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```
clear all
close all
clc

cd code
```

Introduction

The purpose of assignment 3 was to combined assignment 1 and and assignment 2 together.The purpose of assignment 1 was to modeling the carriers as a population of electrons in an N-type Si semiconductor crystal. The purpose of assignment 2 was to solve Laplace's equation using finite difference method for electrostatic potential problems.

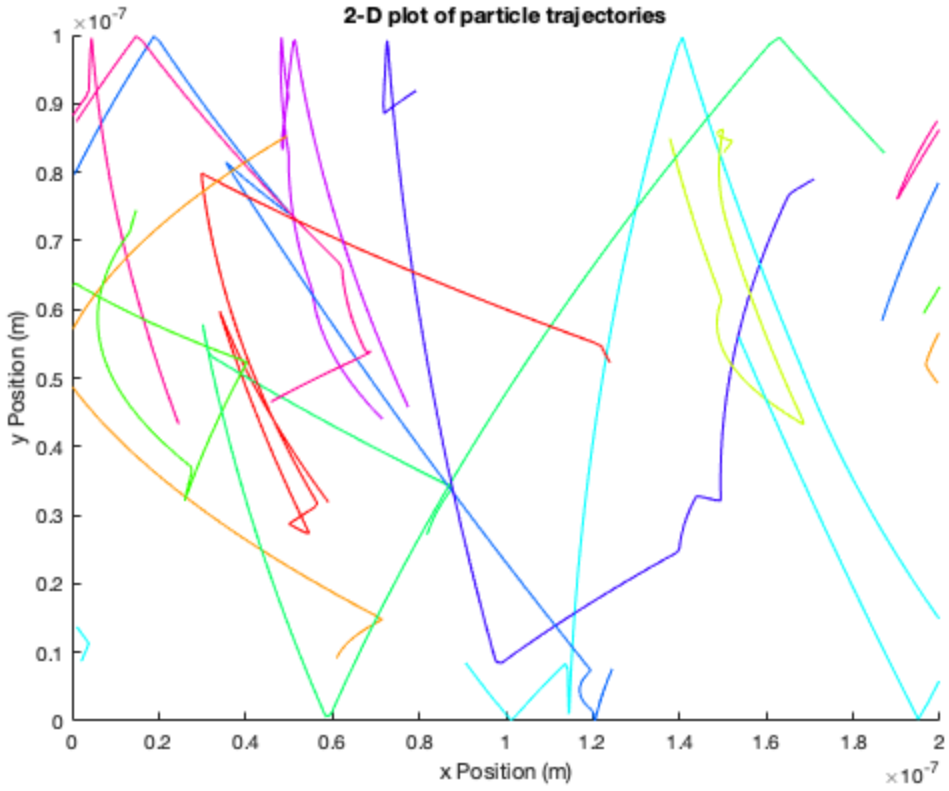
Part 1 Introduction

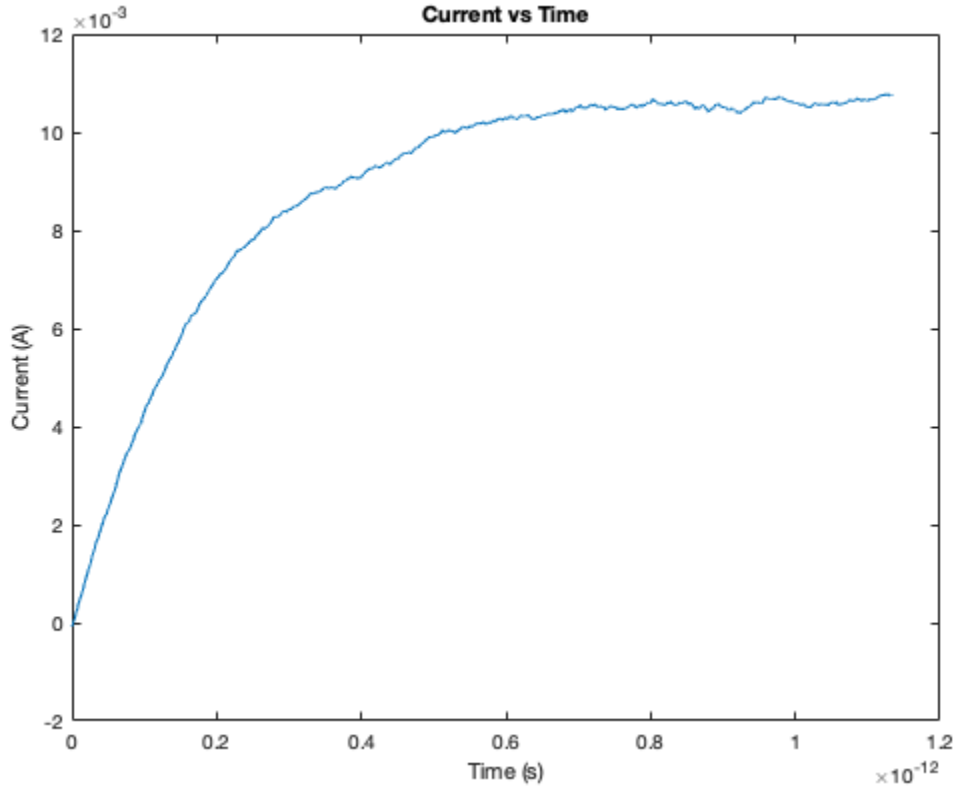
For part 1 of the assignment I started with the Monte-Carlo simulator from Assignment-1 without the bottle-neck. The applied voltage was set to 0.1 volts on the right side and 0 volts on the left side. The first objective was calculating the electric field, force on the electron and acceleration of the electron. The second objective was to create a 2-D plot of particle trajectories. The third objective was to determine the formula for calculating current and to plot current as a function of time. The final objective was to create an electron density and temperature map at the end of the simulation.

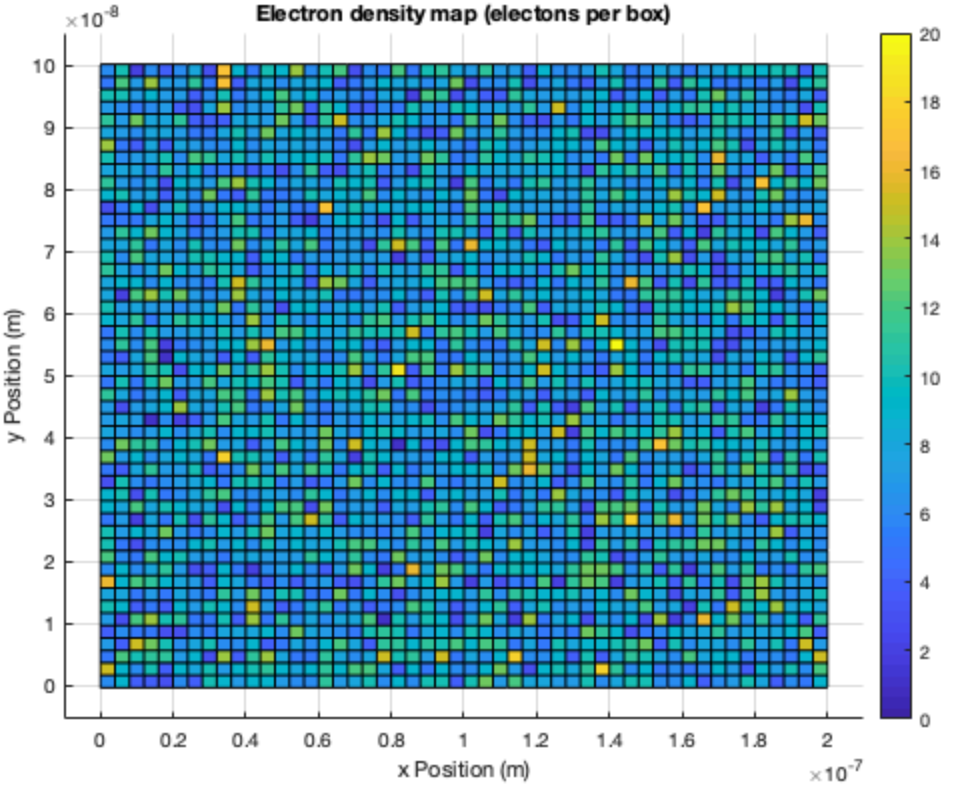
Part 1 Figures and Command Line Outputs

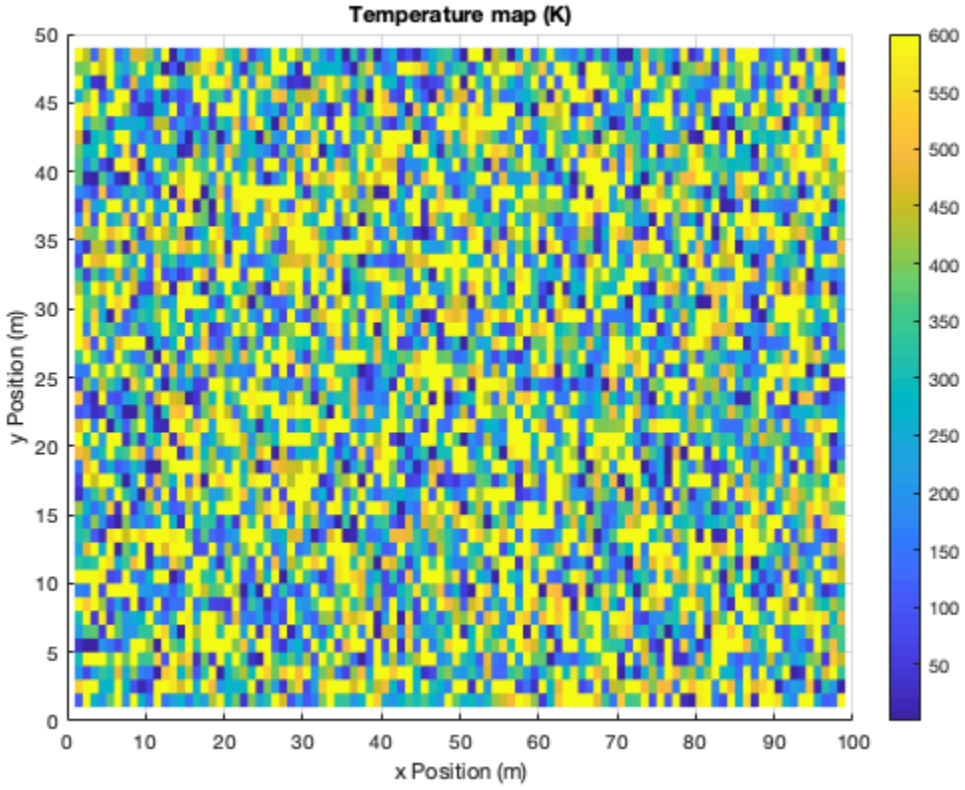
```
cd part_1_final

part1

cd ..
```

```
The electric field strength is 5.000e+05 V/m
The force on a electron is 8.010e-14 N
The acceleration of an electron is 3.382e+17 m/s^2
```


2-D plot of particle trajectories
×10^-7
y Position (m)
x Position (m)
×10^-7


Current vs Time
×10^-3
Current (A)
Time (s)
×10^-12


Electron density map (electons per box)
×10^-8
y Position (m)
x Position (m)
×10^-7


Temperature map (K)
y Position (m)
x Position (m)

Part 1 Conclusion

The results of part 1 are as expected. The electric field strength is 5.000e+05 V/m. The force on a electron is 8.010e-14 N. The acceleration of an electron is 3.382e+17 m/s^2. When looking at the 2-D plot of particle trajectories the particles still act the same way as they did in part 2 of assignment 1 except for the fact that the electrons paths are curved due to the electron acceleration. The formula for determining current is

$$I = \bar{v_x} * n * q * W$$

where $\bar{v_x}$ is the average drift velocity in the x direction, n is the electron density , q is the elementary charge of an electron, and W is the length of the y direction boundary.

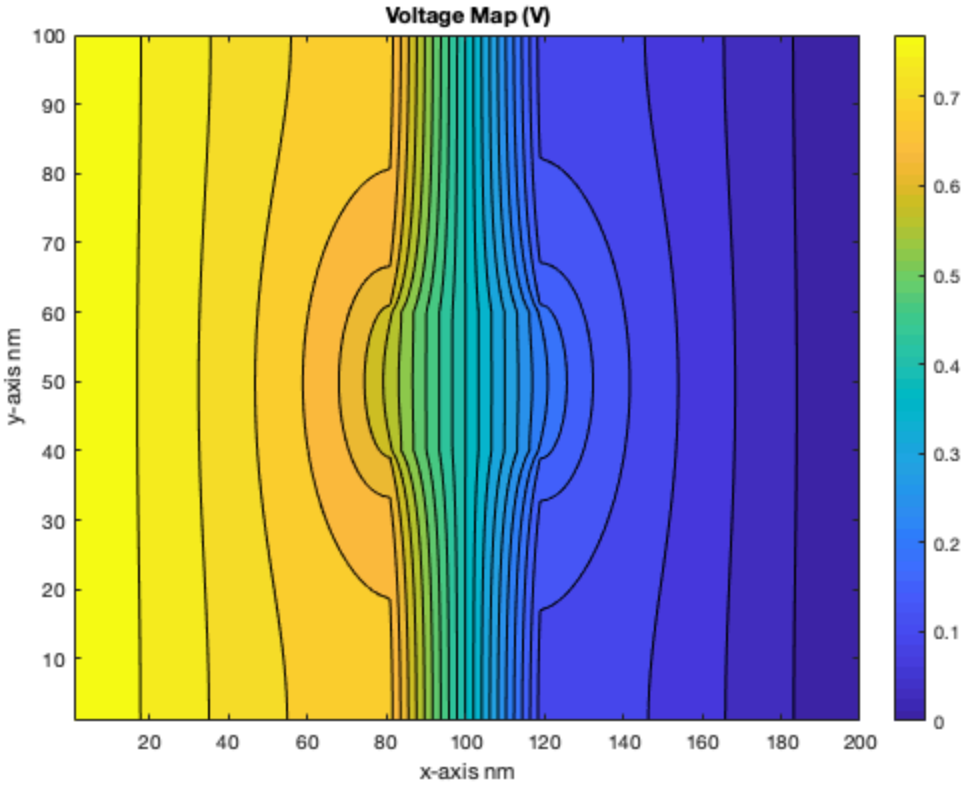
When looking at the current as a function of time the current increases but eventually remains relatively constant at around 0.0106 A. This observation agrees with theory because the electrons continue to accelerate due to the electric field but is eventually limited by scattering. When looking at the electron density and temperature map at the end of the simulation both the electrons and temperature were uniformly distributed. This makes sense given that the forces on the electron do not change depending on the location of the electron.

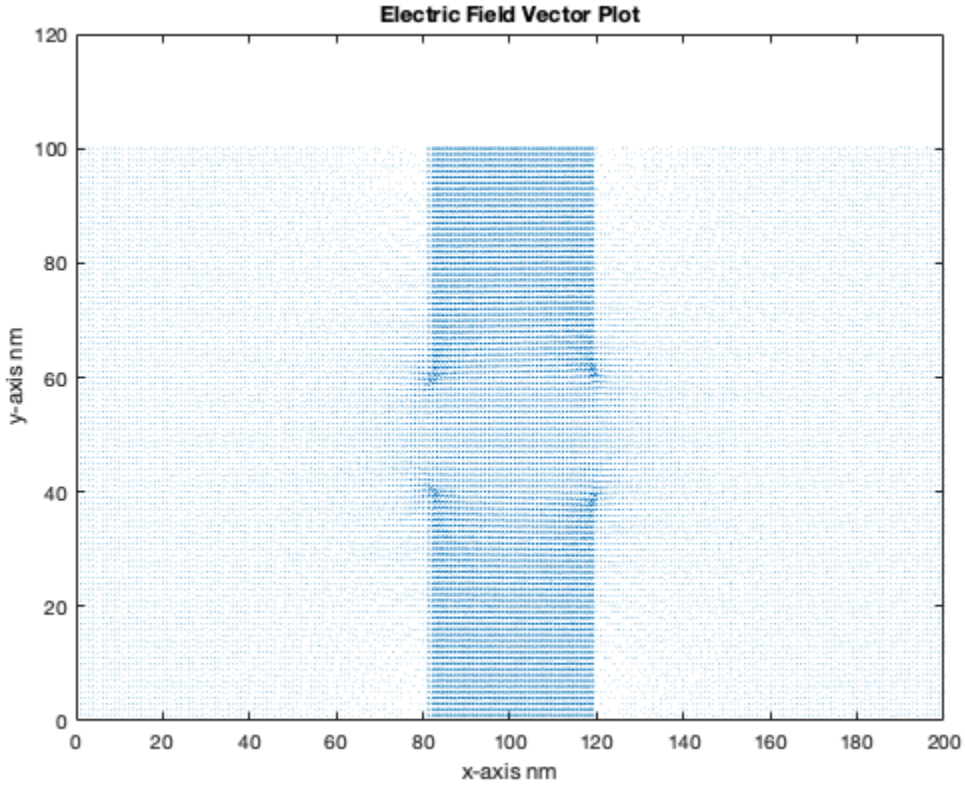
Part 2 Introduction

The objective of part two was to create a model where V = 0.8 Volt at x=0 and V = 0 volts at x = 200 nm. The top and bottom boundary conditions where set so that dV/dy = 0. Two boxed areas where also added with low conductivity which created a bottleneck. A voltage map was than solved for using finite difference method and using the voltage map an electric field vector plot was created.

Part 2 Figures and Command Line Outputs

```
cd part_2_final

part2

cd ..
```


Voltage Map (V)
y-axis nm
x-axis nm
100
90
80
70
60
50
40
30
20
10
20
40
60
80
100
120
140
160
180
200
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Electric Field Vector Plot
y-axis nm
x-axis nm
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200

Part 2 Conclusion

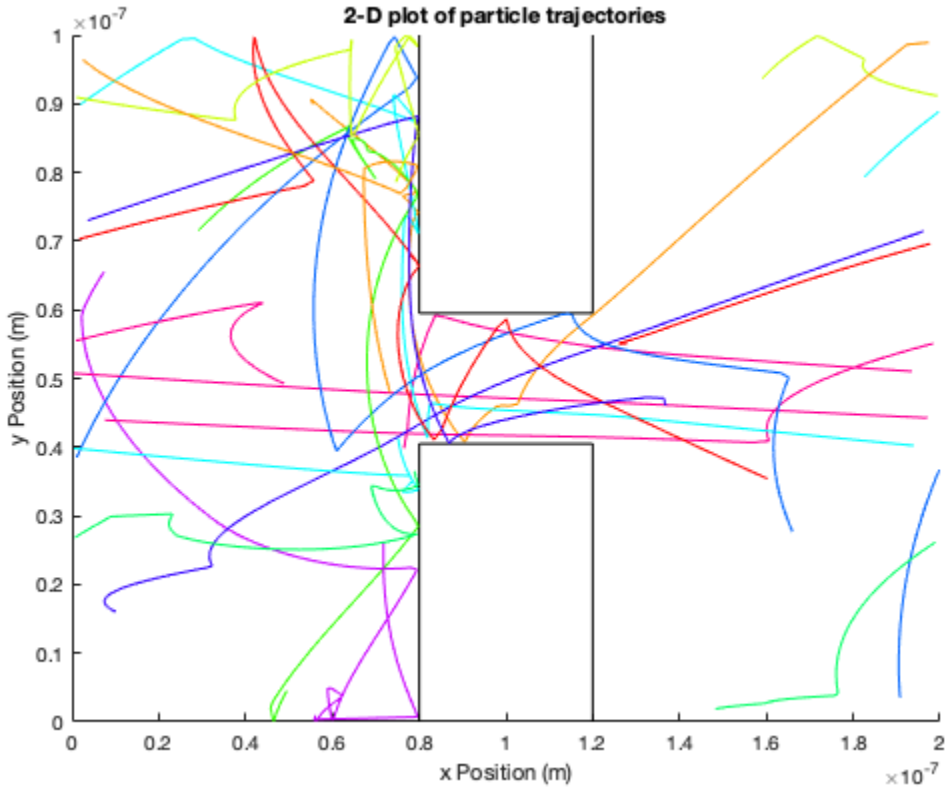
The results of part two are as expected. The voltage map relating to the first objective changed quickly near the barrier and satisfied the boundary conditions. The voltage changing quickly near the barrier makes sense given the resistance is large near the barrier and ohms law states that the voltage drop is proportional to resistance. The electric field in general points from left to right and are strongest at the barrier corners. The electric field is also strong within the barrier. This result agrees with theory as areas with high resistance and constant current have relatively large electric field strengths.

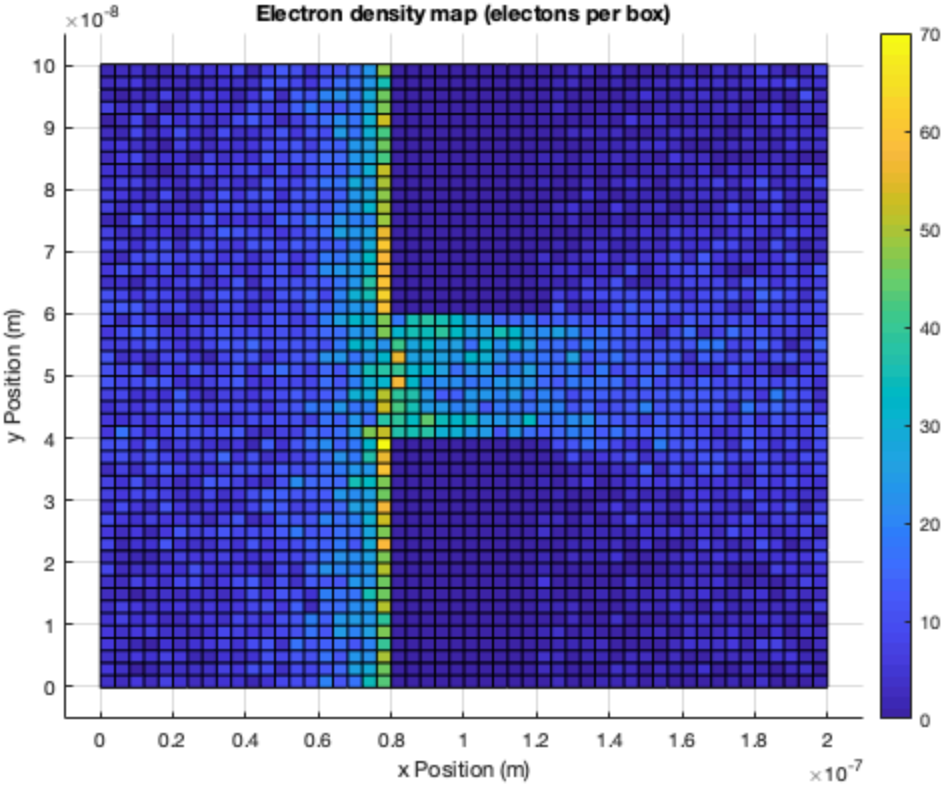
Part 3 Introduction

The objective of part three was to use the electric field calculated for the bottle neck in part 2 as input to the Monte Carlo simulation in part 1. Once part 1 and part 2 were working properly together two figures where created. The first figure was a 2-D plot of particle trajectories. The next plot was an electron density map for the final electron positions.

Part 3 Figures and Command Line Outputs

```
cd part_3_final

part3

cd ..
```





Part 3 Conclusion

The results of part 3 where as expected. When looking at the 2-D plot of particle trajectories the particles bounce off the boxes correctly and the electrons paths are curved due to the electron accelerating in the electric field. When looking at the electron density map for the final electron positions you can see a build up of electrons on the left side of the barrier. This observation agrees with theory because the electrons are accelerated towards the barrier but can not enter the barrier so they build up. One future step to make this simulation more accurate is by adding more electrons and increasing the mesh size when calculating the voltage map. Another future step to make this simulation more accurate is including the effect of other electrons in the simulation due to that fact that they are charge carriers.

Conclusion

Overall Assignment 3 was a success. I was able to complete every objective and my results matched my expectation.

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