ELEC 4700 Assignment-3 Monte-Carlo/Finite Difference Method

Due: Sunday, Mar. 20, 2022 23:59

Submission

The assignment submission should be two files, a .zip of the repo and code, and a .pdf of the report. BrightSpace will accept only two files on your submission so make sure they are these.

The code should be organized such that the master branch of the repo contains the submission version and the entry point script (the one that creates the report or runs all the other code) is titled as the repo. Any additional code should be stored in a folder titled code.

In order to create a repo for your assignment, you can follow these instructions:

1. On your local machine, make sure you do git init in your assignment folder.
2. In the same directory as your assignment code and PDF commit all changes you've made to your project with first git add −A and then git commit −m "MyMessage"

As mentioned before, the submission should have the format of:

1. The report
2. A zip folder name "code" containing the code used to create the report

Your code will be checked using the version of MATLAB as found on DOE computers. Please ensure that your code clearly indicates which question and which part it is answering.

This is an extension of the first two assignments where we will couple the two simulators from those assignments.

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

   (a) 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.

   (b) What is the force on each electron?

   (c) Calculate the acceleration on the electrons and use this in your model to update the velocity of each electron at each time step. Add the capability for the electrons to respond to a static electric field with both an x and a y component. Plot the trajectories of the electrons. They should be curved! Increase the electric field and see the curve! Be careful that your time step is appropriate!

   (d) What is the relationship between the electron drift current density and average carrier velocity? Give the formula for current and generate a plot of the current over time in the x direction. Assume an electron concentration of $10^{15} cm^{-2}$. Note that the electron concentration is used to find out how many electrons each of the model's "particles" represent. Comment on the current behaviour over time.

   (e) As before generate the density and temperature maps at the end of the simulation.

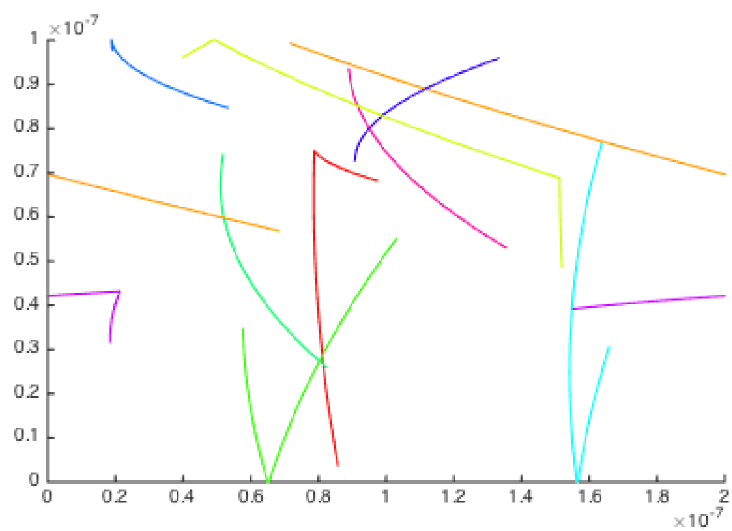

Figure 1: Sample trajectory plot after the first 50 steps.

Include in Report

(a) E (b) F (c) Acceleration. 2-D plot of particle trajectories (d) Current formula , plot and comment (e) Density and temp. plots

Sample plots are shown in Figure 1 and Figure 2.

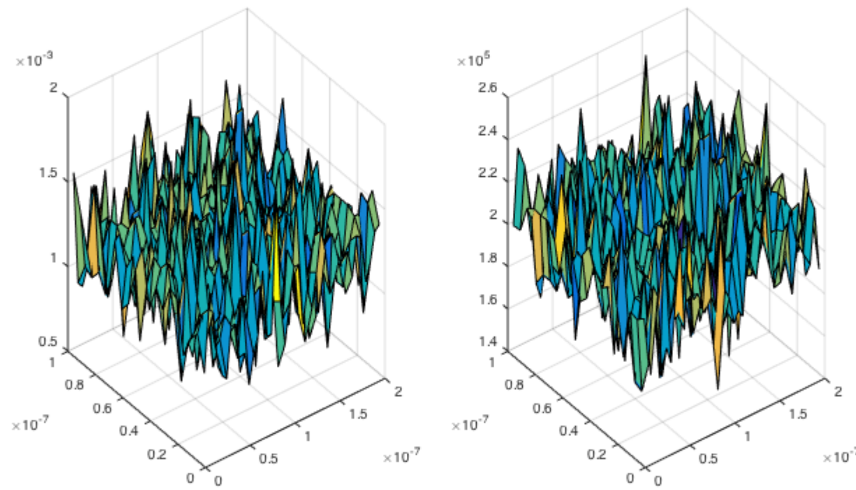

Figure 2: Sample density and temperature plots for 30000 electrons after the first 50 steps.

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.

   (a) Use the code from Assignment-2 to calculate the potential with the bottle-neck inserted. Plot this in 3-D as before.

   (b) Calculate the electric field from the potential. Plot this as a vector plot in 2-D using a the matlab plot function 'quiver'.

   (c) Use the field calculated for the bottle neck in question 2 as input to the Monte-Carlo simulation in question 1. Plot the trajectories of the electrons under this new field. Do this for a minimum of 1000 electrons for a minimum of 1000 timesteps.

   Include in Report

   (a) Surface plot of V(x,y) (b) 2-D electric field vector plot. (c) 2-D plot of particle trajectories

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

   (a) Plot the density map and comment on what is going on (especially noticable with a 0.8V field).

   (b) Calculate and plot the average current at different bottleneck widths

   (c) What would the next step be to make this simulation more accurate?

   Include in Report

   (a) Density plot. Comments (b) Plot of current vs bottleneck (c) Next step.

   Sample plot is shown in Figure 3.

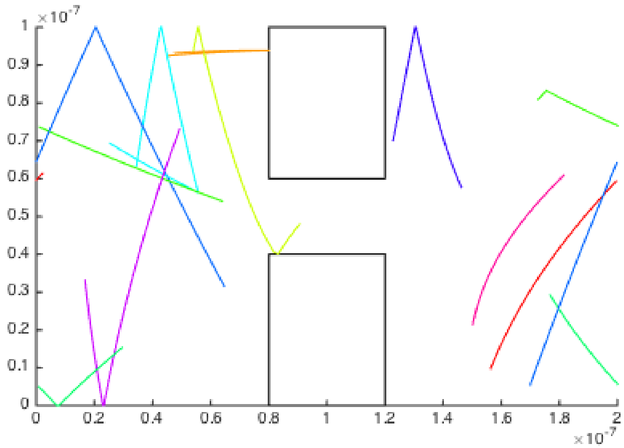

Figure 3: Sample trajectory plot after the first 50 steps.