EE2301-Electronic Devices and Circuits-Experiment-2:Fundamentals of Semiconductors

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Contents

1 Aim

- To verify the occupation probability as a function of the energy varies with respect to time.

- To verify how the 3D density of states changes with respect to the energy
- To verify the change in the Fermi energy with respect to doping(Group-1:p-type)
- To verify the change in the intrinsic carrier concentration with respect to the temperature.(Group-1:n-type)
- To verify the electron density varies with energy.

2 Procedure

2.1 Problem-1

The probability of an electron to occupy a particular energy level is given by Fermi-Dirac statistics

$$f(E) = \frac{1}{1 + e^{\frac{E-E_f}{k_B T}}} \tag{1}$$

where k_B is Boltzmann constant and T is temperature in K.
The Maxwell-Boltzmann distribution is given by

$$g(E) = \frac{1}{e^{\frac{E-E_f}{k_B T}}} \tag{2}$$

From equations f(E) and g(E) we can say that if $E >> E_f$ then $f(E)$ reduces to $g(E)$

2.1.1 Plotting

1)Plot the graph of f(E) vs E at different temparatures in MATLAB.
2)Plot the graph of f(E) vs t vs E at different temperatures in MATLAB.
3)Plot the graph of f(E) vs d(E) to observe how Fermi-Dirac apporximates Maxwell-Boltzmann statistics in MATLAB.

2.2 Problem-2

Density of states is given by

$$D(E) = \frac{m^*}{\pi^2 h^3}(2m^* E)^{0.5} \tag{3}$$

where m^* is effective mass.
To find $D(E)$, E is taken as E-E_C, let us assume E_c=0.25eV

2.2.1 Plotting

Plot a graph of Density of states changes with respect to energy in MATLAB

2.3 Problem-3

Fermi level for p-type semiconductor is given by

$$E_F = E_i + k_B T log(\frac{p_o}{n_i}) \tag{4}$$

where E_i is actual fermi energy level.

2.3.1 Plotting

Plot the graph of the position of the Fermi energy vs p-type doping.

2.4 Problem-4

The intrinsic carrier density is given by

$$n_i = \sqrt{N_c N_v} \times e^{\frac{-E_g}{2k_B T}} \tag{5}$$

where E_g is band gap between conduction and valency bands,n_i is intrinsic concentration.

2.4.1 Plotting

1)Plot the graph of Intrinsic carrier concentration vs temperature in MATLAB.
2)Plot the graph of Intrinsic carrier concentration on a semilog scale versus (1000/T) in MATLAB.

2.5 Problem-5

Electron /Hole density is given by

$$n(E) = D(E)f(E) \tag{6}$$

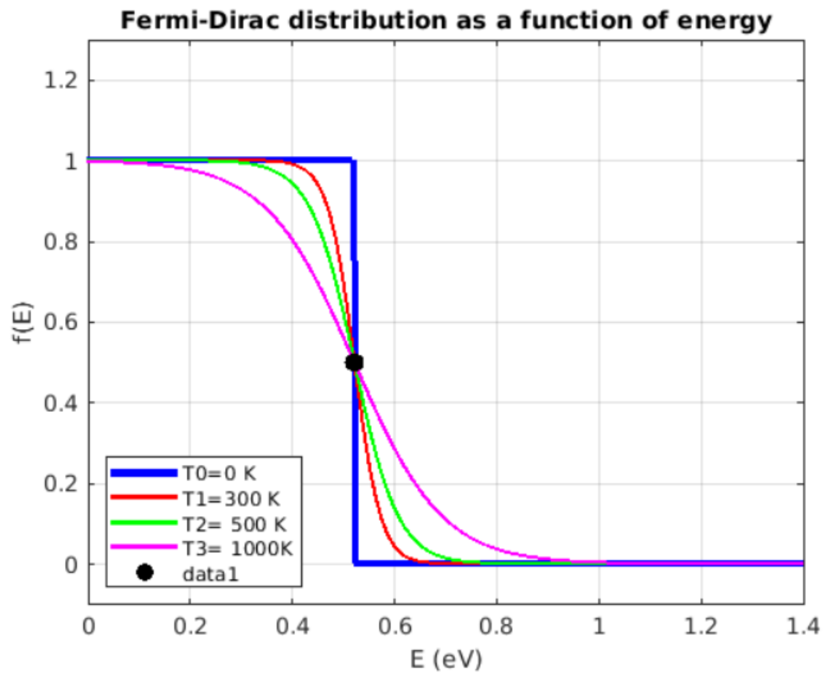
2.5.1 Plotting

Plot the graph of electron vs energy using Fermi-Dirac Distribution in MATLAB.

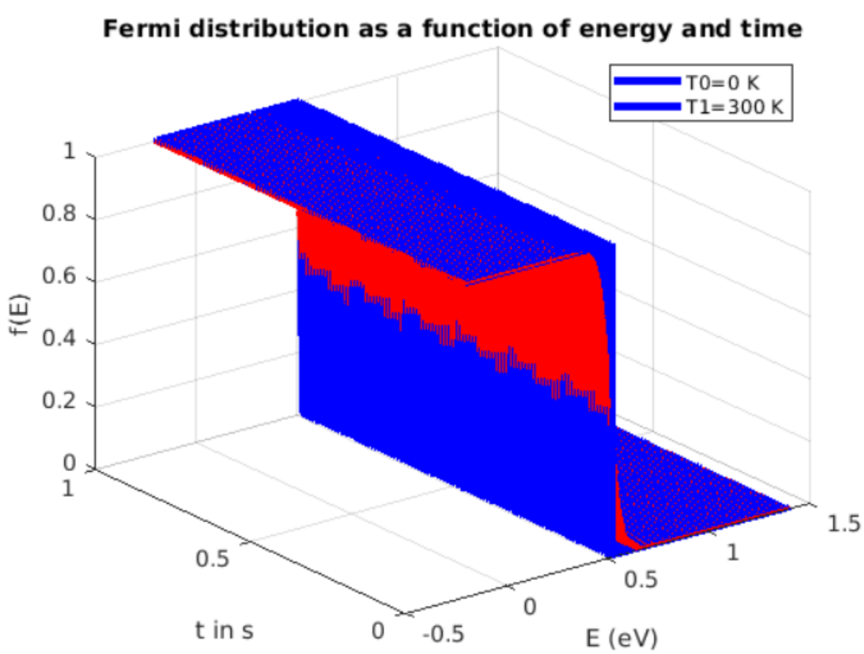
3 Results and Discussion

3.1 Problem-1

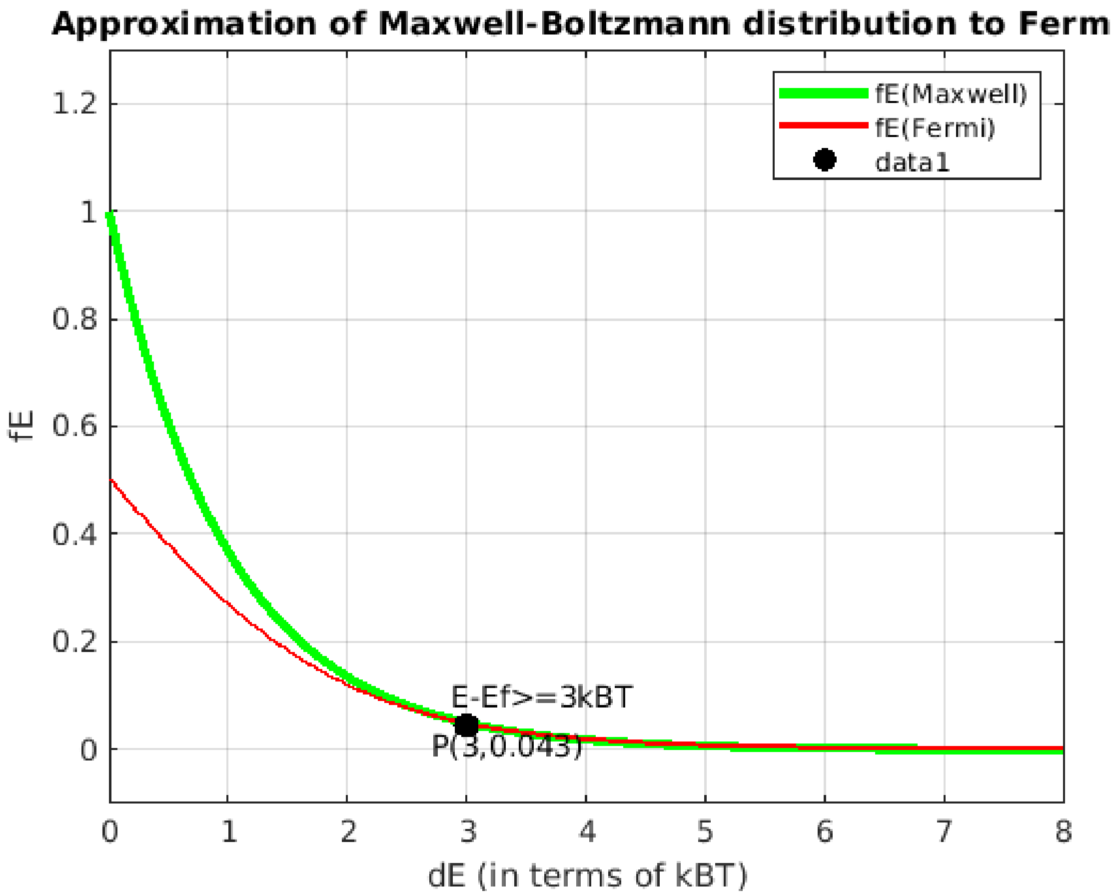
The graph of f(E) vs g(E) at different temparatures i.e;0K,300K,500K,1000K is



From the graph we can observe that, when $E > E_F$ then f(E) as temperature increases,when $E < E_F$ then f(E) decreases as decrease in temperature.As temperature increases the graph becomes wider.
The graph of f(E) vs E and t at different temparature is



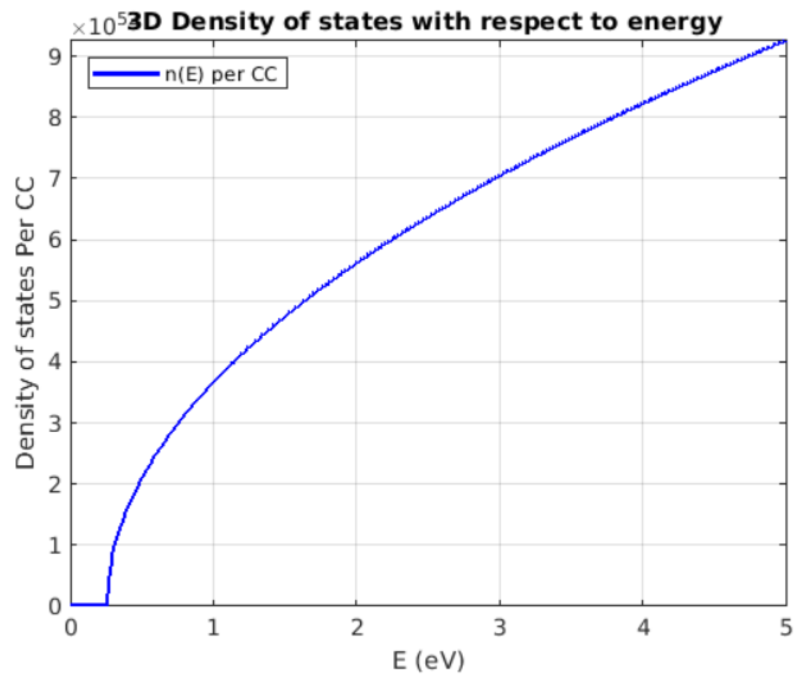
The graph of approximation of Fermi-Dirac distribution to Maxwell-Boltzmann Distribution



From the above graph we can observe that f(E)(Maxwell) and f(E)(Fermi) conicides each other at E-$E_F > 3k_BT$.The Fermic-Dirac distribution reduces to Maxwell-Boltzmann as the graph coincides.

3.2 Problem-2

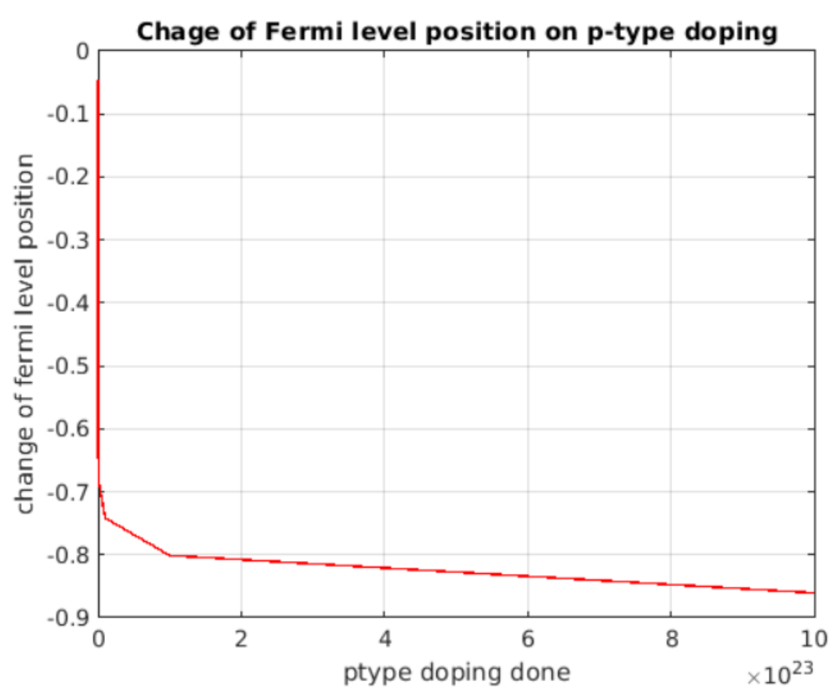
The graph of Density of states wrt energy is



From the above graph we can observe that as $\sqrt{E}$, increases Density of states per volume increases.Because as energy level increases the occupation of electrons increases.

3.3 Problem-3

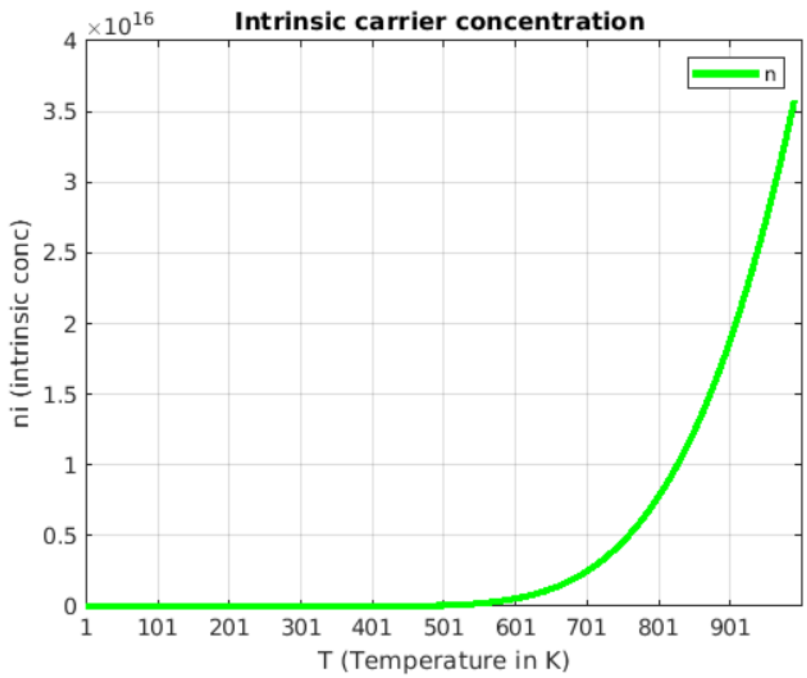
The graph of Fermi energy level position vs p-type doping



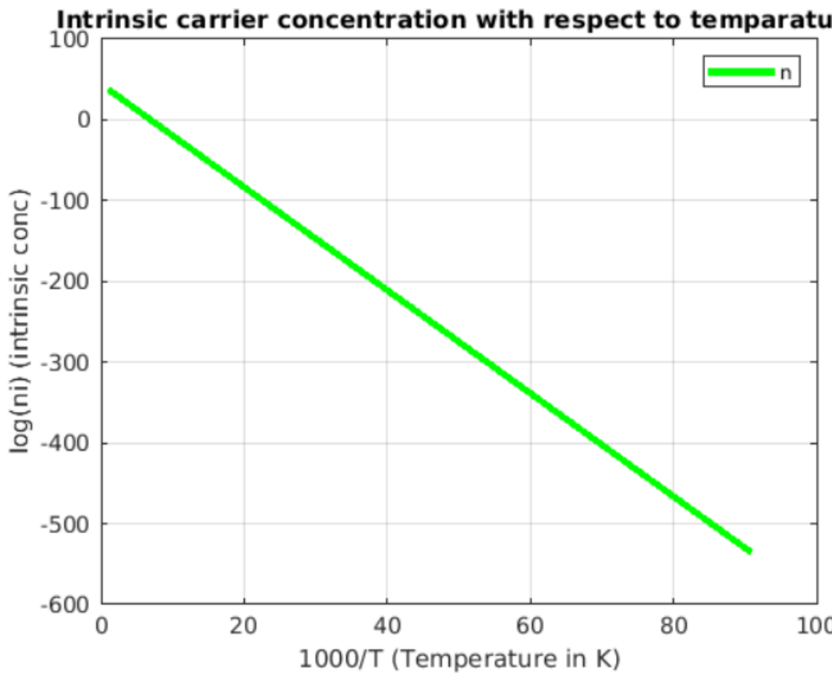
From the graph we can observe that the fermi level position is below the actual fermi level.

3.4 Problem-4

The graph of Intrinsic carrier concentration vs temperature



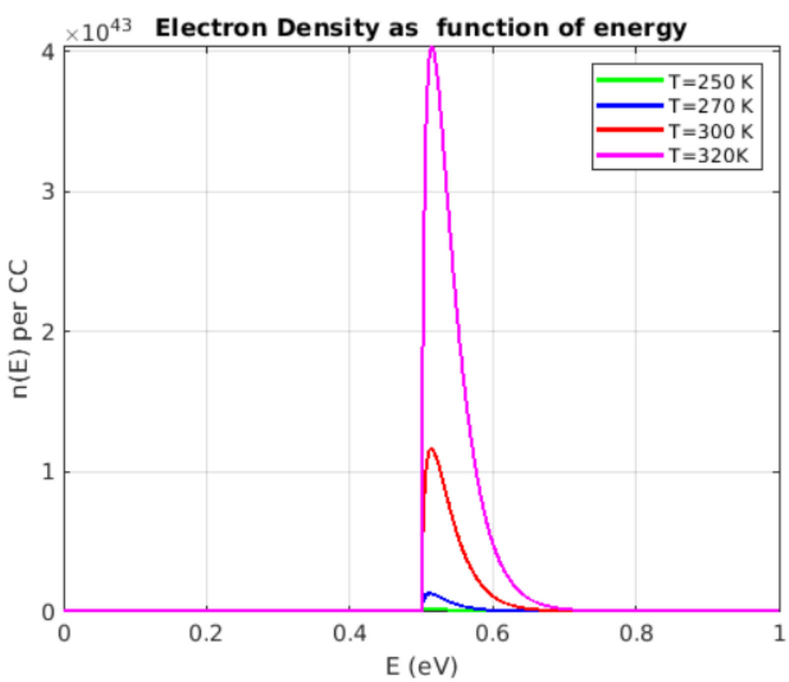
From the graph we can observe that as temperature increases the intrinsic carrier concentration is incresing.
As temperature the electrons in valence band will be excited to conduction band,this increases the intrinsic carrier concentration. The graph of Intrinsic carrier concentration on a semilog scale versus (1000/T) is



Frow the graph we can observe that their is no change in intrinsic carrier concentration even after doping the graph is a straight line with negative slope.

3.5 Problem-5

The graph of electron density vs energy using Fermi-Dirac Distribution at different tempara-tures i.e;250K,270K,300K,320K is



From the above graph we can observe that th electron density is zero upto certain energy then raises to maximum and decreases accordingly.
Because as n(E) is product of D(E) and f(E),D(E) is increasing and f(E) is decreasing with respect to increase in energy.

4 Conclusion

- From Fermi-Dirac vs energy graph we can conclued that as the energy increases the probability of finding electrons above the fermi level increases.
- From Density of states vs Energy graph we can conclude that the density of states is zero upto E_c and increases as the energy increase.
- From Fermi energy level position vs p-type doping graph we can conclude that the fermi level goes down to the valence band.
- From Intrinsic carrier concentration vs Temperature graph we can conclude that upto some temparature the concentration is zero and increases drastically with increase in temperature and the intrinsic carrier concentration on semilog scale vs 1000/T is decreasing wrt to increase in temparature.
- From electron density vs energy graph we can conclude that f(E) is dependent on temparature and D(E) is independent on temparature.So,n(E) increases with increase in temperature