ELEC 4700
Assignment – 1

Monte-Carlo Modeling of Electron Transport

By: Alina Jacobson [101055071]

1 Electron Modelling (40)

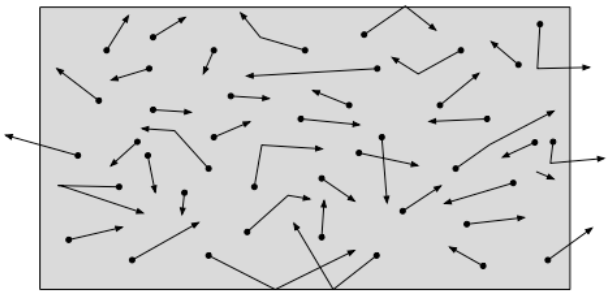


Figure 1. Semiconductor with a population of electrons moving with thermal velocities and scattering. [from assign1.pdf]

The modeling of the carriers as a population of electrons in an N-type Si semiconductor crystal.

The thermal velocity (Vth) describes the velocity of particles in the system. This system has a known mass and therefor the thermal velocity depends on the temperature (T) and universal constant (k = 1.38x10^-23 J/K).

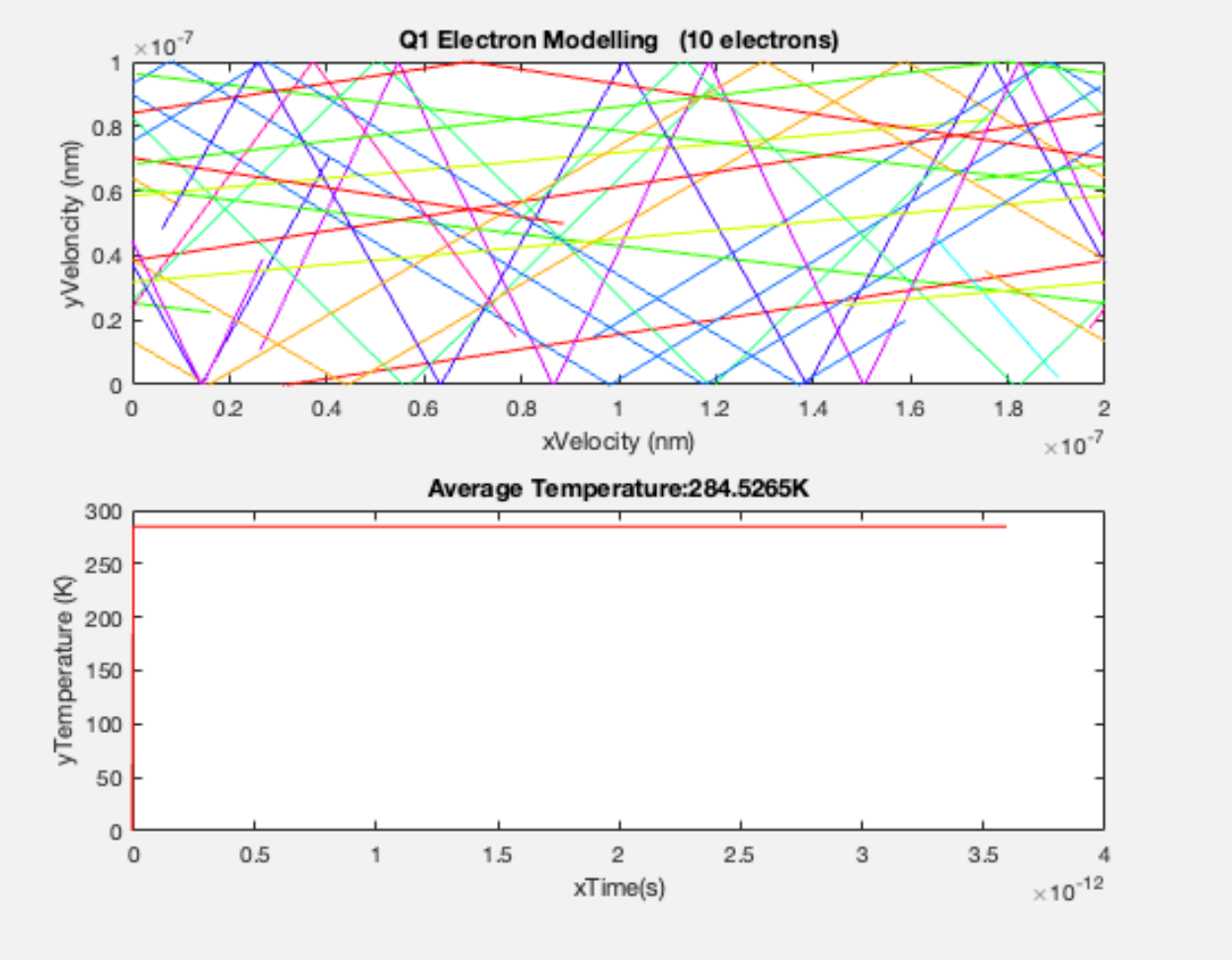
Therefor the thermal velocity of this system is calculated using the effective mass of electrons $m_n = 0.26m_0$ where m_0 = electron mass (9.11x10^-31 kg) is the rest mass, and assumed T = 300 k. Using the kinetic energy to form the thermal velocity equation.

$$V_{th} = \sqrt{\frac{2kT}{m_n}} = \sqrt{\frac{2(1.38x10^{-23})(300)}{0.26(9.11x10^{-23})}} = 1.8702\ x\ 10^5 = 187.02\ km/s \qquad (1)$$

If the mean time between collisions is $\tau_{mn} = 0.2$ ps then the mean free path (mfp) is calculated as follows.

$$mfp = \tau_{mn} * V_{th} = (0.2x10^{-12}) * (1.8702x10^5) = 3.7404x10^{-8} = 37.404\ ns \qquad (2)$$

Results of MATLAB simulator 2D particle trajectories. The iterations is 20 and the number of electrons is 30 with 20 to plot.



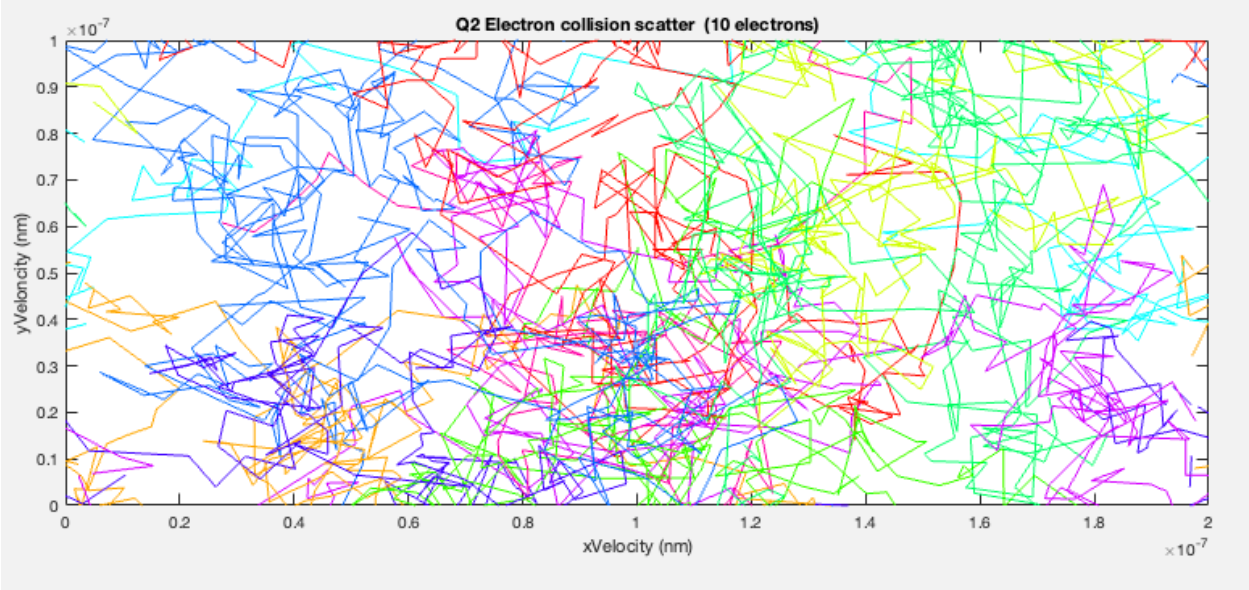
The electron projection in the top subplot shows them bounce off the top and bottom boundaries. The reflection from the boundaries is the angular projection where the electron continues to the other direction at the collision point.

It took multiple attempts to develop the temperature code, however, was able to obtain a result shown at lower subplot. The temperature of the system remained constant during the simulation but was different temperature and was not 300K. Maybe more electron in place to simulate the process would incur higher temperature. The average temperature obtained through out the simulation is 284.5265 K

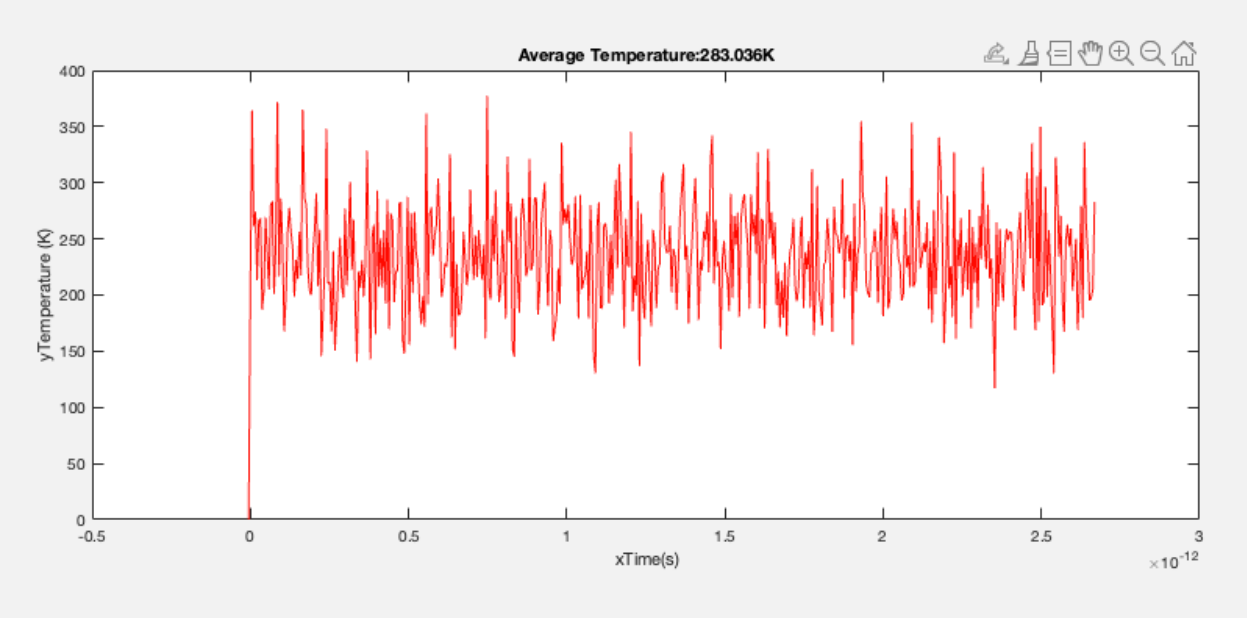
Include in Report a) v_{th} b) MFP c) i) 2-D plot of particle trajectories ii) Temperature plot

2 Collisions with Mean Free Path (MFP) (25)

Below is the result obtained from modelling the scattering of electrons using the exponential scattering probability equation: Pscat = 1 – e^(-dt/t_mn). The number of electrons plotted is 10 and the iterations is 20 ,and the number electrons is 30.



For the simulation of the temperature the value varied in range as the simulation progressed, the average temperature over the range is 283.036 K



The measured MFP from matlab was obtain by;

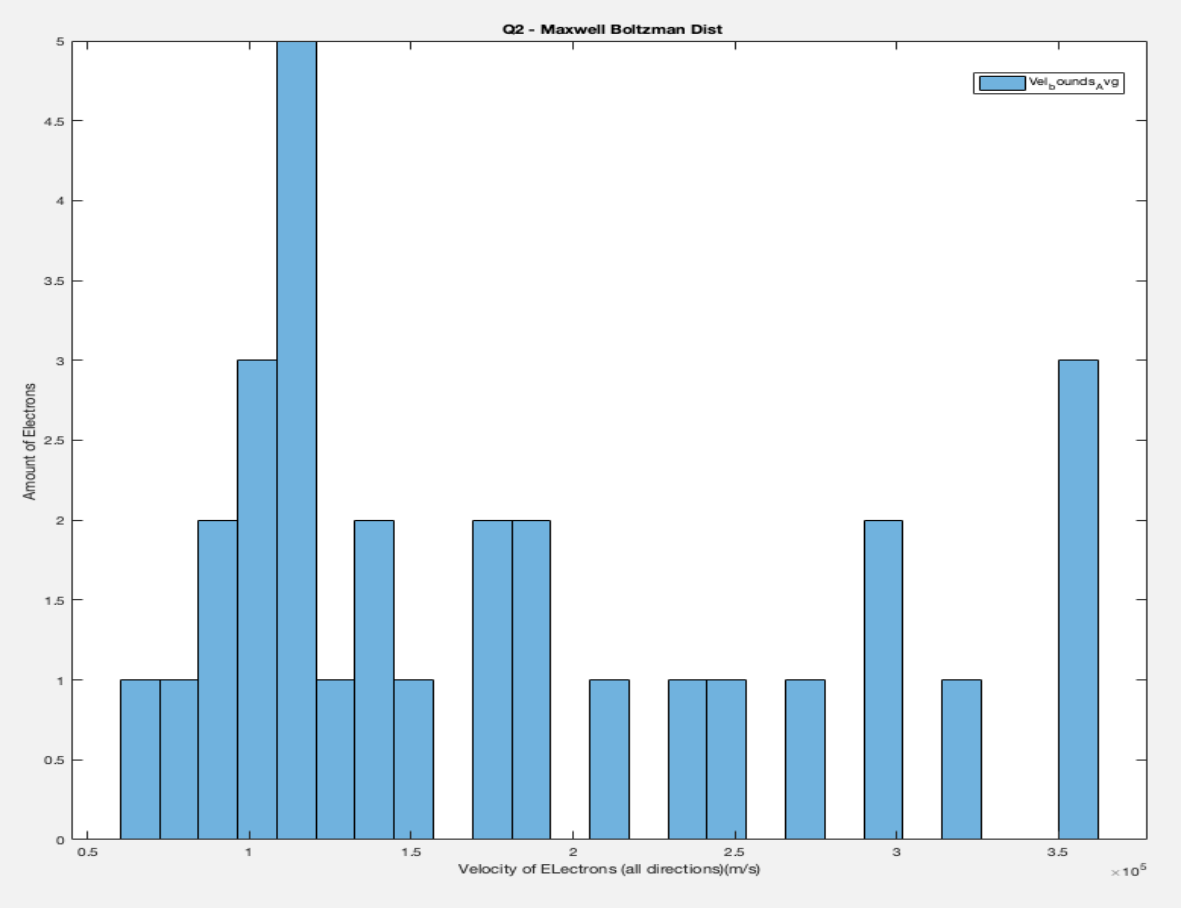
```
k_B = 1.38064852e-23;                % universal constant (Boltzman )
mass_o = 9.10938356e-31;             % in kg is the rest mass
m_n = 0.26*mass_o;                   % in kg is effective mass of electrons

%The thermal velocity vth - Assume T = 300 K and m_n.
V_thermal = sqrt(2*k_B*tempK/m_n);   % in m/s
t_mn = 0.2e-12;                      %mean time between collision
mean_fp = V_thermal*t_mn;            %mean free path = 3.7404e-8
```

the calculated mean_fp = 3.740382516073210e-08

The mean_fp from the scatter particles = 1.361140011979120e-06
The t_m_m from the scatter particles = 4.143573317476706e-13

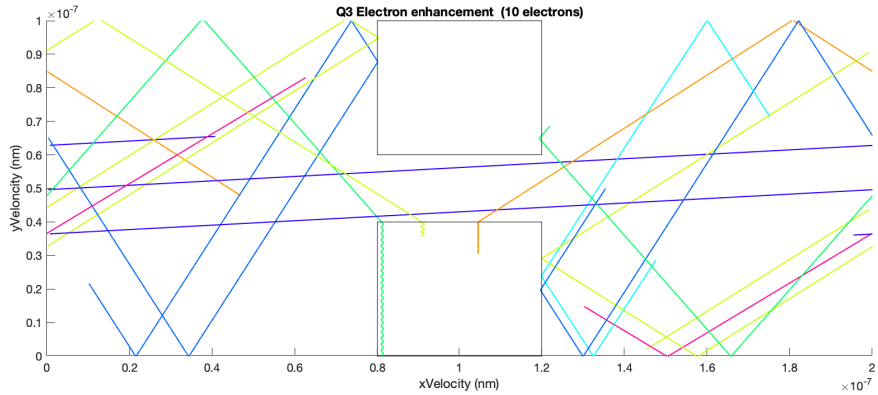
After processing the electron trajectory a Maxwell Boltzman was produced using MATLAB functions. Using 25 bins and the total velocity.

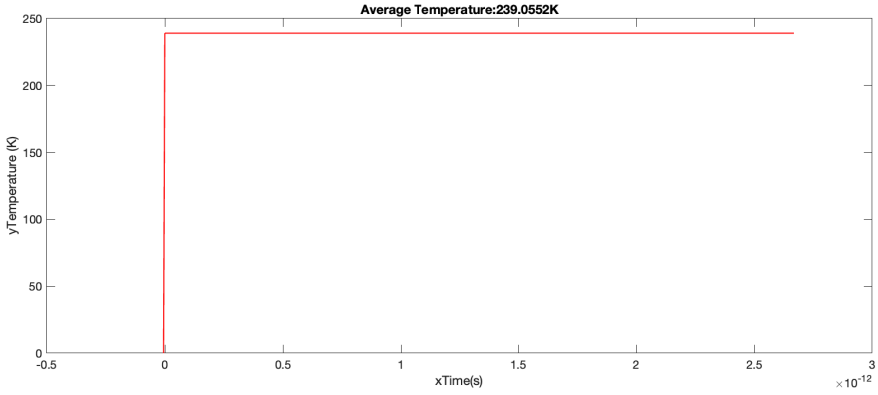


Include in Report a) Histogram b) 2-D plot of particle trajectories c) Temperature plot d) MFP and τ_{mn}

3 Enhancements (35)

The following shows a bottleneck added to the electron pathway. However there is issue with the code for pathways coming from the middle section. This plot shows the scatter turned off.





This plot shows the Electron Density at iteration = 100 and 30 particles.

There is no electron density plot or temperature plot

Include in Report a) 2-D plot of particle trajectories c) Electron density map d) Temperature map