Electronic Devices and Circuits Lab (EE2301)
Experiment 3 : Diode Analysis

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October 7, 2020

1 Aim

Our aim is to Understand characteristics of diode by plotting some graphs of below questions and analysing their behaviour.

1. Analyse the electron and hole concentration on the p-side and n-side respectively in equilibrium and $V_a = 0.2$ V and $V_a = 0.4$ V.

2.Analyse the band structure for $V_a = 0$ V (equilibrium), $V_a = 0.2$ V and $V_a = 0.4$ V.

3.Explain the electric field in the device at $V_a = 0$ V (equilibrium), $V_a = 0.2$ V and $V_a = 0.4$ V.

4.Analyse the current-voltage characteristics (Explain the flow of the carriers in the diode)

Diode:

When two blocks of n-type and p-type are brought in contact a depletion region is formed due to transfer of charge carriers and a diode is made.

2 Procedure

Question 1

• In the question 1 we need to simulate the diode Electron and Hole density with respect to position with doping on the n-type 7E18 cm^{-3} and on the p-type 8E17 cm^{-3} at equilibrium (V_a=0), V_a=0.2, V_a=0.4 with T=300 K

• Using ABACUS tool in nanohub.org and take the values in to a text file and plot in octave.

• Now we need to analyse the results in a theoretical way.

• The length of both n-type and p-type is 6 μm and with 120 nodes each.

• X-axis is the position and Y-axis is the hole or electron density.

Question 2

• In the question 2 we need to simulate the diode Band structure with respect to position with doping on the n-type 7E18 cm^{-3} and on the p-type 8E17 cm^{-3} at equilibrium (V_a=0), V_a=0.2, V_a=0.4 with T=300 K

• we need find the values of conduction band energy, valance band energy and fermi level.

• Now we need to do the same as in the first question

• X-axis is the position and Y-axis is the Energy of valance or conduction or fermi level.

Question 3

• In the question 3 we need to simulate the diode Electric field with respect to position with doping on the n-type 7E18 cm^{-3} and on the p-type 8E17 cm^{-3} at equilibrium (V_a=0), V_a=0.2, V_a=0.4 with T=300 K

• we need find the values of electric field and plot in octave.

• Now we need to do the same as in the first question

• X-axis is the position and Y-axis is the Electric field.

Question 4

• In the question 4 we need to simulate the diode Current with respect to applied voltage with doping on the n-type 7E18 cm^{-3} and on the p-type 8E17 cm^{-3} .

• we need find the values of I and V ,plot in octave.

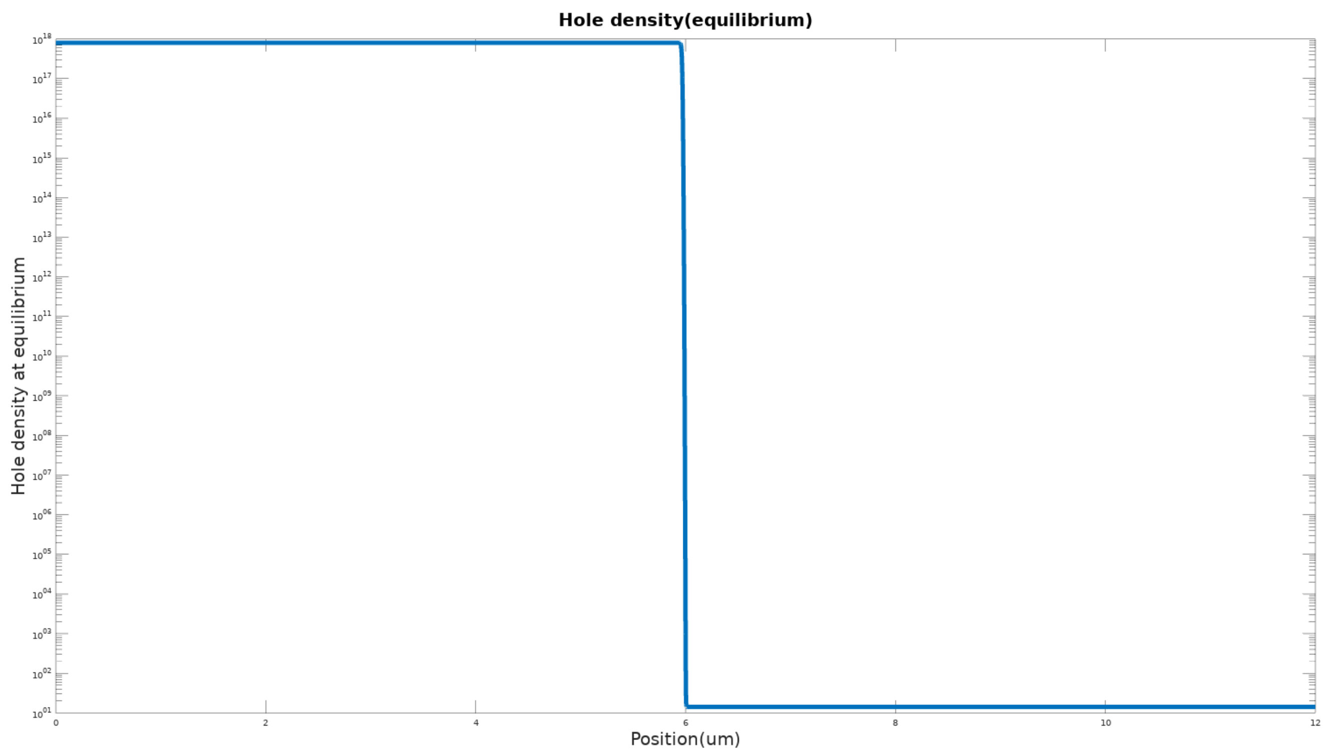
• Now we need to do the same as in the first question

• X-axis is the Voltage and Y-axis is the Current.

• Now we need to analyse the results.

Question 1

V_a=**0V**

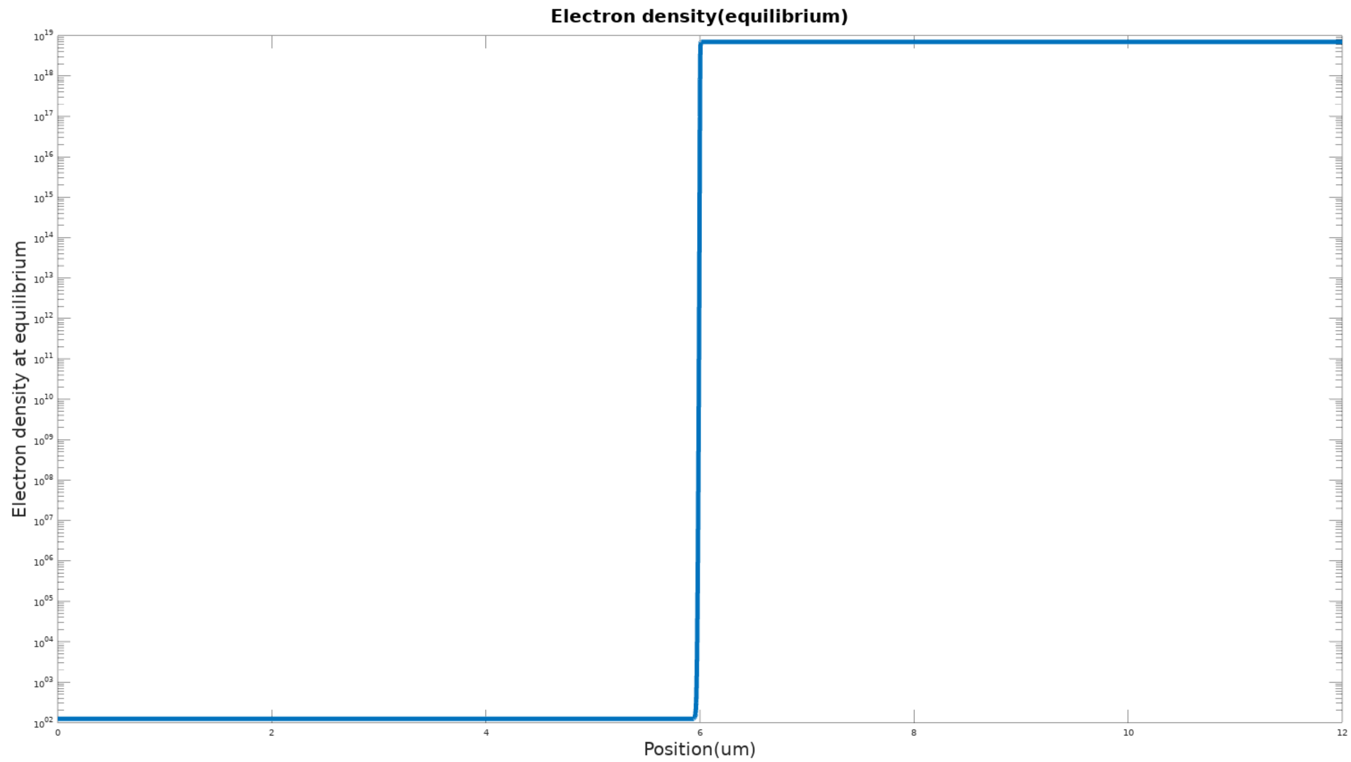


Plot: Hole density(semilog scale) Vs position

• The above plot shows how the hole density changes with position at equilibrium i.e Applied voltage is 0.

• The hole density stays constant on the p-type side and then decreases drastically at 6μm i.e on the n-type side

• since there is no voltage the holes in p-type side don't move to n-type side



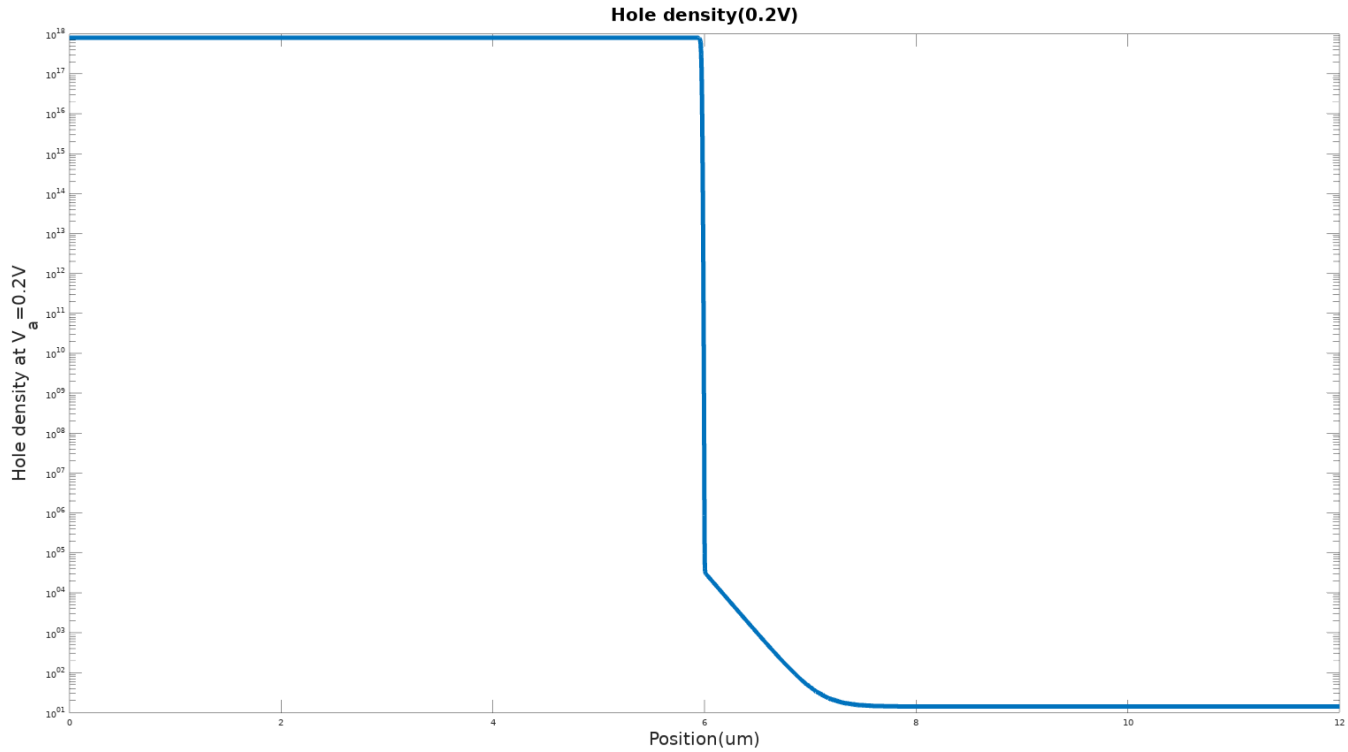
Plot: Electron density(semilog scale) Vs position

- The above plot shows how the Electron density changes with position at equilibrium i.e Applied voltage is 0.

- The hole density stays zero on the p-type side and then increases drastically at 6μm i.e on the n-type side

- its vice versa of above holes situation.

V_a=**0.2V**

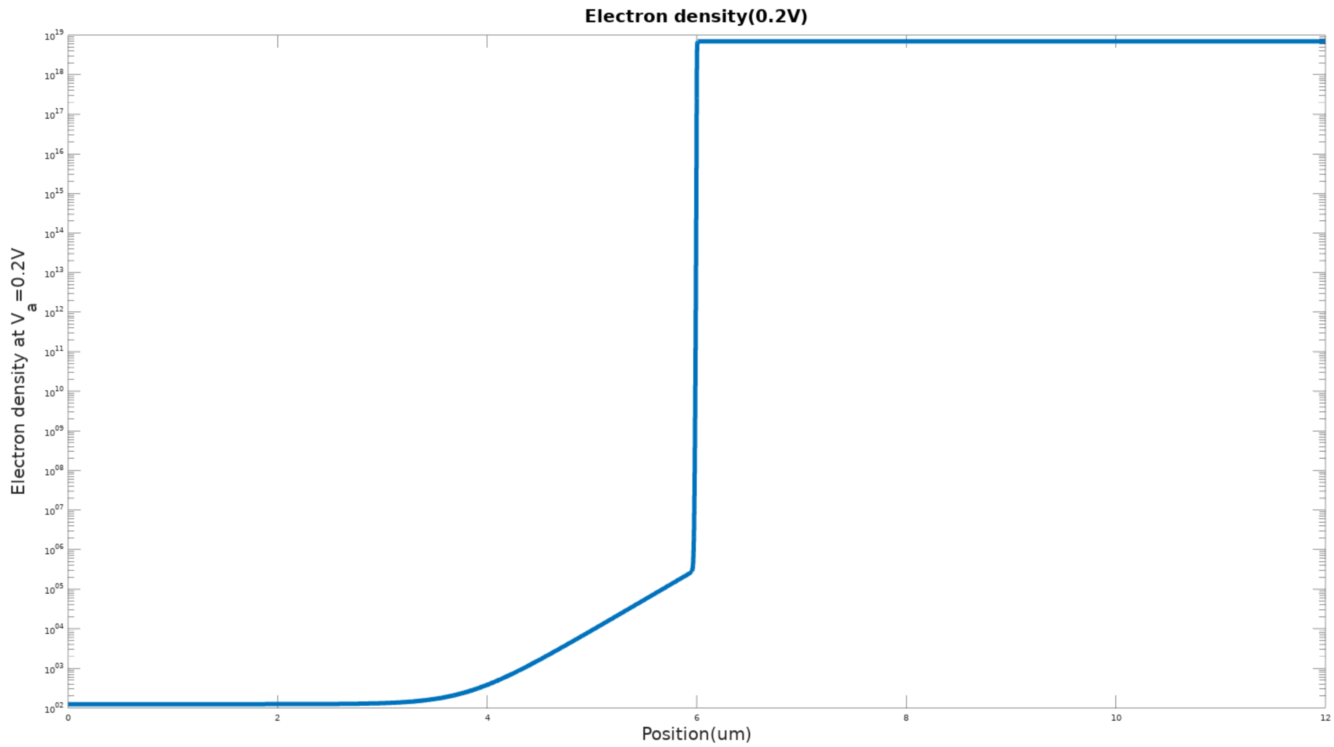


Plot: Hole density(semilog scale) Vs position

• The above plot shows how the hole density changes with position at equilibrium i.e Applied voltage is 0.2V.

• The hole density stays constant on the p-type side decreases drastically at 6μm and then decreases slowly after 6μm i.e on the n-type side and then becomes zero.

• This is because when voltage as applied the charge carries shift from ntype to ptype and vice versa.



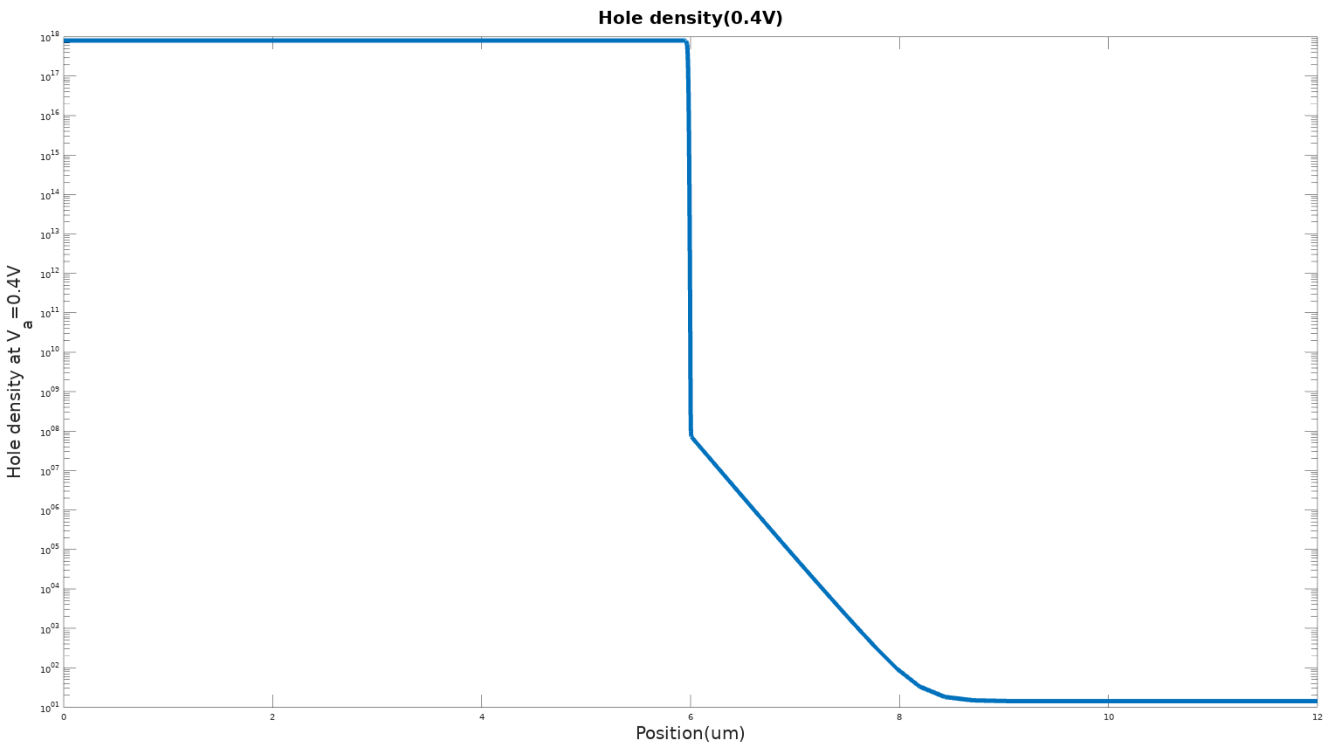
Plot: Electron density(semilog scale) Vs position

• The above plot shows how the Electron density changes with position at equilibrium i.e Applied voltage is 0.2V

• The hole density stays zero on the p-type side and then increases slowly before 6μm and then increases drastically at 6μm .

• its vice versa of holes situation.

V_a=**0.4V**

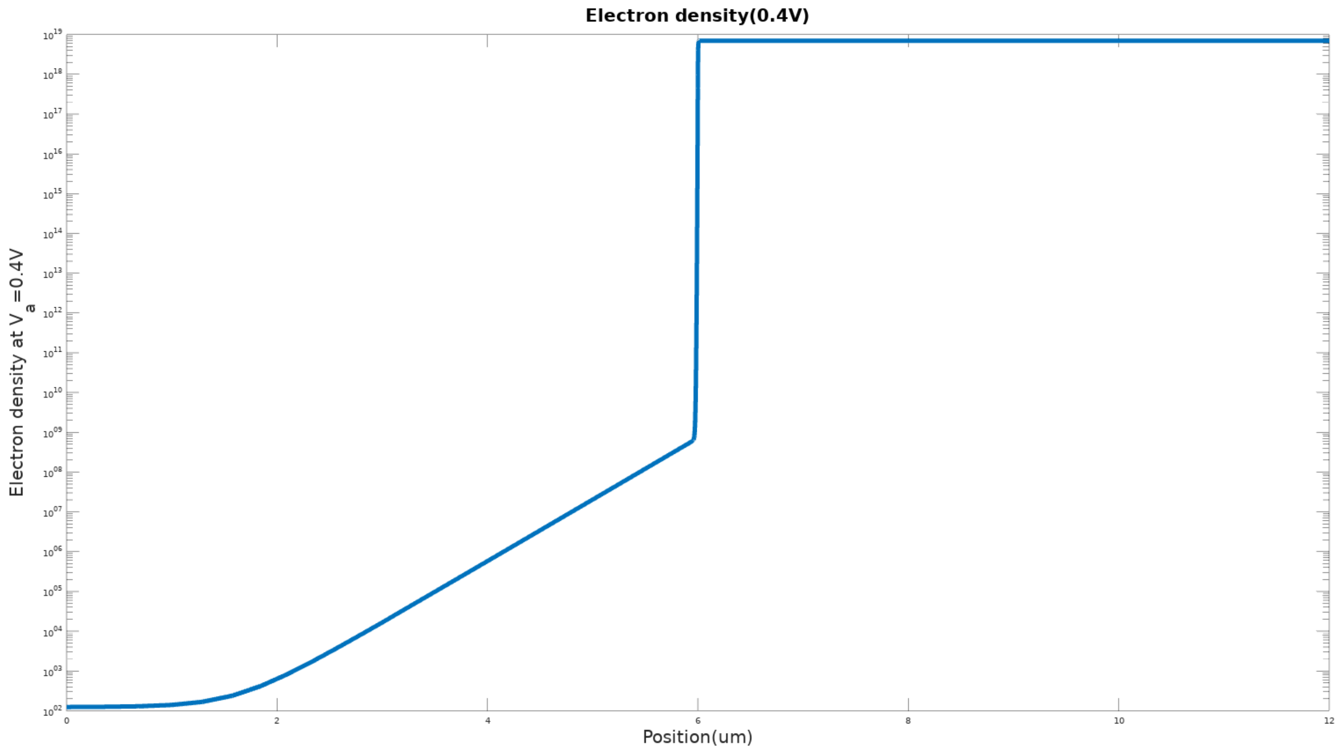


Plot: Hole density(semilog scale) Vs position

• The above plot shows how the hole density changes with position at equilibrium i.e Applied voltage is 0.4V.

• The hole density stays constant on the p-type side decreases drastically at 6μm and then decreases slowly after 6μm i.e on the n-type side and then becomes zero.

• This is because when voltage as applied the charge carries shift from ntype to ptype and vice versa.and the shift increases as voltage increases



Plot: Electron density(semilog scale) Vs position

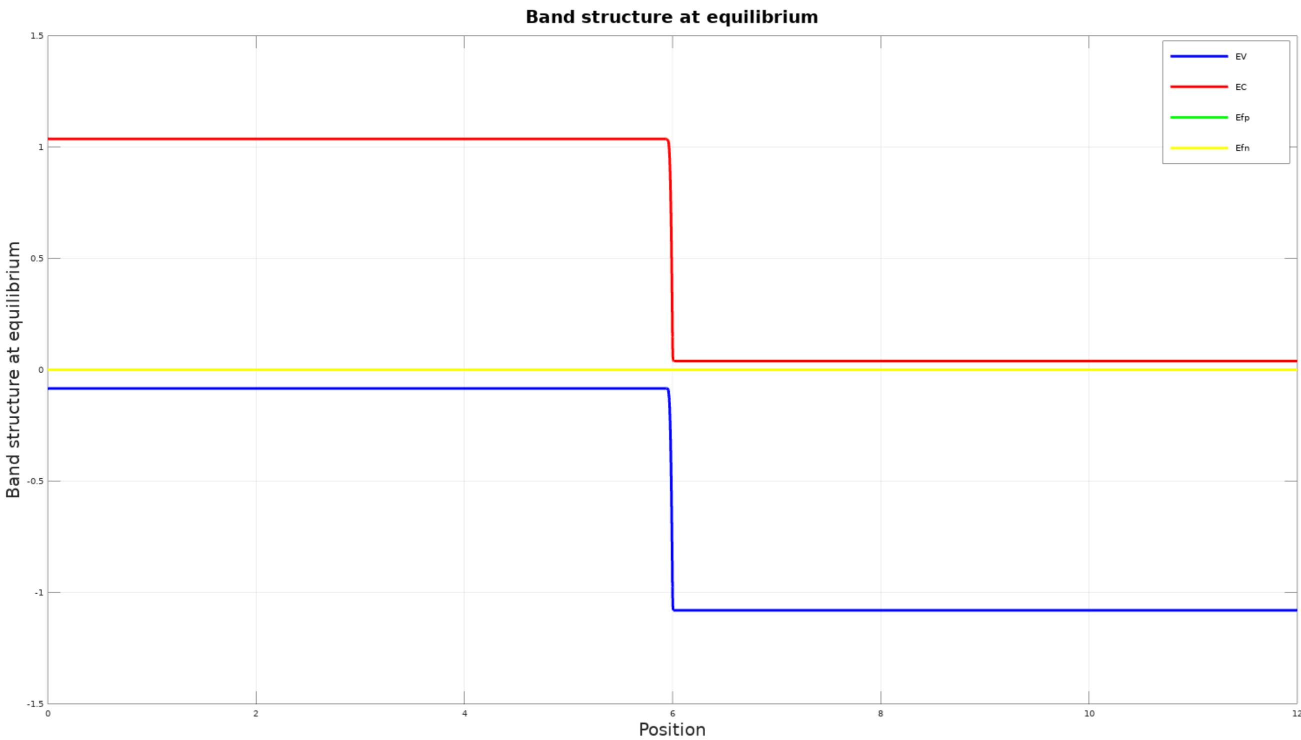
• The above plot shows how the Electron density changes with position at equilibrium i.e Applied voltage is 0.4V

• The hole density stays zero on the p-type side and then increases slowly before 6μm and then increases drastically at 6μm .

• its vice versa of holes situation.

Question 2

V_a=**0V**



Plot: Band structure Vs position

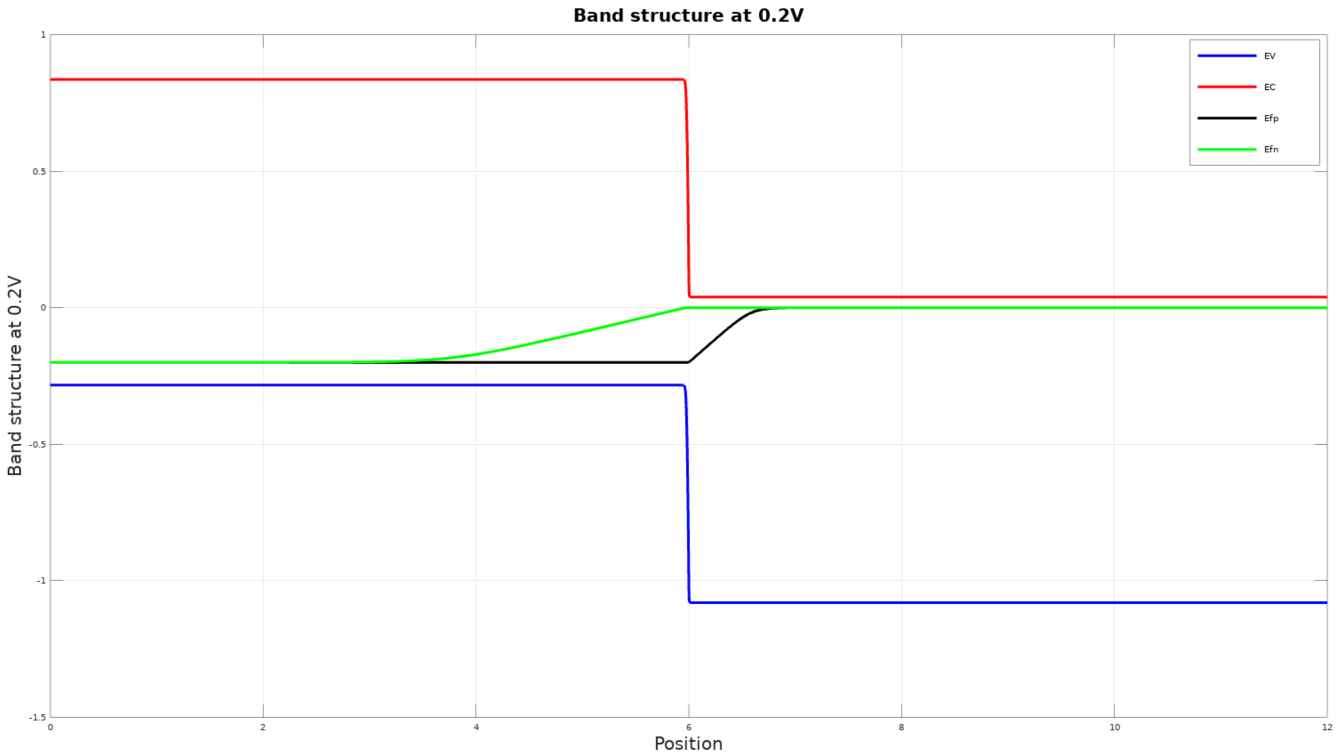
- The above plot shows how the band structure varies with position in a semiconductor.

- As we can see both E_v and E_c decrease after 6 μm but fermi energy stays constant.

- we can also see that the band gap doesn't change.

- Conduction level and valance energy level decreases because of the voltage in the depletion region.

V_a=**0.2V**



Plot: Band structure Vs position

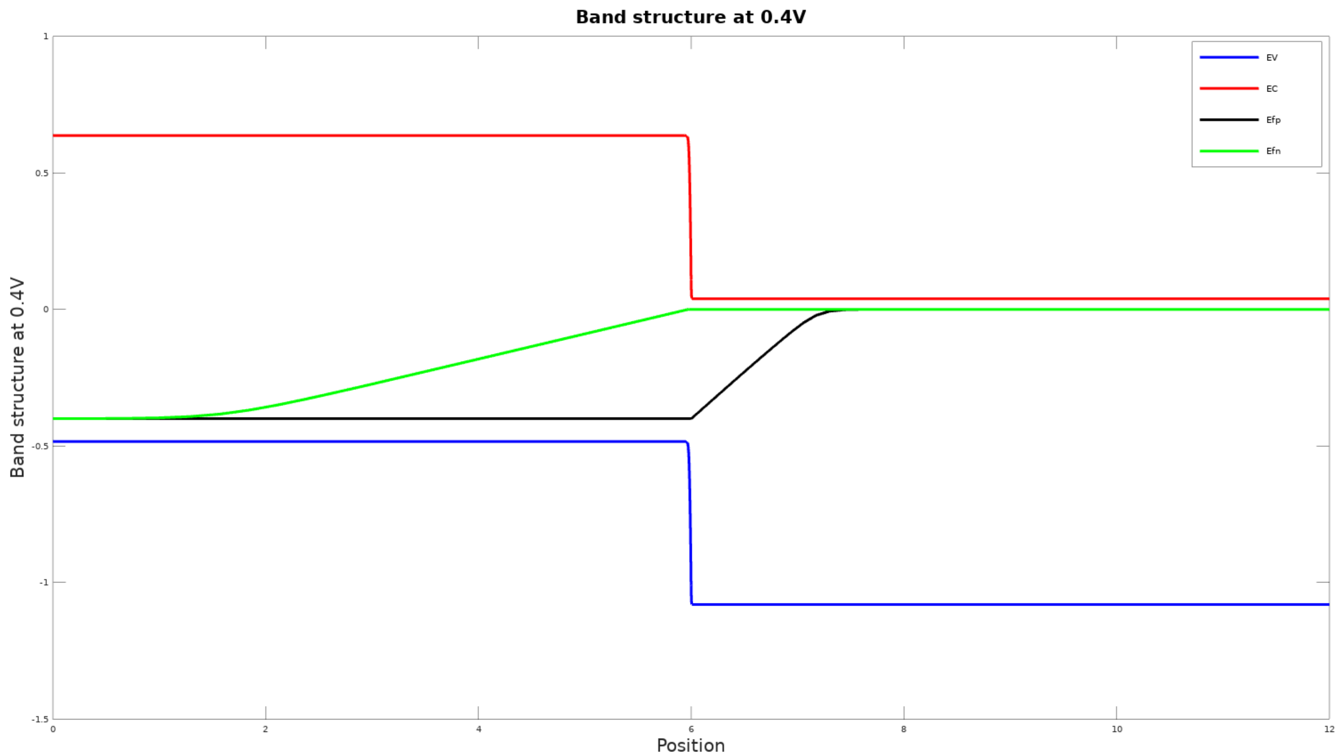
- The above plot shows how the band structure varies with position in a semiconductor.

- As we can see both E_v and E_c decrease after 6 μm but the decrease is lesser than at equilibrium due to voltage which causes decrease in depletion region.

- we can also see that the band gap doesn't change but fermi level of holes increases before 6 μm and the electrons after6 μm but eventually they come to a constant value.

- Conduction level and valance energy level decreases because of the voltage in the depletion region which is now lesser compared at equilibrium.

V_a=**0.4V**



Plot: Band structure Vs position

- The above plot shows how the band structure varies with position in a semiconductor.

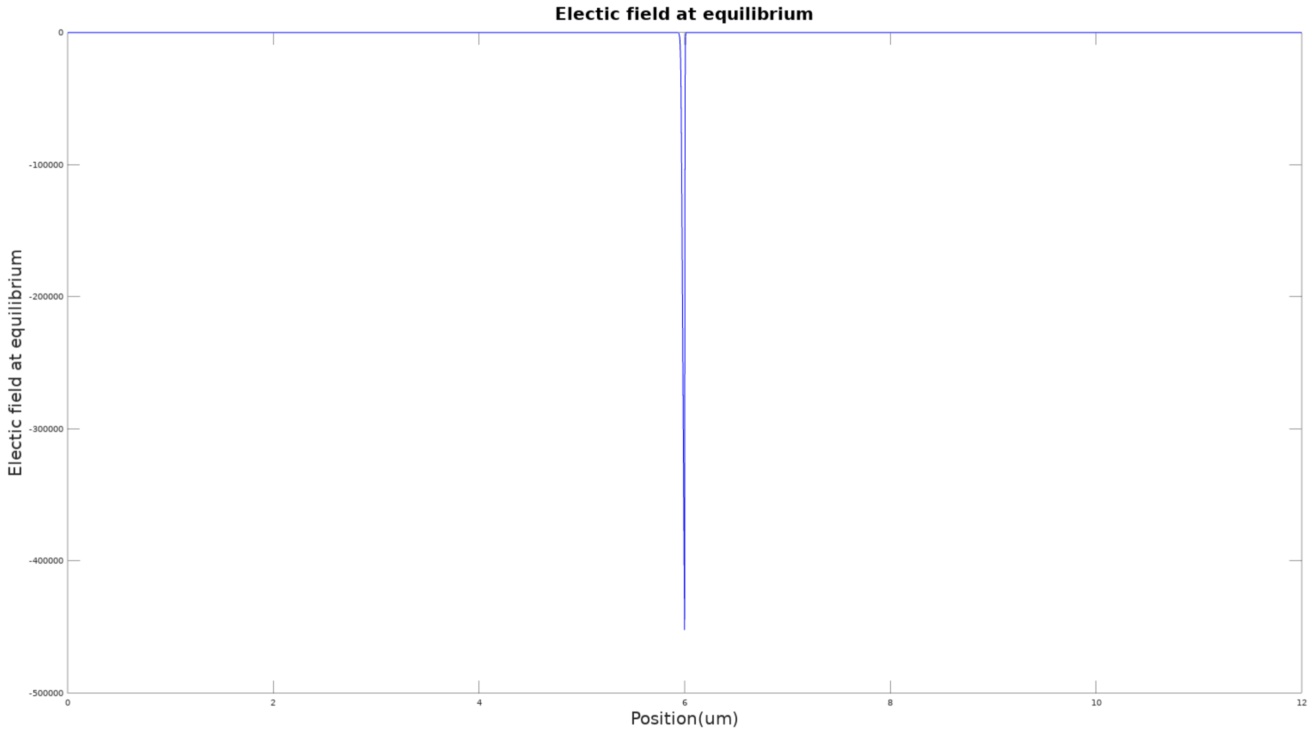
- As we can see both E_v and E_c decrease after 6 μm but the decrease is lesser than at equilibrium due to voltage which causes decrease in depletion region.

- we can also see that the band gap doesn't change but fermi level of holes increases before 6 μm and the electrons after 6 μm but eventually they come to a constant value.this time starting comes much before compared to 0.2v.

- Conduction level and valance energy level decreases because of the voltage in the depletion region which is now lesser compared at 0.2v.

Question 3

V_a=**0V**



Plot: E_f**(Electric field) Vs position**

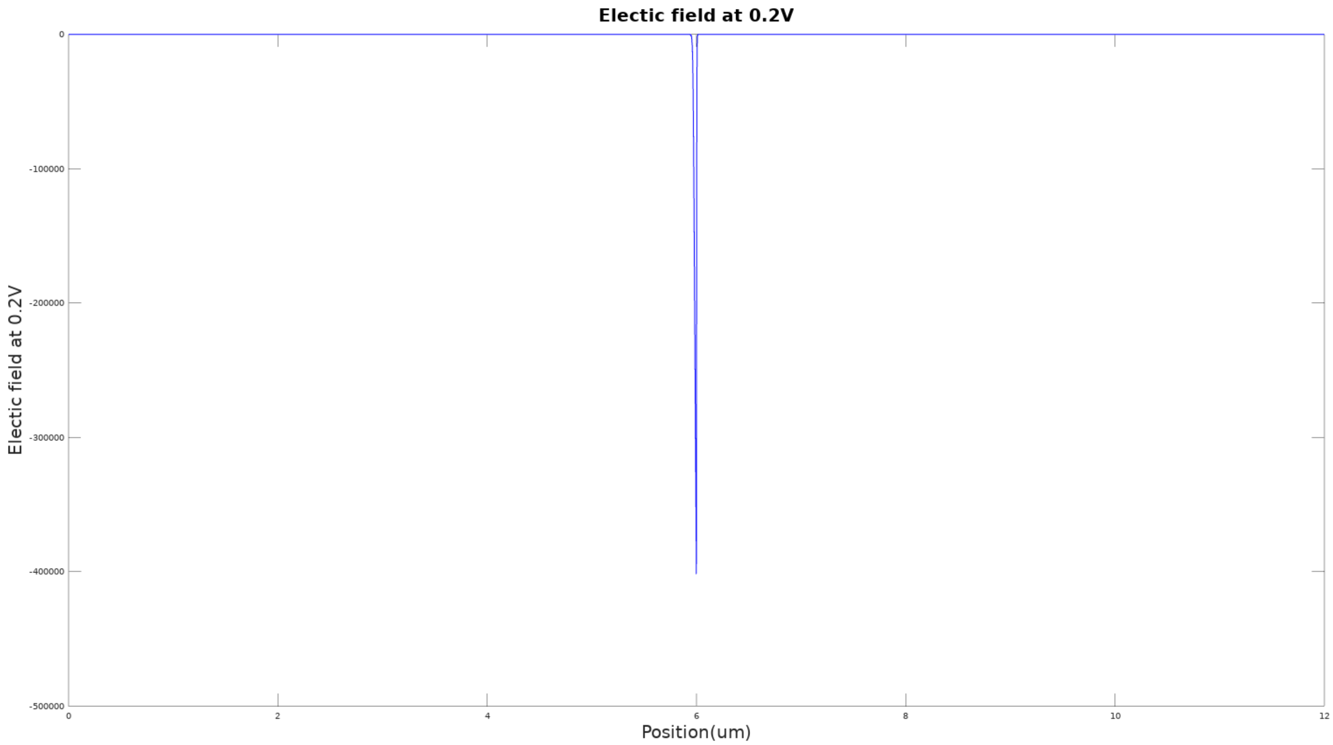
- The above plot shows Electric field with respect to position at equilibrium.

- As we can see the electric field on the p-type side and n-type side is zero but in the depletion region it decreases to a minimum and then from 6 μm increases to zero.

- This is because on p or n type side the electric field due to other carriers is uniform and cancels each other which gives zero but in depletion region we have different charges on boths sides .

- E_{fmin}=-45000.

V_a=**0.2V**



Plot: E_f(Electric field) Vs position

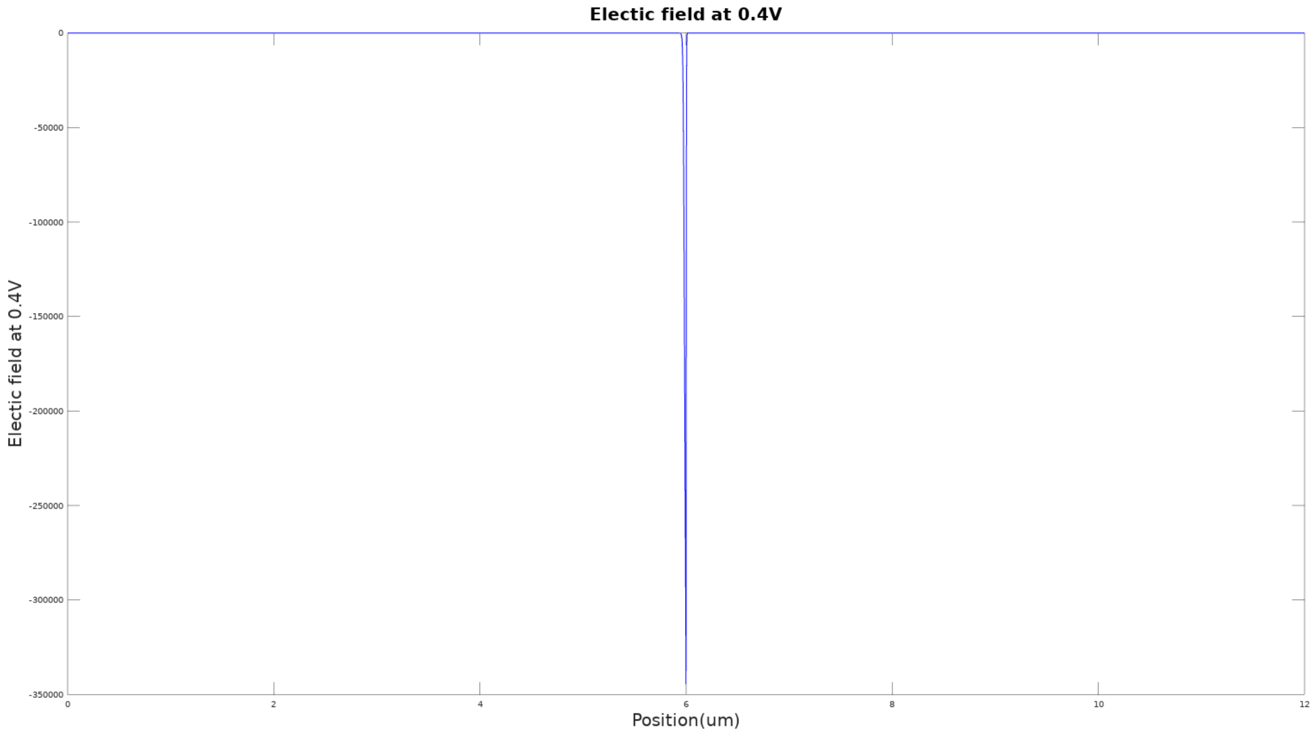
- The above plot shows Electric field with respect to position at equilibrium.

- As we can see the electric field on the p-type side and n-type side is zero but in the depletion region it decreases to a minimum and then from 6 μm increases to zero.

- This is because on p or n type side the electric field due to other carriers is uniform and cancels each other which gives zero but in depletion region we have different charges on boths sides but as voltage increases depletion region decreases so is the magnitude of electric field at 6 μm.

- E_{fmin}=-40000.

V_a=**0.4V**



Plot: E_f(Electric field) Vs position

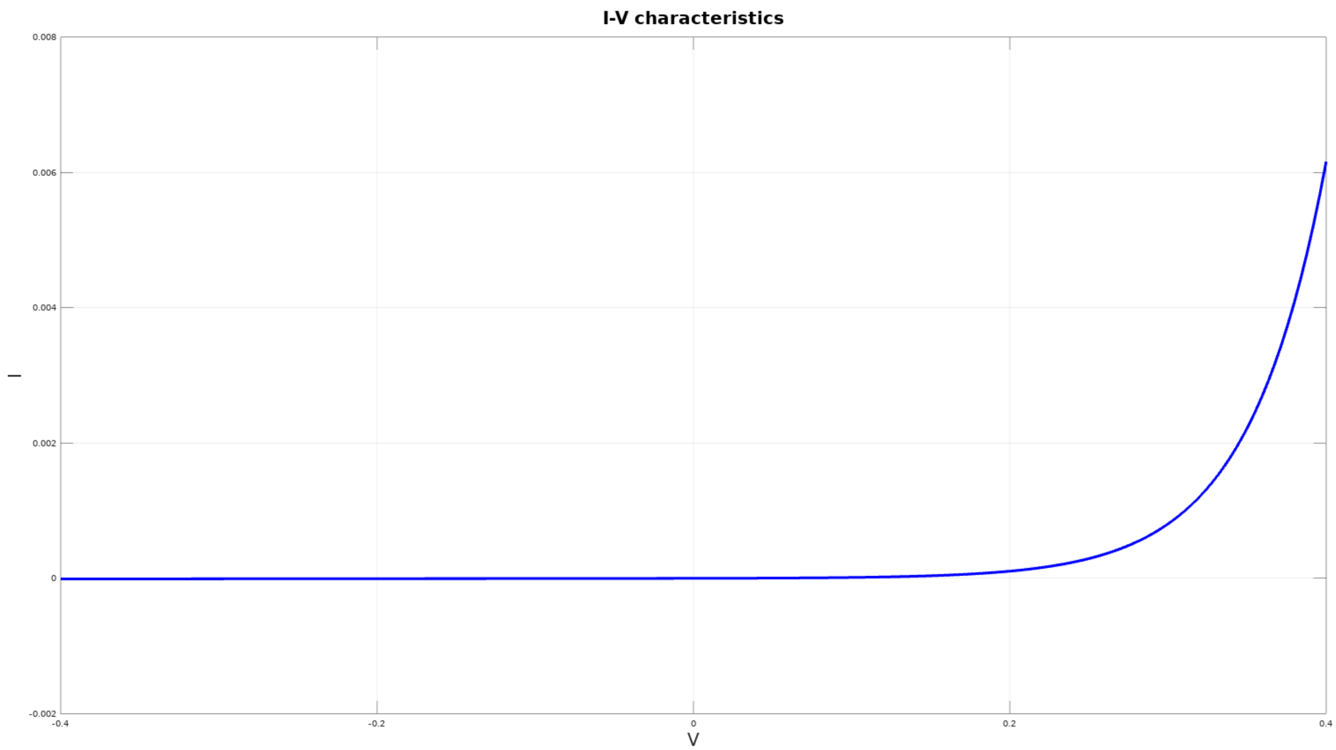
• The above plot shows Electric field with respect to position at equilibrium.

• As we can see the electric field on the p-type side and n-type side is zero but in the depletion region it decreases to a minimum and then from 6 μm increases to zero.

• This is because on p or n type side the electric field due to other carriers is uniform and cancels each other which gives zero but in depletion region we have different charges on boths sides but as voltage increases depletion region decreases so is the magnitude of electric field at 6 μm. as in 0.2v case.

•E_{fmin}=-35000.

Question 4



Plot: I Vs V

• The above plot shows I-V characteristics of the diode.

• In the forward bias case i.e when voltage applied is positive the current stays constant for some voltage and then increases exponentially.

• But in the reverse bias case the current stays zero assuming voltage doesn't exceed breakdown voltage.

• This is because as voltage in forward bias increases the depletion region decreases leading the potential barrier in depletion region to decreases which allows carriers to move according in applied voltage direction.

• But in the reverse bias case the depletion region increases as voltage increases causing the potential barrier to increase for the flow of carriers.

3 Conclusions

Question 1

• we can conclude that electron density looks like step function at equilibrium and as voltage increases electron density increases on the p-side .

• we can conclude that hole density looks like vice versa ofstep function at equilibrium and as voltage increases hole density increases on the n-side

Question 2

• we can conclude that conduction energy and valance energy looks like vice versa of step function at equilibrium shifted in y-direction and and fermi levels are parallel to x-axis.

• As voltage increase amplitude of step function decreses and fermi levels increase to a constant value.

Question 3

• Magnitude of Electric field is maximum at center of diode no matter the applied voltage. .

• The value of electric field magnitude at center decreaes with increase in voltage.

Question 4

• Current increases in the forward bias as voltage increases but not according to ohm's law.

• current on the negative bias is zero until breakdown voltage i.e no movement of charge carriers.

Thank you