EE2301: Electronic Devices and Circuits Lab

Experiment 2- Group 2

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Aim-

1) To plot the occupation probability vs energy according to Fermi-Dirac Statistics and Maxwell Boltzmann Statistics and also to find out under what circumstances Fermi-Dirac Statistics reduce to Maxwell-Boltzmann Statistics.
2) To plot the variation of carrier density with respect to energy in n-type semiconductors.
3) To plot the Intrinsic Carrier Concentration vs Temperature and analyse the type of semiconductor.

Procedure-

All the codes are written and simulated on OCTAVE and inferences are drawn from the output plots.

Theory-

Question 1-

The probability of an electron occupying the energy level E in Fermi-Dirac Statistics is given by-

$$f(E) = \frac{1}{1 + e^{\frac{(E-Ef)}{kT}}}$$

And in Maxwell-Boltzmann Statistics-

$$g(E) = \frac{1}{e^{\frac{(E-Ef)}{kT}}}$$

Where E is the energy, Ef is the Fermi energy level, k is Boltzmann constant and T is temperature.

From the formulas of f(E) and g(E) we can say that when $E-E_f >> kT$,

$e^{\frac{(E-Ef)}{kT}} >> 1$ and so f(E) is approximately equal to g(E). So when $E-E_f >> kT$, the Fermi-Dirac Statistics converges to Maxwell-Boltzmann Statistics.

Question 2-

An n-type semiconductor is doped with group 15 elements which have one more electron than the crystal atoms. So there are excess electrons which are excited into the conduction band and hence the density of electrons in the conduction band is higher than those of holes in the valence band. The electron carrier density is given by
n(E) = D(E)*f(E), where D(E) is the density of states and f(E) is from the Fermi-Dirac Statistics and the hole carrier density is given by n(E) = D(E)*(1-f(E)).
The Fermi Level of a n-type semiconductor is slightly higher than that of a pure semiconductor as at Fermi level, $f(E_f) = 0.5$ and the number of electrons is increased in the conduction band so it is more probable to find an electron in the conduction band. Hence for this question E_v=-0.6 eV, E_c=0.6 eV and E_f=0.04 eV.

Question 3-

The formula for intrinsic carrier concentration is-

$$n_i = \sqrt{NcNv e^{\frac{-Eg}{2kT}}}$$

Where Nc is the effective density of states in the conduction band, Nv is the effective density of states in the valence band, E_g is the band gap for silicon and is given as 1.12 eV, k is Boltzmann constant and T is temperature.
We can infer from the formula that the intrinsic carrier concentration is independent of the Fermi Level, Ec, Ev and the doping concentration.

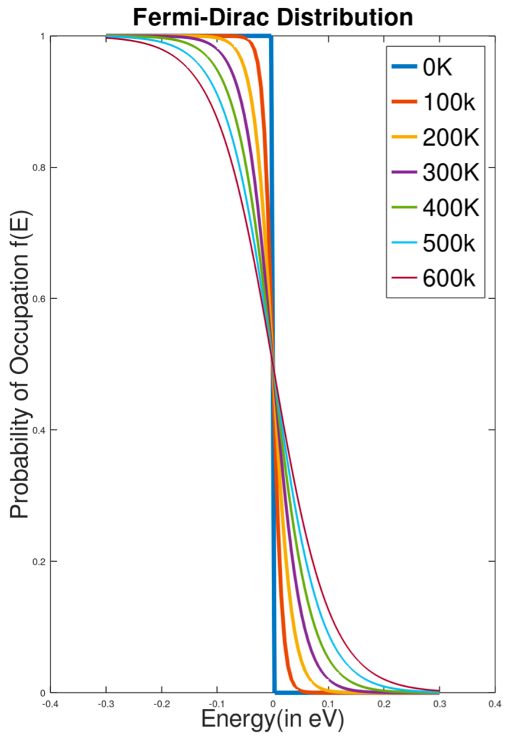
Conclusions from plots-

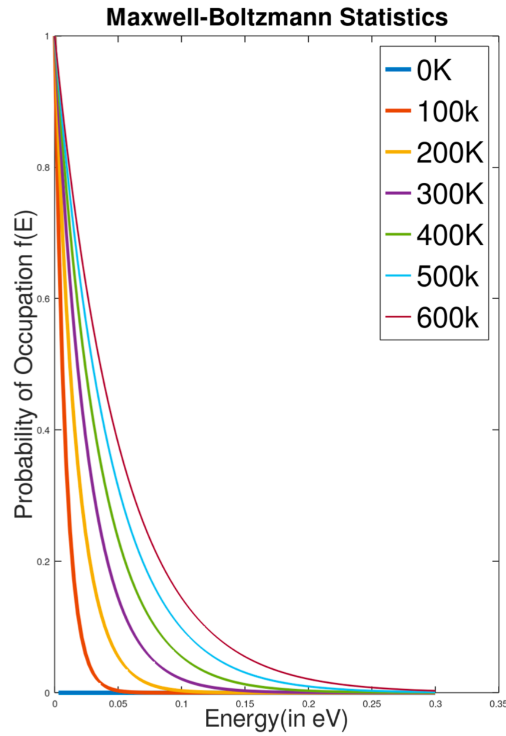
1) In the 1st question, the probability of occupation decreases with increase in energy and the graph smoothes out with increase in temperature for both Statistics. Also the Fermi-Dirac statistics reduces to Maxwell-Boltzmann statistics when $E >> E_f$ or at very low temperatures.
2) In the 2nd question, the electron density in the conduction band is much greater than the density of holes in the valence band due to the impurity atoms being of donor type from group 15.
3) In the 3rd question, as temperature increases the intrinsic carrier concentration increases because the electrons absorb energy and excite to higher energy levels which eventually leads them into the conduction band. Due to doping there are 10^{17} more electrons in the conduction band at room temperature but at very high temperatures, many electrons are excited into the conduction band leaving behind many holes in the valence band and due to that an extrinsic semiconductor starts behaving as an

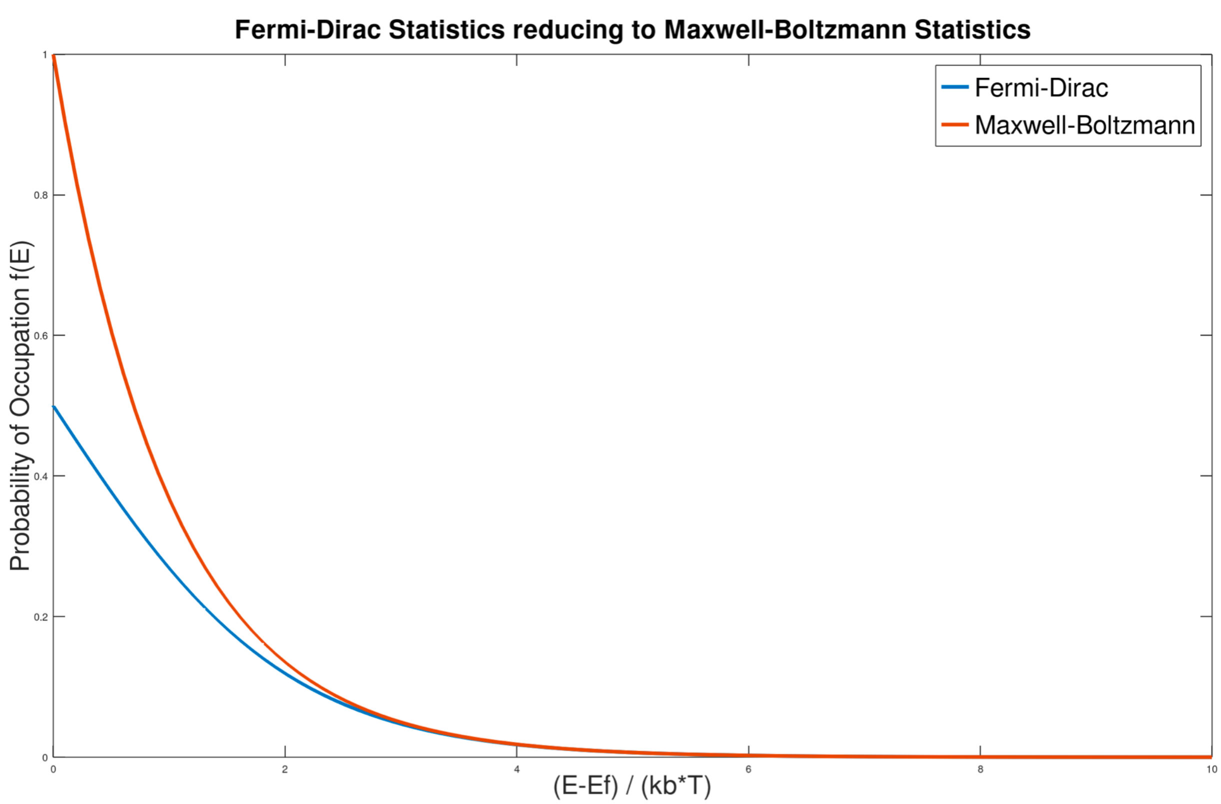
Intrinsic semiconductor because the ratio of number of electrons to number of holes is not very high for the semiconductor to behave like an extrinsic semiconductor.

<u>Plots</u>-

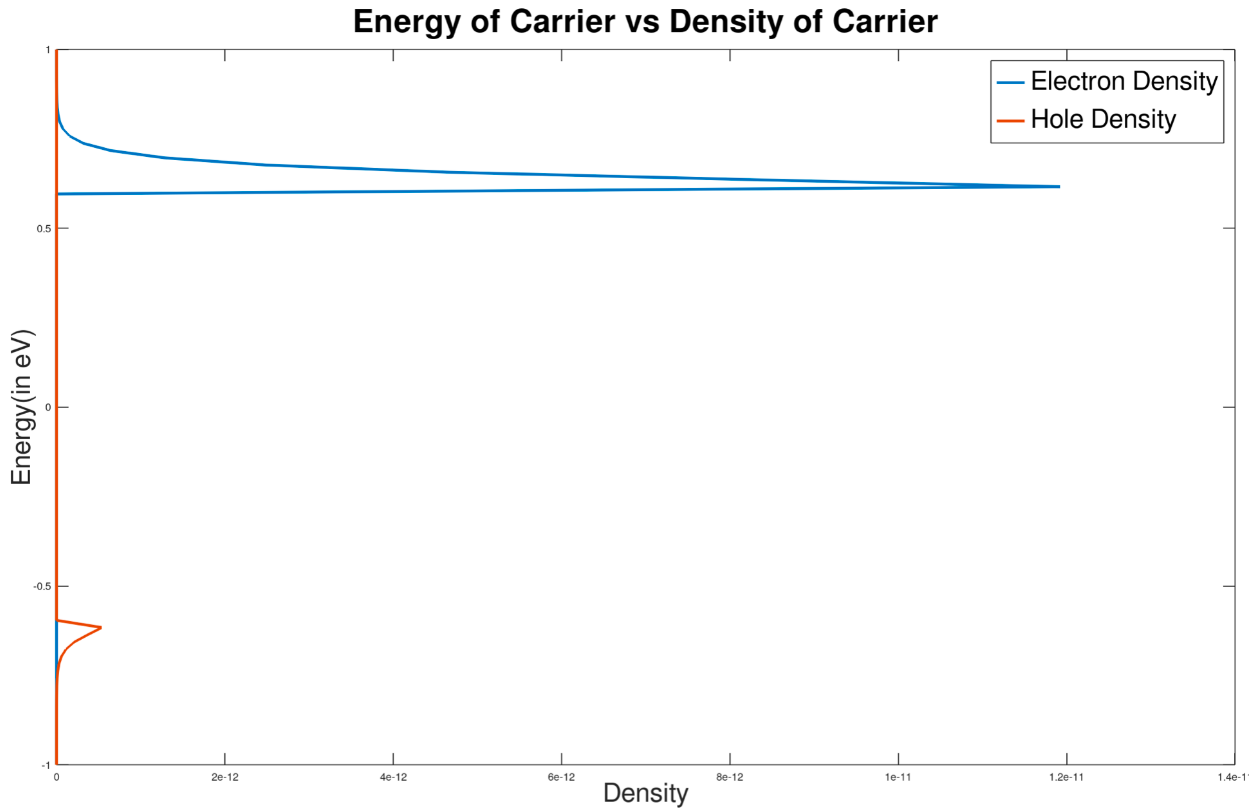
1) Question 1







2) Question 2



3) Question 3