Assignment 3 Report
ELEC 4700

Author: Chandler Aitken 101033675

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1 Part 1: Start with your Monte-Carlo simulator from Assignment-1 without the bottle-neck

1.1 If a voltage of 0.1V is applied across the x dimension of the semiconductor, what is the electric field on the electrons? You can assume it is constant over the semiconductor

The voltage and electric field across the x-dimension can be related by the equation

$$E = \frac{dV}{dx} \tag{1}$$

given that the voltage (V) is 0.1V and the distance x is 200nm, the resulting electric field on the electrons would be,

$$E = \frac{0.1V}{200nm} = 500,000[\frac{V}{m}]$$

1.2 What is the force on each electron?

The force on each electron can be given as,

$$F = qE \tag{2}$$

where the charge (q) on the electrons would be 1.602e-19 Coulombs. The resulting force on each electron is,

$$F = (1.602e-19C)(500,000\frac{V}{m}) = 8.01e-14N$$

1.3 Calculate the acceleration on the electrons and use this in your model to update the velocity of each electron at each time step.

The acceleration on the electrons can then be obtained from

$$F = ma \tag{3}$$

where the mass of the electron is 0.26*(9.109e-31) giving an acceleration of,

$$a = \frac{8.01e-14}{(0.26)(9.109e-31)} = 3.38e17\frac{m}{s^2}$$

A sample of the trajectories of the particles under acceleration is shown in Figure 1

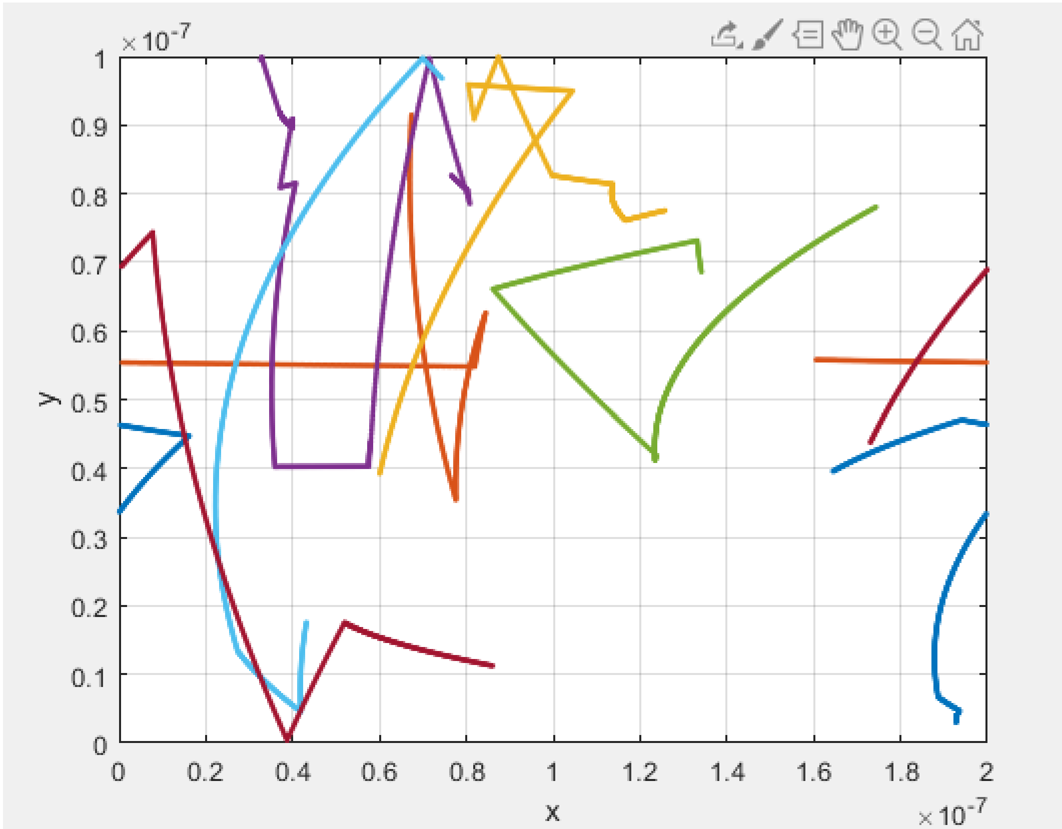

Figure 1: Trajectory of particles under the acceleration of the electric field

1.4 What is the relationship between the electron drift current density and average carrier velocity?

The electron drift current density can be modeled by the equation

$$J = qn\mu E \tag{4}$$

where q is the charge, n is the electron concentration which is assumed to be $10^{15}\mathrm{cm}^2$, μ is the mobility of the electrons, and E is the electric field. The drift velocity can then be modeled by

$$J_x = qnV_x \tag{5}$$

where V_x is the velocity. The current density is then as in Figure 2,

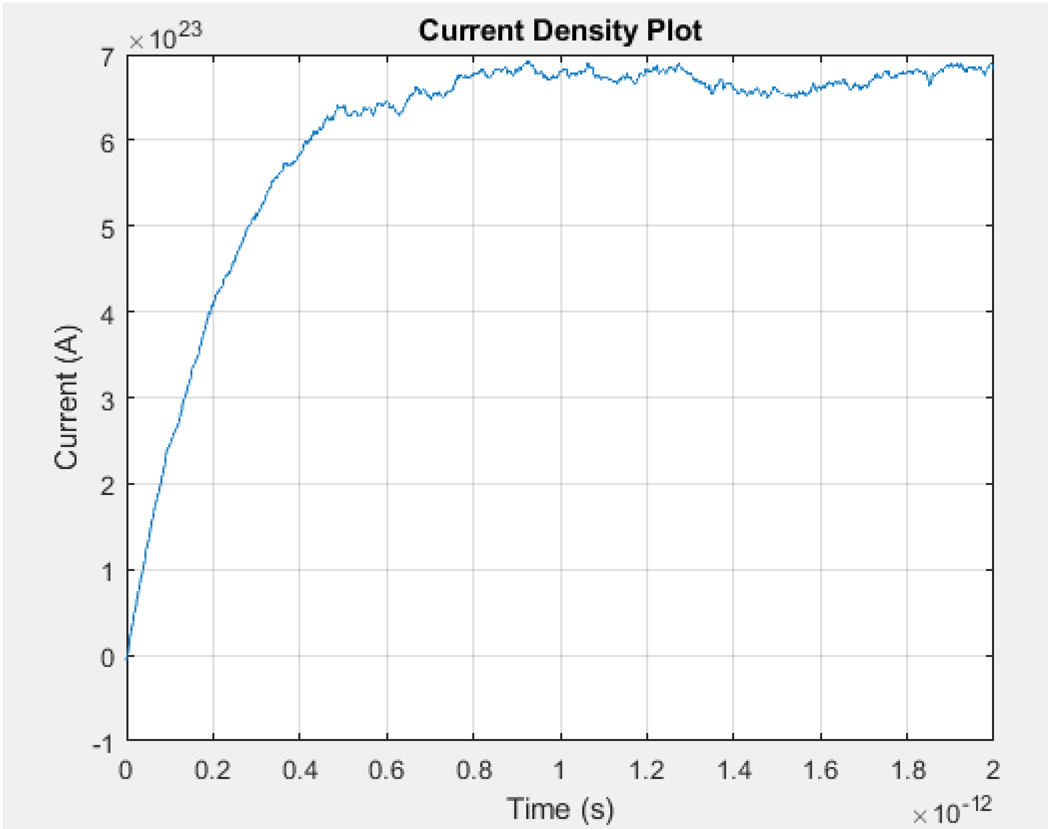

Figure 2: Plot of the current density over time

The current over time increases and then flattens out as the contribution of the electric field to increase current and the contribution of the scattering to decrease current evens out.

1.5 generate the density and temperature maps at the end of the simulation

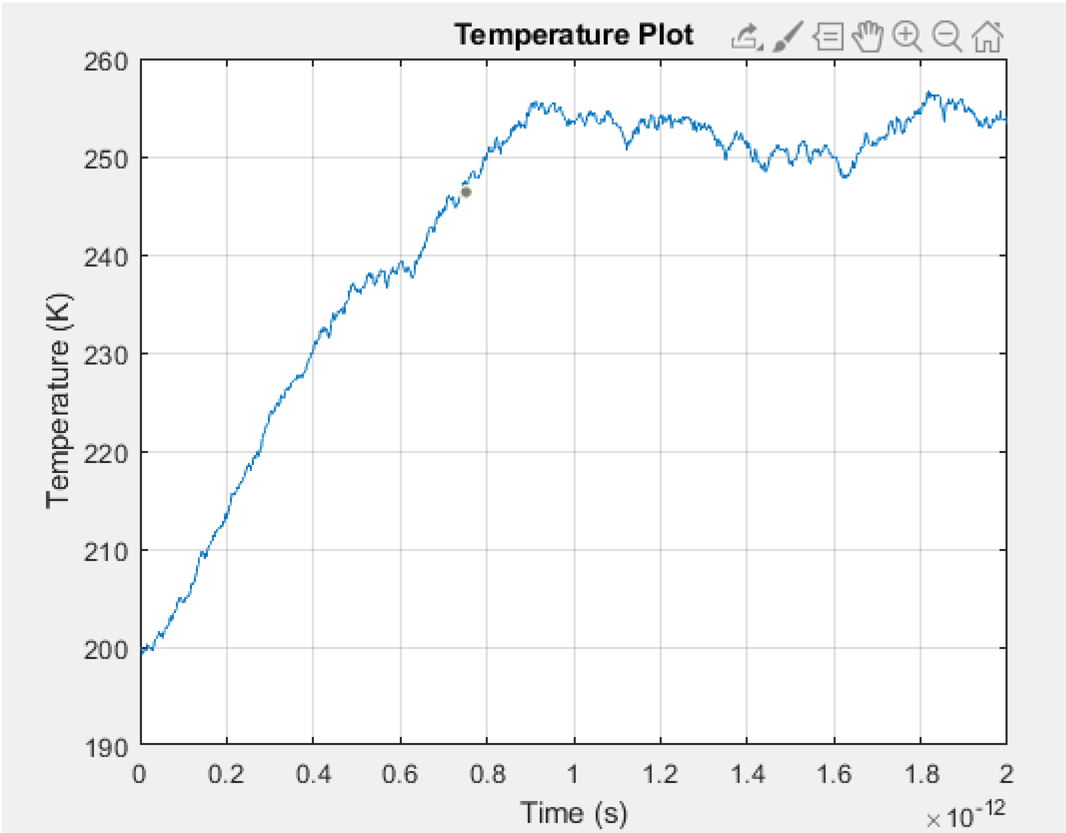

Figure 3: Temperature over time

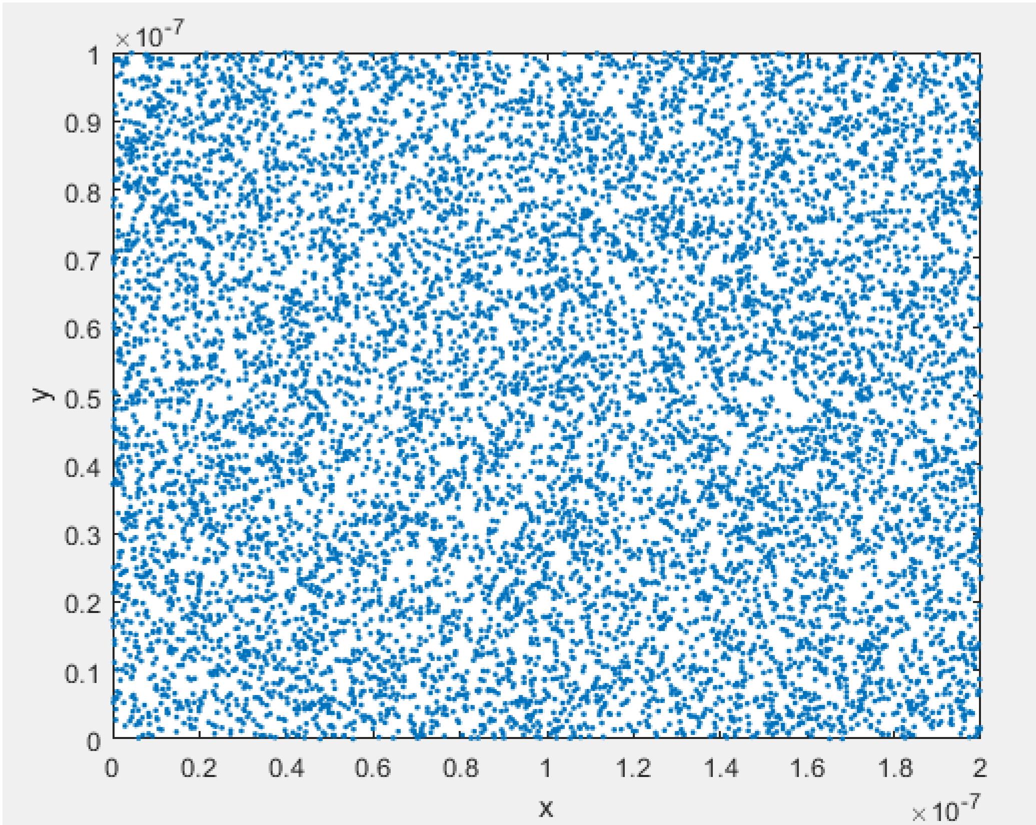

Figure 4: Density Plot

2 Part 2: Use the Finite Difference Method in Assignment-2 to calculate the electric field and then provide a field for the Monte-Carlo bottle-neck simulation

2.1 Surface plot of V(x,y)

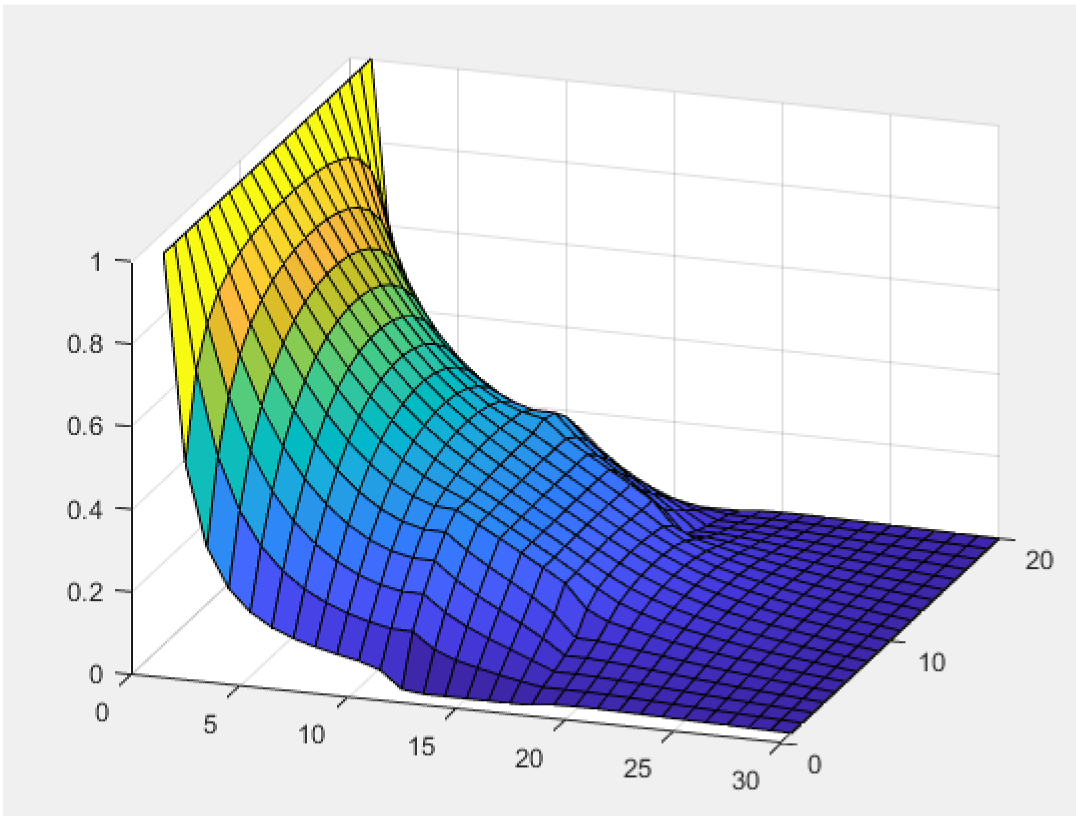

Figure 5: Plot of voltage over bottleneck using monte-carlo

2.2 2-D electric field vector plot

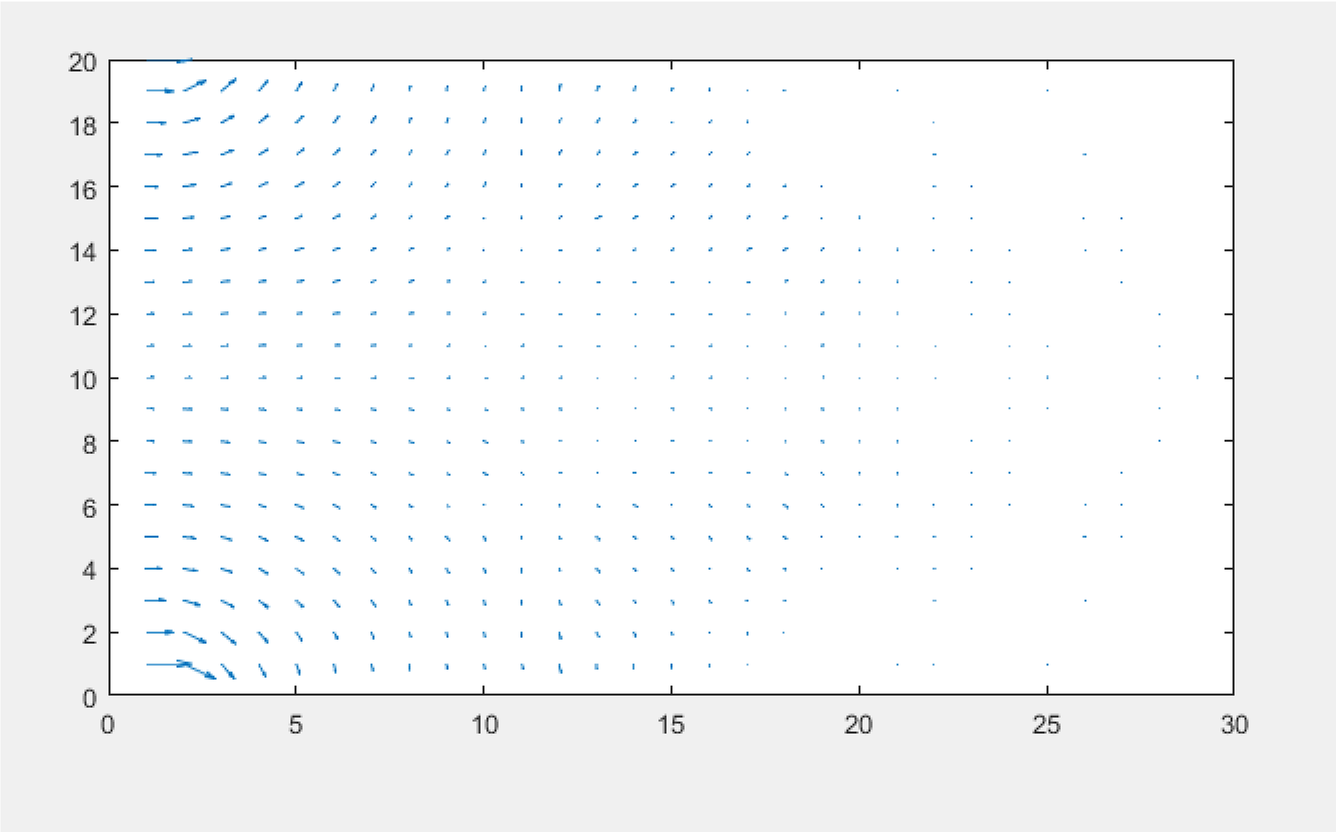

Figure 6: Plot of electric field over bottleneck

2.3 2-D plot of particle trajectories

Figure 7 shows the trajectory of the particles in an electric field when the bottle neck is applied. The particles seem to bunch up on the left edge of the bottle neck as the accelerate to the right but have trouble passing through the gap. This is seen clearer on the density plot in Figure 8 where the particles are more densely packed on the left edge of the bottle-neck.

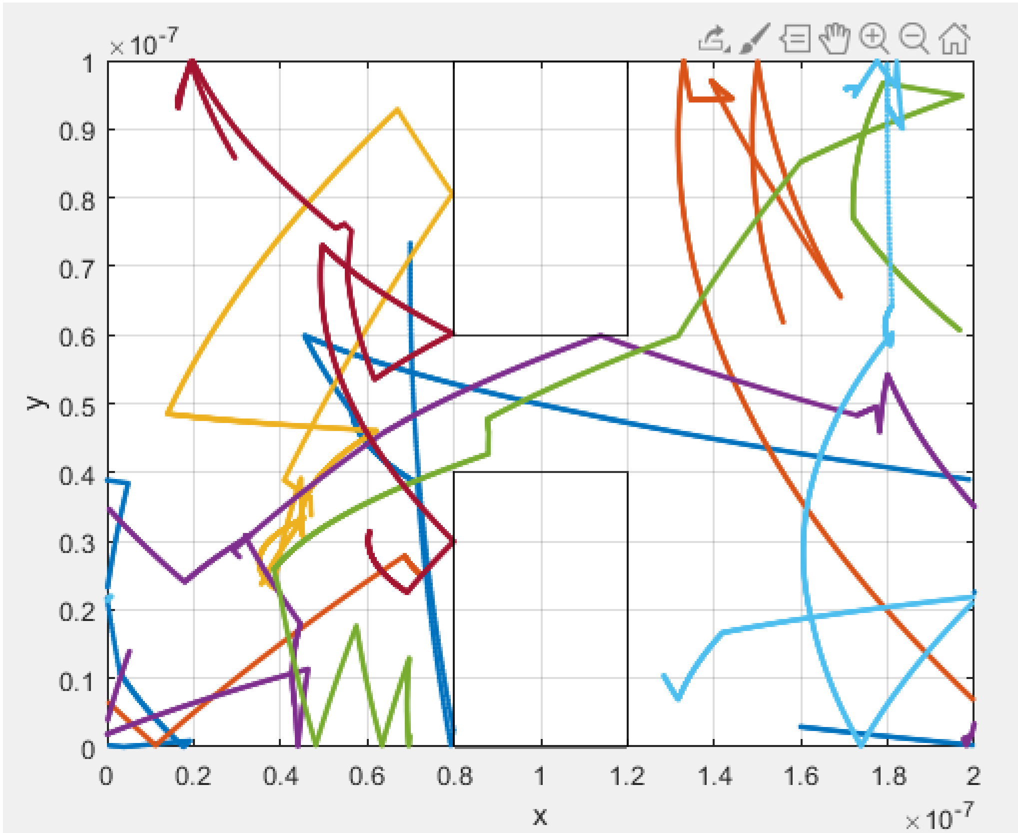

Figure 7: Trajectories of particles in electric field with bottle-neck

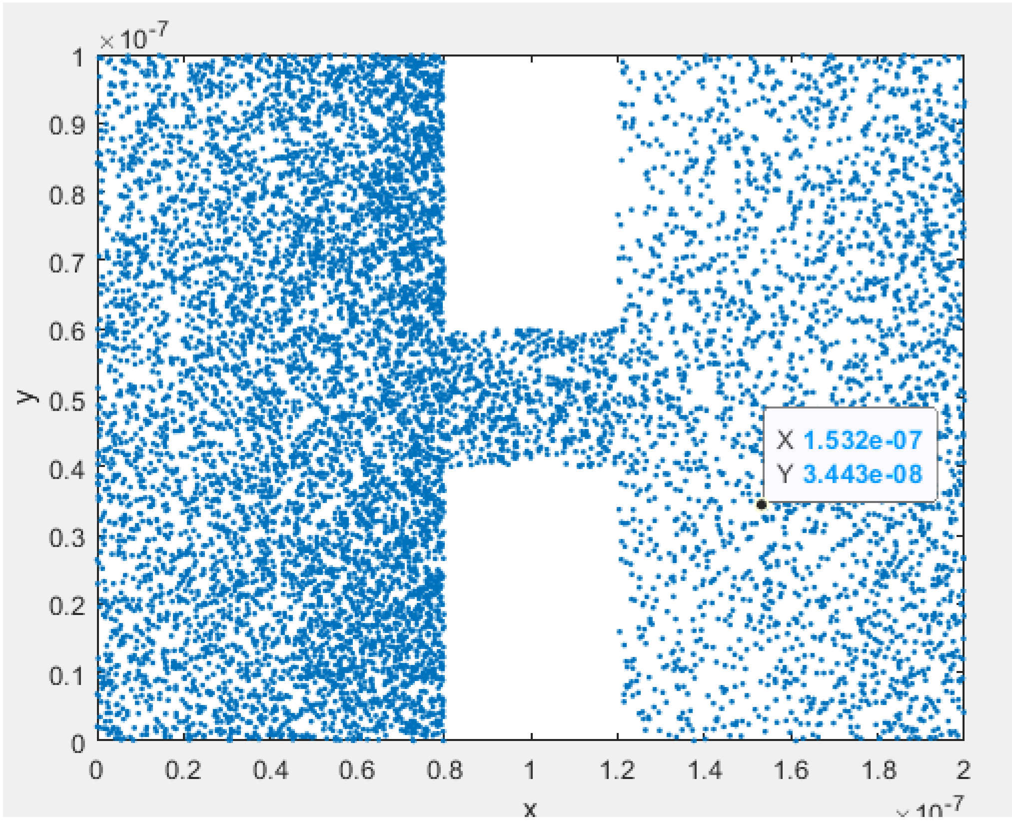

Figure 8: Density of particles for bottle-neck

3 Part 3: Use the coupled simulations to investigate the "device" and extract simple parameters

3.1 Density plot

It is even more clear with Figures 9 and 10 that the trajectories bunch up on the side of the bottleneck.

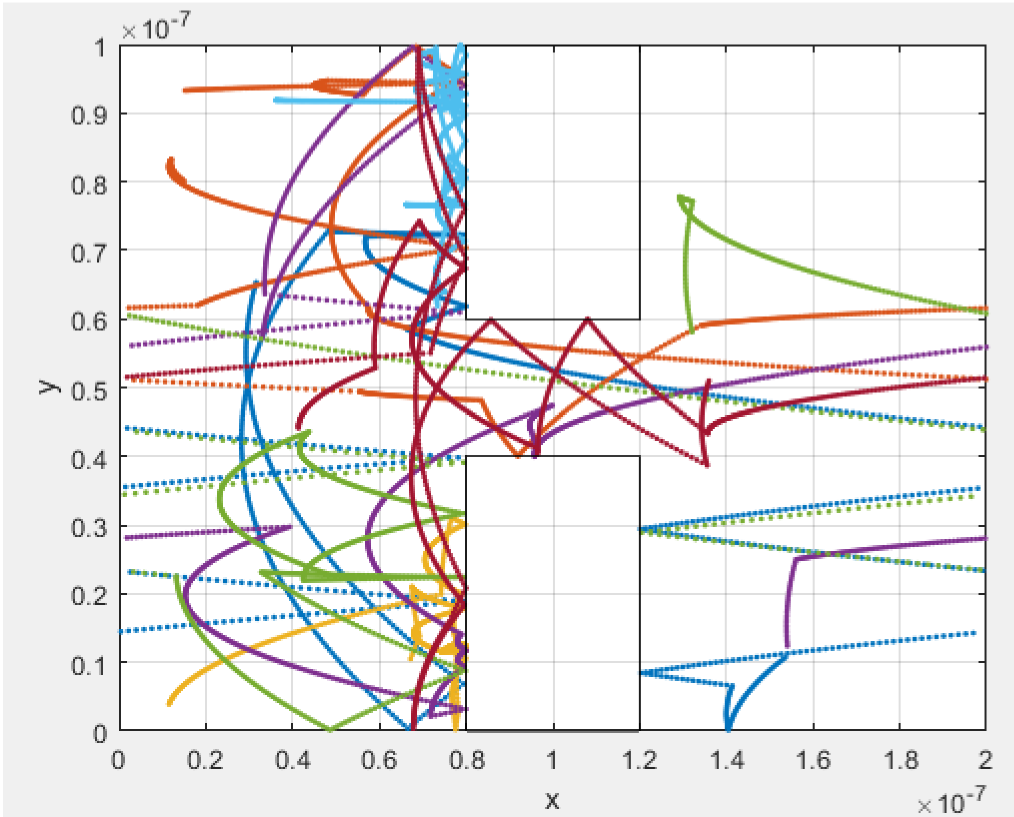

Figure 9: The particle trajectory for a bottle neck with 0.8V applied

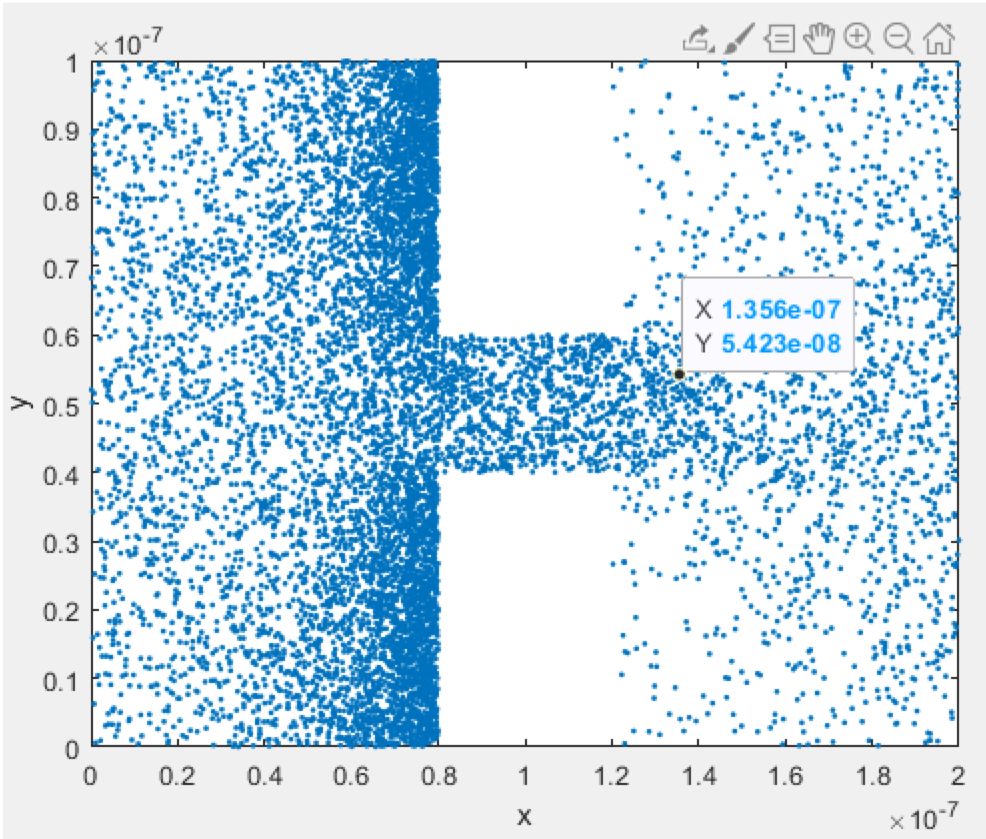

Figure 10: The particle density for a bottle neck with 0.8V applied

3.2 Plot of current vs bottleneck

The current with 0.8V and the bottle-neck seems to jump up past the point where it settles before settling as in Figure 11. This is likely due to the high acceleration initially generated by the voltage which is eventually in equilibrium with the scattering.

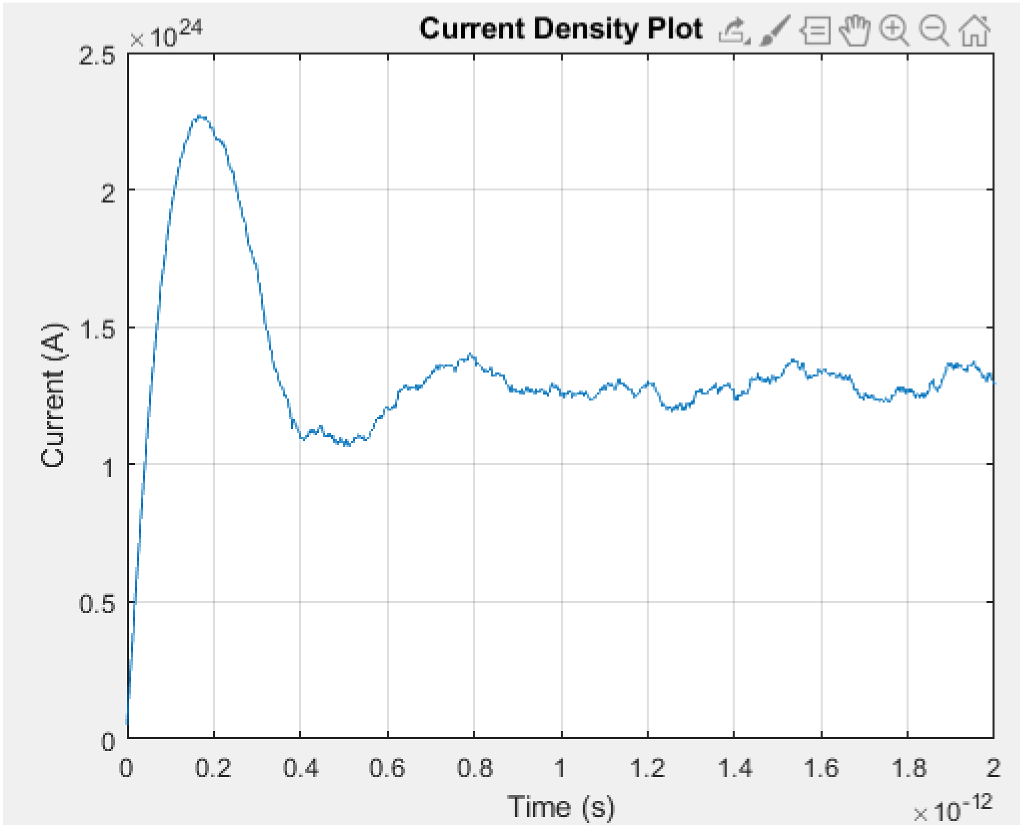

Figure 11: Current over time with 0.8V applied with bottle neck

3.3 Next step be to make this simulation more accurate?

This simulation could be made more accurate. One way could be to make the particles scattered when they actually come into contact with each other. Another way could be to instead of making the velocity of the scatter random, it would depend on the kinetic energy of the collision. The conservation of energy would need to be checked for each particle collision. Creating an electric field that acts on each particle individually may also make the particle acceleration more accurate. There may also be inelastic collisions between electrons which could be accounted for as a loss in kinetic energy when they scatter.