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clc;
clear;
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Assignment 3 ELEC 4700 Monte-Carlo/Finite Difference Method

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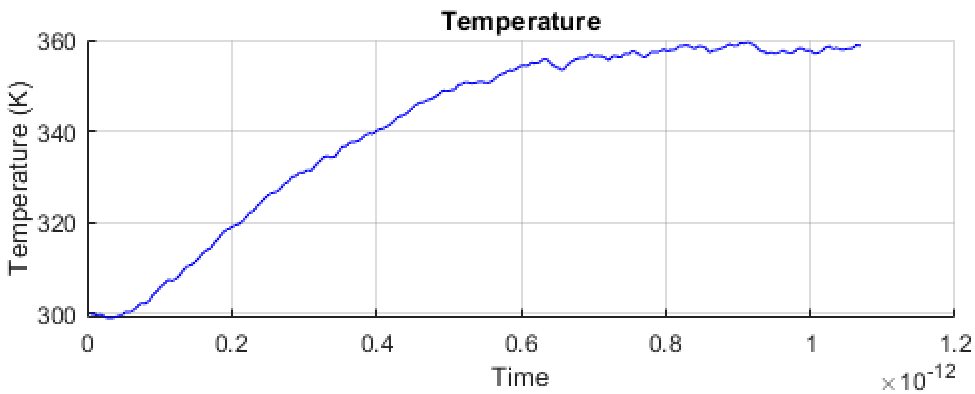
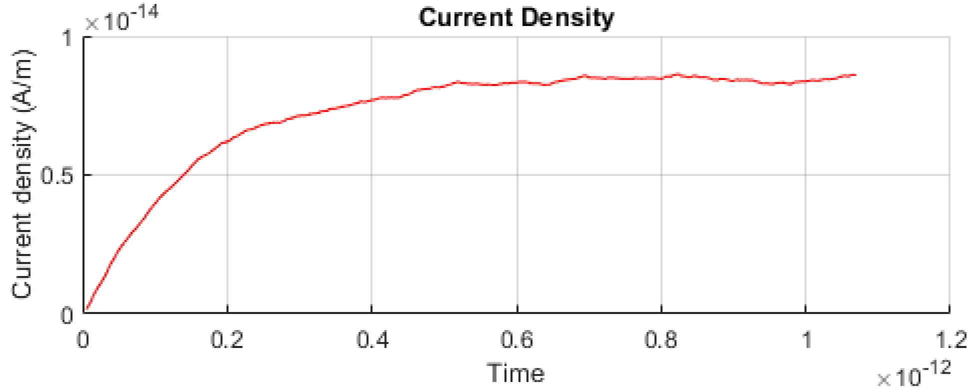
This assignment combines the finite difference and monte carlo methods to simulate a silicon wafer under the influence of an electric field and with bottle-necks. As shown in both parts 1 and 3 there is no force on the particles in the Y direction. This is because there is no potential in the Y-direction. Therefore in this direction the particles rely solely on scattering to influence there behaviour. However in the X direction we see that the particles are influenced by both scattering and the magnitude of the electric field across the semi-conductor. The force on each electron is extremely small, this is to be expected as the electric field we are applying is quite small and therefore should not cause a major force on the particles in question. The current reaches a steady state at around 10^-12 seconds.

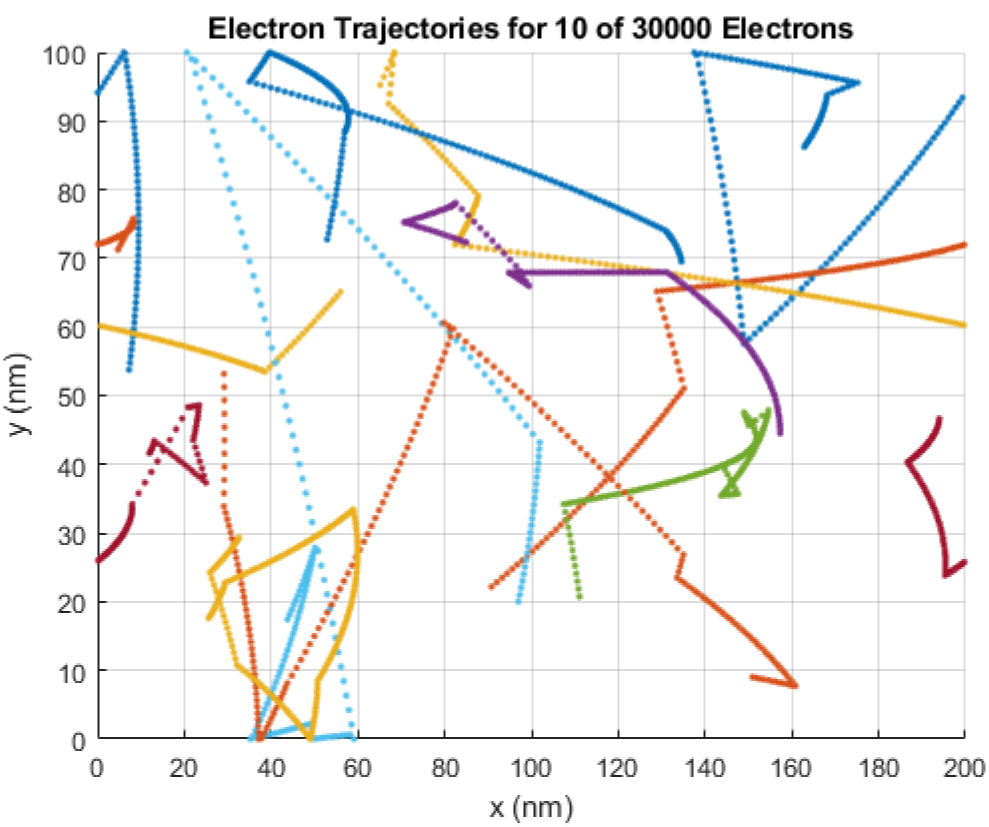
Part 1

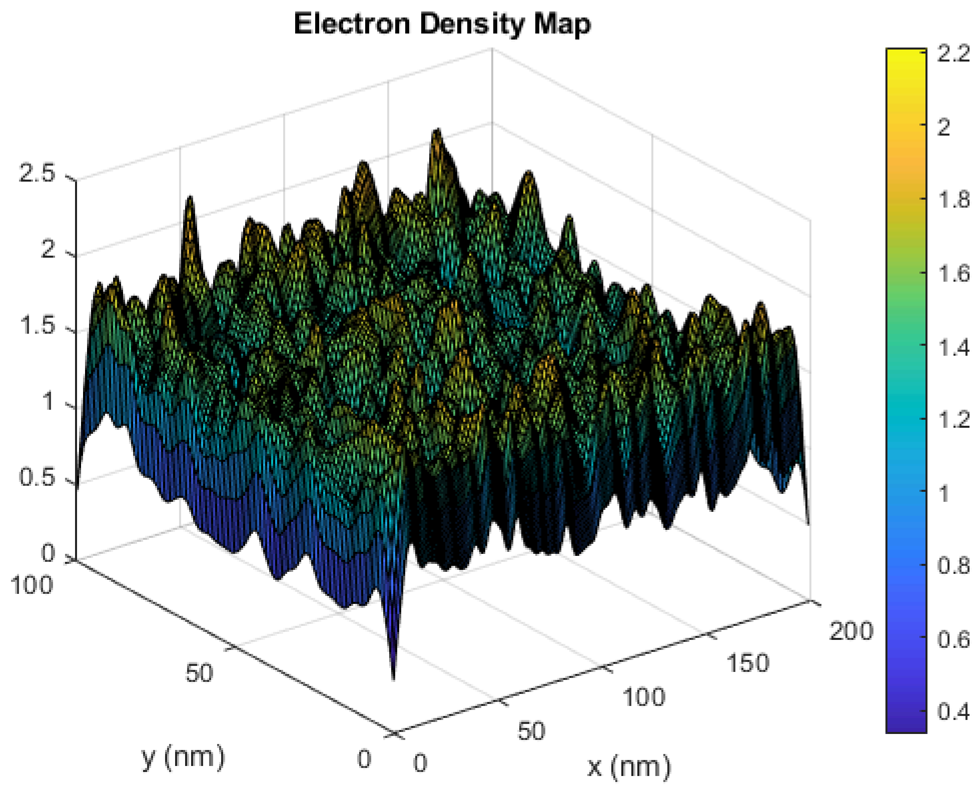
```
Assignment3_Part1;
```

```
Electric Field experienced in the X direction Part 1 0.500000 MV/m
Force experienced in the X direction Part 1 -80.108831 fN
Average Electron Velocities in Silicon Crystal for part 1 are
 204.509392 km/s
Average time for part 1 is 32.082280 ns
Mean free Path for part 1 is 6.561128 mm
```


Temperature
Temperature (K)
360
340
320
300
0
0.2
0.4
0.6
0.8
1
1.2
Time
×10^-12


Current Density
×10^-14
Current density (A/m)
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1.2
Time
×10^-12


Electron Trajectories for 10 of 30000 Electrons
y (nm)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
x (nm)


Electron Density Map
2.5
2
1.5
1
0.5
0
100
50
0
y (nm)
0
50
100
150
200
x (nm)
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4

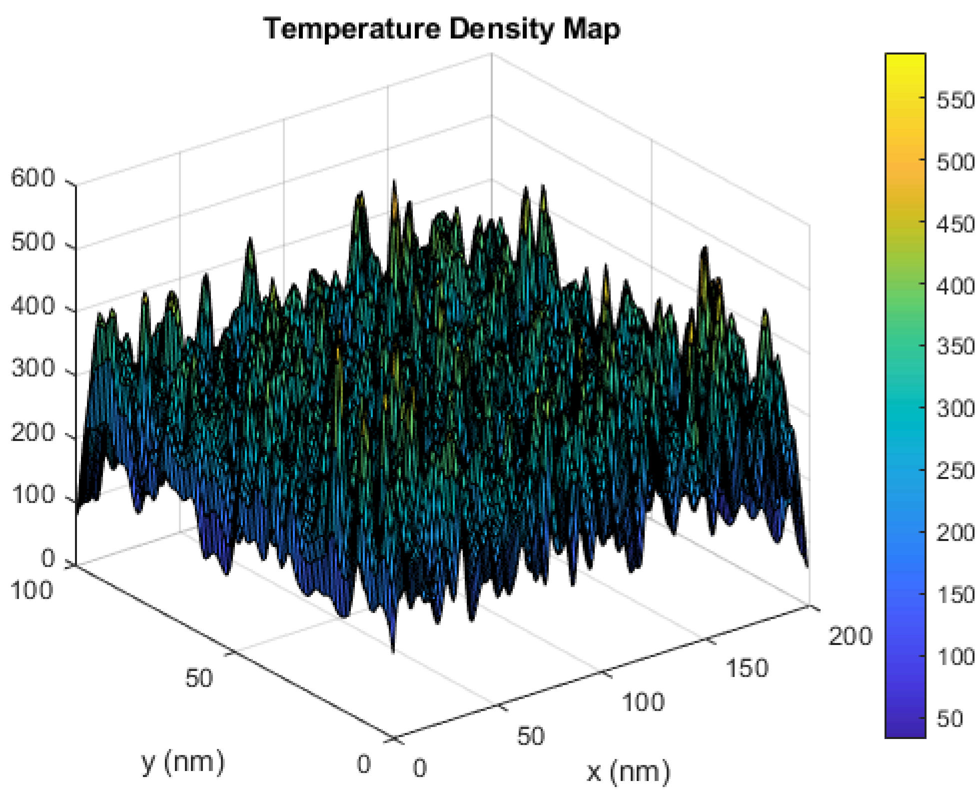
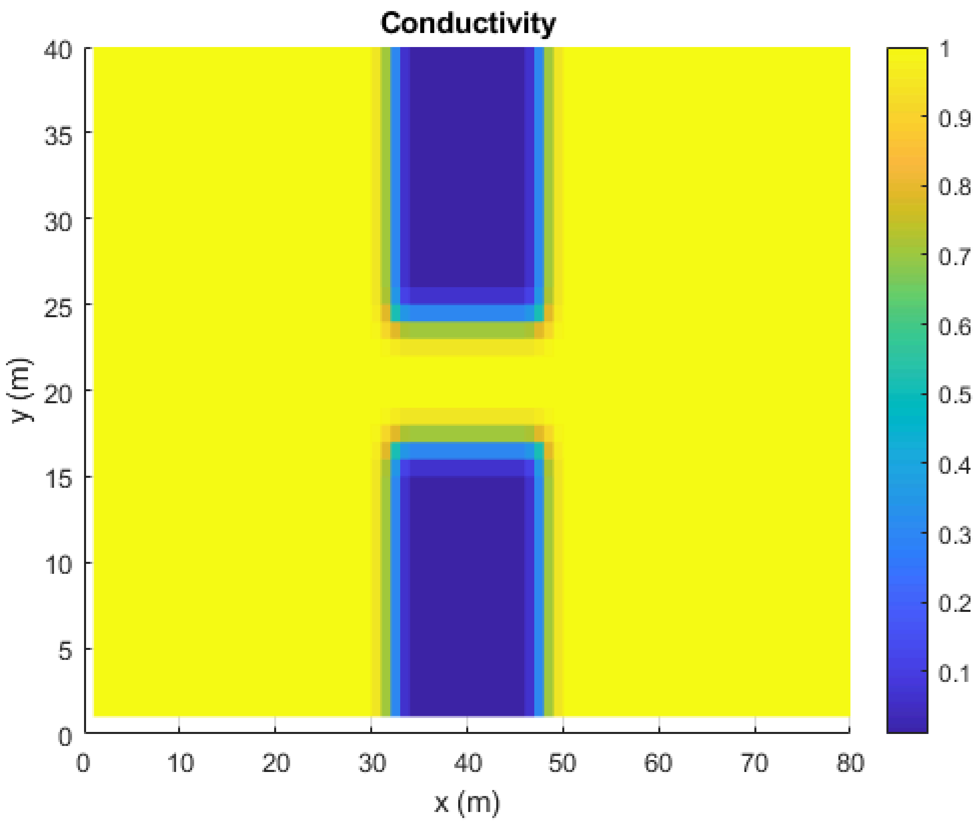
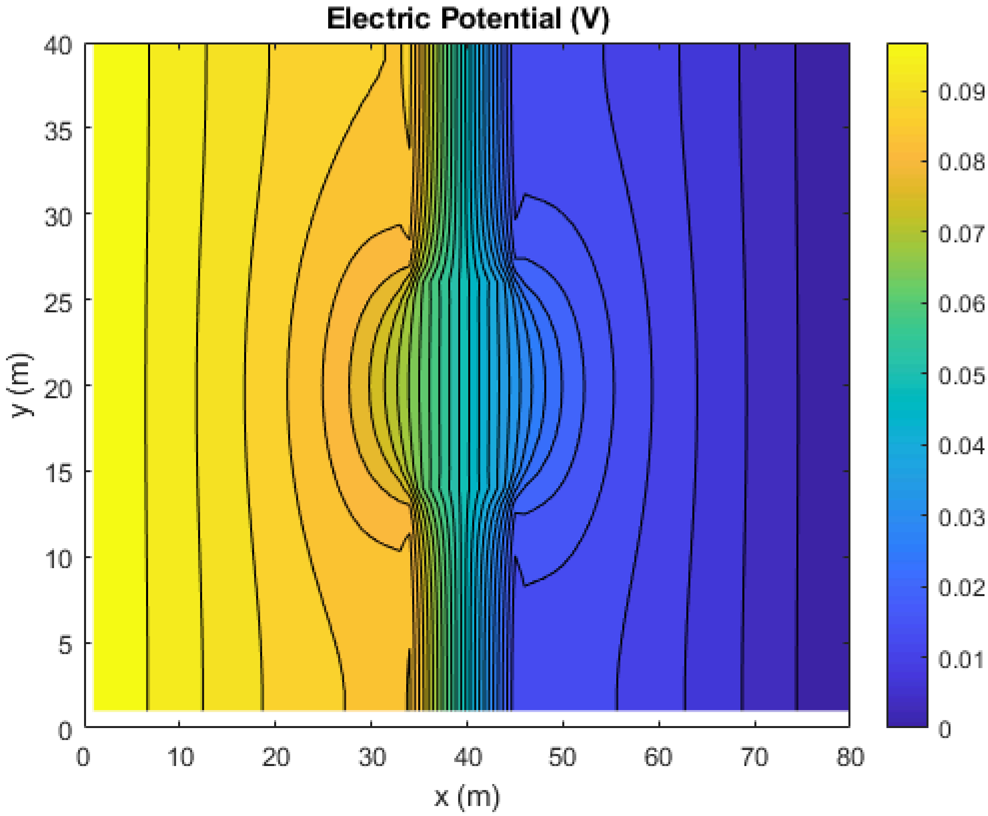

Temperature Density Map
600
500
400
300
200
100
0
100
50
0
y (nm)
0
50
100
150
200
x (nm)
550
500
450
400
350
300
250
200
150
100
50

Figure 1 shows the trajectories of a couple of particles in the particle population that were plotted for the number of time steps specified. The particles are being shifted towards the right and that is because there is a voltage applied to the left hand side of the semiconductor. This is creating an electric field that is forcing the particle to the right. Figure 2 shows the semiconductor temperature and the drift current of that semi-conductor over the total time for our simulation. Temperature and drift current varry until they reach a steady state around 1x10^-12 seconds. Figure 3 plots the electron density with no bottle neck present in the simulation, Figure 4 plots the temperature density map showing the temperatures at various locations on the silicon crystal.

Part 2

```
Assignment3_Part2;
```




Electric Potential (V)
y (m)
x (m)
0
10
20
30
40
50
60
70
80
5
15
25
35
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01

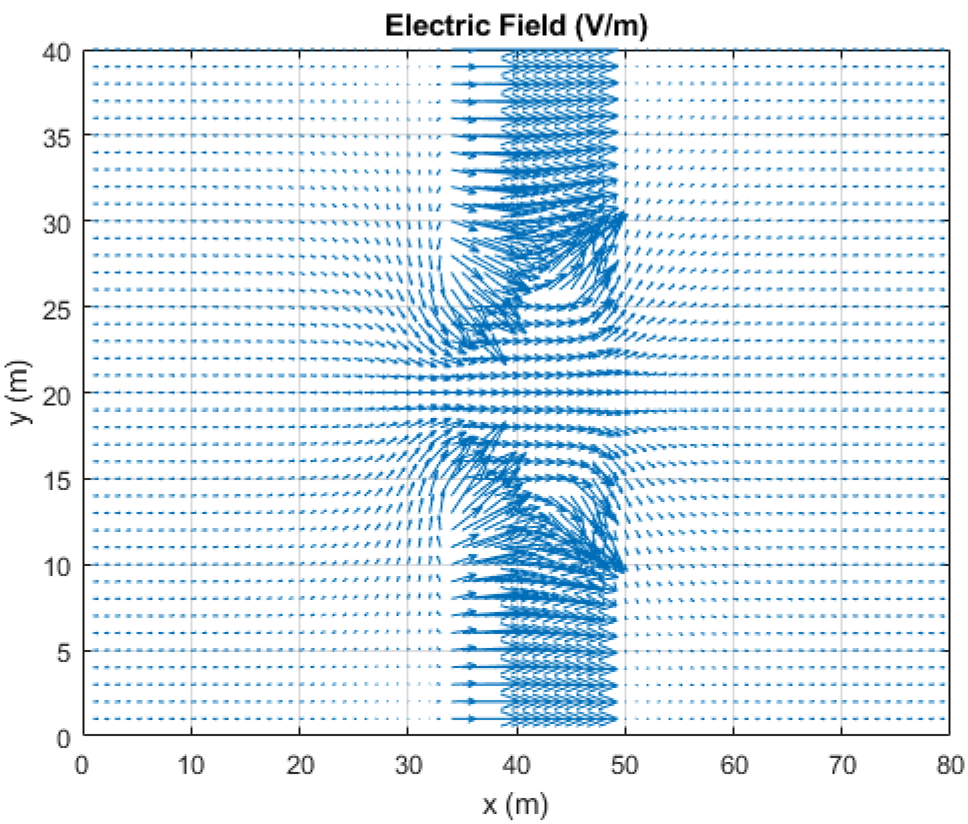
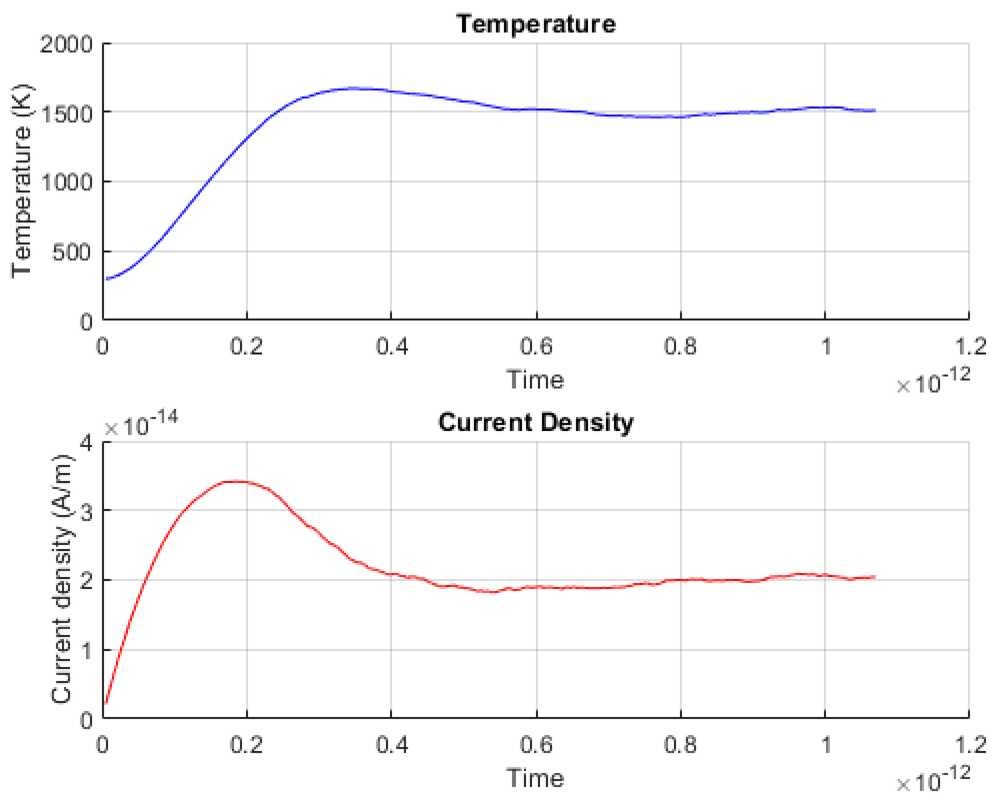

Electric Field (V/m)
y (m)
x (m)
0
10
20
30
40
50
60
70
80
5
15
25
35

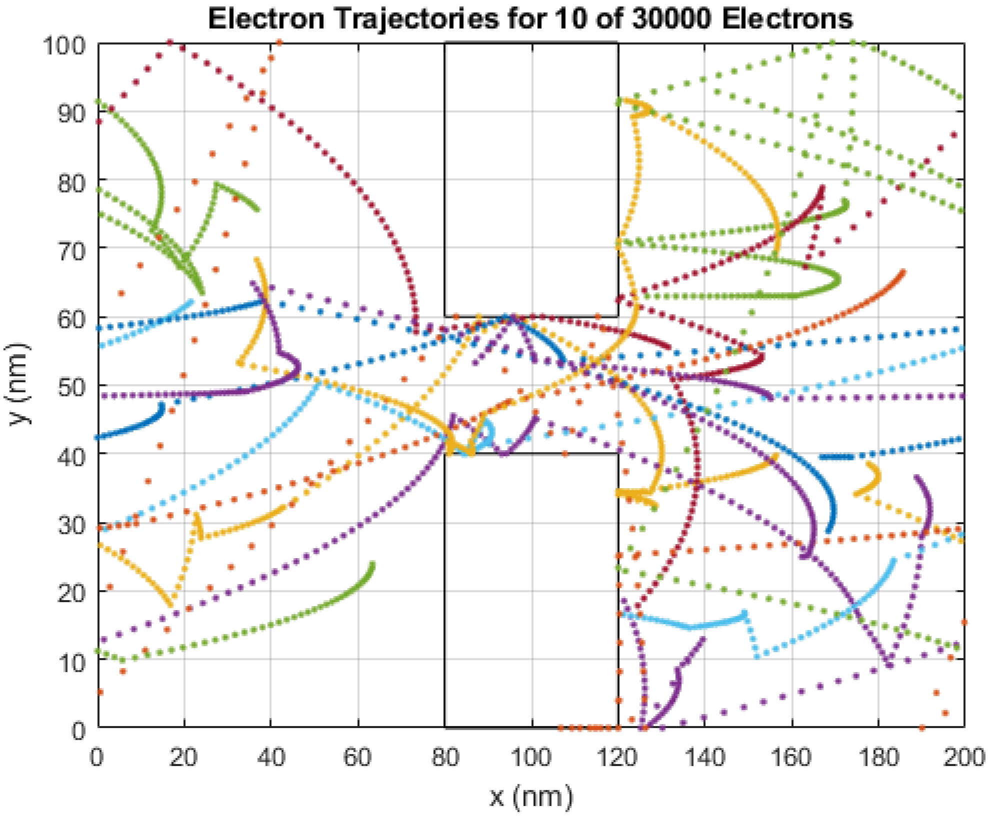
Figure 5 shows the conductivity map of the mesh grid with bottle-necks as in assignment 2. Figure 6 shows the potential voltage over the contour of the silicon crystal.The potential is highest around the boxes as there is very high resistance/low conductivity. Therefore according to ohm's law this region should have the highest potential. Figure 7 is showing the electric field of the mesh grid when a potential of 0.1V is applied to the left side of the silicon wafer. All the electric field lines point away from the higher potential and therefore all the electrons that experience this path will be forced to the right due to the magnitude of the electric field.

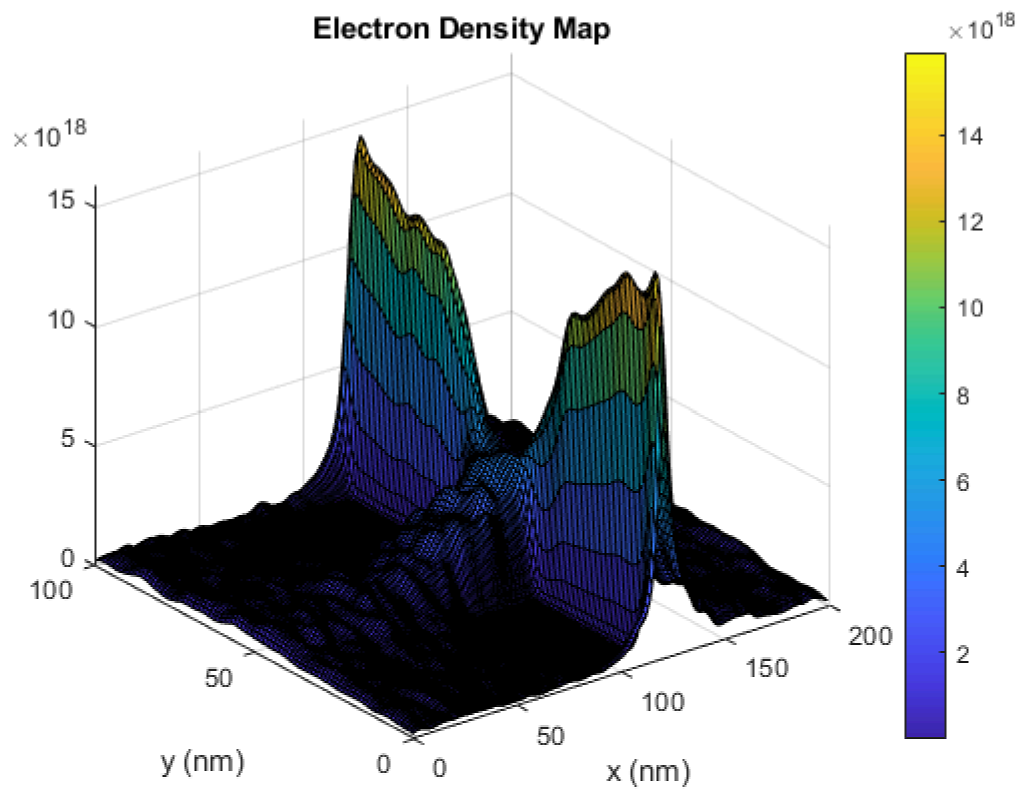
Part 3

```
Assignment3_Part3;
```

```
Electric Field experienced in the X direction Part 3 4.000000 MV/m
Force experienced in the X direction Part 3 -640.870648 fN
Average Electron Velocities in Silicon Crystal for part 3 are
 419.855775 km/s
Average time for part 3 is 32.082280 ns
Mean free Path for part 3 is 13.469931 mm
```




Electron Trajectories for 10 of 30000 Electrons
y (nm)
x (nm)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200


Electron Density Map
$\times 10^{18}$
0
5
10
15
y (nm)
100
50
0
x (nm)
0
50
100
150
200
$\times 10^{18}$
2
4
6
8
10
12
14

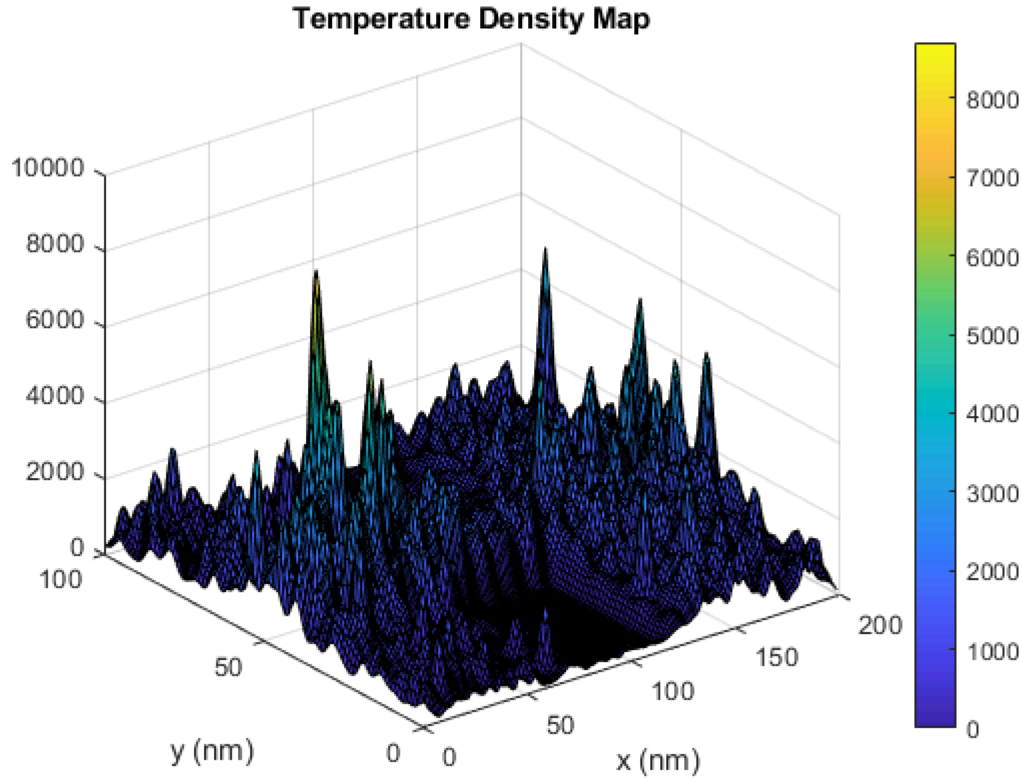


Figure 8 is showing the trajectories for 10 of 30000 particles in the simulation with the bottle neck box included. Figure 9 models the drift current vs time and the temperature of the semi-conductor over the same time frame. Figure 10 shown above is showing the density of electrons in the mesh grid. These electrons are bunching up due to the electric field acting on them and the fact that the boxes are acting as a bottle neck. Figure 11 shows the bottle neck vs temperature in the silicon crystal.

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