Carleton University

ELEC 4700 A

Assignment-3: Monte-Carlo/Finite Difference Method

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PART 1

The primary part of the assignment involves modifying the Monte-Carlo simulator from Assignment 1 and adding a voltage across the x-axis of the semiconductor crystal. Moreover, this voltage results in an electric field forming within the semiconductor. It should be noted that the applied voltage was set to 0.1 V, but to clearly see the effects of the electric field, it was increased to 0.4 V.

The electric field seen by the electrons is given by the following equation, where ΔV is the applied voltage and d is the length of the region across the x-axis:

$$E = \frac{\Delta V}{d} = \frac{0.8\ V}{200x10^{-9}m} = 5.00\text{x}10^{5}\ \text{V/m} \qquad (1)$$

The force on the electrons within the region is given by the following equation, where q is the charge of the electron and E is the electric field:

$$F = qE = (1.602x10^{-19}C)\left(5.00\text{x}10^{5}\,\frac{\text{V}}{\text{m}}\right) = 8.01x10^{-14}N \qquad (2)$$

The acceleration on each electron is given by the following equation, where F is the force on the electrons within the region and m is the effective mass of the electron:

$$a = \frac{F}{m} = \frac{8.01x10^{-14}N}{0.26(9.11x10^{-31}kg)} = 3.38x10^{17}m/s^{2} \qquad (3)$$

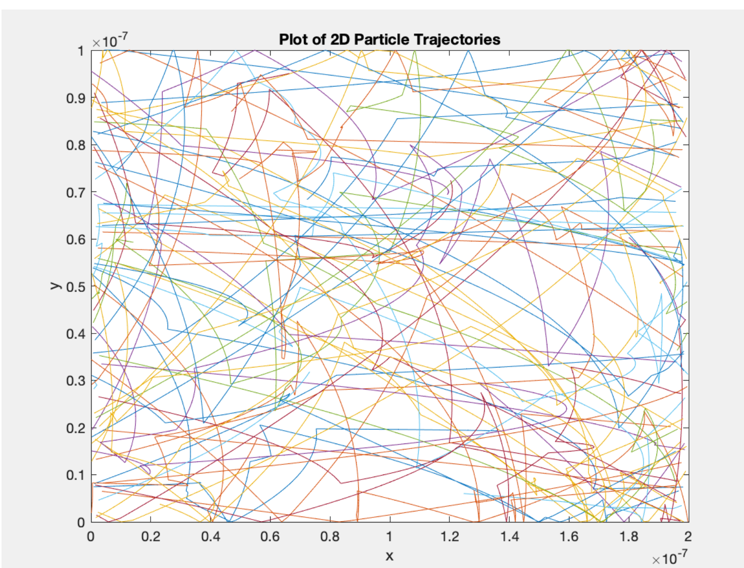

Figure 1. Plot of 2D Particles Trajectories

The electron drift current density is calculated from the following equation, where e is the charge of the electron, n is the number of electrons, and Vx is carrier velocity:

$$J_x = enV_x \qquad (4)$$

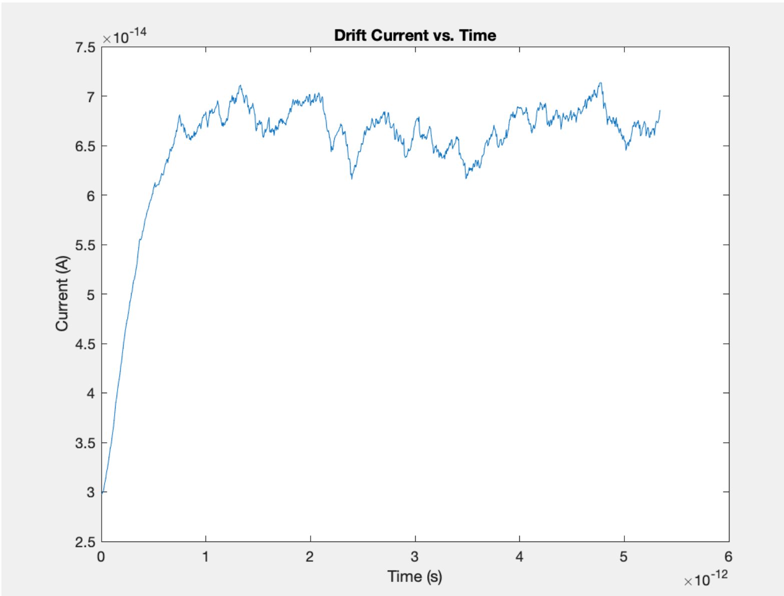

Figure 2. Plot of Drift Current Versus Time

As can be seen in Figure 2 above, the drift current drastically increases at first and then levels out. This effect is most likely due to the initialization of the velocities, since the electric field begins to accelerate the electrons as time goes on.

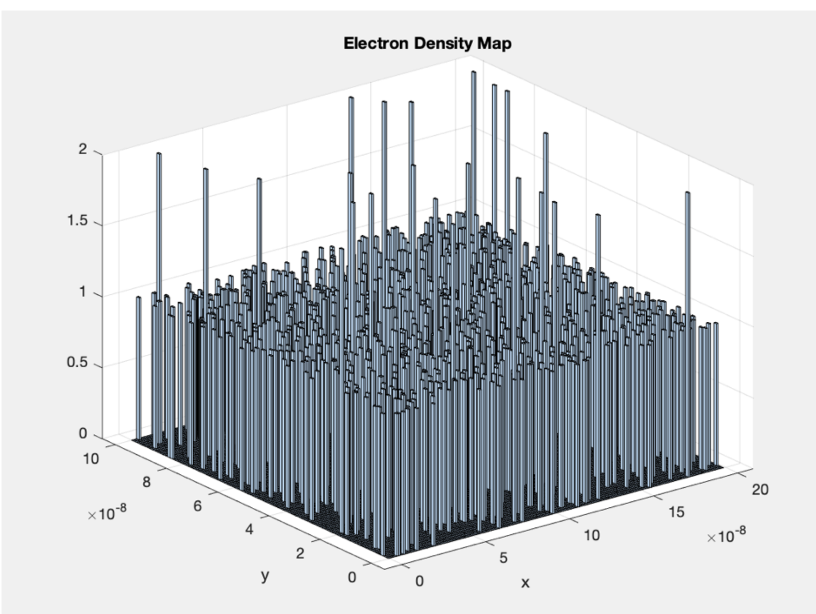

Figure 3. Electron Density Map

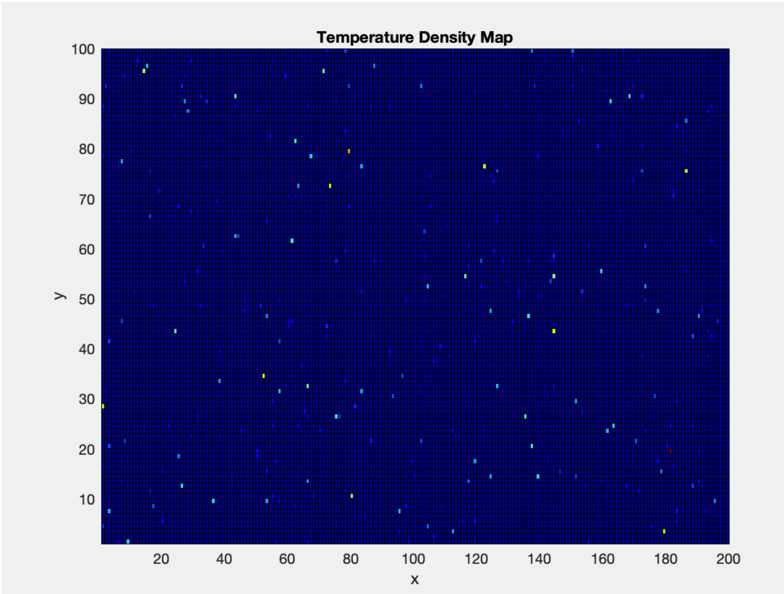

Figure 4. 2D Temperature Density Map

PART 2

The secondary part of the assignment involved modifying Assignment 2 to calculate and plot the potential over the semiconductor crystal with a bottle-neck. The potential across the x-axis was set to 0.8 V to clearly demonstrate the effects. Moreover, the electric field was calculated from the potential and plotted.

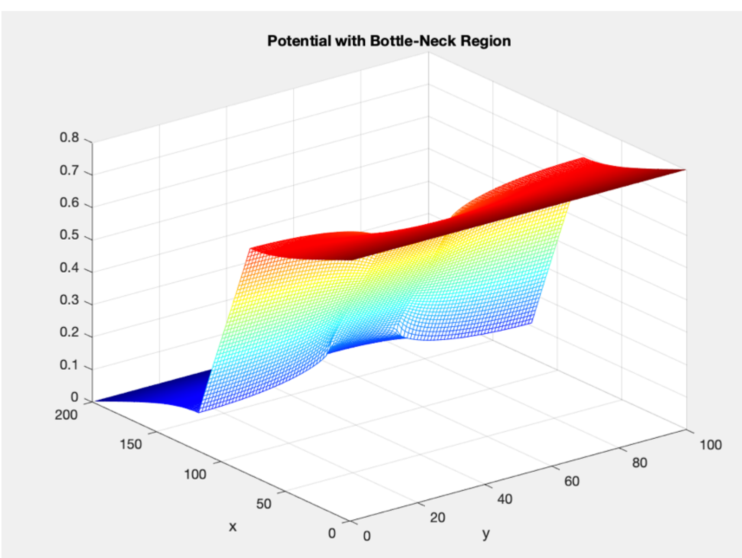

Figure 5. Plot of Potential with Bottle-neck Region

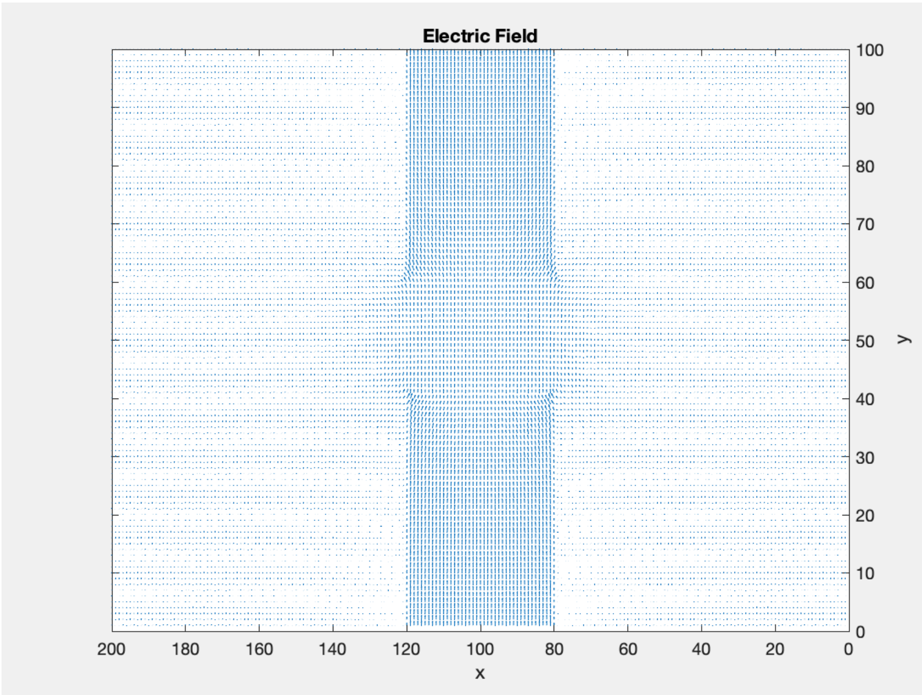

Figure 6. Plot of 2D Electric Field

As seen in Figure 5 and 6 above, the potential and electric field are consistent with Assignment 2.

PART 3

The last part of the assignment involved coupling Part 1 and Part 2. Part 2 was used to establish a potential of 0.8 V across the x-axis of the semiconductor and form the resulting electric field. Moreover, Part 1 was modified to include the bottle-neck barrier and determine the electrons' acceleration due to the electric field at each time step.

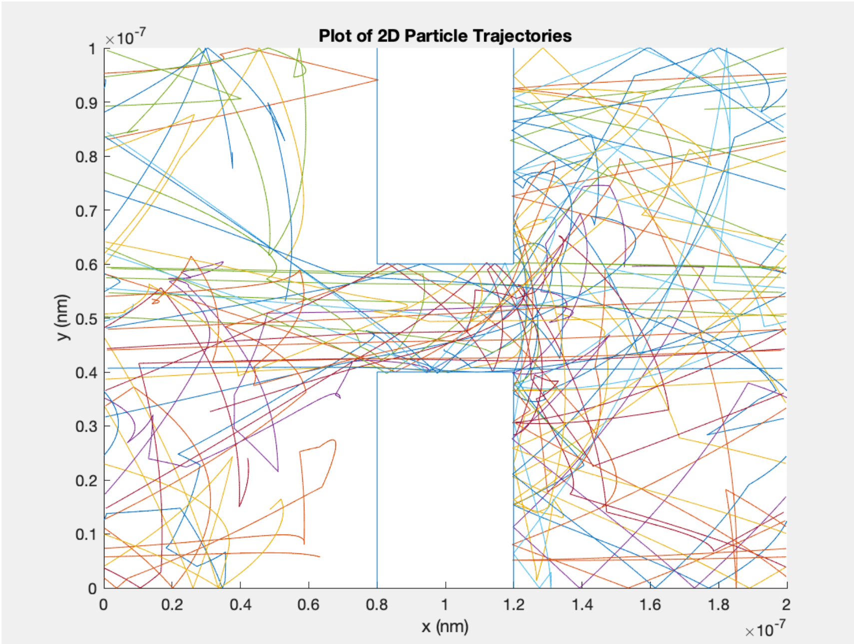

Figure 7. Plot of 2D Particle Trajectories with Bottle-neck

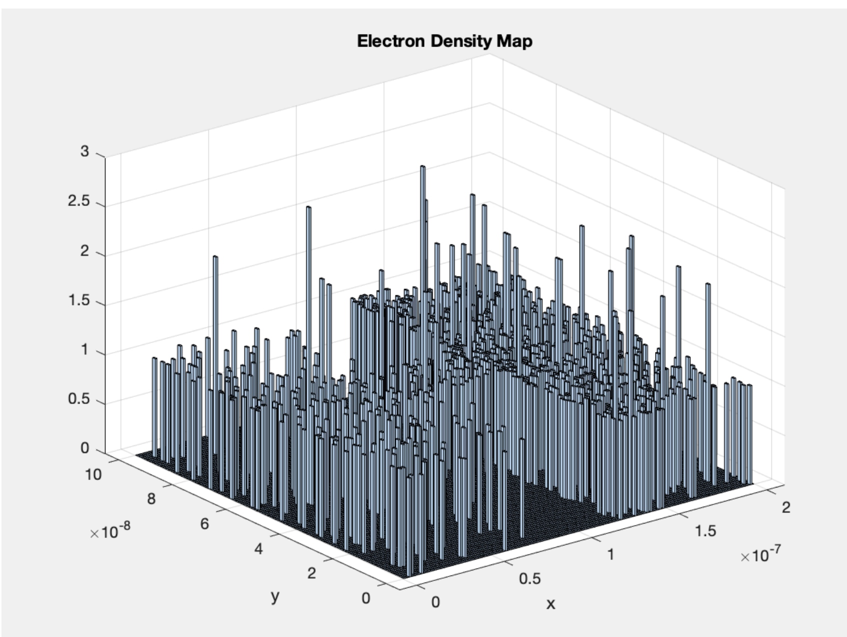

Figure 8. Electron Density Map

As can be seen in Figure 7 above, there is an electric field present in the semiconductor; therefore, the expected behaviour of the electrons is that they will tend to travel towards the right side of the crystal. Moreover, this effect can further be seen in the electron density map in Figure 8.

The next step to make this simulation more accurate would be to make the region more realistic by adding collision behaviour between electrons – the probability of scattering of electrons could realistically be lower or higher – adding more realistic boundary conditions – there may be different boundary materials and the energy of the electrons may be absorbed or exuded – or adding more realistic region behavior – there may be imperfections in the material of the boundaries of the region.