Assignment 3

ELEC 4700

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1 a) When a 0.1V Voltage is applied the x dimension of the semiconductor, the electric field on the electrons is -5.0000e+05 V/m.

1 b) The force on each electron is 8.0100e-14 N.

1 c) The acceleration on the electrons is 3.3820e+17 m/s^2.

In order to include the acceleration in the velocities to curve the trajectories, the following equations were used:

For Position:

```
X = X + dt*Vx + 1/2*(accx*(dt^2)) ;
```

This line of code made sure that the new position of the particles were being changed by the previous position with an addition of velocity changing with a time step, as well as half the acceleration and a squared time step.

For the velocities:

```
Vx = Vx + accx*dt;
Vy = Vy + accy*dt;
```

These lines of code made sure that the velocity was updated with the acceleration in x and y. In this case, the acceleration in y is 0 since the electric field was only found in the x direction of the semiconductor.

The following figure, Figure 1 is showing the curved trajectories.

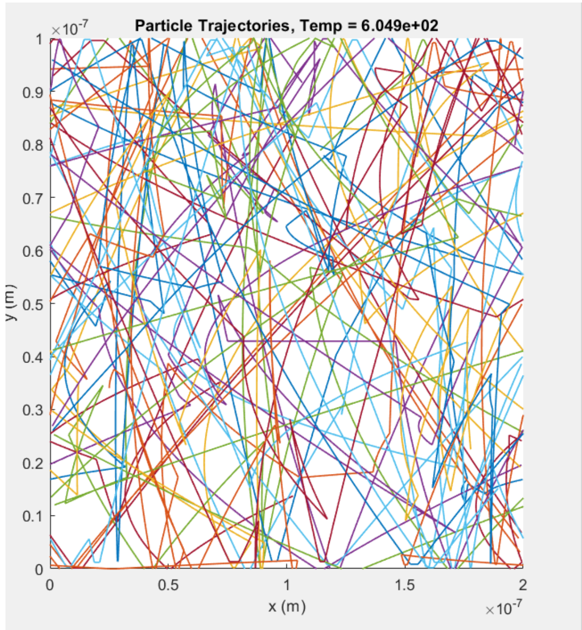

Figure 1: Curved Trajectories

d) The next figure is displaying the Electron Drift Current. This was found by finding how many electrons after travelling left and how many are travelling right. From there, the difference was found over the time step. Then the current was calculated. This plot can be seen in Figure 2. First, the current is zero since the electrons are just beginning to move around. As electrons move and change current and increase acceleration due to the electric field, the drift current rises (in this case in the negative direction). Then over time, the current saturates around 2.25 A.

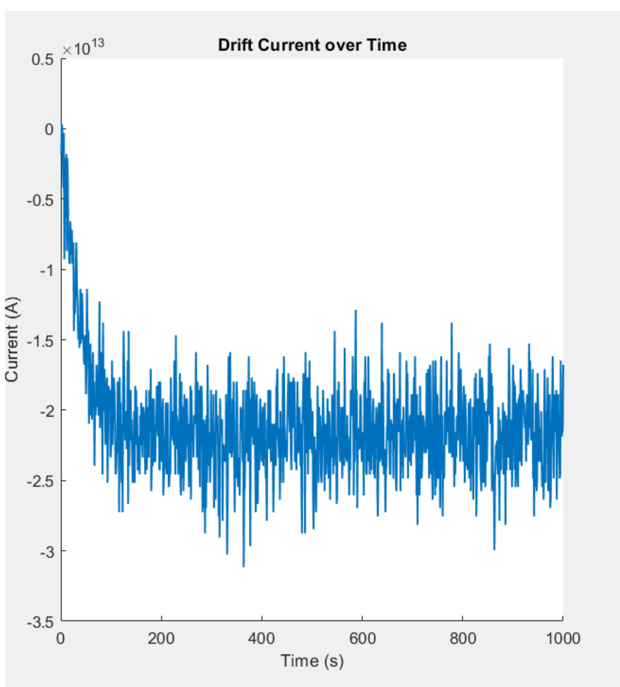

Figure 2: Drift Current vs Time

e) The following figures are the electron density map as well as the temperature map.

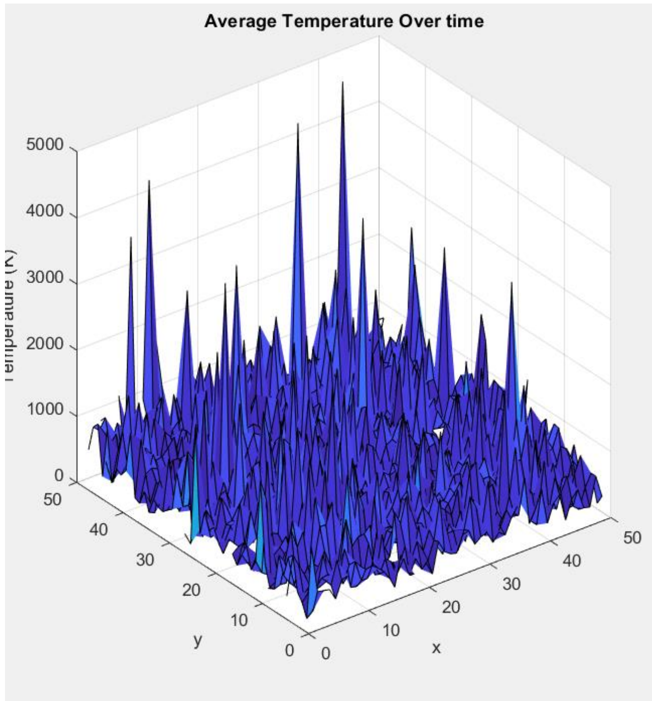

Figure 3: Electron Density Map

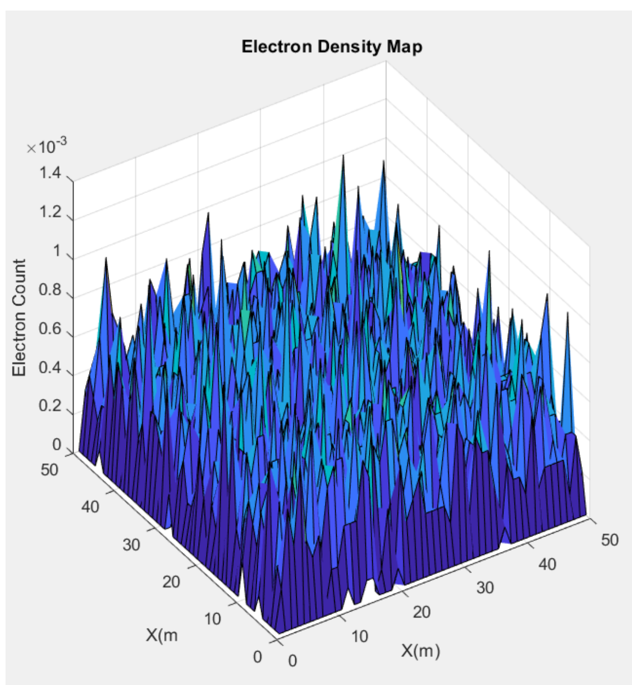

Figure 4: Temperature Map

2 a) In order to do this question, the bottle neck question from assignment 2 was used. From there, gradient was used to find the Electric field in the X and Y direction, as seen below:

```
dx = Length/nx;
[Ey, Ex] = gradient(V);
Ey = Ey/dx;
Ex = Ex/dx;
```

From there, the particles were mapped to each mesh area in the field. In this case, nx = 30 and ny = 20 was fit to the actual length and width of the area. Then the electron mapping took place. This was done using interp2 as well as meshgrid as seen below:

```
lx = linspace(0,Length,nx);
ly = linspace(0,W,ny);

[LX,LY]= meshgrid(lx,ly);

Ex_p= interp2(LX,LY,Ex.',Xp, Yp);
Ey_p= interp2(LX,LY,Ey.',Xp, Yp);
Ex_p(isnan(Ex_p)) = 0;
Ey_p(isnan(Ey_p)) = 0;
```

From there, the force, acceleration, velocities, and positions were changed due to Ex and Ey. And then to finish the question, the bottleneck was added in. Below in Figure 5 to Figure 7, we can see the Potential with the bottle neck, the Electric Field with the bottleneck, and the curved trajectories with the bottle neck.

a)

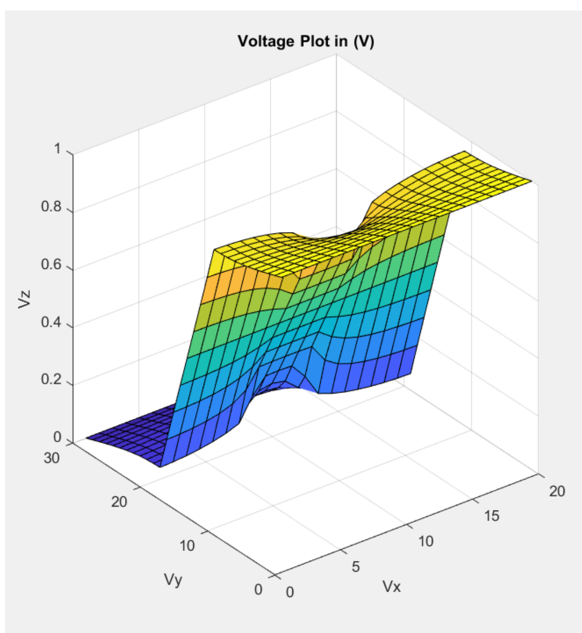

Figure 5: Potential with Bottleneck

b)

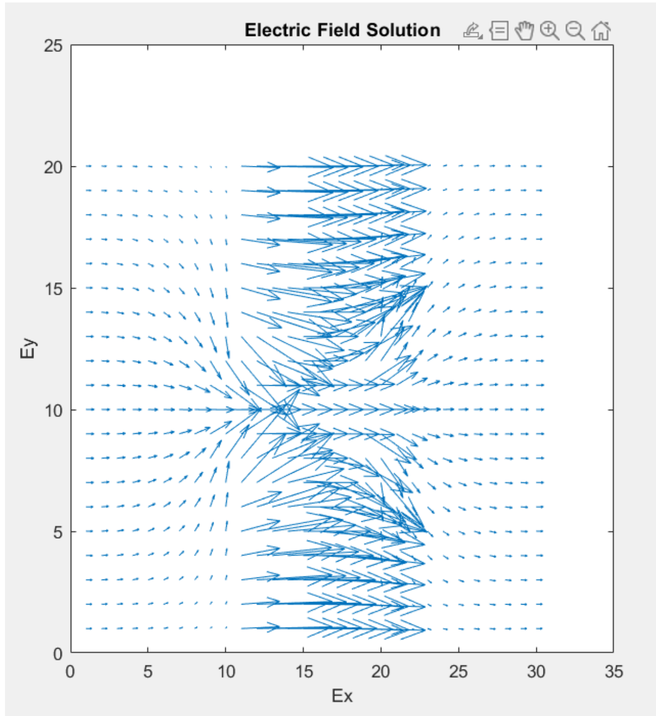

Figure 6: Electric Field with Bottleneck

c)

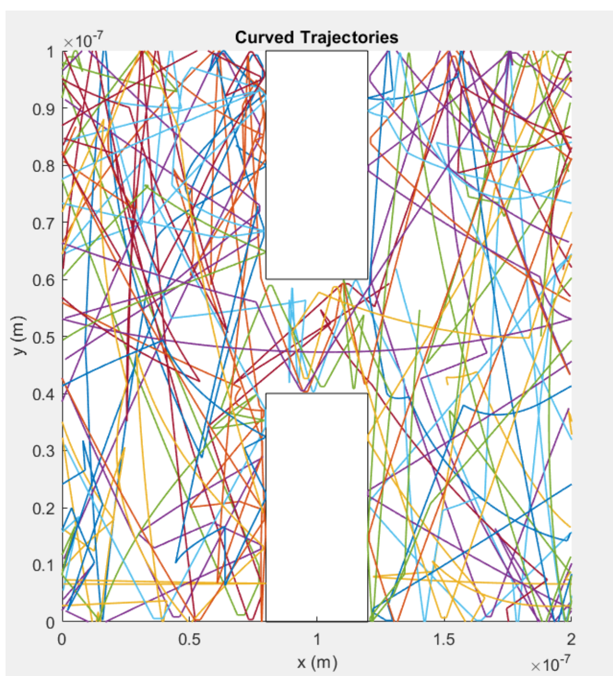

Figure 7: Curved Trajectories with Bottleneck

3a) The density map can be seen below. Figure 8 shows the overview of the density map and Figure 9 shows the top view. This density map is accurate since no electrons can be found in the boxed regions, since no electrons were allowed to enter those regions.

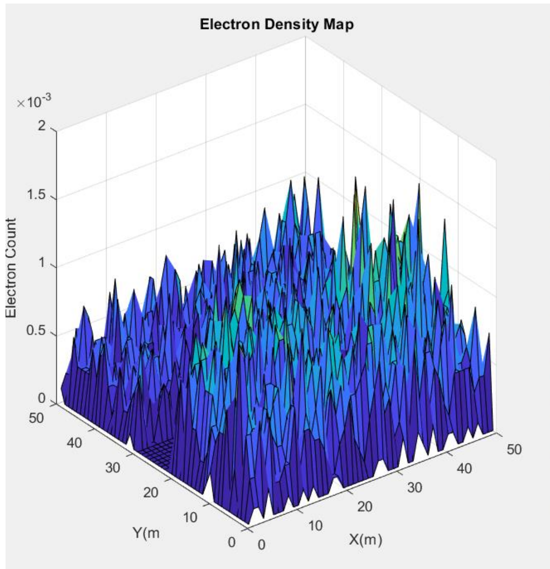

Figure 8: Electron Density Plot – Overview

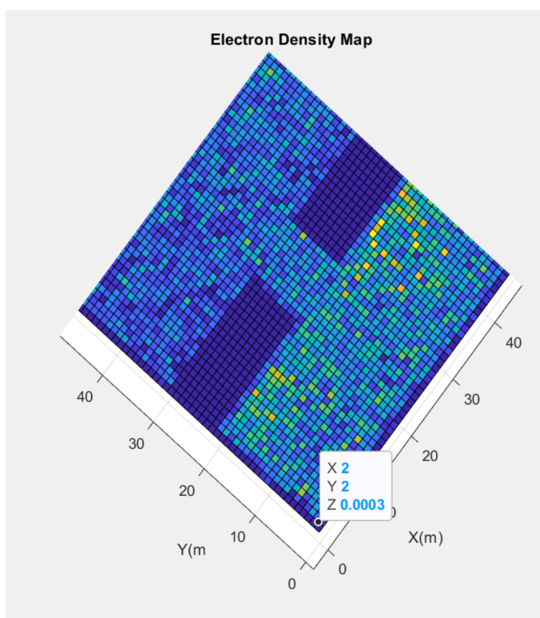

Figure 9: Electron Density Plot - Top View

3b) The following is the current when the bottleneck is being changed.

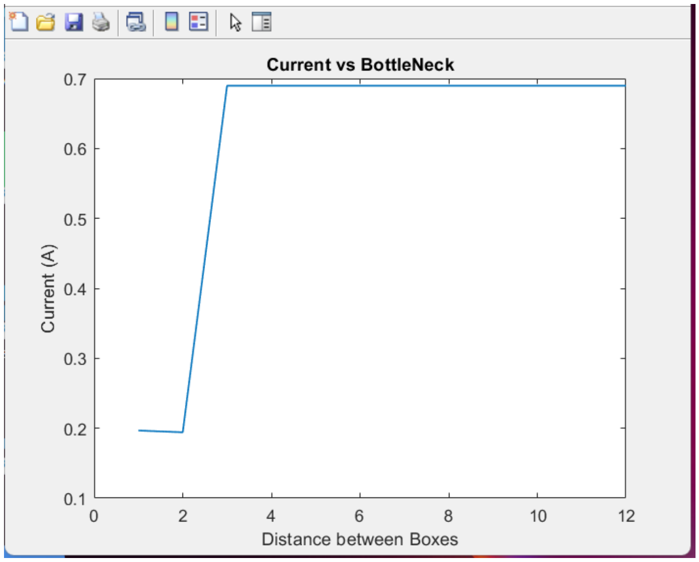

Figure 10: Current and Changing Bottleneck

3c) In order to make this simulation more accurate, smaller step sizes, more particles, and smaller mesh sizes can be used. This will allow us to evaluate a lot of particles in very small time steps in order to see the most accurate simulation. This would lead to a very long run time as well.