DEPARTMENT OF ELECTRONIC ENGINEERING

N.E.D. UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOLID STATE DEVICE

BATCH 2017-18

LAB SESSION # 6,7,8

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ROLL # EL-17062 SECTION: C

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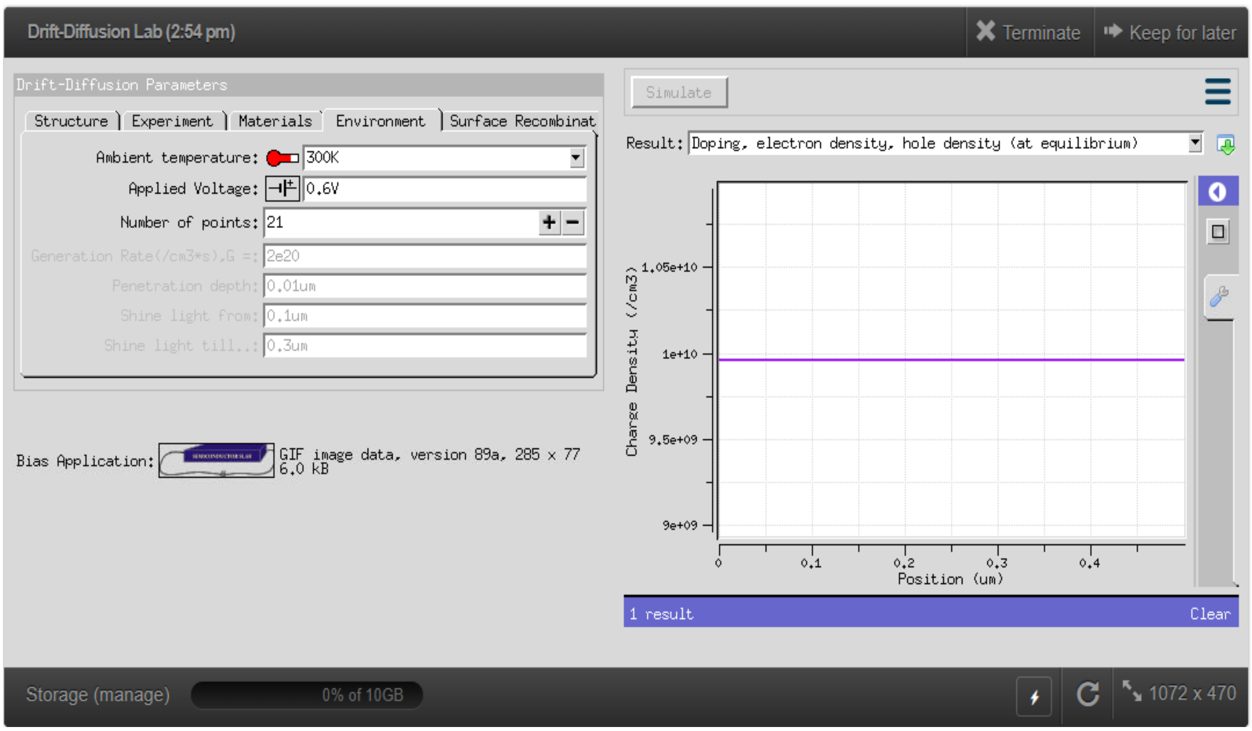
LAB SESSION #6

TASKNO#1: Apply potential across an intrinsic semiconductor material

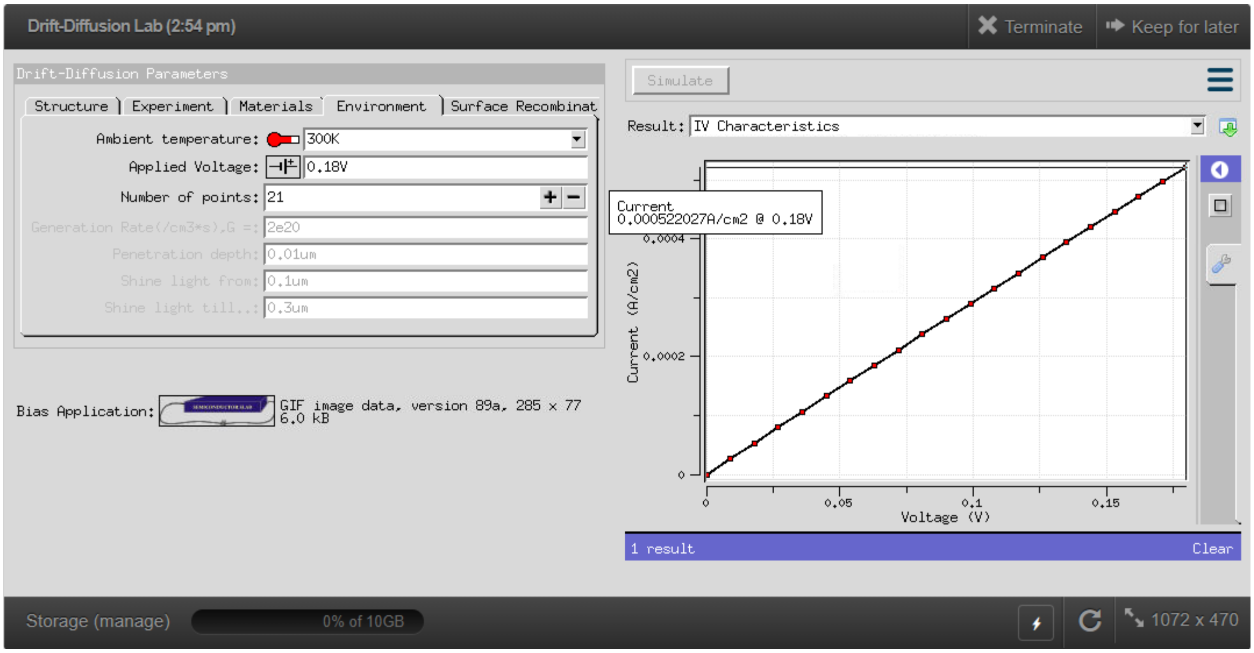
Q1) from the simulation results determine doping, electron and hole density at equilibrium. Don't forget to attach the simulation results.



Comments:

In an intrinsic semiconductor, electrons and holes concentrations are equal i.e. 1e+10 (300k room temp)

Q#2: What is the current density when 0.18v is applied across the semiconductor? Verify the simulation results by mathematical calculations.



Verifying by Calcultaion:

J_{drift}=q*ni*un*E + q*ni*up*E

J_{drift}=q*ni*E(un+up)

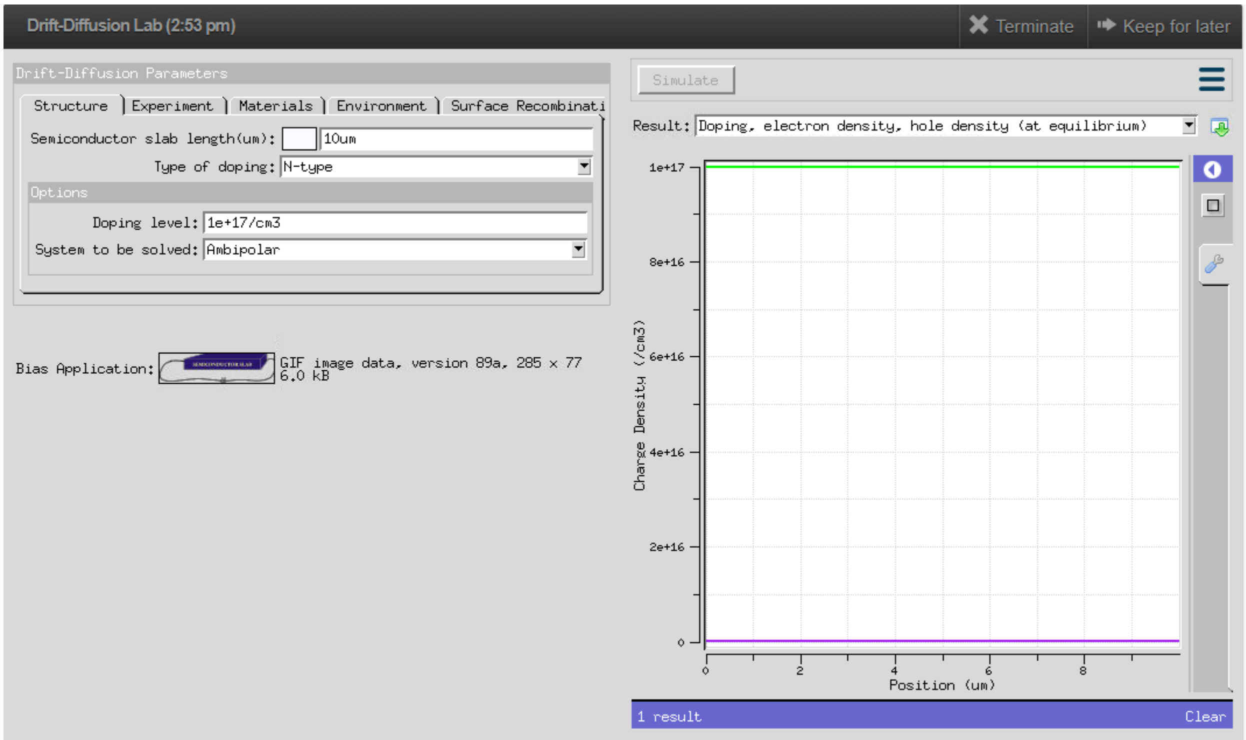
J_{drift}=(1.6*10^-19)*(10^10)*(V/L)*(un+up)

J_{drift}=(1.6*10^-19)*(10^10)*(0.18/10*10^-4)*(1350+480)

$J_{drift=}$0.000527A/cm^2 ……. Hence Proved

TASKNO#2: Apply potential across an n-type semiconductor

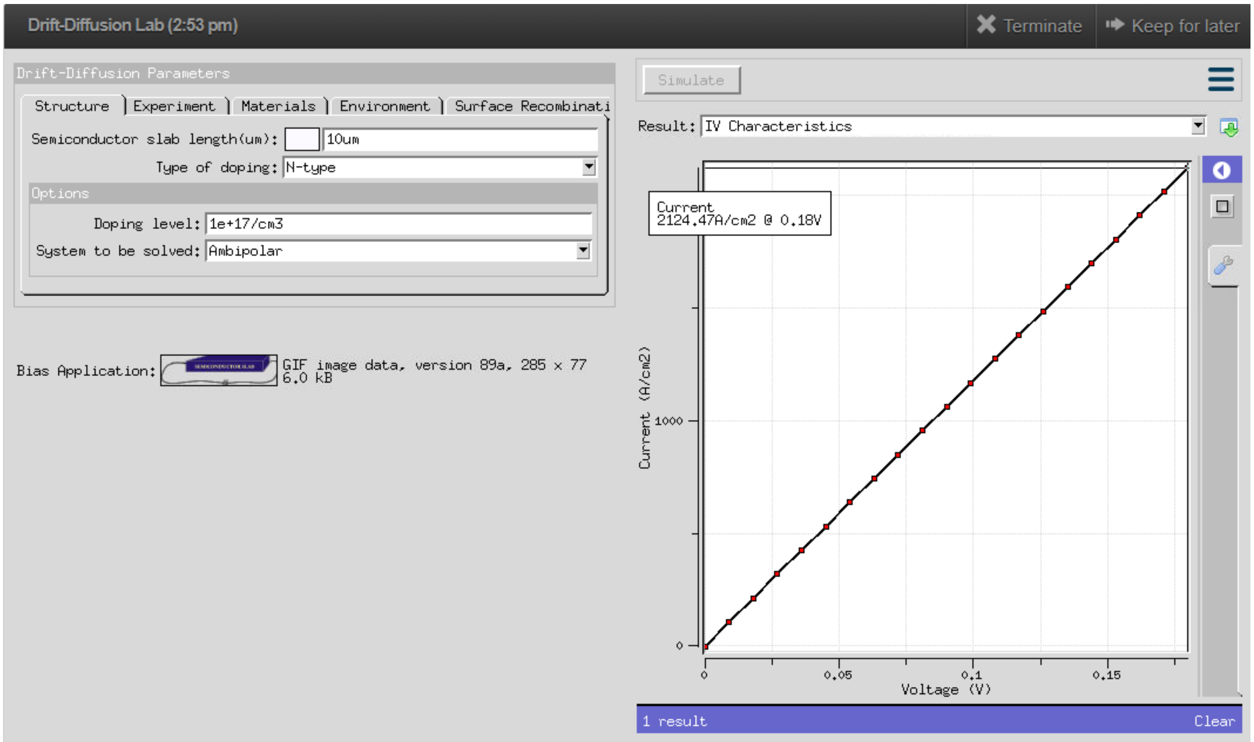
Q1): From the doping results determine doping, electron and hole density at equilibrium. Don't forget to attach the simulation results.



Comments:

As we applied doping is 1e+17 so here it is 1e+17/cm^3.The electron density is 1e+17/cm^3 (green line). The hole density is very small (purple line) which is 992.538/cm^3 since it is a n-type material.

Q#2) what is current density when 0.18V is applied across a semiconductor? Verify the simulation results by mathematical calculations.



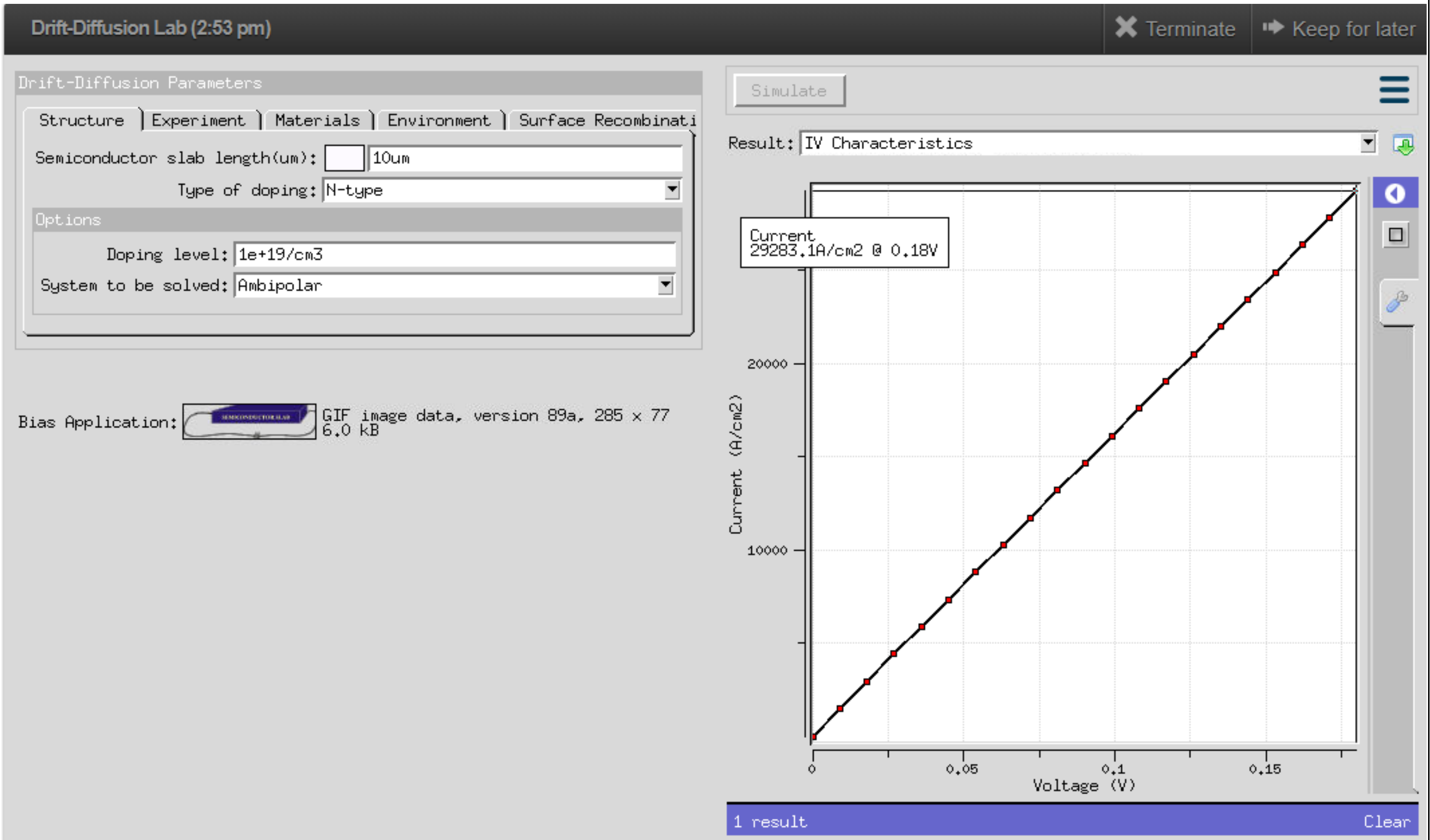
Comments:

The current density for an n-type semiconductor when 0.18V is applied is observed to be 2124.47A/cm^2 from the simulation. Now verifying it by using mathematical formula.

Verifying by Calculation:

Jdrift = q*u_nn*E ; E=(V/L)
Jdrift=(1.6*10^-19)*750*10^17*(0.18/10*10^-4)
Jdrift = 2160A/cm2

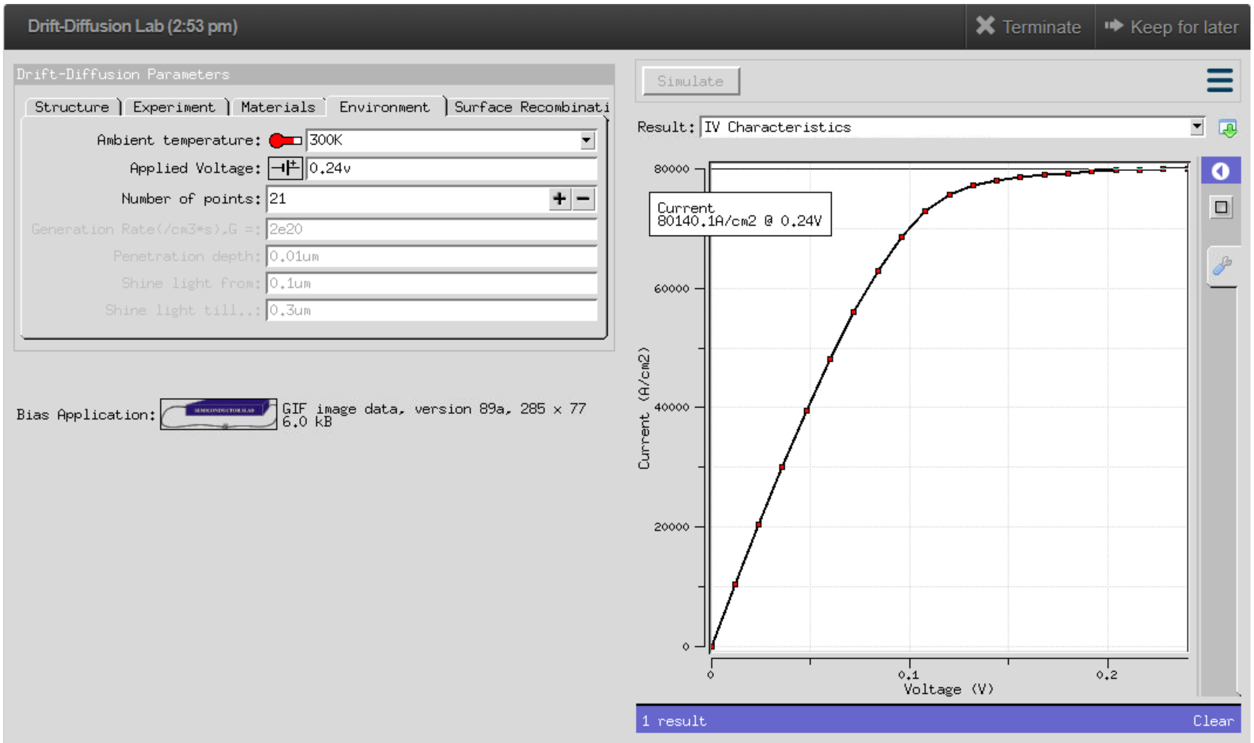
TASKNO#3: Apply a potential across an n-type semiconductor. Find out the current density. Now vary the doping and from the simulation results, observe effect of doping on current density.



Comments:

In task 2 (Q2), current density at doping level 1exp17 was found to be 2124.47A/cm^2. Here, we can clearly observe a significant rise in current density with the increase in doping level upto 1exp19,the new value of current density is 29283.1 A/cm^2. So, by increasing doping level,current density also increases.

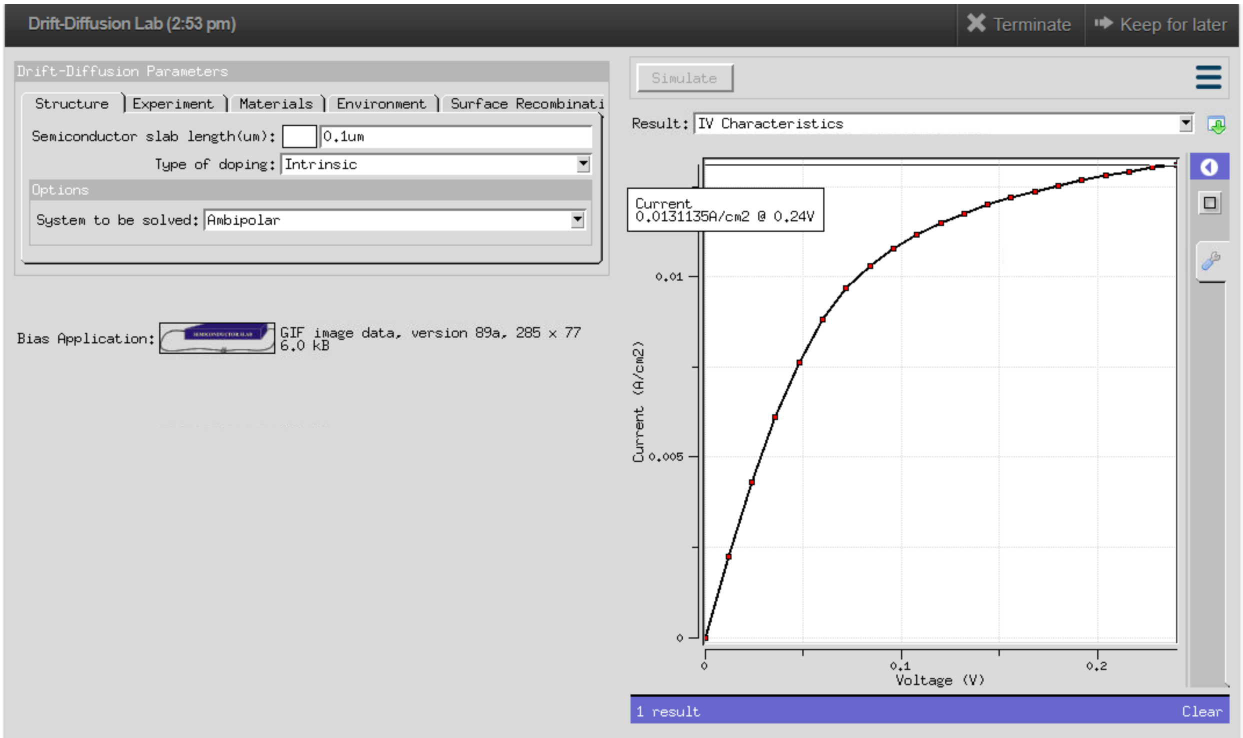
TASKNO#4: Observe the effect of current saturation at high electric fields in an n-type semiconductor.



Comments:

The value of current density at 0.24 volts and 0.1um is 80140A/cm^2

TASKNO#5: Observe the effect of current density in an intrinsic semiconductor material



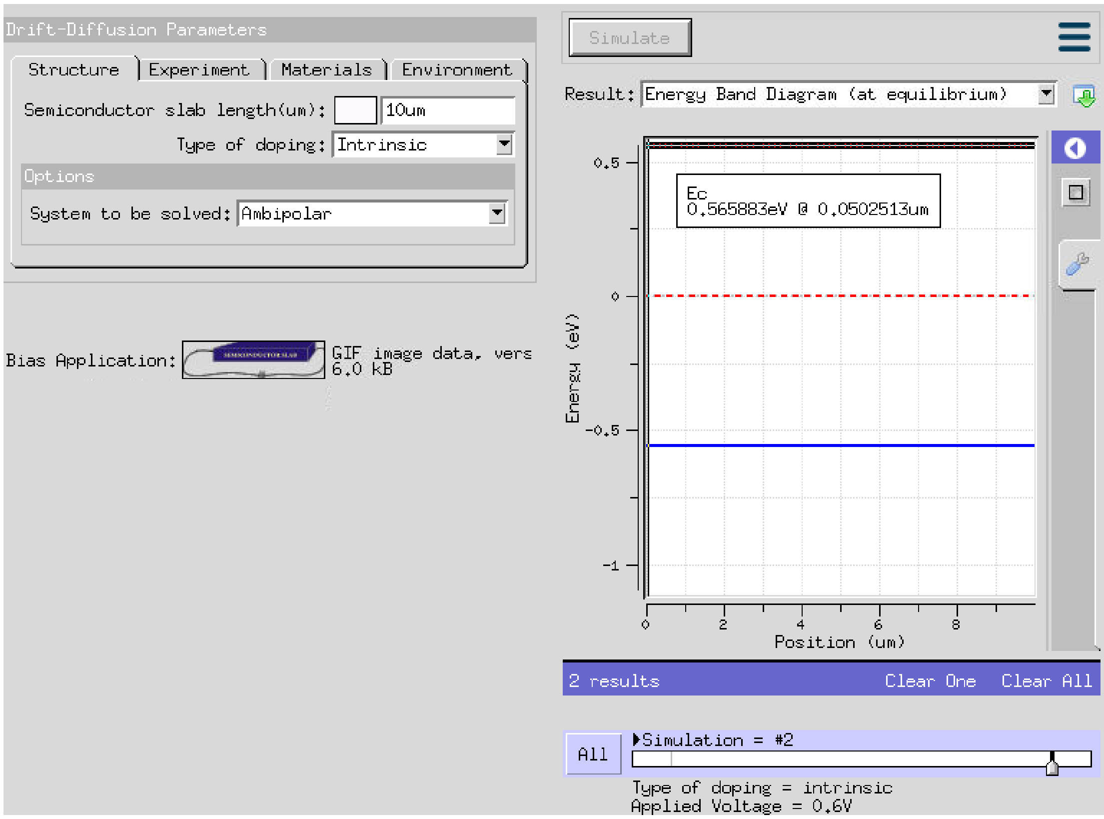
Comments:

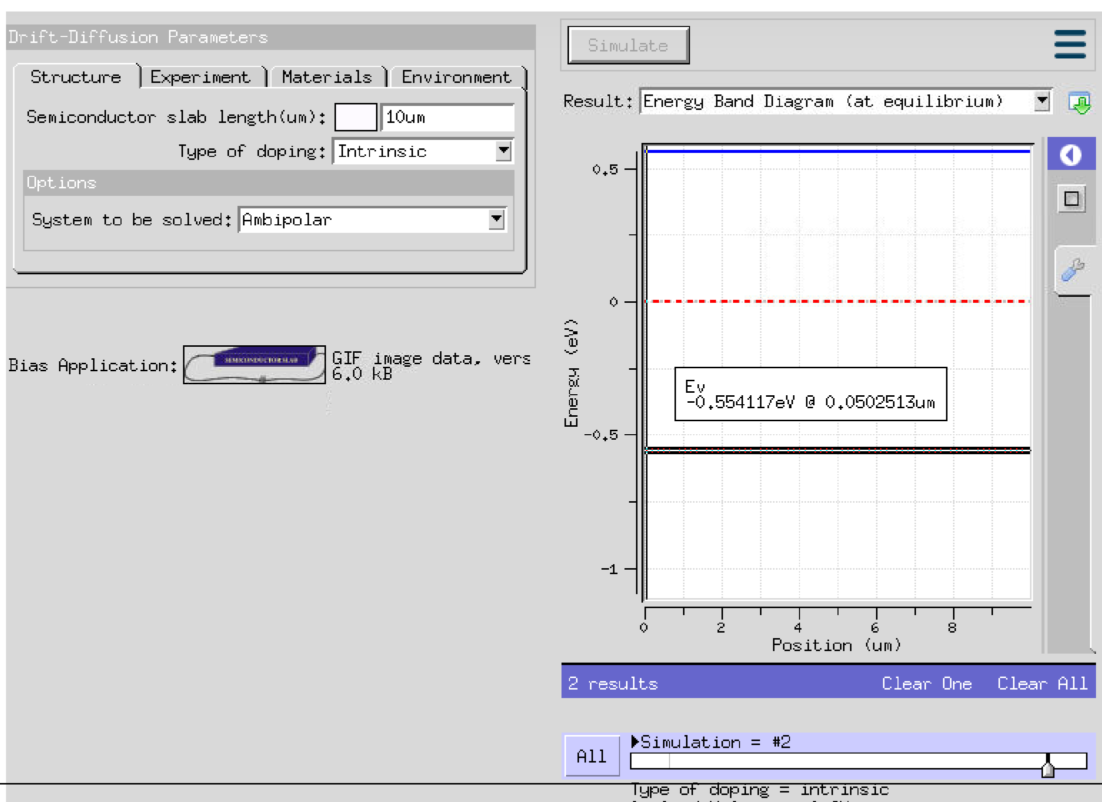
The current density is smaller at 0.24 volts and 0.1um for an intrinsic material. The value of current density is 0.0131135A/cm^2.

LAB SESSION #7

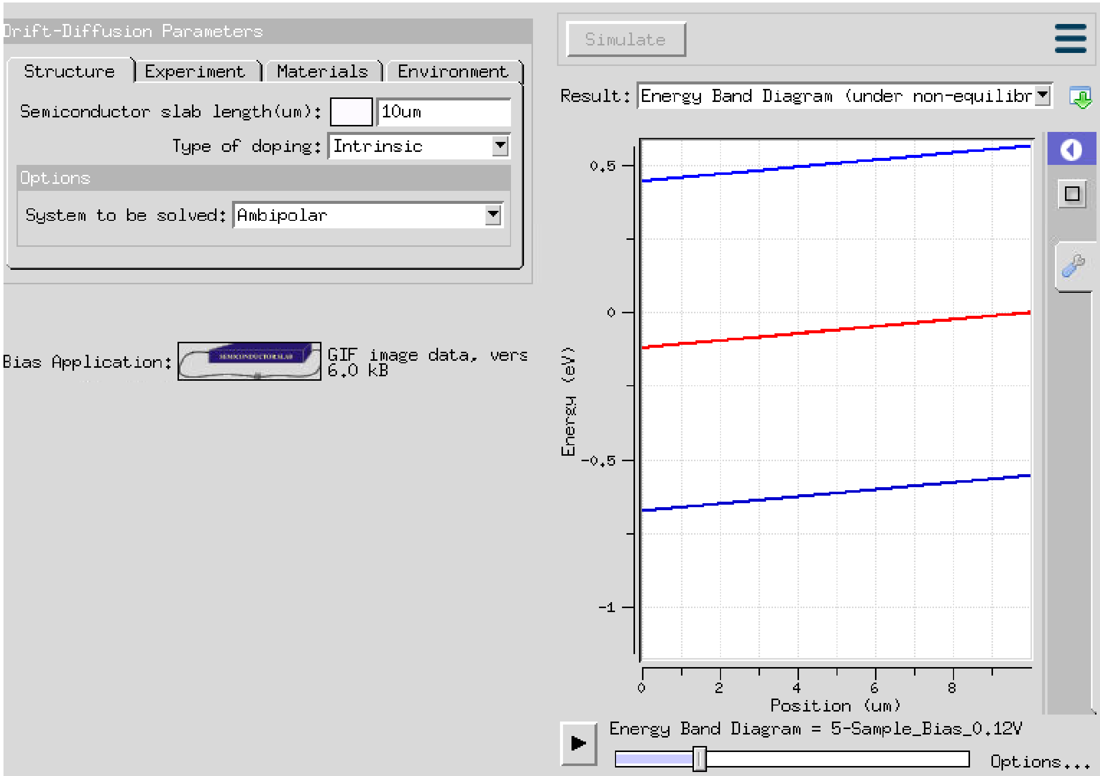
TASKNO#1: Apply potential across an intrinsic semiconductor

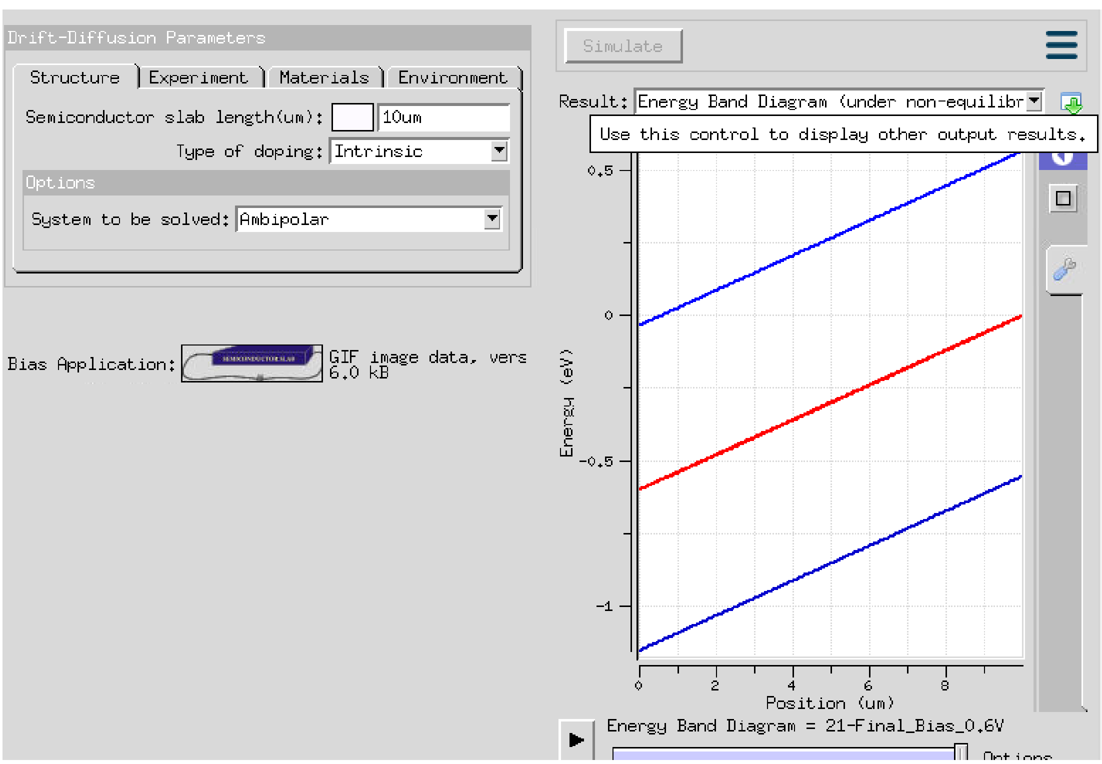
Q#1: Energy band diagram of semiconductor before applying potential across it.





Q#2: Energy band diagram of biased semiconductor

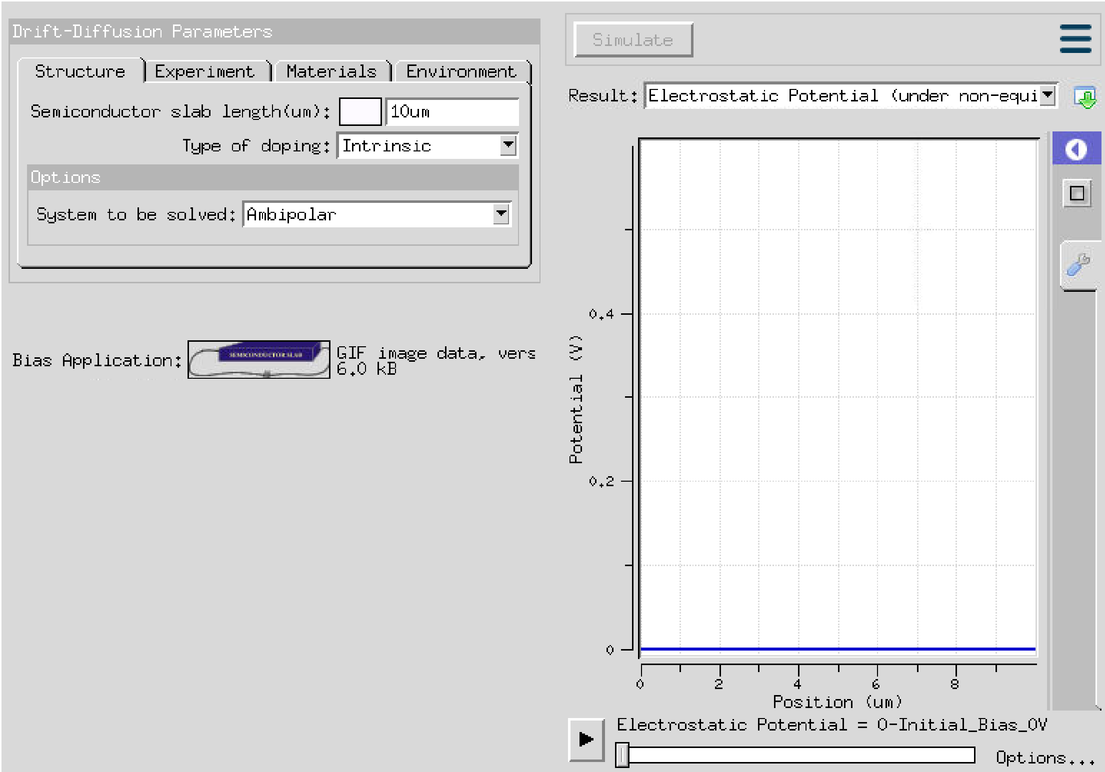


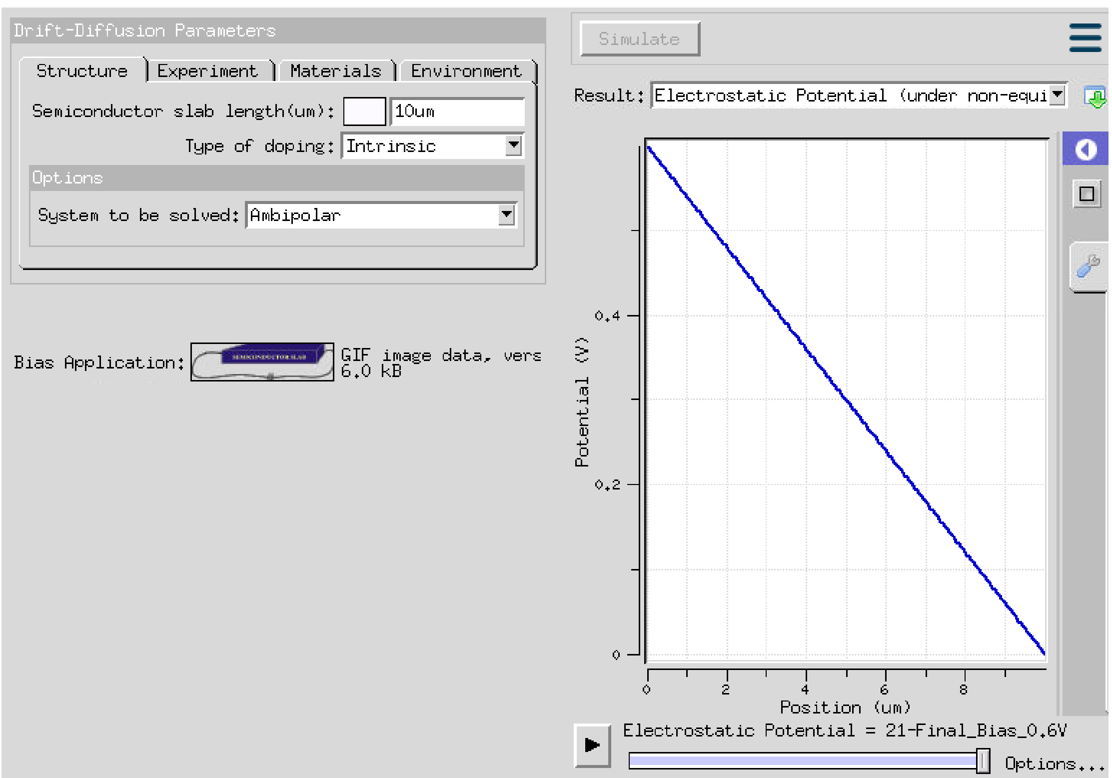


Q#3: Elecrostatic potential under non-equilibrium

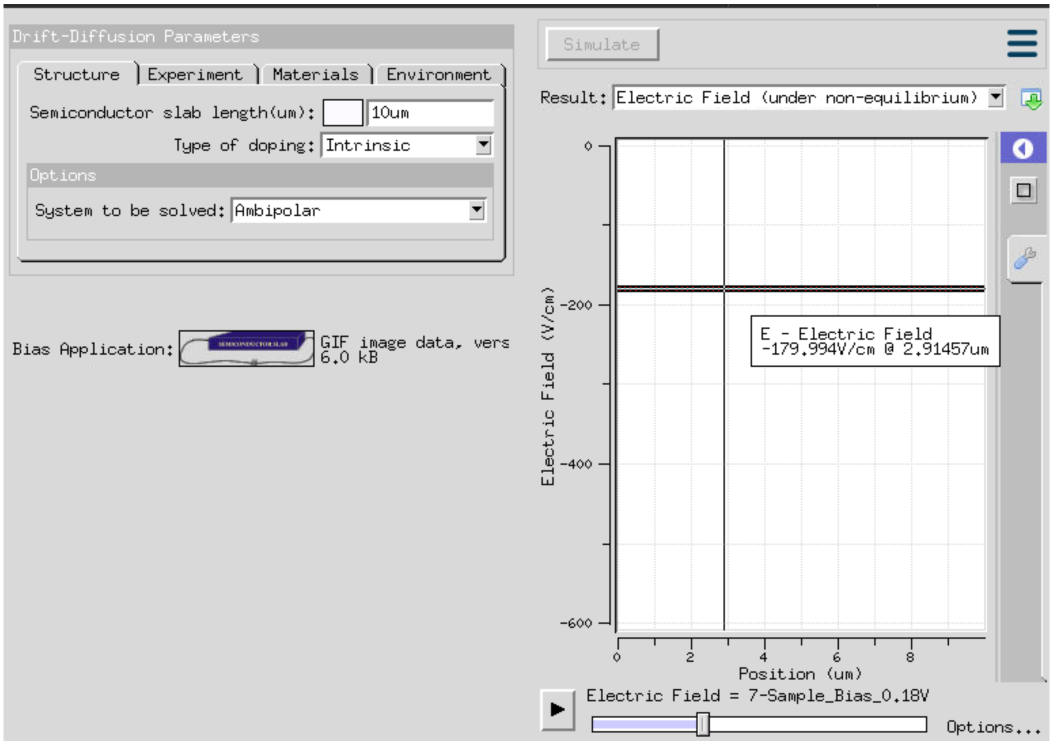
ANS:

As we increase voltage electrostatic potential also increases.

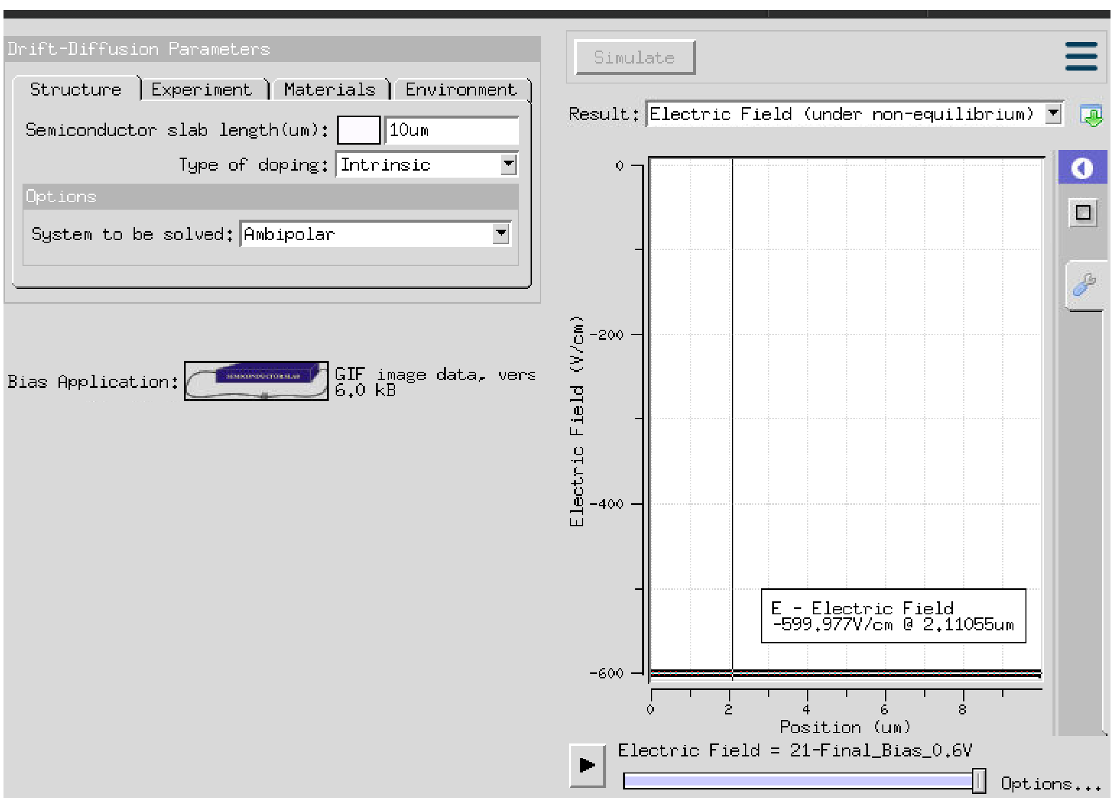




Q#4: Electric field that exist across the semiconductor under biased conditions



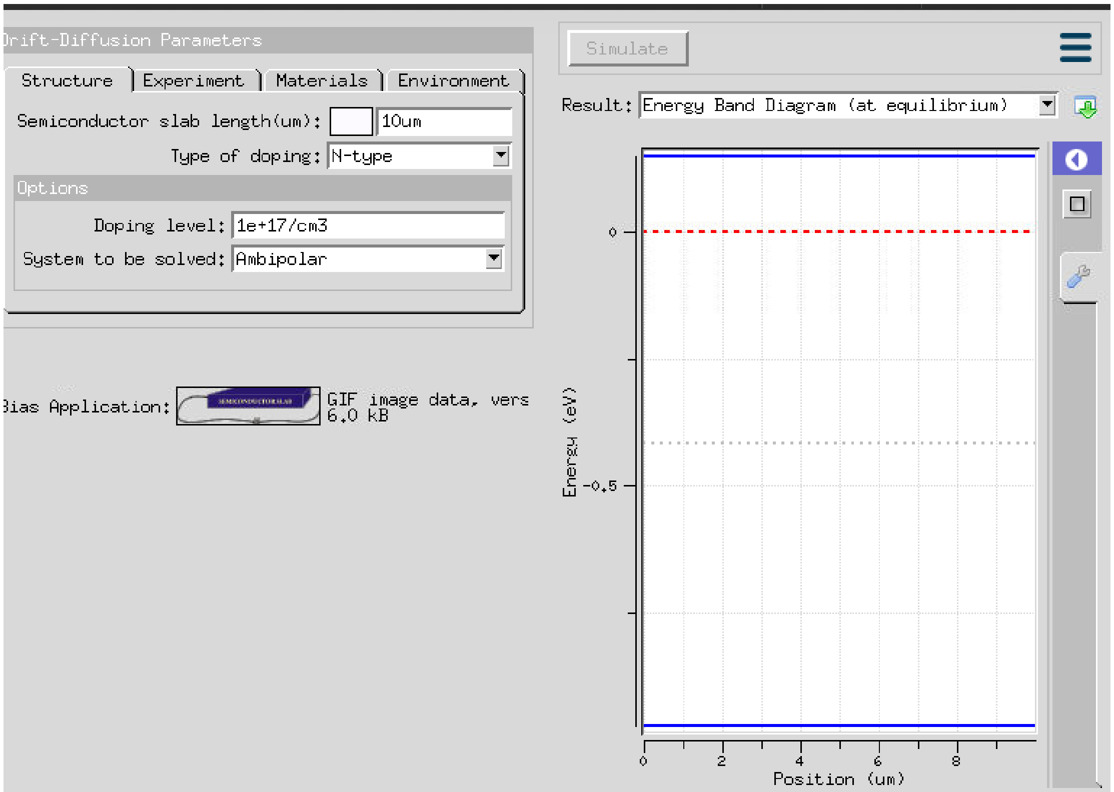
ELECTRIC FIELD= -179.994V/cm at 0.18V



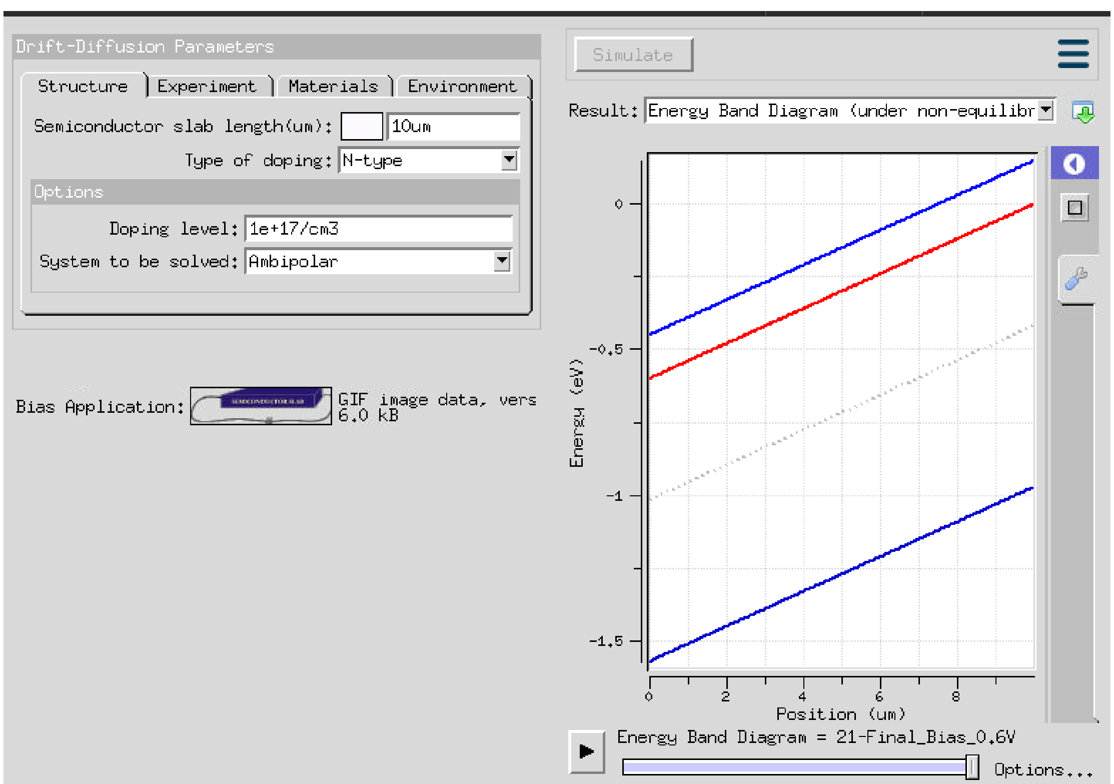
ELECTRIC FIELD= -599.977V/cm at 0.6V

TASKNO#2 Apply potential across a N-TYPE semiconductor

Q#1: Energy band diagram of semiconductor before applying potential across it.



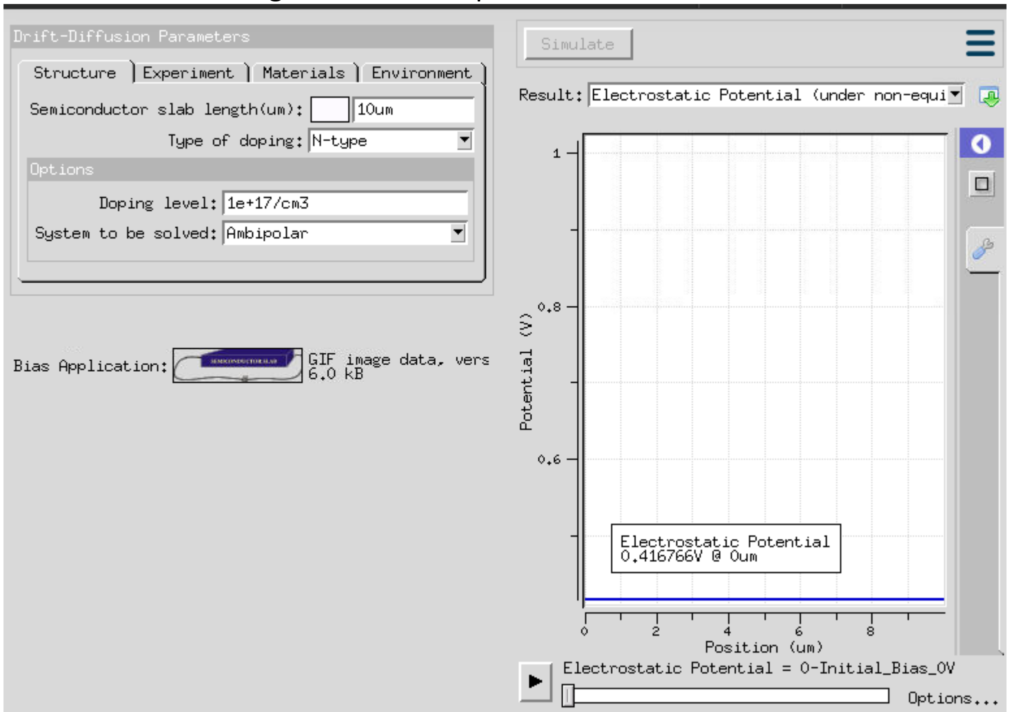
Q#2: Energy band diagram of biased semiconductor

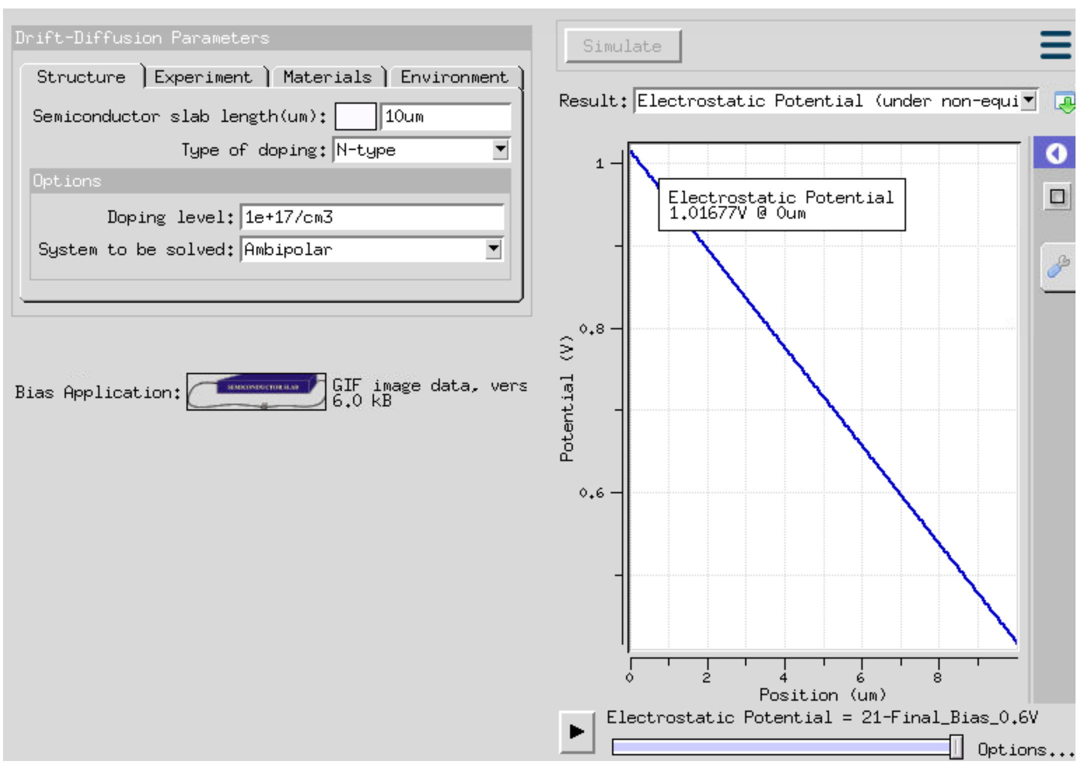


Q#3: Elecrostatic potential under non-equilibrium

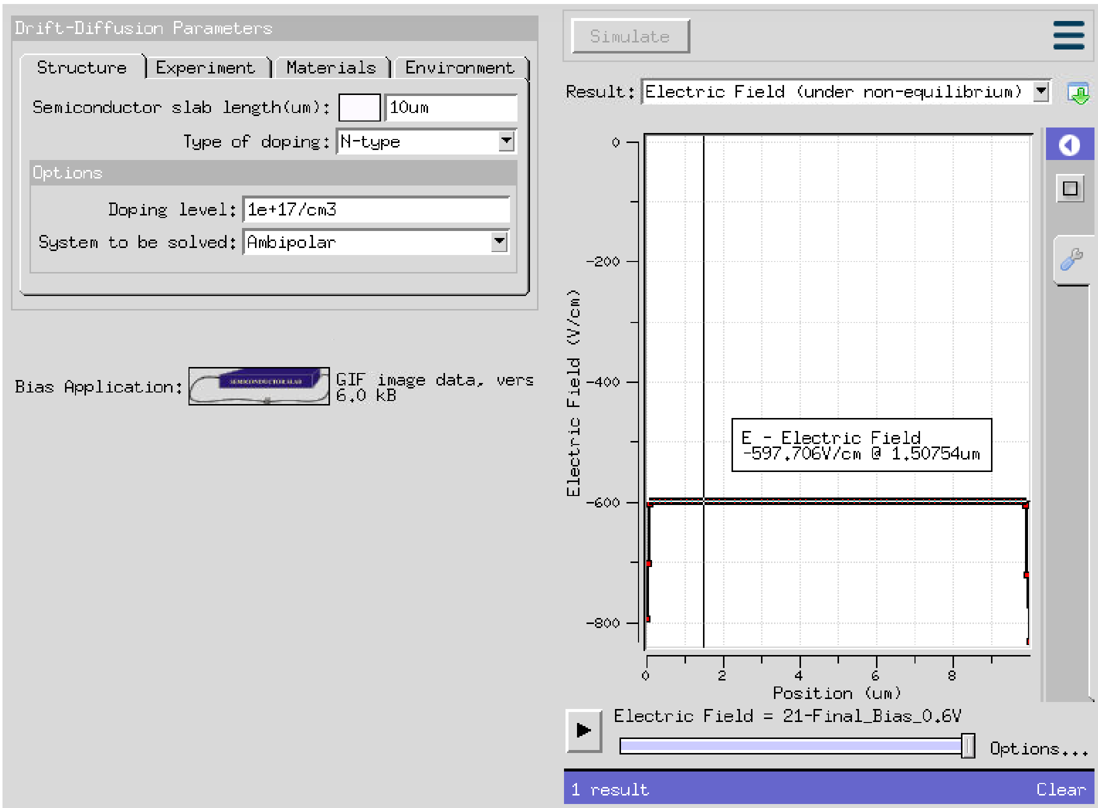
ANS:

As we increase voltage electrostatic potential also increases.





Q#4: Electric field that exist across the semiconductor under biased conditions



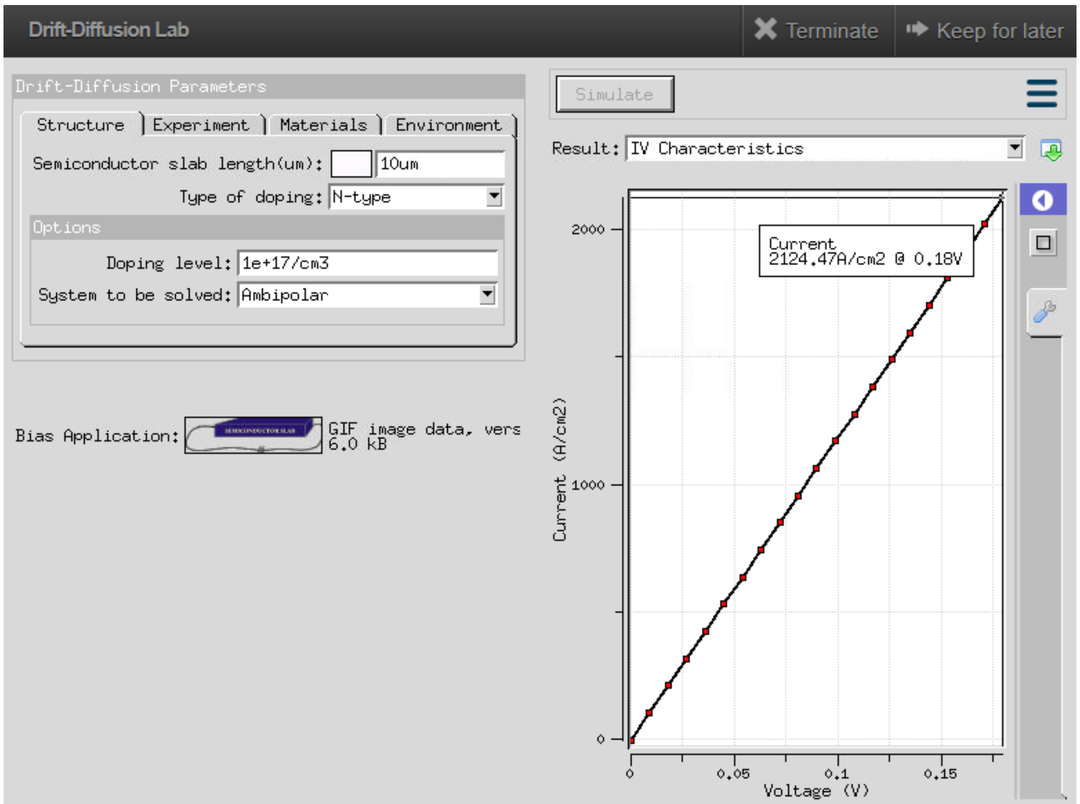
ELECTRIC FIELD= -597.705V/cm at 0.6V or approx -600V/cm

LAB SESSION #8

TASKNO#1

Mobility of electron in an intrinsic semiconductor at room temperature(300K) is 1350 cm2 /V*sec.

TASKNO#2



Current

Voltage (V), Current (A/cm2)

Voltage (V)	Current (A/cm2)
0,	-4.58547582e-11
0,	-4.58547582e-11
0.009,	106.23245
0.018,	212.464768
0.027,	318.69682
0.036,	424.928473
0.045,	531.159595
0.054,	637.390053
0.063,	743.619713
0.072,	849.848444
0.081,	956.076112
0.09,	1062.30258
0.099,	1168.52773
0.108,	1274.75141
0.117,	1380.9735
0.126,	1487.19386
0.135,	1593.41236
0.144,	1699.62888
0.153,	1805.84326
0.162,	1912.05539
0.171,	2018.26512
0.18,	2124.47234

CALCULATION OF MOBILITY OF ELECTRONS FROM SIMULATION:

$J_{drift} = q\mu_n n\varepsilon.$

$J_{drift} = \mu_n.10^{17}\ (1.6x10^{-19})(v/L)$

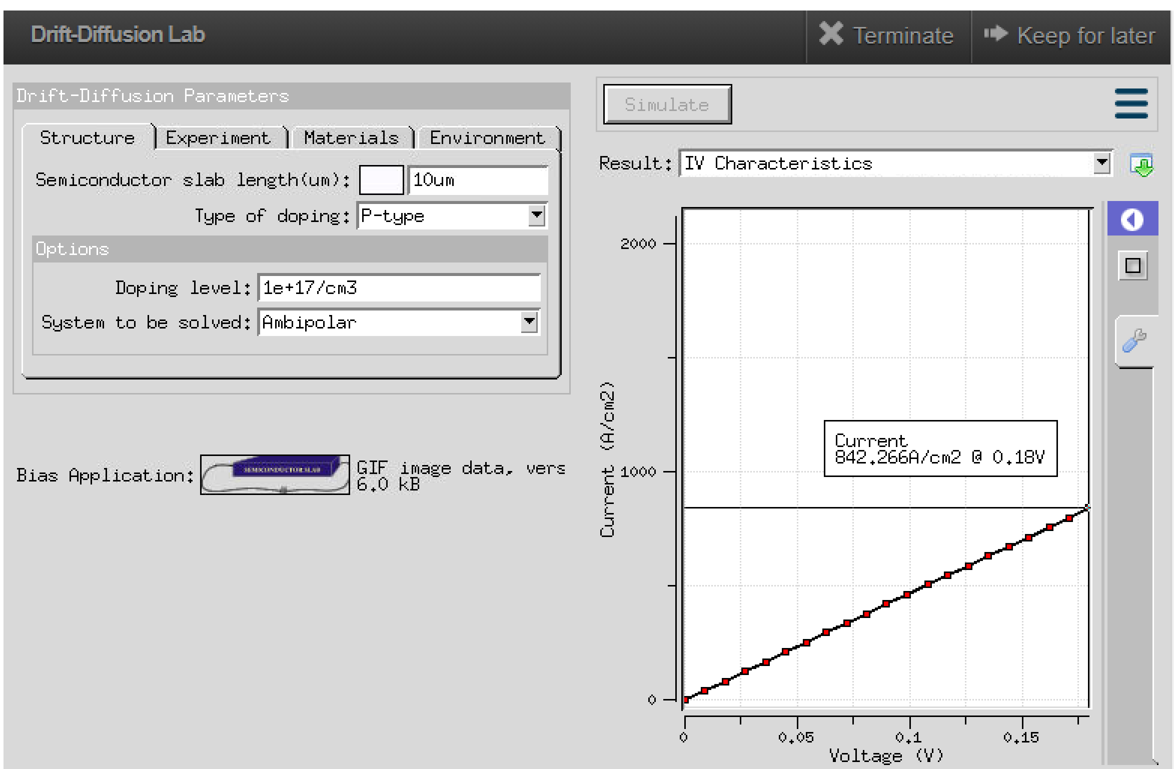
$2124.47=\mu_n.\ 10^{17}\ (1.6x10^{-19})(0.18/10x10^{-4})$

$\mu_n =$ 737.66 cm²A/Vsec

Comparison of the mobility of electrons in an intrinsic and an n-type doped semiconductor.Any effect of doping on mobility? Yes/No?

In an intrinsic semiconductor at room temperature(300K) μ_n is
1350 cm2/Vsec.Where as in n-type doped semiconductor μ_n is
737.66 cm²A/Vsec
Yes, there is an effect of doping on mobility, for intrinsic material μ_n greater as we increase doping level to $10^7/cm^3$ so impurity scattering takes place within material so μ_n decrease.

TASKNO#3



```
---------------------------------------------------------
 Current
---------------------------------------------------------
Voltage (V), Current (A/cm2)
                  0,       4.10643043e-11
                  0,       4.10643043e-11
              0.009,           42.3657489
              0.018,           84.7047753
              0.027,           127.017104
              0.036,            169.30276
              0.045,           211.561769
              0.054,           253.794154
              0.063,           295.999942
              0.072,           338.179157
              0.081,           380.331824
               0.09,           422.457967
              0.099,           464.557612
              0.108,           506.630782
              0.117,           548.677504
              0.126,           590.697801
              0.135,           632.691698
              0.144,            674.65922
              0.153,           716.600391
              0.162,           758.515236
              0.171,           800.403779
               0.18,           842.266045
```

CALCULATION OF MOBILITY OF HOLES FROM SIMULATION:

$J_{drift} = q\mu_p n\varepsilon.$

$J_{drift} = \mu_p.10^{17}\,(1.6x10^{-19})(v/L)$

$842.26=\mu_p.\,10^{17}\,(1.6x10^{-19})(0.18/10x10^{-4})$

$\mu_p =$ **292.45 cm²**A/Vsec

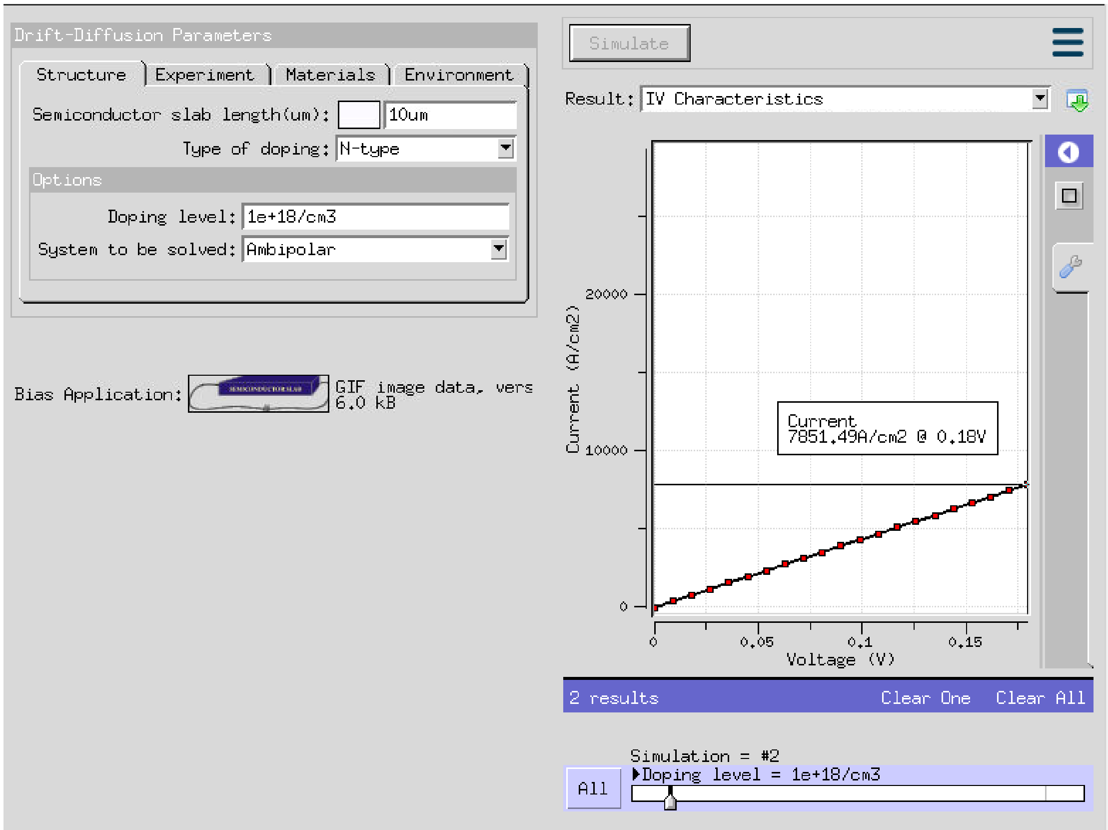
Comparison of the mobility of holes in an intrinsic and an p-type doped semiconductor.

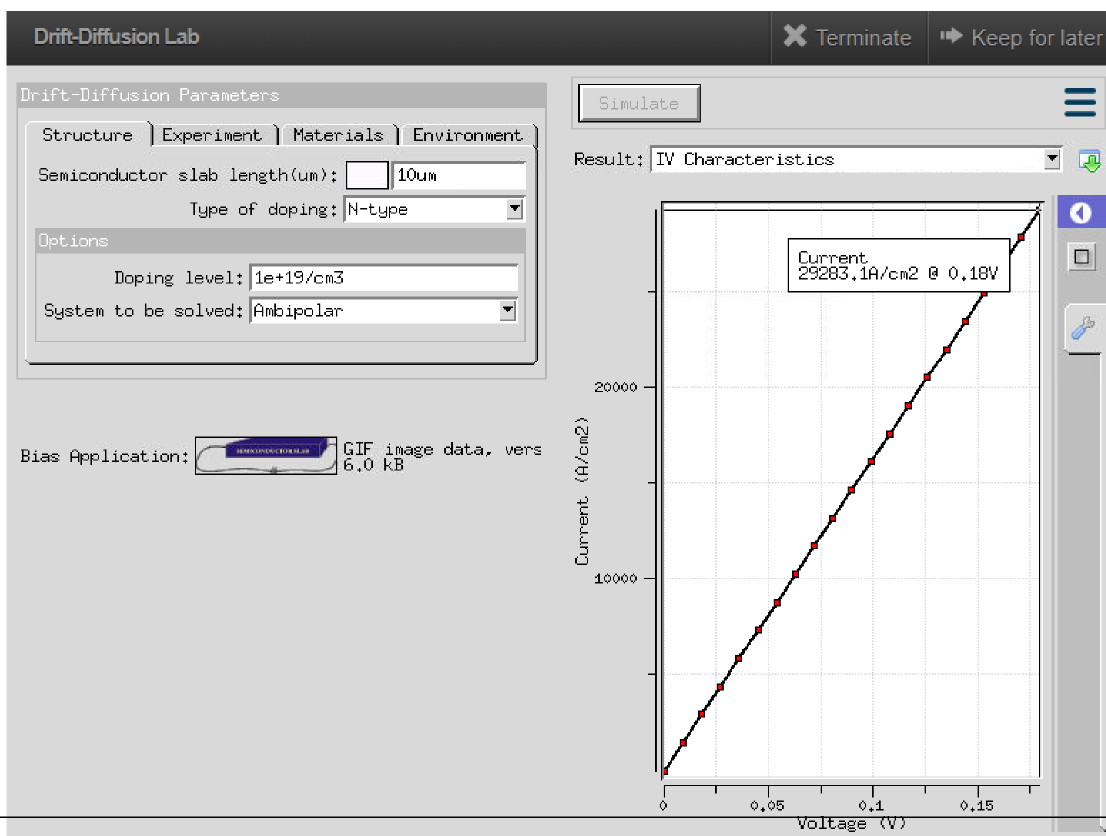
In an intrinsic semiconductor at room temperature(300K) μ_p is **480 cm2/Vsec**.Where as in n-type doped semiconductor μ_p is **292.45 cm²A/Vsec**

Yes, there is an effect of doping on mobility, for intrinsic material μ_p greater as we increase doping level so μ_p decrease.

TASKNO#4:

As in task#2 of this lab we calculated mobility of electron is 737.66 $cm^2A/Vsec$ from simulation.Then very the doping concentration to 10^{18} and $10^{19}/cm^3$





CALCULATION OF MOBILITY OF ELECTRONS FROM SIMULATION:

1. $J_{drift} = q\mu_n n\varepsilon.$
   $J_{drift} = \mu_n.10^{18}\ (1.6x10^{-19})(v/L)$
   $7851.49=\mu_n.\ 10^{18}(1.6x10^{-19})(0.18/10x10^{-4})$

   $\mu_{n} =$ 272.62 cm²A/Vsec

2. $J_{drift} = q\mu_n n\varepsilon.$
   $J_{drift} = \mu_n.10^{19}\ (1.6x10^{-19})(v/L)$
   $29283.1=\mu_n.\ 10^{19}(1.6x10^{-19})(0.18/10x10^{-4})$

   $\mu_{n} =$ 101.678 cm²A/Vsec

EFFECT OF DOPING CONCENTRATION ON MOBILITY:

In n-type doped semiconductor μ_n is **737.66 cm²A/Vsec** with doping level $10^{17}/cm^3$**.**Yes, there is an effect of doping concentration on mobility, as we increase doping level to $10^{18}/cm^3$so μ_n decrease to **272.62 cm²A/Vsec** and then if we further increase doping level to $10^{19}/cm^3$so μ_n further decrease to 101.678 **cm²A/Vsec.**