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ELEC 4700A

Assignment 3: Monte Carlo/Finite Difference Method

Part 1:

a) E is calculated by dividing the voltage in each direction (x,y) by the distance between the edges. The following equations were used to determine the x and y Electric fields

$E_x = V_x/W$

$E_y = V_y/H$

Given that the only voltage applied is 0.1V in the x-direction, $V_y = 0$, therefore $E_y = 0$

$E_x = 0.1V/200nm = 500000V/m$

To determine the total electric field, the following equation is used.

$E = sqrt(E_x^2 + E_y^2)$

With no y-direction electric field, the total field $E = E_x = 500000V/m$

b) Using the Electric field determined in (a), the force applied to each electron can be calculated using the following equations

$F_x = q*E_x$

$F_y = q*E_y$

where q is the charge of an electron.

Without a y-direction electric field, there is no force applied in the y-direction, meaning $F = F_x = q*500000V/m = -8.0109e^{-14}$ N

c) Using the Force determined in (b), the following equations can be used to calculate the acceleration of each electron.

$a_x = F_x/m_o$

$a_y = F_y/m_o$

With no force in the y-direction, there is no acceleration in the y-direction, meaning $a = a_x = -8.0109e^{-14}/m_o = -8.7941e^{16}$ m/s^2

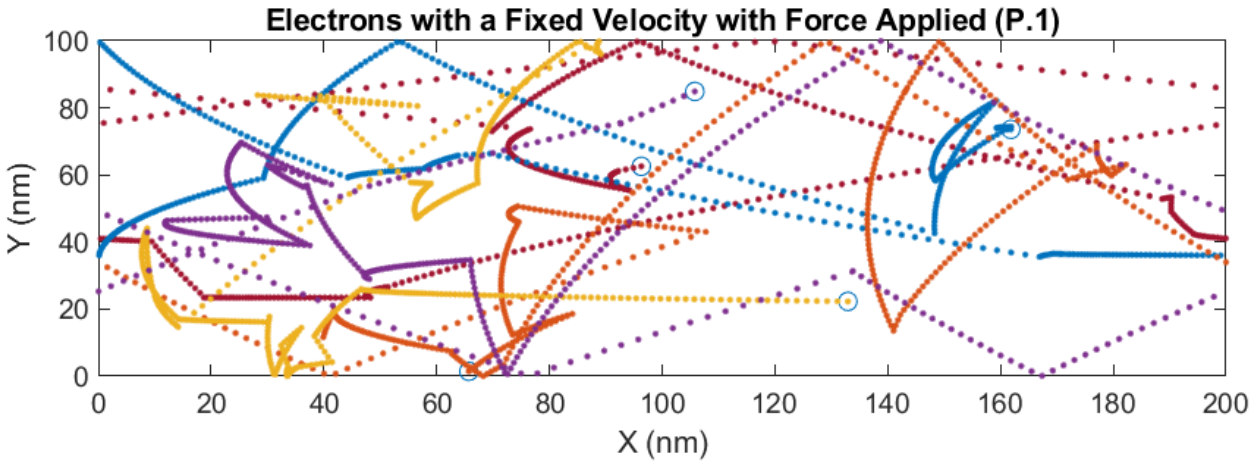

Figure 1: 2-D trajectory plot of electron with electric field applied

d) The current is calculated by using the given density along with the charge of an electron and the average speed of every electron in the semi-conductor. The following equation is used to determine the current at a given time in the x-direction.

J = q*density*mean(x-speed of all electrons)

The following plot displays the x-direction throughout the modelling time. Note how as the electric field applies a force and acceleration in the x-direction, the current increases. Because each electron has a probability to scatter, resetting its speed, the current evens out and remains near a value of roughly $2.2*10^5$ A.

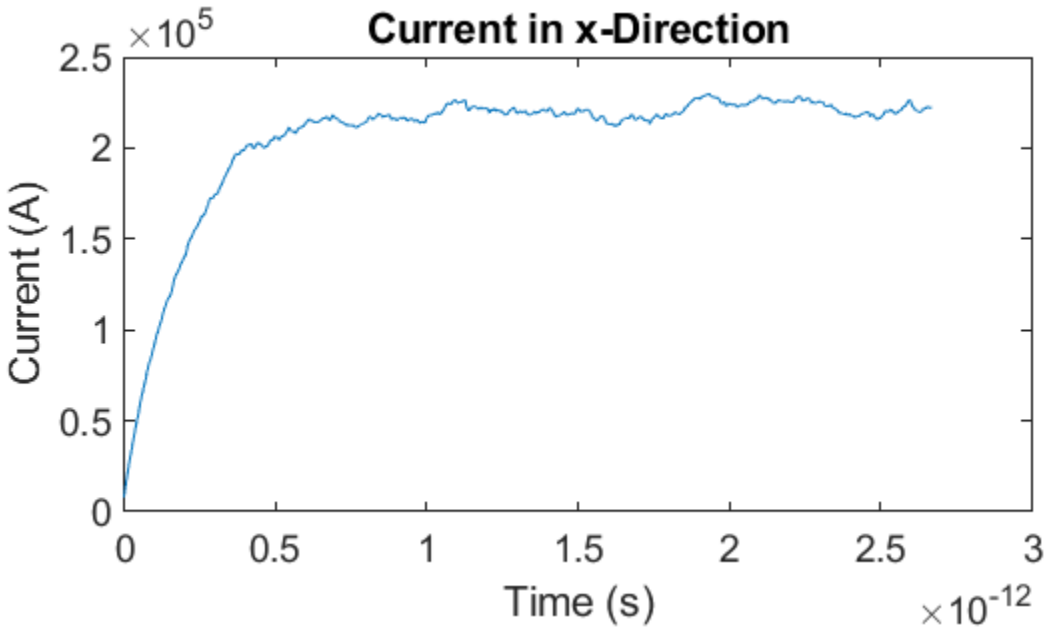

Figure 2: Current plot over time

e)

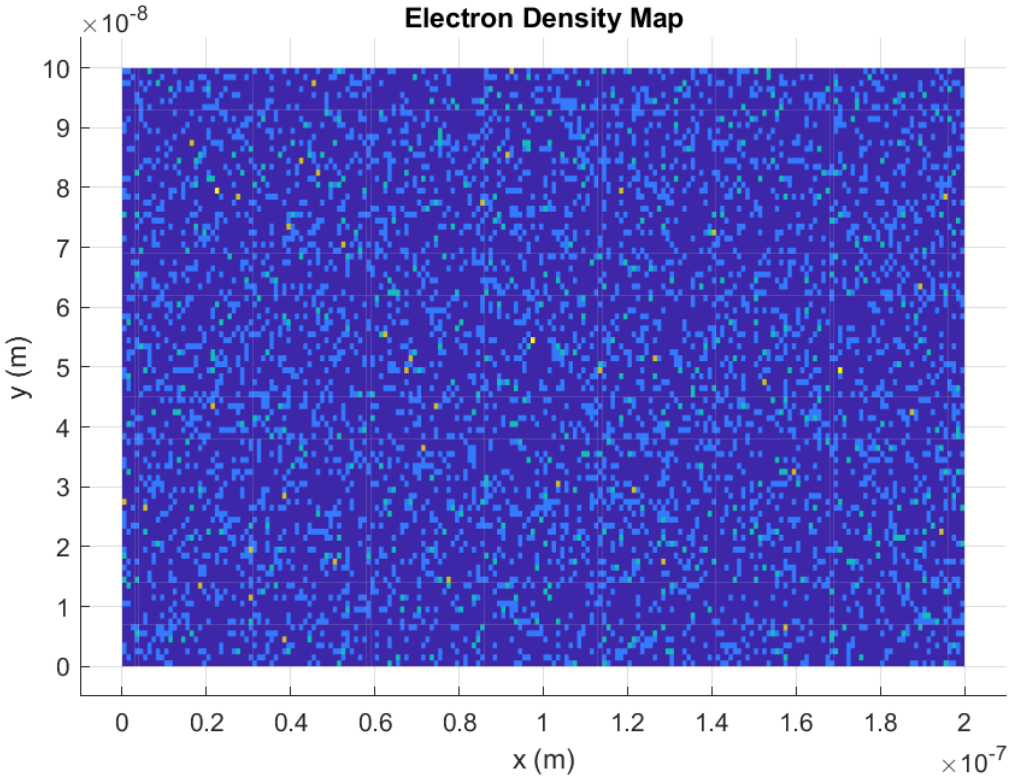

Figure 3: Electron Density Map for Semi-Conductor with Applied Electric Field

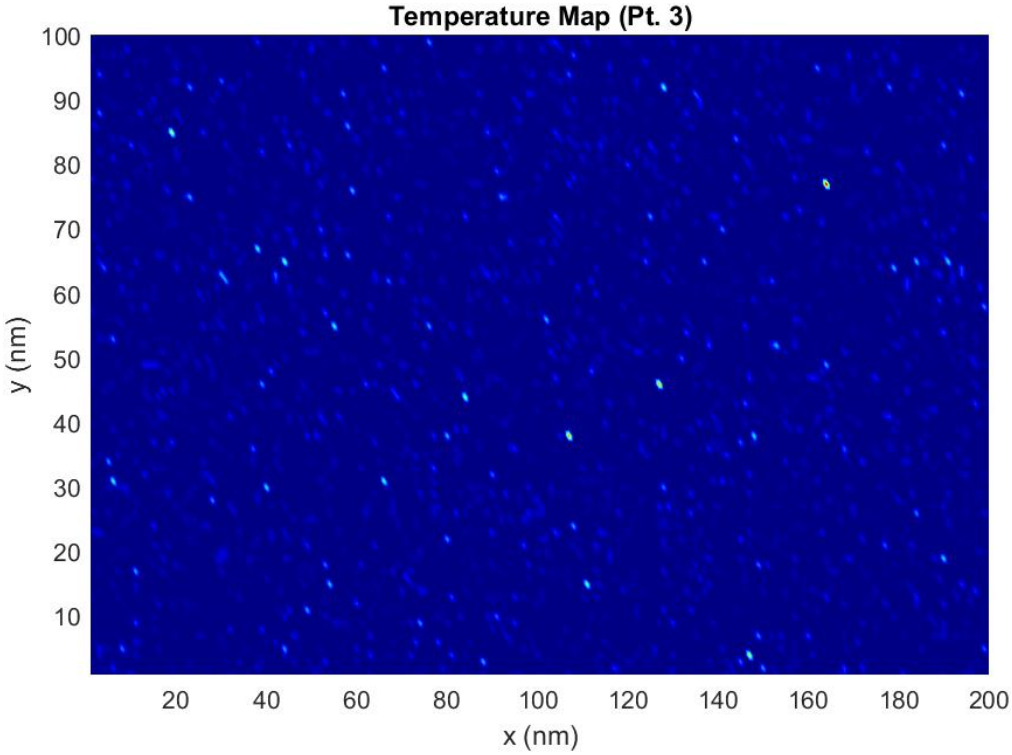

Figure 4: Temperature of Semi-Conductor with Electric Field Applied

Part 2:

a)

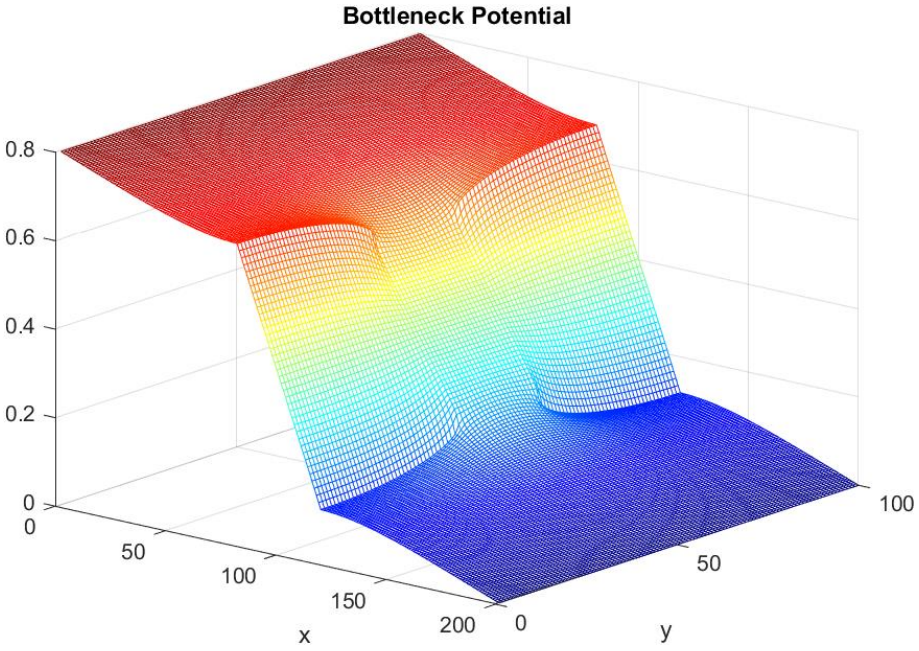

Figure 5: Surface plot of V(x,y)

b)

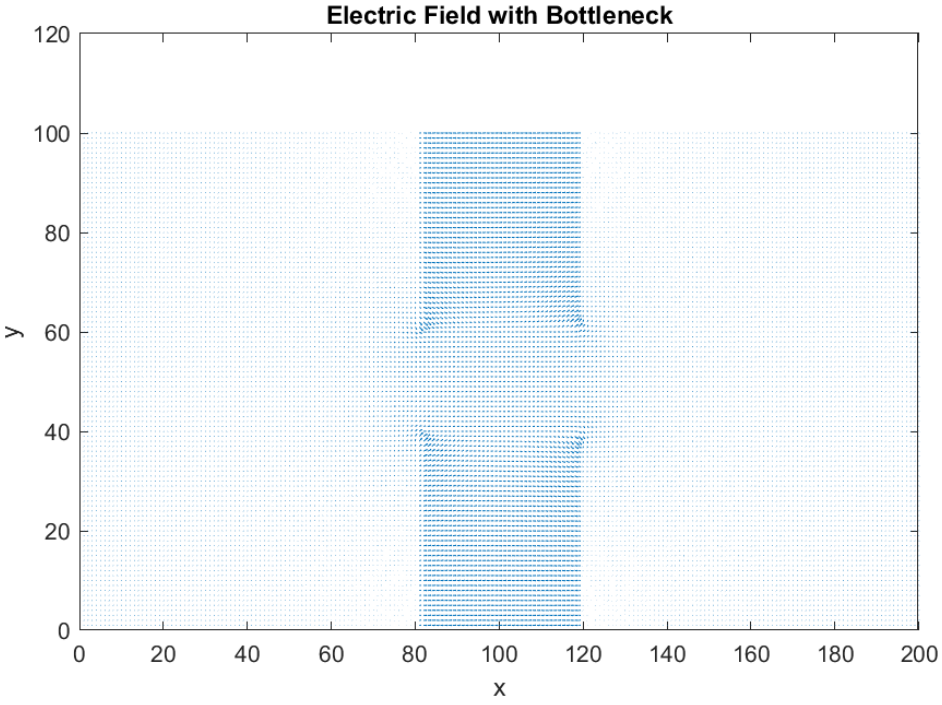

Figure 6: 2-D Electric Field Vector plot

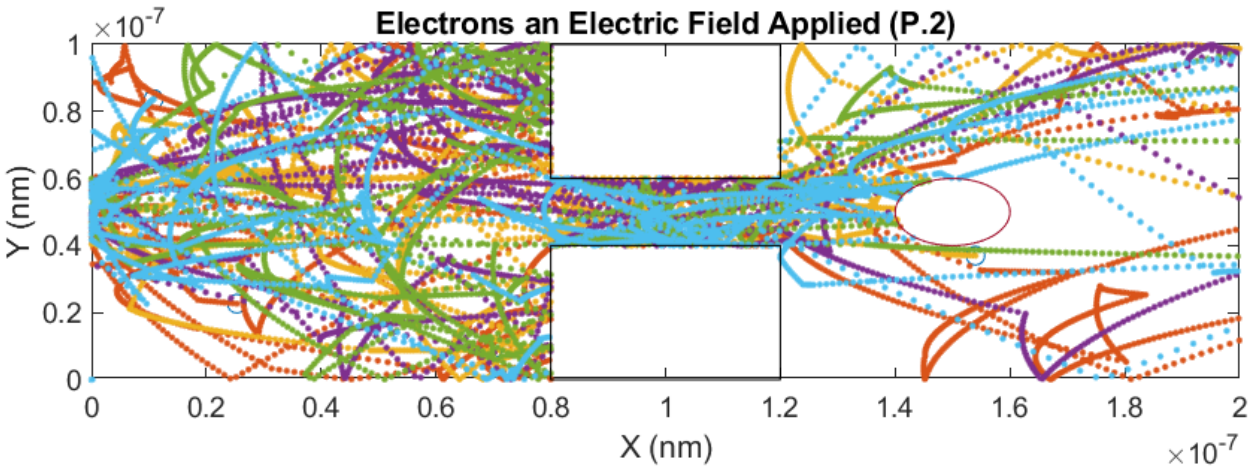

Figure 7: Trajectory map with bottleneck and circular blockage

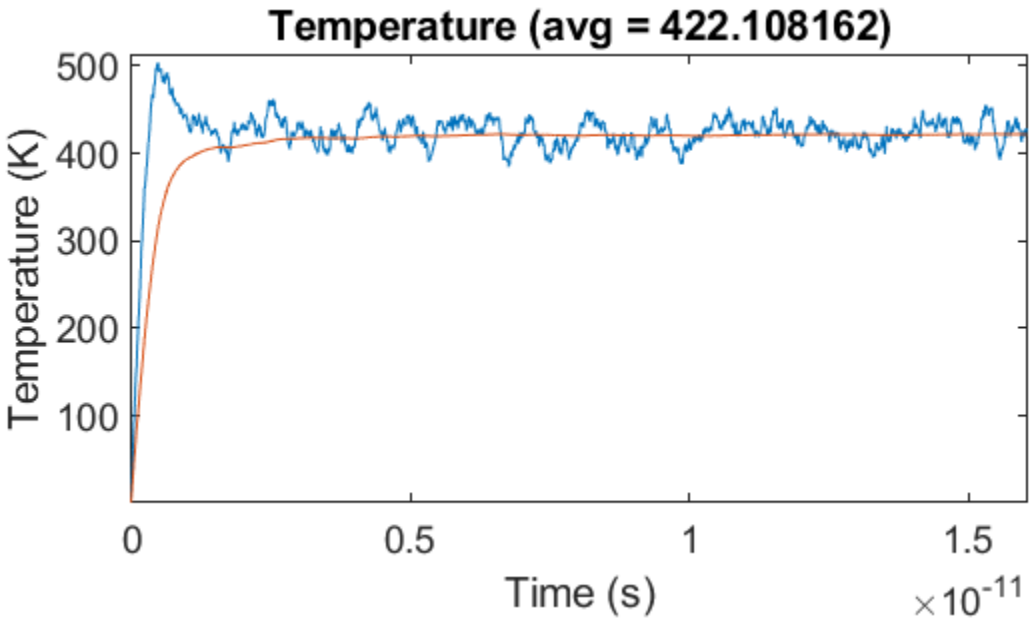

Figure 8: Temperature Tracking of Electrons with Average

Discussion:

The code for assignments 1 and 2 were combined to create an applied potential with the bottleneck in a semi-conductor. After the plots for the potential and the electric field were completed, the force and acceleration were then calculated for each 1x1nm point in the 100x200 grid. Using this, each electron in a grid location can have a specific acceleration applied to it. However, when tested, the acceleration was low enough that it did not have a visual effect on the electrons. Therefore, when displaying the temperature and trajectory, a general 0.8V in the x-direction was applied.

Part 3:

a)

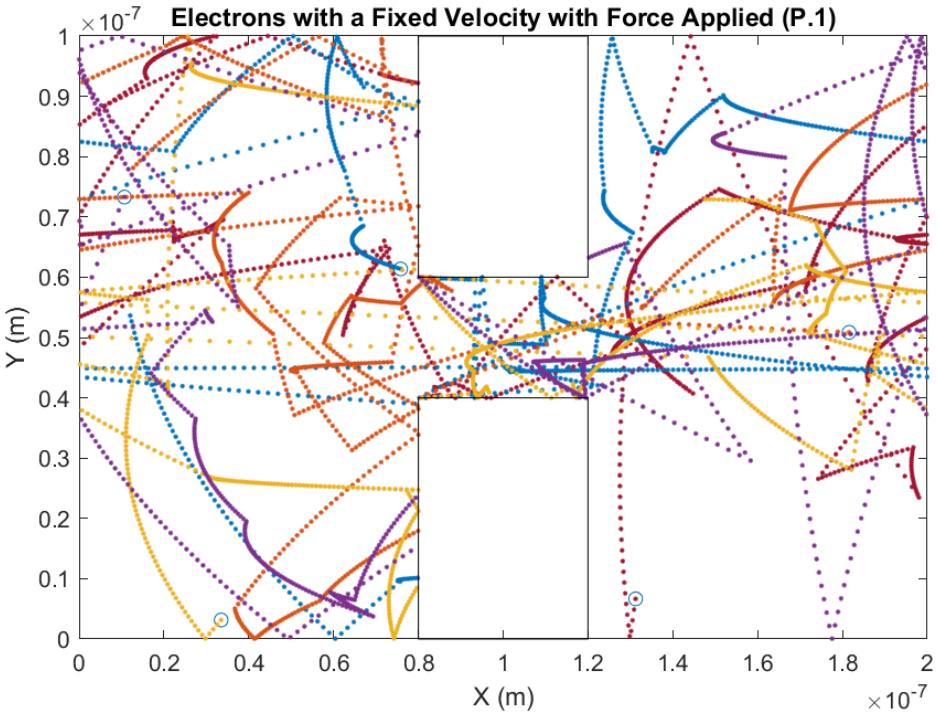

Figure 9: 2-D Plot of electron Trajectories

b)

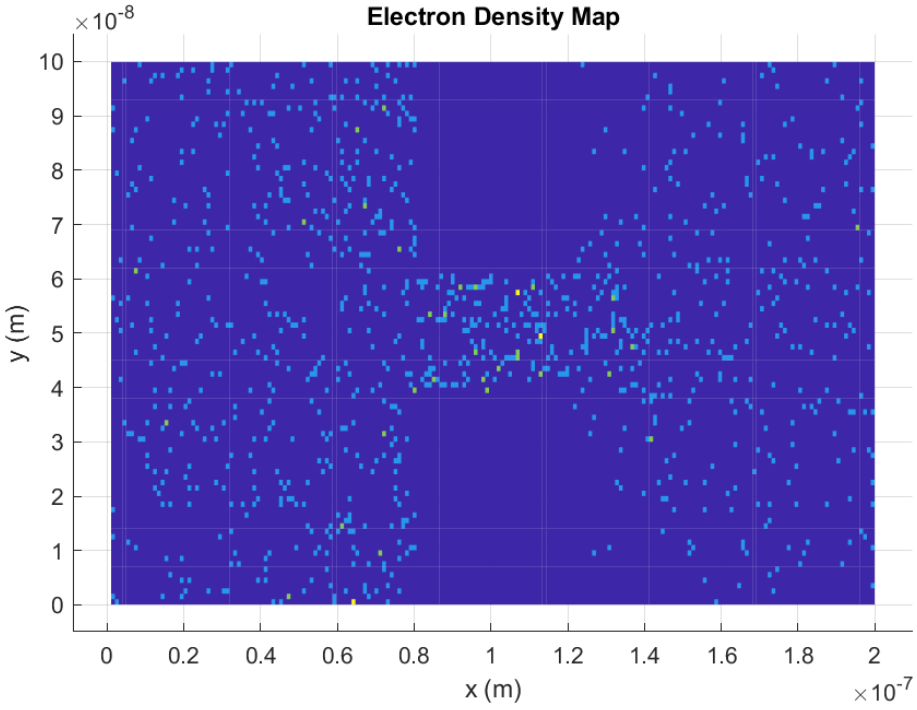

Figure 10: Electron Density map

Figure 10 above shows the density map of electrons in the semi-conductor with a potential applied. Note that it appears as if the density is relatively evenly spread on either side. However, when comparing this to the same density plot that has no potential applied, there is a large difference. With no potential, the electrons would be far more densely packed on the left side due to the bottleneck blocking them. With an x-direction potential applied pushing the electrons to the right, they tend to flow to the right, giving a more even dispersion with a constant flow of electrons.

c) Another step that can be taken that would make the simulation more realistic would be to add materials with different boundary conditions. The current perfect reflection is not realistic, and the dispersive reflection that can be applied still is not ideal. Some materials may absorb energy. Another improvement would be to add more precise collision between electrons. The current system gives each electron a probability to reflect that simply changes the speed and direction. Simulating actual collisions between electrons will add to the realism with a negative of being drastically less efficient for a reasonable number of electrons.