```
%clear all


%          ELEC 4700 - Assignment 3          %
%    Monte-Carlo/Finite Difference Method    %
%            Patrobas Adewumi                %
%            Sunday, March 17, 2019          %
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 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;                          %   Electron mass
Temp = 300;                             %   Given in kelvin
rTime = 10000;                            %   Run time in timesteps
MTBC = 0.2e-12;
Vleft = 0.1;                            %   Voltage of left side
electronConc = 10e15;


Vth = sqrt(2*C.kb*Temp/mn);             %  Thermal velocity

%   Establish inital electron positions
%   Working area 200nm x 100nm

workX = 200*10^-9;
workY = 100*10^-9;
area = workX*workY;

size = 1000;
displaySize = 10;

X = rand(2,size);
Y = rand(2,size);

%   Positions initialize
Xpos(1,:)= X(1,:)*workX;
Ypos(1,:)= Y(1,:)*workY;

colour = rand(1,displaySize);
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%   For normal distribution of velocity
Vthn = Vth/sqrt(2);
Xvel = Vthn*randn(1,size);
Yvel = Vthn*randn(1,size);

%   Set timestep of function
spacStep = 0.01*workY;
dt = spacStep/Vth;
steps = 1000;

%   Variable change
Xvel(1,:) = Xvel(1,:)*dt;
Yvel(1,:) = Yvel(1,:)*dt;

%   Percent scatter
Pscat = 1-exp(-(dt/MTBC));

MFPcount = zeros(1,size);

Efield = Vleft/workX;
force = Efield*C.q_0;
acceleration = force/mn;
accelVelocity = acceleration*(dt^2);

figure(1)
currentHistory = zeros(1,steps);

for i = 1:1:steps


    Xvel(:,:) = Xvel(:,:) + accelVelocity;  %Accelerate velocities

    %   Scattering
    scattered = rand(1,size);
    scatterCheck = scattered <= Pscat;
    velocity = Vthn*randn(1,size);
    Xvel(scatterCheck) = velocity(scatterCheck)*dt;
    velocity = Vthn*randn(1,size);
    Yvel(scatterCheck) = velocity(scatterCheck)*dt;
    tvelocity = sqrt((Xvel/dt).^2 +(Yvel/dt).^2);
    MFPcount(~scatterCheck) = MFPcount(~scatterCheck) + spacStep;

    % Position advance and Logical indexing
    checkXright = Xpos + Xvel > 2e-7;
    Xpos(checkXright) = Xpos(checkXright)+ Xvel(checkXright)- workX;
    checkXleft = Xpos + Xvel<0;
    Xpos(checkXleft) = Xpos(checkXleft) + Xvel(checkXleft) + workX;

    % Leftover x
    leftover = ~(checkXright | checkXleft);

    Xpos(leftover) = Xpos(leftover) + Xvel(leftover);
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```
    % Reflect Y boundary
    checkY = (Ypos + Yvel > 1e-7 | Ypos + Yvel<0);
    Yvel(checkY) = Yvel(checkY).*(-1);
    Ypos(1,:) = Ypos(1,:)+ Yvel(1,:);

    % Temperature calculations
    calcTemp = 0.5*mn*(tvelocity.^2)/(2*C.kb);
    averageTemp = sum(calcTemp)/size;

    % MFP calculation
    MFP = sum(MFPcount)/size;

    %   Current tracking
    avgVel = sum(tvelocity)/size;
    mu = (avgVel)/Efield;
    currentHistory(i) = C.q_0*electronConc*mu*Efield/area;

    %   Plotting here
    prevX(i,:) = Xpos(1,:);
    prevY(i,:) = Ypos(1,:);
end

for j = 1:1:displaySize
        plot(prevX(:,j),prevY(:,j),'color',[colour(1,j) 0 j/
displaySize])

        xlim([0 workX])
        ylim([0 workY])
        hold on
        drawnow
end
title('Plot of Particle Trajectories'),xlabel('X direction'),ylabel('Y
 direction')
hold off

figure(2)
plot(linspace(1,steps,steps),currentHistory)
title('Current Plot')
xlabel('Time step')
ylabel('Current')

%   Display for submission
disp('Electric Field:')
disp(Efield)
disp('Force')
disp(force)
disp('Acceleration')
disp(acceleration)

disp('current = q*n*mu*E/area')
%   Temperature maps
resX = 25;
resY = 25;
Xedges = linspace(0,workX,resX);
```

```
Yedges = linspace(0,workY,resY);

Xbins = discretize(Xpos,Xedges);
Ybins = discretize(Ypos,Yedges);

binTemp = zeros(resX,resY);
for k = 1:1:resX
    for L = 1:1:resY
        logicX = Xbins == k;
        logicY = Ybins == L;
        logic = logicX & logicY;
        sumX = sum(Xvel(logic))/dt;
        sumY = sum(Yvel(logic))/dt;
        meanvel = sqrt((sumX)^2+(sumY)^2);
        binTemp(k,L) = mn*(meanvel)^2/(2*C.kb);
    end
end

figure(3)
surf(binTemp)
xlim([1 resX])
ylim([1 resY])
title('Temperature Map')
colorbar;

%   Density map
resX = 25;
resY = 25;
Xedges = linspace(0,workX,resX);
Yedges = linspace(0,workY,resY);

Xbins = discretize(Xpos,Xedges);
Ybins = discretize(Ypos,Yedges);

binDens = zeros(resX,resY);
for k = 1:1:resX
    for L = 1:1:resY
        logicX = Xbins == k;
        logicY = Ybins == L;
        logic = logicX & logicY;
        binDens(k,L) = sum(Xbins(logic))/k + sum(Ybins(logic))/L;
    end
end

figure(4)
surf(binDens)
title('Density Map')
xlim([1 resX])
ylim([1 resY])
colorbar;
```

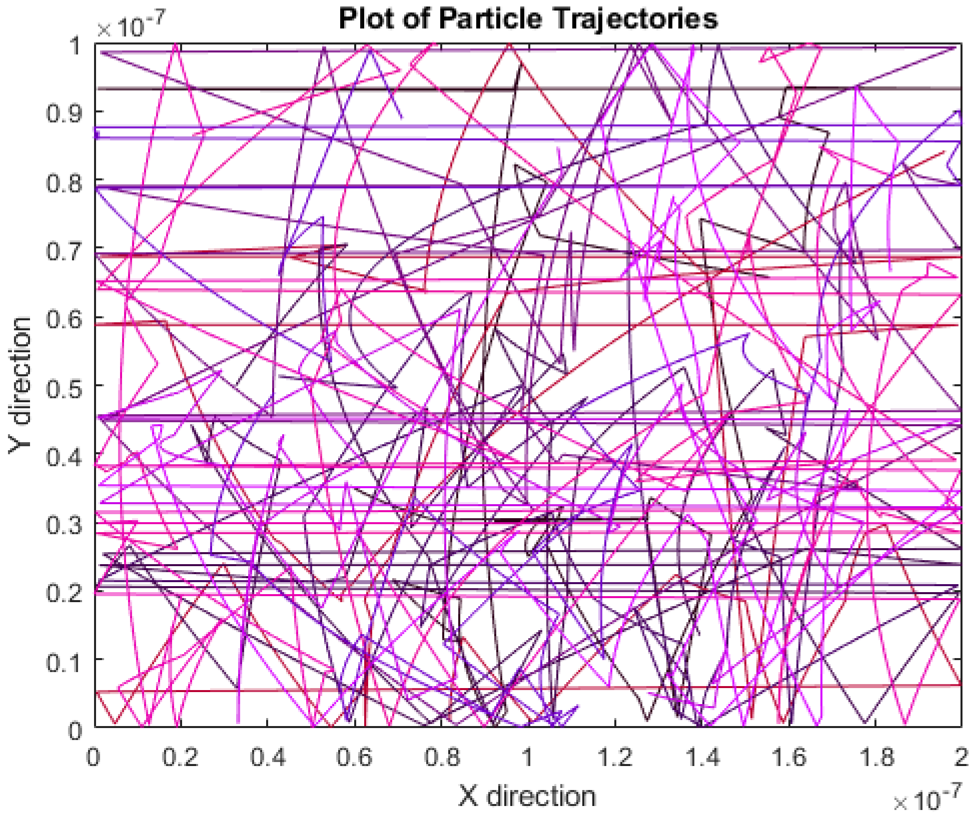
Electric Field:

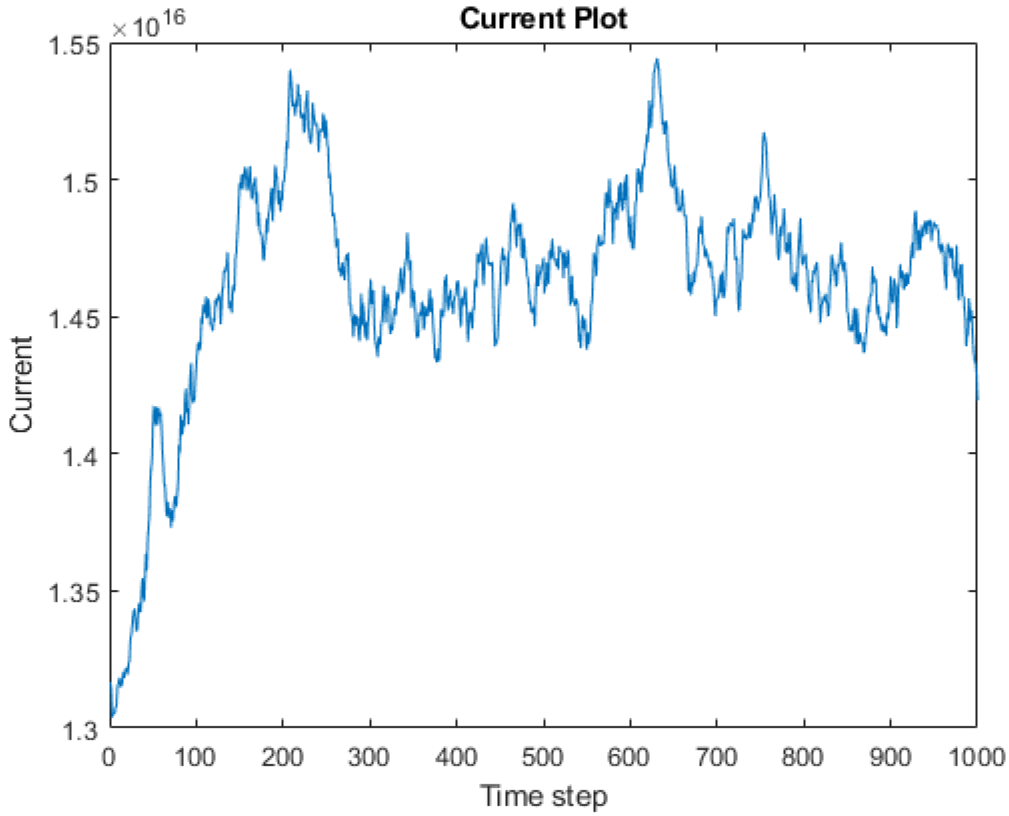
500000

```
Force
   8.0109e-14

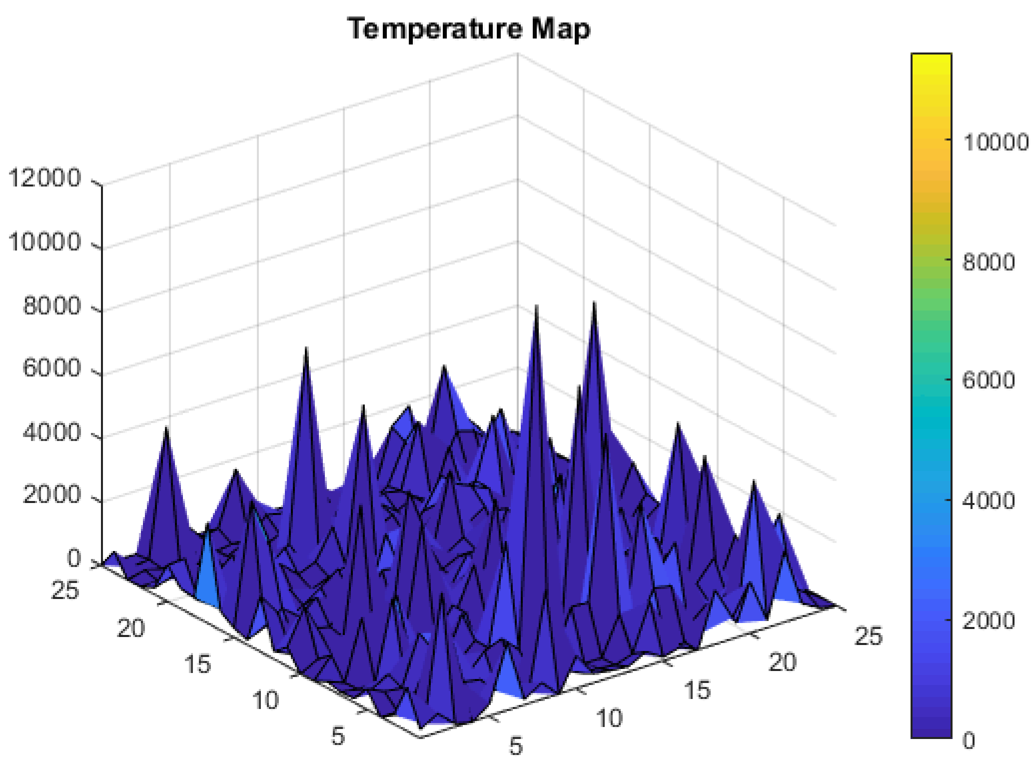
Acceleration
   3.3823e+17

current = q*n*mu*E/area
```

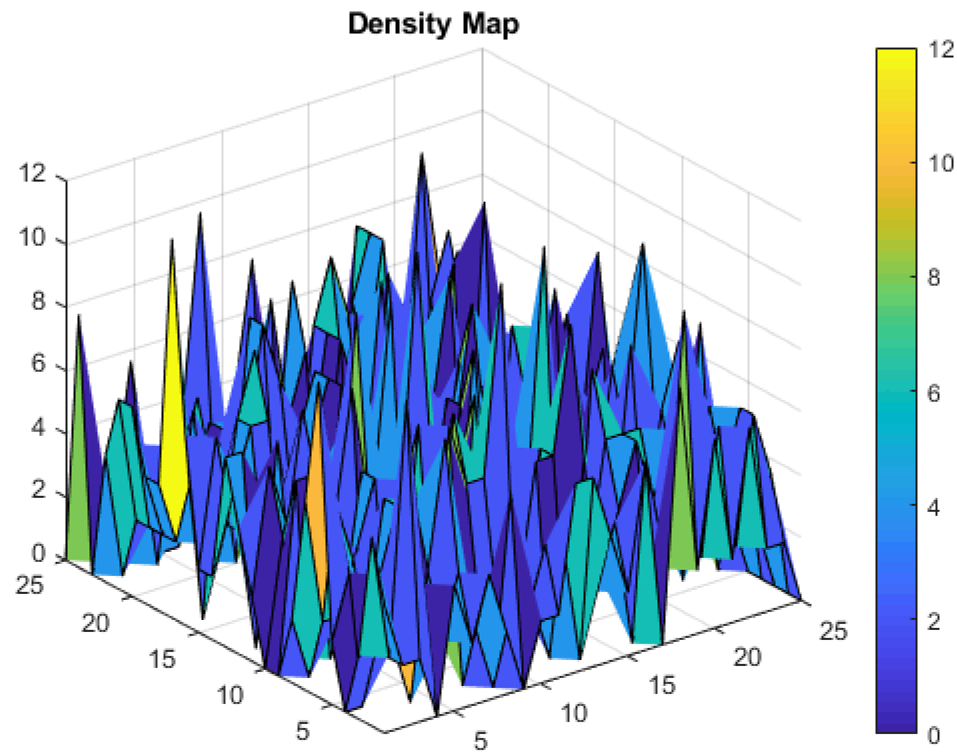




Current Plot
$\times 10^{16}$
1.55
1.5
1.45
1.4
1.35
1.3
Current
0
100
200
300
400
500
600
700
800
900
1000
Time step



Temperature Map
12000
10000
8000
6000
4000
2000
0
25
20
15
10
5
5
10
15
20
25
10000
8000
6000
4000
2000
0



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