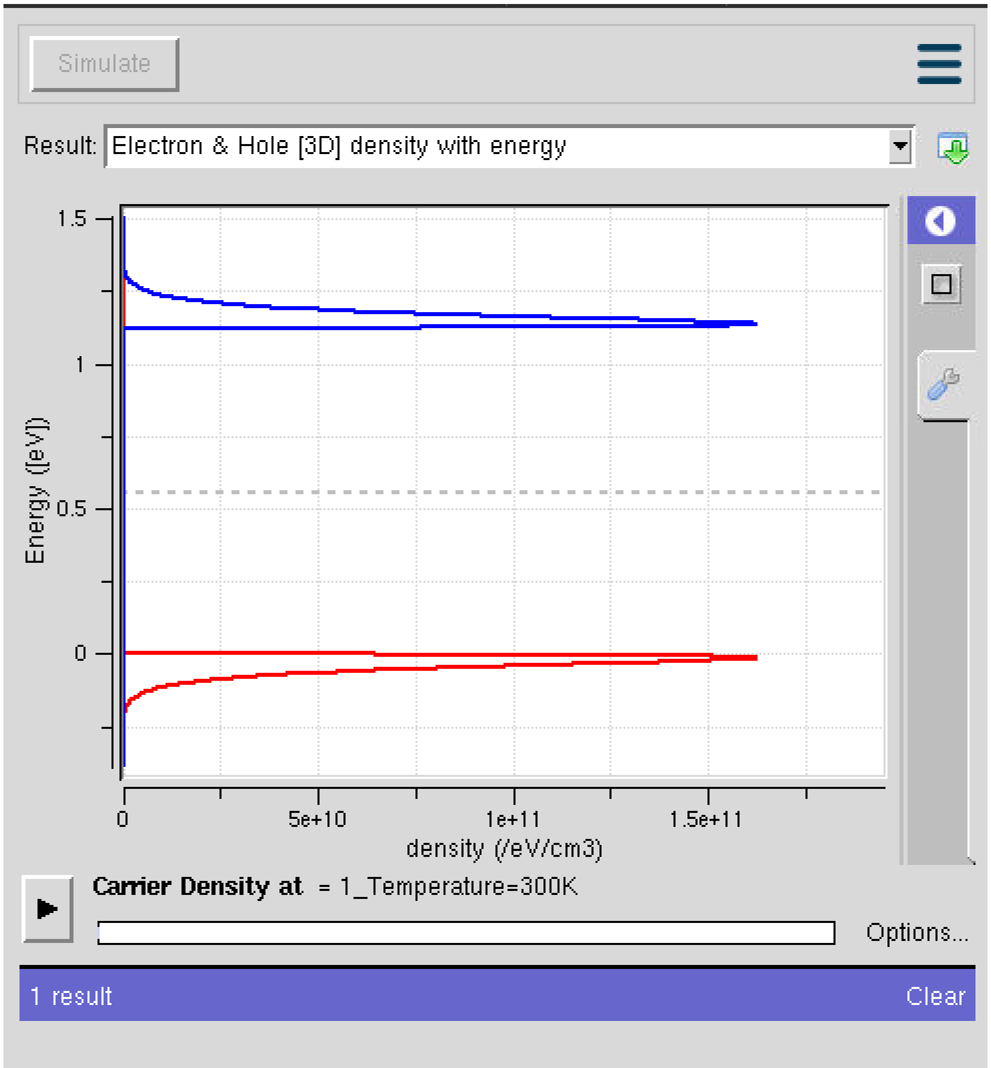
<u>Q11)</u> observe the hole density at 300k.



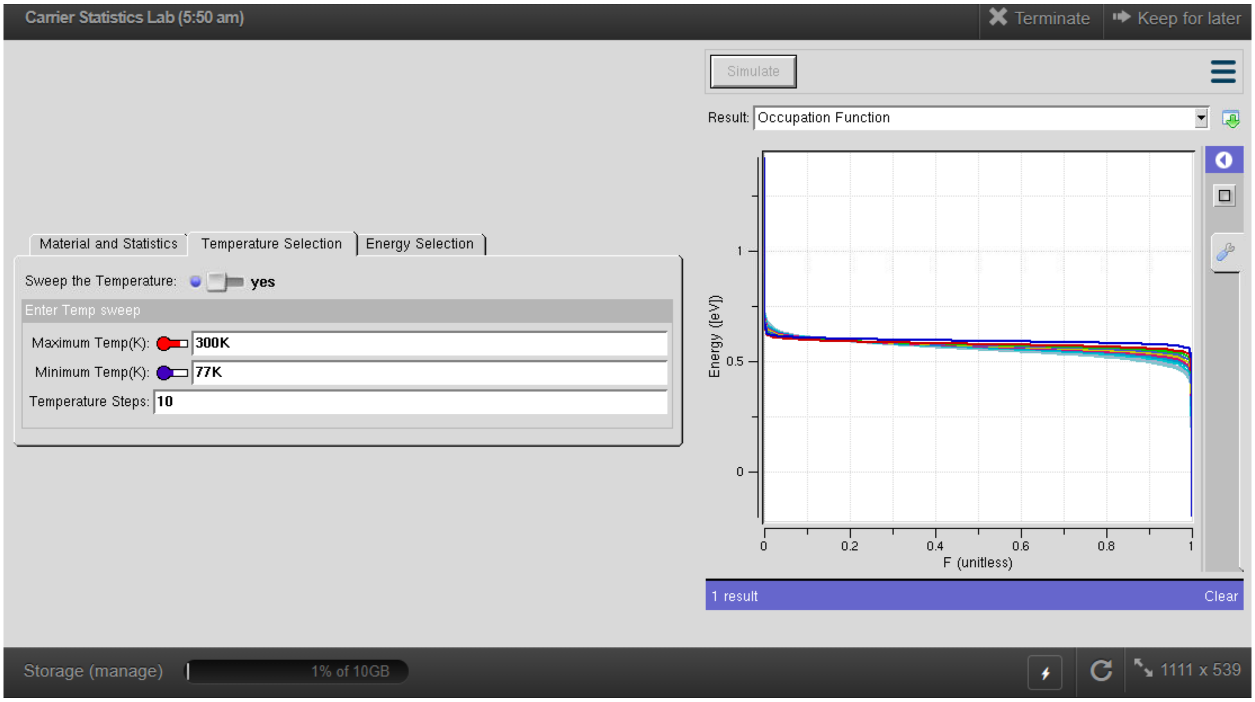
<u>Comments:</u>

The electron density at 300k is 1.6211e+11eV/cm3

Q12) observe both electron and hole densities with respect to temperature at 300k

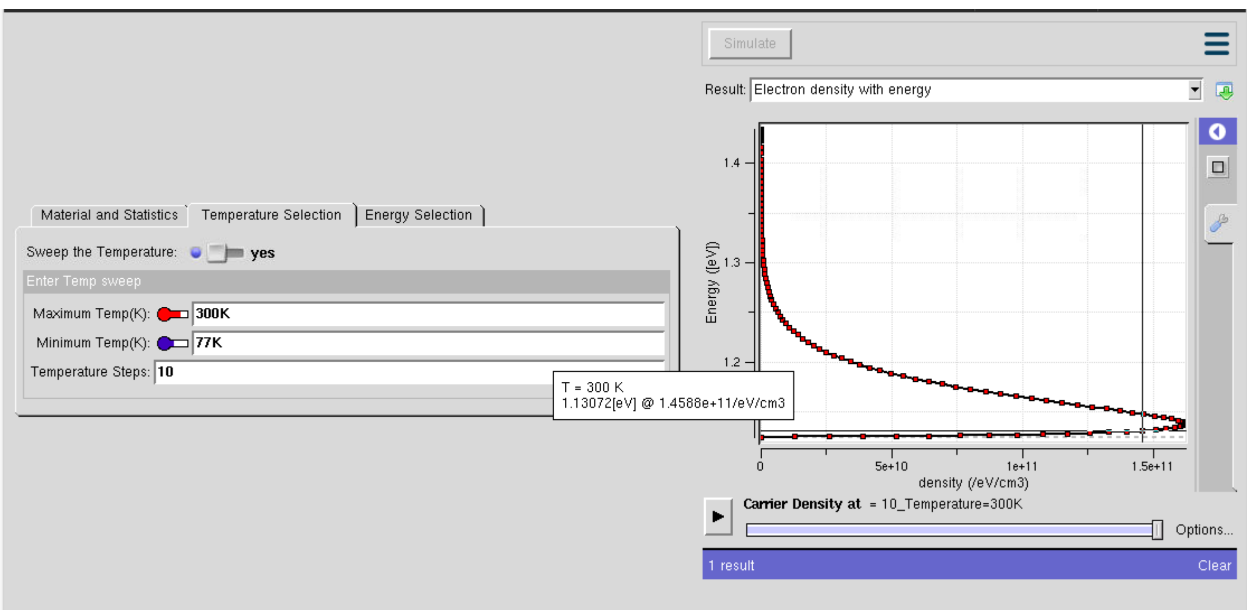


TASK#NO4: Now observe the occupational factor over a wide range of temperature.

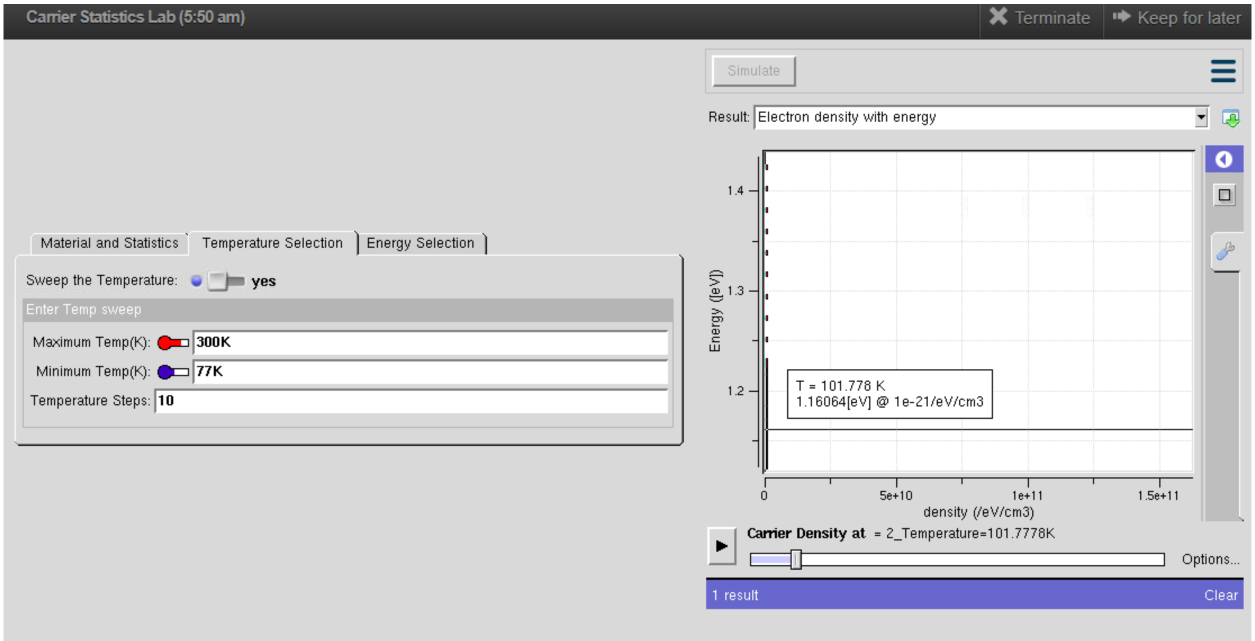


Q1) view electron density with energy and find electron density at

1) 1.13eV @ 300k



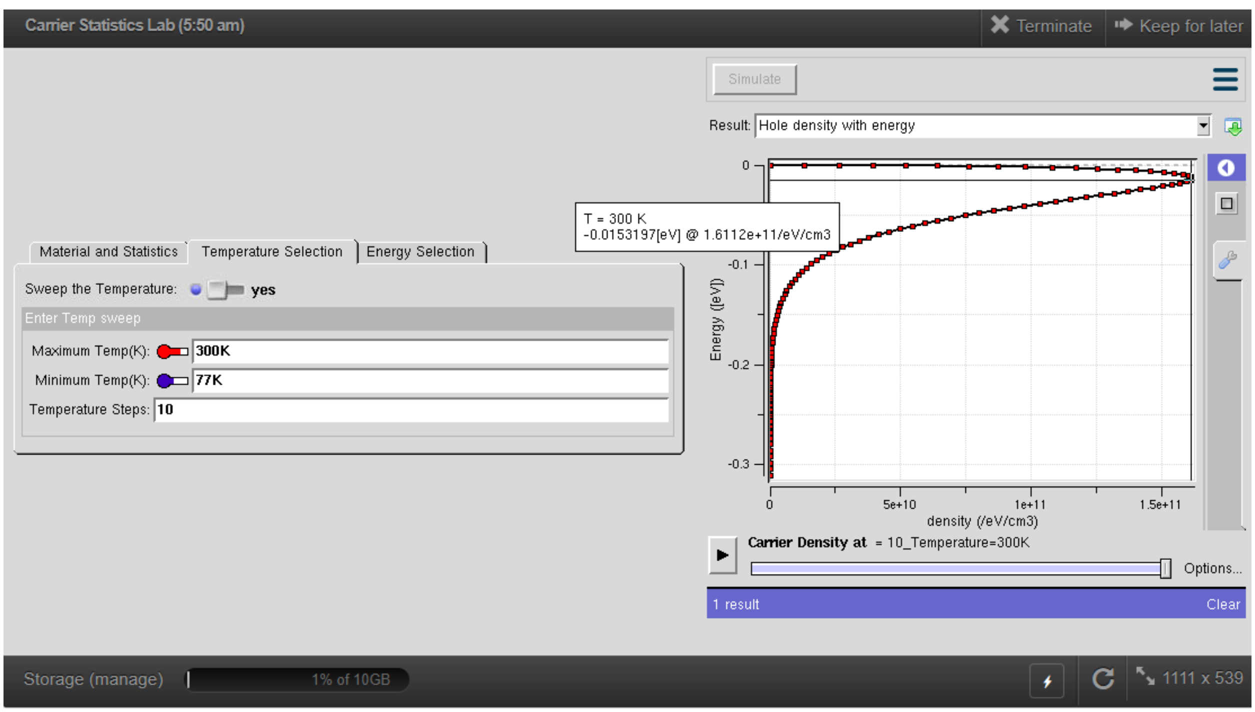
2) [1.16eV @ 101k](#)



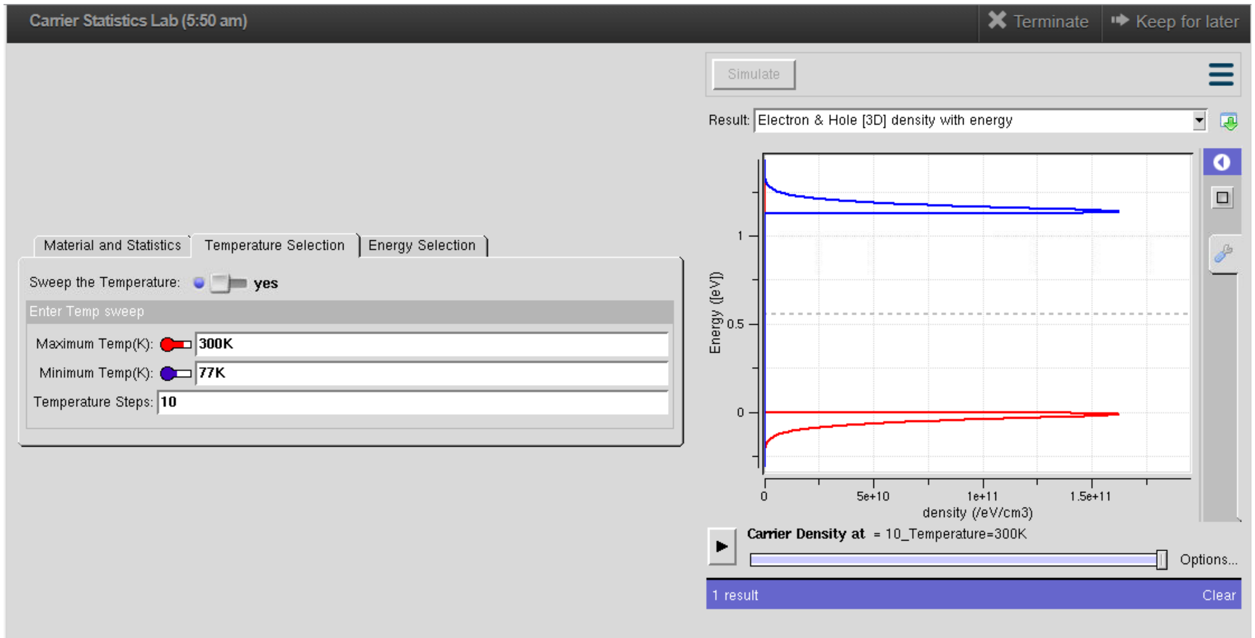
Comments:

The electron density at 101k is 1e-21eV/cm3

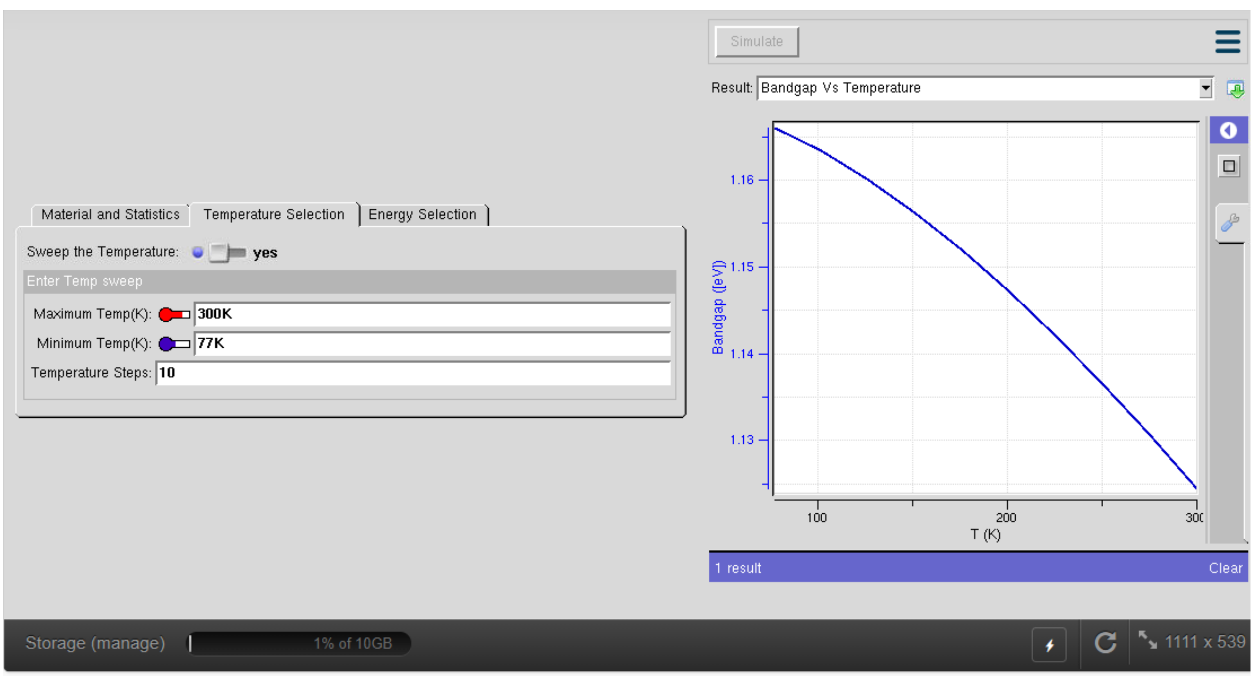
Q2) view the hole density with respect to energy at different temperatures.



Q3) view the electron and hole density with respect to energy at different temperature



Q4) view the variation in band gap with respect to temperature.

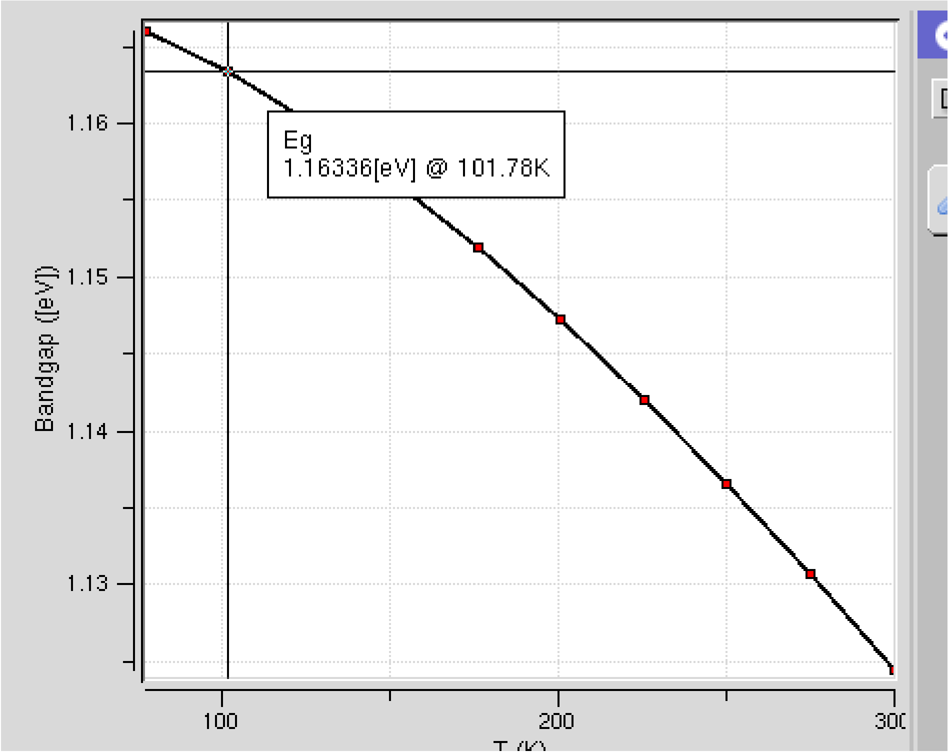


Comments:

With the increase in temperature the value of band gap is changing.

Q5) what is the band gap of silicon at 100k, 200k, and 300k.

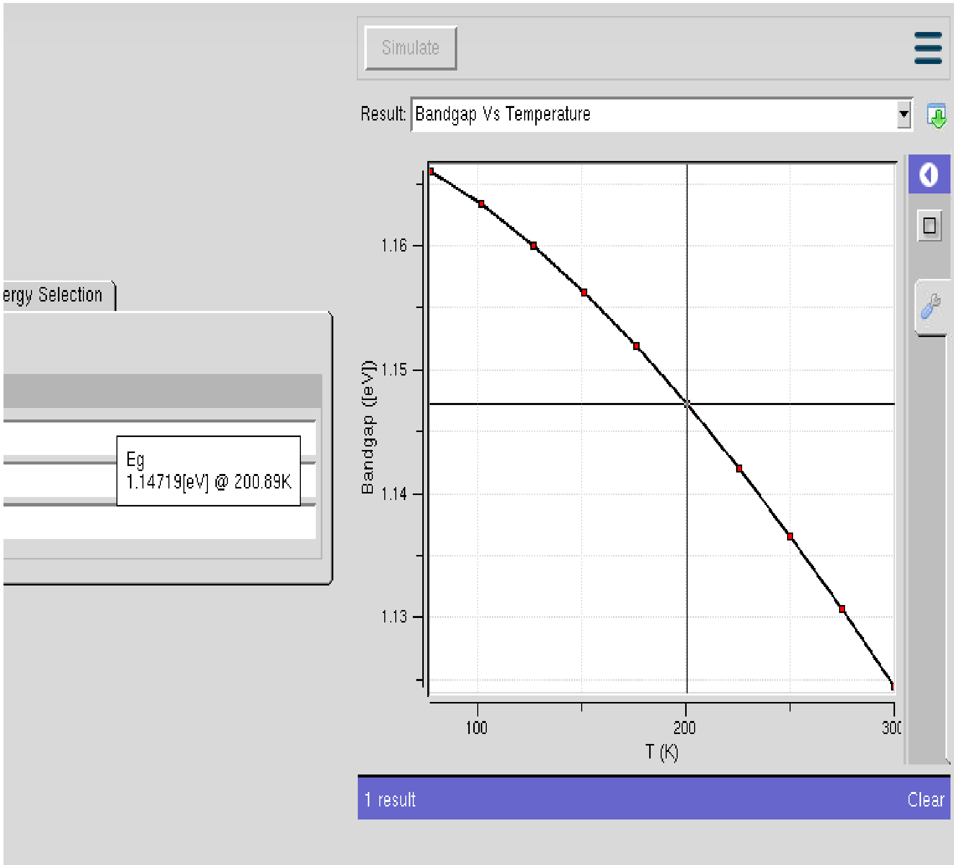
AT 100k:



Comments

The band gap at 100k is 1.16336[Ev]

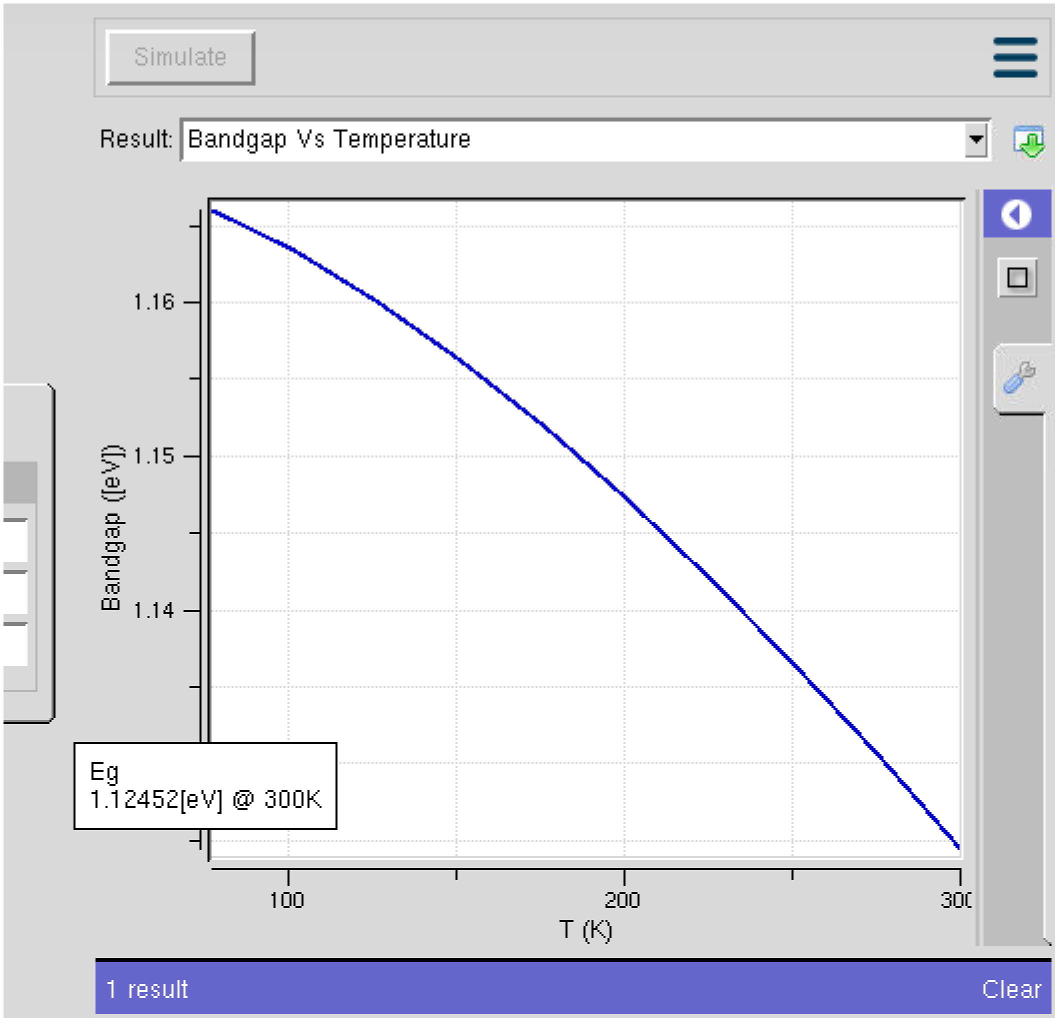
AT 200K:



Comments:

The band gap at 200k is 1.4719[eV]

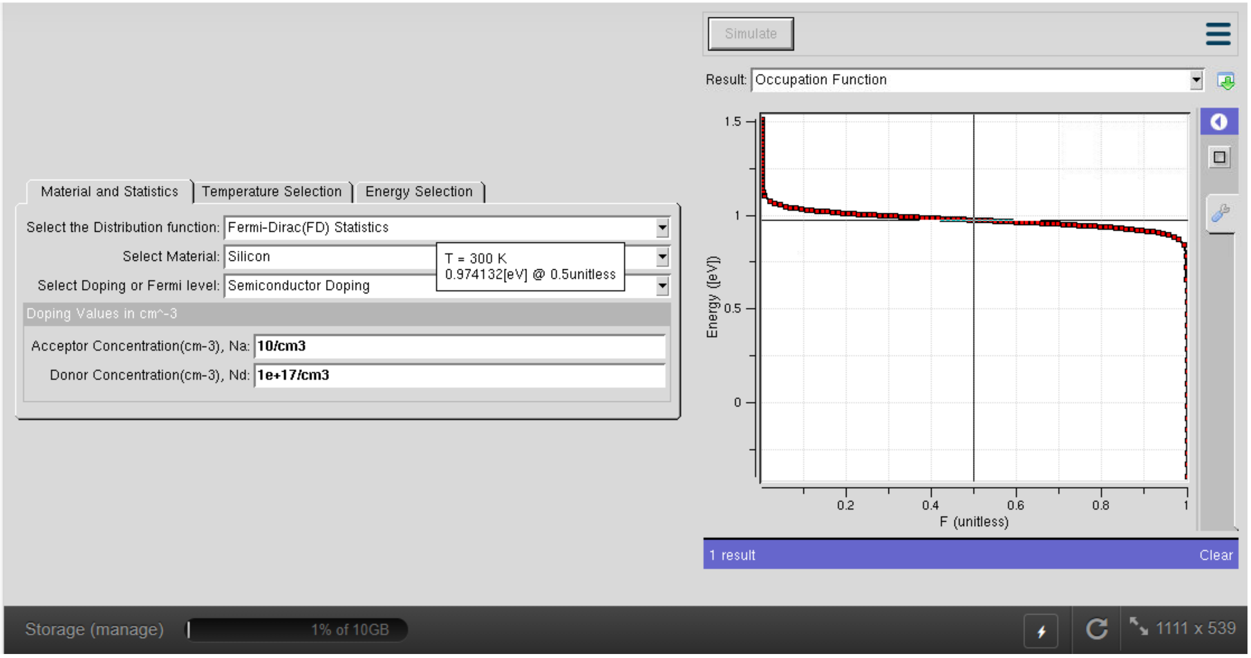
AT 300K



Comments:

At 300k the band gap is 1.12452[eV]

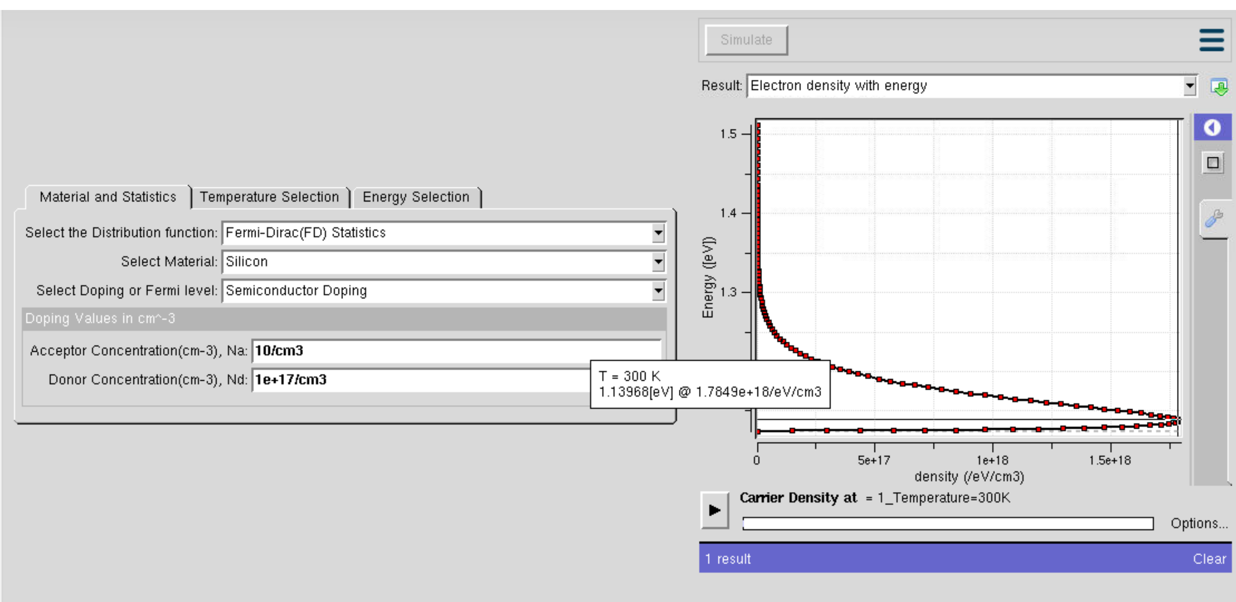
<u>TASK NO #5:</u> View the occupation function of n type semiconductor at room temperature



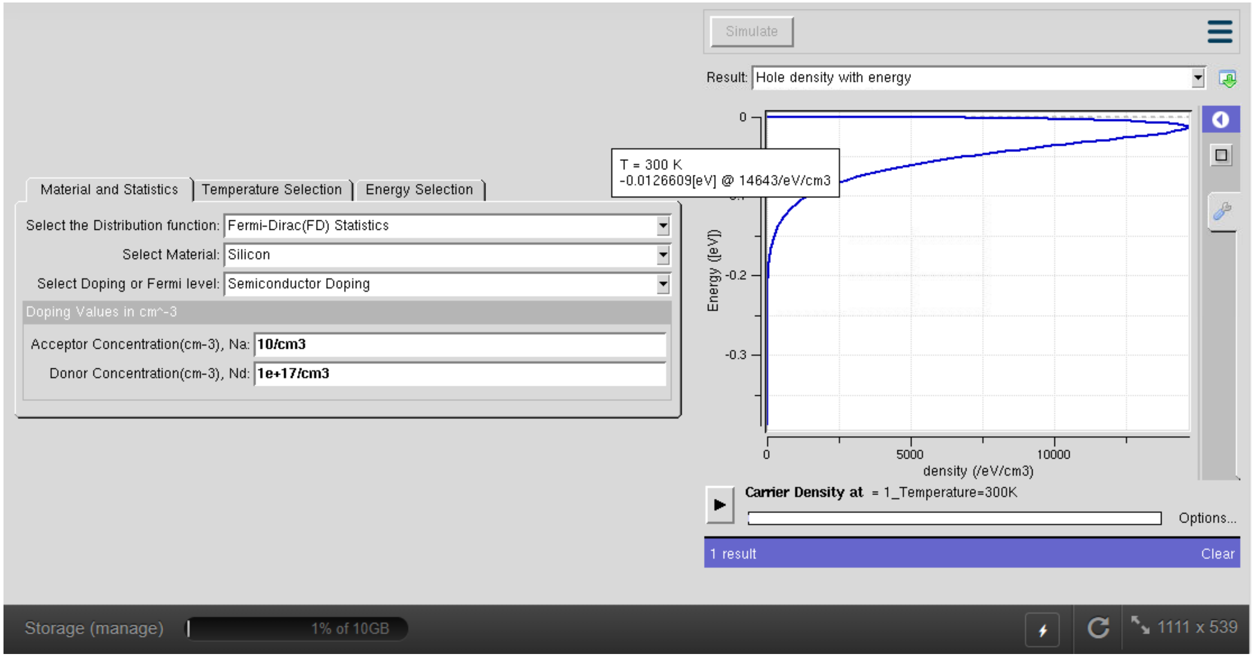
<u>Q1)</u> Fermi level lies at energy level?

ANS: The Fermi level lies at 0.974[eV]

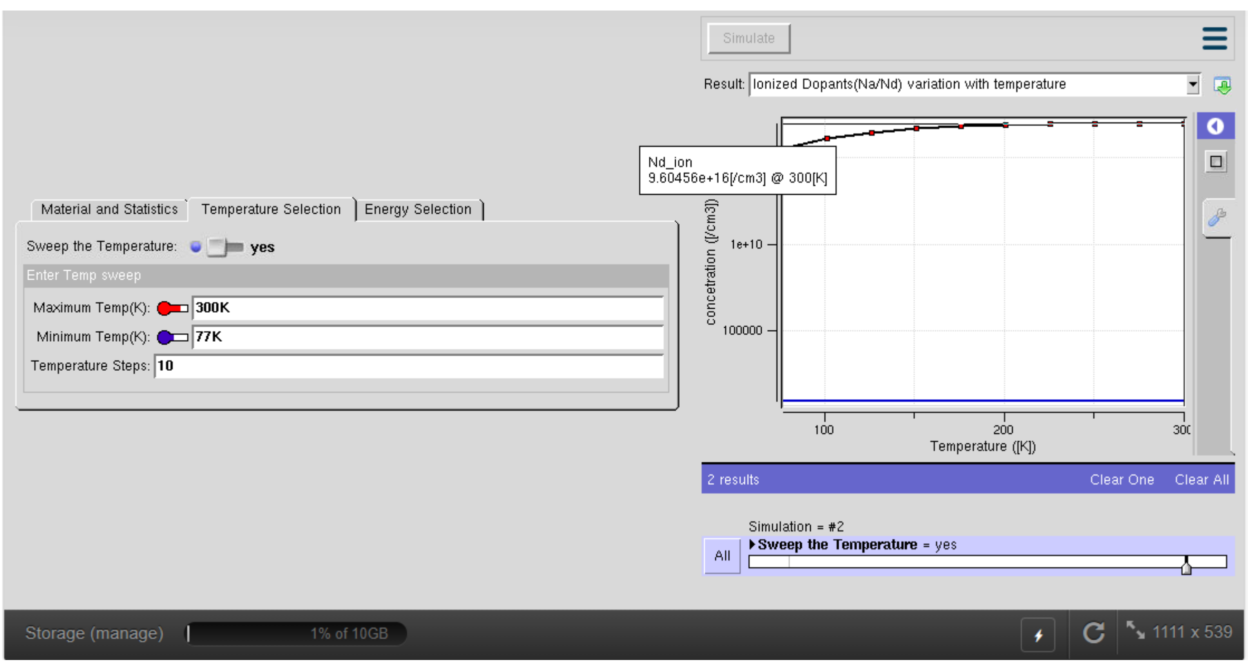
<u>Q2)</u> View electron density with respect to energy



Q3) View hole density with respect to energy

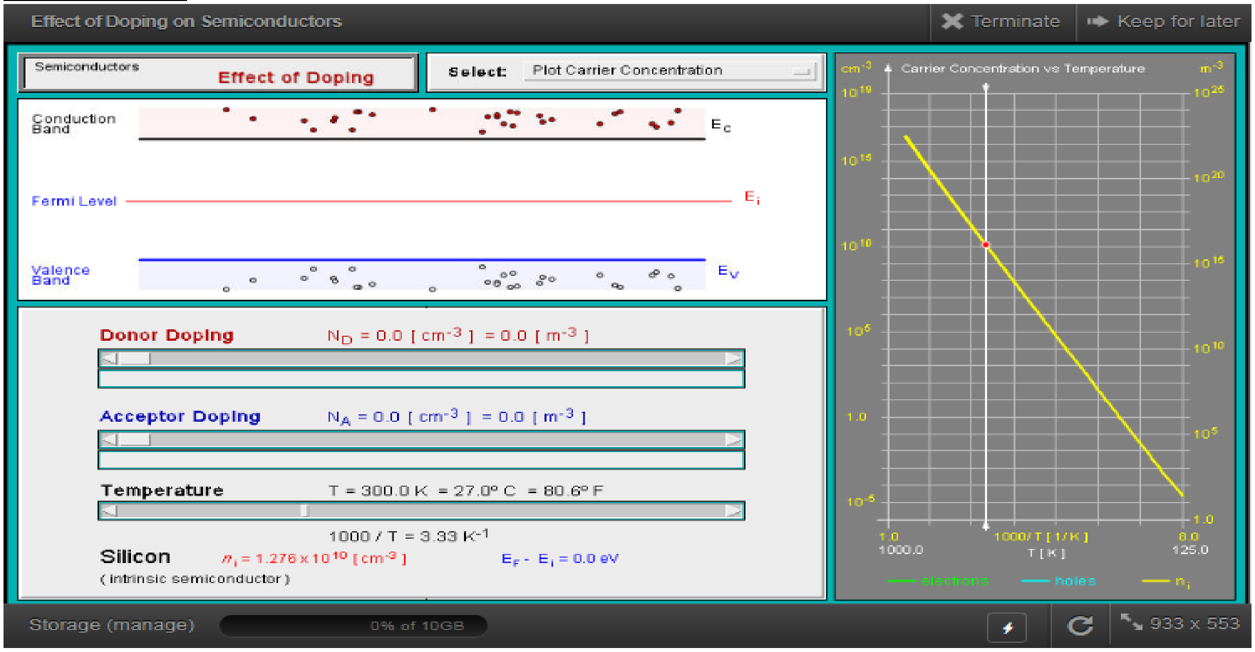


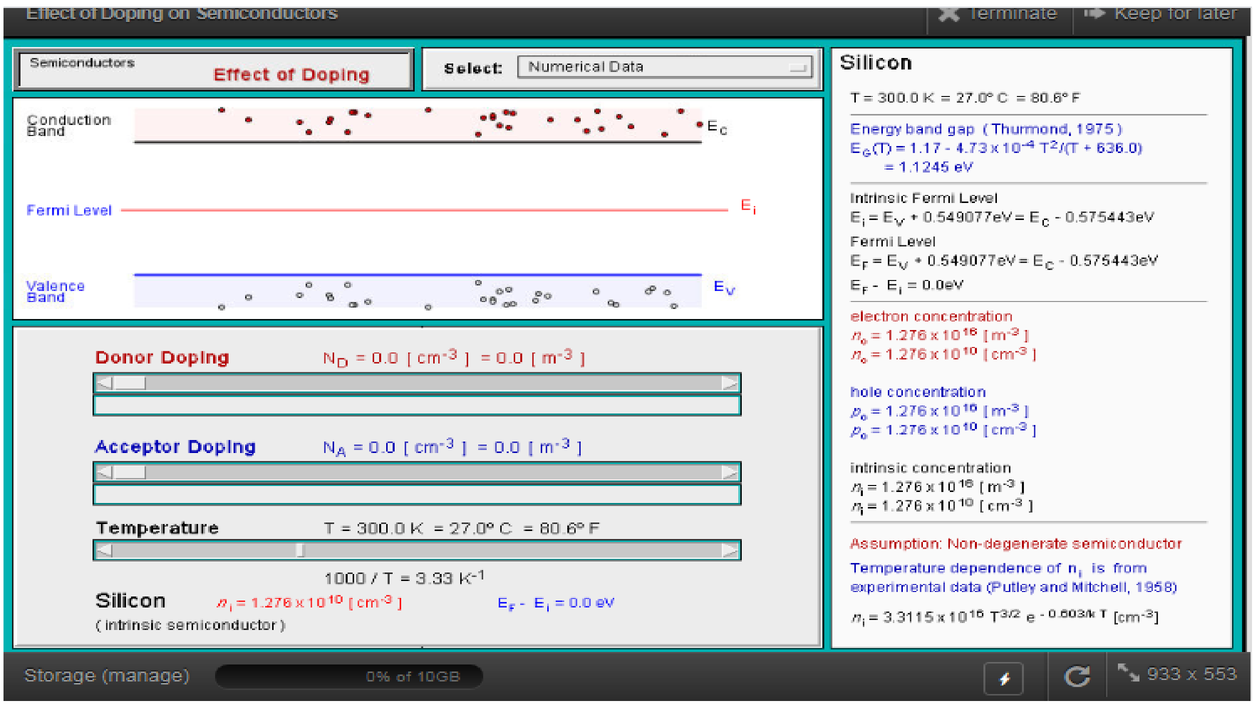
TASK#NO 6: Now observe the variation in ionization dopants with increase in temperature (of the above mentioned doped semiconductor)



LAB NO: 04

TASK NO 1: At 300k observe the intrinsic semi conductor



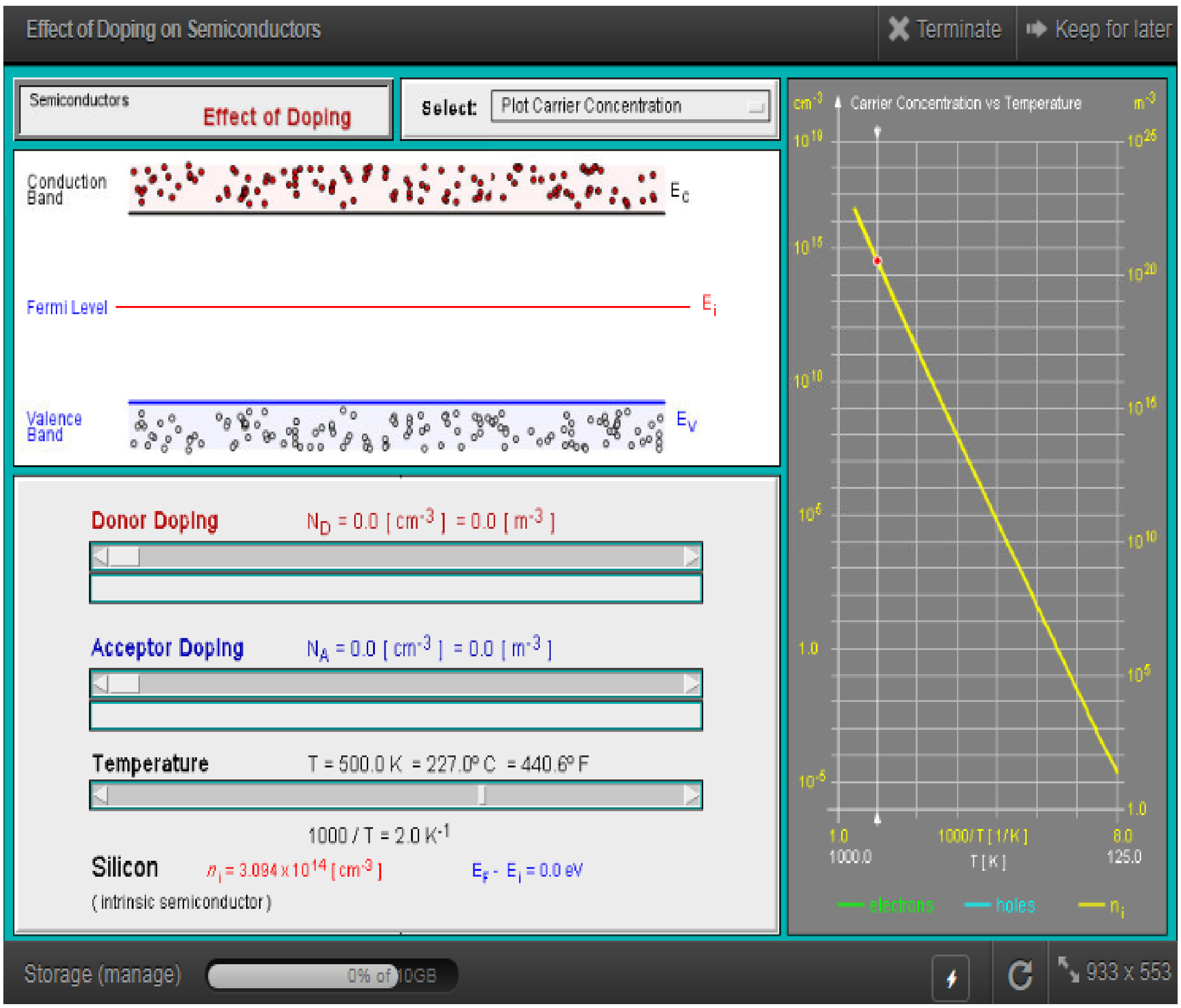


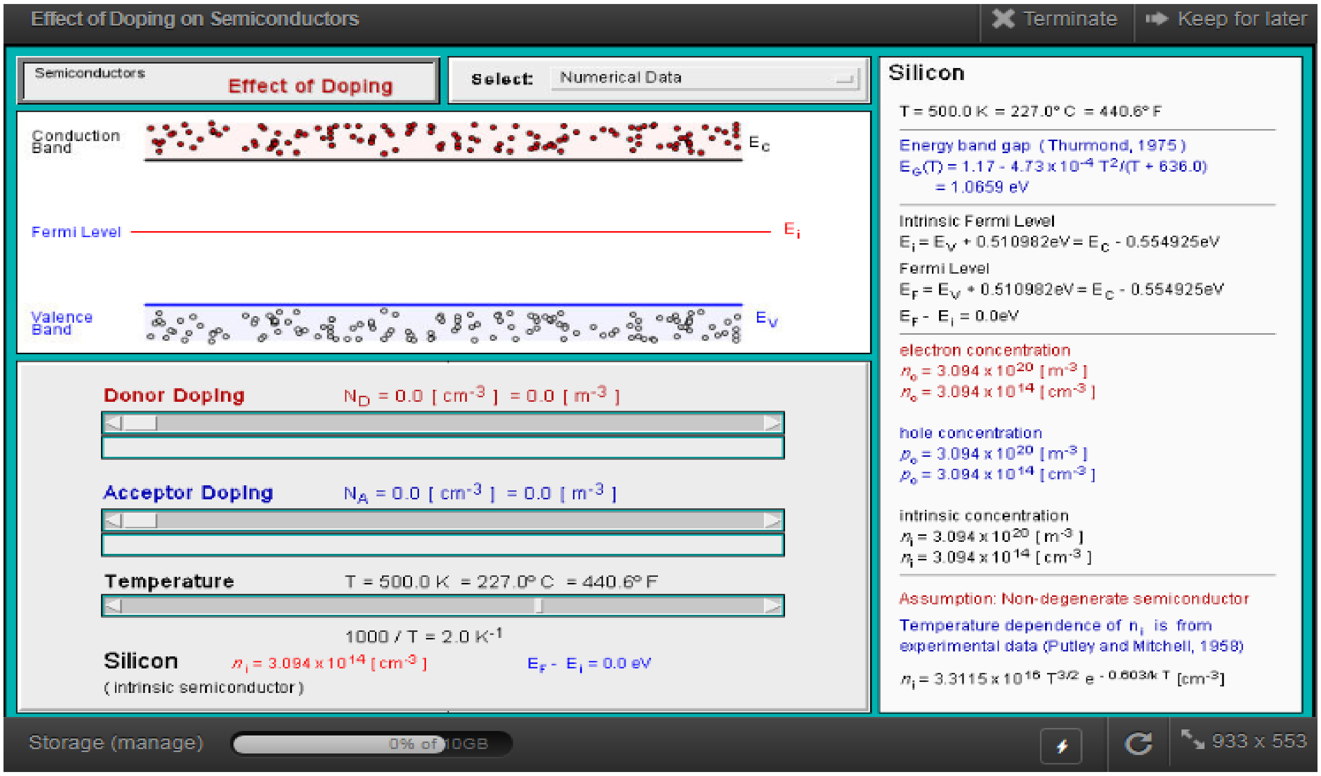
Q:1 What is the intrinsic carrier concentration?
The intrinsic carrier concentration is ni = 1.276x10^10/cm^3.

Q:2 where does the Fermi level lie?
Fermi level lies at Ei.

Q:3 Write down the concentration of electron and holes?
Concentration of electrons=Concentration of holes=Intrinsic concentration (ni)= 1.276x10^10/cm^3.

<u>Task No. 02:</u> Increase the temperature and observe the semiconductor





Q.1: - Write down the intrinsic carrier concentration.

Intrinsic carrier concentration is 3.09x10^14/cm^3

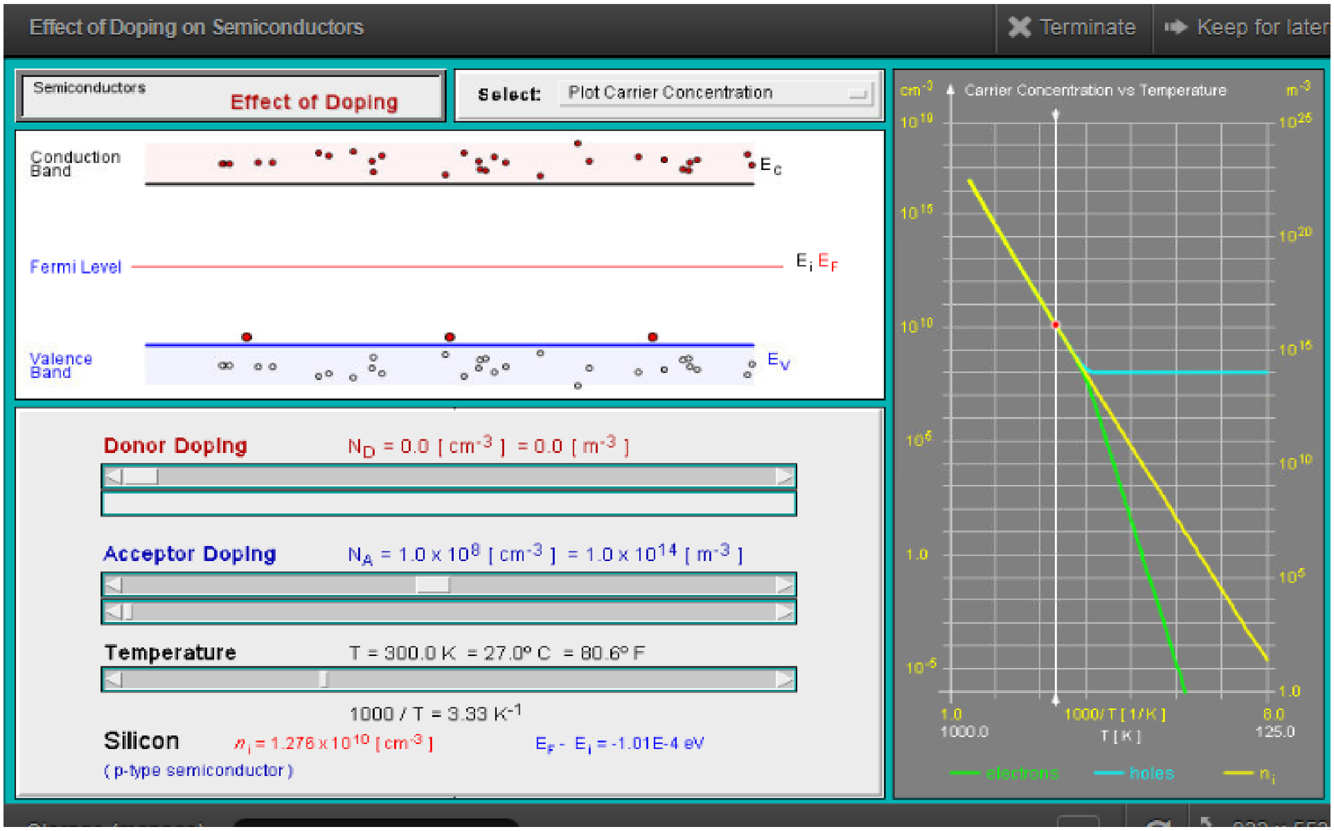
Q.2: - Where does Fermi level lie? Is there any effect of temperature on position of Fermi level? Yes/No. Give reason.

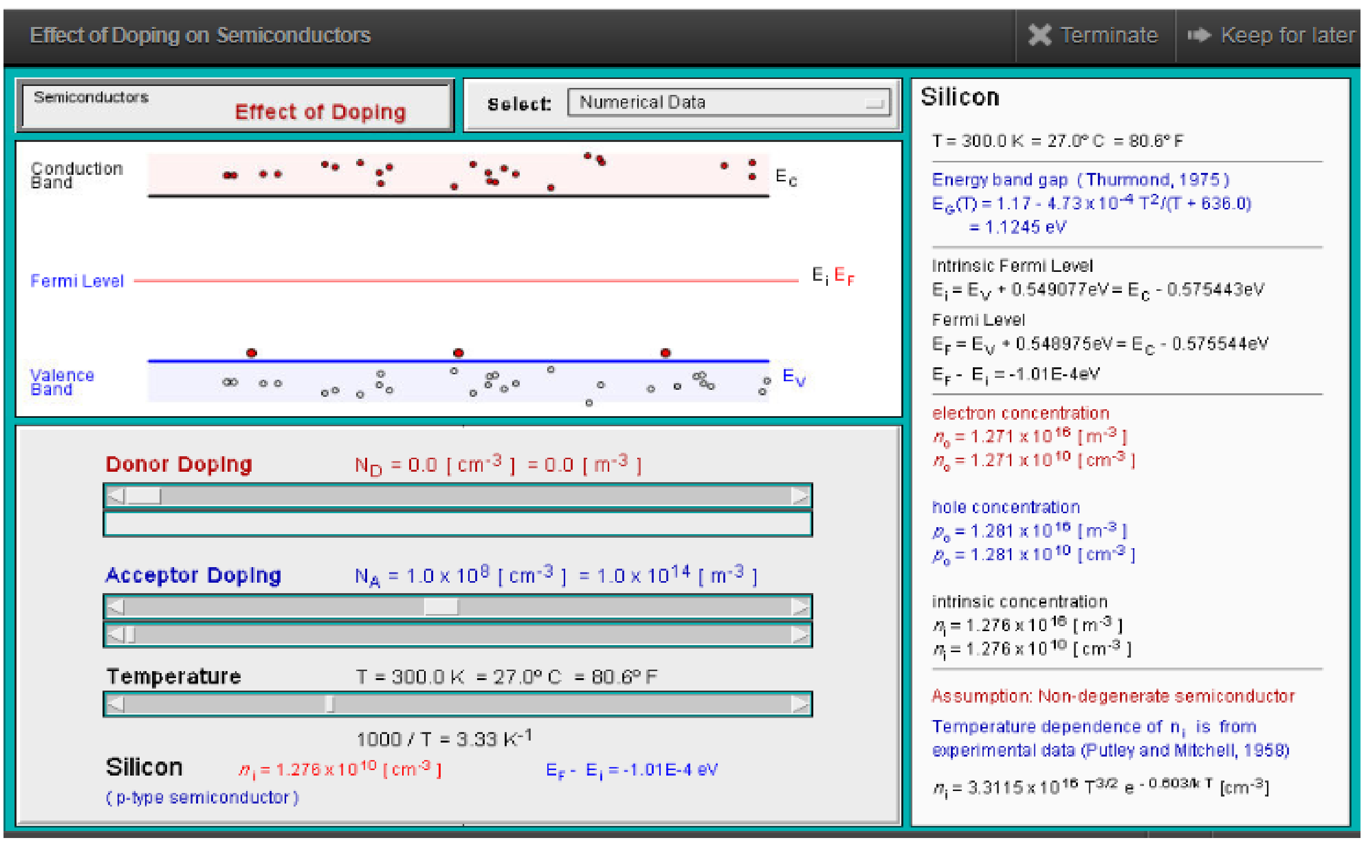
Fermi level lies exactly at Ei. No, there is no effect of temperature at the position of Fermi level. Because the material is intrinsic, the electron and hole concentration is same so Ef is at Ei

Q.3: - Write down the concentration of electron and hole. Is there any effect on the concentration of electron and hole? Yes/no. Give reason

Concentration of electrons=Concentration of holes=Intrinsic concentration= 3.09x10^14cm/^3
Yes, because if we increase the temperature more silicon bonds will break and large number of electron hole pair (EHP) will generate.

Task No. 03: Suppose the semiconductor is doped with acceptor atoms. Observe the semiconductor at 300K





Q.1: - What is the intrinsic carrier concentration?

Intrinsic carrier concentration is 1.27x10^10/cm^3

Q.2: - Write down the concentration of electrons and holes.

Concentration of electron =no= 1.271x10^10/cm^3
Concentration of hole =po=1.281x10^10/cm^3

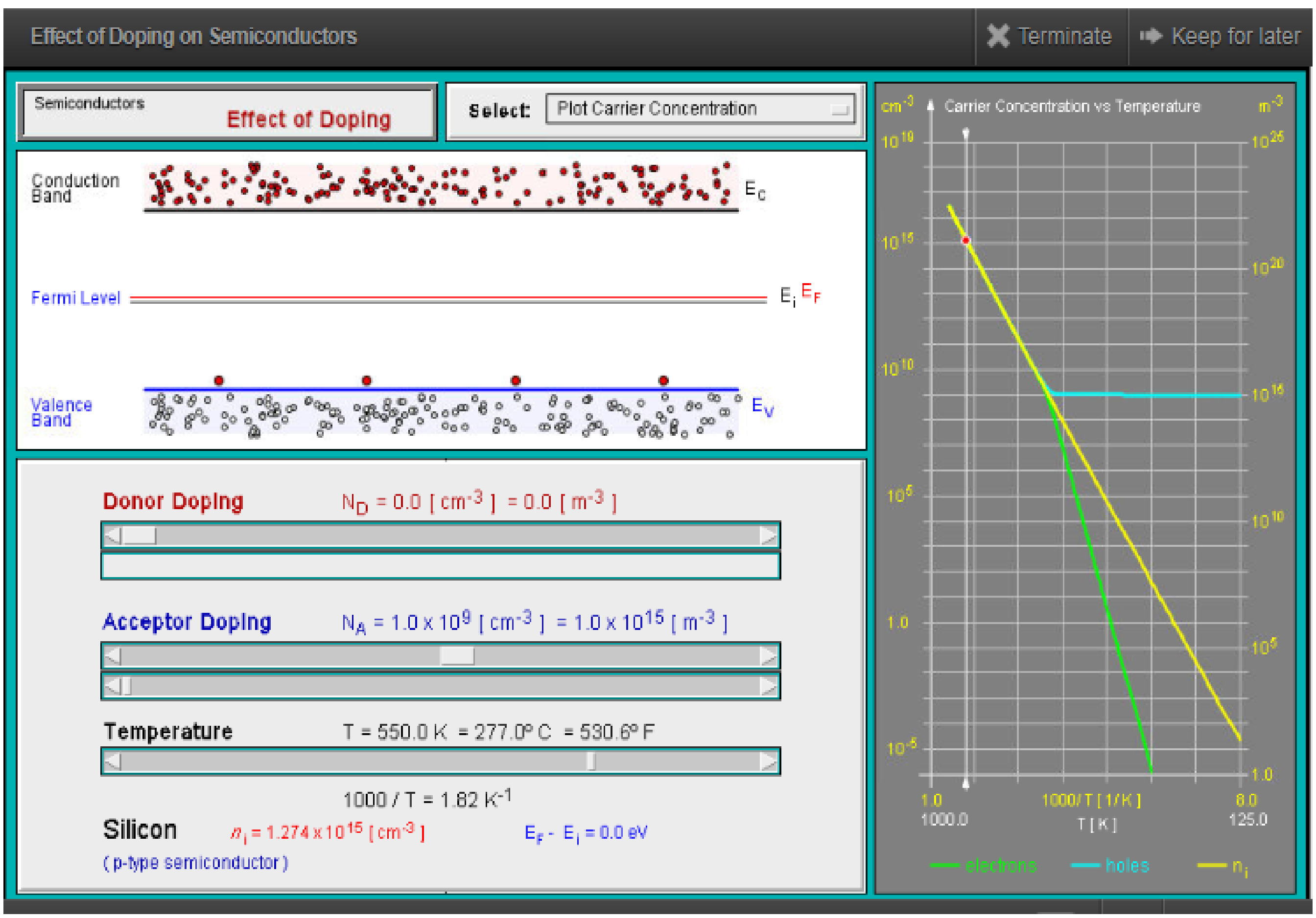
Q.3: - Where does Fermi level lie? At, above or below E ? Give reason.

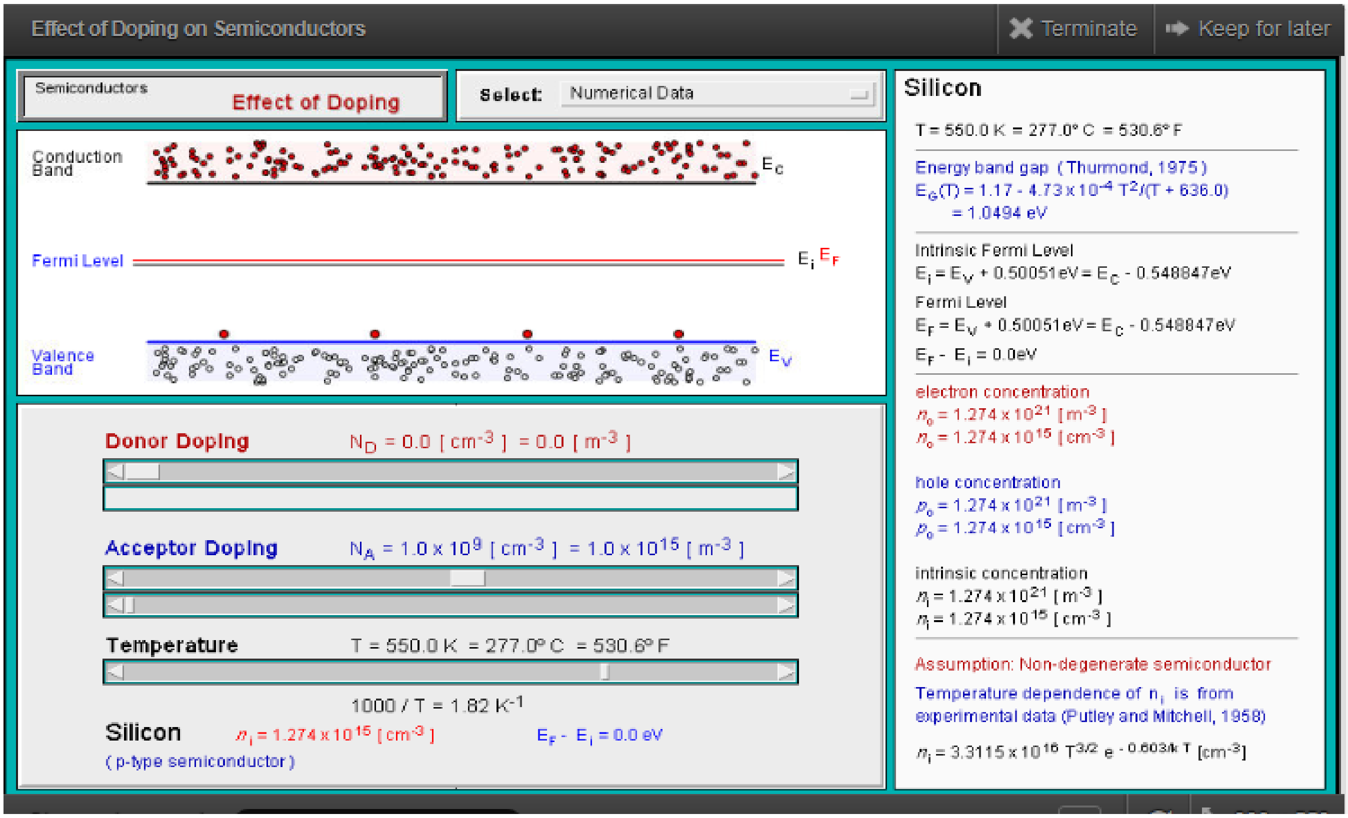
Fermi level lies below Ei. Closer to valence band

Q.4: - What is the position of EF relative to Ei?

Ef lies below Ei. Because it is a p-type semi conductor.

<u>Task No. 04:</u> Observe the above doped semiconductor at 550K.





Q.1: - What is intrinsic carrier carrier concentration?

Intrinsic carrier concentration is 1.274x10^15/cm^3

Q.2: - What is the concentration of electron and holes?

Concentration of electron =no= 1.27x10^15/cm^3
Concentration of hole =po=1.27x10^15/cm^3

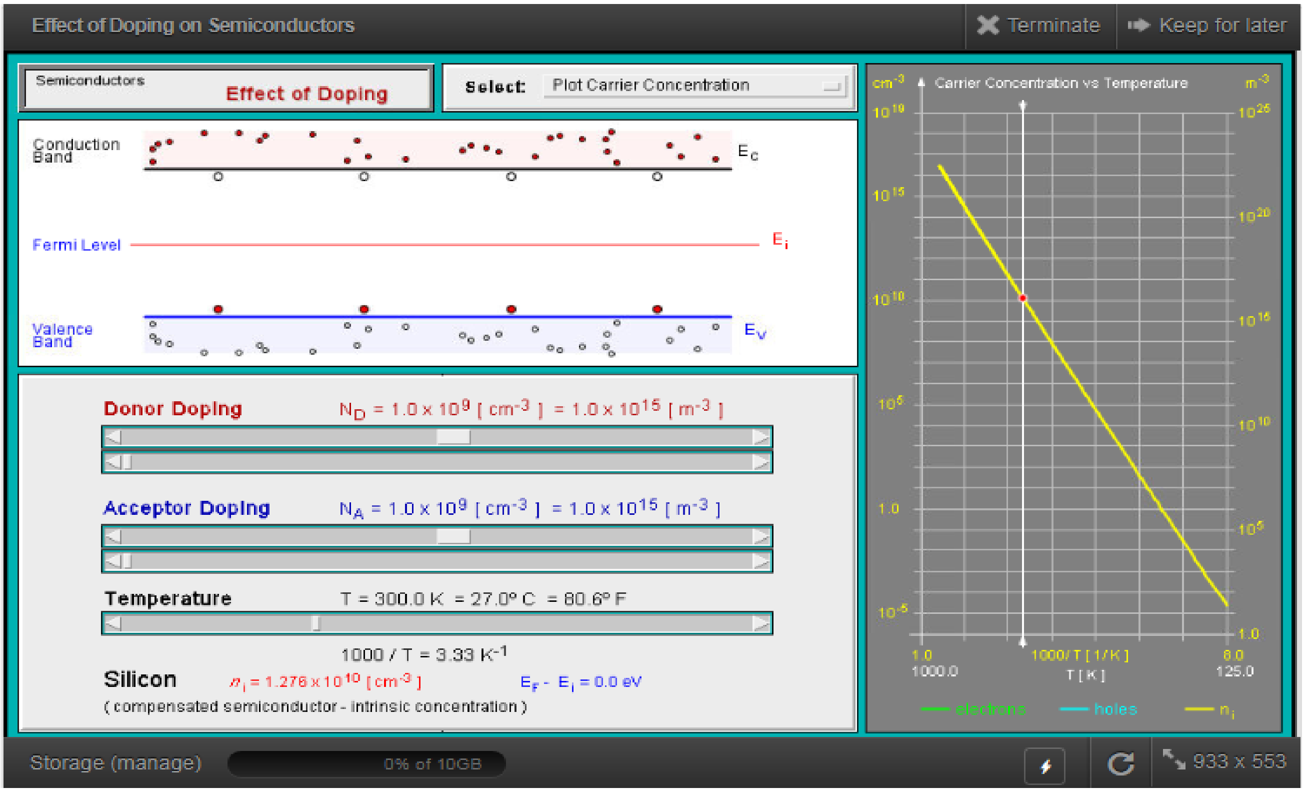
Q.3: - What is the position of EF relative to Ei?

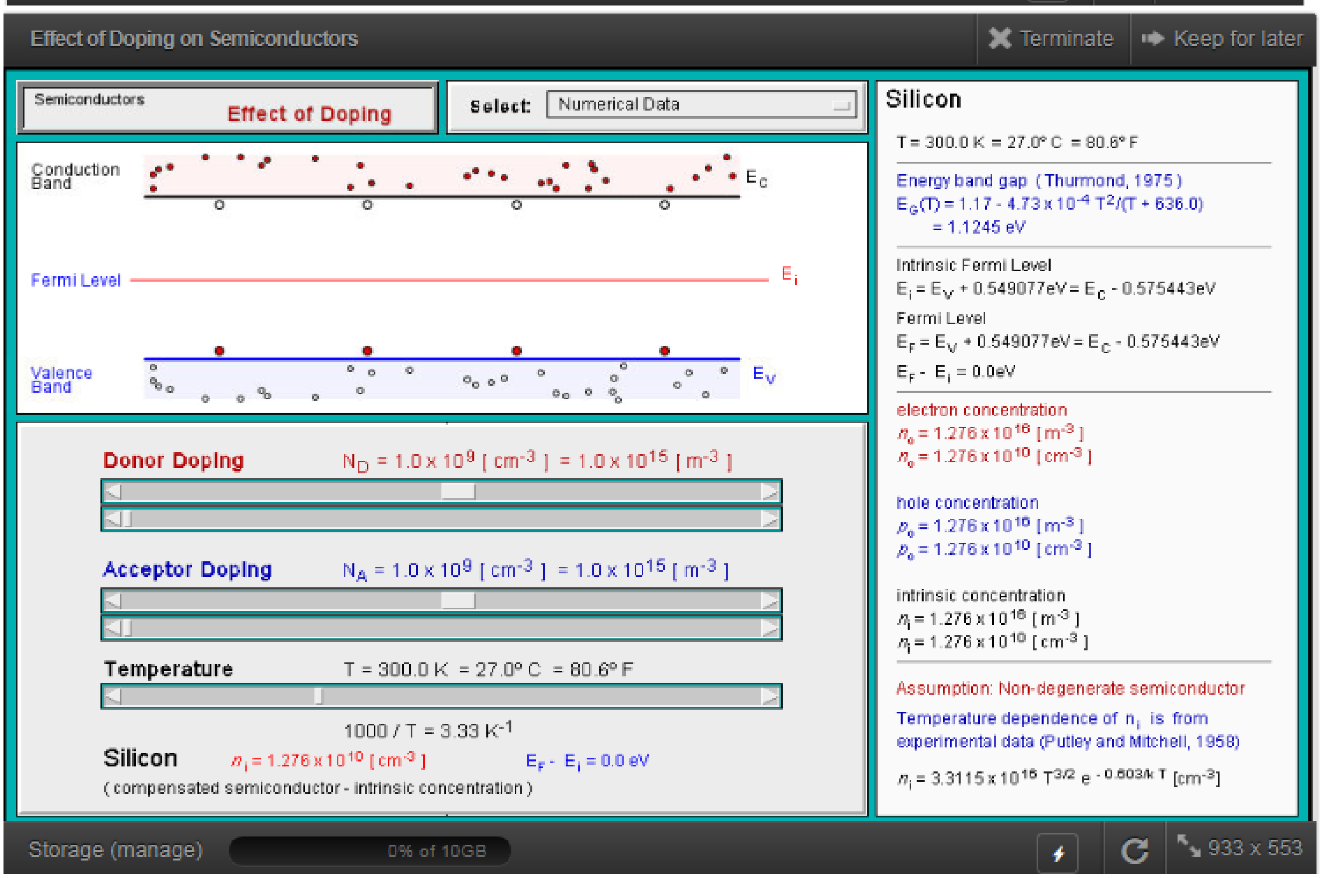
Ef lies at Ei.

Q.4: - Despite of the fact that semiconductor is doped only by acceptor atoms, electron concentration is almost equal to the hole concentration. Explain why?

At room temperature this material was p-type that is po is greater than no, but if we increase the temperature more and more silicon bonds will break and a large number of EHP will generate and the resultant electron and hole concentration will almost equal thus the effect of doping has almost vanish.
i.e electron and hole concentration is almost equal because temperature is very high 550K and at high temperature no and po has negligible effect of doping.

Task No.05: Observe the semiconductor at 300K for which $NA = ND$





Q.1: - What is the intrinsic carrier concentration, concentration of electrons and holes?

The intrinsic carrier concentration is ni = 1.276x10^10/cm^3.
Concentration of electron = 1.276x10^10/cm^3.
Concentration of hole = 1.276x10^10/cm^3.

Q.2: -What is the position of EF relative to Ei?

Ef lies at Ei.

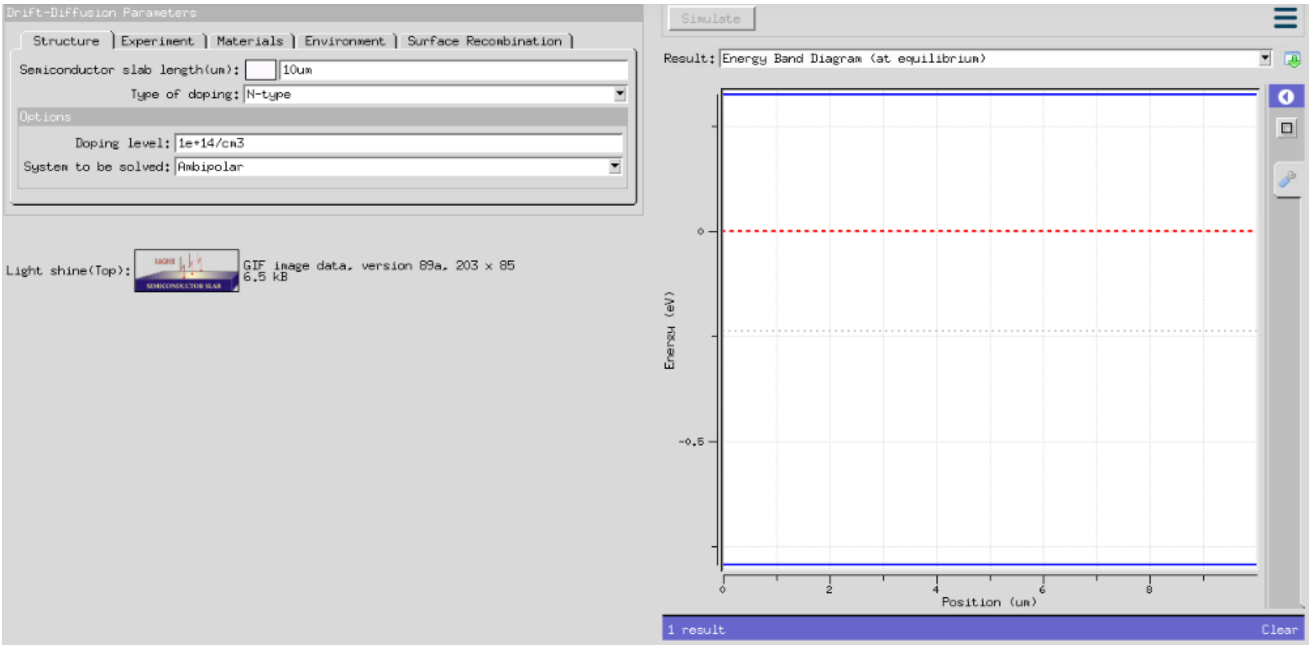
Q.3: - Based on the results of question 1, is there any advantage of equal acceptor and donor doping (i.e. NA = N)? If yes, specify its application. If no, give reason?

If we keep NA=ND the material will behave like intrinsic material. In IC designing we use this method to make intrinsic materials. Common example of equal doping is PN junction diode where we convert a portion of holes region into intrinsic region by keeping equal doping of acceptor and donor atoms.

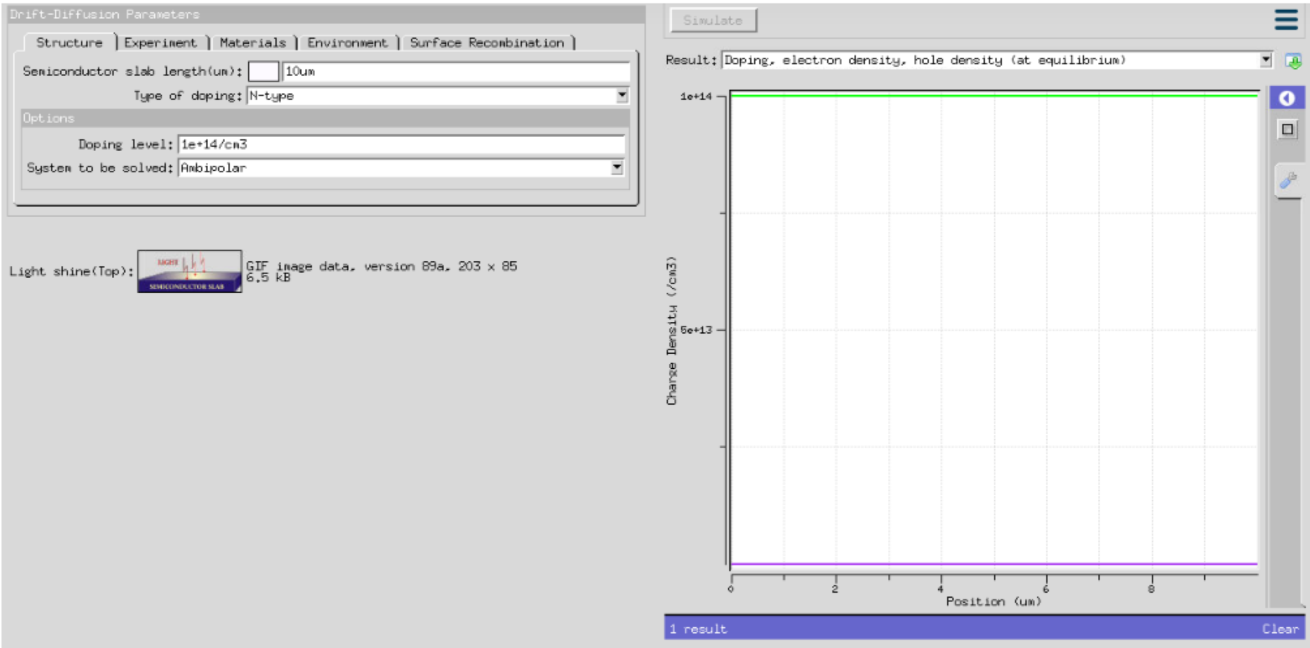
LAB NO: 05

Task No.01: A silicon wafer (ND=1014/cm3 ,T=Room Temperature) is illuminated with light which generates 1015 electron-hole pairs per cm3 -sec throughout the volume of the silicon

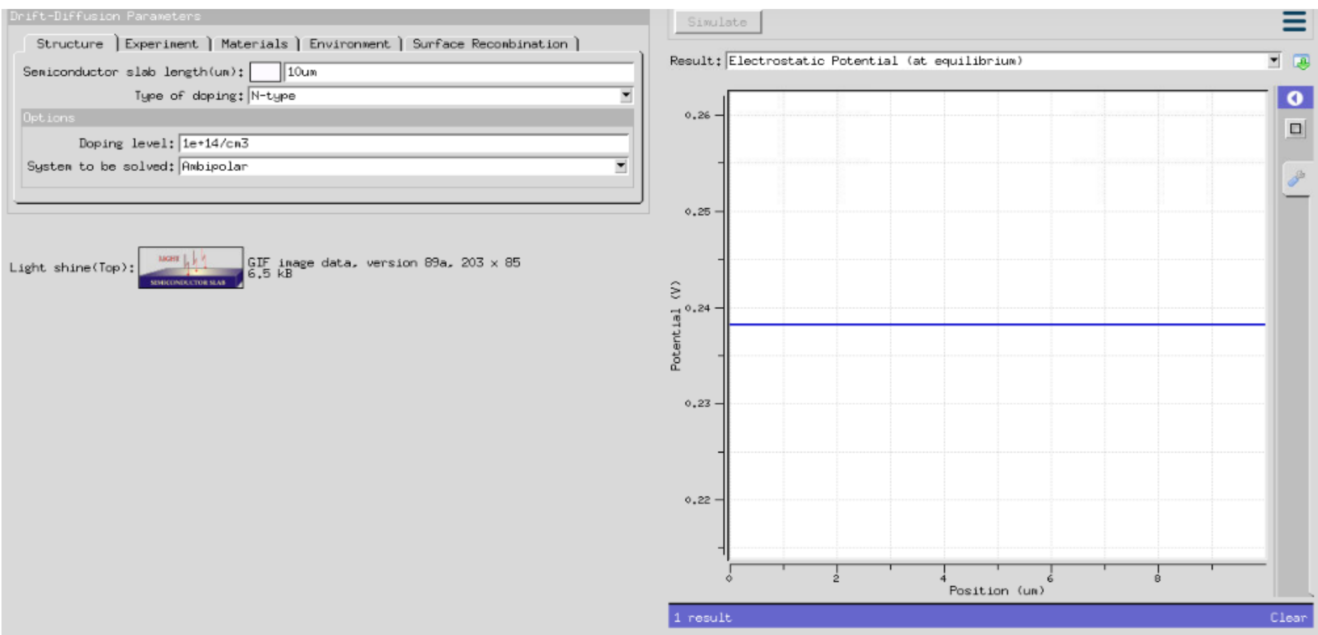
Q.1: View the energy band diagram before illumination.



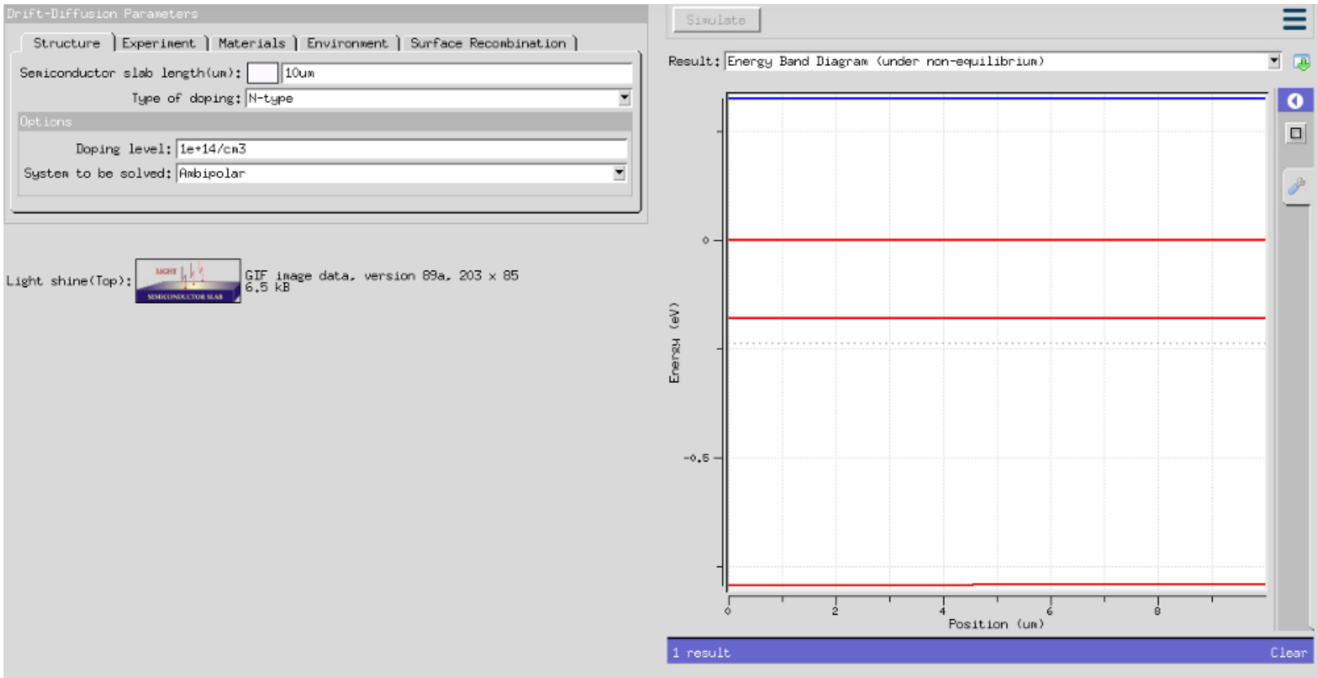
Q.2: From the simulation results determine doping, electron and hole density at equilibrium. Don't forget to attach simulation results.



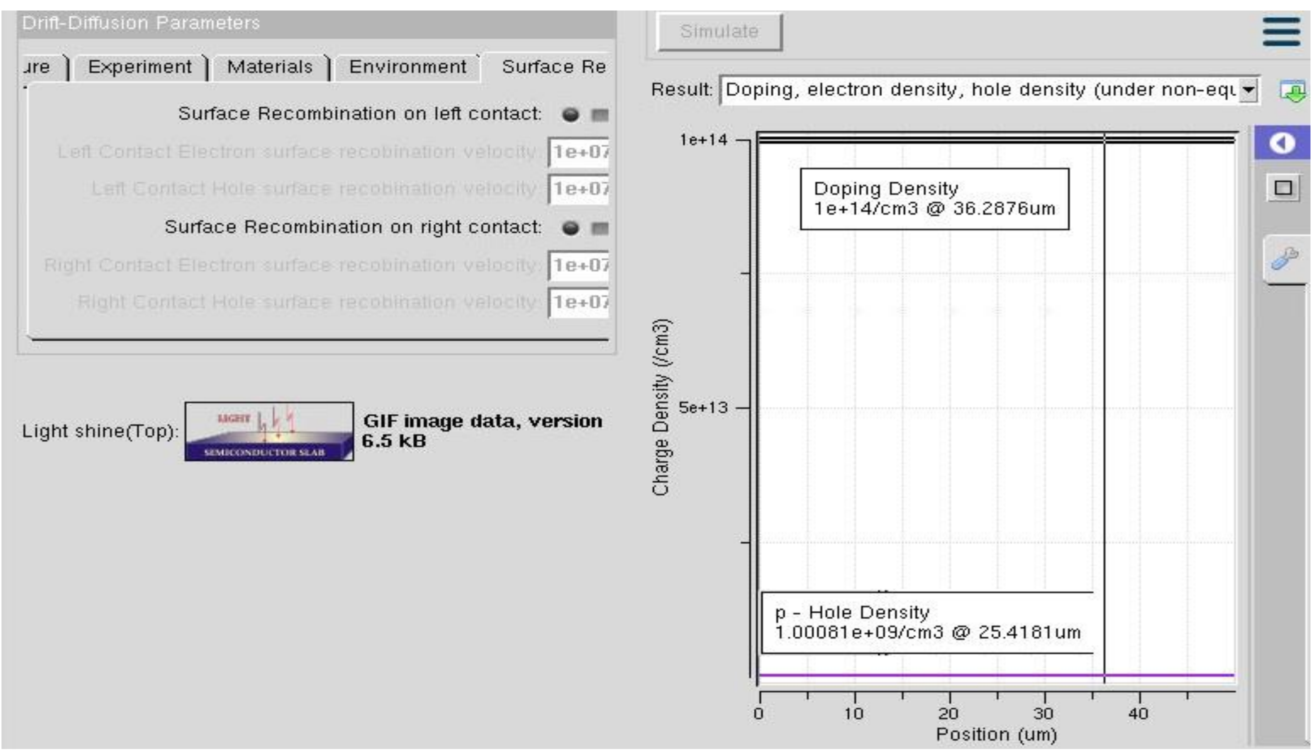
Q.3: From the simulation results determine electrostatic potential at equilibrium. Don't forget to attach simulation results.



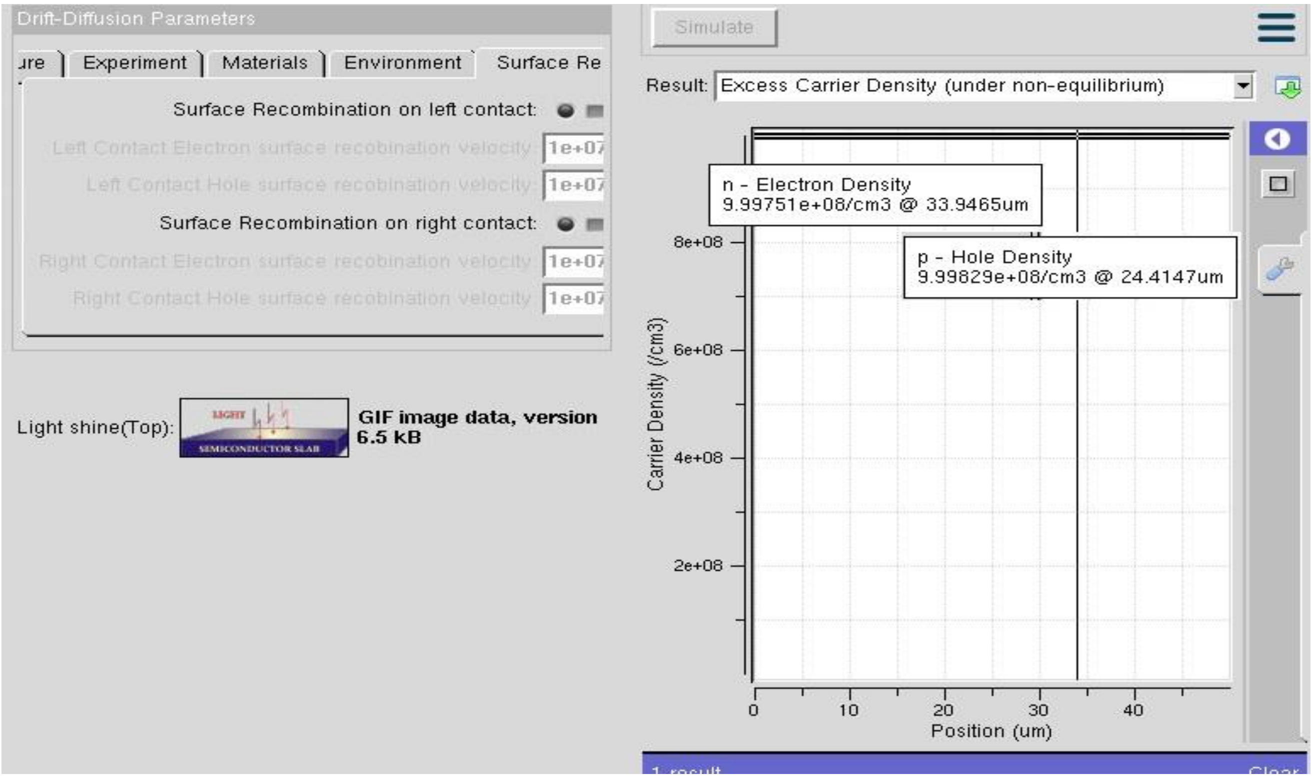
Q.4: View the energy band diagram under non-equilibrium



Q.5: By using simulation results determine the value of doping, electron and hole density under non equilibrium.

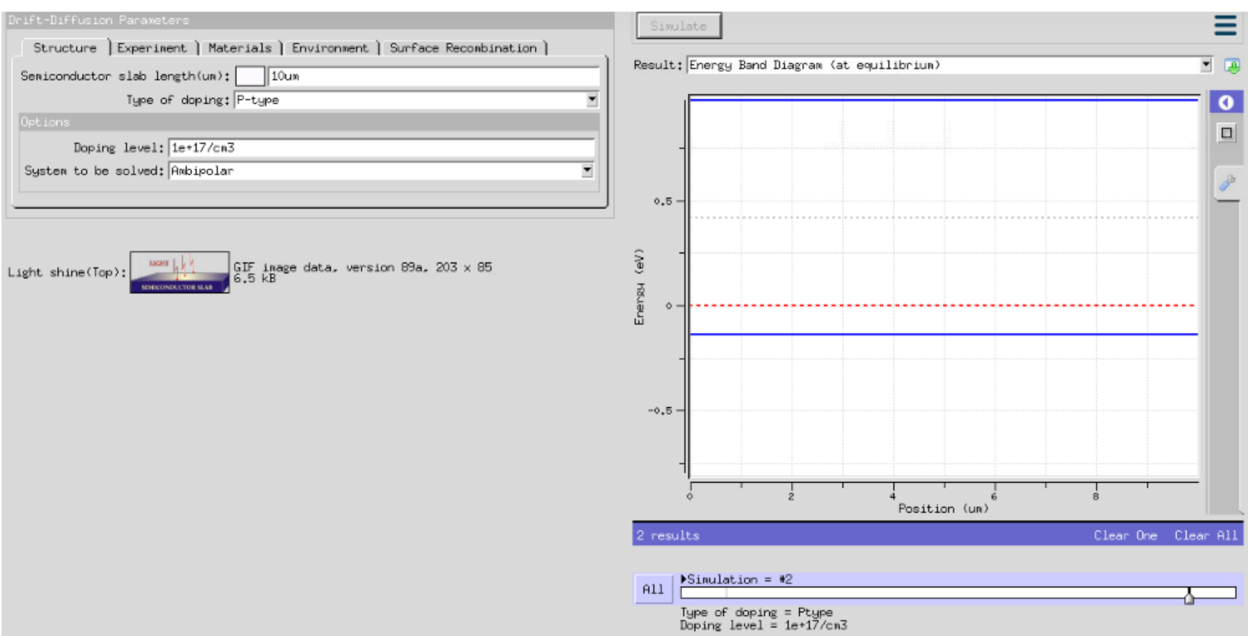


Q.6: View the excess carrier profile. Determine the excess electron and hole density

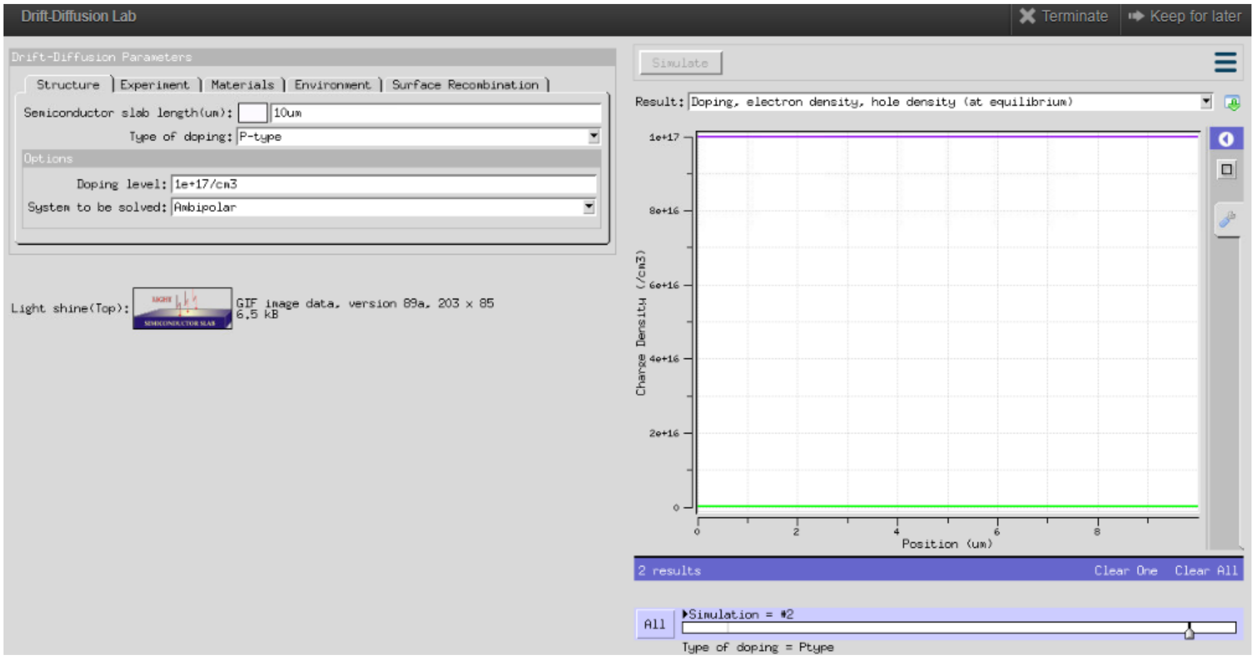


Task No.02: A p-type silicon wafer is illuminated with light throughout the volume of the wafer

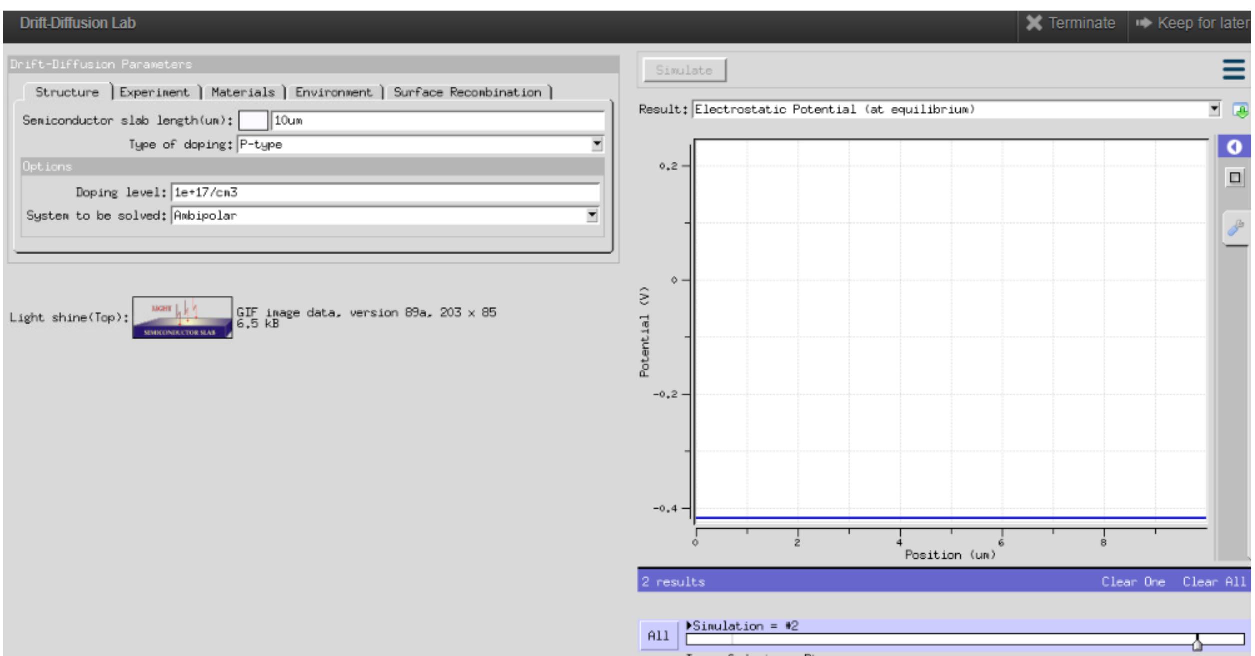
Q.1: View the energy band diagram before illumination.



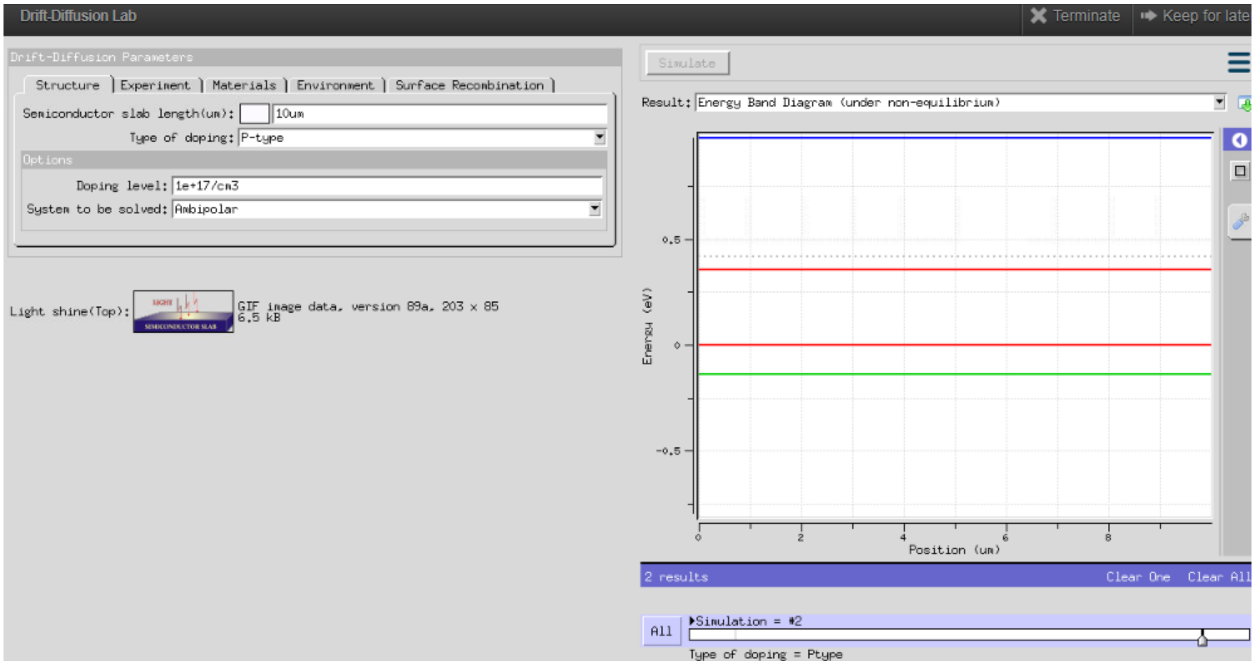
Q.2: From the simulation results determine doping, electron and hole density at equilibrium. Don't forget to attach simulation results.



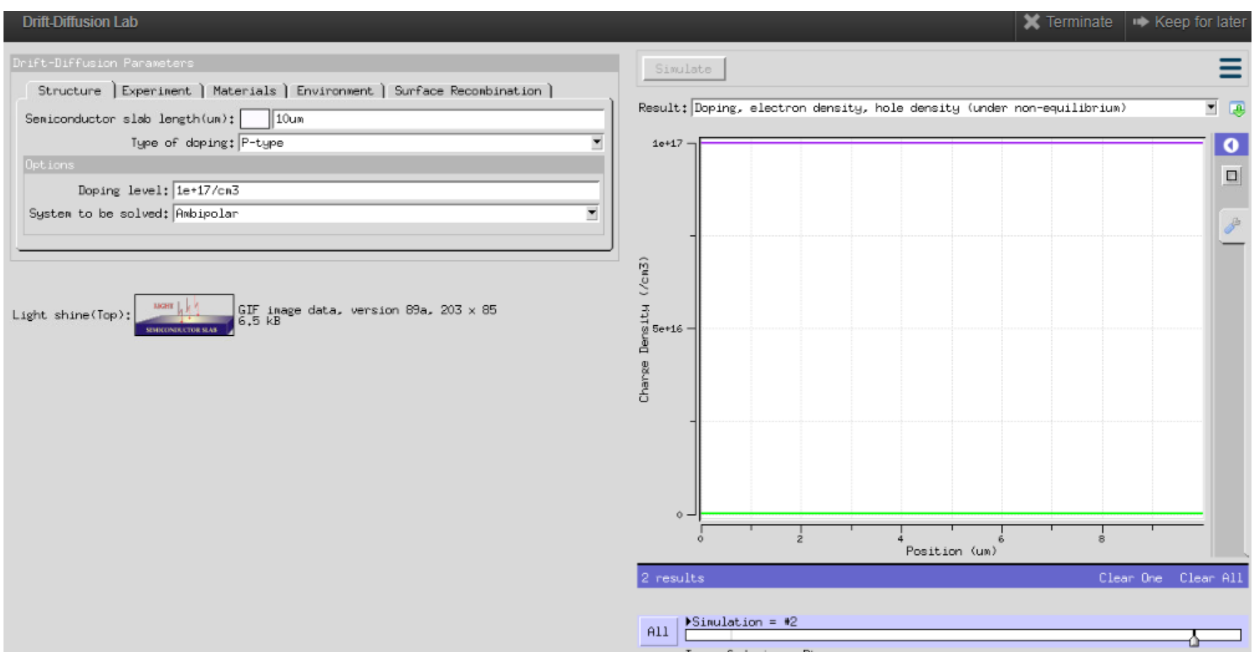
Q.3: From the simulation results determine electrostatic potential at equilibrium. Don't forget to attach simulation results.



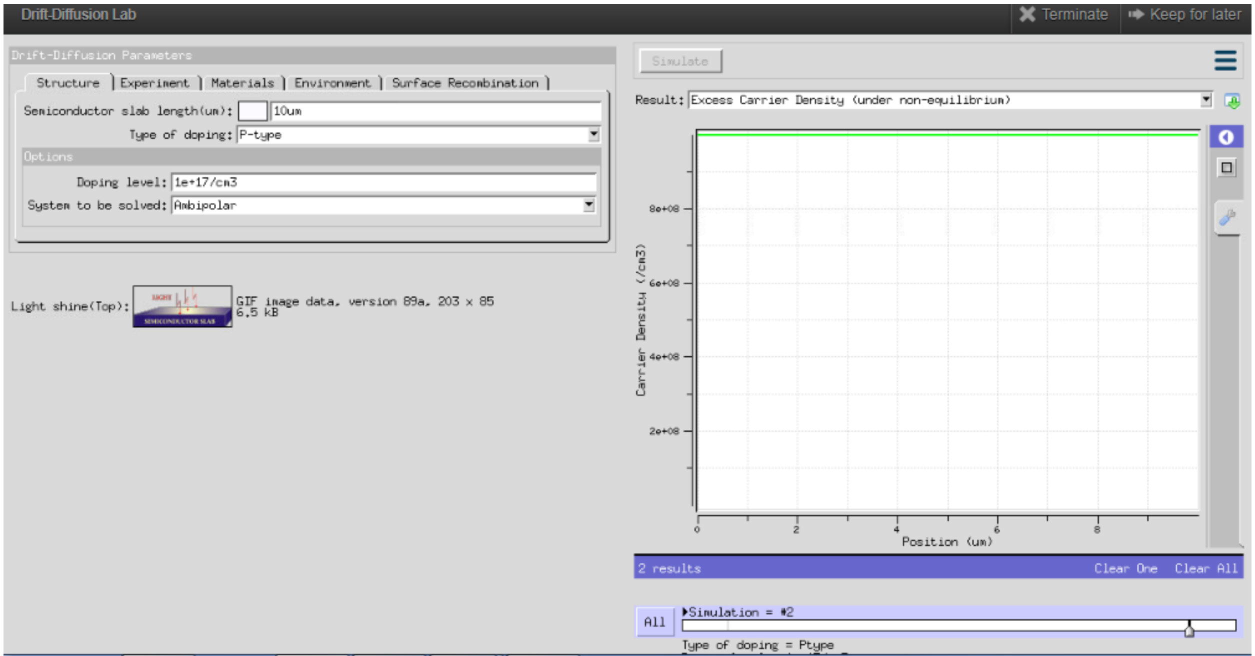
Q.4: View the energy band diagram under non-equilibrium



Q.5: By using simulation results determine the value of doping, electron and hole density under non equilibrium.

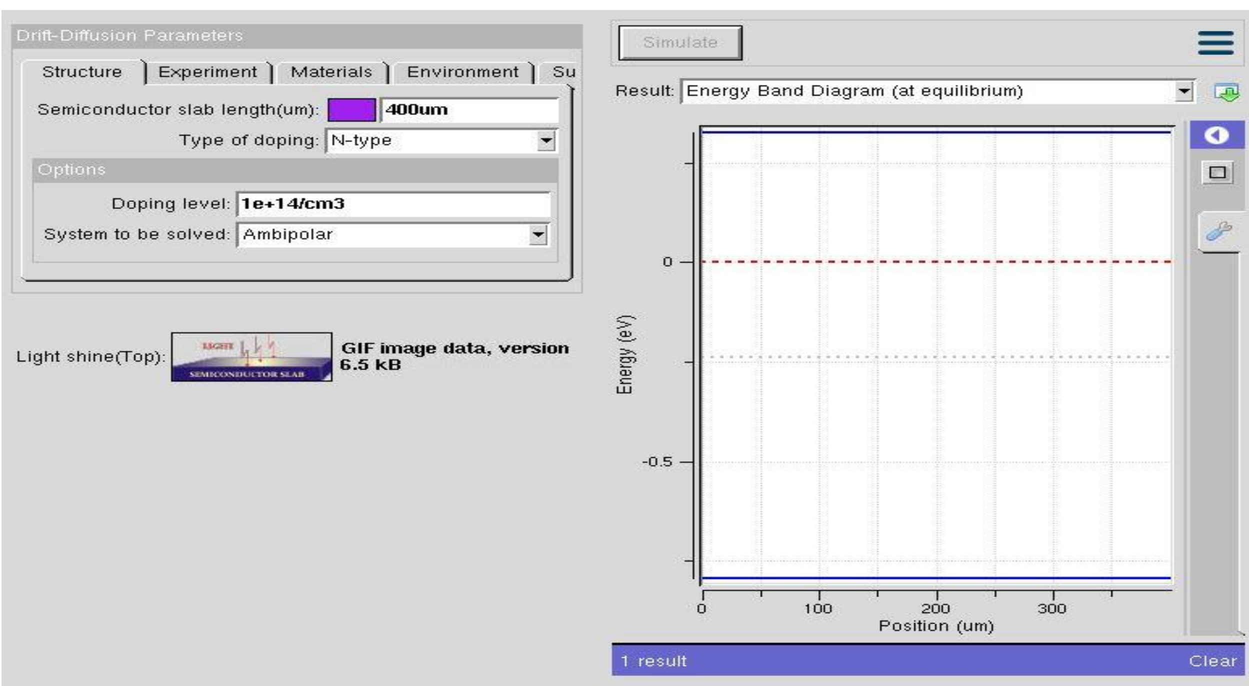


Q.6: View the excess carrier profile. Determine the excess electron and hole density

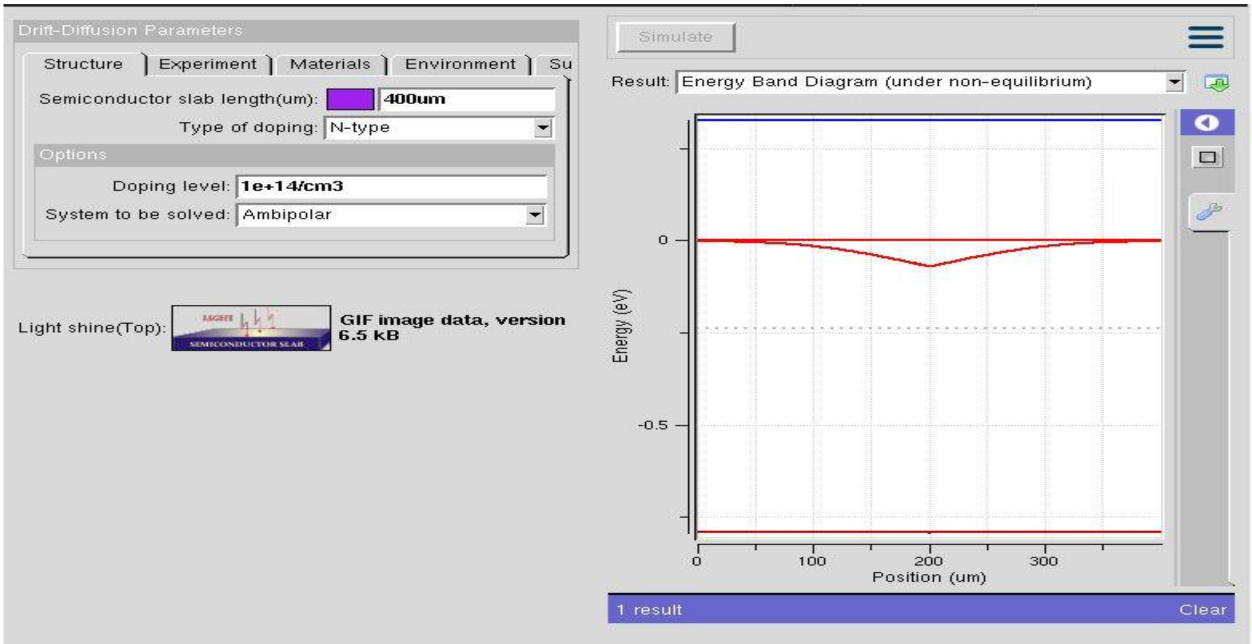


Task No.3: An n-type semiconductor slab is illuminated with light at its center

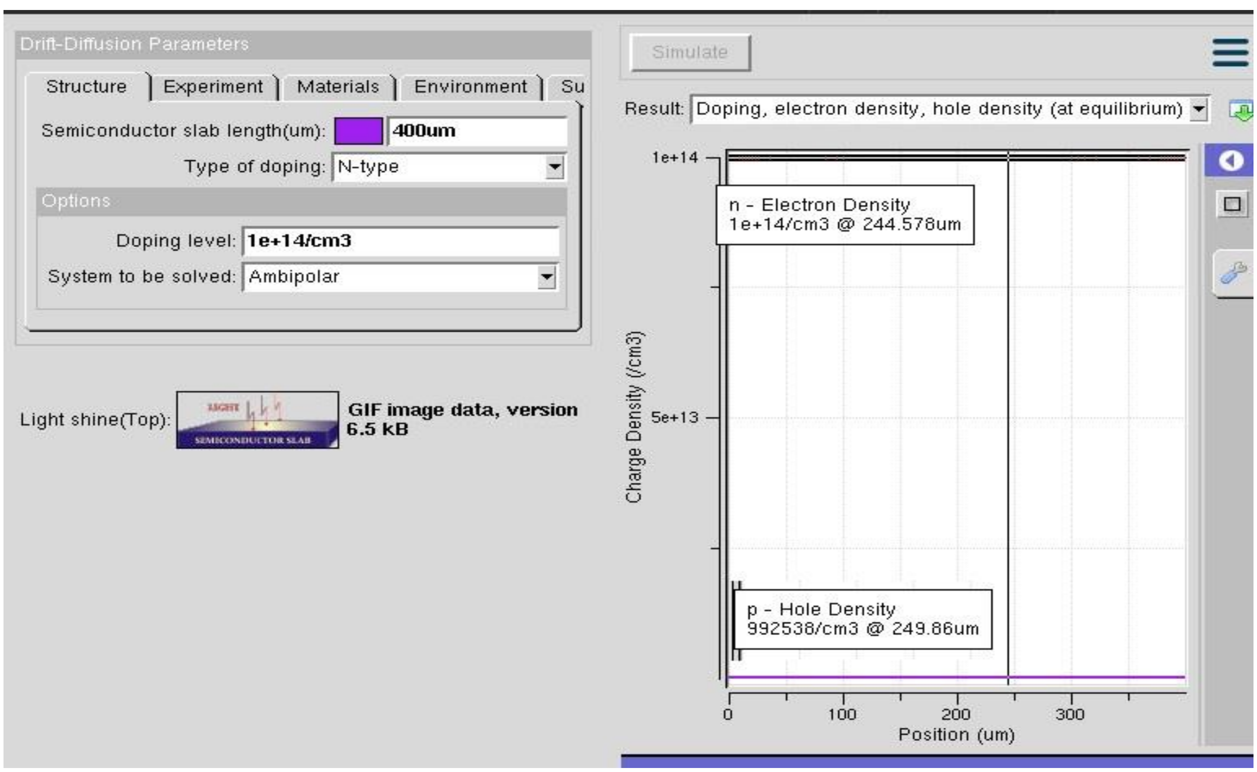
Q.1: View the energy band diagram before illumination



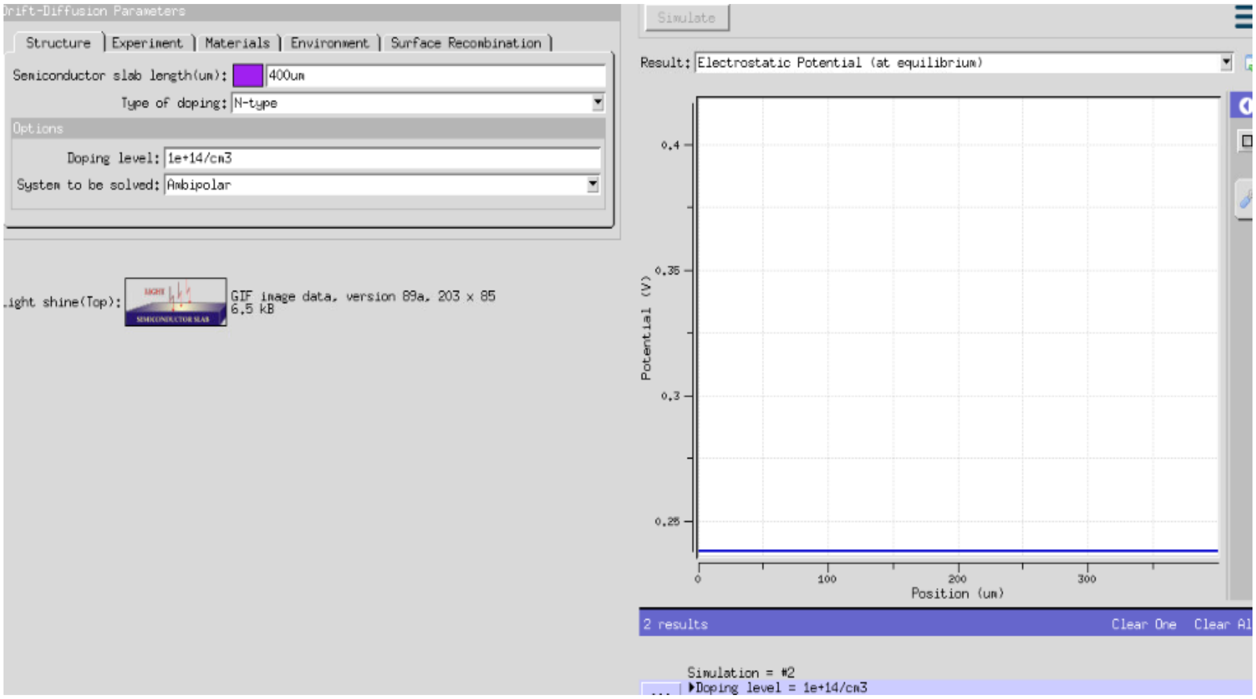
Q.2: View the energy band diagram under non-equilibrium



Q.3: From the simulation results determine doping, electron and hole density at equilibrium. Don't forget to attach simulation results.



Q.4: From the simulation results determine electrostatic potential at equilibrium. Don't forget to attach simulation results.



Q.5: View the excess minority carrier profile. Find out excess carrier concentration at the point where semiconductor is illuminated.