Elec 4700

Assignment – 1

Monte-Carlo Modeling of Electron Transport

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<u>Introduction:</u>

This lab requires us to write MATLAB code to model semiconductor electrons moving with thermal velocities and scattering in the semiconductor crystal. The dimension of the semiconductor is 200 * 100nm and the particles must move only with that boundary. Monte-Carlos technique was used to model the motion of the particles. We used random numbers determine the starting point of the electrons. Using the modelling result we need the 2-D plot of particle trajectories, Temperature plot, Histogram, Electron density map and Temperature map.

Part1

<u>Electron Modelling:</u>

Thermal velocity is the speed of thermal motion in particles which makes up matter which is a measure of temperature. We used the effective mass to model the silicon particles by finding the Thermal velocity at 300k temperature and a fixed velocity which is velocityTherm = sqrt ((kb * 300) / effMass) = 1.3224*10^5.

After assigning each particles a random location in the x-y plane within our defined region of 200*100. When a random particle is generated it travels in the x-y direction within its boundaries at a random angle(direction) at a calculated speed. And we had different particles within the boundary.

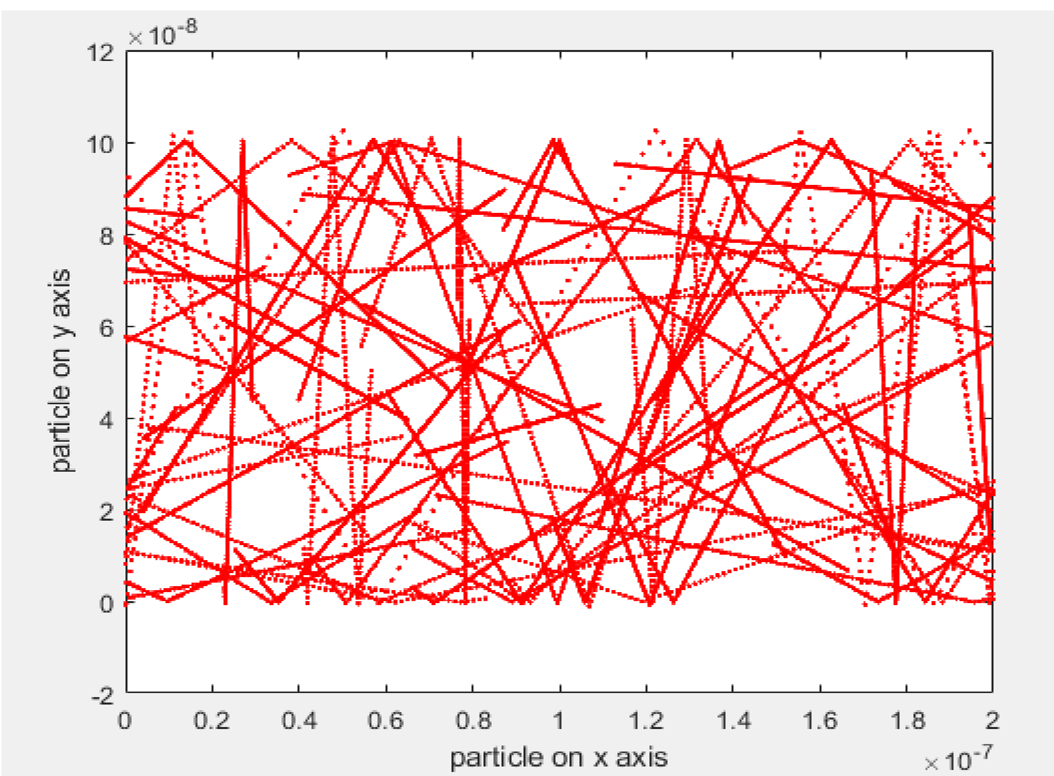

Figure 1 2-D plot of particle trajectories

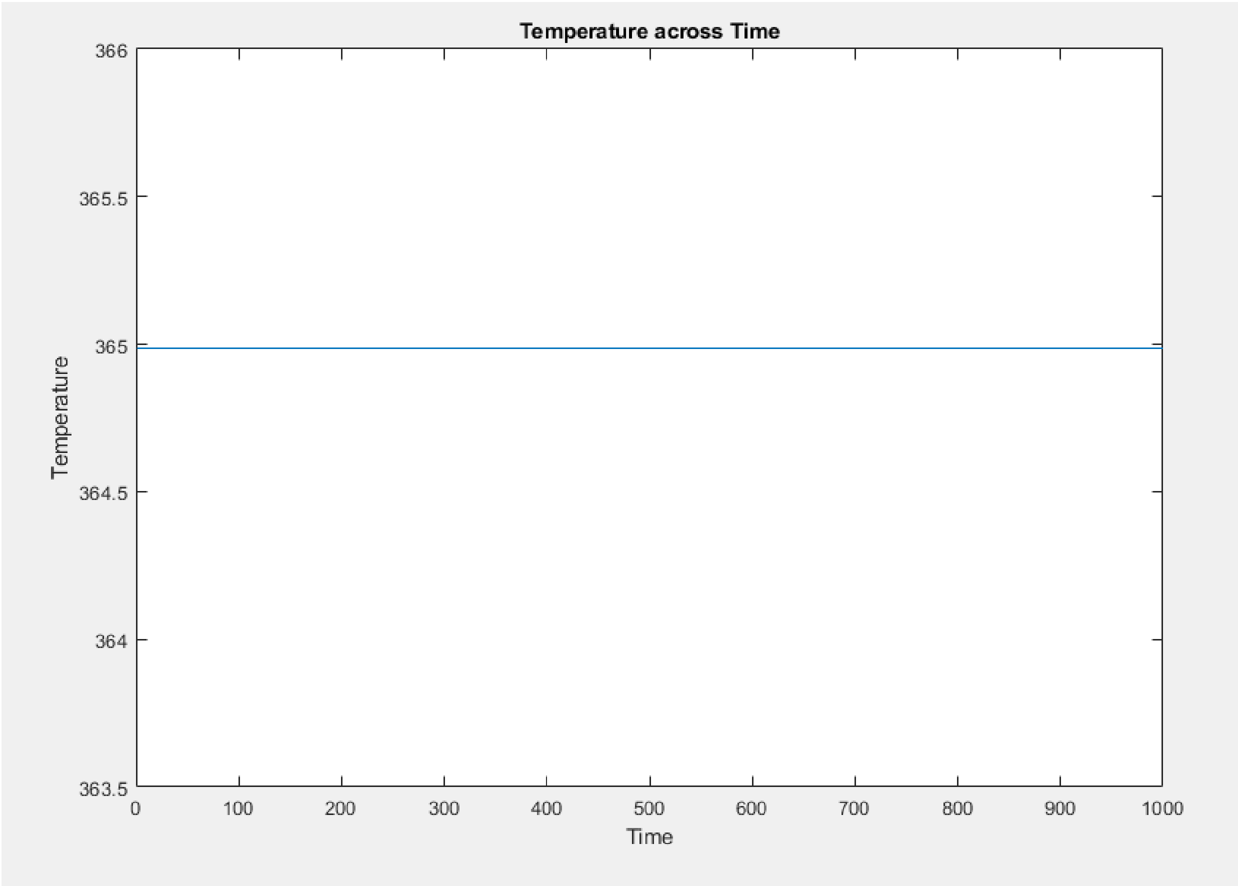

Figure 2 Temperture plot

Mean Free Path = (1.3224*10^5)*(0.2*10^-12) = 2.6448*10^-8

Part2

<u>Collisions with Mean Free Path (MFP):</u>

The Mean Free Path was the distance between collision of particles travelling with the boundary and the Mean Free Time is 0.2ps. The Mean Free Path will be the MFT * thermal velocity. Using the Maxwell-Boltzmann distribution for each velocity component we got random velocity and by modelling the scattering of particles. Exponential scattering probability P_{scat} was calculated and a graph was trajectories plot for figure 3 shows this.

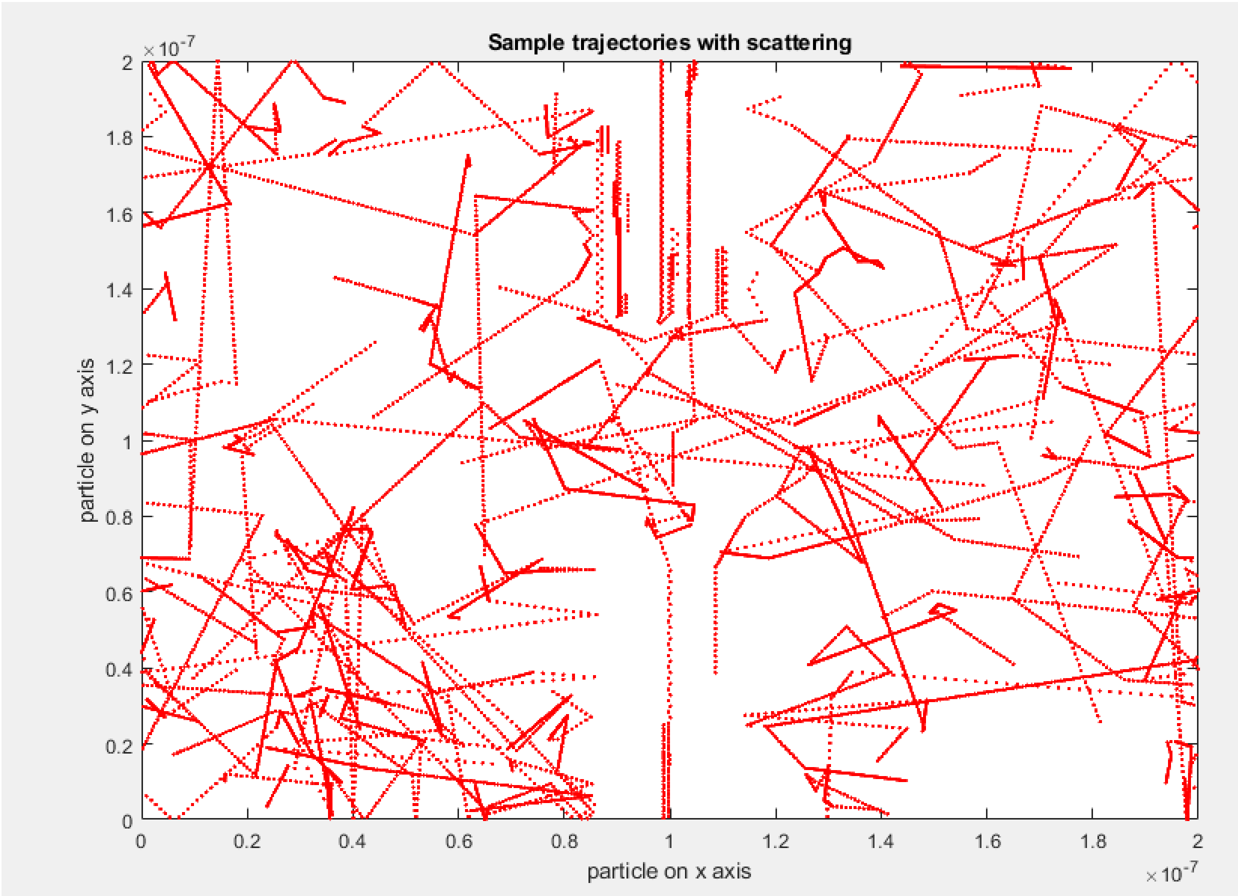

Figure 3 Sample trajectories with scattering

Over time the average temperature stayed at a constant value over time. We have a time span of 1000 and it stayed at a temperature above 300k.

The measured value for the Mean Free Path and Mean time between collision are: are the code that was submitted with the report.

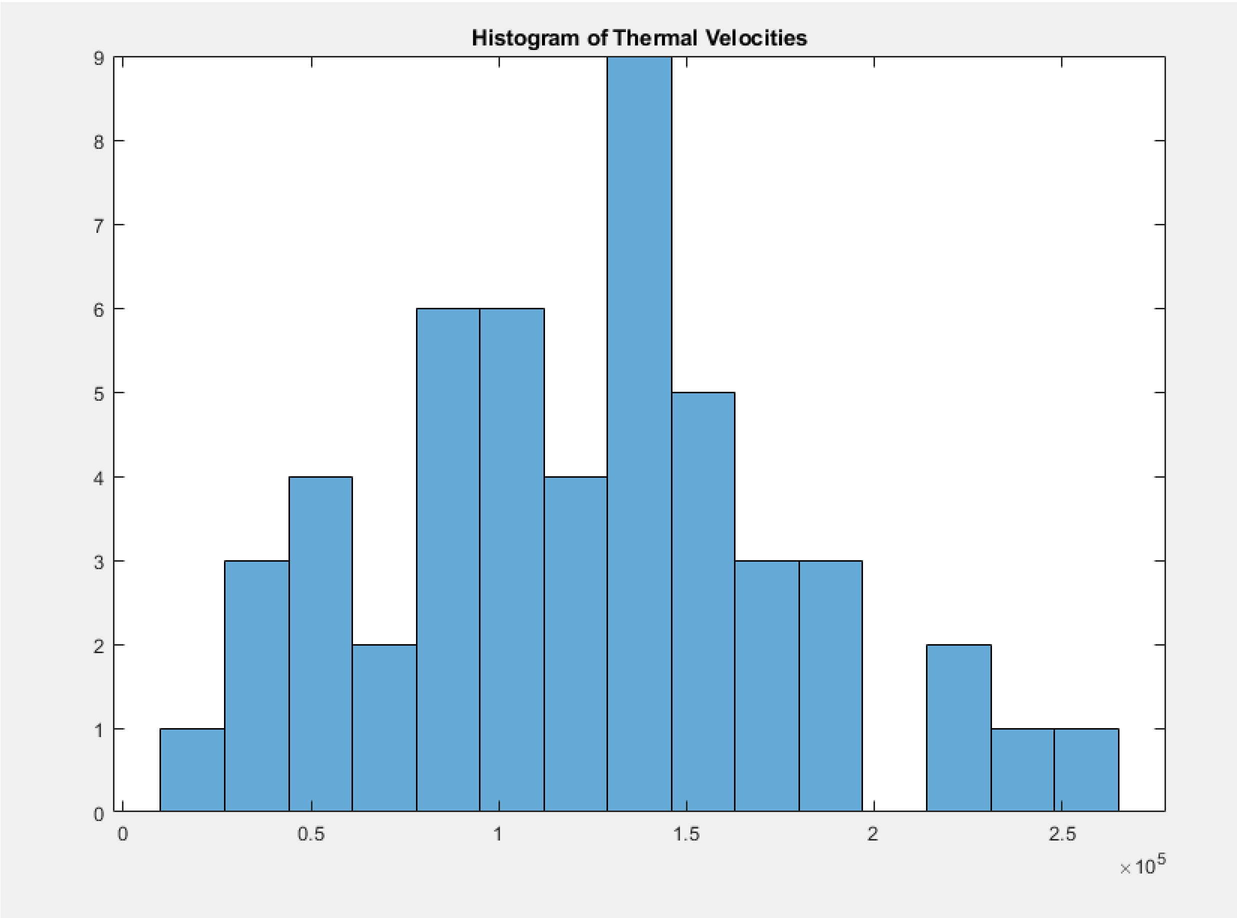

Figure 4 Histogram

Part3

<u>Enhancements:</u>

We add to two inner rectangles to create a bottle neck boundary of dimension 0.90 to 1.30 of the width region. The two rectangles were imputed to see the path of the electron when its been blocked. We had a difficult time with this path of the code because the particles where not reflecting of the y- boundary. We also had to make sure an electron does not start inside the bottle neck boundary. Upon hitting the boundary it electron will have a random velocity also we plotted graphs for both the Density Map and the Temperature Map.

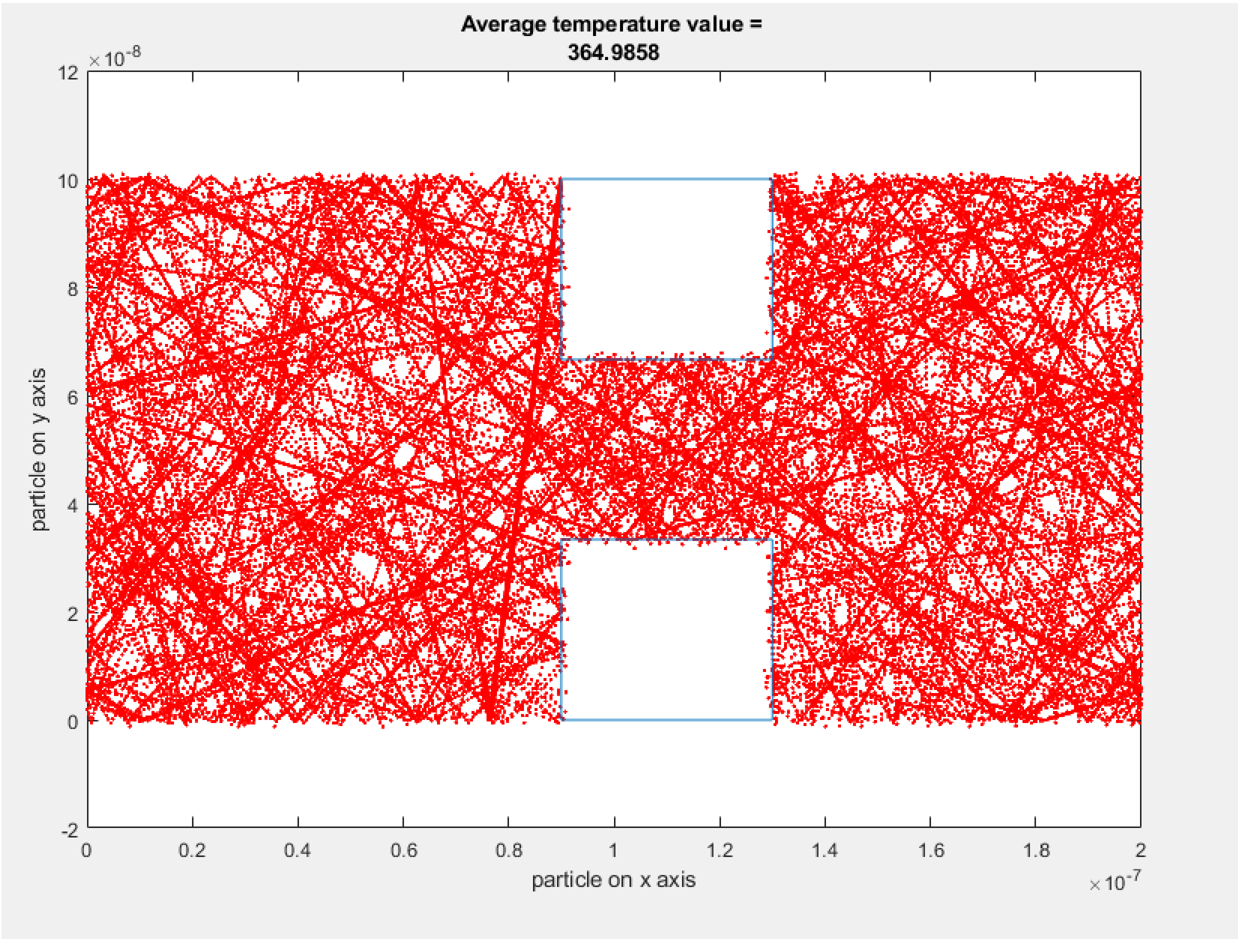

Figure 5 All boundaries capable to either specular or diffusive

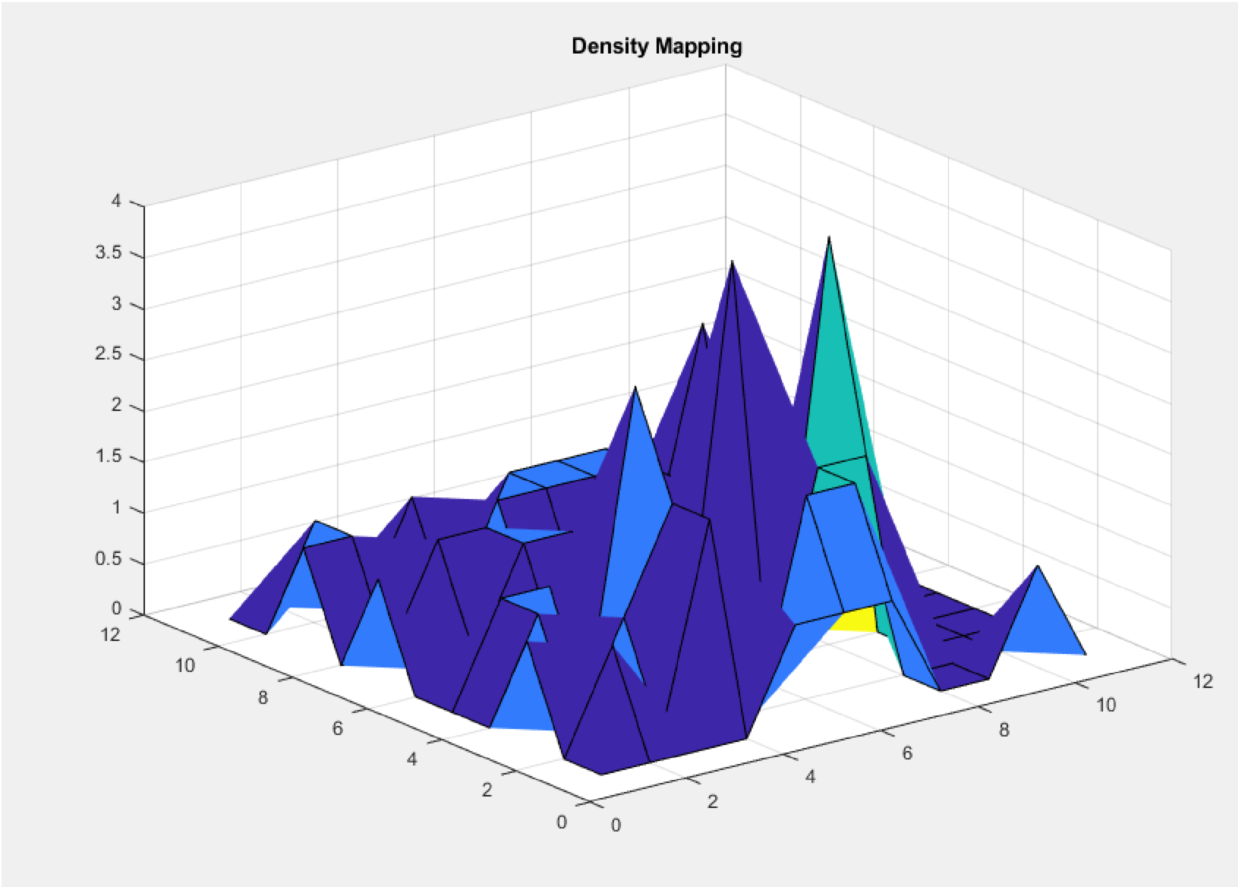

Figure 6 Electron Density map

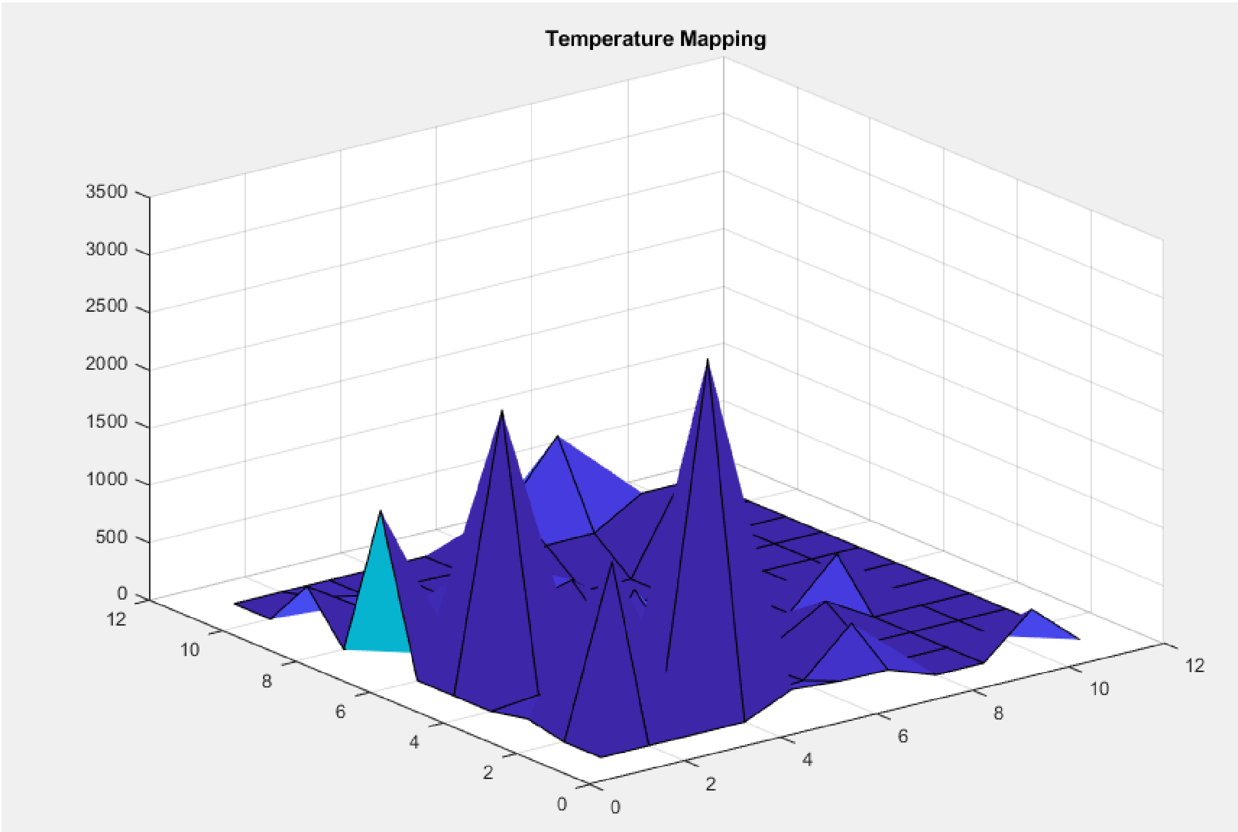

Figure 7 Temperature Map

Conclusion:

The code was writing to observe the behavior of particles in different situation. In some cases, the result was what we expected and in other it was not. The matlab code was able to perform the required task because matlab is best used for simulation. Most of the goals set down for this lab was achieved and help us understand the Monte-Carlo Modeling of Electron Transport much better and how electron behave in some situations.