Contents


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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)
```

Publishing Documents with MATLAB

Part 1

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%%%%%%%%%%%%%%%%%%%%%%%% Electron Modelling %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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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.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

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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;
Vel_X(1,:) = Vth*cos(angle(1,:));
Vel_Y(1,:) = Vth*sin(angle(1,:));


%%%%% Set timestep of function and variable change %%%%%%%%%%%%%%%%%%%%%%%%
spacStep = 0.01*sizeY;
dt = spacStep/Vth;
timesteps = 1000;

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

AvgTemp = zeros(1,size);

% prev_Pos_X(1,:) = size(Pos_X(1,:));
% prev_Pos_Y(1,:) = size(Pos_Y(1,:));

figure (1)
for i = 1:1:timesteps
    %%%%%%%%%%% Particle Reflection %%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%% RHS period boundary condition check %%%%%%%%%%%%%%%
    CheckRHSPos_X = Pos_X + Vel_X > 2e-7;
    Pos_X(CheckRHSPos_X)=Pos_X(CheckRHSPos_X) + Vel_X(CheckRHSPos_X)- sizeX;

    %%%%%%% LHS period boundary condition check %%%%%%%%%%%%%%%
    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);

    %%%%%%%%%%% Particle 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,:);
```
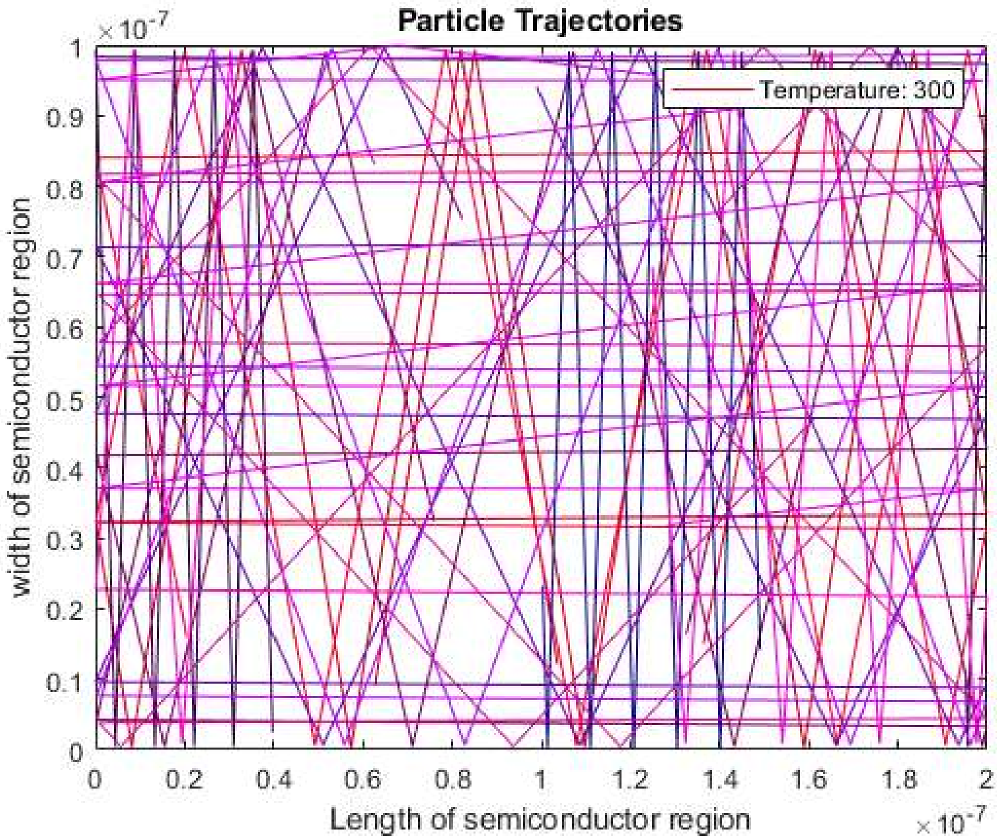
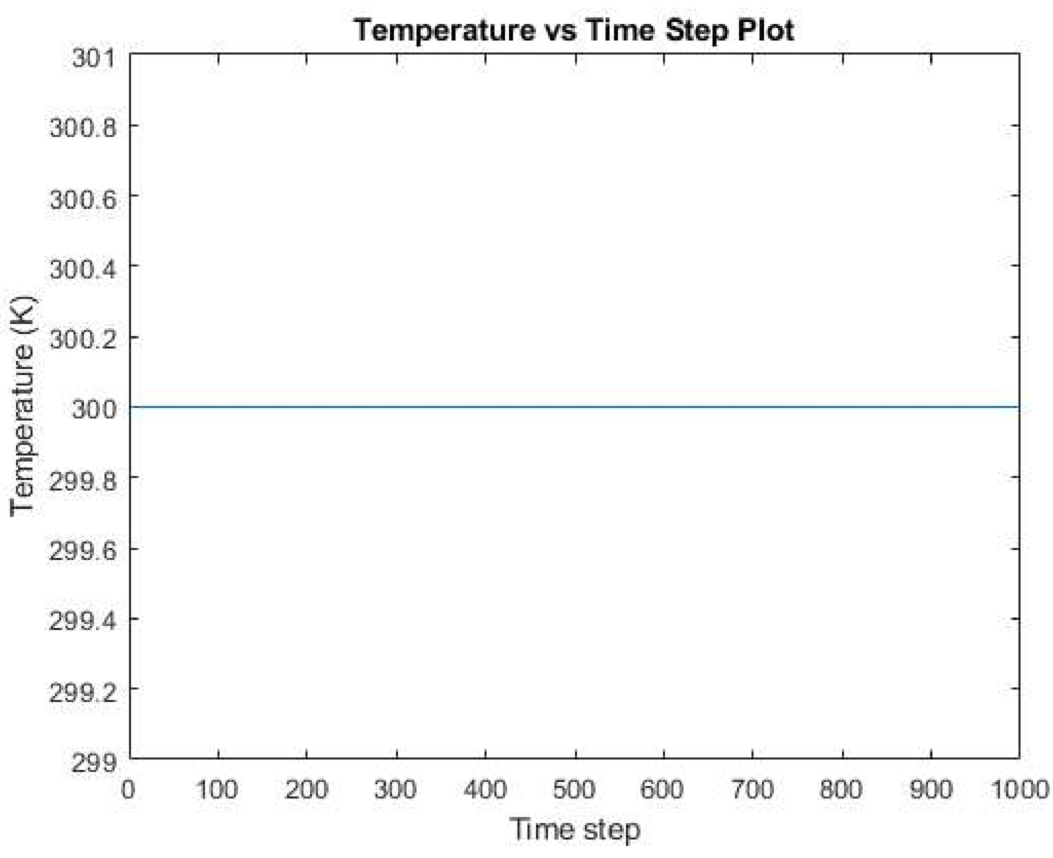

```
    %%%%%%%%%%% Semiconductor Temperature calculations %%%%%%%%%%%%%%%
    Xtmep_sum = sum((Vel_X/dt).^2);
    Ytemp_sum = sum((Vel_Y/dt).^2);
    calcTemp = mn*((Ytemp_sum)+(Xtmep_sum))/(2*C.kb);
    AvgTemp(1,i) = calcTemp/size;

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



for j = 1:1:dispSize

     plot(prev_Pos_X(:,j),prev_Pos_Y(:,j),'color',[colour(1,j) 0 j/dispSize])
     title('Particle Trajectories')
     xlabel ('Length of semiconductor region')
     ylabel ('width of semiconductor region')
     xlim([0 sizeX])
     ylim([0 sizeY])
     legend(['Temperature: ' num2str(sum(AvgTemp)/size)])
     drawnow
     hold on
end

figure(2)
plot(linspace(1,size,size),AvgTemp);
title('Temperature vs Time Step Plot')
xlabel('Time step')
ylabel('Temperature (K)')

display('The thermal velocity, Vth asuming a temperature of 300K is')
display(Vth)
display('The Mean Free Path given a mean time between collision of 0.2 ps is')
display(Vth*Tmn)
```

```
The thermal velocity, Vth asuming a temperature of 300K is

Vth =

   1.8702e+05

The Mean Free Path given a mean time between collision of 0.2 ps is
   3.7404e-08
```


Particle Trajectories
Temperature: 300
width of semiconductor region
Length of semiconductor region


Temperature vs Time Step Plot
Temperature (K)
Time step