ELEC 4700

ASSIGNMENT 3 – MONTE CARLO/ FINITE DIFFERENCE METHOD

Name: Amir Kalmoni

Student Number: 100987101

Introduction

This experiment is the continuation of the previous assignments which uses Monte-Carlo in assignment 1, combined with the finite difference method in assignment 2. The simulation was first done with Monte-Carlo simulation with an electric field applied. The second part of the experiment involved using the finite difference method to calculate the electric field to be applied to the electrons in the Monte Carlo simulation. The third part of the experiment involved applying the electric field in part 2 to the simulation in part 1.

Part 1: Monte-Carlo Simulation

a. The electric field is the voltage applied across, divided by the distance. In this part, the width of the material is 0.2μm and the electric field applied was 0.1V. The electric field was calculated as seen E = 0.1/0.2μm = 500,000V/m.
b. The force is the charge times the electric field = q x E = 1.602e-19 * 500000 = 8.01e-14
c. This part was done with code that was submitted on GitHub along with the assignment report. Example calculation:

$$a = F/m$$
$$a = (8.01e\text{-}14)/(9.11e\text{-}31) = 8.79 m/s^2$$

d. The drift current is directly proportional to the average carrier velocity.

$$I = nAvQ$$

Where;

I is current

n is the charge carrier density

A is the cross-sectional area of the conductor

v is the drift velocity

Q is the charge on each particle.

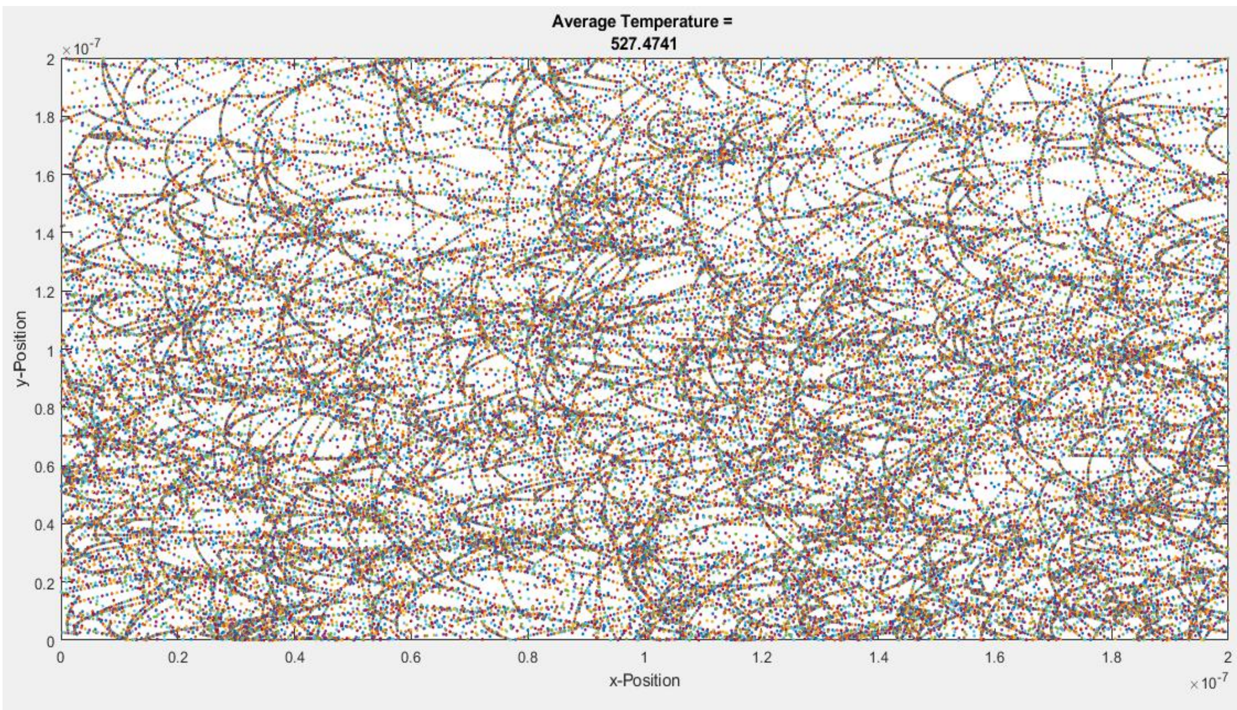

Figure 1: Trajectory Path after 1000 Steps

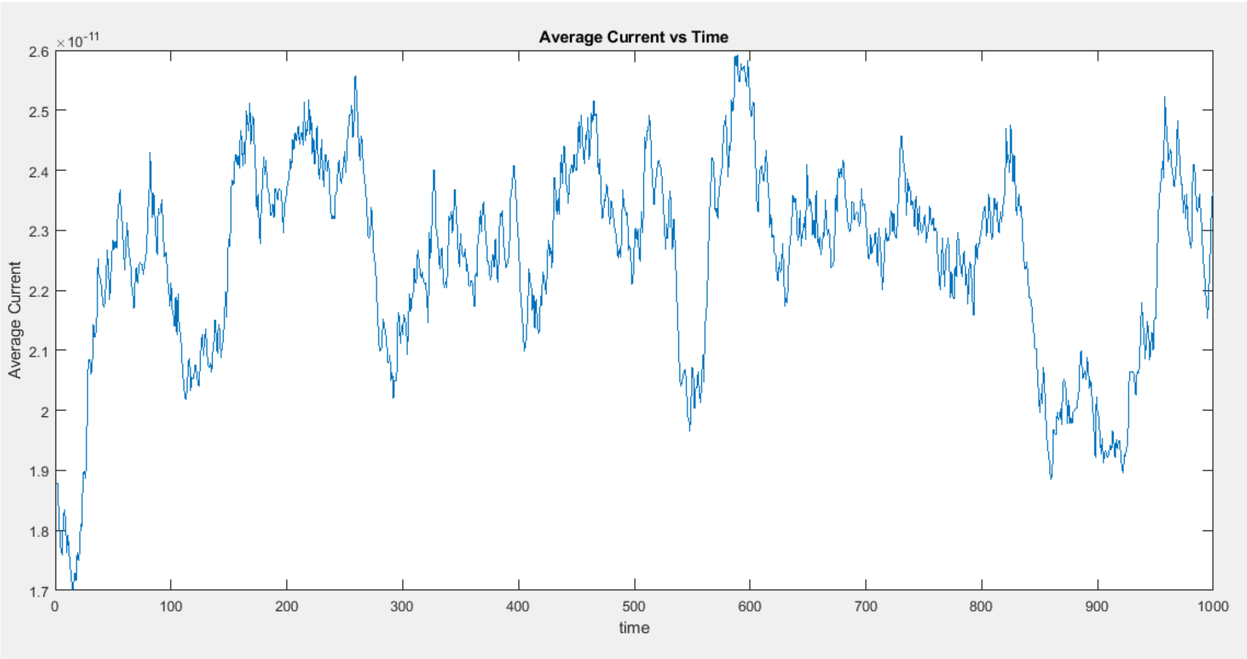

Figure 2: Average Current vs Time

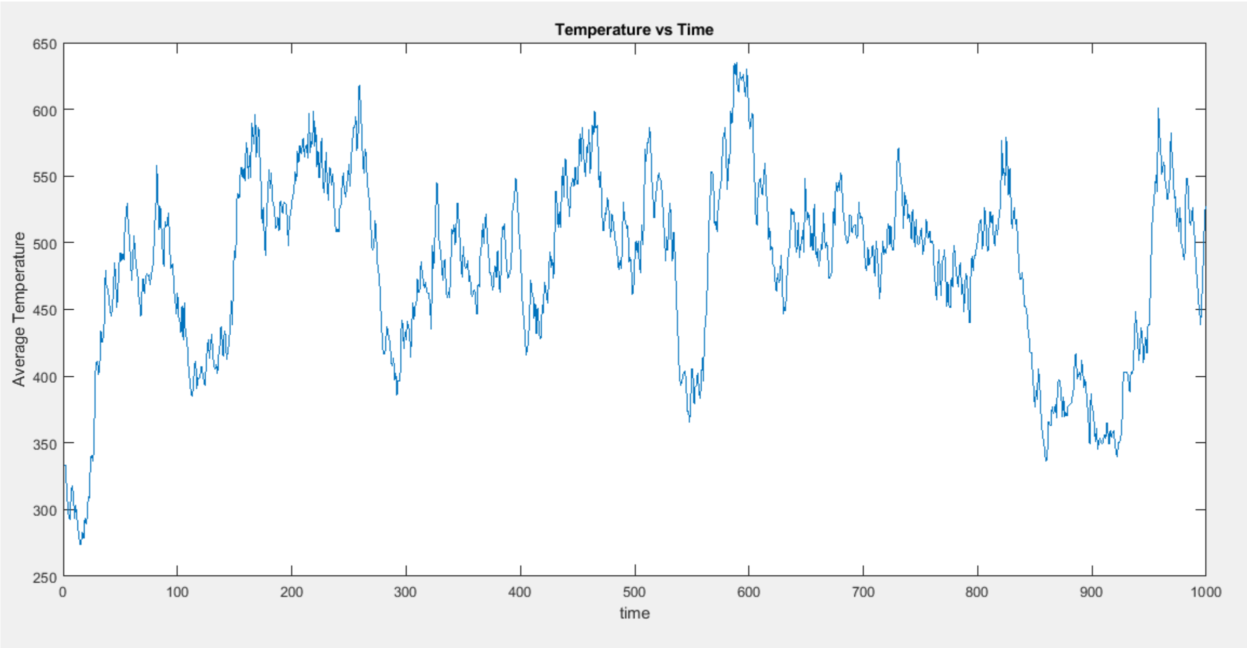

Figure 3: Average Temperature vs Time

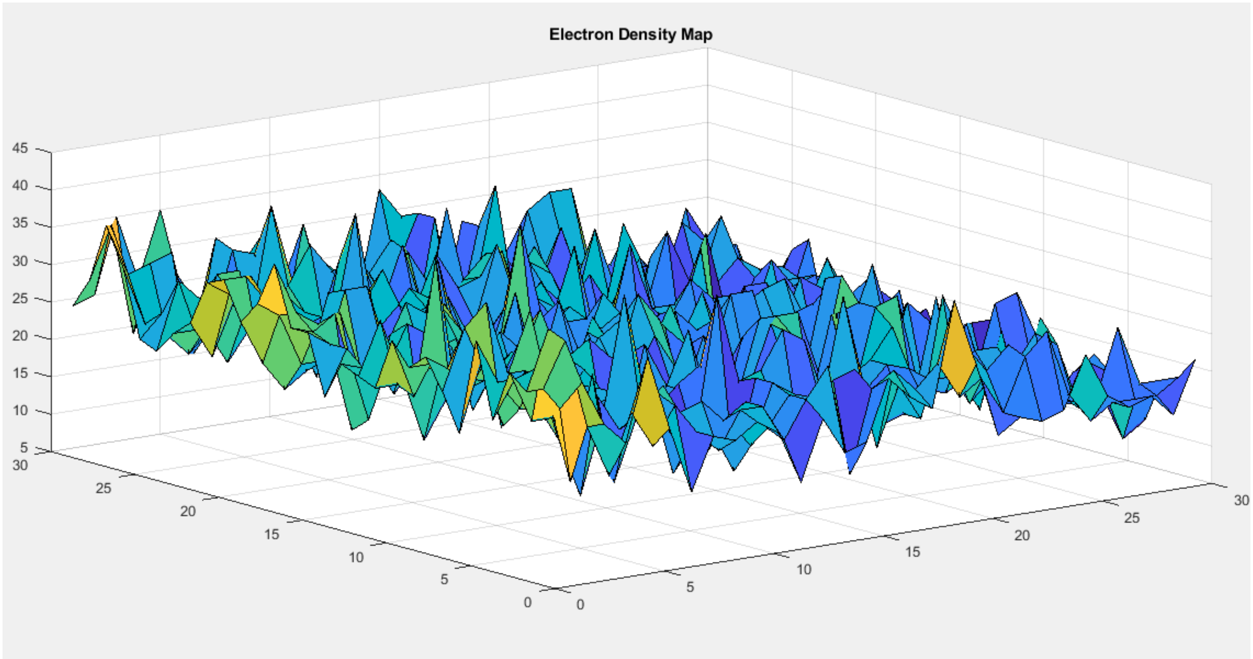

Figure 4: Electron Density Map

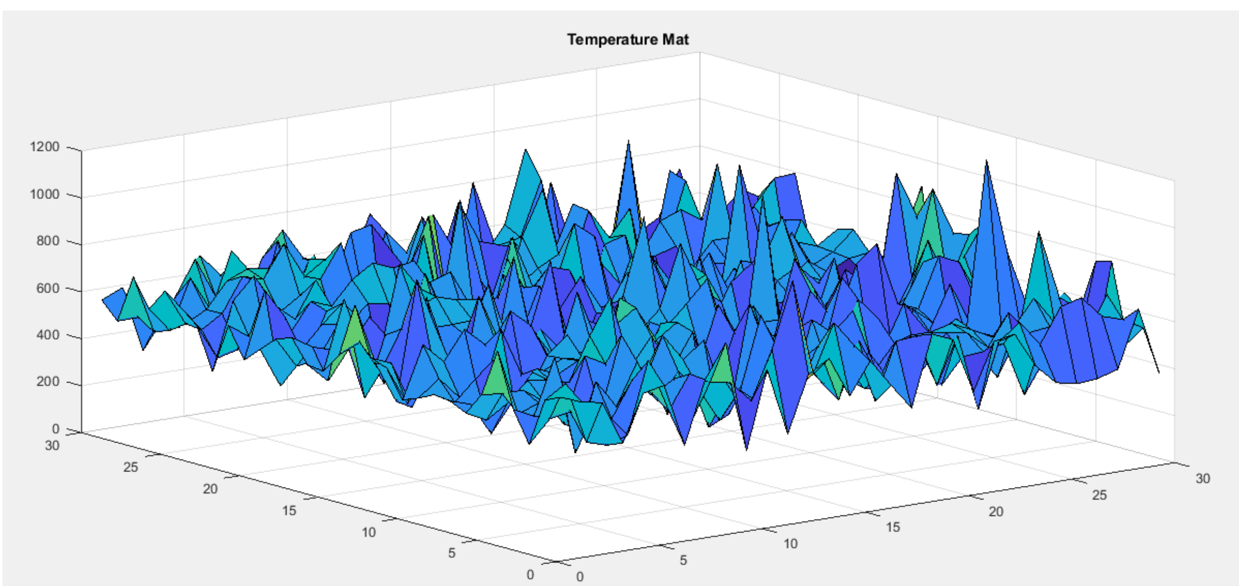

Figure 5: Temperature Map

Part 2: Finite Difference Method

This part involved calculating a voltage and electric field using the finite difference method.

The requested voltage and electric field plots are shown below:

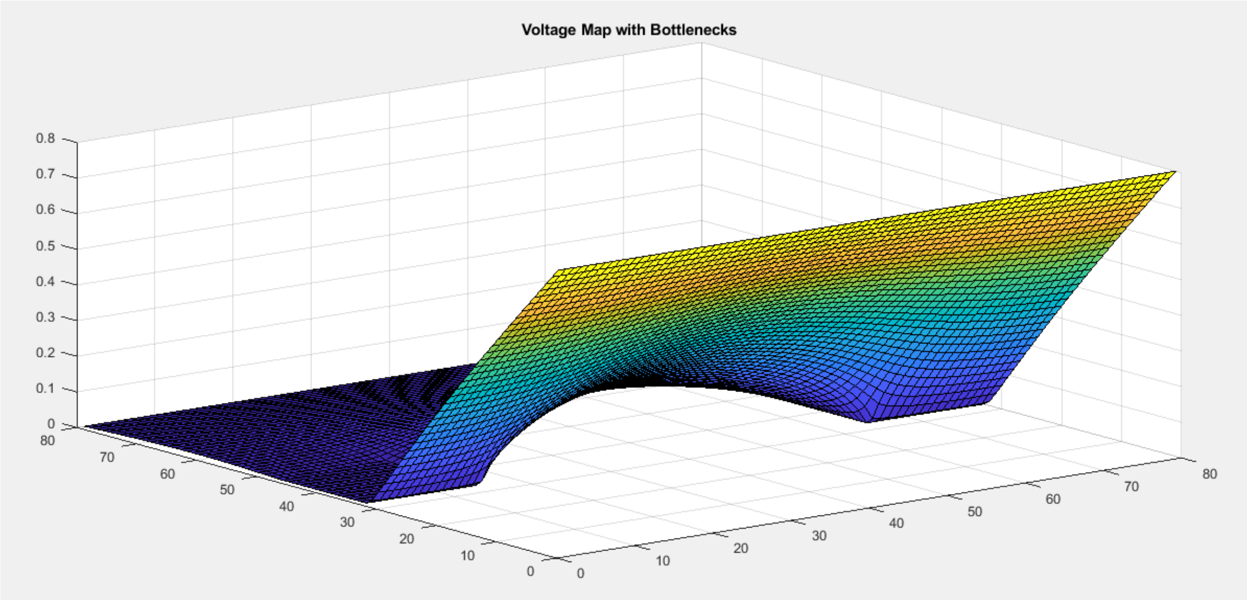

Figure 6: Voltage Surface Plot

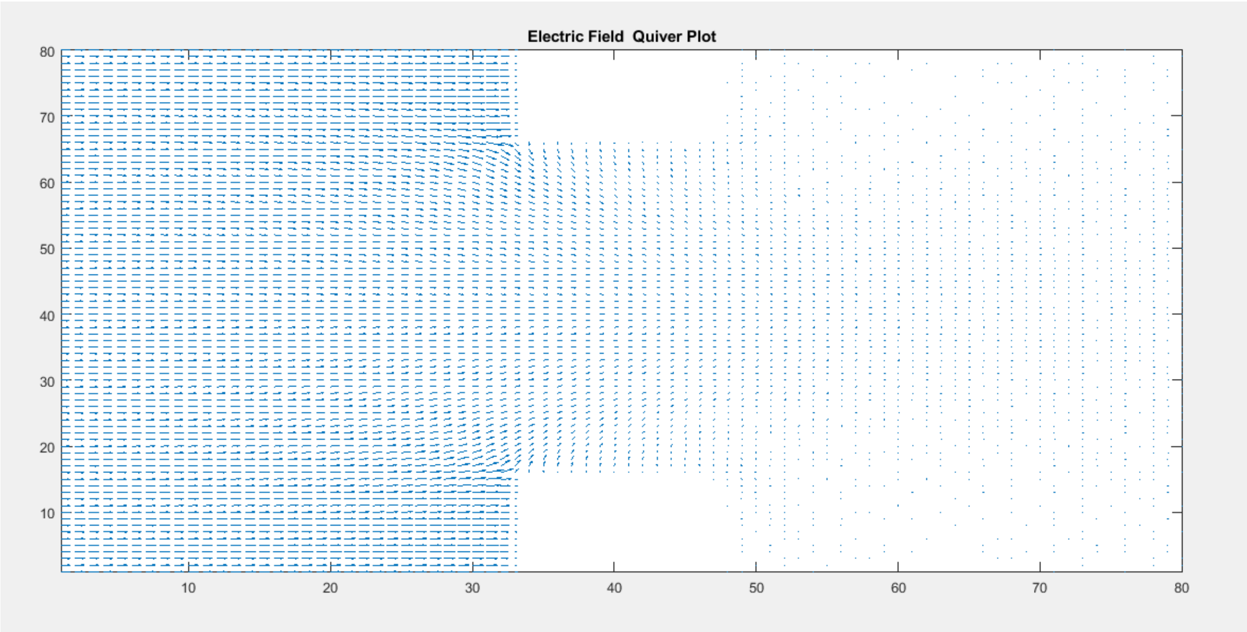

Figure 7: Electric Field Quiver Plot

Part 3: Monte-Carlo Simulation and Finite Difference Method

This part involved combining the simulation in part 1 with the electric field in part 2, with the added enhancement. The 2D plot of the particle trajectories is shown below:

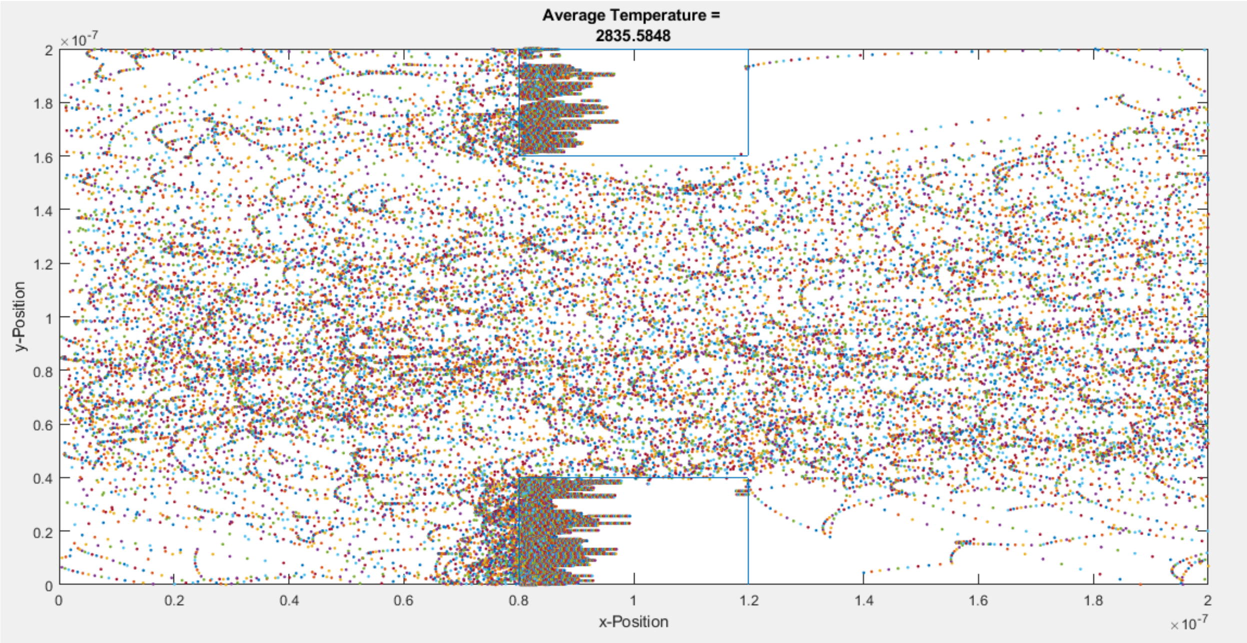

Figure 8: 2D plot after 1000 time steps

The electrons are concentrated on one side of the insulator and cannot escape due to the electric field (x-direction). **Some electrons are leaking into the boxes**.

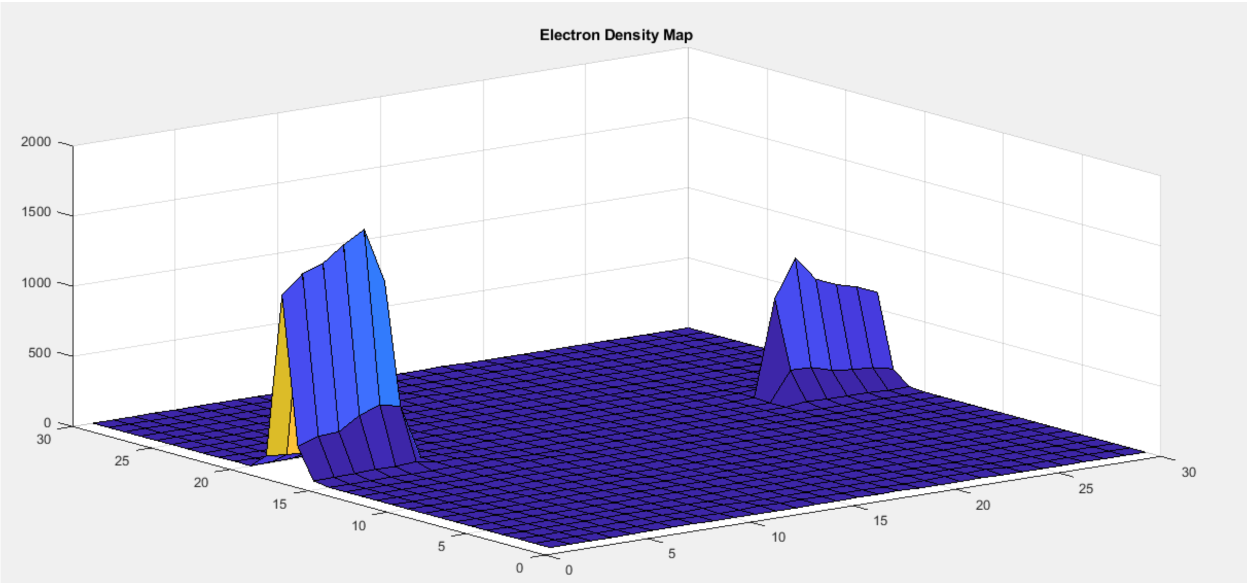

Figure 9: Final Electron Density Map

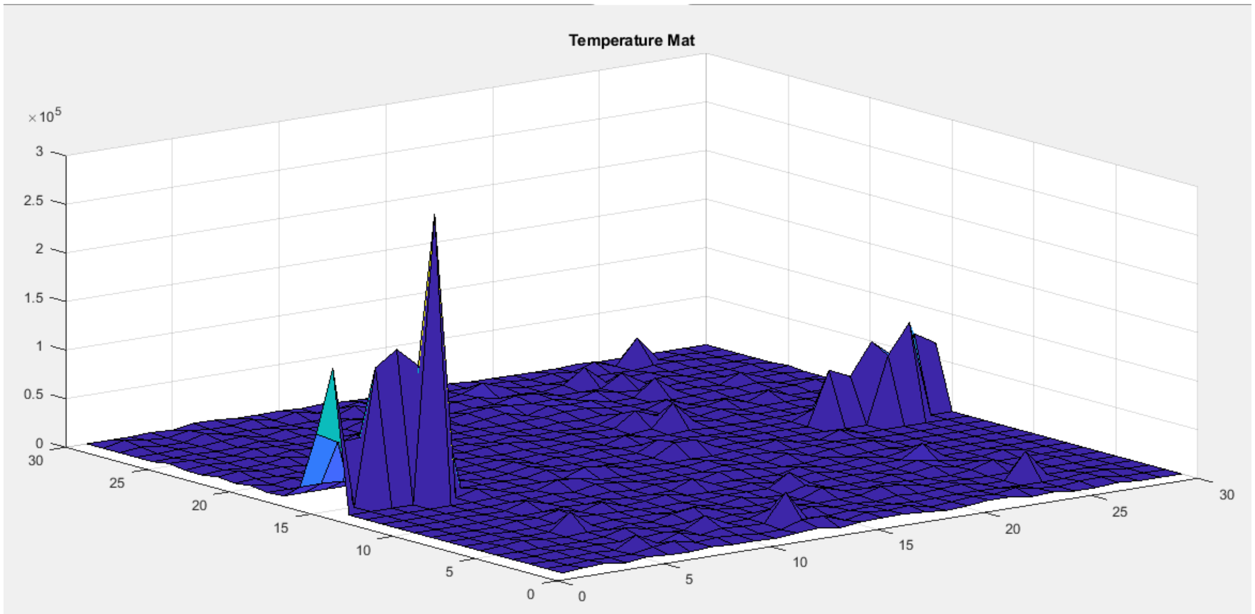

Figure 8: Final Temperature Map

Due to the electric field force, the electrons are bounded to one side of the material. The electric field pushes the electrons them towards the sides of the insulators, and the insulators keep trying to bounce them off. This makes the electrons to get concentrated around that side and causes an increase in collision which leads to the increase in temperature.

Conclusion

The experiment was successful. The first part was successfully modelled with an electric field in the x-direction, causing the particle trajectories to be curved as expected, and boundary conditions were obeyed. The second part of the experiment was also successful, the voltage was successfully modelled, and the electric field was solved for successfully. The third part of the experiment went well, except from some electrons leaking into the insulators.