Contents


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% Student Name: Patrobas Adewumi
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% ELEC 4700: The Physics and Modeling of Advanced Devices and Technologies
% Assignment#1: Monte-Carlo Modeling of Electron Transport
clearvars
clearvars -GLOBAL
close all

global C
global X Y
    C.q_0 = 1.60217653e-19;             % electron charge
    C.hb = 1.054571596e-34;             % Dirac constant
    C.h = C.hb * 2 * pi;                % Planck constant
    C.m_0 = 9.10938215e-31;             % electron rest mass
    C.kb = 1.3806504e-23;               % Boltzmann constant
    C.eps_0 = 8.854187817e-12;          % vacuum permittivity
    C.mu_0 = 1.2566370614e-6;           % vacuum permeability
    C.c = 299792458;                    % speed of light
    C.g = 9.80665;                      % metres (32.1740 ft) per s²

mn = 0.26*C.m_0;                        % effective masss of electron
Temp = 300;                             % In kelvin
runTime = 10000;                        % run time in timesteps
Tmn = 0.2e-12;                          % mean time between collisions
sizeX = 200e-9;                         % normal size of the region in x dir (length)
sizeY = 100e-9;                         % normal size of the region in y dir (width)

%%%%%%%%%%%%%%%%%%%%%%%% Electron Modelling %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Modeling the electrons in the silicon as particles with the effective %

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%%%% mass above using a simplistic Monte-Carlo model %%%%%%%%%%%%%%%%%%%%%%
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Thermal Velocity %%

Thermal velocity is the velocity that a particle in a system %%%%%%%%%%

would have if its kinetic energy were equal to the average energy %%%%%

of all the particles of the system.

%%

```
Vth = sqrt(2*C.kb*Temp/mn);
%%%%%%%%%%%%% Setting up the semiconductor region given %%%%%%%%%%%%%%%%%%%

size = 1000;
dispSize = 10;
%%%%%%%% Assigning each particle a random location in the x?y plane %%%%%%%
%%%%%%%% within the region defined by the extent of the Silicon %%%%%%%%%%%
X = rand(2,size);
Y = rand(2,size);

Pos_X(1,:)= X(1,:)*sizeX;
Pos_Y(1,:)= Y(1,:)*sizeY;
colour = rand(1,dispSize);

%%%%% Assigning each particle with the fixed velocity given by vth %%%%%%%%
%%%%% but give each one a random direction %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
angle(1,:) = X(2,:)*2*pi;

%%%%%%%%%%%%%%%%%% Collisions with Mean Free Path (MFP) %%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%% Normal distribution of velocity %%%%%%%%%%%%%%%%%%%%%%

sigma = sqrt(C.kb*Temp/mn)/4;
mu = Vth;
MB_dist = makedist('Normal',mu,sigma);
Vel = random(MB_dist,1,size);
Vel_X(1,:) = Vel(1,:).* cos(angle(1,:));
Vel_Y(1,:) = Vel(1,:).* sin(angle(1,:));

Vel_sum = sum(Vel)/size;
%%%%%%%%%%%%%%%%%%%%%%%%%% Histogram of velocity %%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%% Set timestep of function and variable change %%%%%%%%%%%%%%%%%%%%%%%%
spacStep = 0.01*sizeY;
dt = spacStep/Vth;
steps = 1000;

Vel_X(1,:) = Vel_X(1,:)*dt;
Vel_Y(1,:) = Vel_Y(1,:)*dt;
```

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Part 2

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%%%%%%%%%%%% Modeling the scattering of the electrons using an %%%%%%%%%%%%
%%%%%% exponential scattering probability %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Pscat = 1 - exp(-(dt/Tmn));

MFP_count = zeros(1,size);
calcTemp = zeros(1,size);

for i = 1:1:steps
    %%%%%%%%% Modeling the scattering of electrons using exp scat prob %%%%
    Scat = rand(1,size);
    ScatCheck = (Scat <= Pscat);
    angle(ScatCheck) = rand*2*pi;
    Vel = random(MB_dist,1,size);
    Vel_X(ScatCheck) = Vel(ScatCheck).*cos(angle(ScatCheck)).*dt;
```
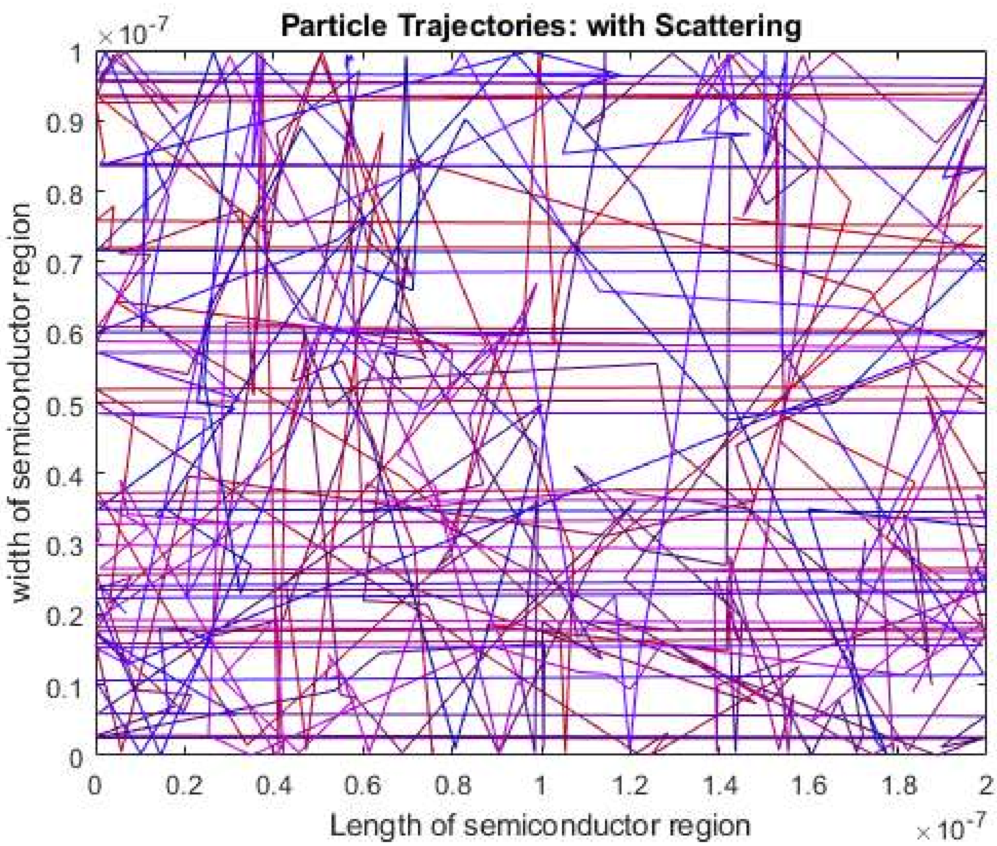
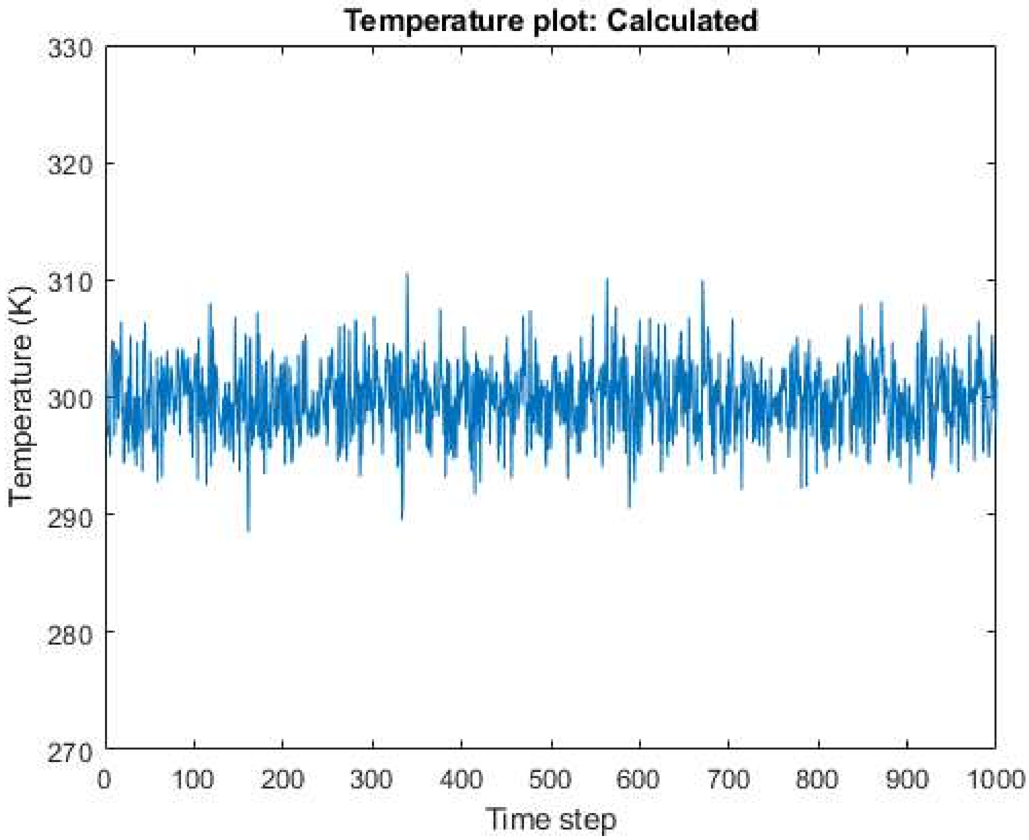
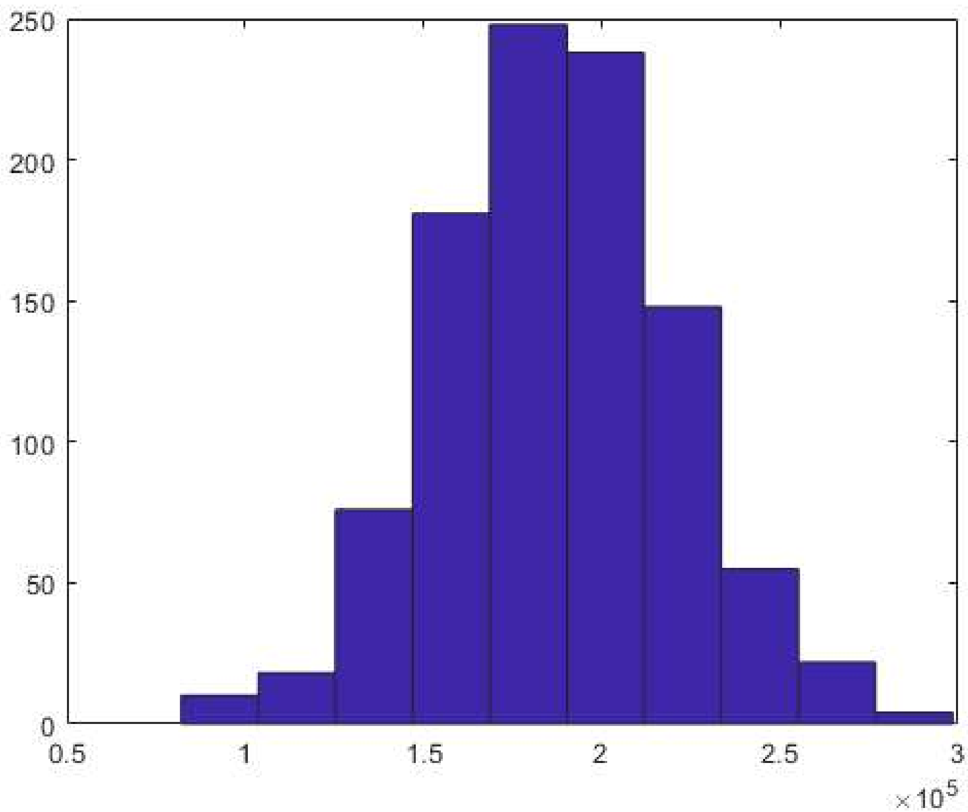

```
    Vel_Y(ScatCheck) = Vel(ScatCheck).*sin(angle(ScatCheck)).*dt;
    MFP_count(~ScatCheck) = MFP_count(~ScatCheck)+ spacStep;
    MFP_count(ScatCheck) = 0;


    CheckRHSPos_X = Pos_X + Vel_X > 2e-7;
    Pos_X(CheckRHSPos_X) = Pos_X(CheckRHSPos_X)+ Vel_X(CheckRHSPos_X)- sizeX;
    CheckLHSPos_X = Pos_X + Vel_X < 0;
    Pos_X(CheckLHSPos_X) = Pos_X(CheckLHSPos_X) + Vel_X(CheckLHSPos_X)+ sizeX;


    leftover = ~(CheckRHSPos_X | CheckLHSPos_X);
    Pos_X(leftover) = Pos_X(leftover) + Vel_X(leftover);

    %%%%%%%%%%%%%%%%%%%% Y boundary reflection %%%%%%%%%%%%%%%%%%%%%%%%%%%%
    checkPos_Y = (Pos_Y + Vel_Y >1e-7 | Pos_Y + Vel_Y < 0);
    Vel_Y(checkPos_Y) = Vel_Y(checkPos_Y).*(-1);
    Pos_Y(1,:) = Pos_Y(1,:)+ Vel_Y(1,:);

    %%%%%%%%%%% Semiconductor Temperature calculations %%%%%%%%%%%%%%%%
    mean_Vel = sum(Vel)/size;
    calcTemp(1,i) = mn*(mean_Vel)^2/(2*C.kb);

    %%%%%%%%%%%%%%% Mean Free Path calculation %%%%%%%%%%%%%%%%%%%%%%%%
    MFP = sum(MFP_count)/size;
    Tmn_avg = MFP/mean_Vel;

    %%%%%%%%%%% Setting up PlotsP %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    prev_Pos_X(i,:) = Pos_X(1,:);
    prev_Pos_Y(i,:) = Pos_Y(1,:);

end

figure(3)
for j = 1:1:dispSize

    plot(prev_Pos_X(:,j),prev_Pos_Y(:,j),'color',[colour(1,j) 0 j/dispSize])
    title('Particle Trajectories: with Scattering')
    xlabel ('Length of semiconductor region')
    ylabel ('width of semiconductor region')
    xlim([0 sizeX])
    ylim([0 sizeY])
    drawnow
    hold on
end

figure(4)
plot(linspace(1,size,size),calcTemp);
title('Temperature plot: Calculated')
xlabel('Time step')
ylabel('Temperature (K)')
ylim([270 330])

figure(5)
title('Velocity Histogram')
hist(Vel)

display('The Mean Free Path (MFP) of electrons using an exponential scattering probability and fo
und to be')
```

```
display(MFP)
display('The Mean Time Between Collisions is is found to be ')
display(Tmn_avg)
```

```
The Mean Free Path (MFP) of electrons using an exponential scattering probability and found to be

MFP =

   3.5142e-08

The Mean Time Between Collisions is is found to be

Tmn_avg =

   1.8741e-13
```







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