Contents


```
function assign1
```

Monte-Carlo Modeling of Electron Transport

ELEC 4700 Assignment - 1 Braden Bale (101072763)

1. Code Comments

First, given variables are assigned values where kB is Boltzmann constant, m0 is the rest mass of an electron, mn is the effective mass of an electron, iterations contains the amount of iterations to un through the for loop, dt is the given timestep, time is an array which contains each time step,T is the assumed temperature in K, tmn is the mean time between collisions as given in seconds, w is the width of the plotting area in nm, h is the height of the plotting area in nm, and NE is the number of electrons to be simulated.

```
set(0, 'DefaultfigureWindowStyle','docked')

close all

kB = 1.38066e-23;
m0 = 9.11e-31;
mn = 0.26*m0;

iterations = 75;

dt = 0.01e-12;

time = zeros(1, 1);

T = 300;
tmn = 0.2e-12;

w = 200e-9;
h = 100e-9;

NE = 10000;
```

From the setup variables above, the thermal velocity can be found as shown below.

```
thm_v = sqrt((2*kB*T)/mn);
```

When the thermal velocity is found the mean free path is found below as thethermal velocity multiplied by the mean time between colisions.

```
lmn = thm_v * tmn;
```

Finally, with the variables set up the initial electron positions are set using the randn() function.

```
x = rand(NE, 1)*w;
y = rand(NE, 1)*h;
```

To ensure electrons are not initialized in the boxes they are pushed to the left or right depending on their position.

```
for j = 1:NE
    if(x(j) < 120e-9) && (x(j) > 80e-9)
        if x(j) > 100e-9
            x(j) = x(j) + (20e-9);
        else
            x(j) = x(j) - (20e-9);
        end
    end
end
```

The previous x and y positions are initialized with the positions of the electrons.

```
xp = x;
yp = y;
```

The velocities of the electrons in the x and y direction are intialized using randn() and multiplying by half of the thermal velocity.

```
vx = 1*sqrt((kB*T)/mn)*randn(NE, 1);
vy = 1*sqrt((kB*T)/mn)*randn(NE, 1);
```

The boxes are intialized below by using classes.

```
box = {};
box{1}.x = [80e-9 120e-9];
box{1}.y = [60e-9];

box{2}.x = [80e-9 120e-9];
box{2}.y = [40e-9];
```

Figure 1 is a histogram representing the average velocity of each intialized electron.

```
figure(1)
histogram(sqrt(vx.^2 +vy.^2), 100);
title('Average Velocity Histogram')

ntraj = 10;
electrons = [1:ntraj];
TrajColours = hsv(ntraj);
```

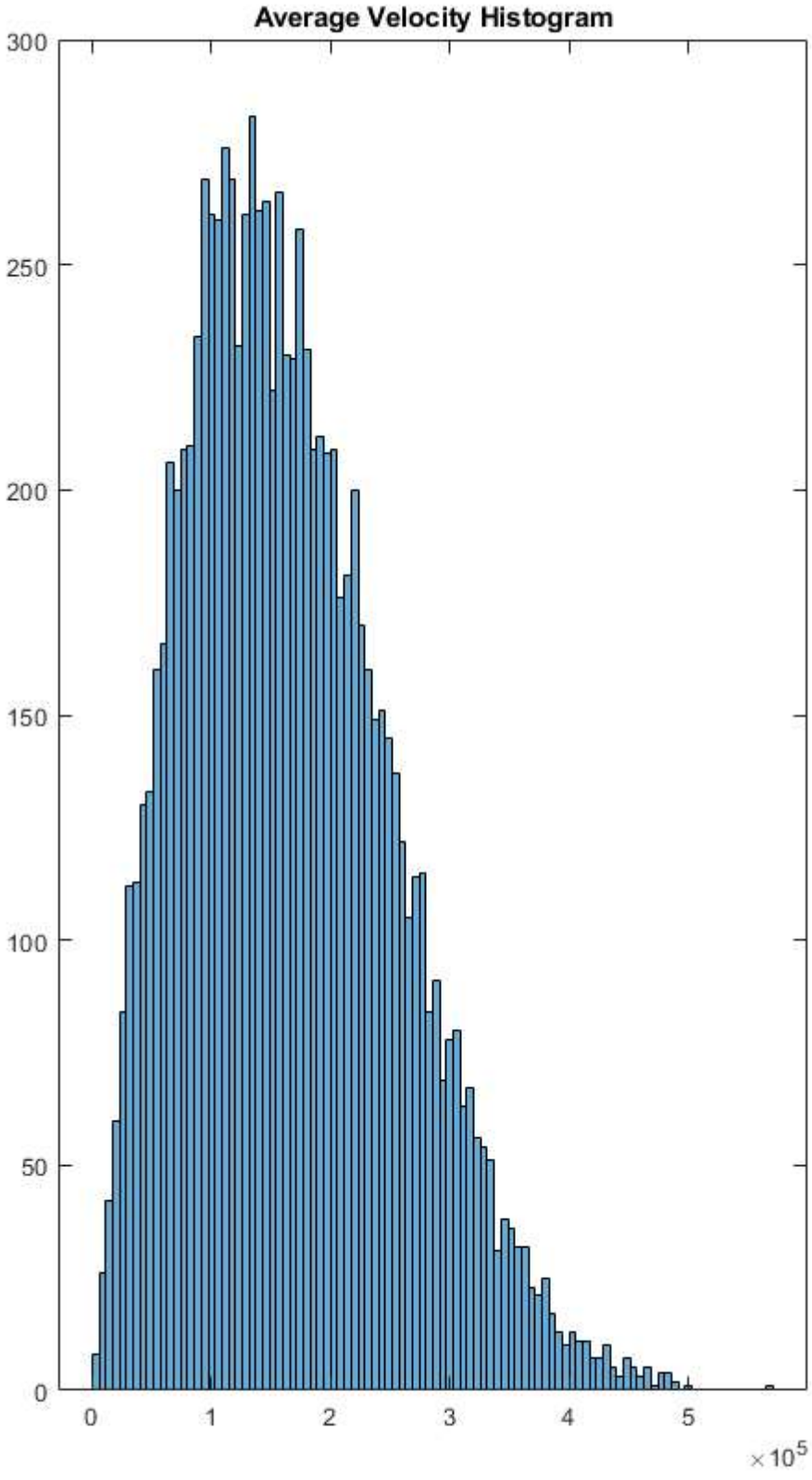
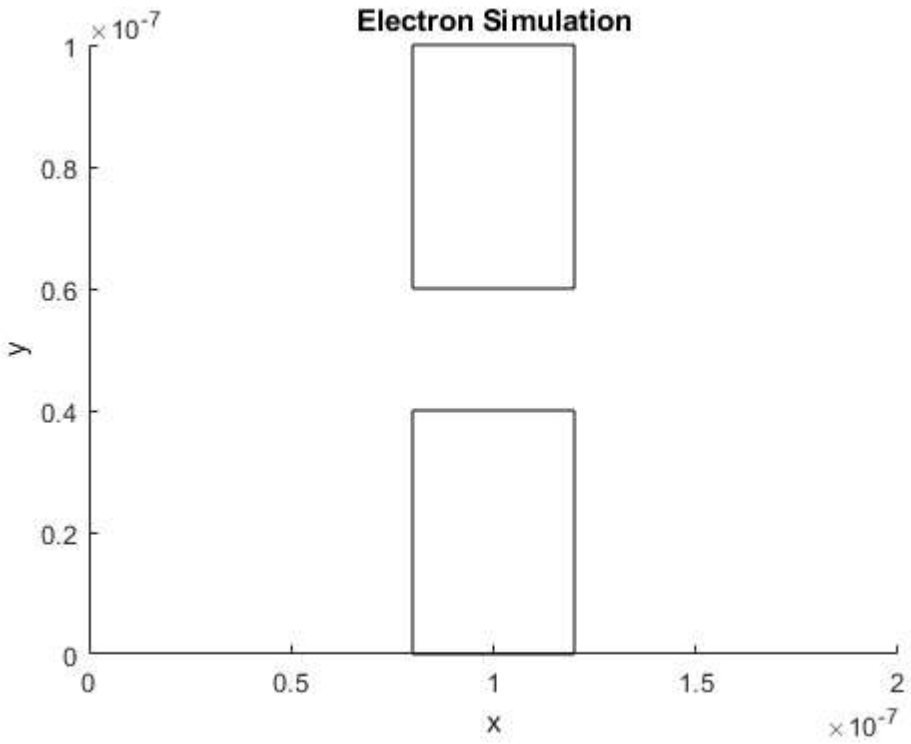


Figure 2 is set up using the traj() function which displays the electrons and their trajectory.

```
figure(2)
subplot(2,1,1)
hold on
traj(electrons, xp, x, yp, y, TrajColours, w, h);
pause(0.01);
axis([0 w 0 h])
```



A second part of Figure 2 is a plot of the average temperature over time for the electron plot.

```
avev = sqrt(vy.^2 + vx.^2);
avet = ((avev.^2)*mn)/(2*kB);
sumavt(1) = (sum(avet)/NE);
```

The for loop runs based off number of iterations.

```
for i = 1: iterations
```

First, a new time is added to the time array and the new x and y positions are updated.

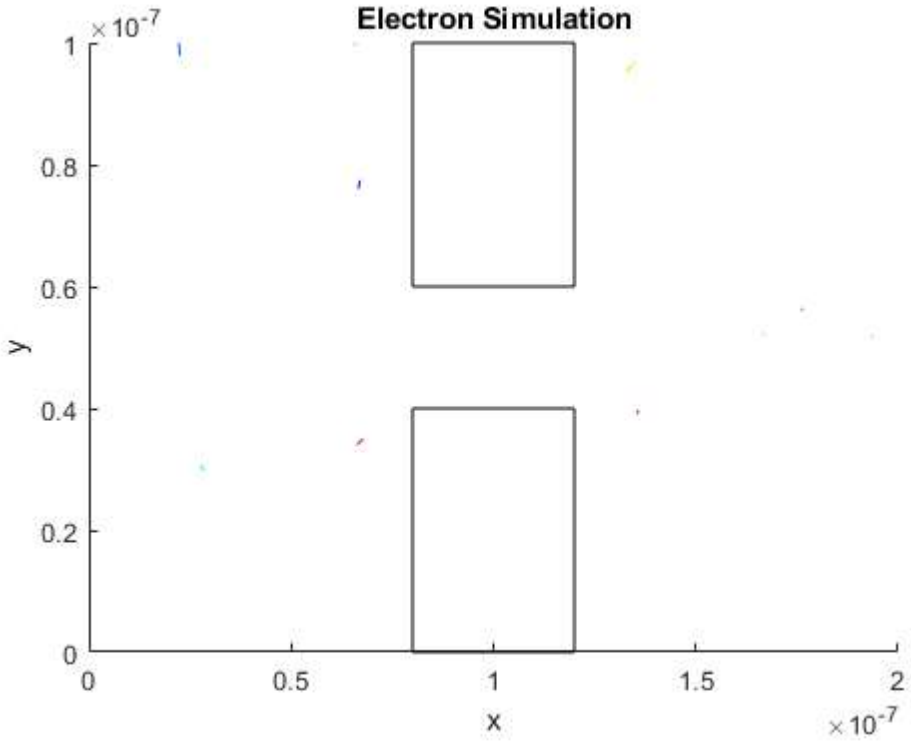
```
    time1 = i*dt;
    time = cat(1, time, time1);
    dx = vx*dt;
    dy = vy*dt;
    x = xp + dx;
    y = yp + dy;
```

Lines 138 through 169 and 191 through 203 house limits to meet the expectations given. Where variables b1* and b2* deal with box one and two, y*t and x*t apply to the axes. Also, the commented code below changes the boxes to specular behaviour, while the currently active code is diffusive behaviour.

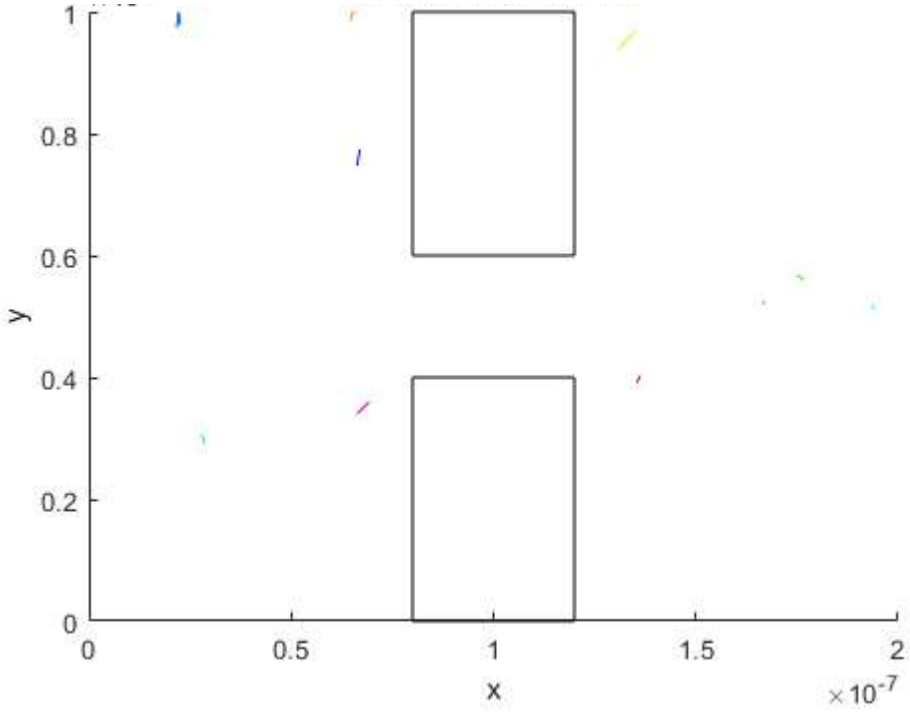
```
    b1l = (x >= 80e-9) & (x <= 120e-9) & (xp <= 80e-9) & (y >= 60e-9);
    b1r = (x >= 80e-9) & (x <= 120e-9) & (xp >= 120e-9) & (y >= 60e-9);
    b1b = (x >= 80e-9) & (x <= 120e-9) & (yp <= 60e-9) & (y >= 60e-9);

    b2l = (x >= 80e-9) & (x <= 120e-9) & (xp <= 80e-9) & (y <= 40e-9);
    b2r = (x >= 80e-9) & (x <= 120e-9) & (xp >= 120e-9) & (y <= 40e-9);
    b2t = (x >= 80e-9) & (x <= 120e-9) & (yp >= 40e-9) & (y <= 40e-9);

    x(b1l) = box{1}.x(1);
    x(b1r) = box{1}.x(2);
    y(b1b) = box{1}.y;

    x(b2l) = box{2}.x(1);
    x(b2r) = box{2}.x(2);
    y(b2t) = box{2}.y;

%     SPECULAR
%     vx(b1l) = -vx(b1l);
%     vx(b1r) = -vx(b1r);
%     vy(b1b) = -vy(b1b);
%
%     vx(b2l) = -vx(b2l);
%     vx(b2r) = -vx(b2r);
%     vy(b2t) = -vy(b2t);
%   DIFFUSIVE
    vx(b1l) = -abs(1*sqrt((kB*T)/mn))*randn(length(NE), 1);
    vx(b1r) = abs(1*sqrt((kB*T)/mn))*(randn(length(NE), 1));
    vy(b1b) = -abs(1*sqrt((kB*T)/mn))*(randn(length(NE), 1));

    vx(b2l) = -abs(1*sqrt((kB*T)/mn))*(randn(length(NE), 1));
    vx(b2r) = abs(1*sqrt((kB*T)/mn))*(randn(length(NE), 1));
    vy(b2t) = abs(1*sqrt((kB*T)/mn))*(randn(length(NE), 1));
```

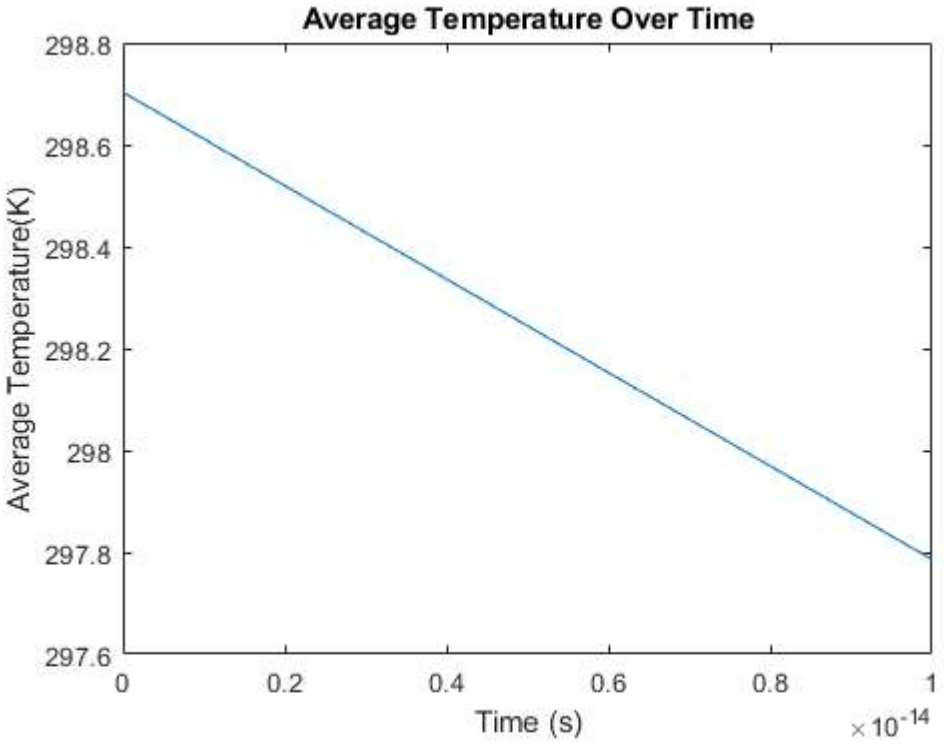
After having the limit tests applied the new positions of x and y along with their trajectories are plotted.

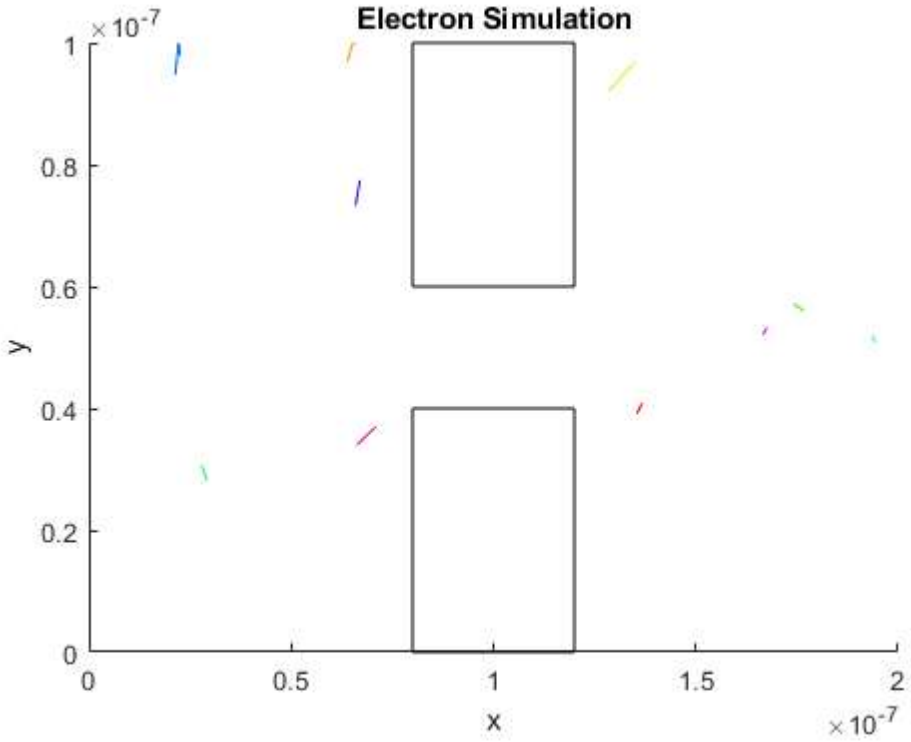
```
    subplot(2,1,1)
    traj(electrons, xp, x, yp, y, TrajColours, w, h);
    pause(0.01);
```

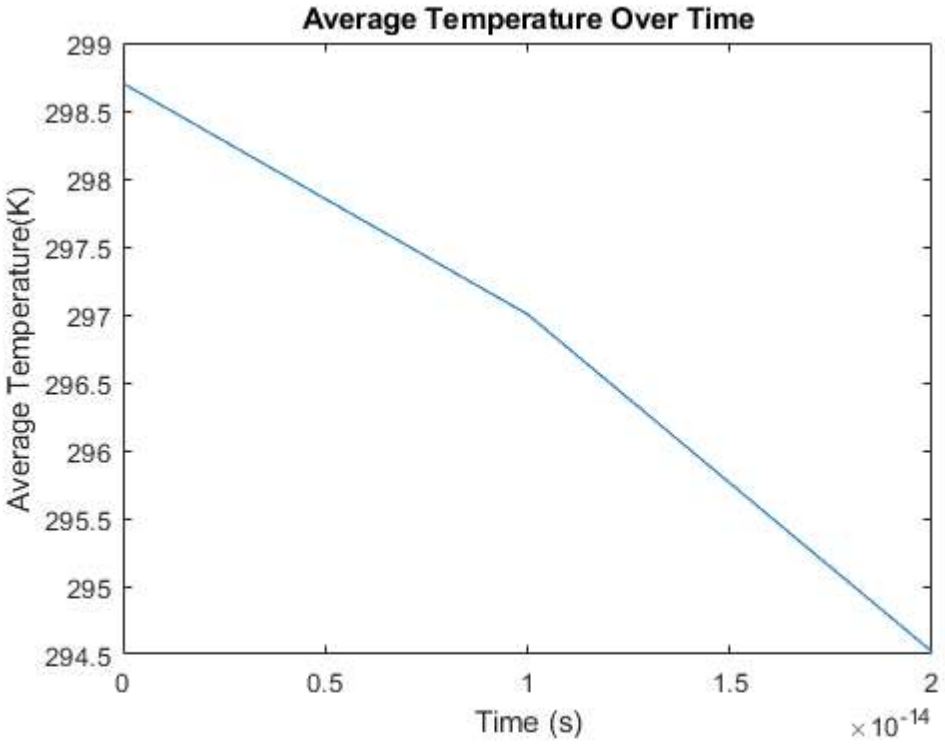

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

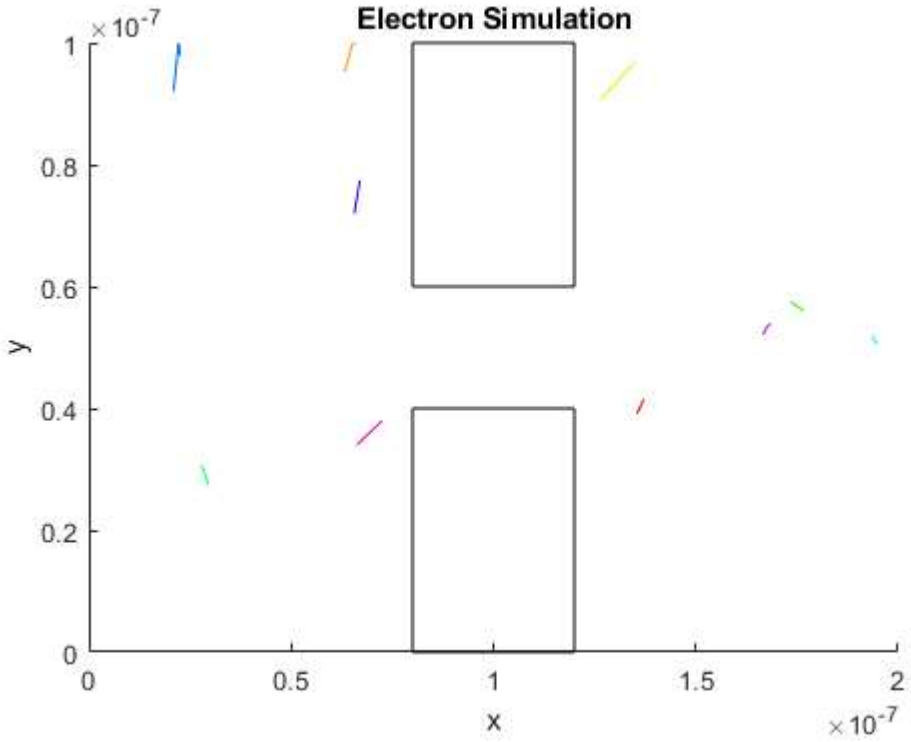
×10^-7
Electron Simulation

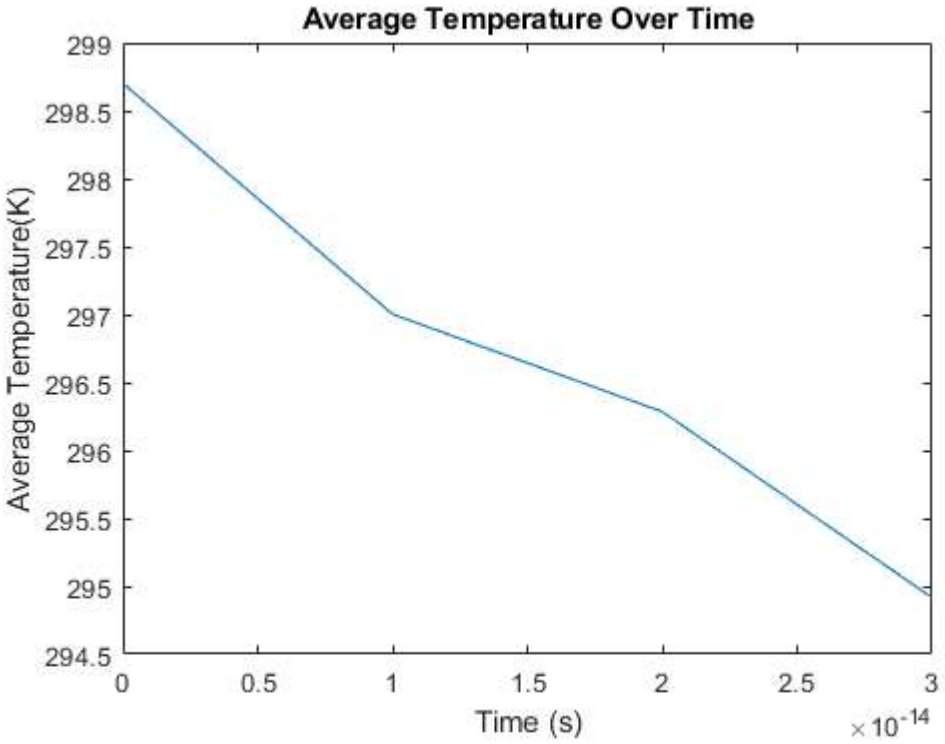

1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

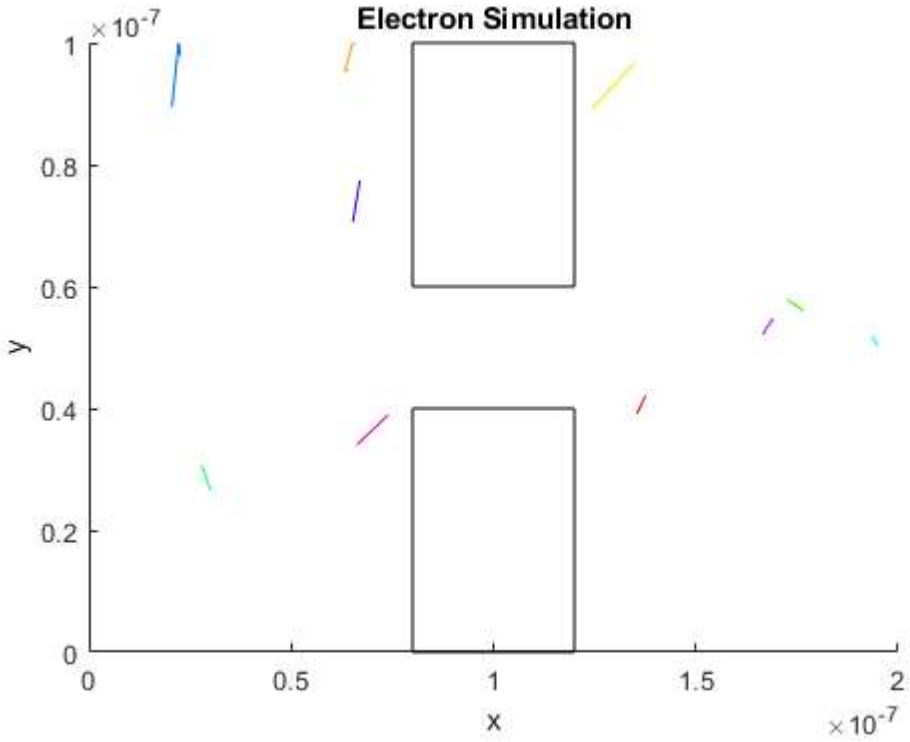

Average Temperature Over Time
298.8
298.6
298.4
298.2
298
297.8
297.6
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
Time (s)
×10^-14

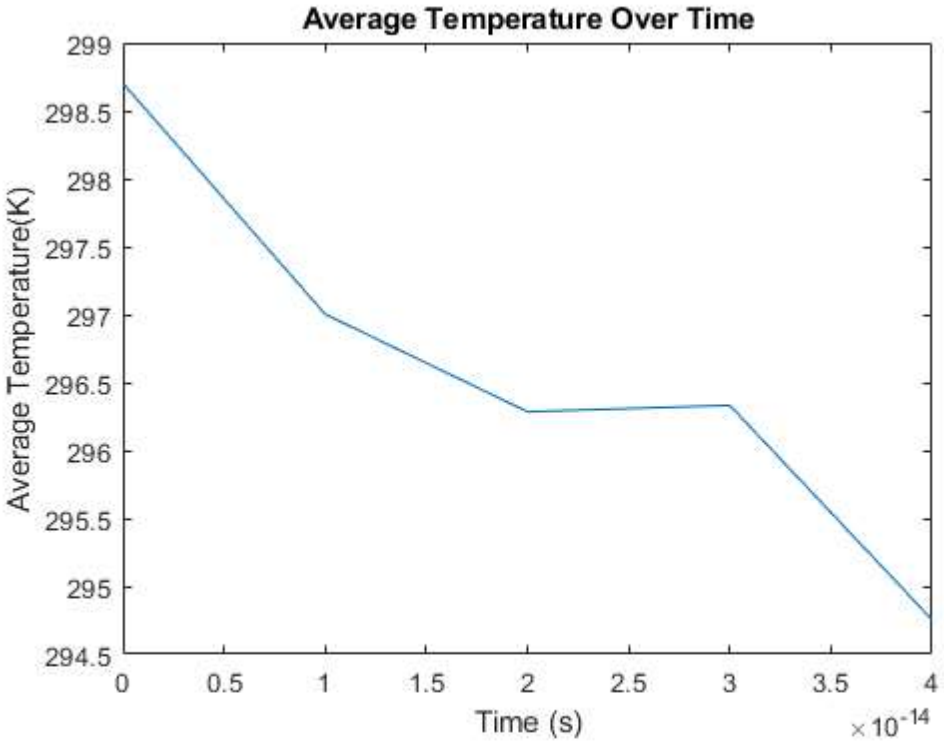

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

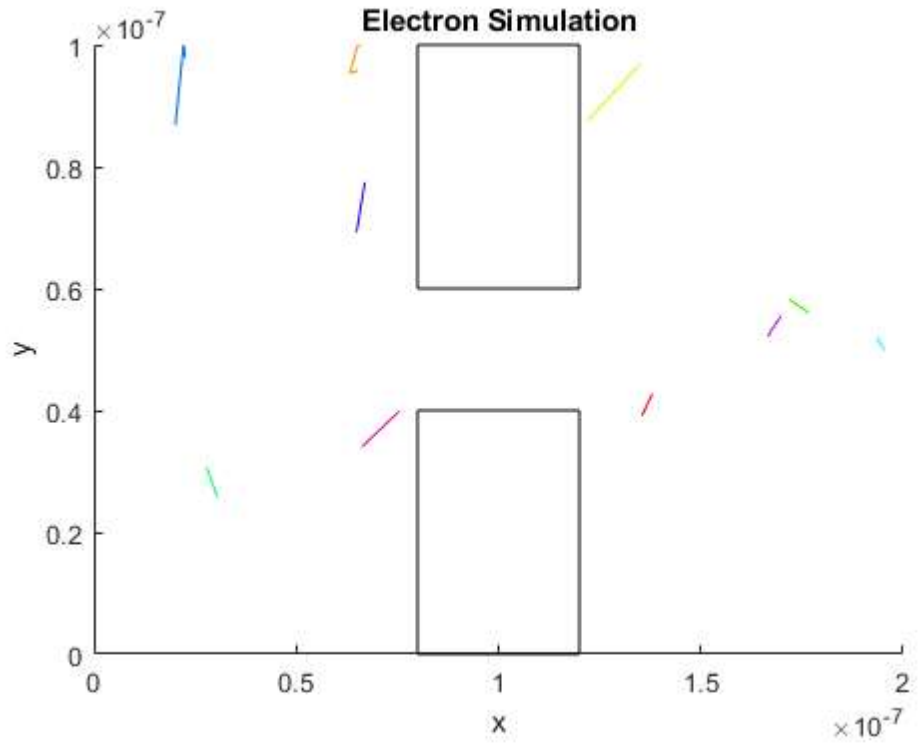

Average Temperature Over Time
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
Average Temperature(K)
0
0.5
1
1.5
2
Time (s)
×10^-14

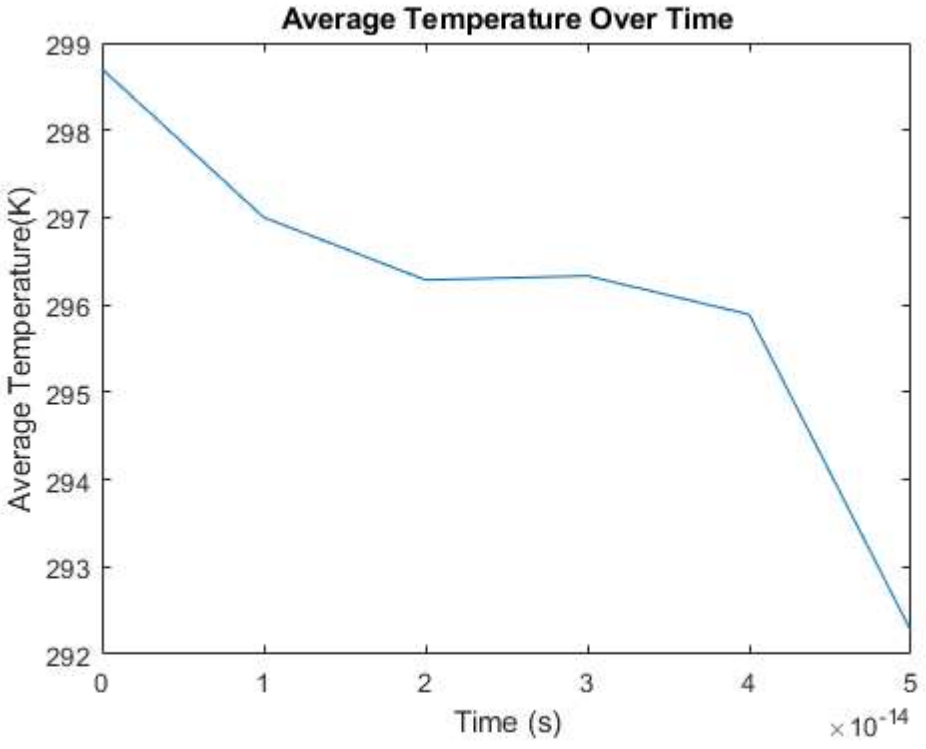

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

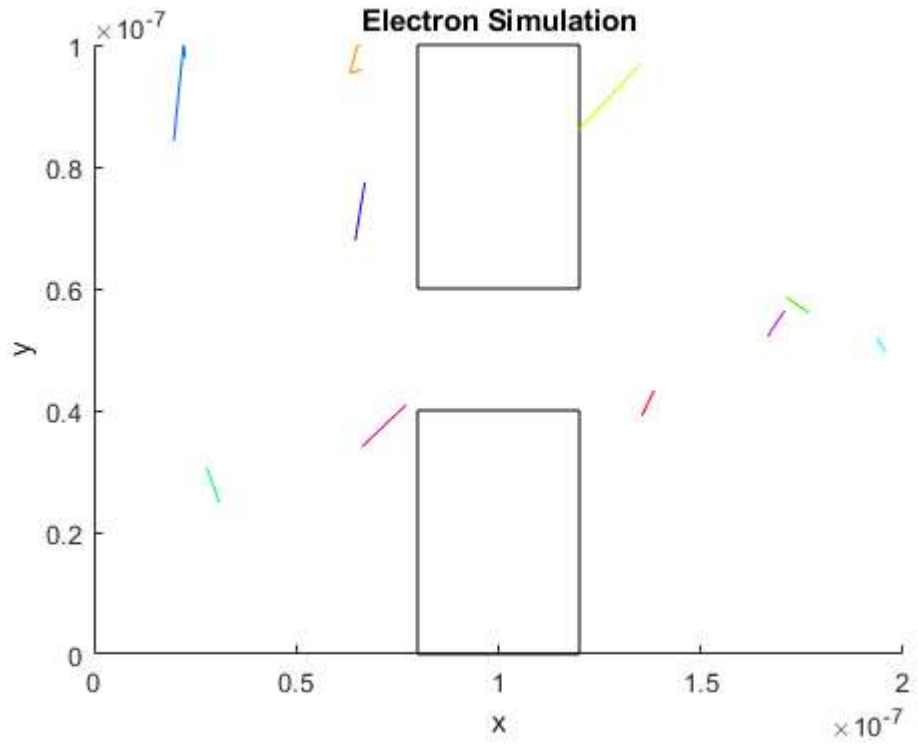

Average Temperature Over Time
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-14

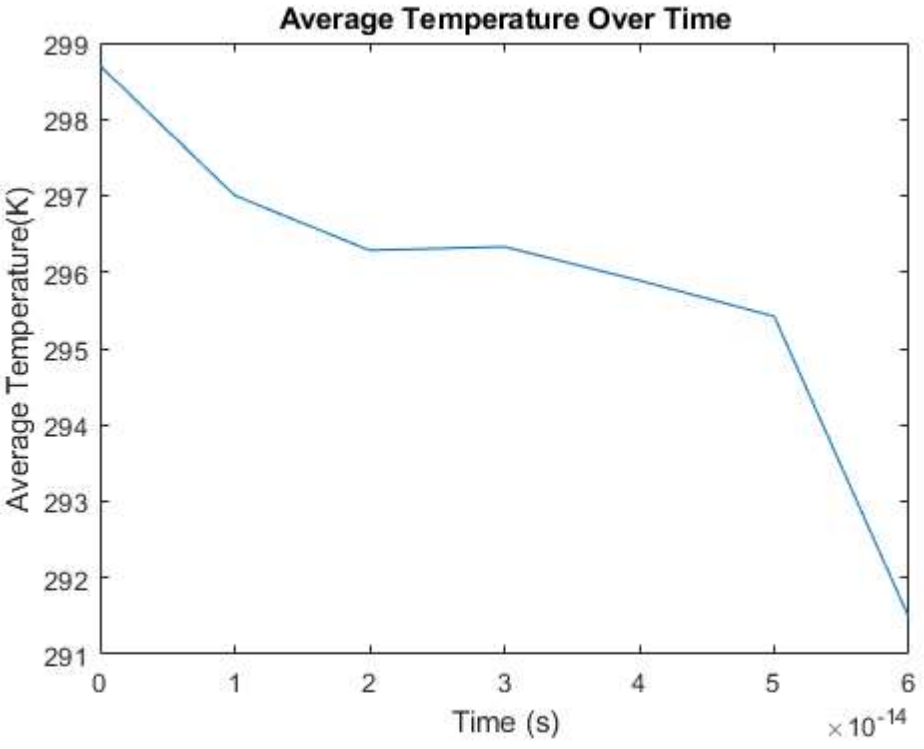

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

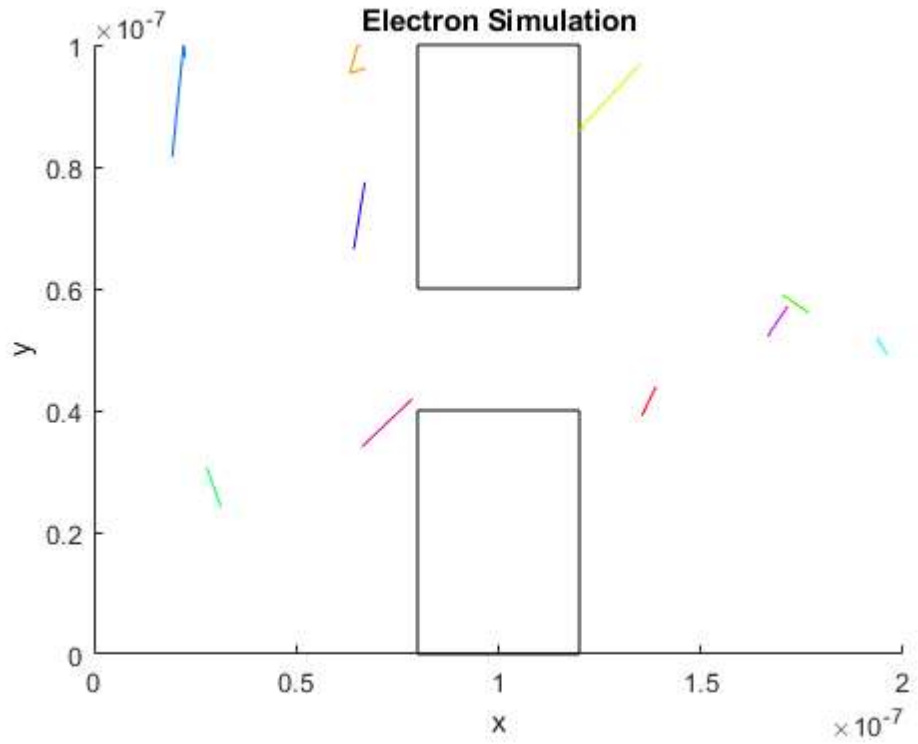

Average Temperature Over Time
Average Temperature(K)
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-14

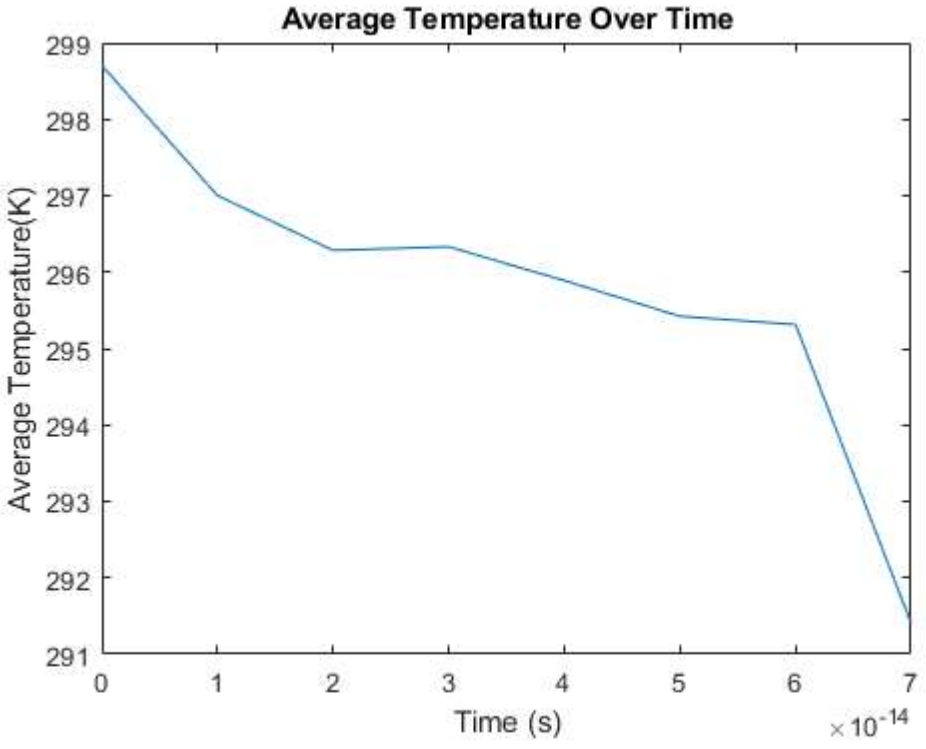

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

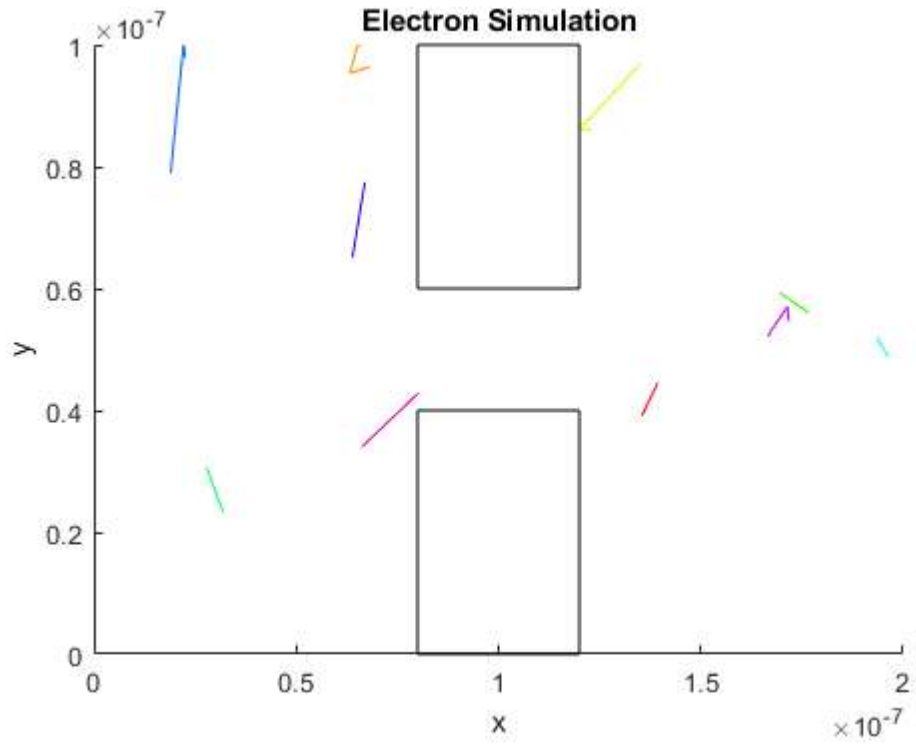

Average Temperature Over Time
299
298
297
296
295
294
293
292
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-14

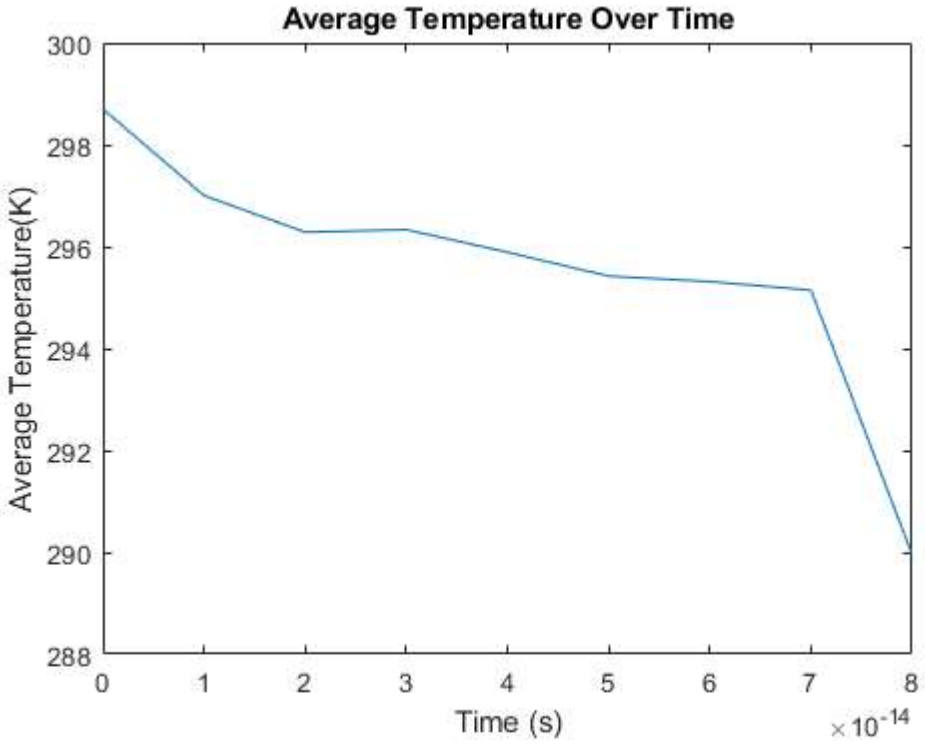

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

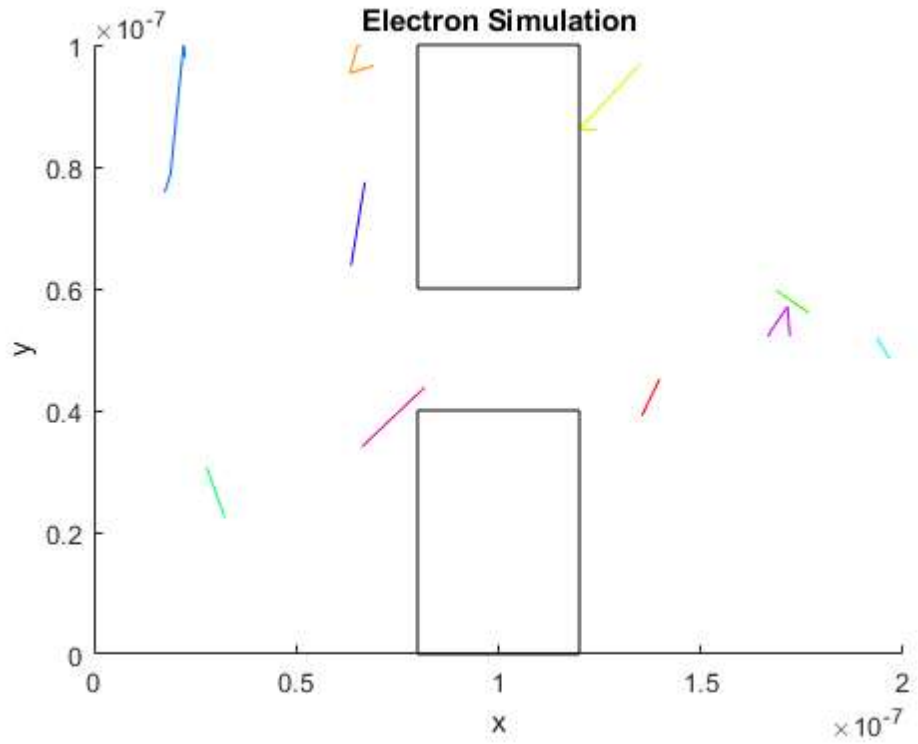

Average Temperature Over Time
299
298
297
296
295
294
293
292
291
Average Temperature(K)
0
1
2
3
4
5
6
Time (s)
×10^-14

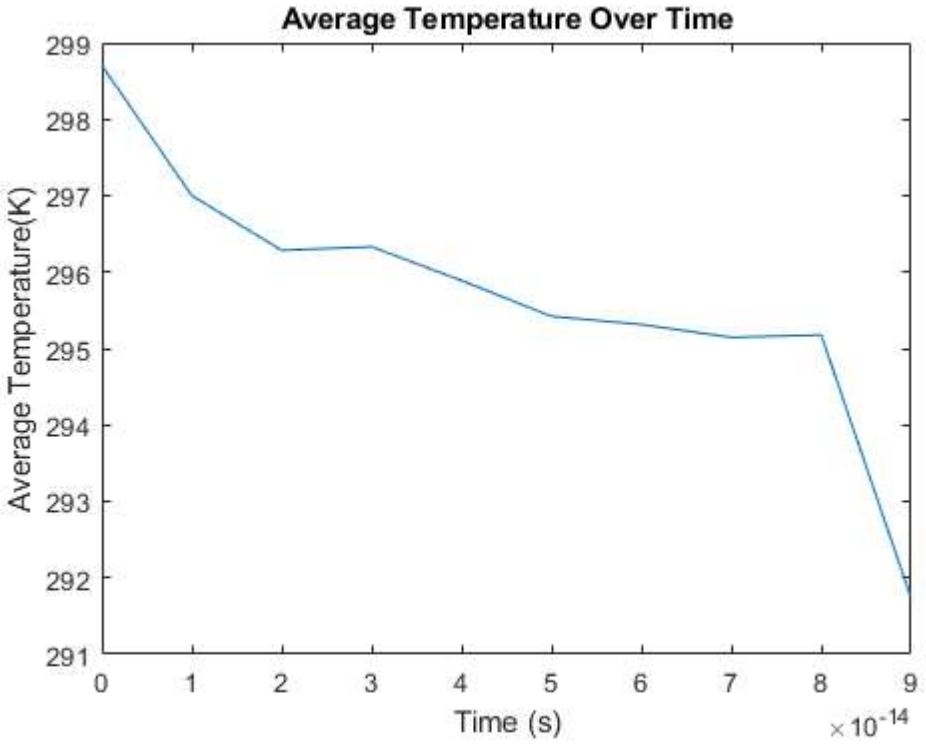

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

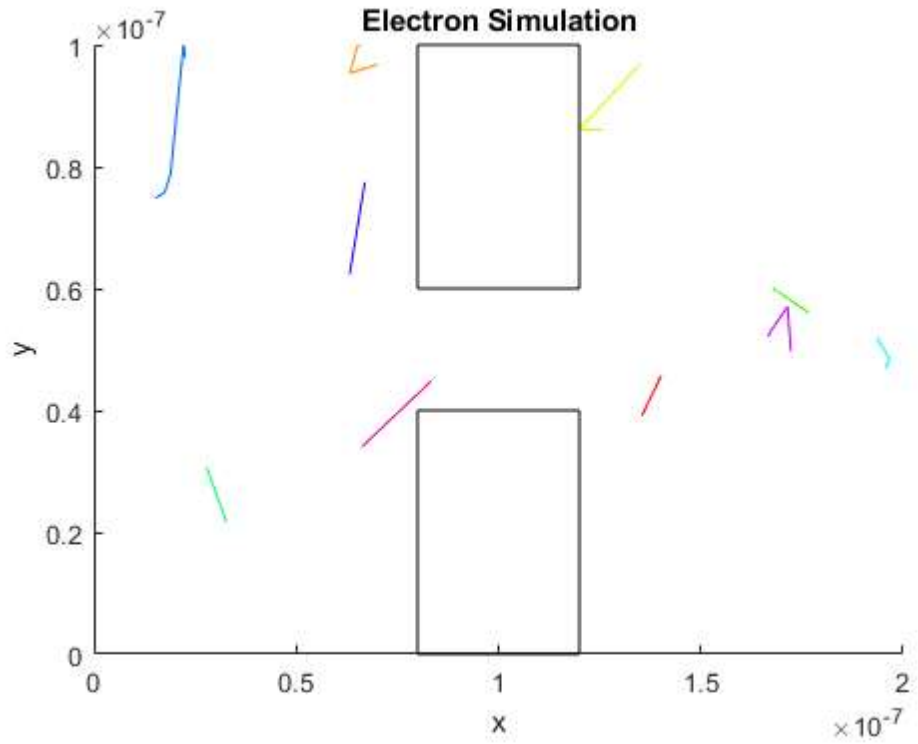

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
0
1
2
3
4
5
6
7
Time (s)
×10^-14

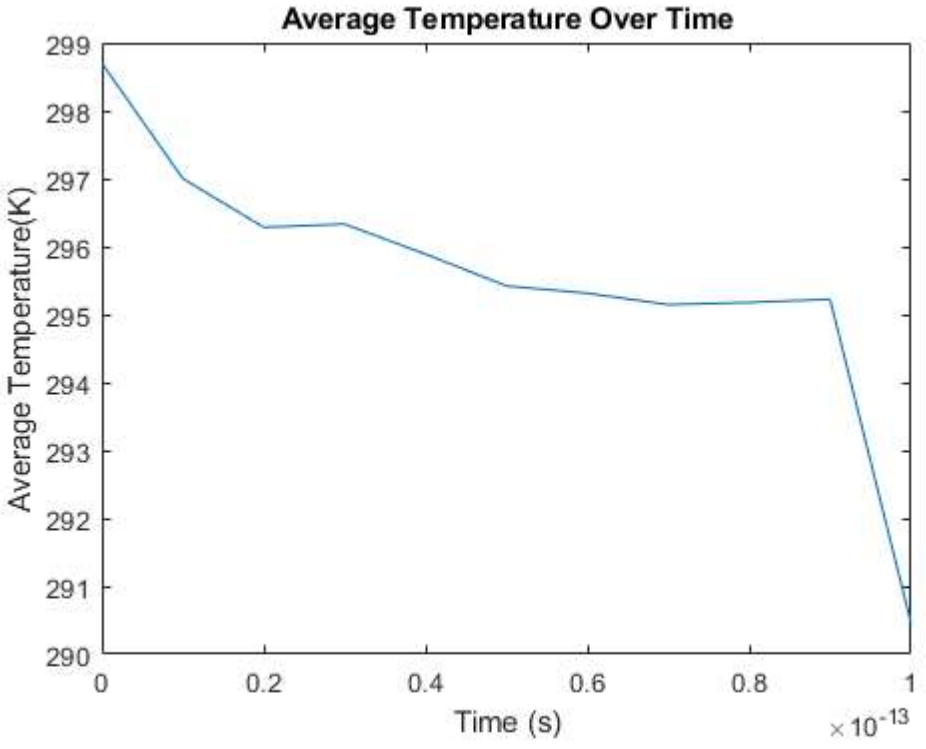

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

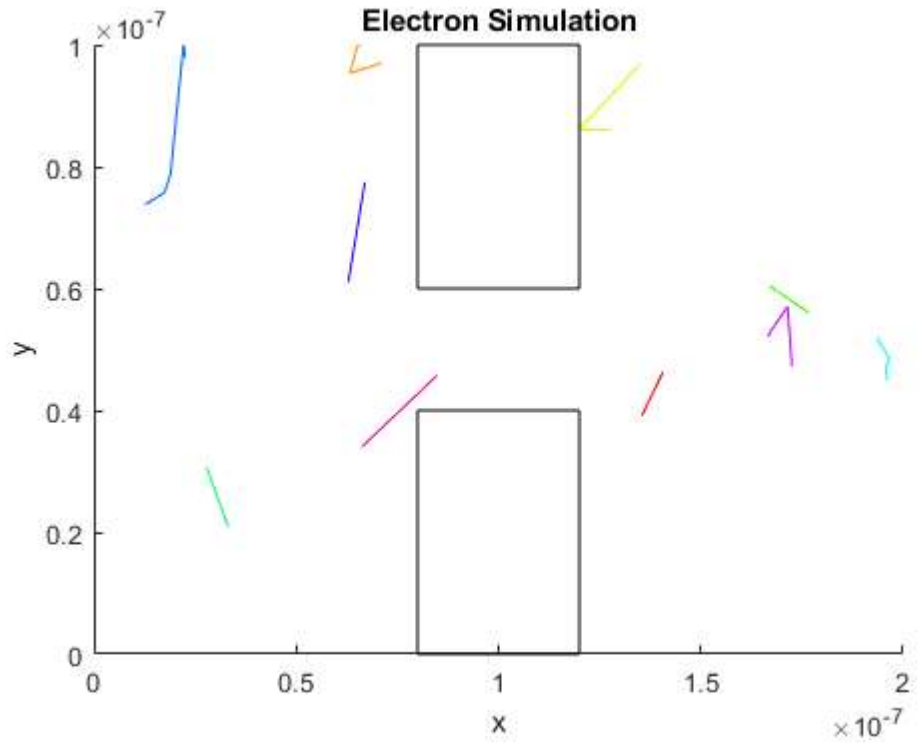

Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-14

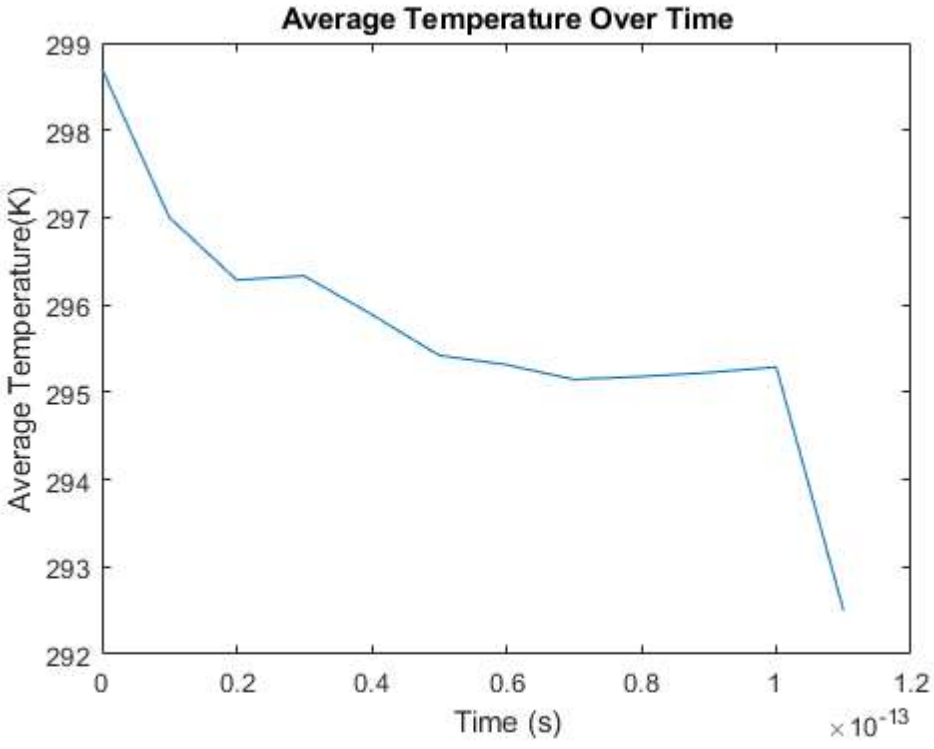

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

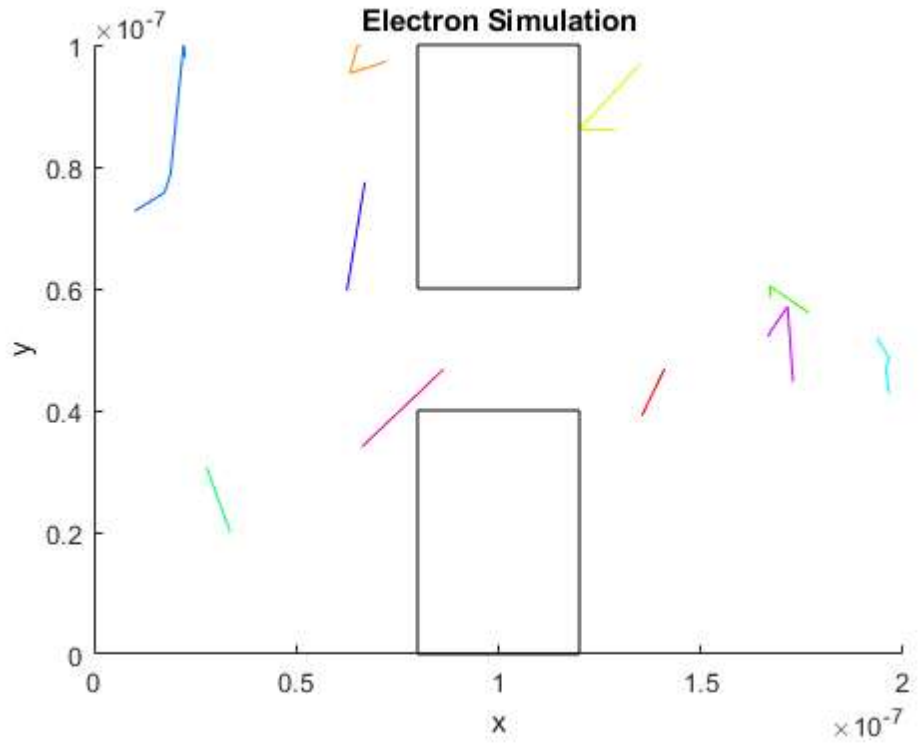

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
0
1
2
3
4
5
6
7
8
9
Time (s)
×10^-14

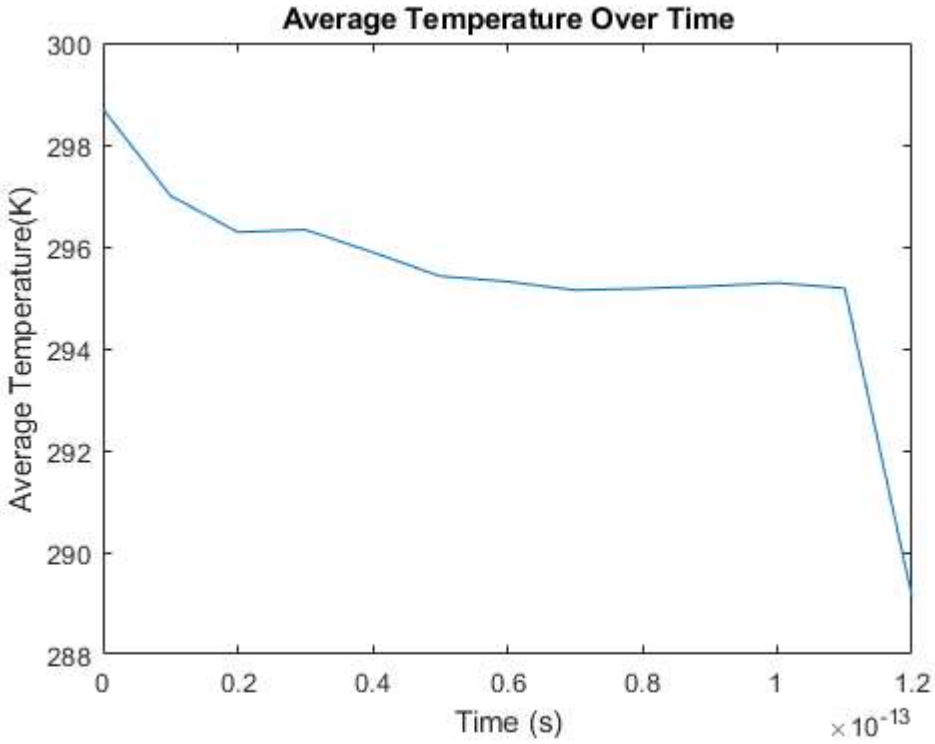

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

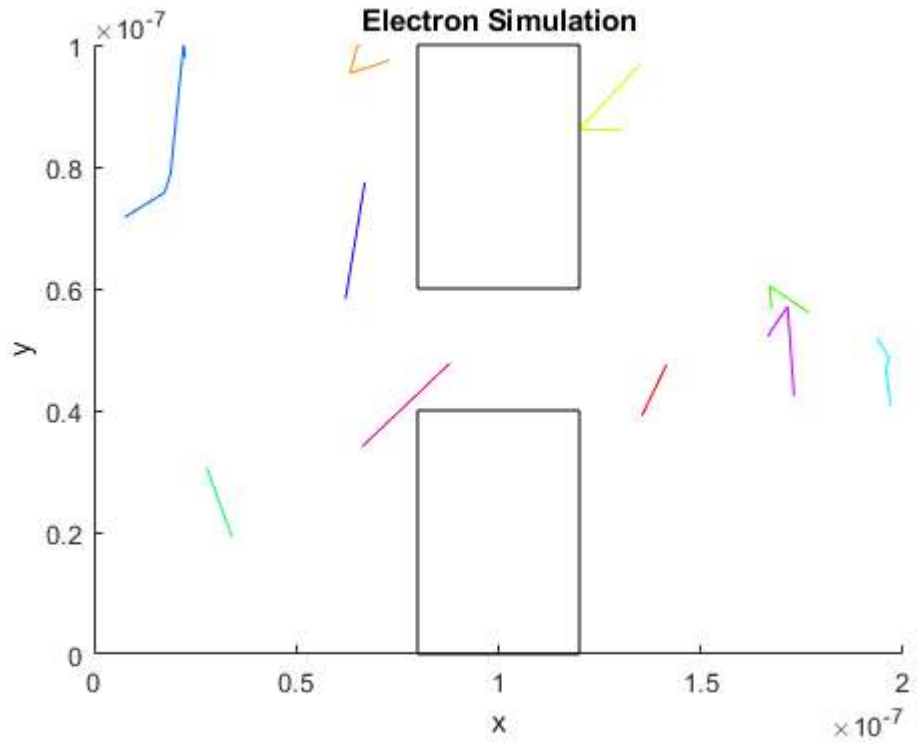

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
290
0
0.2
0.4
0.6
0.8
1
Time (s)
×10^-13

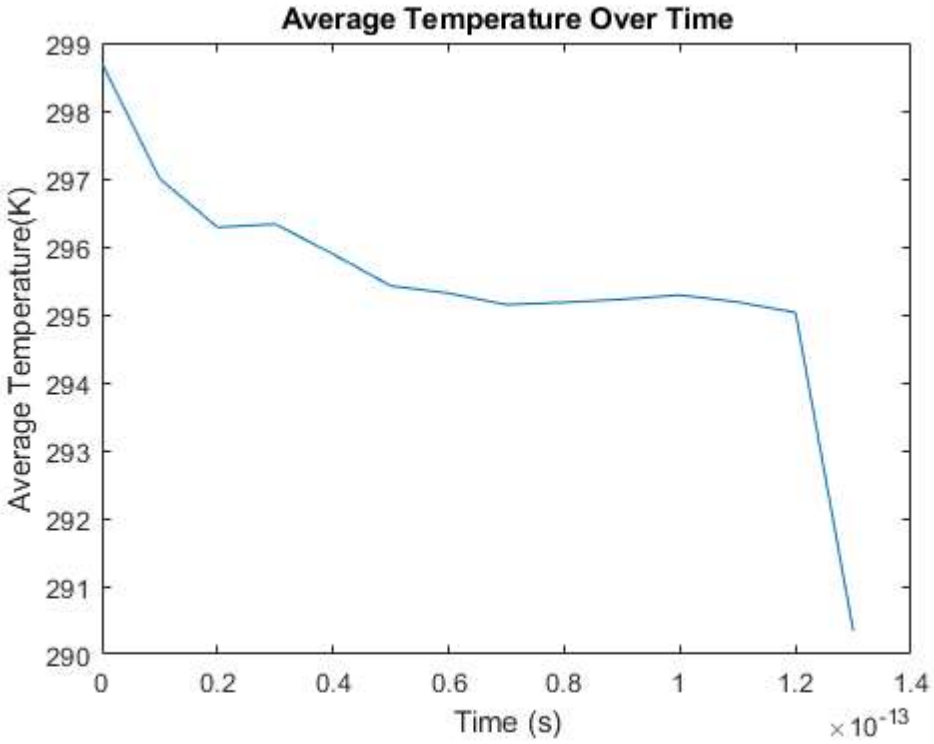

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

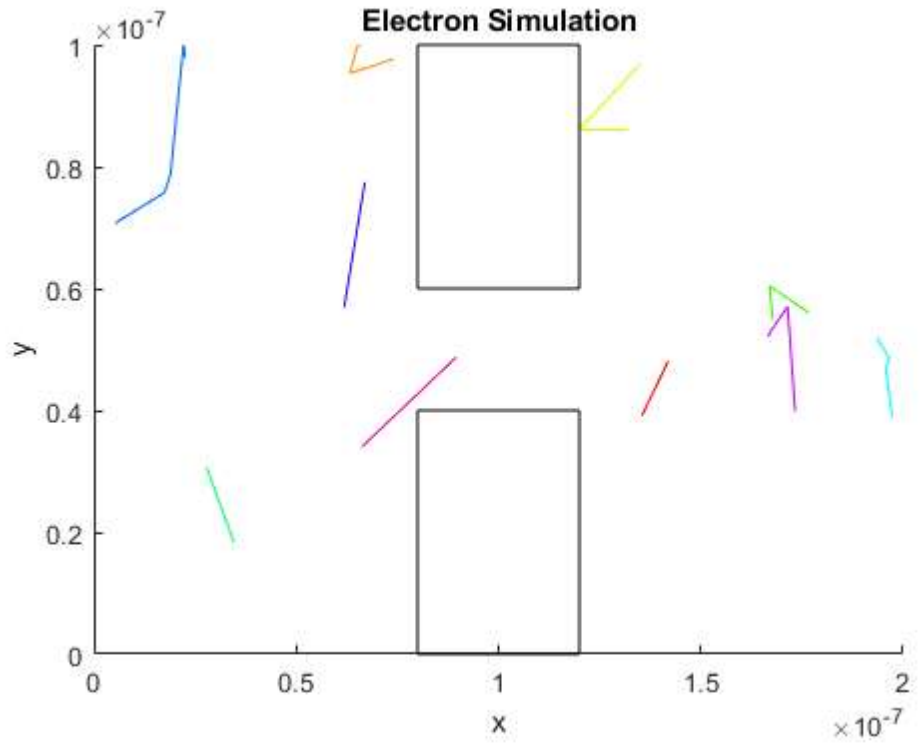

Average Temperature Over Time
299
298
297
296
295
294
293
292
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
Time (s)
×10^-13

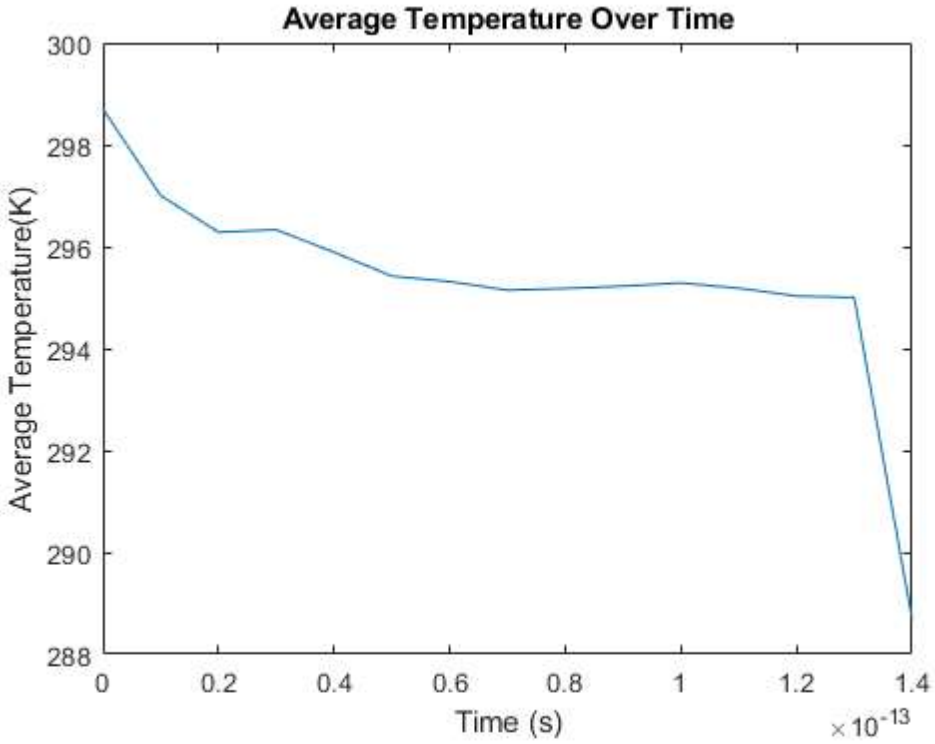

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

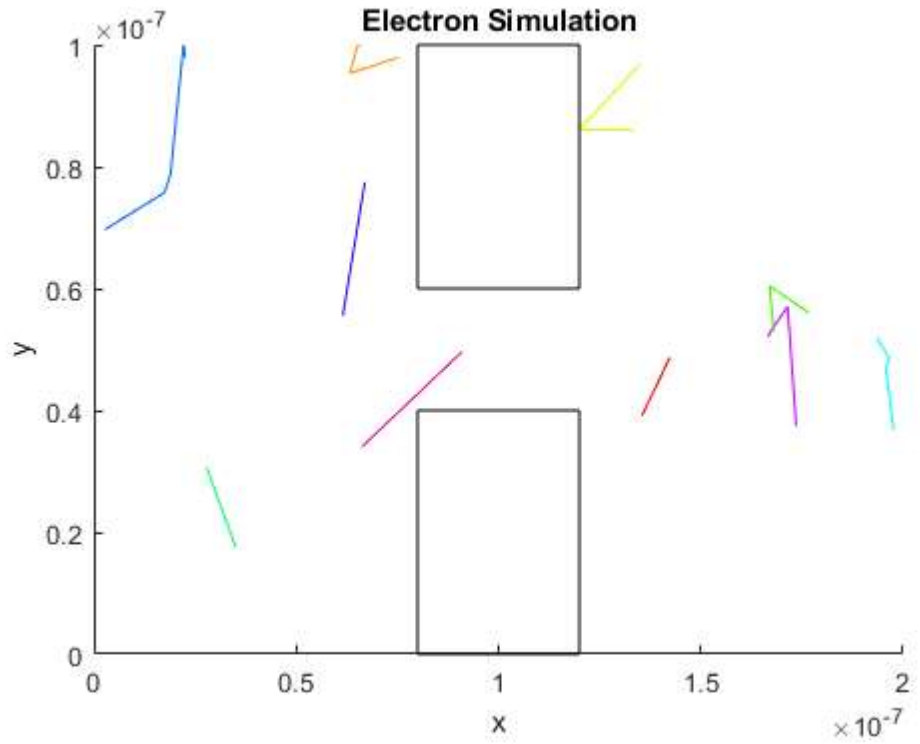

Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
Time (s)
×10^-13

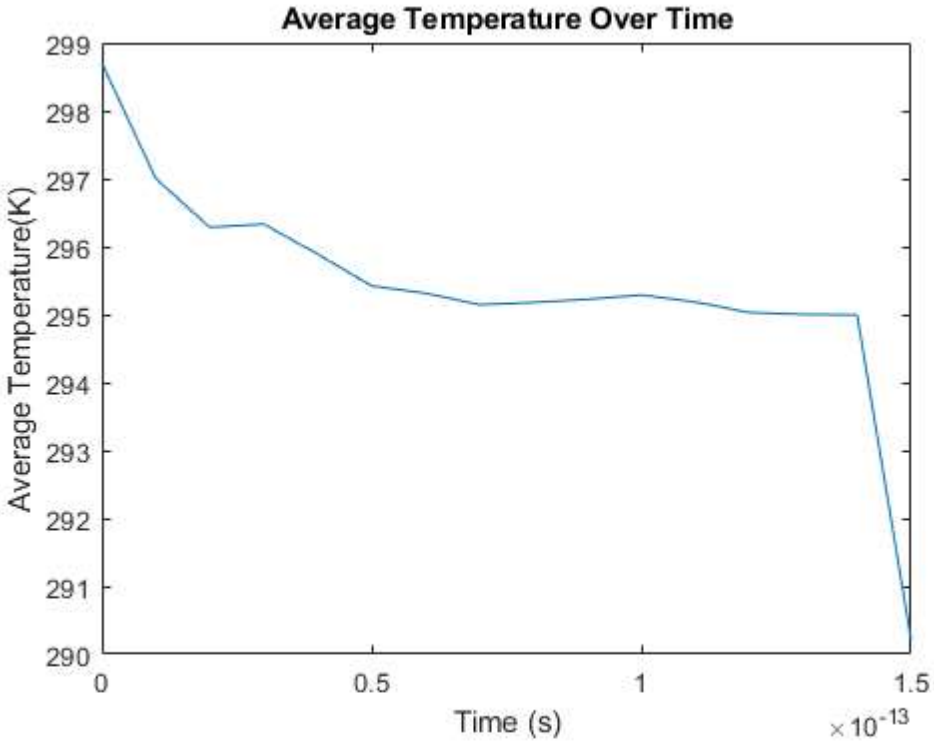

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

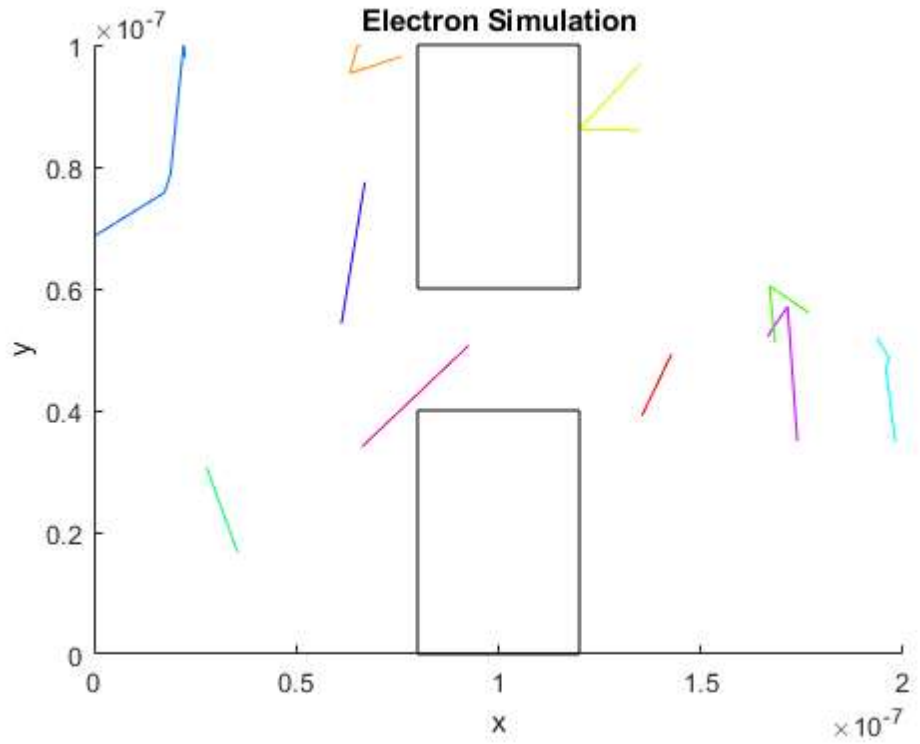

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
290
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Time (s)
×10^-13

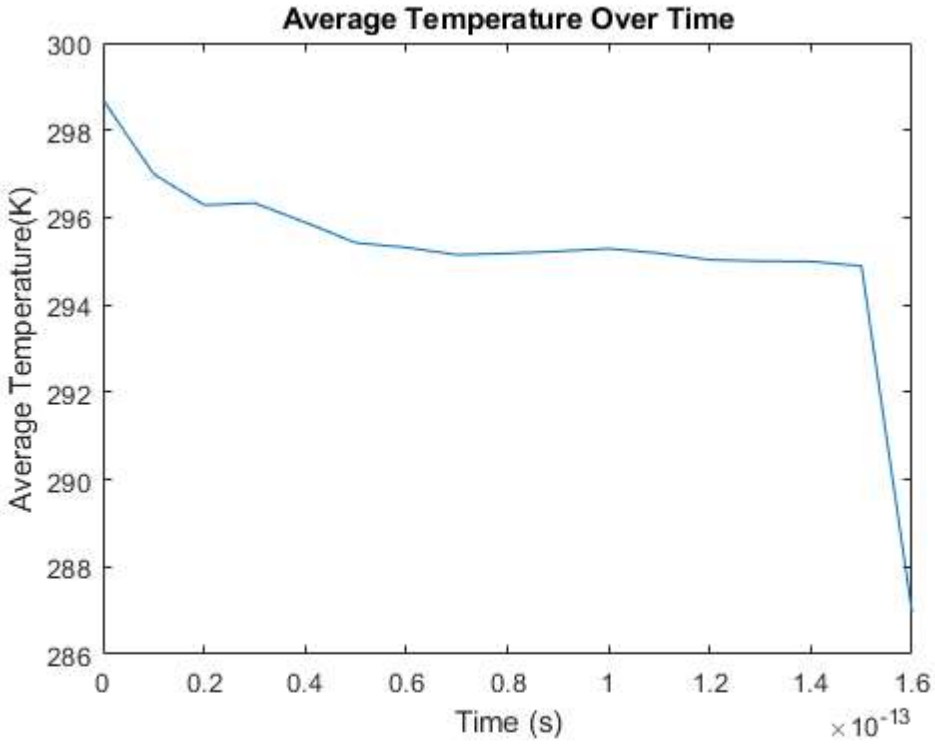

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

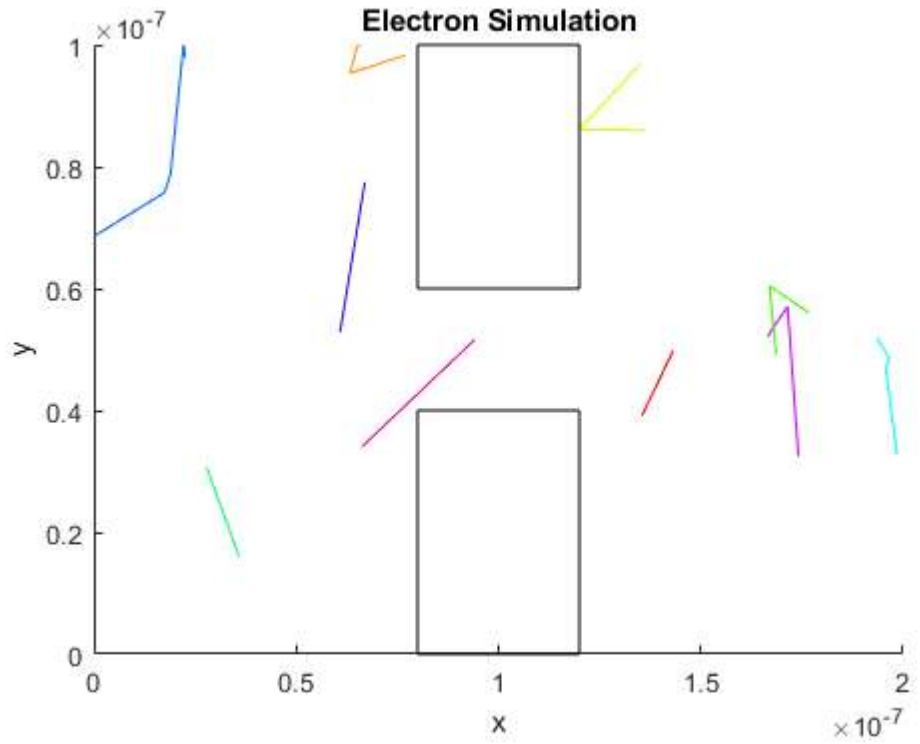

Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Time (s)
×10^-13

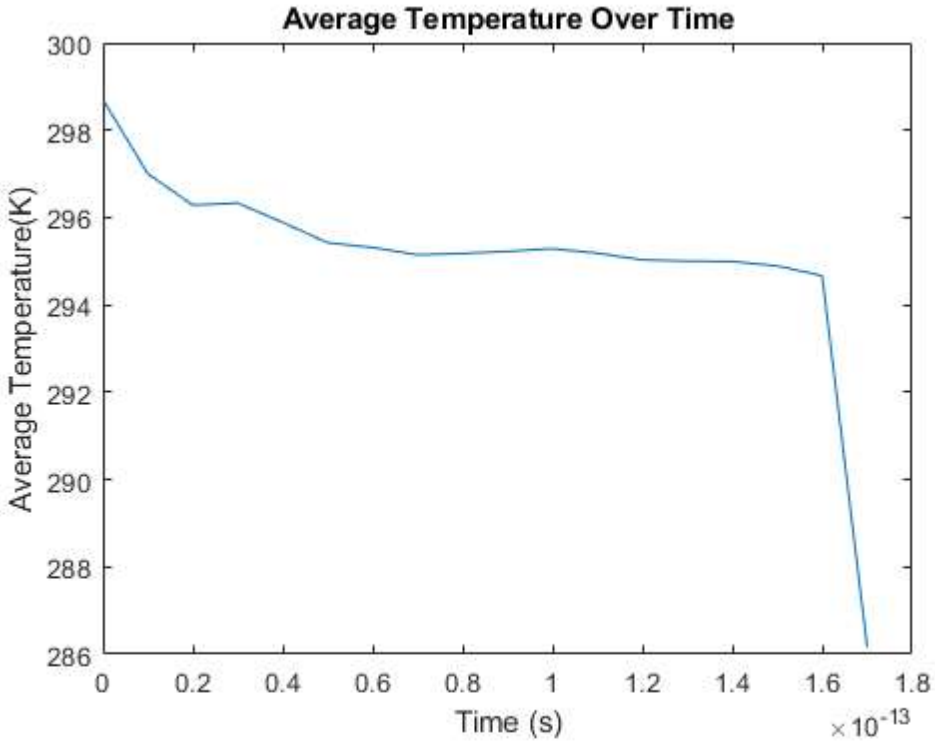

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

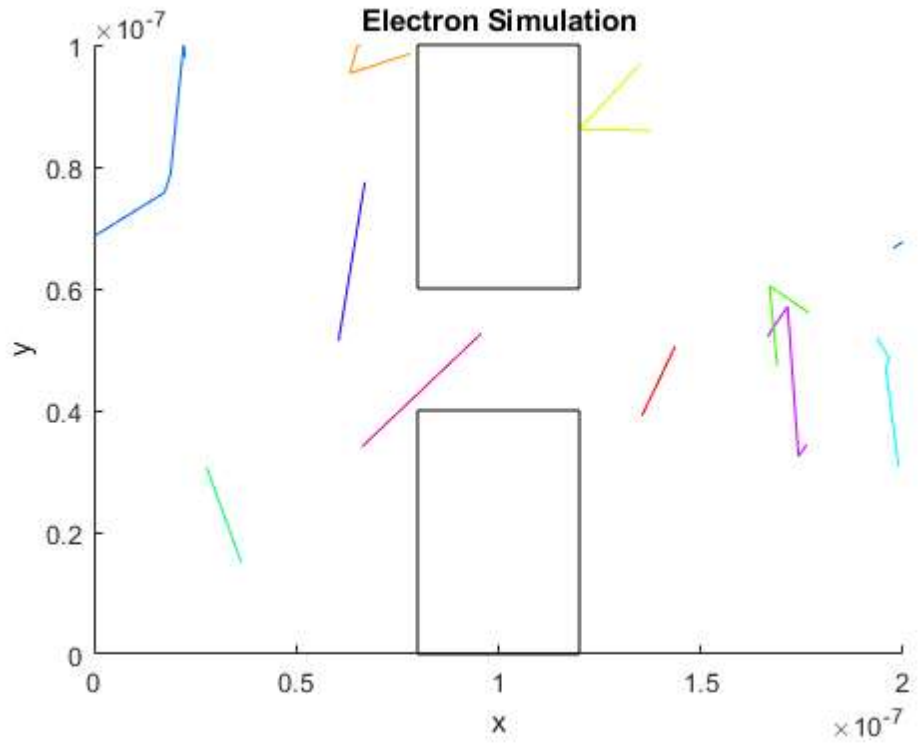

Average Temperature Over Time
299
298
297
296
295
294
293
292
291
290
Average Temperature(K)
0
0.5
1
1.5
Time (s)
×10^-13

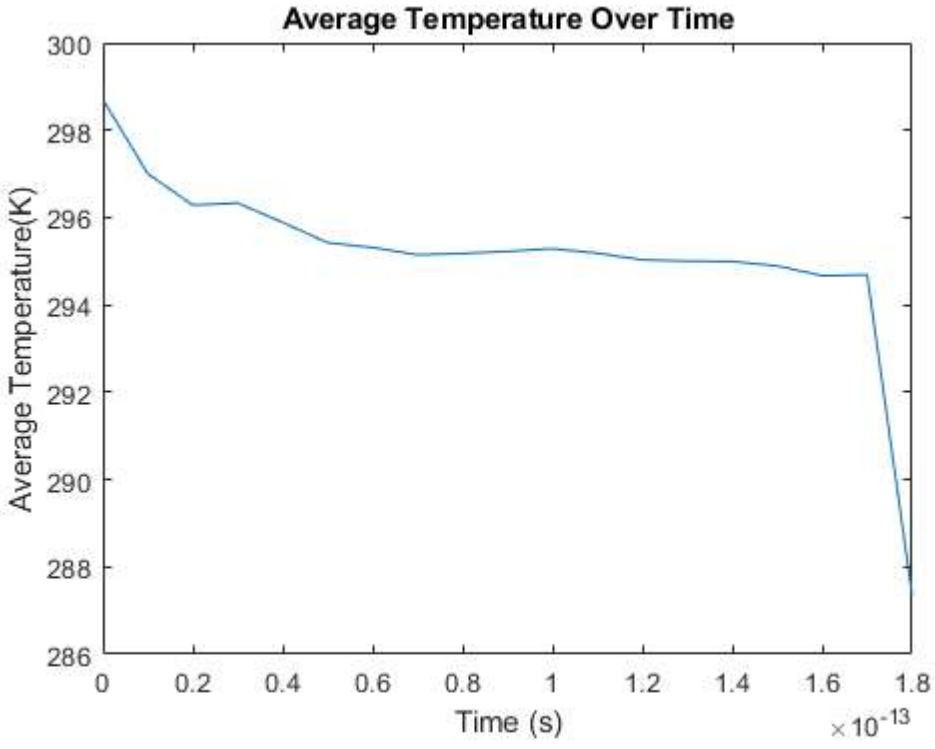

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

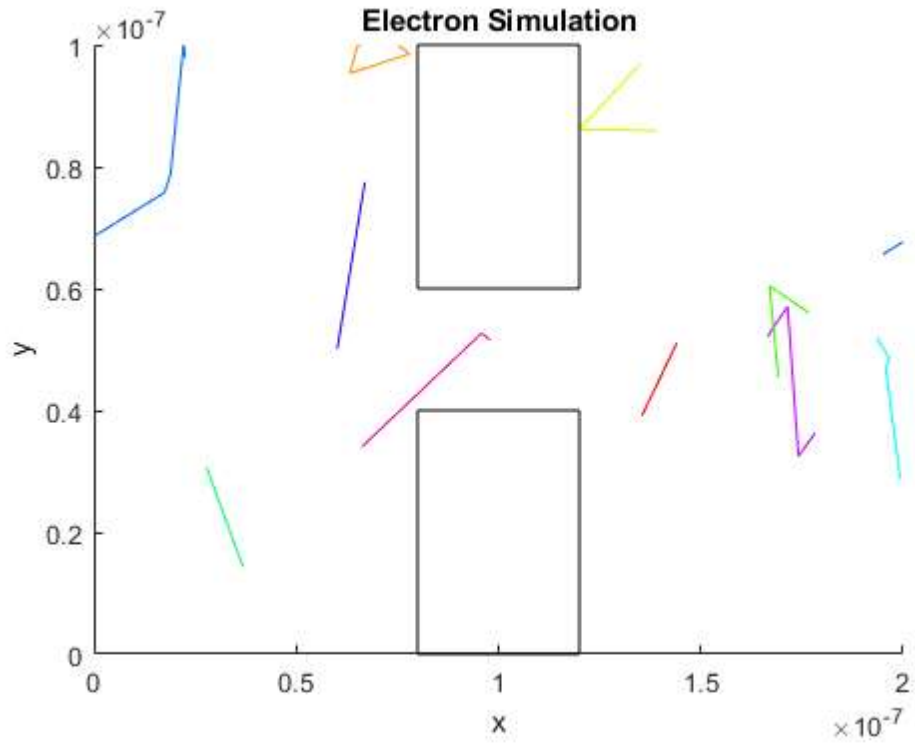

Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time (s)
×10^-13

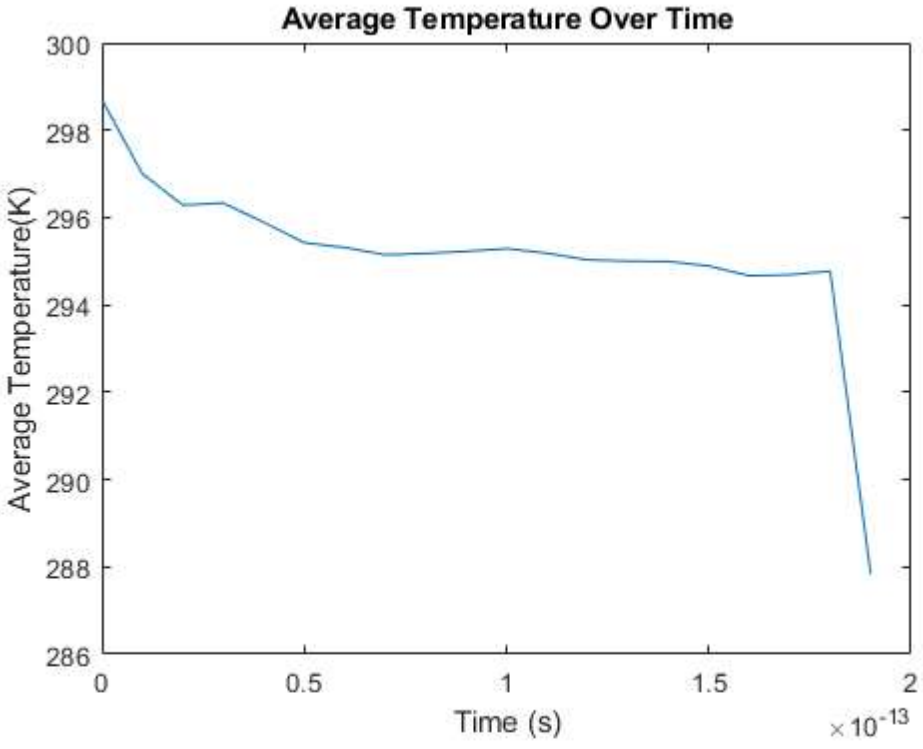

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

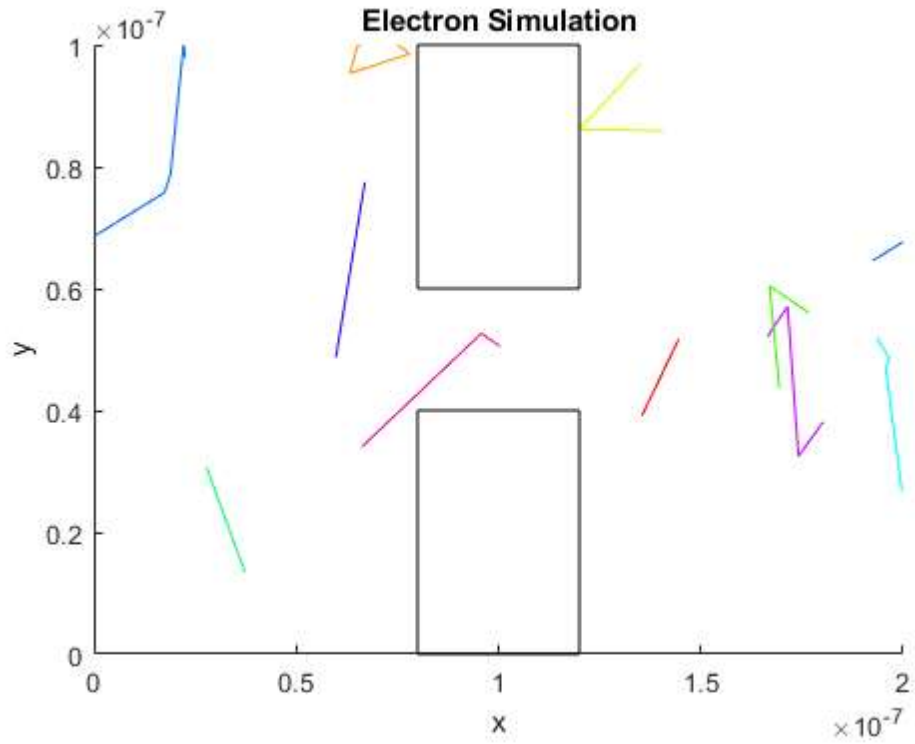

Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time (s)
×10^-13

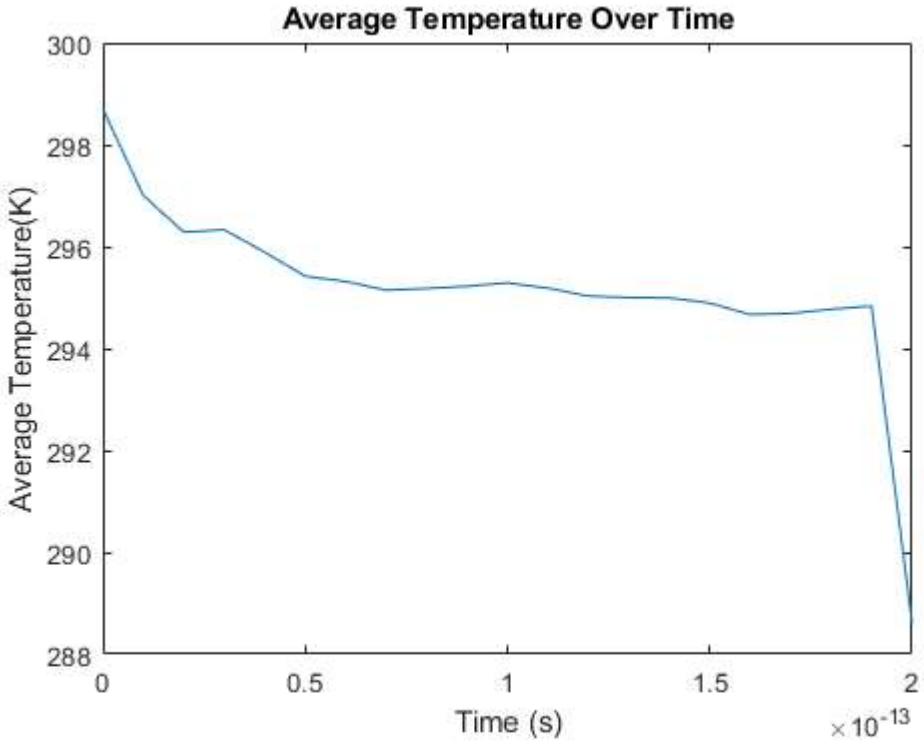

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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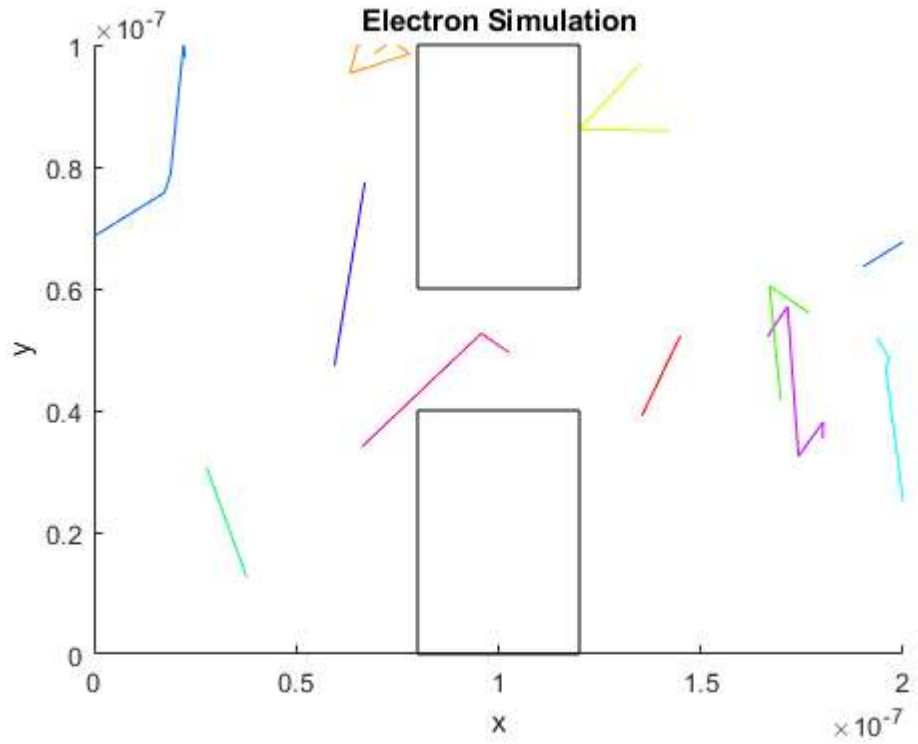
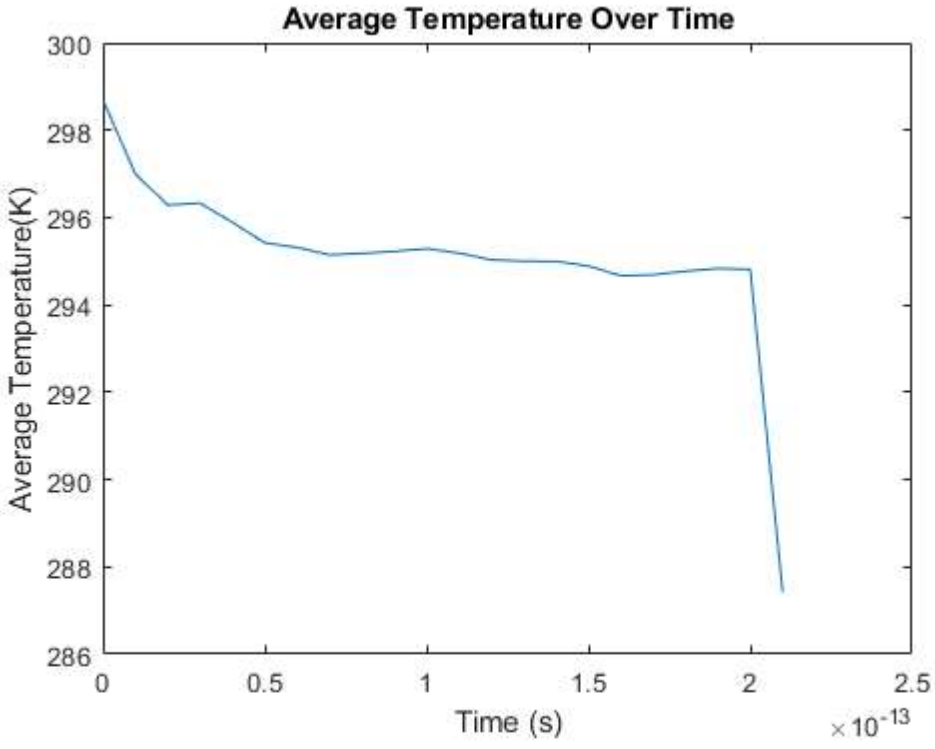
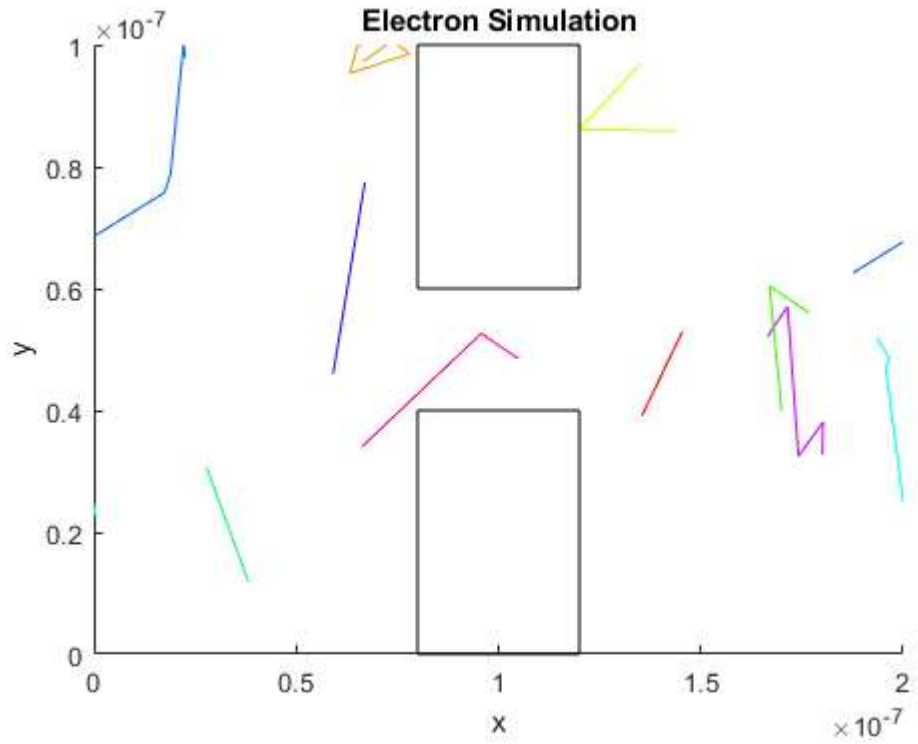
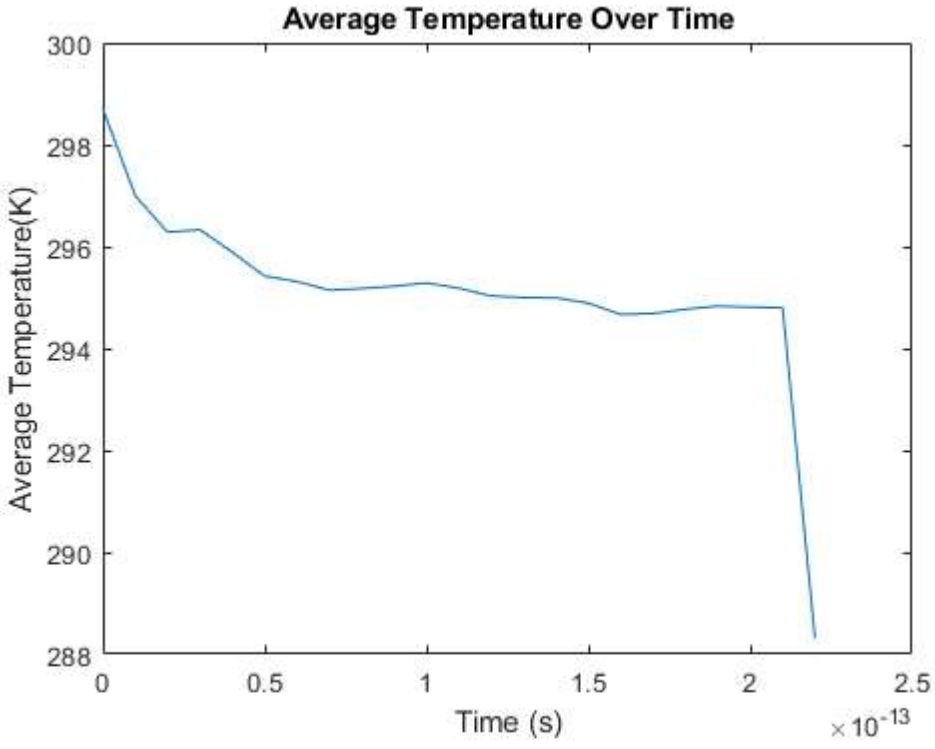
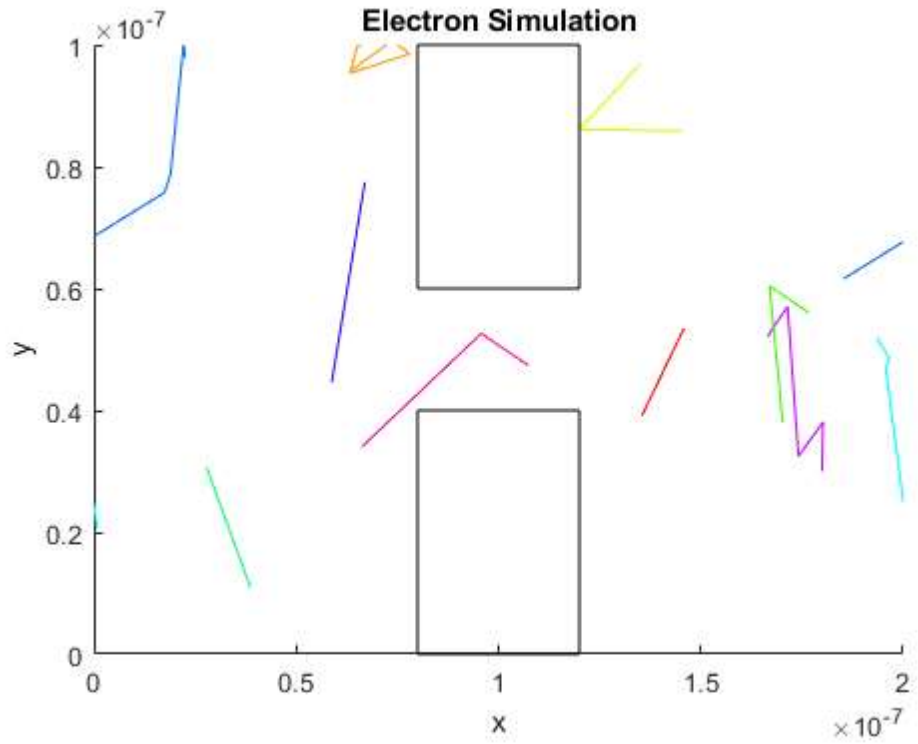
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
Time (s)
×10^-13

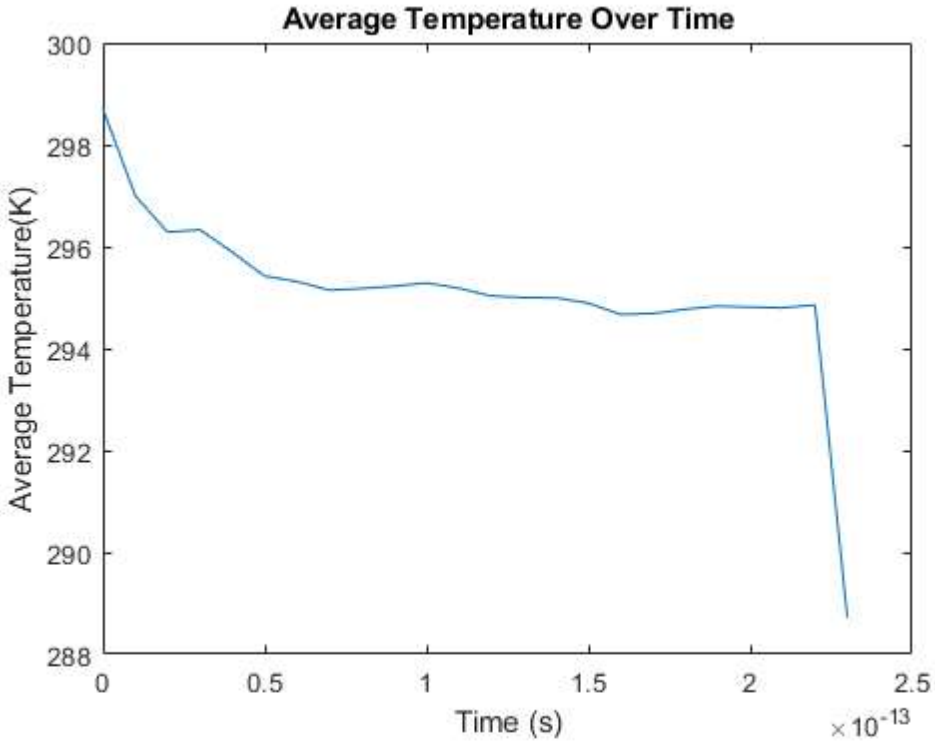

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

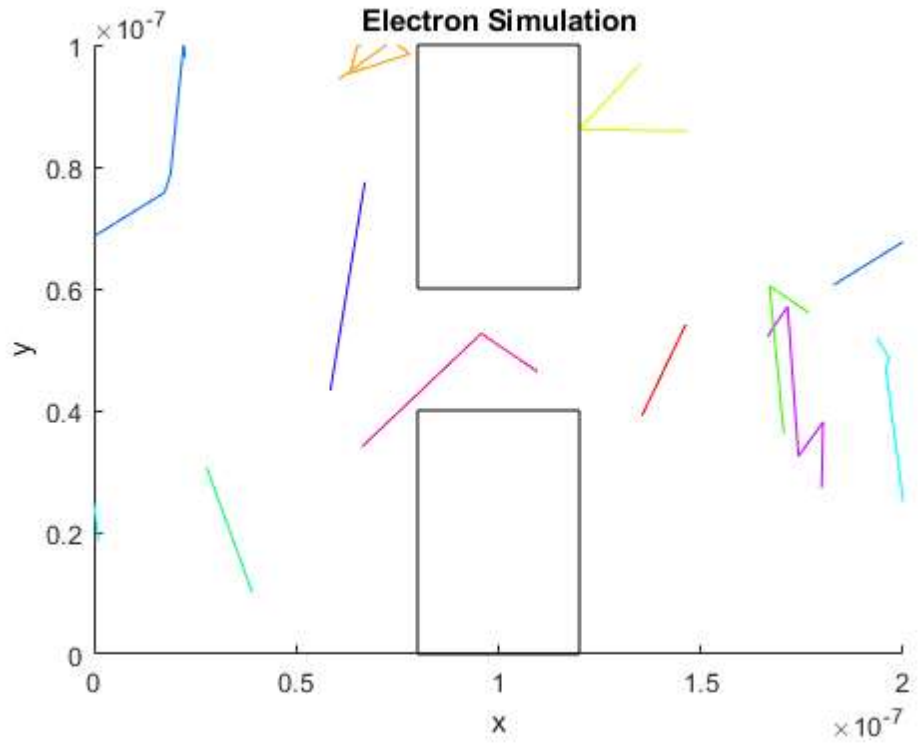

Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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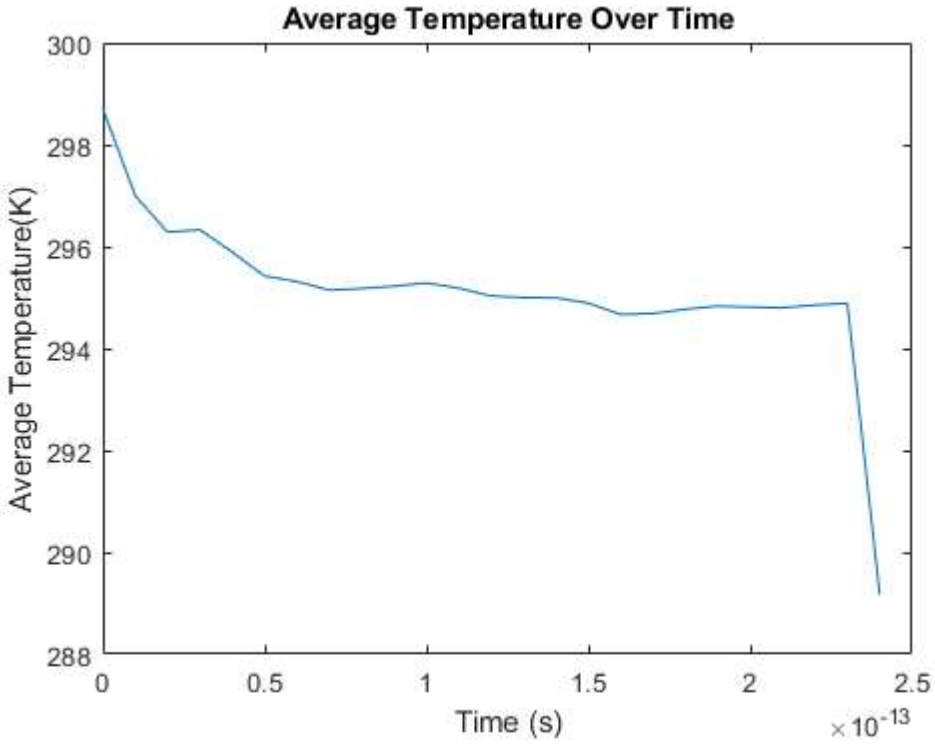
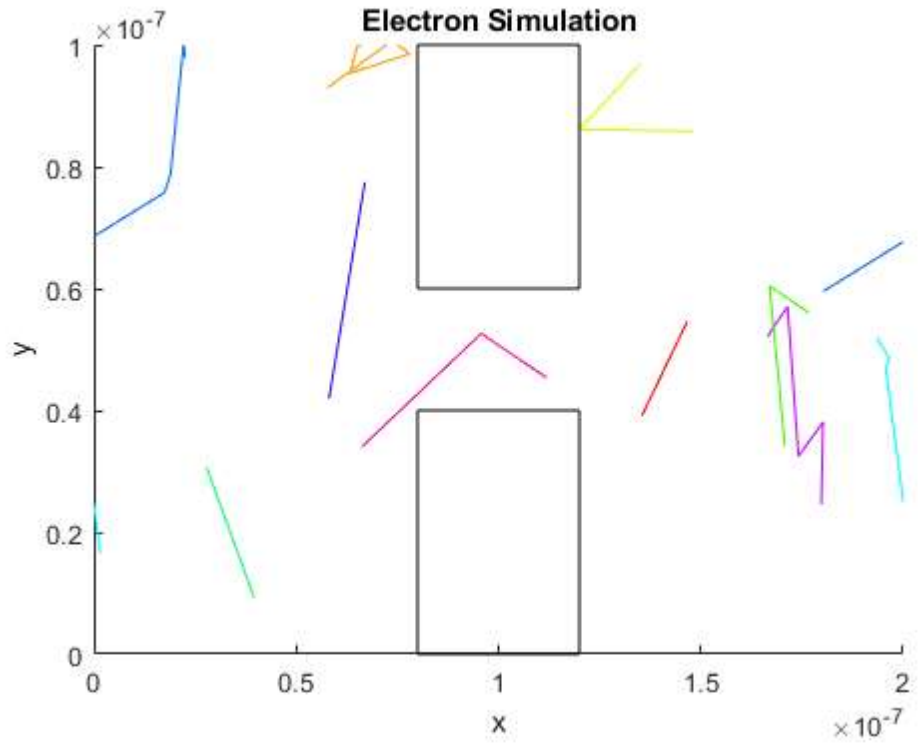
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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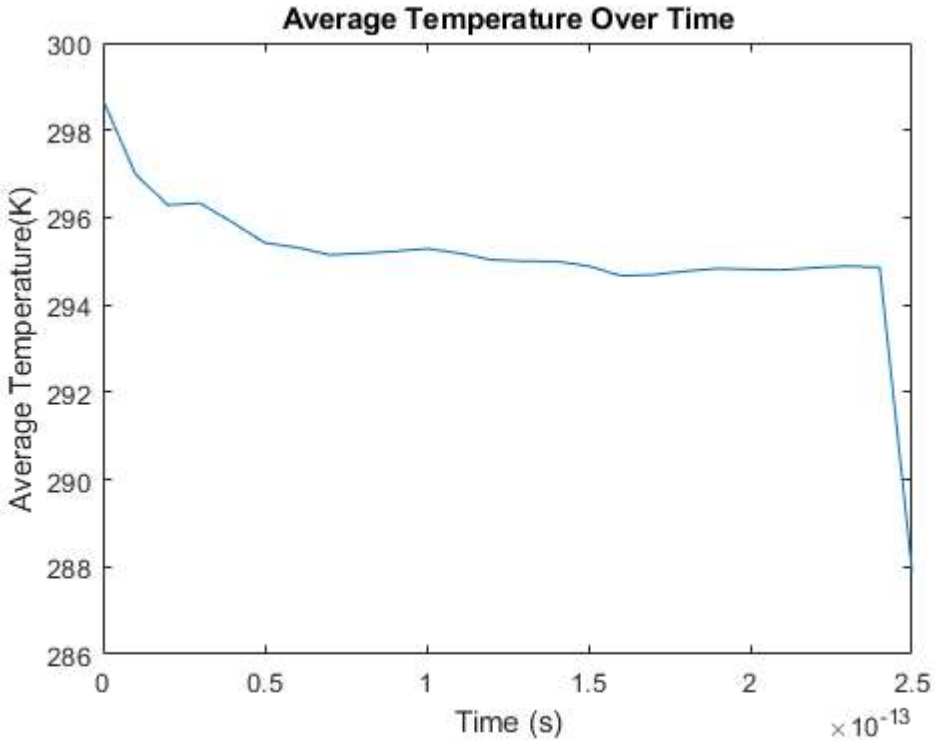
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
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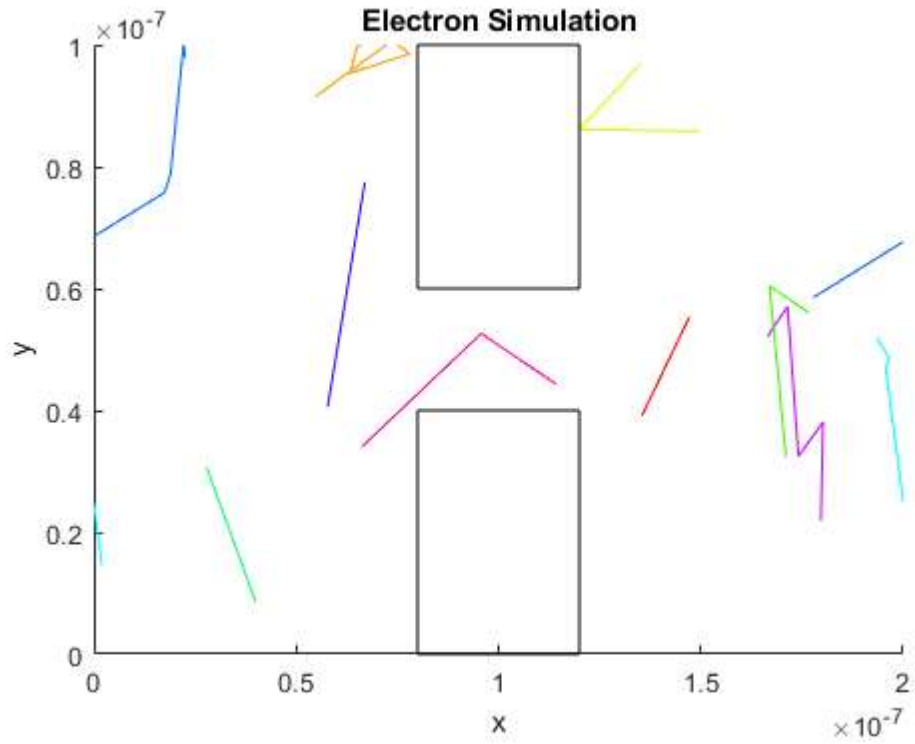
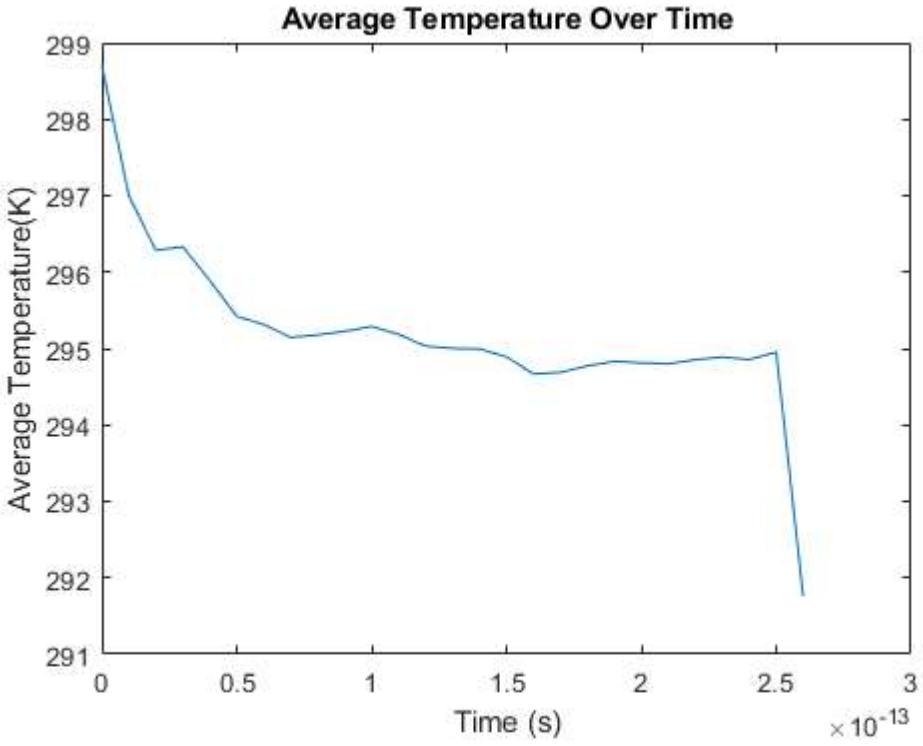
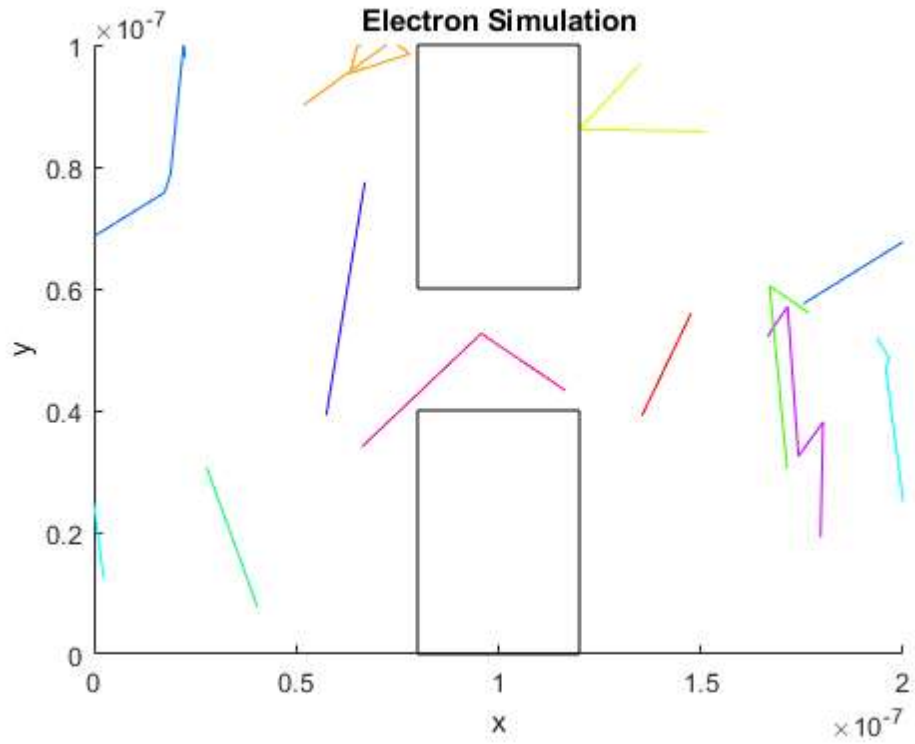
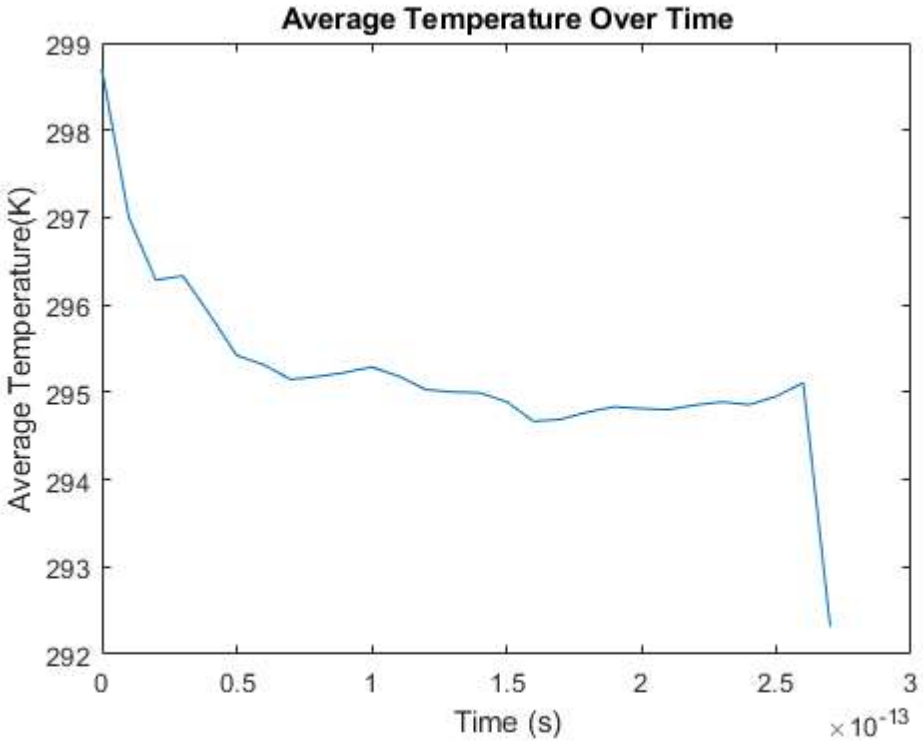
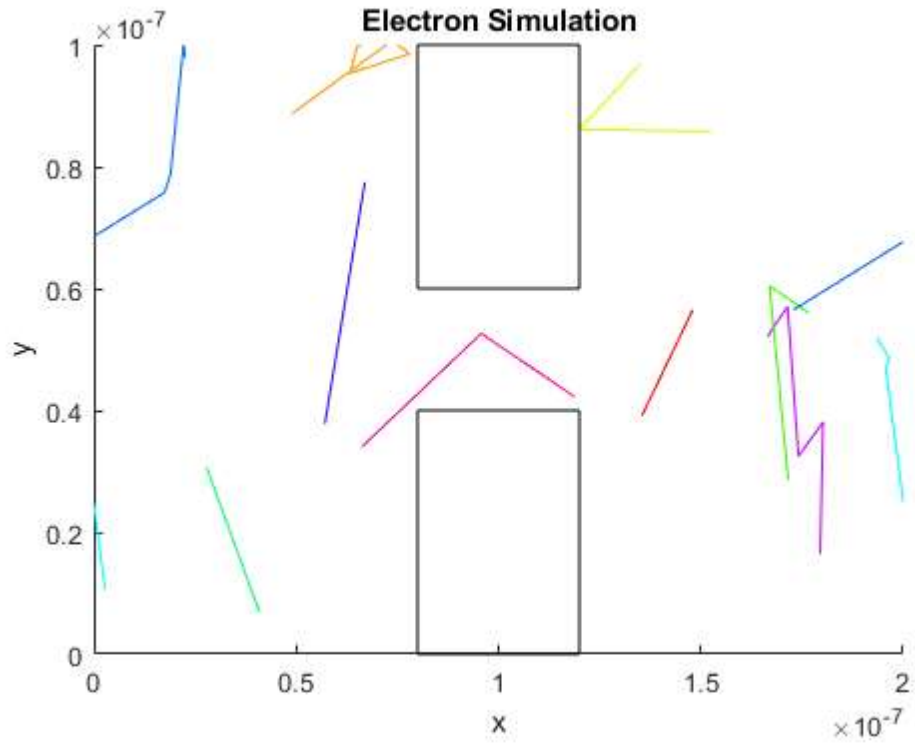
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
297
296
295
294
293
292
291
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
297
296
295
294
293
292
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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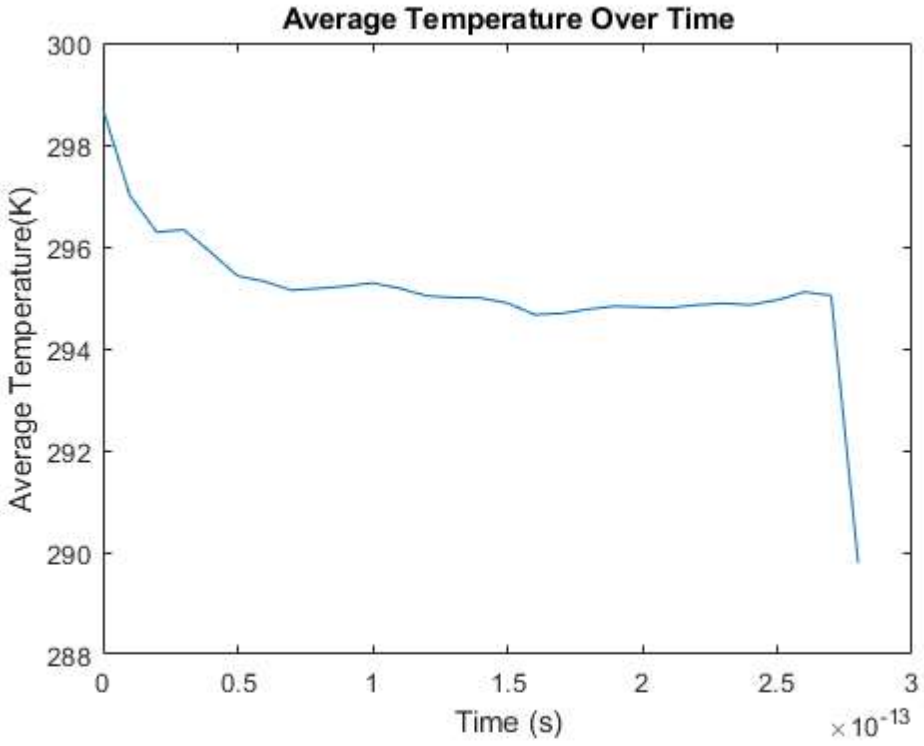
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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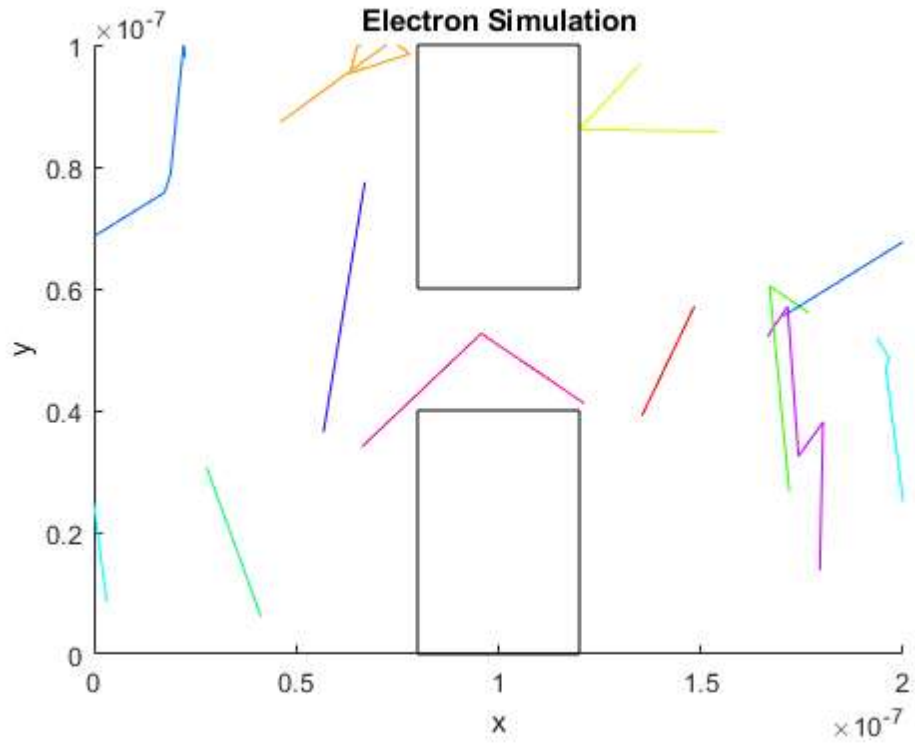
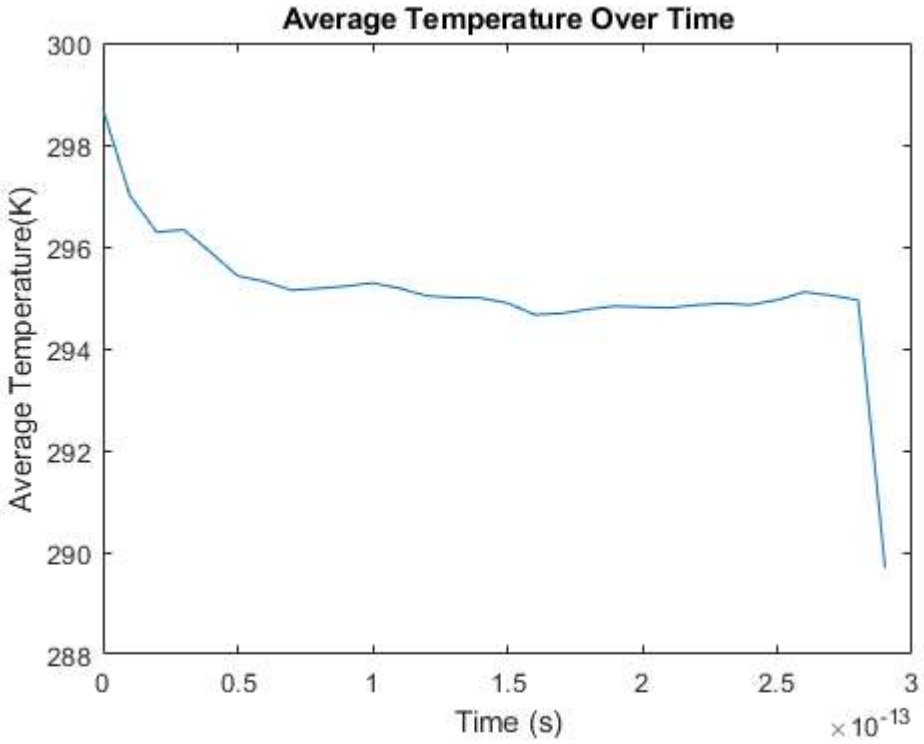
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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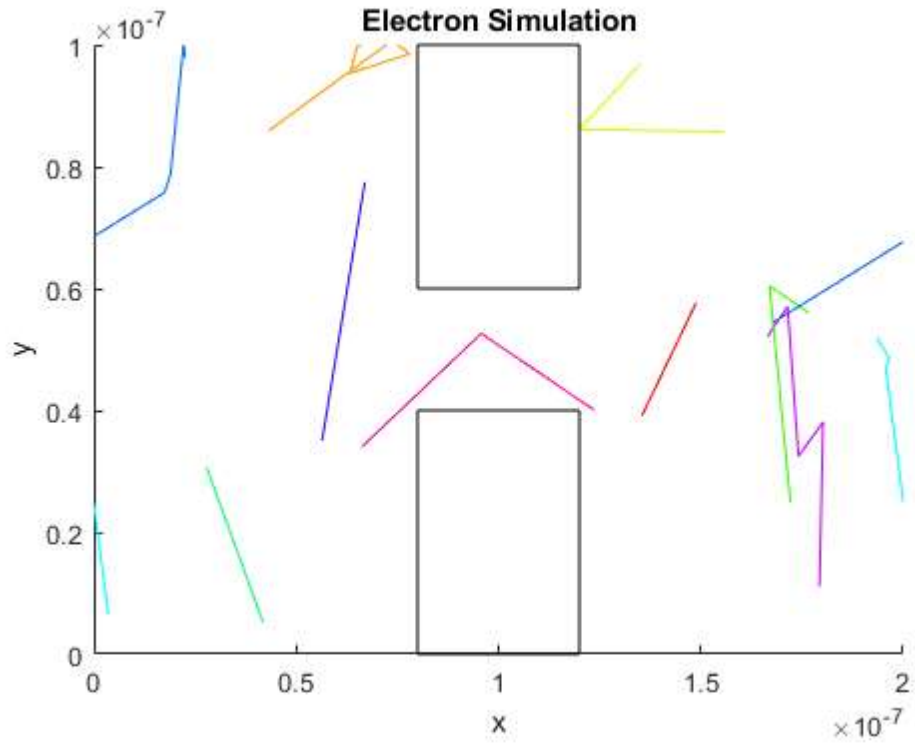
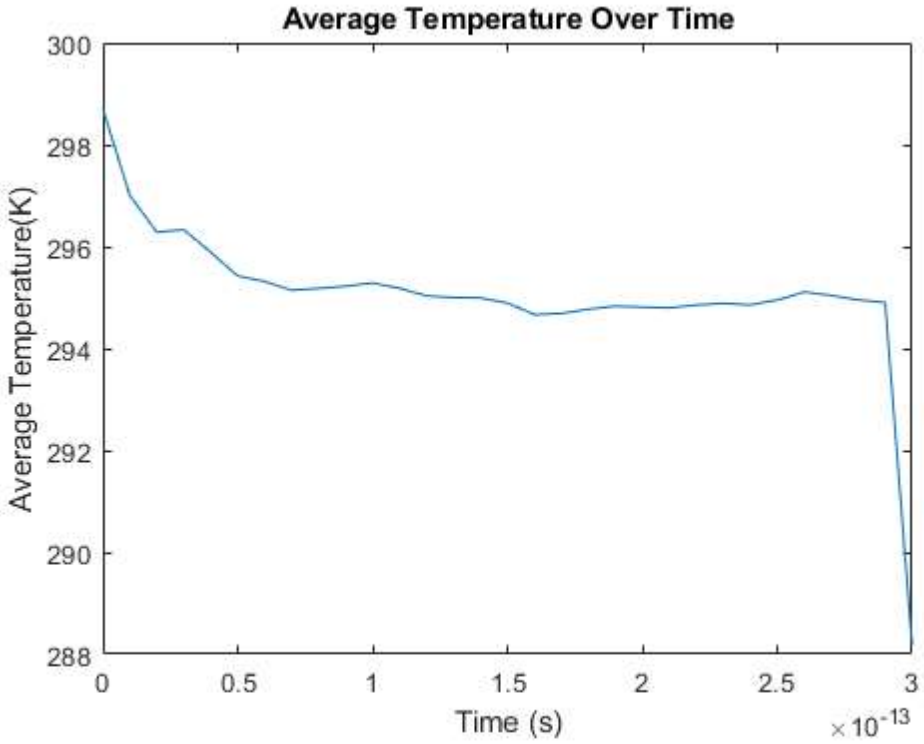
294
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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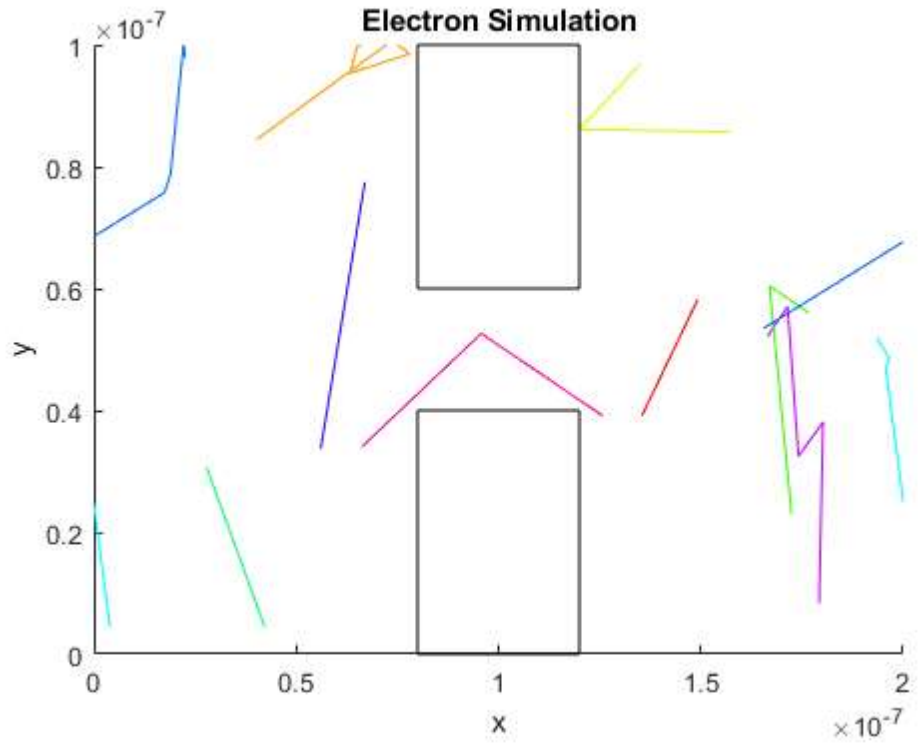
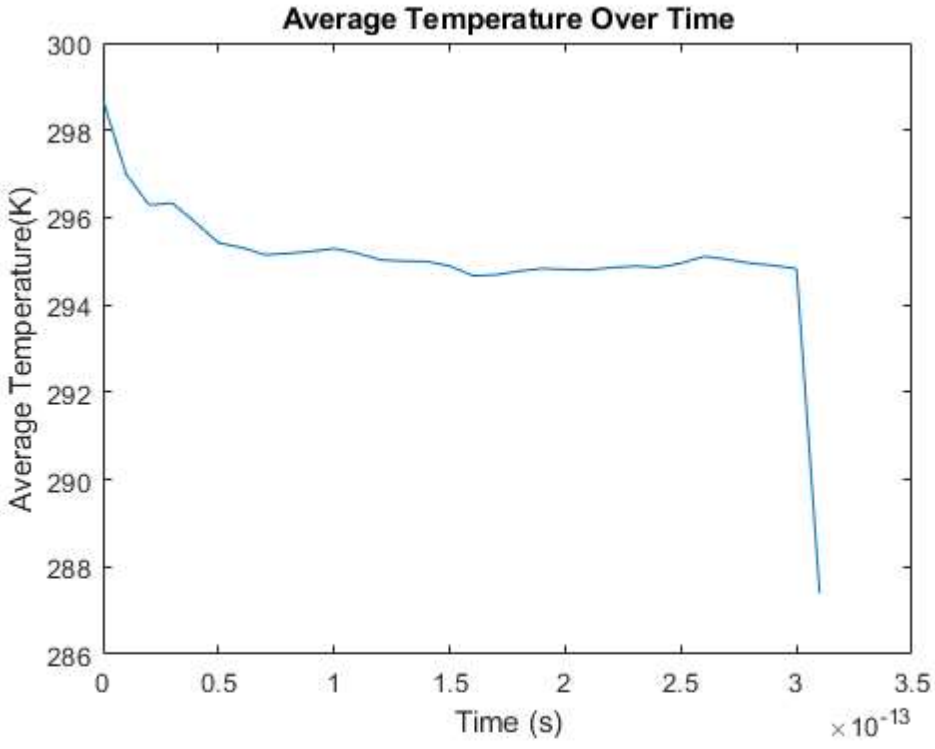
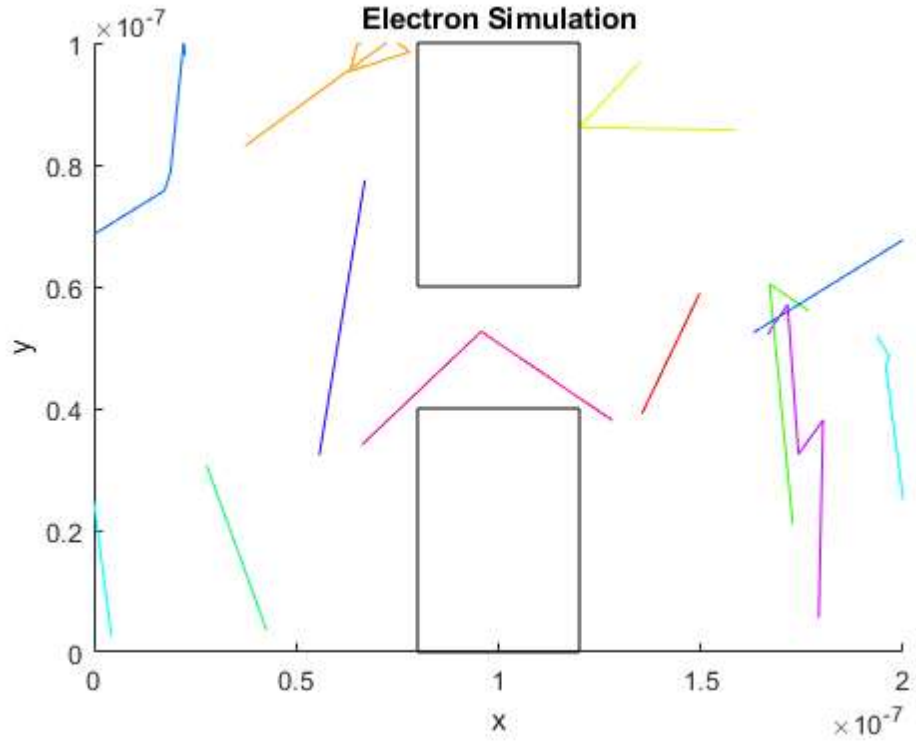
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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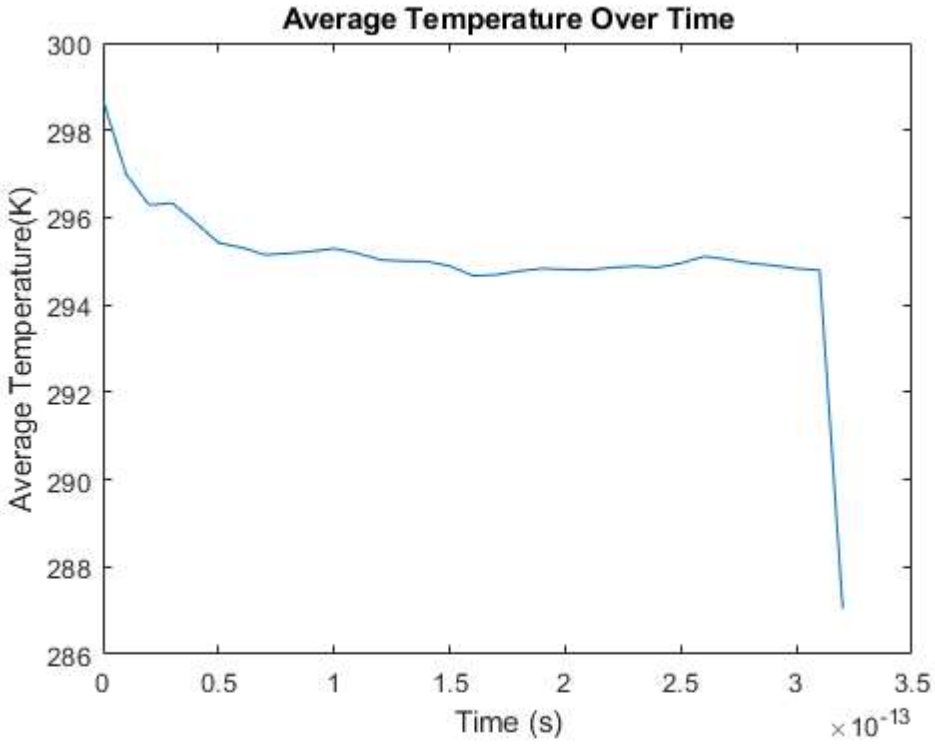
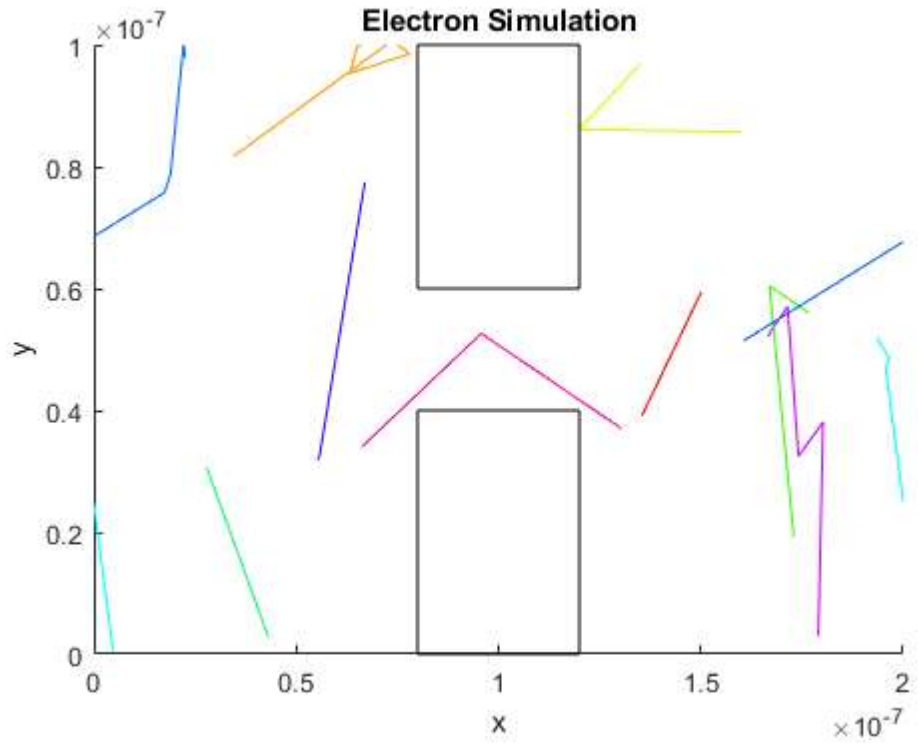
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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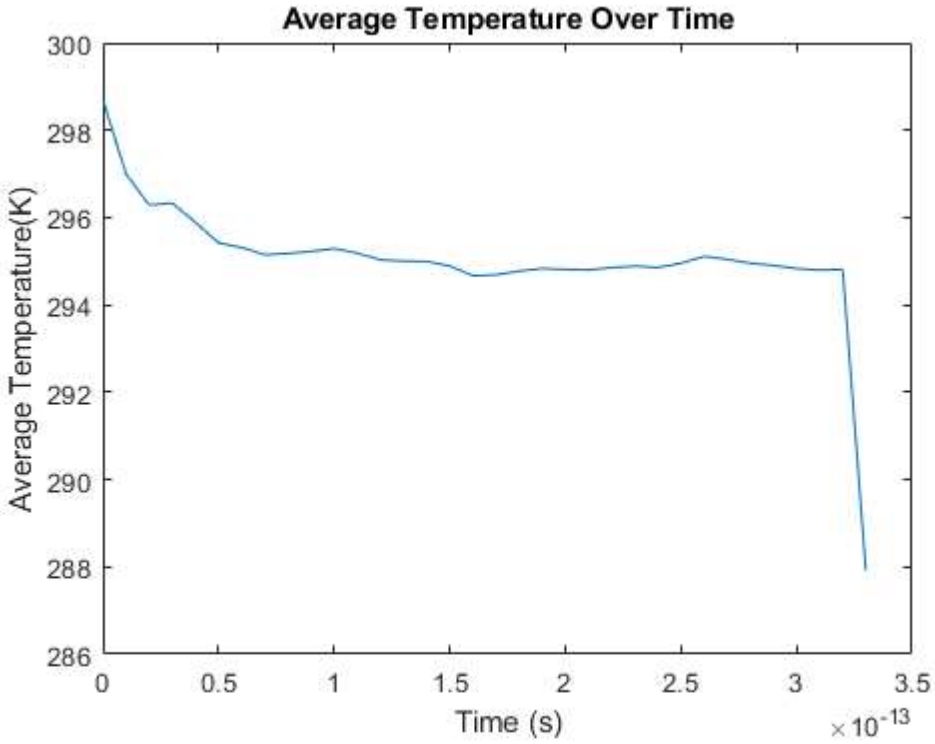
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
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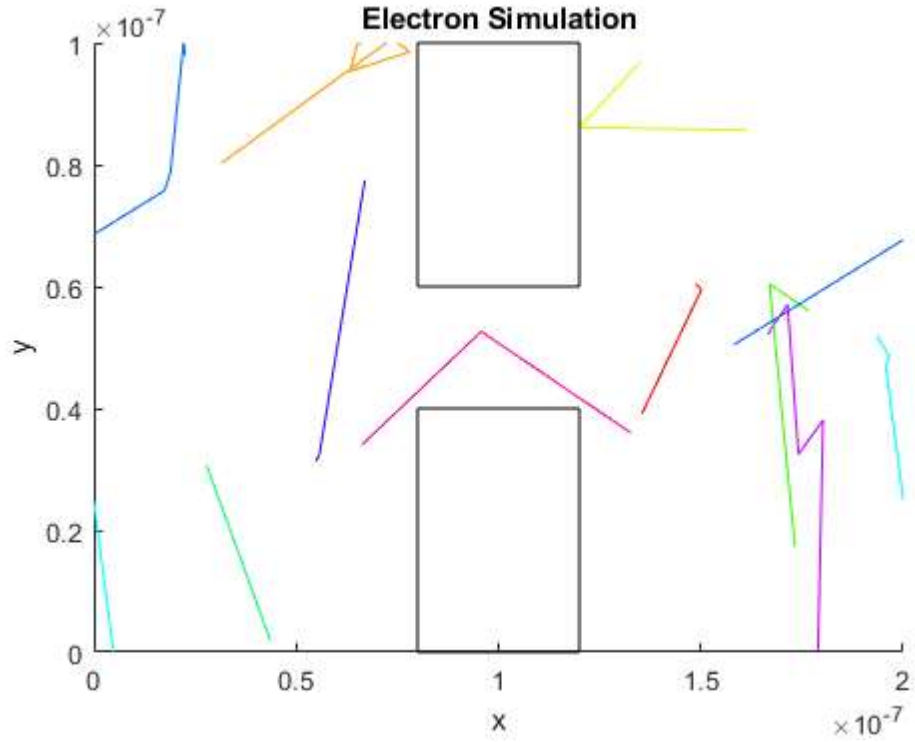
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
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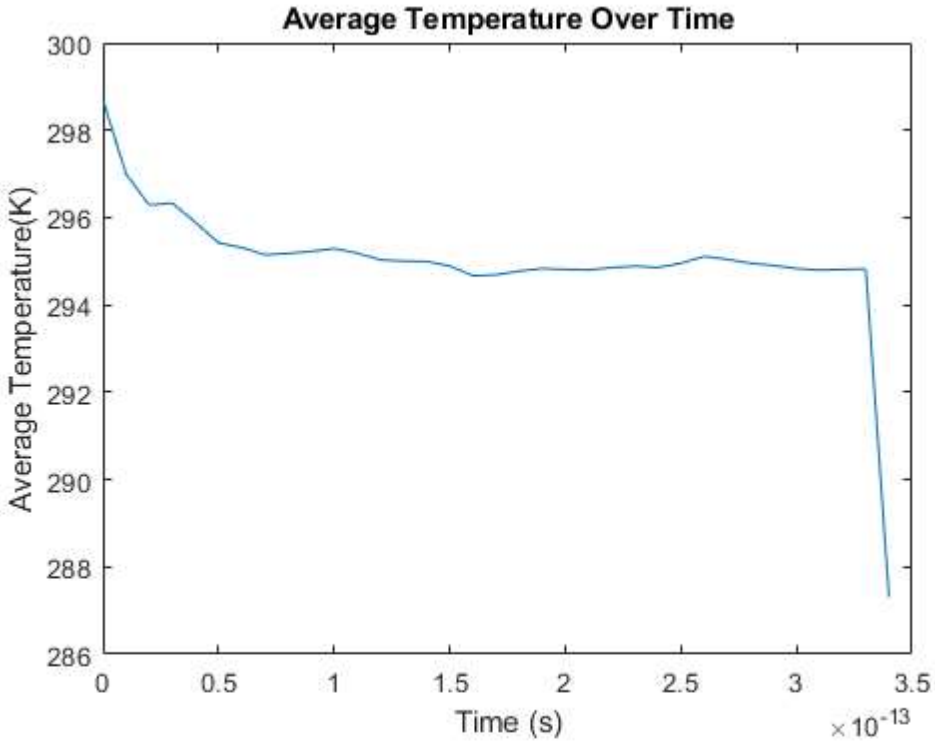
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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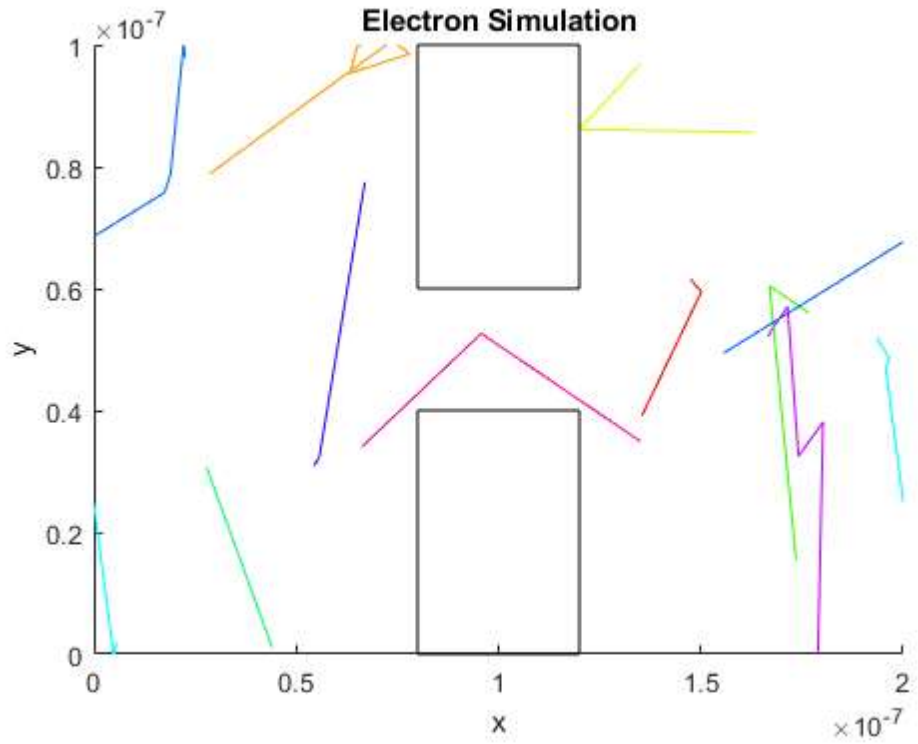
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
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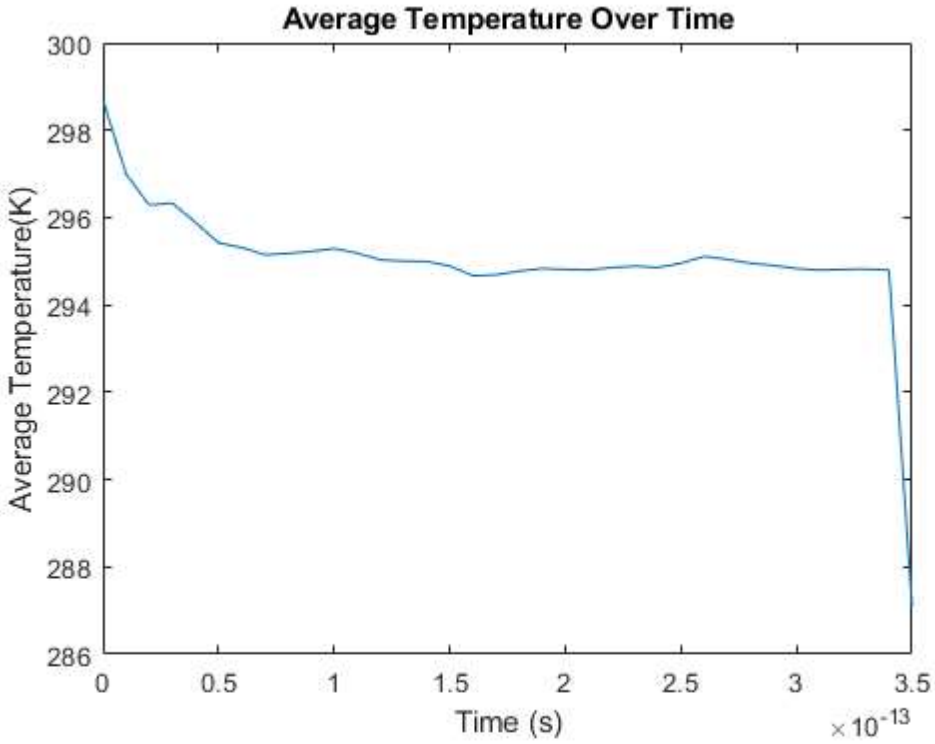
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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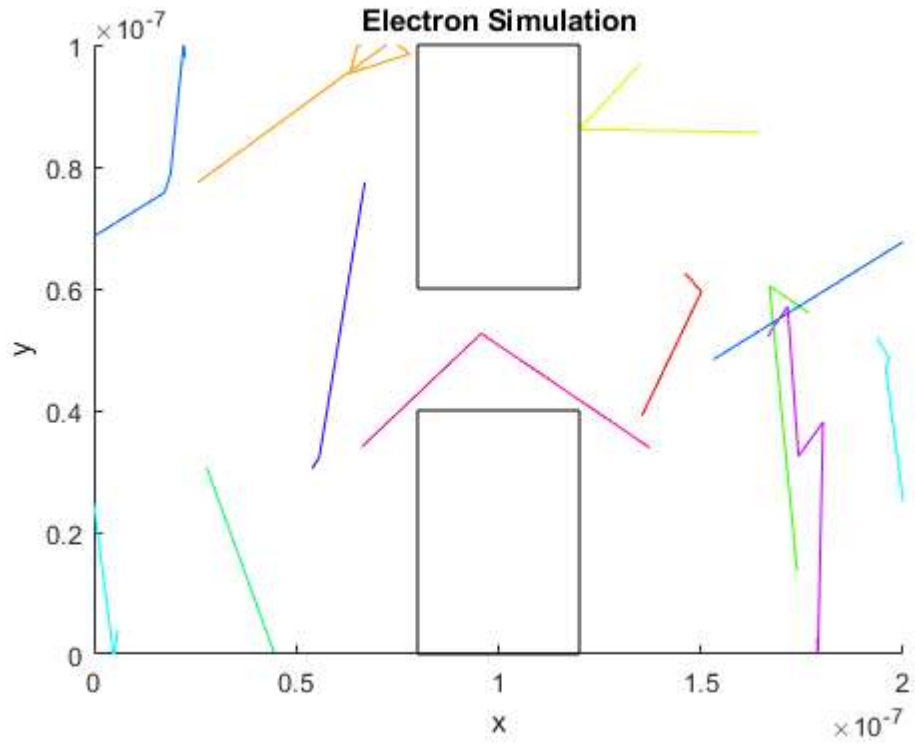
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
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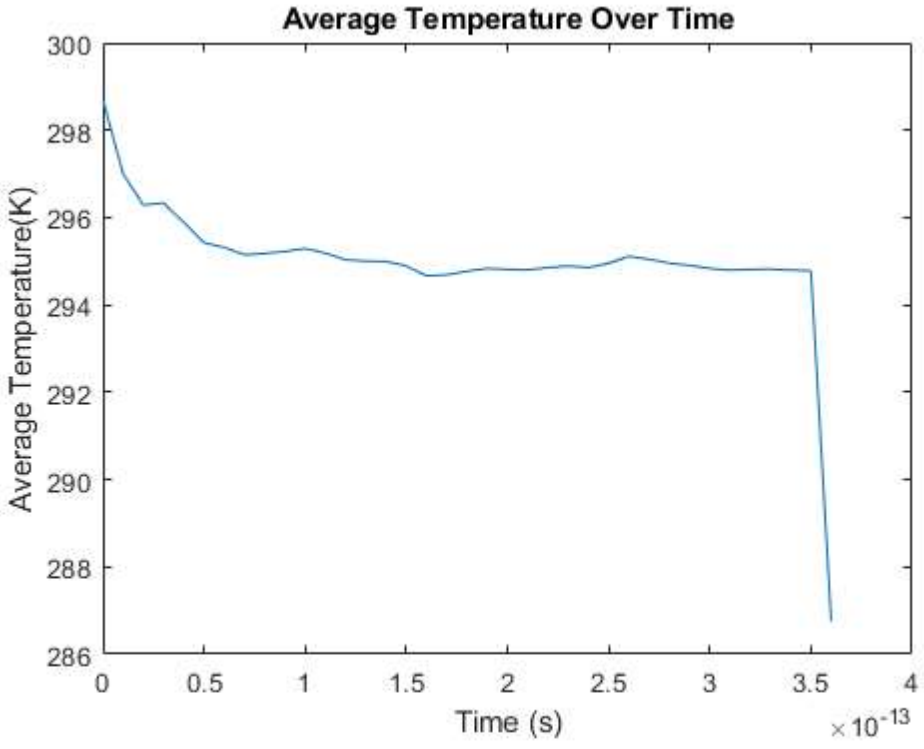
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
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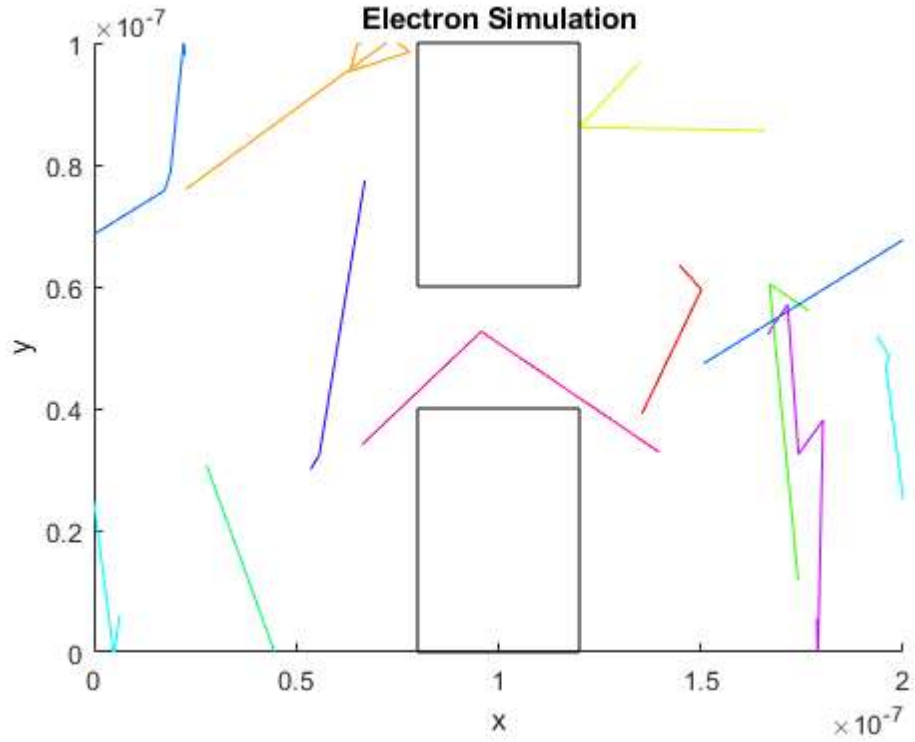
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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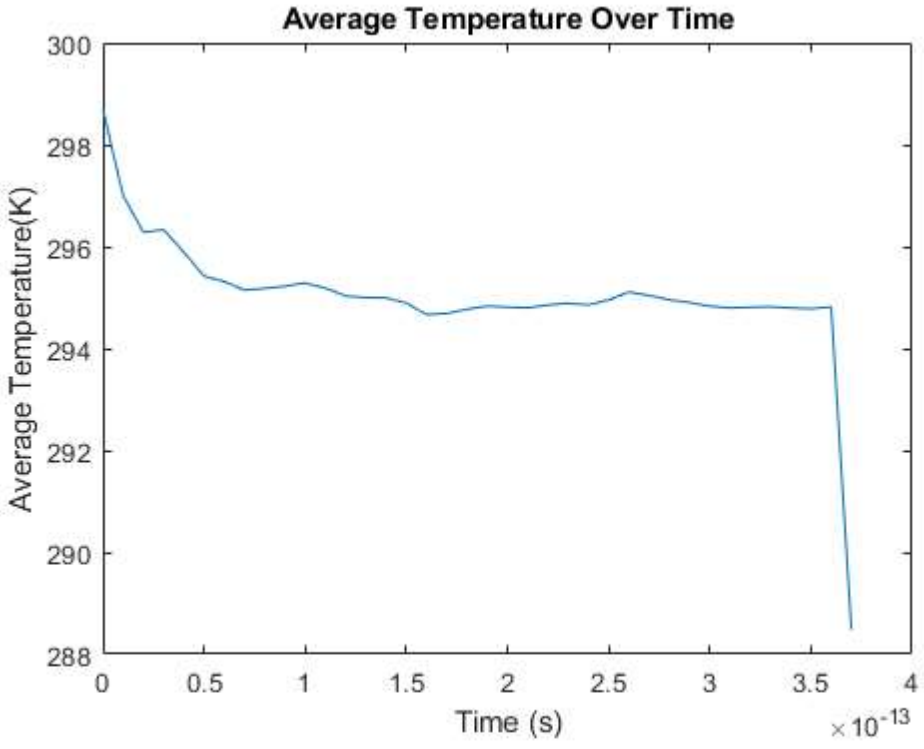
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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296
294
292
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Average Temperature(K)
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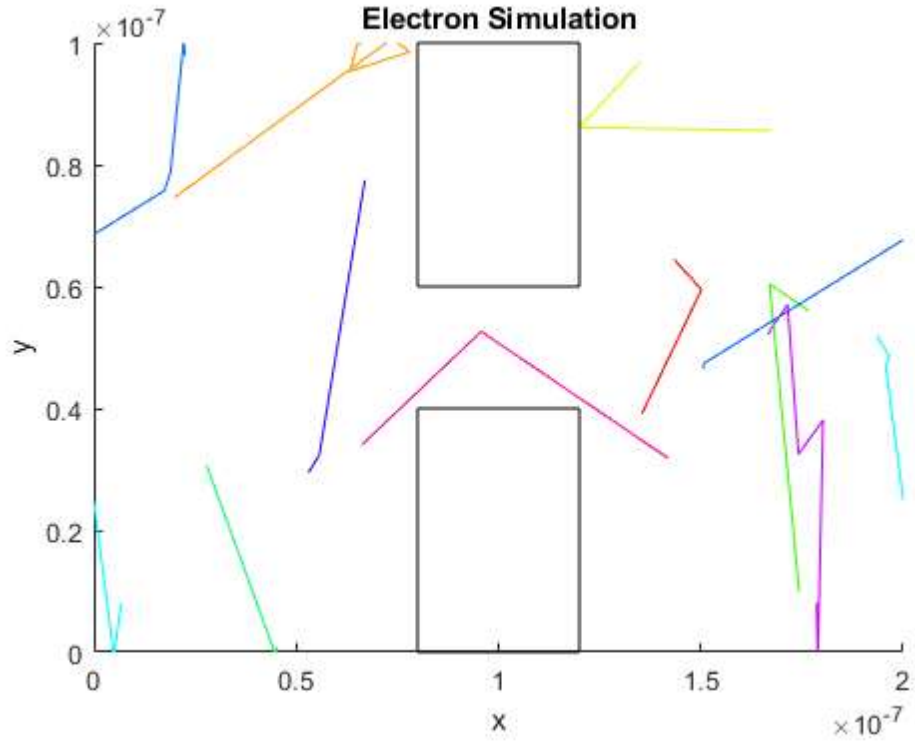
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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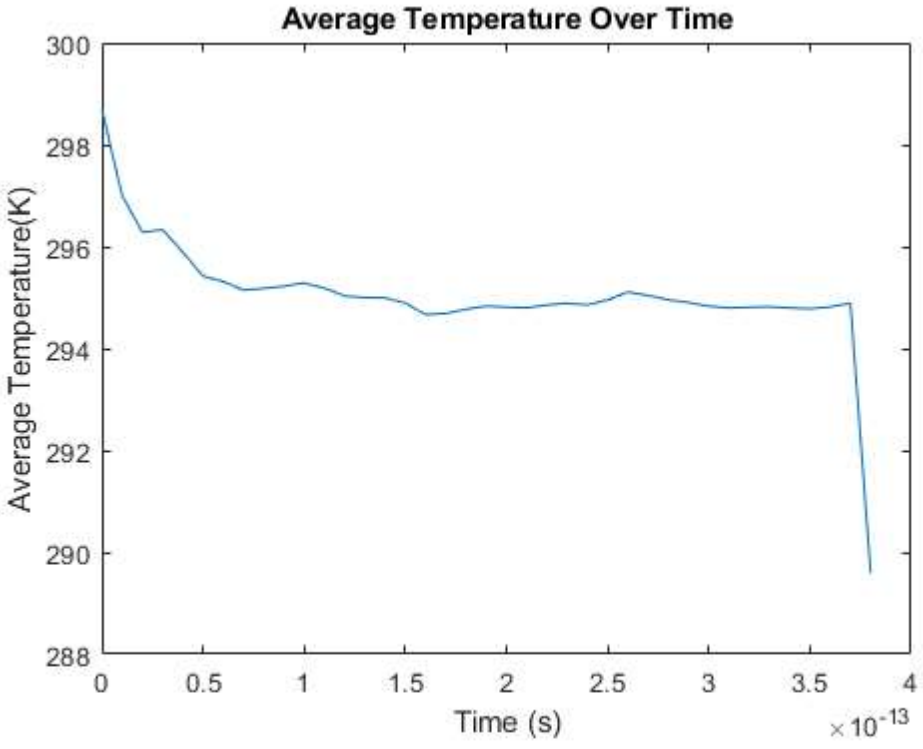
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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Average Temperature(K)
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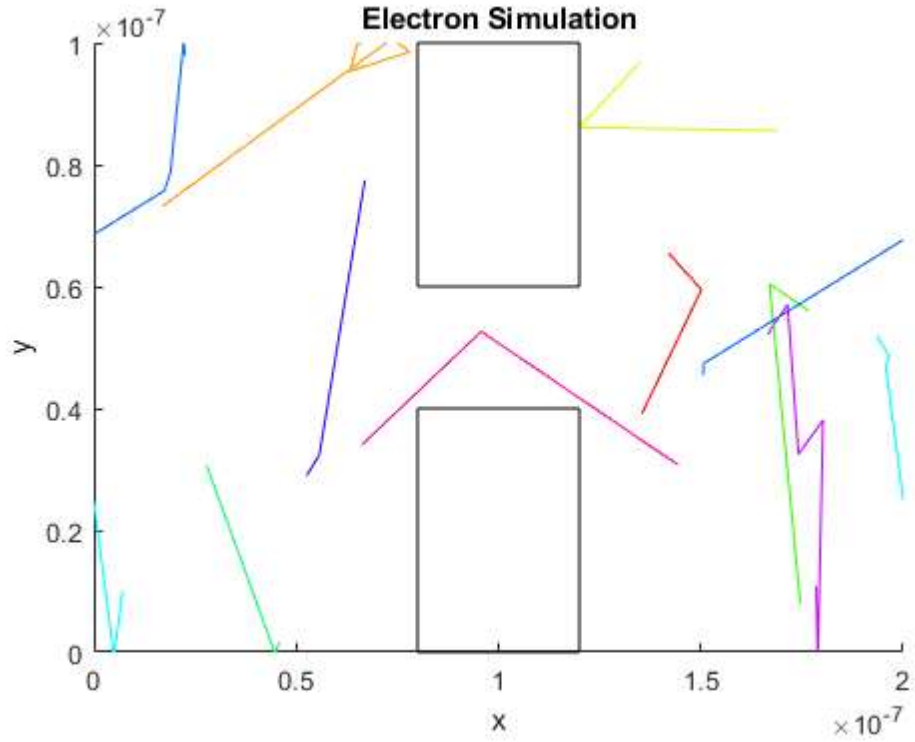
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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0.2
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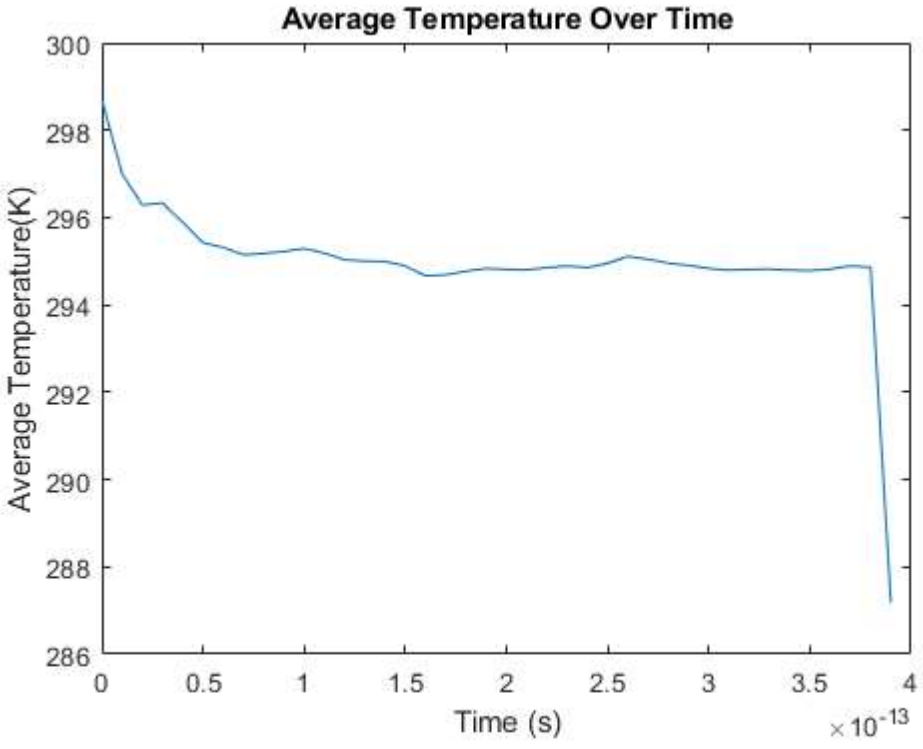
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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Average Temperature(K)
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0.5
1
1.5
2
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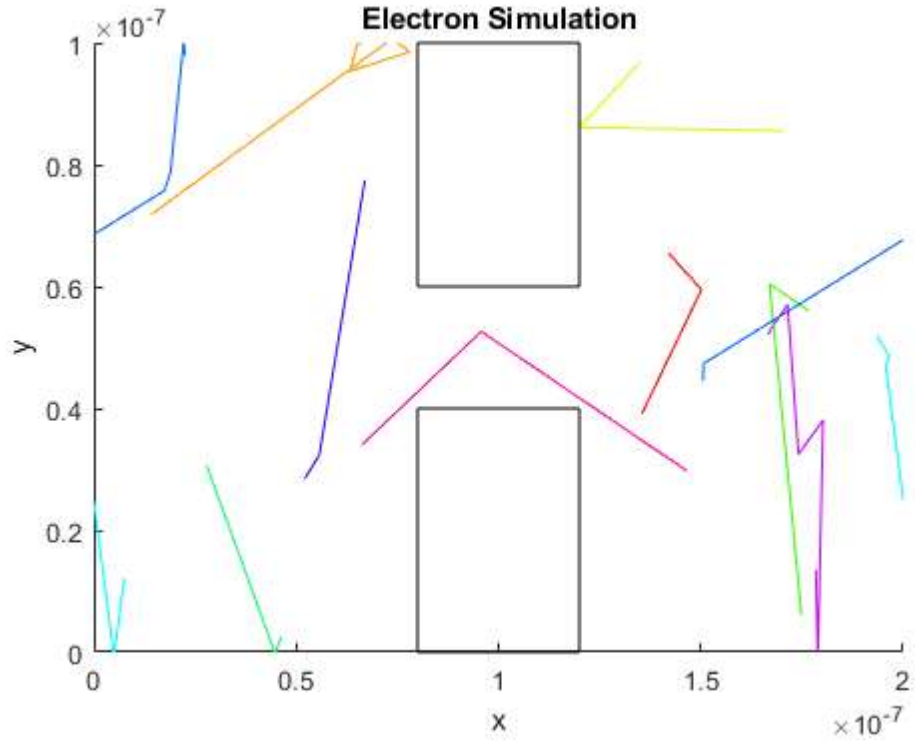
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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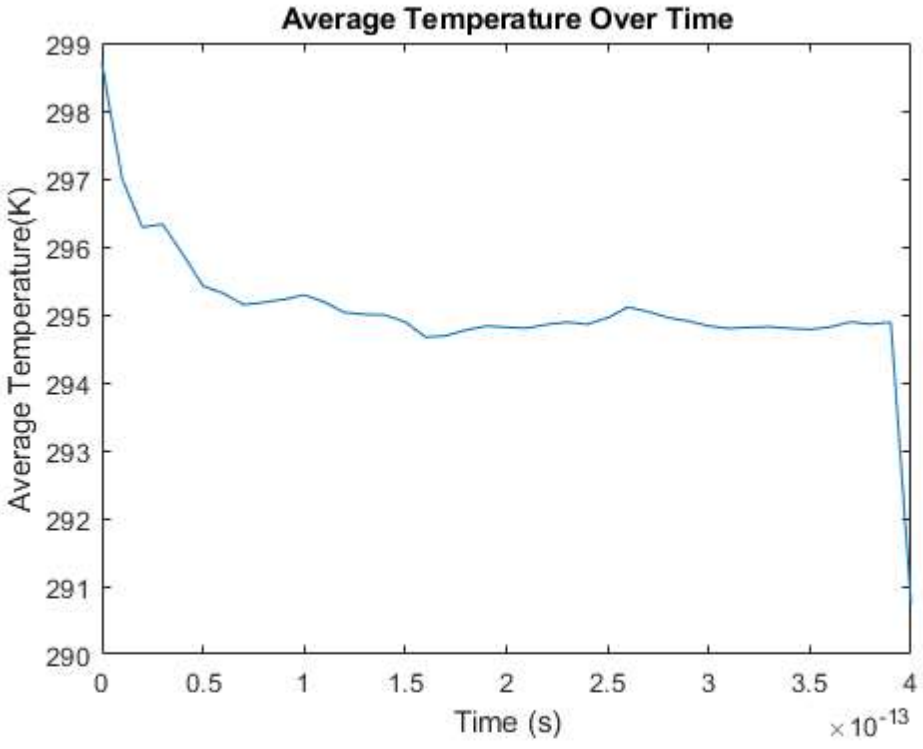
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
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Average Temperature(K)
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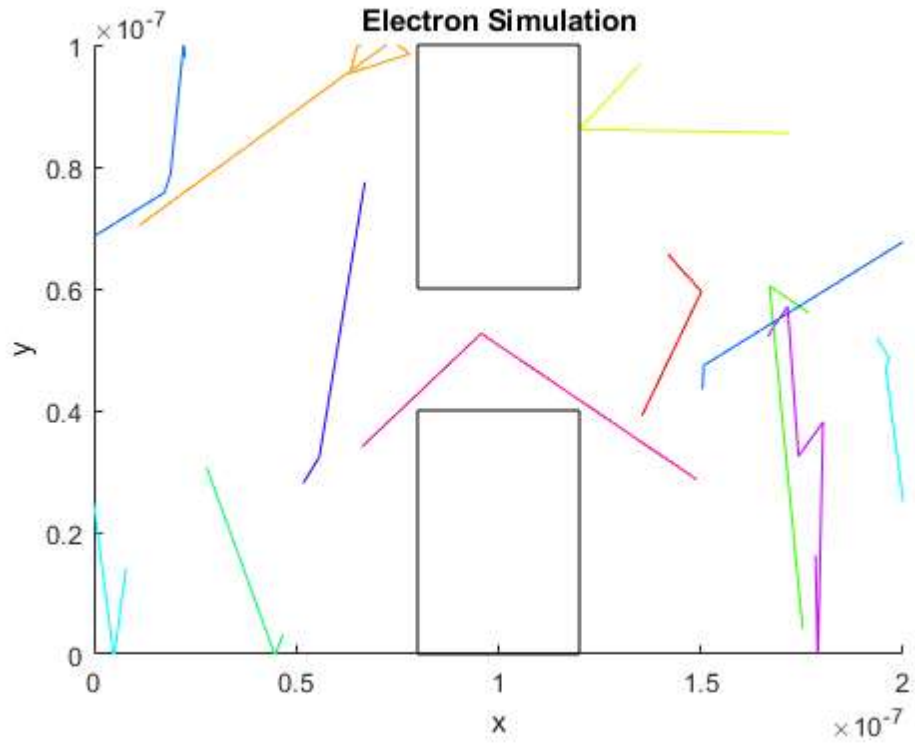
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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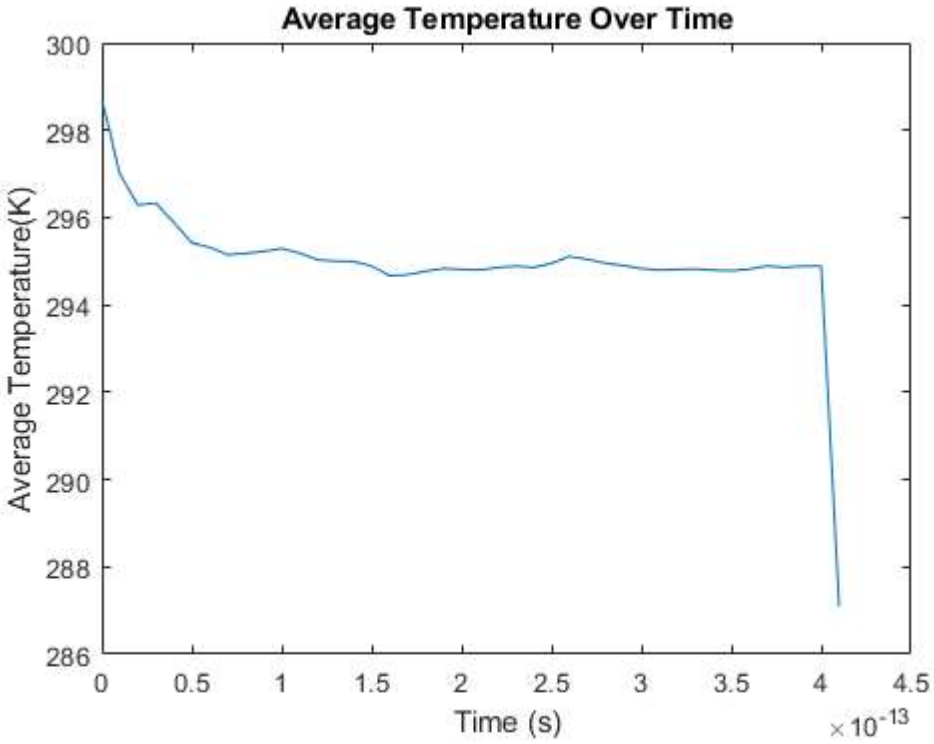
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
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Average Temperature(K)
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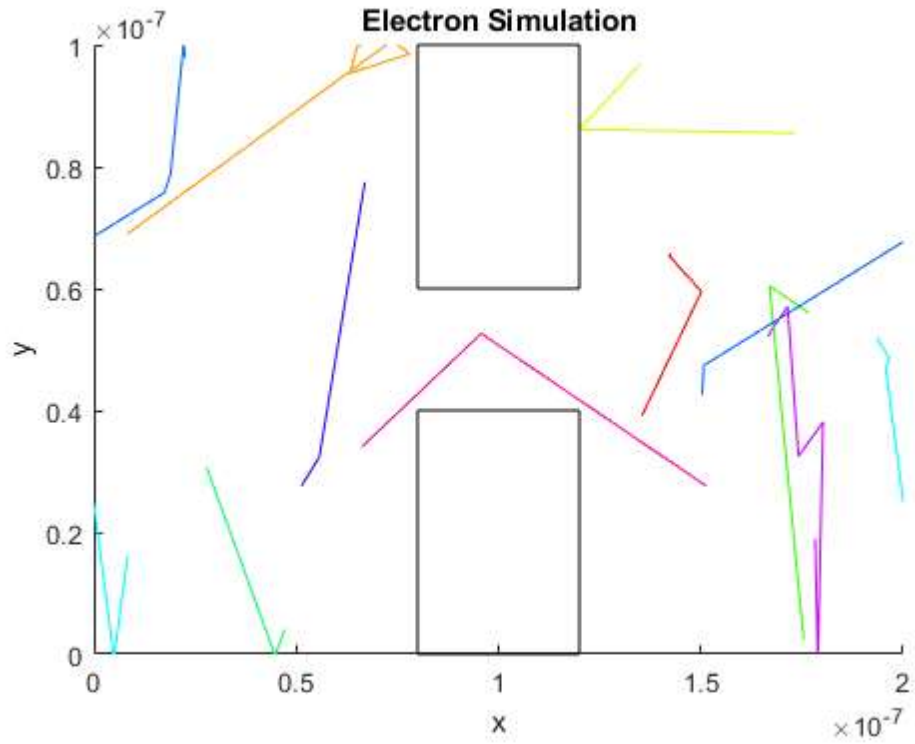
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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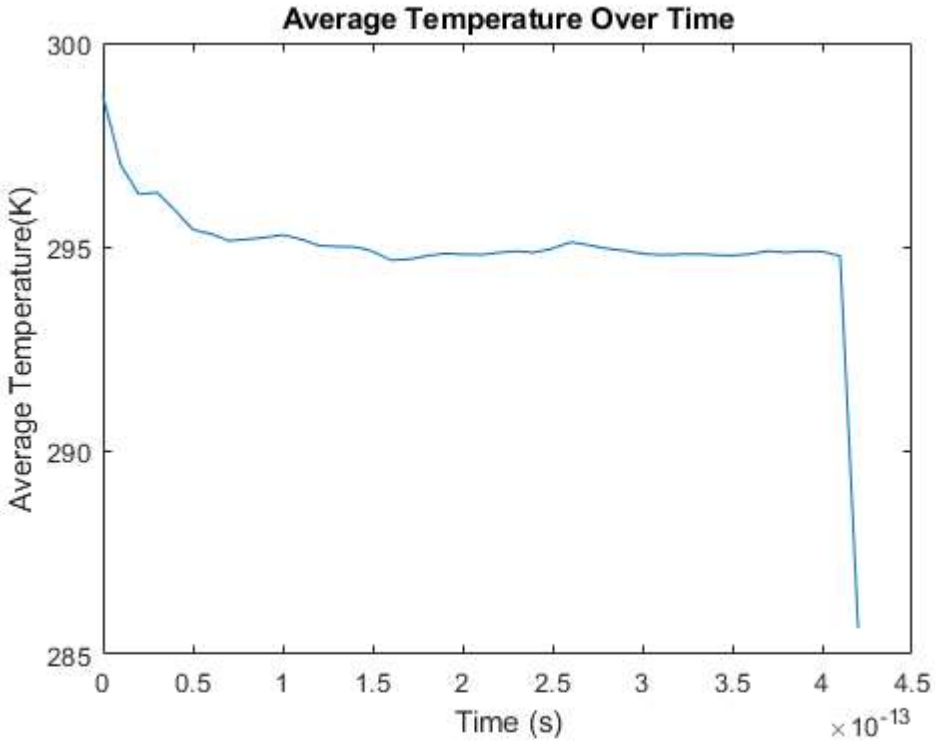
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
Average Temperature(K)
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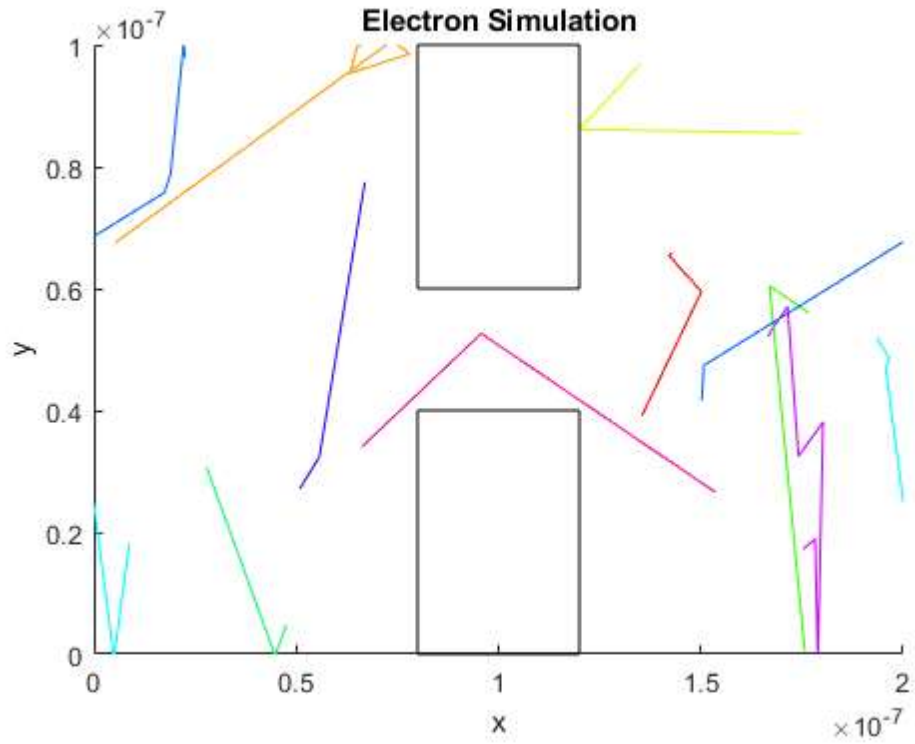
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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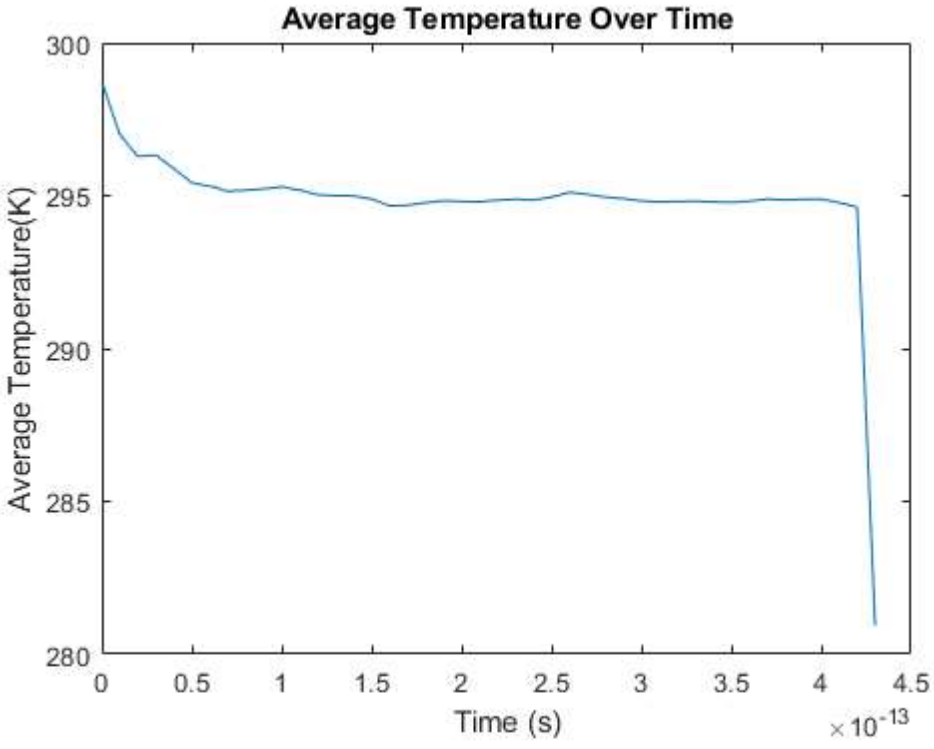
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
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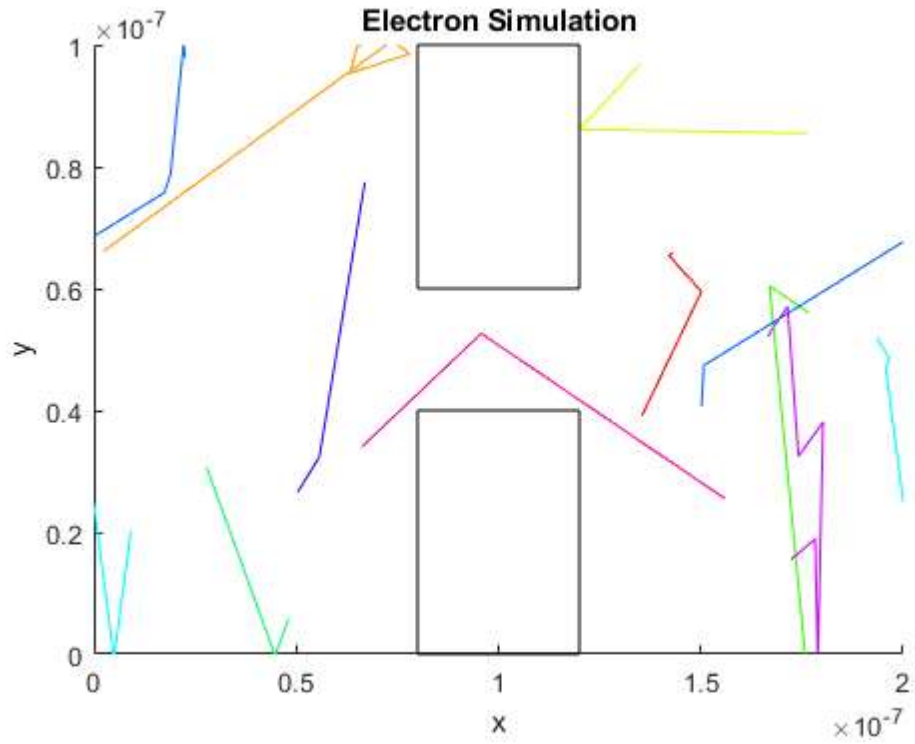
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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0.2
0
y
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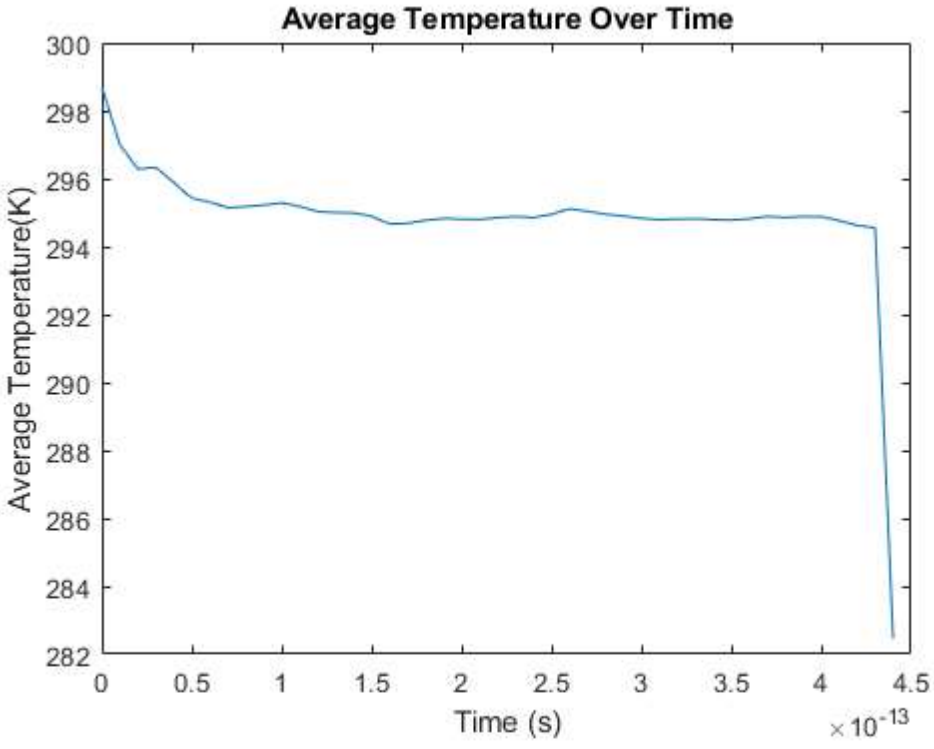
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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298
296
294
292
290
288
286
284
282
Average Temperature(K)
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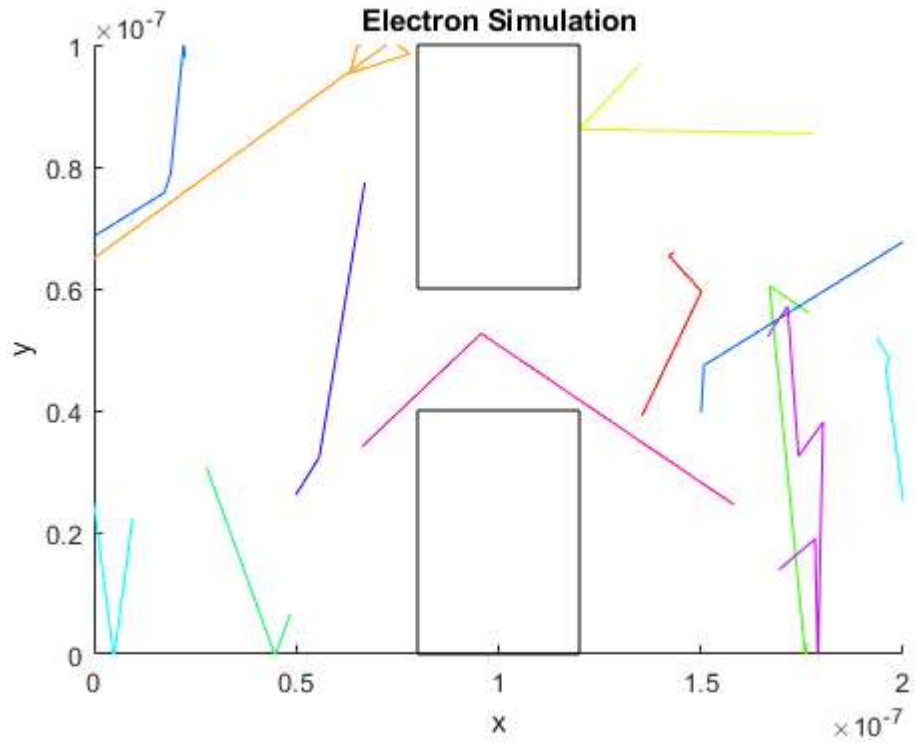
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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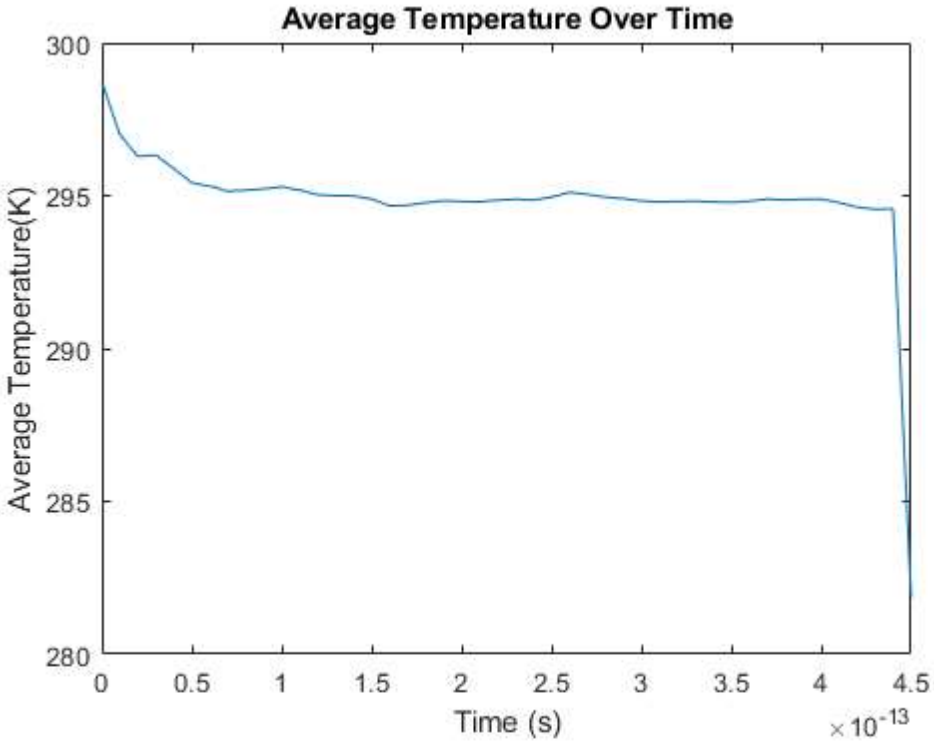
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
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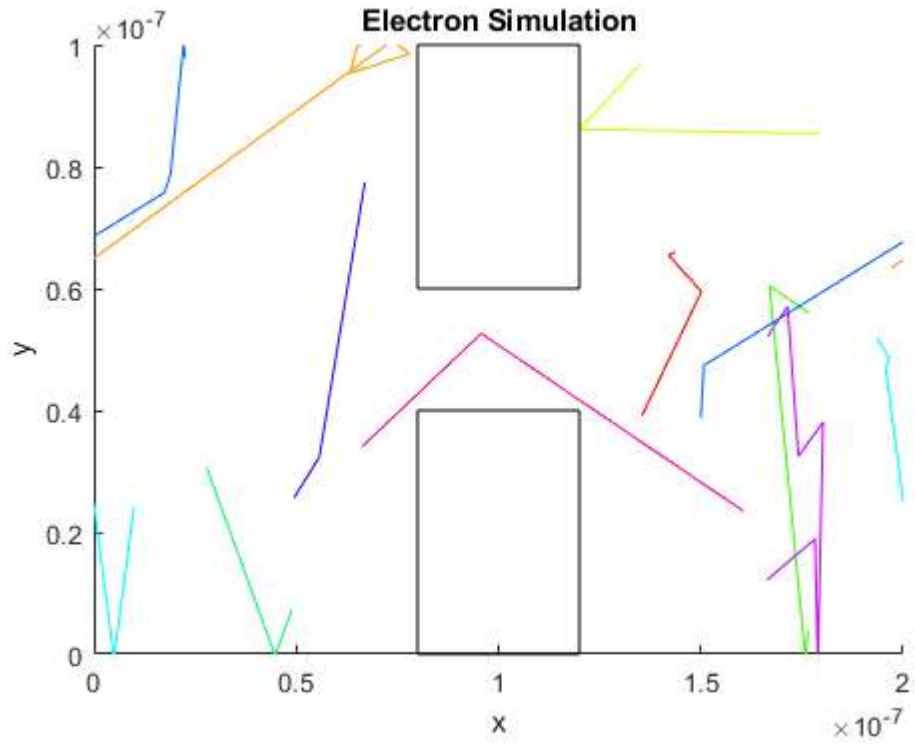
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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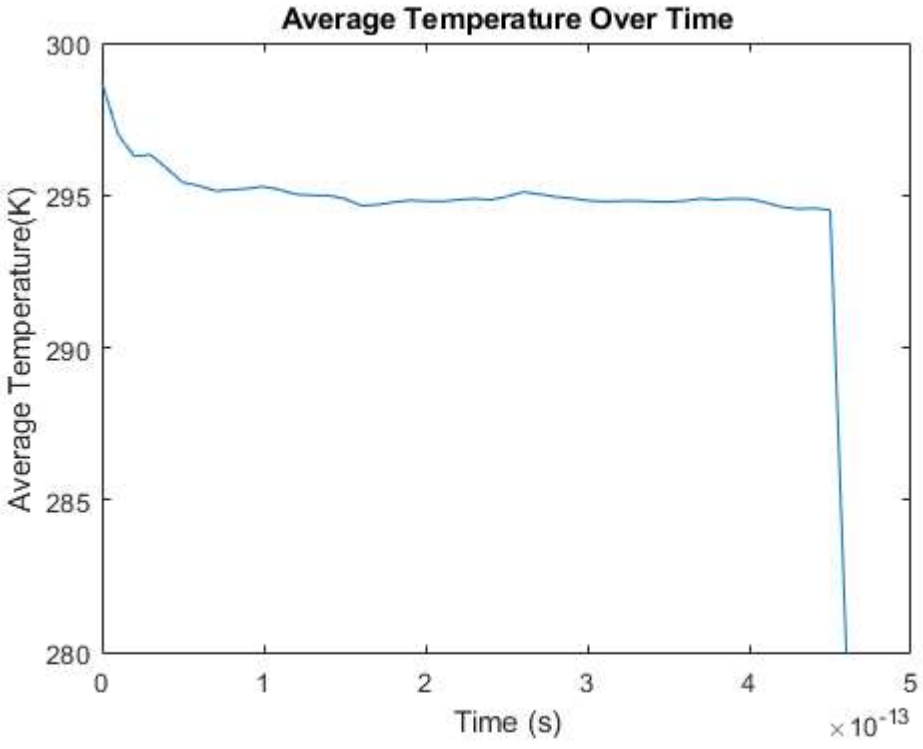
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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295
290
285
280
Average Temperature(K)
0
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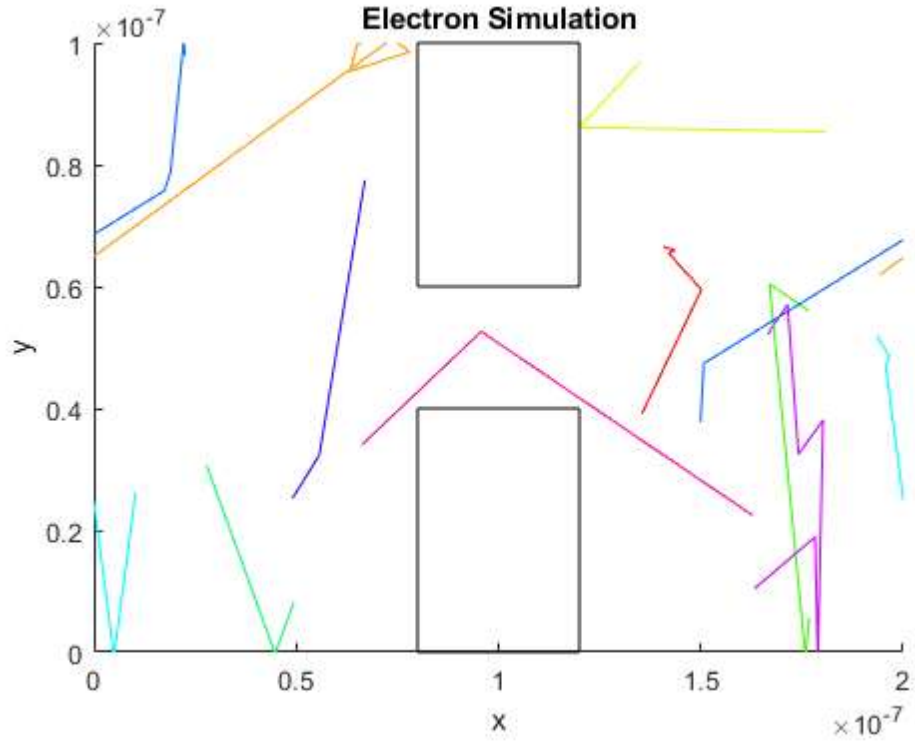
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
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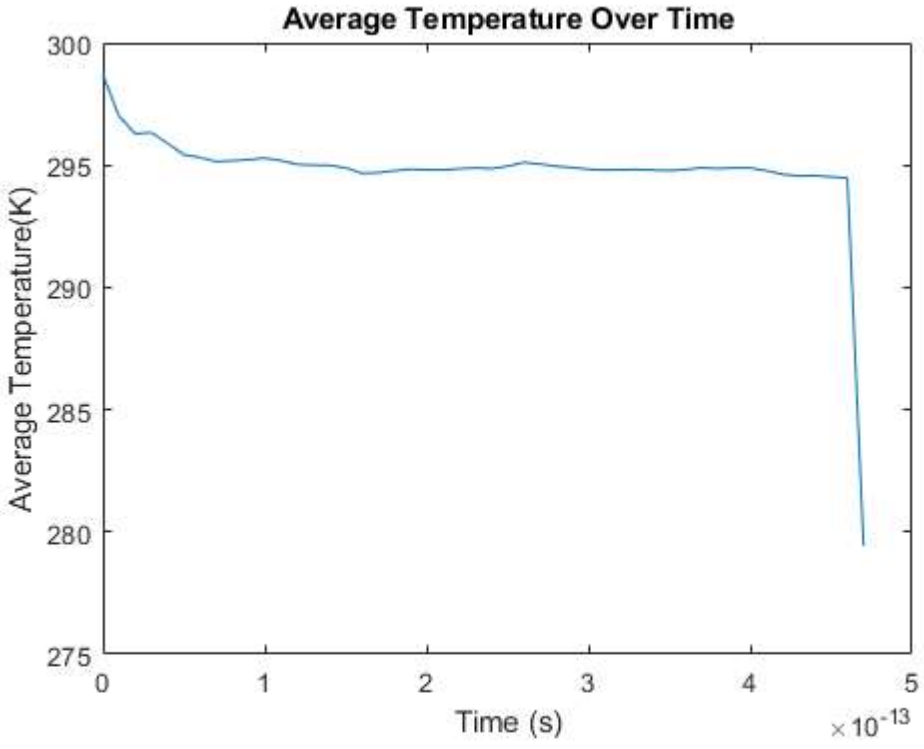
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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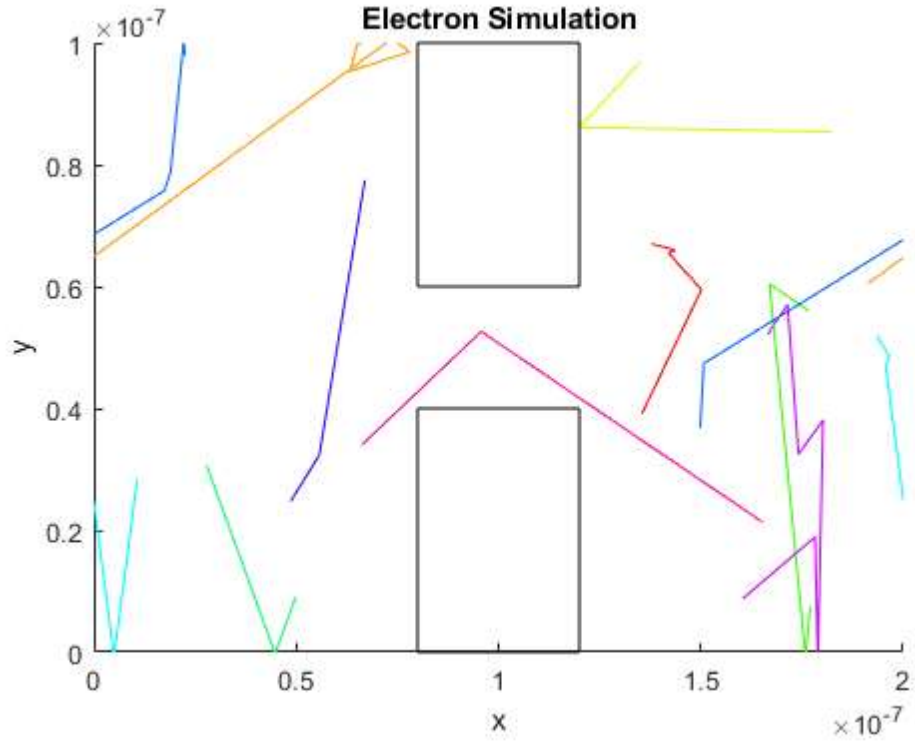
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
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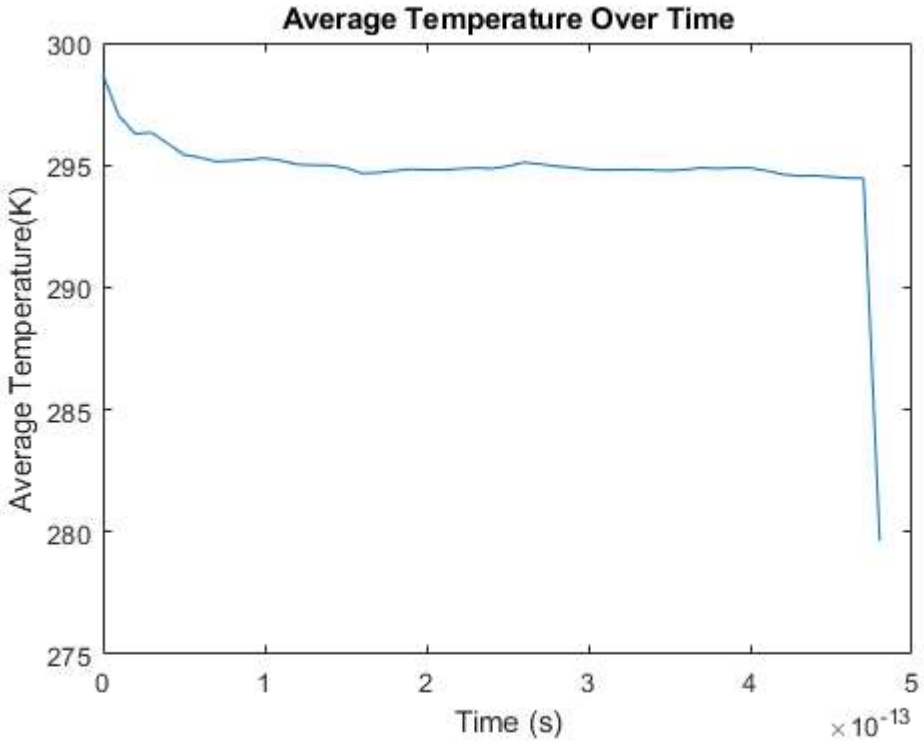
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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290
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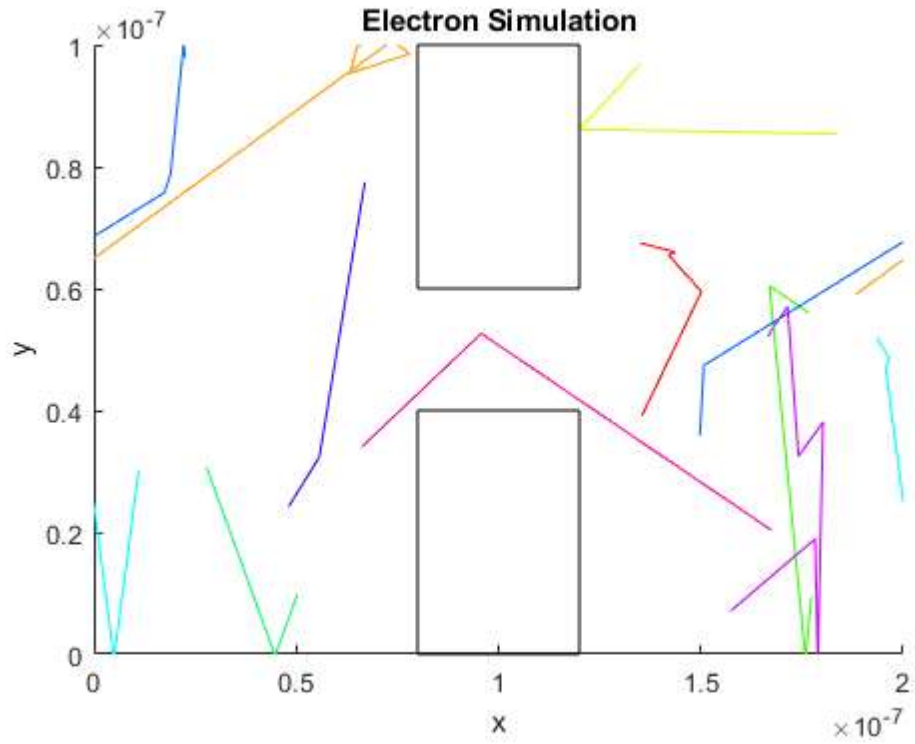
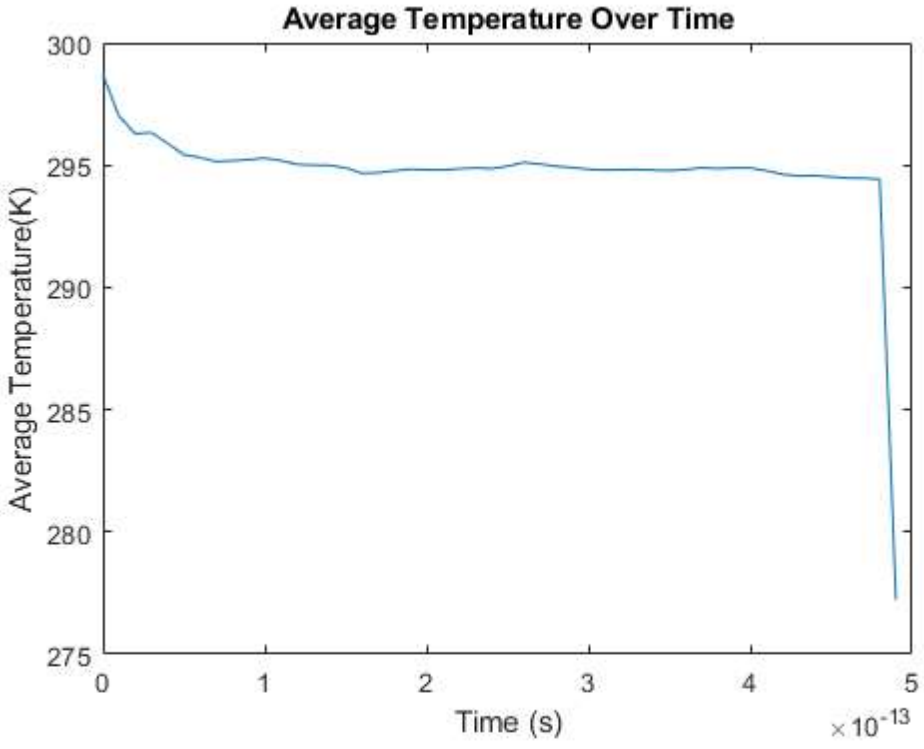
280
275
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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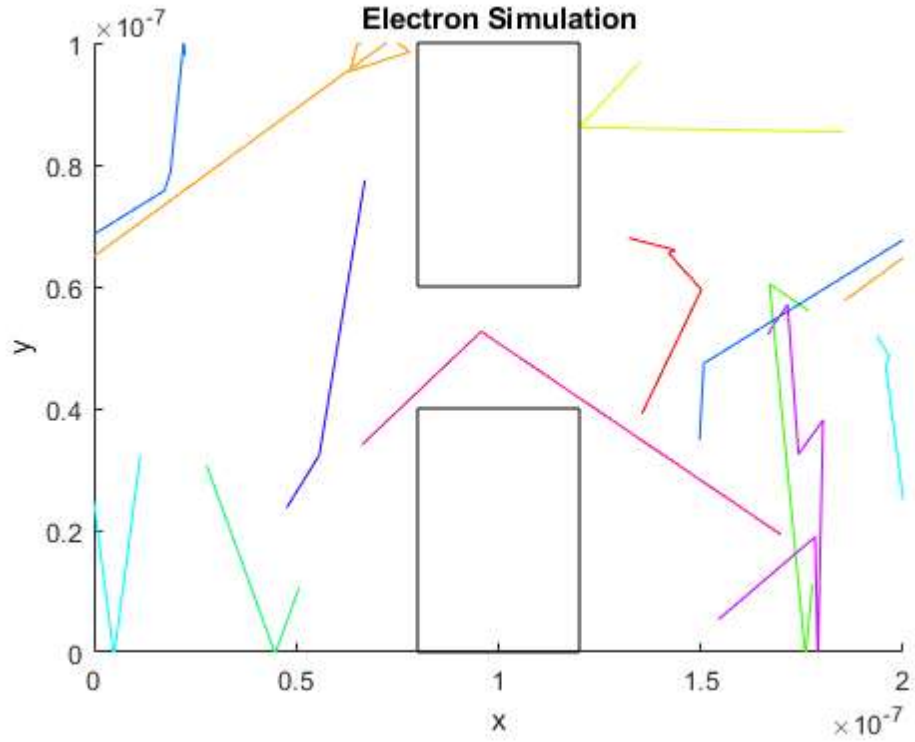
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
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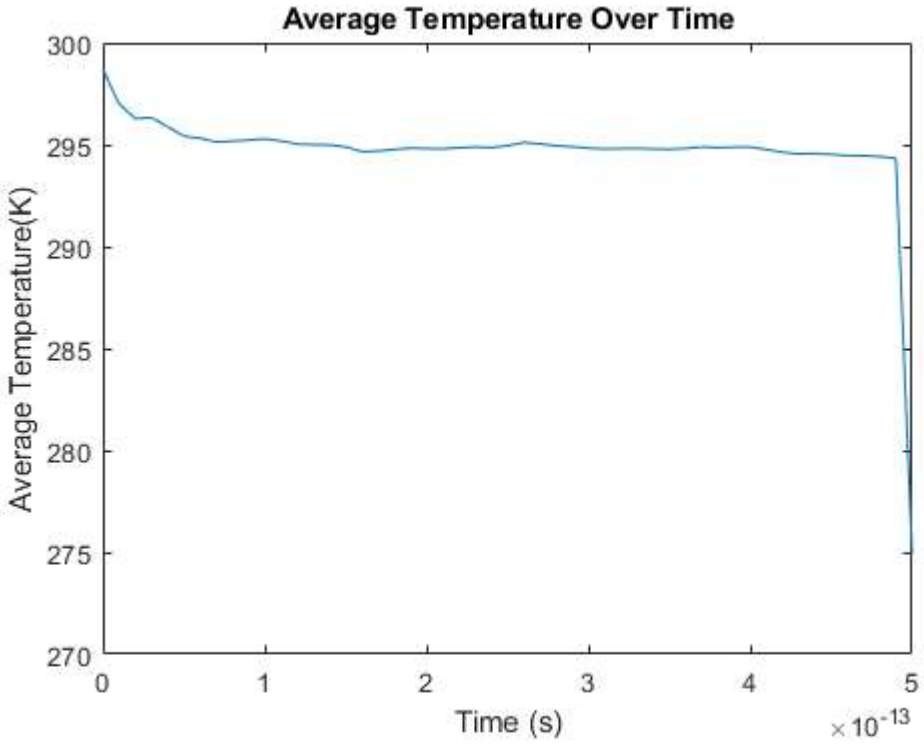
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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1
2
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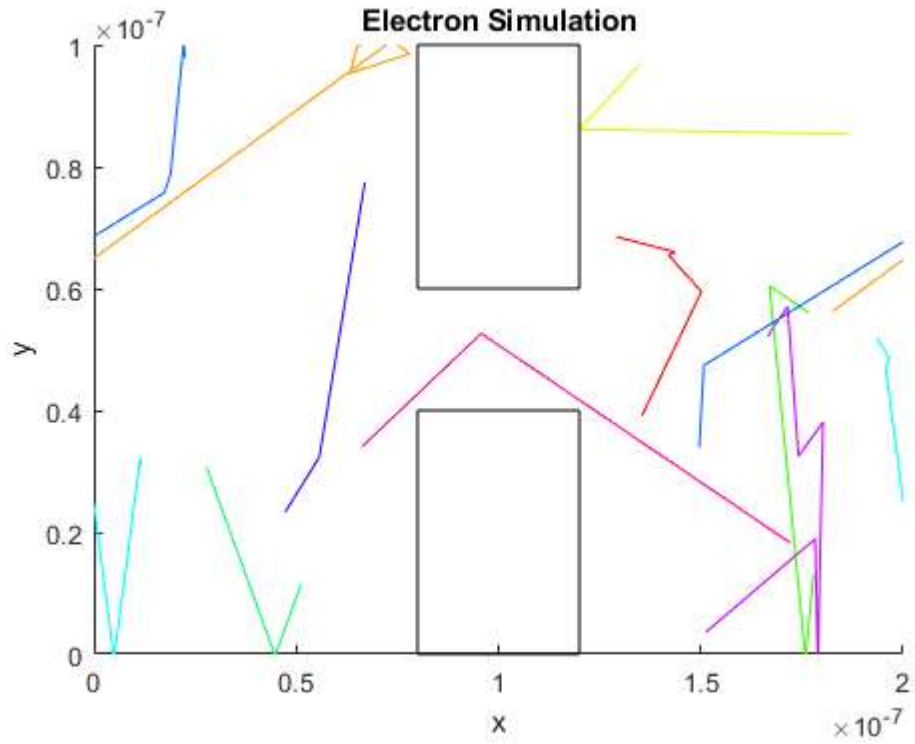
4
5
Time (s)
×10^-13


Electron Simulation
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y
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1
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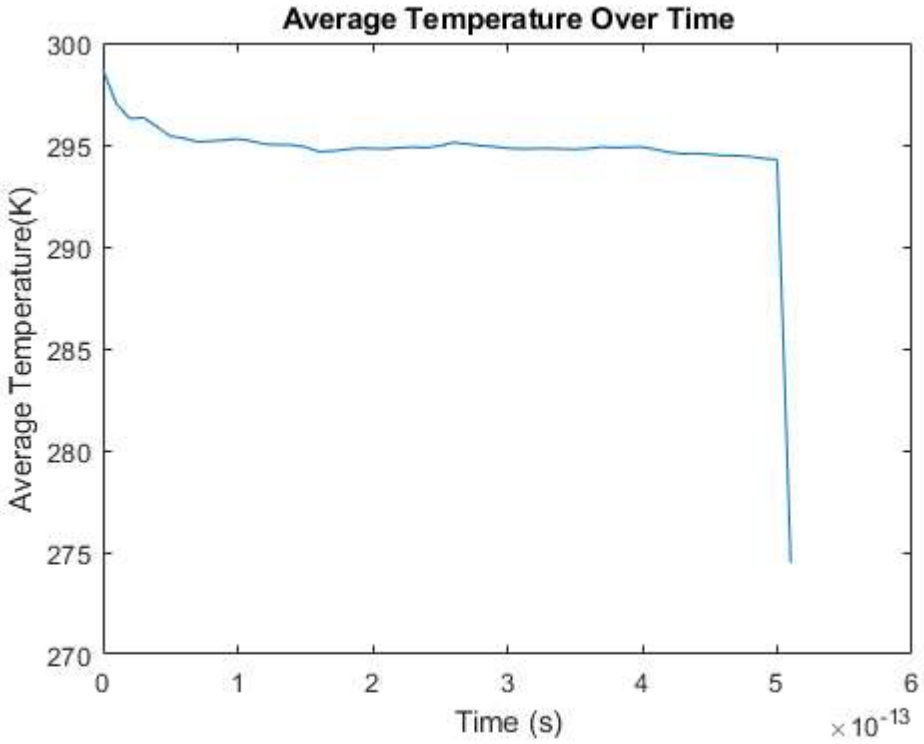
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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1
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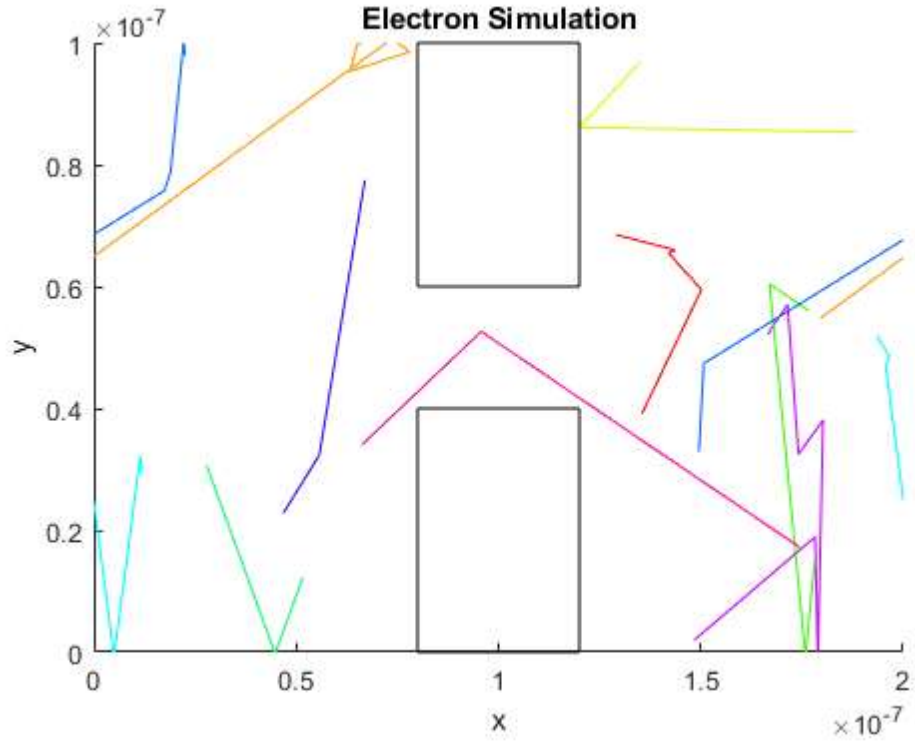
Time (s)
×10^-13


Electron Simulation
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y
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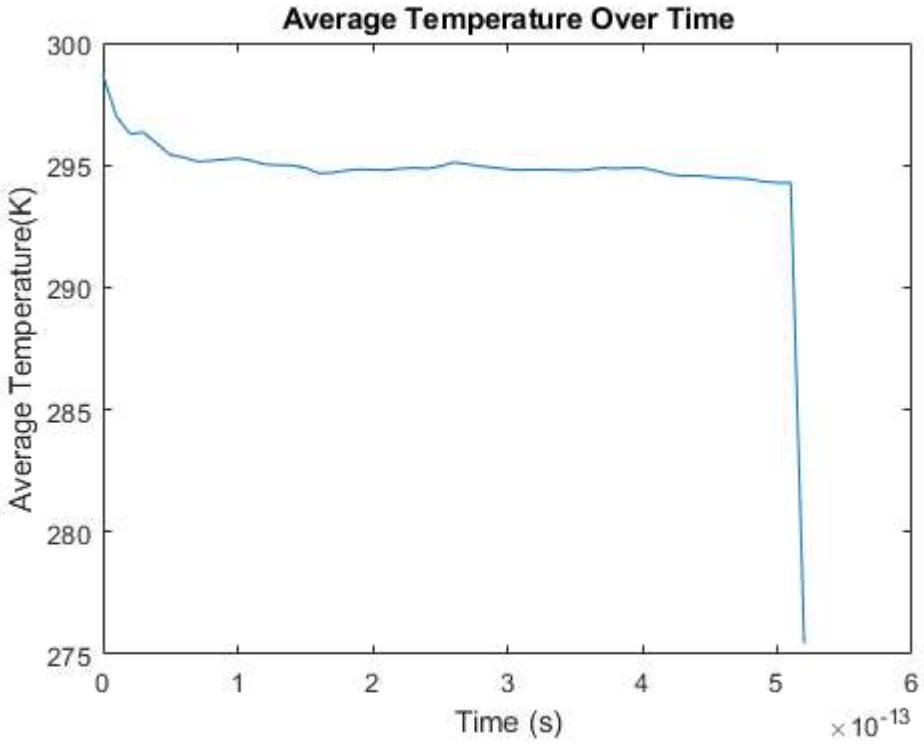
2
x
×10^-7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Average Temperature(K)
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Time (s)
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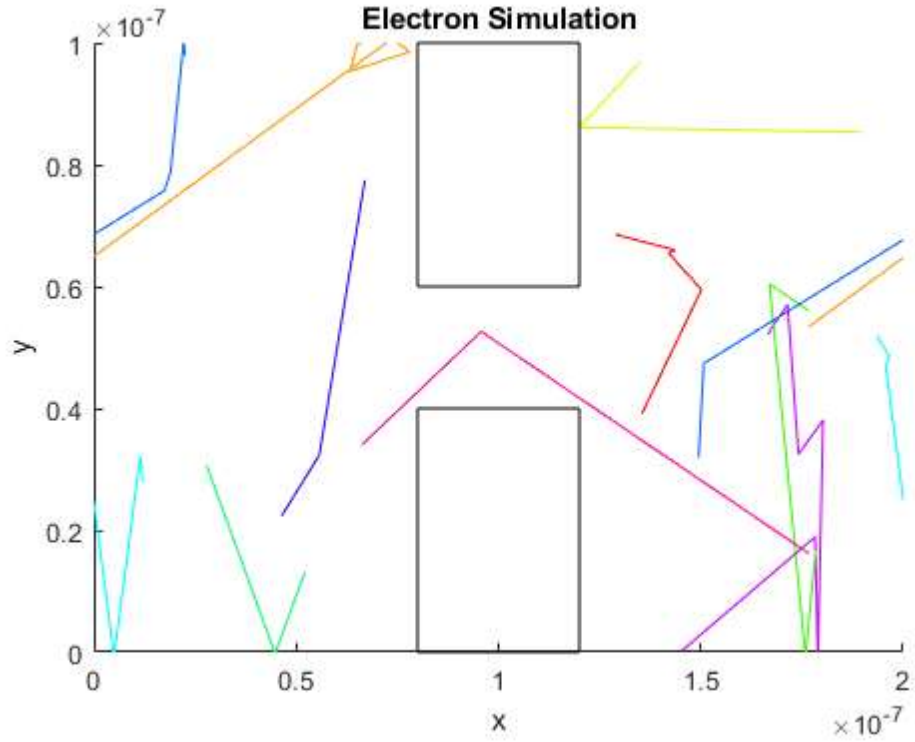
Electron Simulation
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y
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2
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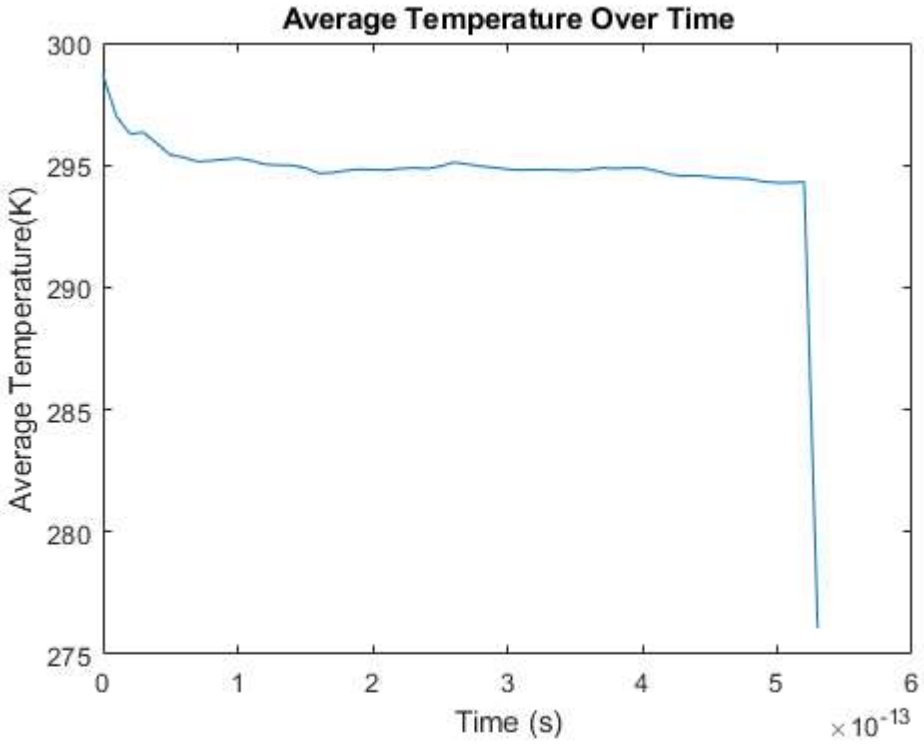
×10^-7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Average Temperature(K)
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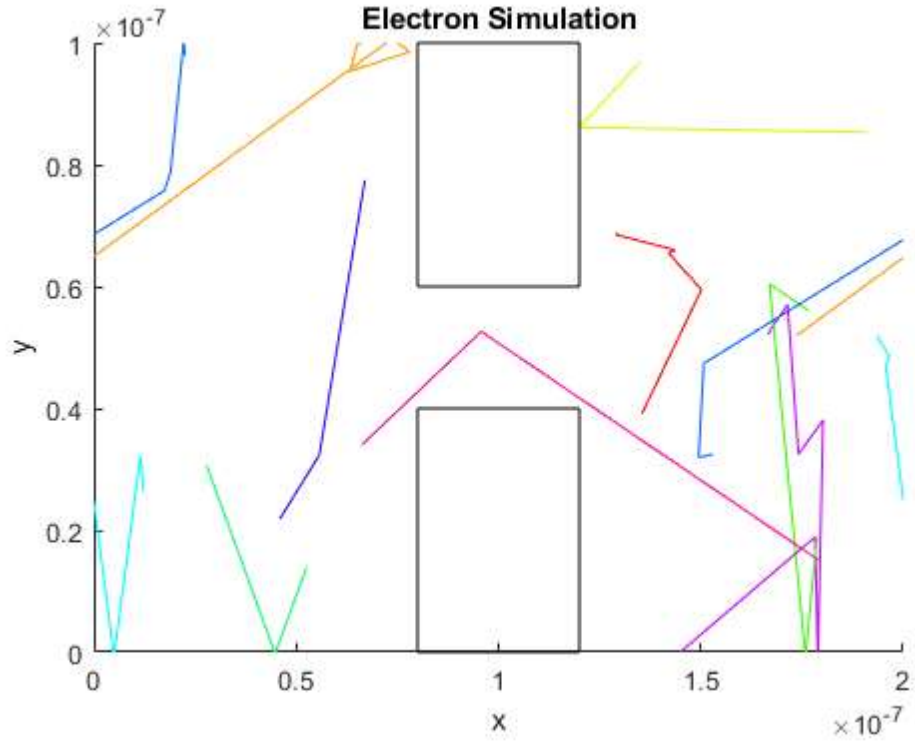
Time (s)
×10^-13


Electron Simulation
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y
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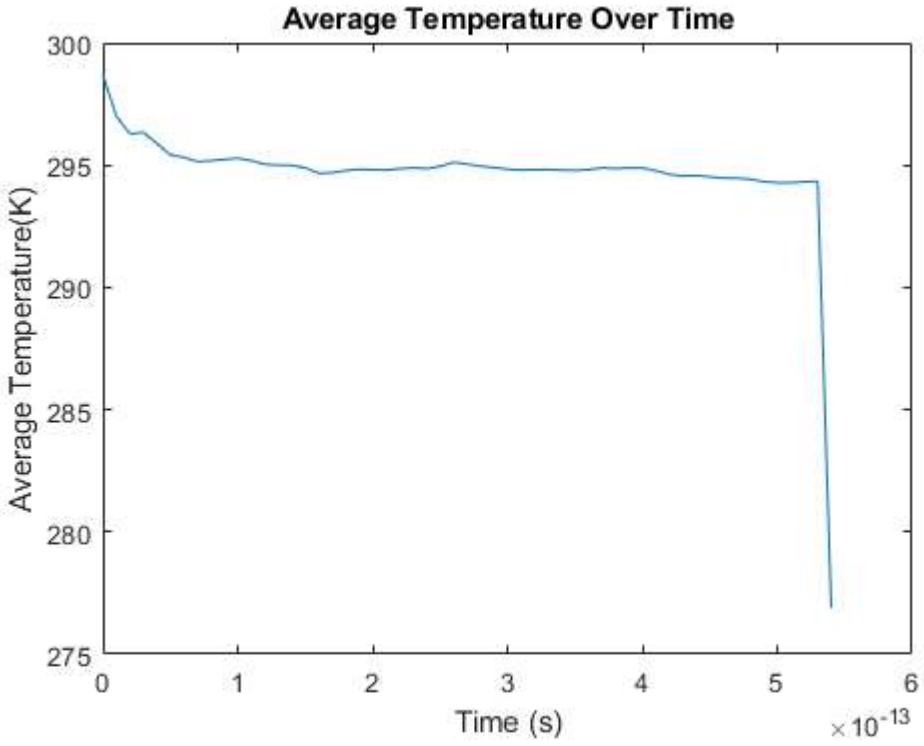
1
1.5
2
x
×10^-7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Average Temperature(K)
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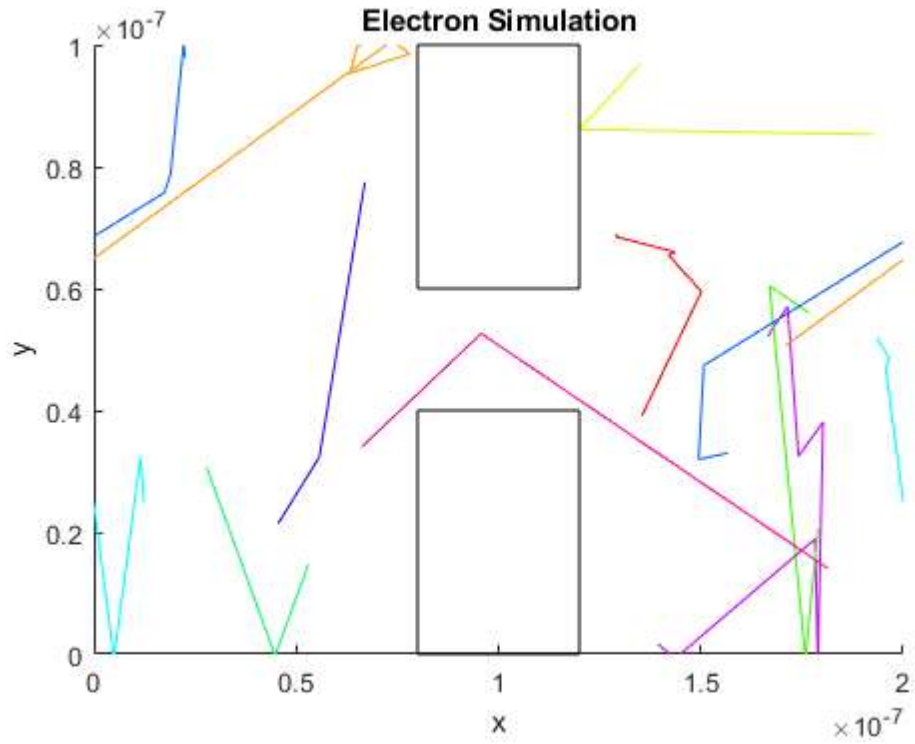
Time (s)
×10^-13


Electron Simulation
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y
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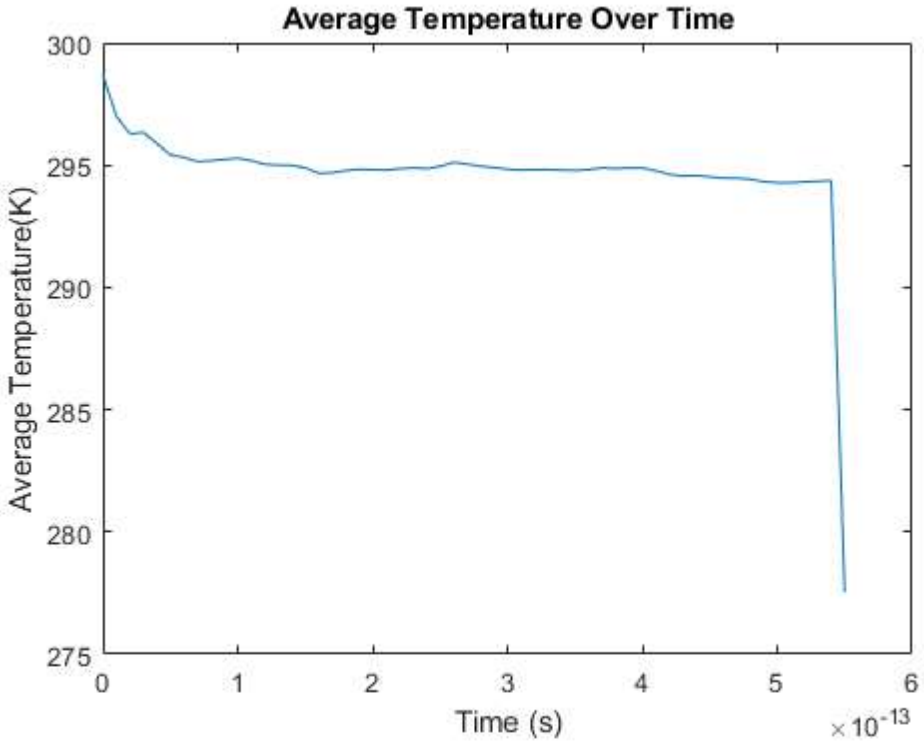
1
1.5
2
x
×10^-7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Average Temperature(K)
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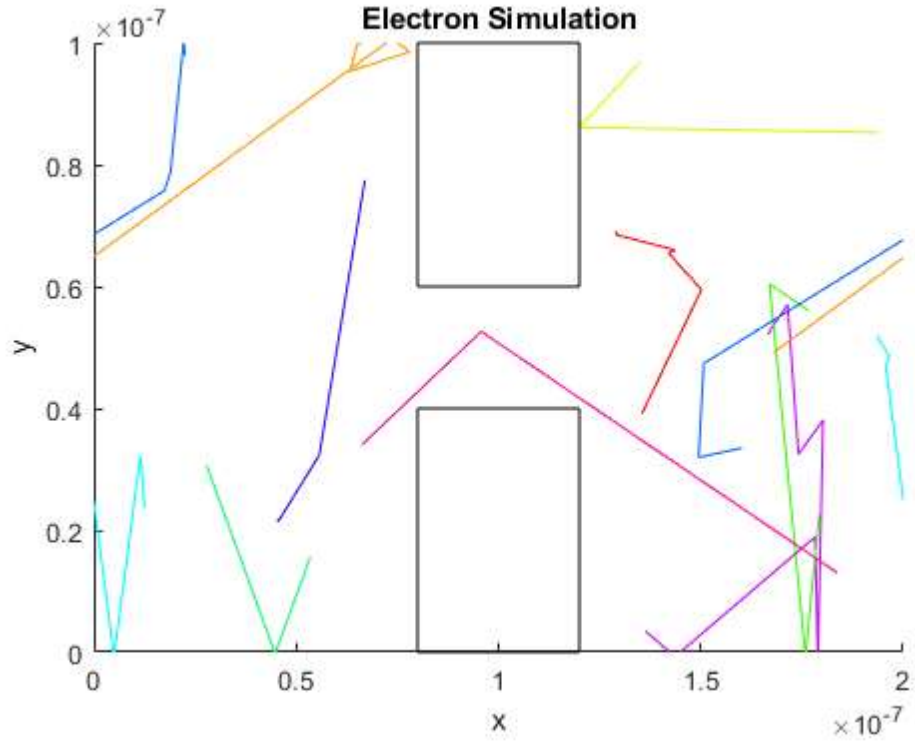
Time (s)
×10^-13


Electron Simulation
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y
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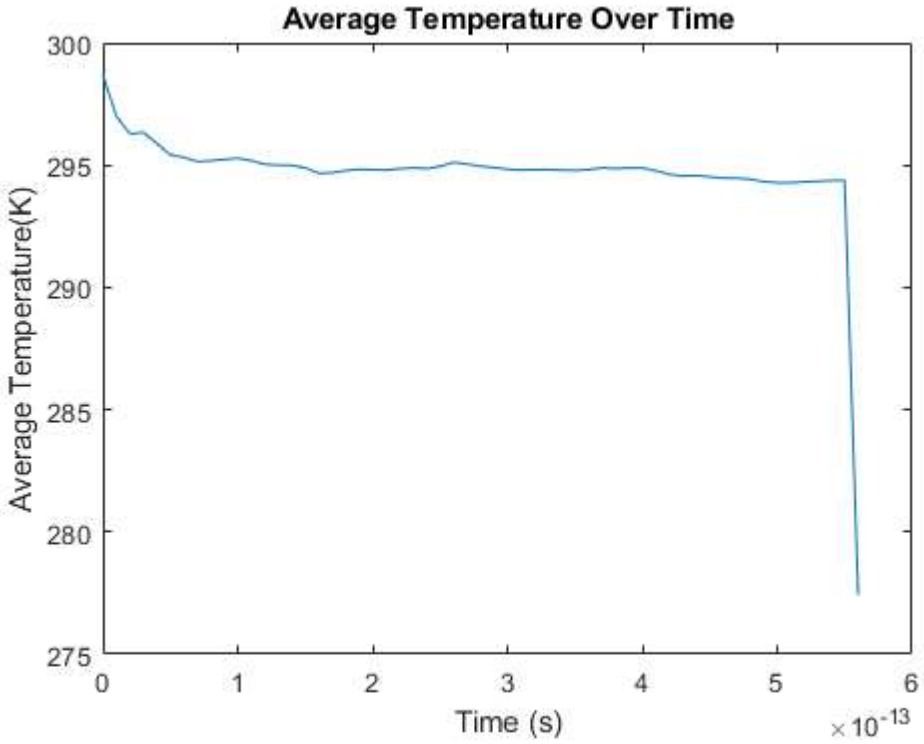
1
1.5
2
x
×10^-7


Average Temperature Over Time
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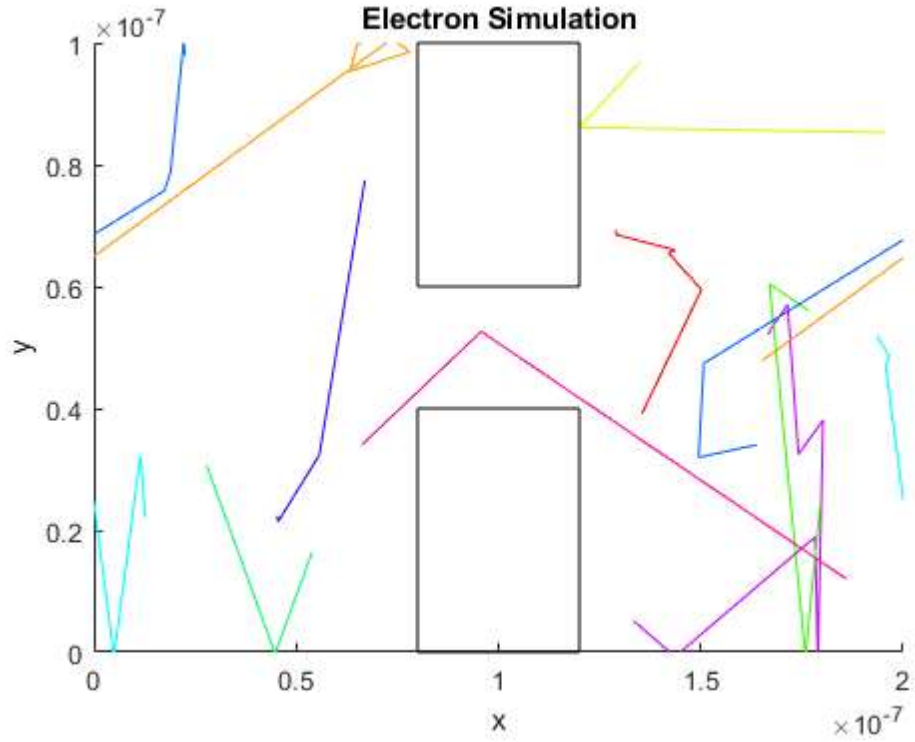
Time (s)
×10^-13


Electron Simulation
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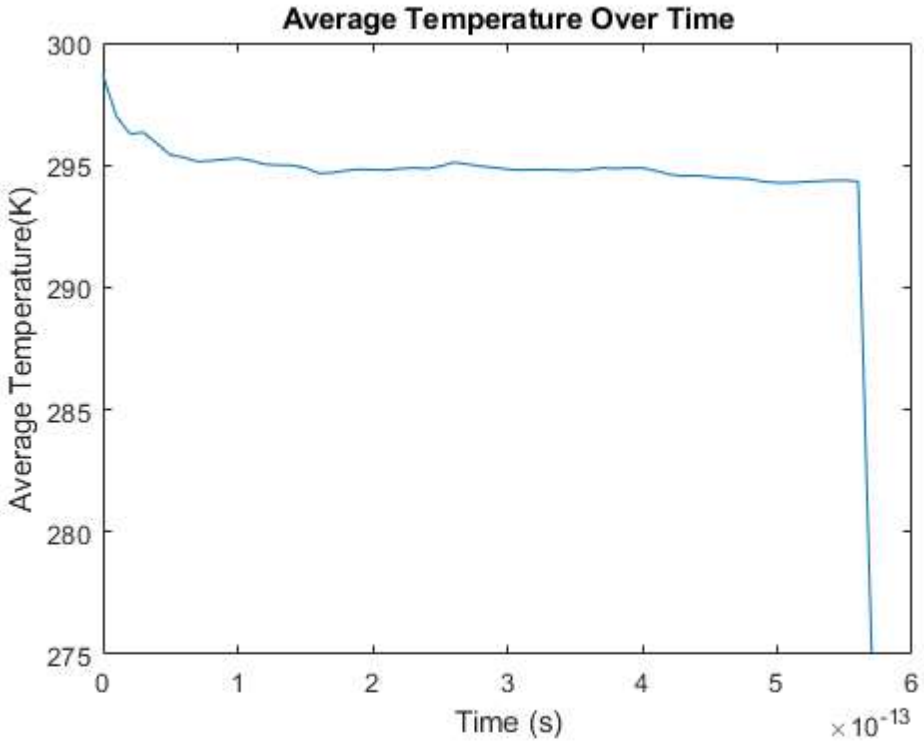
2
x
×10^-7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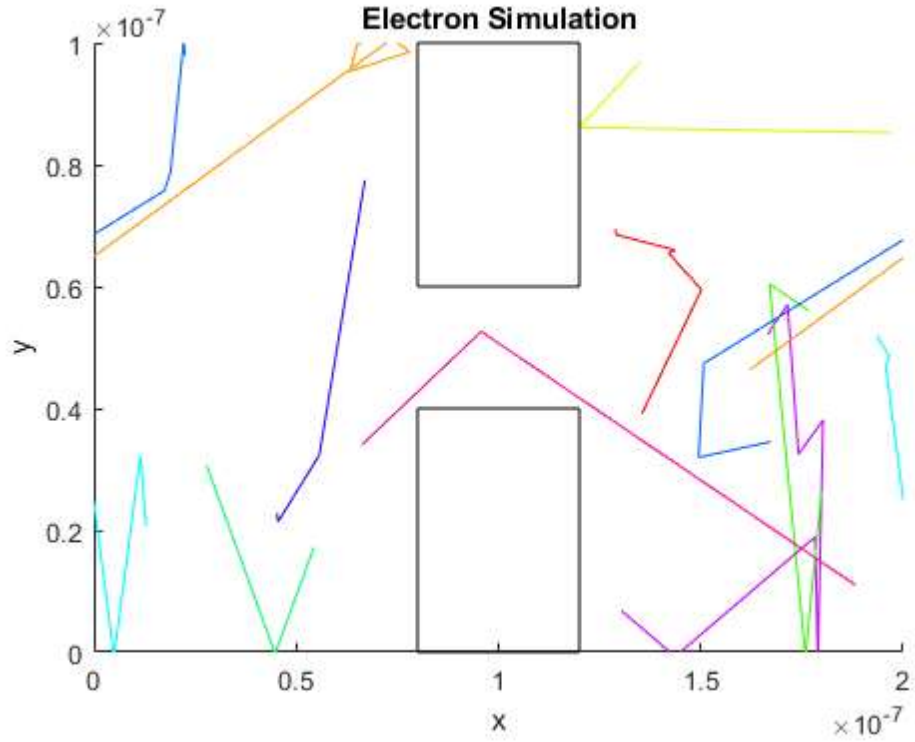
Time (s)
×10^-13


Electron Simulation
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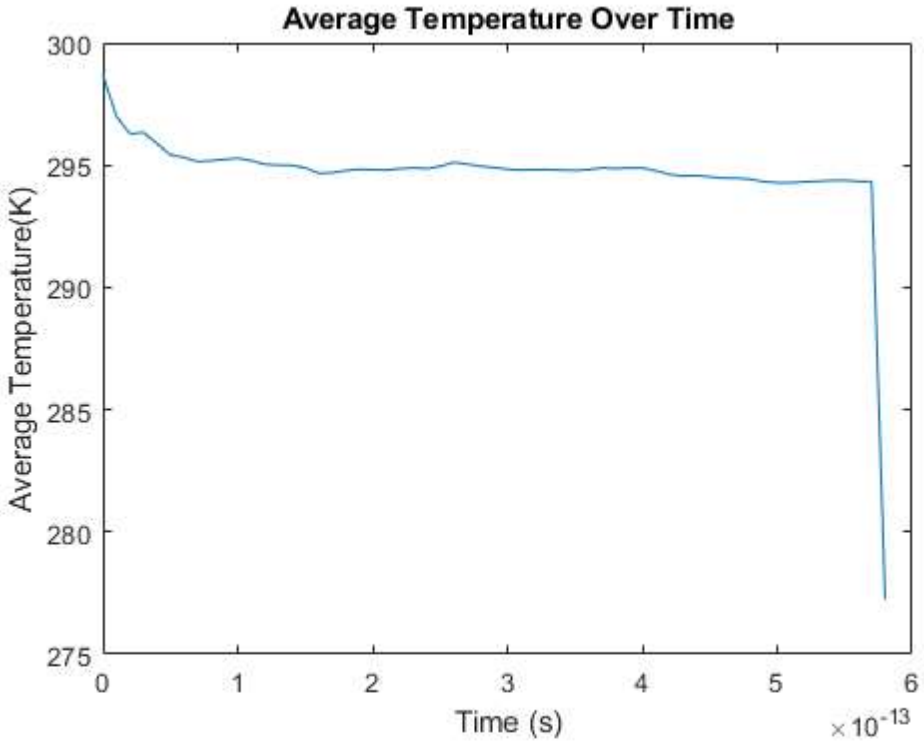
2
x
×10^-7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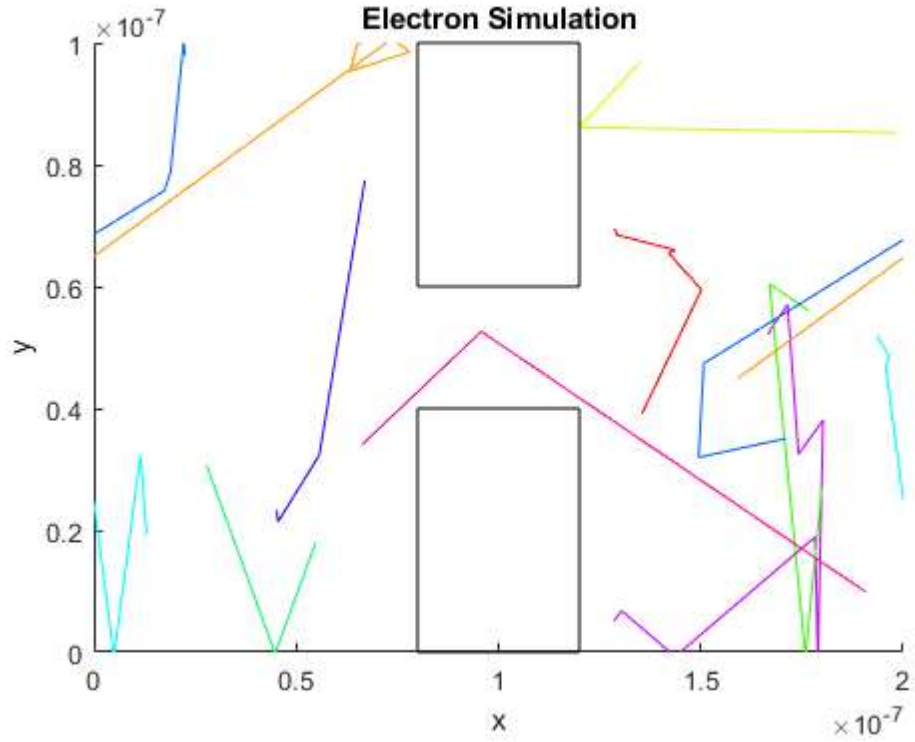
Electron Simulation
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y
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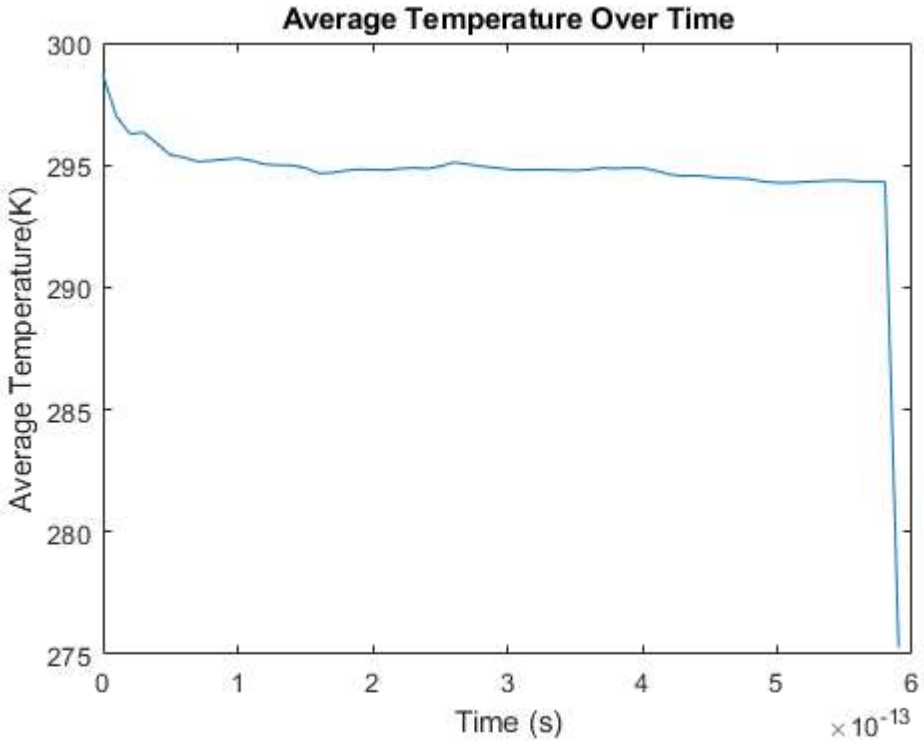
2
x
×10^-7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Average Temperature(K)
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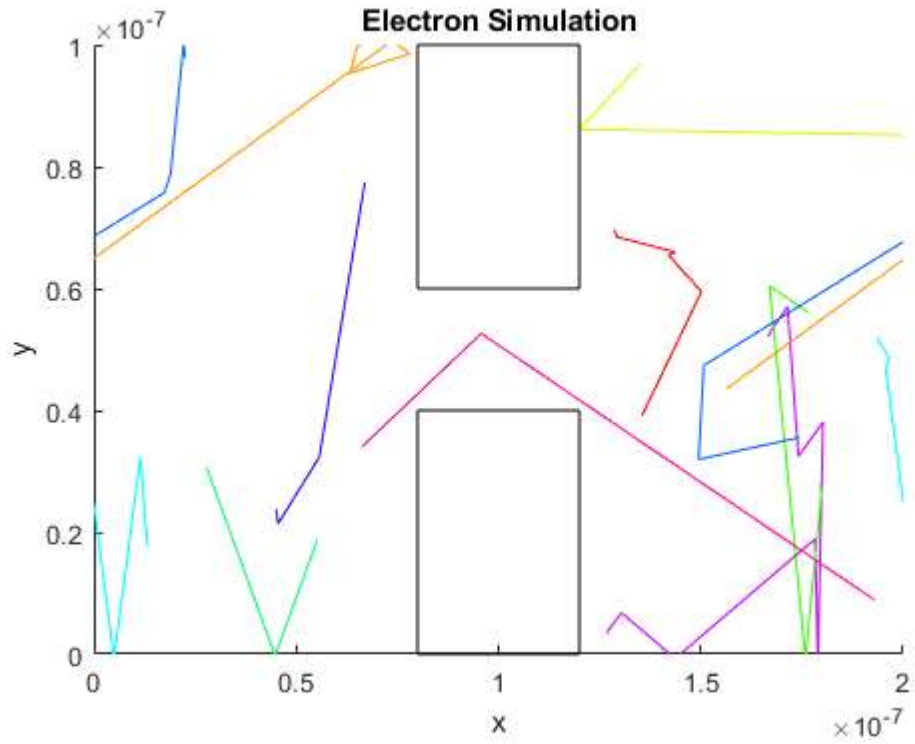
Time (s)
×10^-13


Electron Simulation
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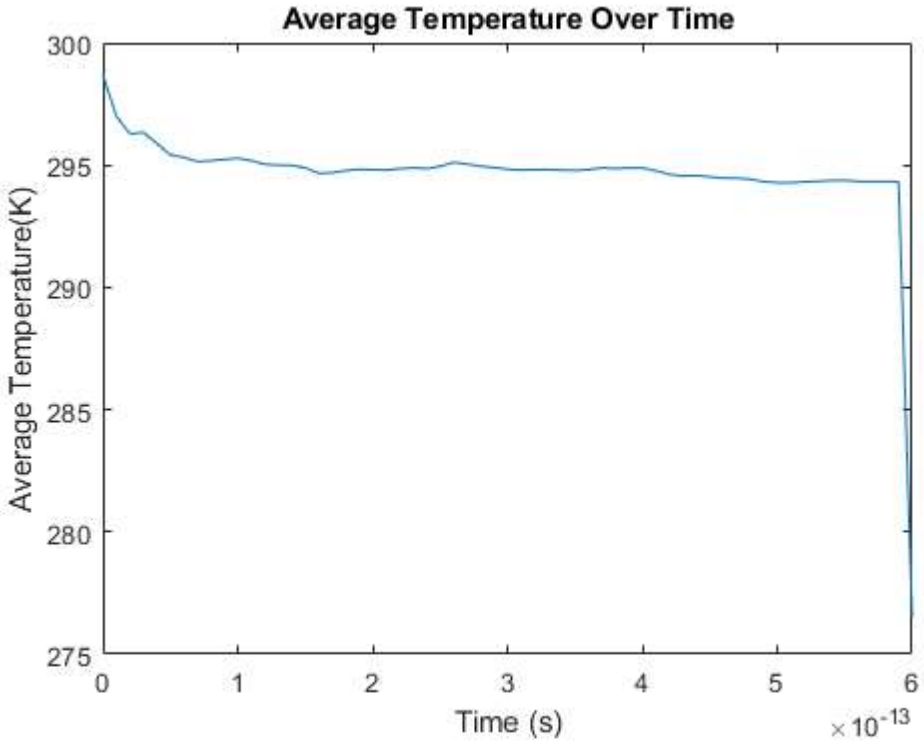
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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Time (s)
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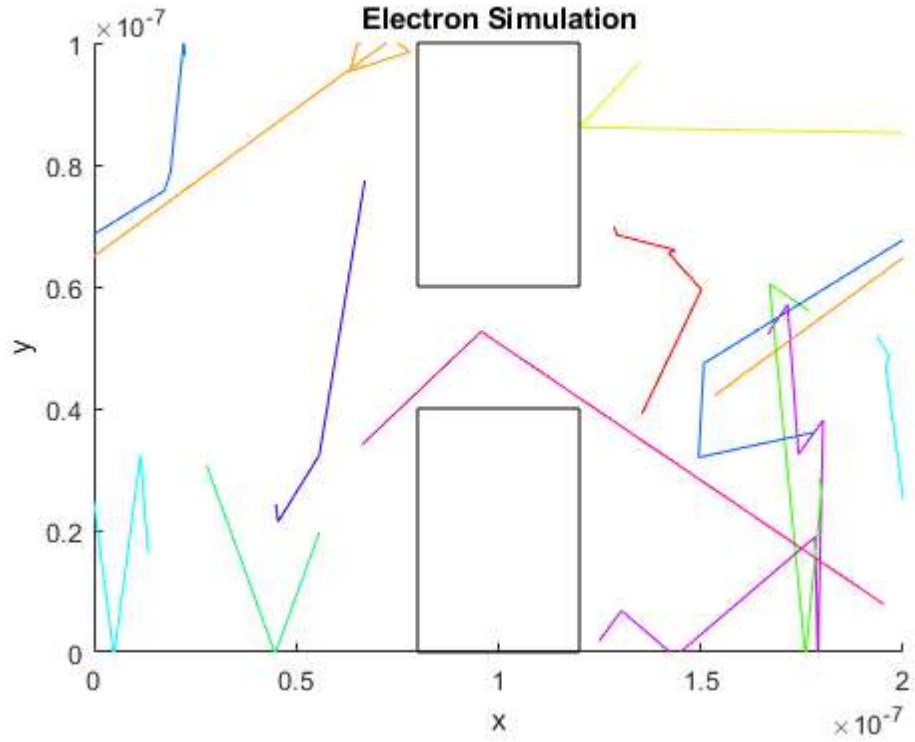
Electron Simulation
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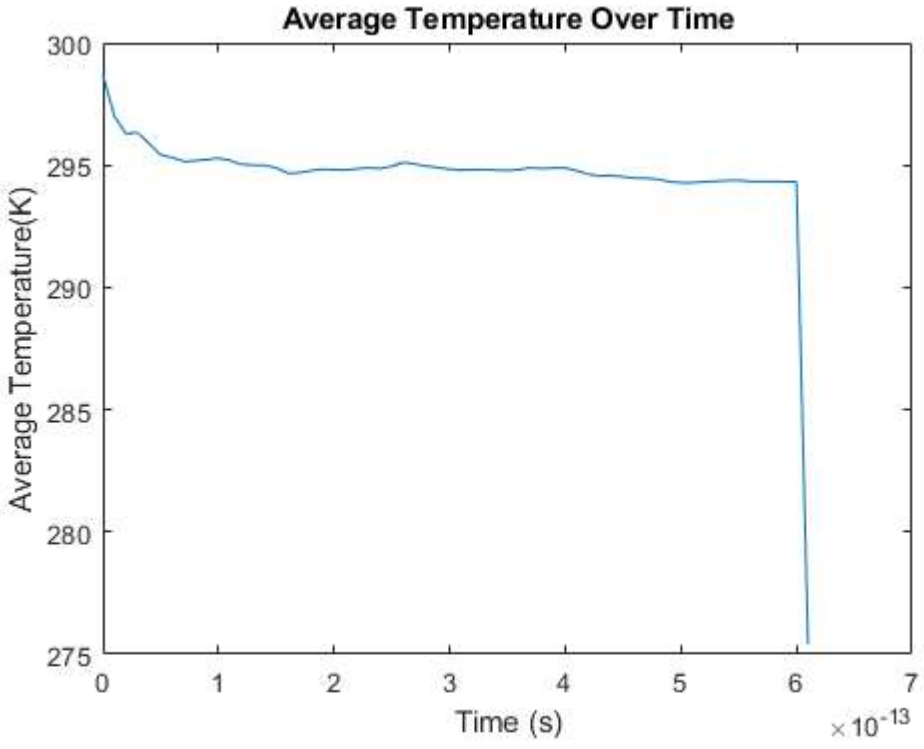
2
x
×10^-7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Average Temperature(K)
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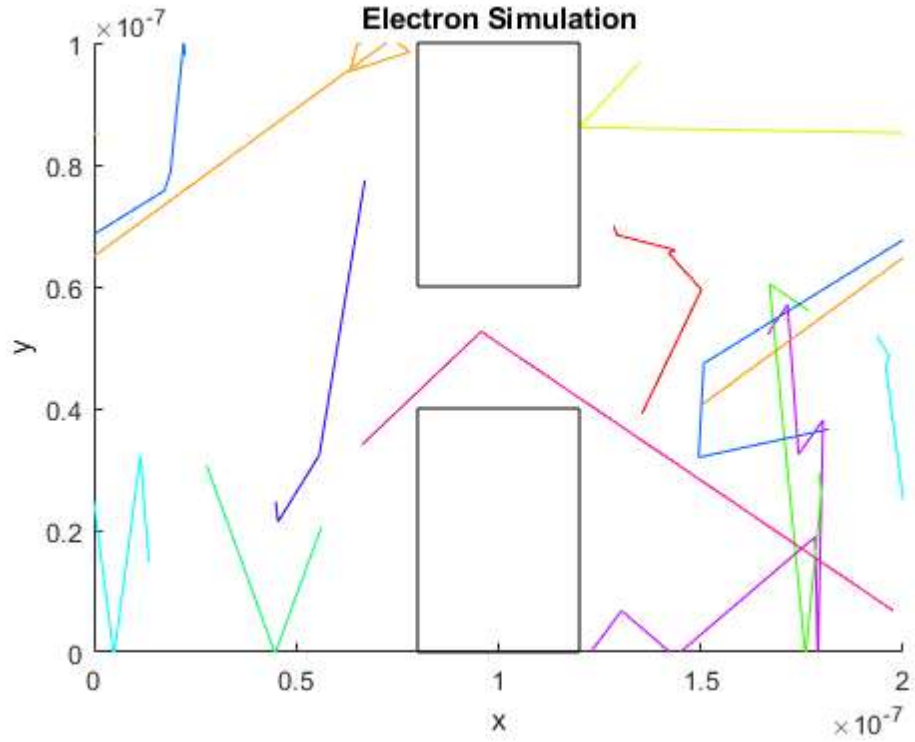
Time (s)
×10^-13


Electron Simulation
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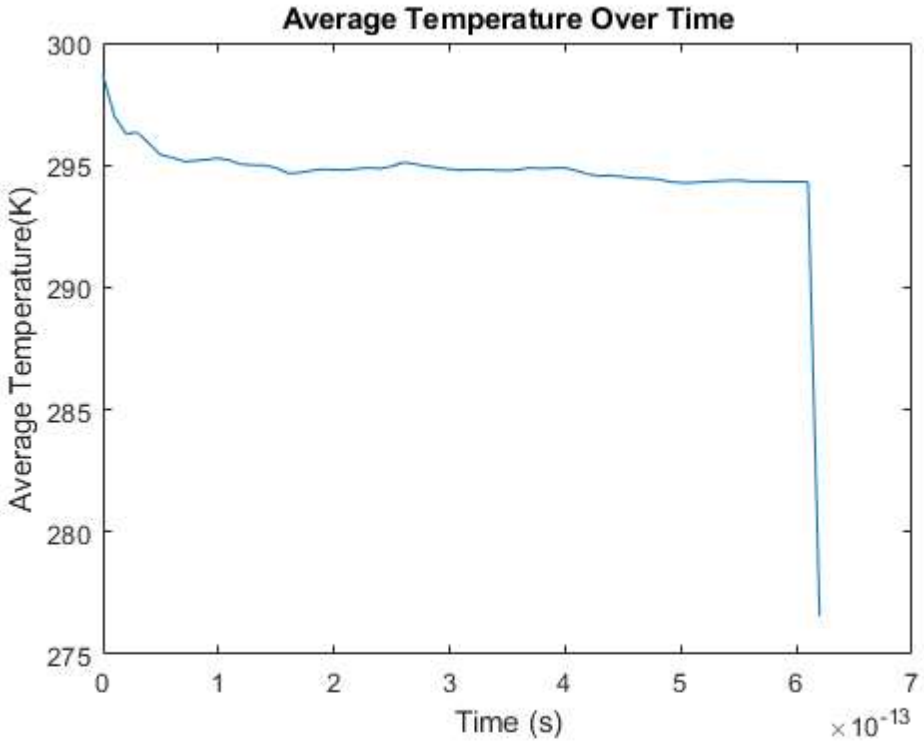
2
x
×10^-7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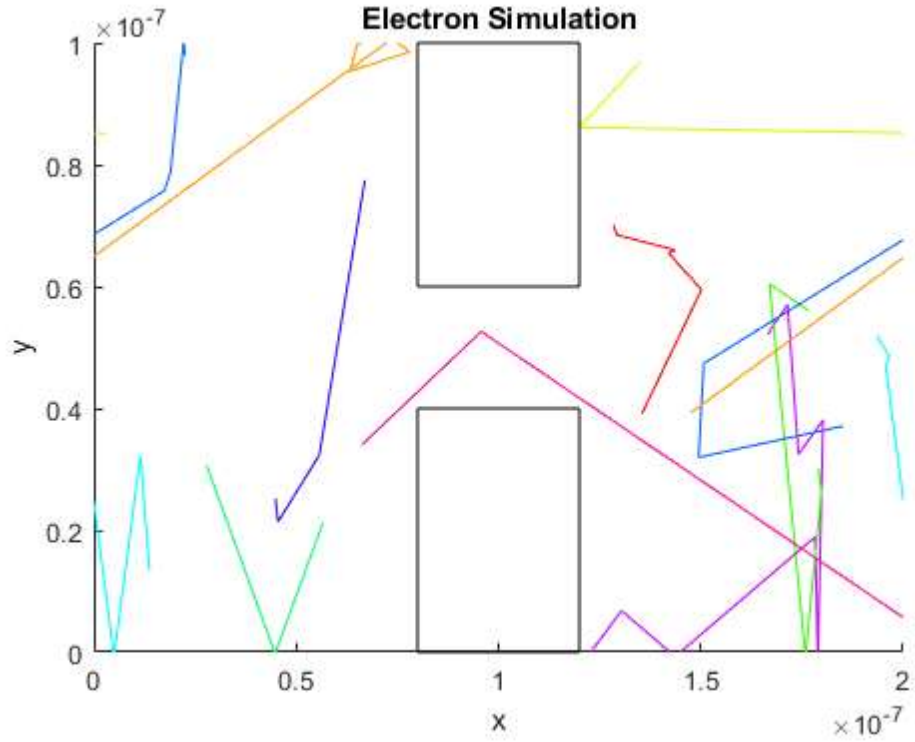
Time (s)
×10^-13


Electron Simulation
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1
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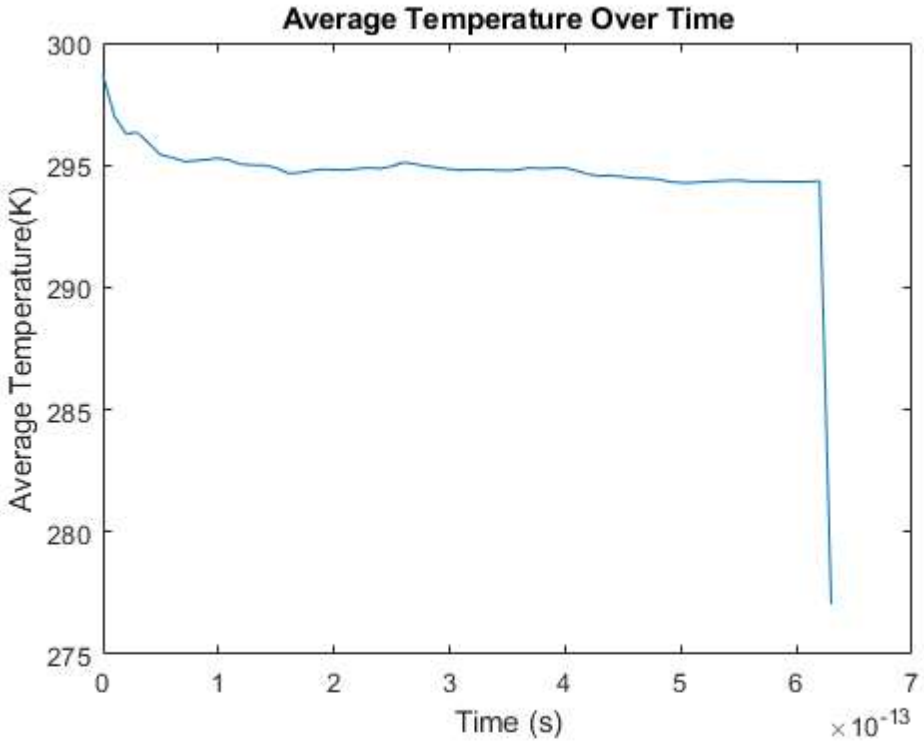
2
x
×10^-7


Average Temperature Over Time
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Time (s)
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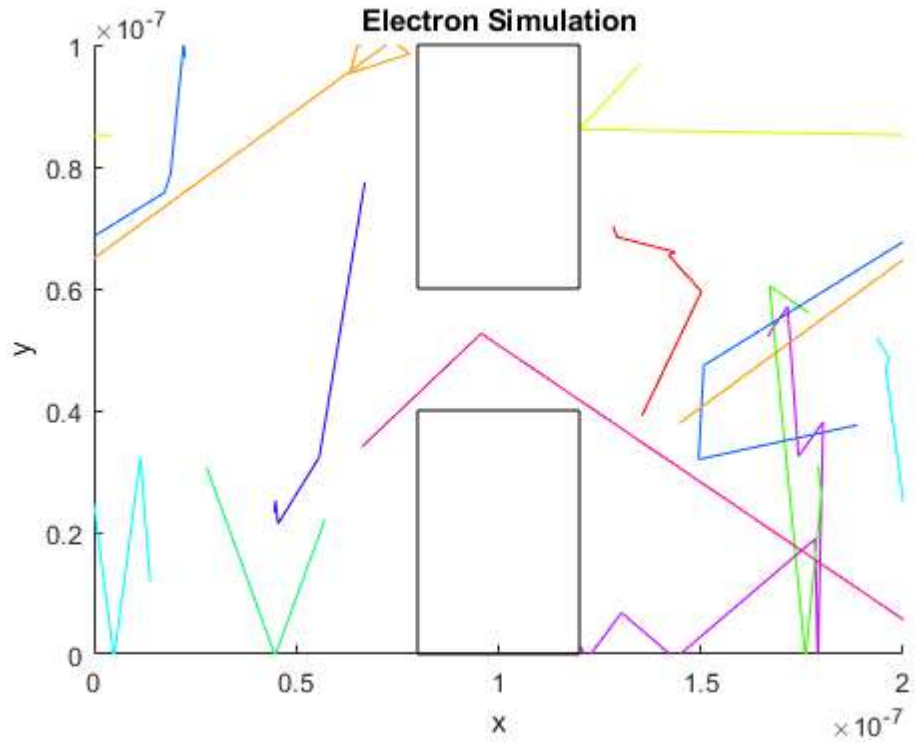
Electron Simulation
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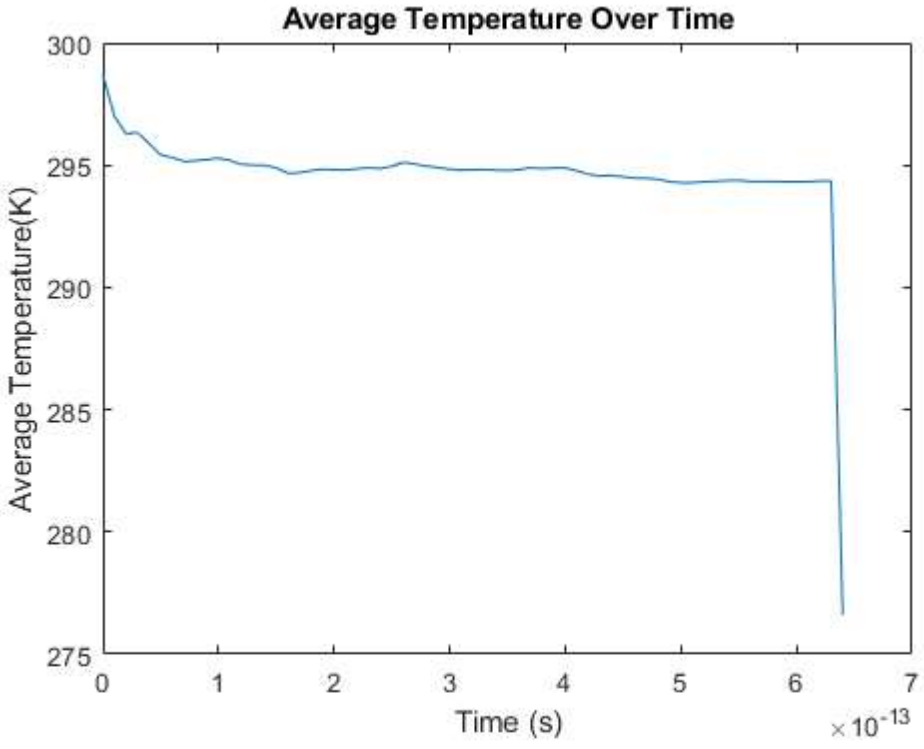
2
x
×10^-7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Time (s)
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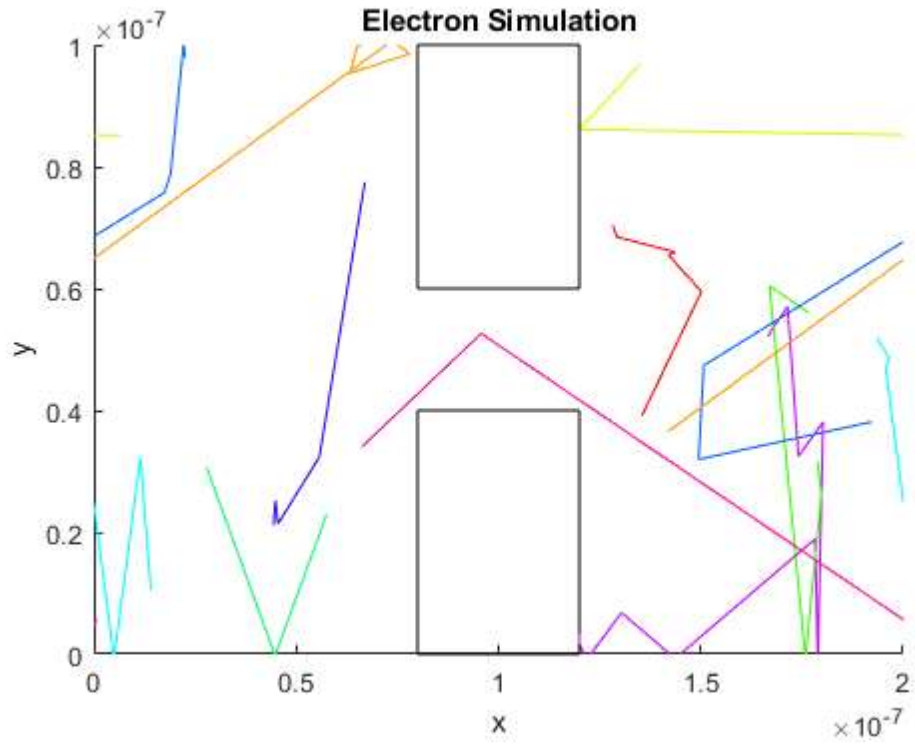
Electron Simulation
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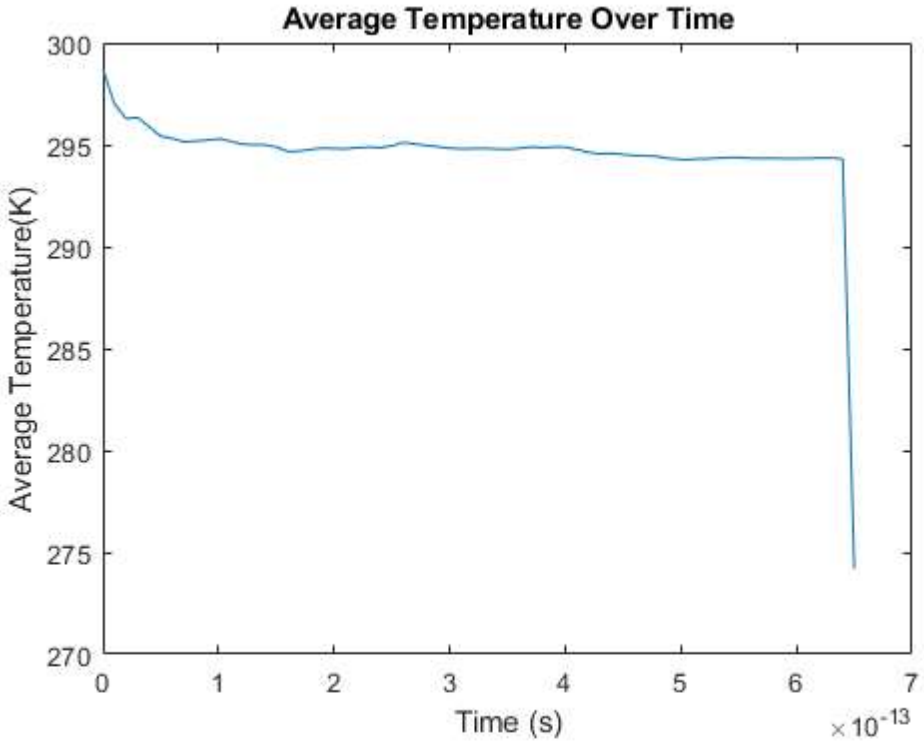
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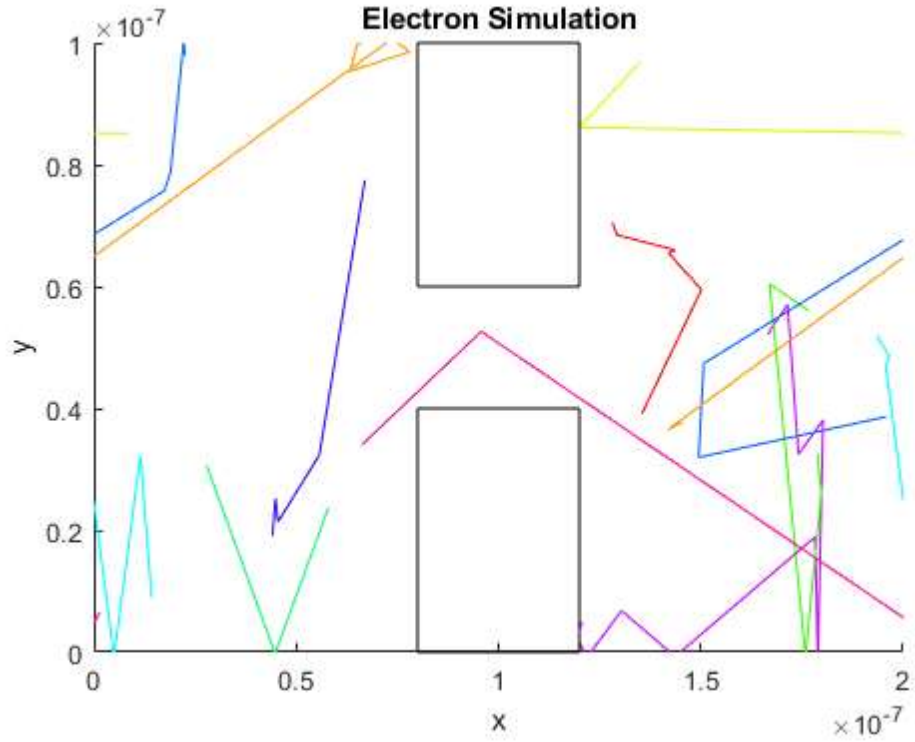
Electron Simulation
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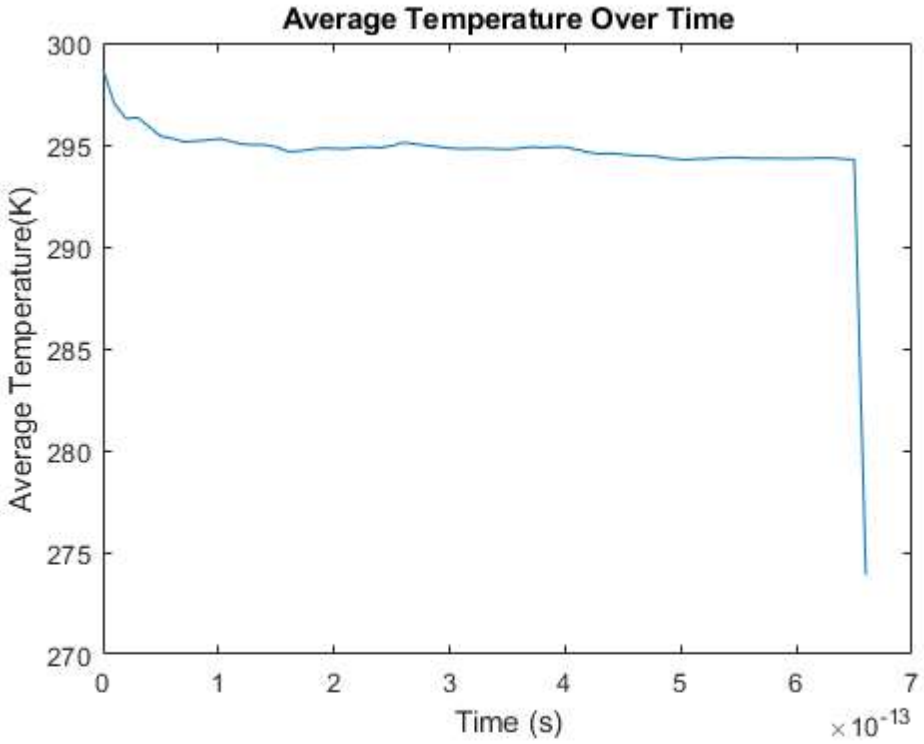
2
x
×10^-7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Time (s)
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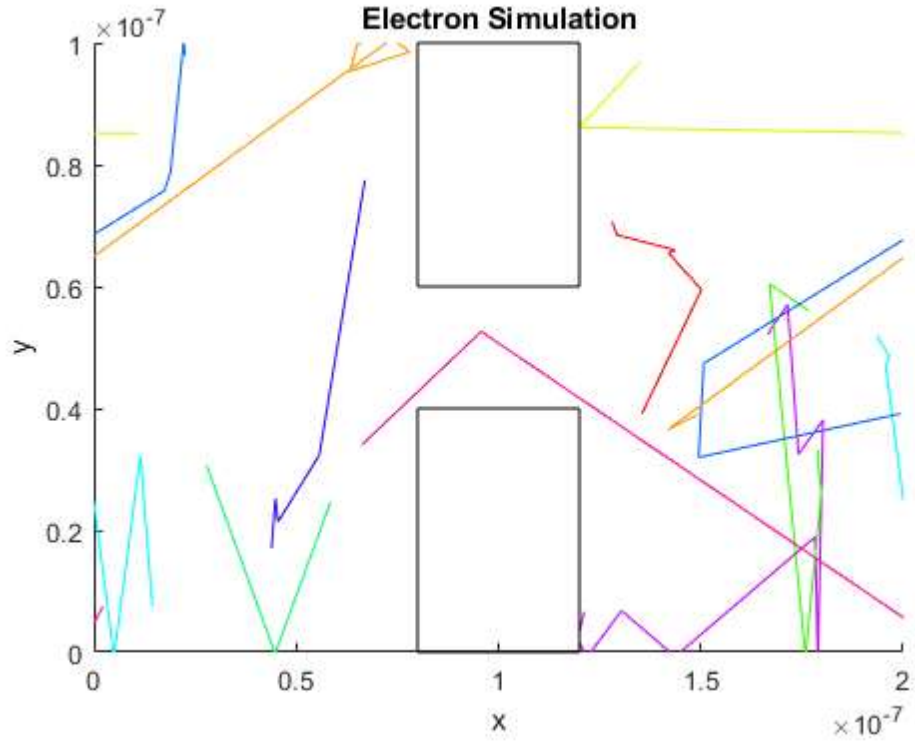
Electron Simulation
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y
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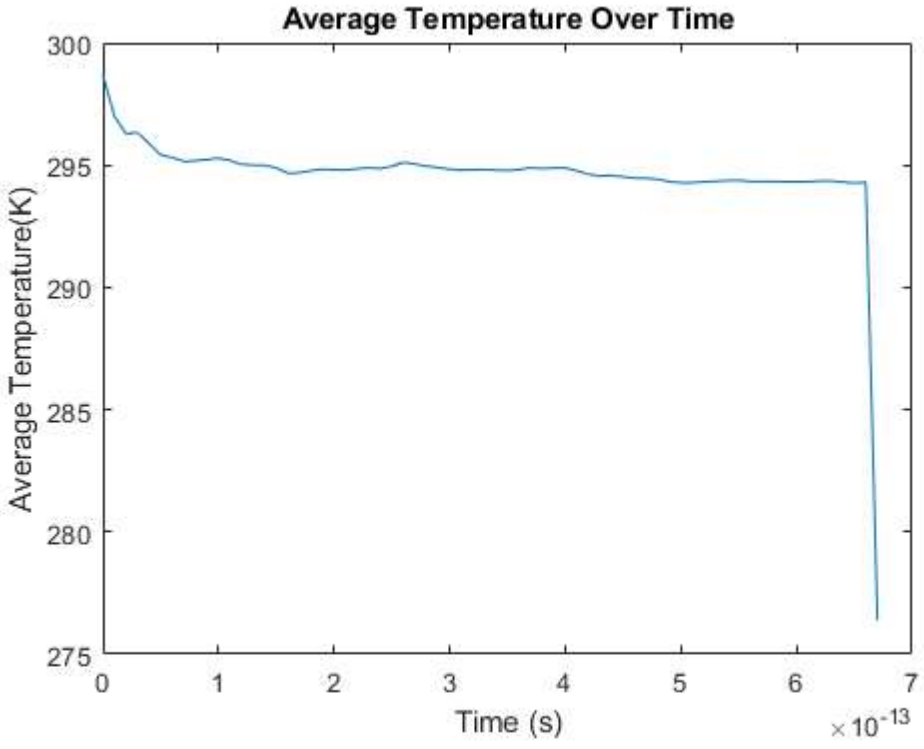
1
1.5
2
x
×10^-7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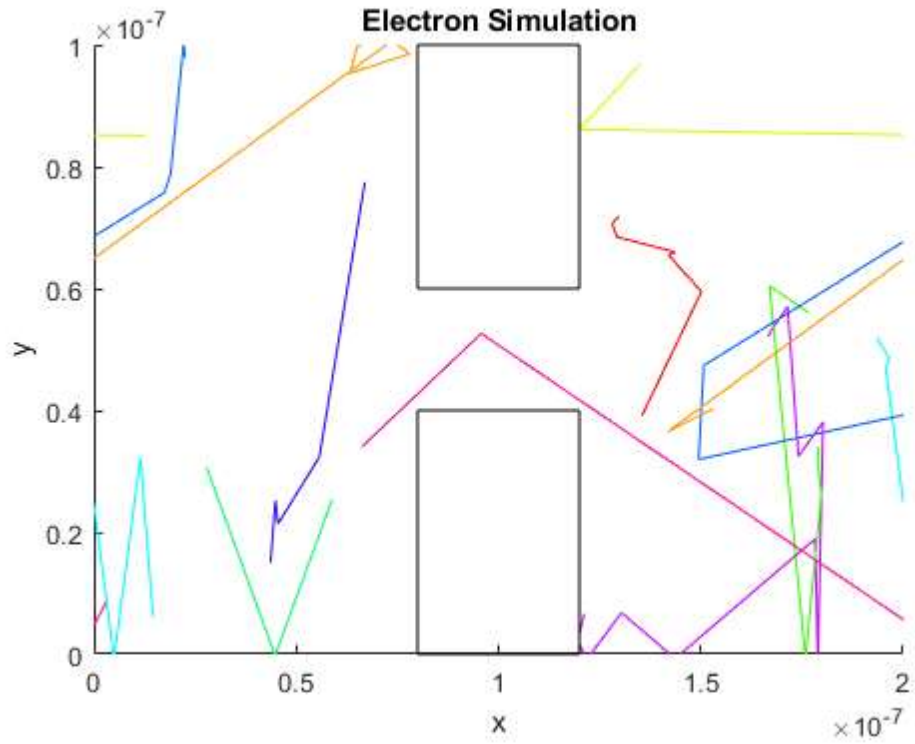
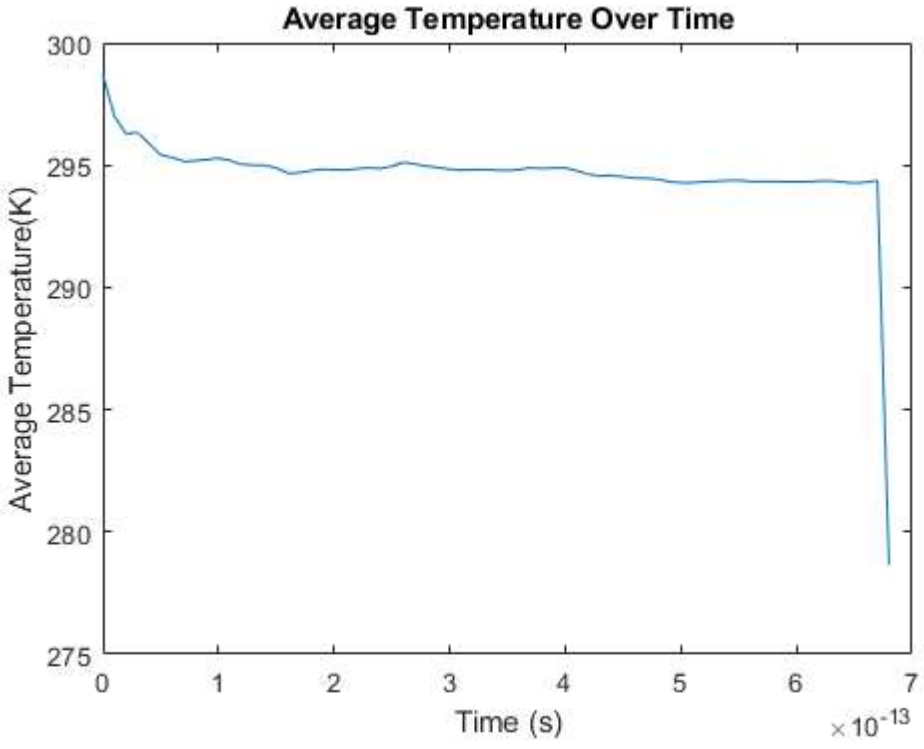
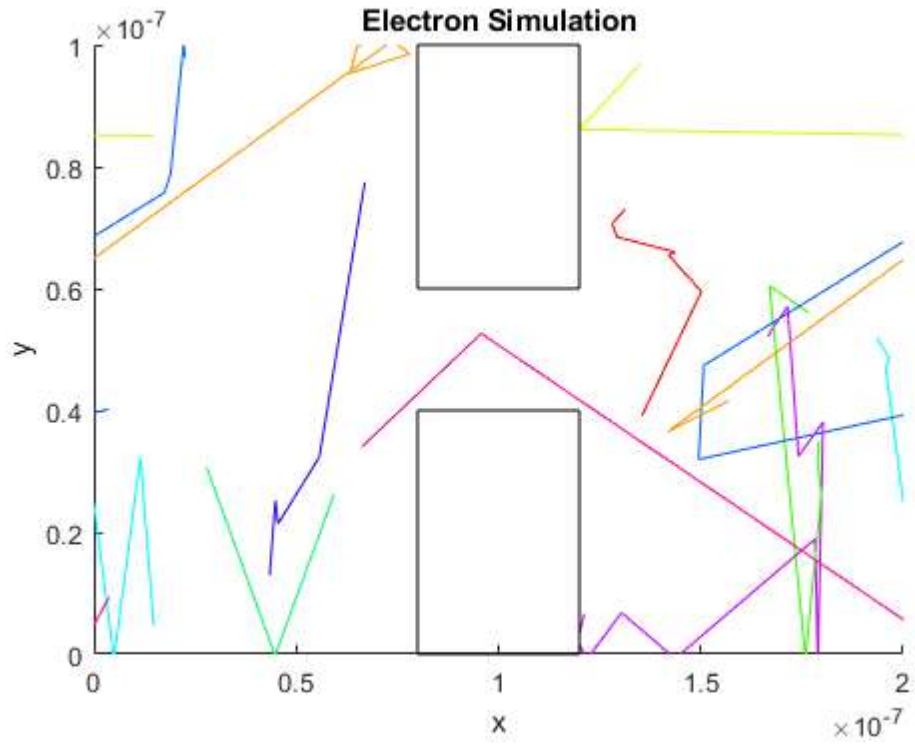
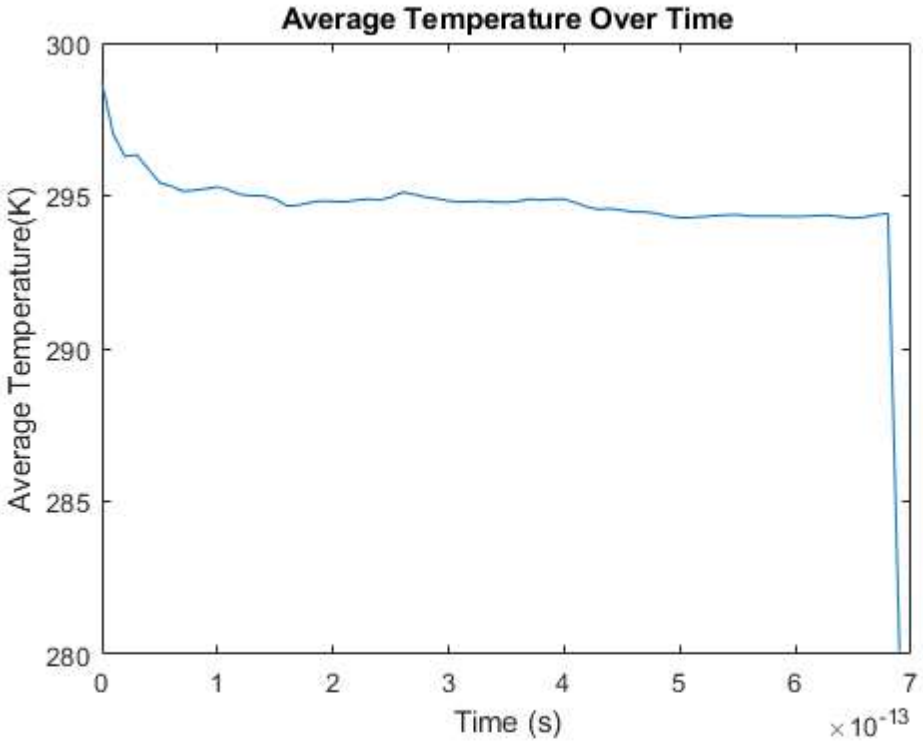
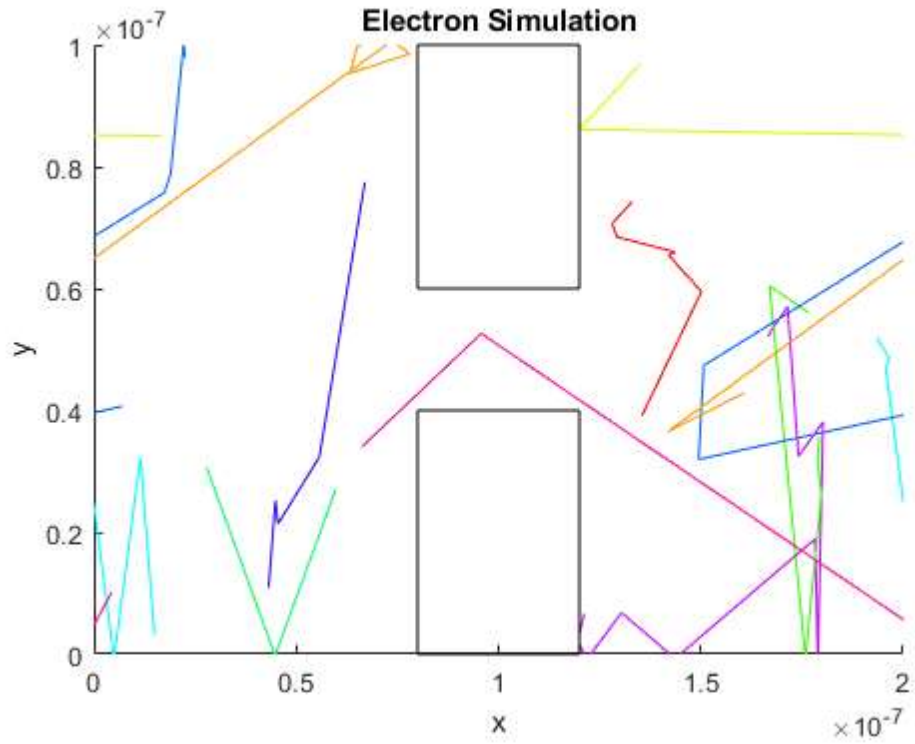
Time (s)
×10^-13

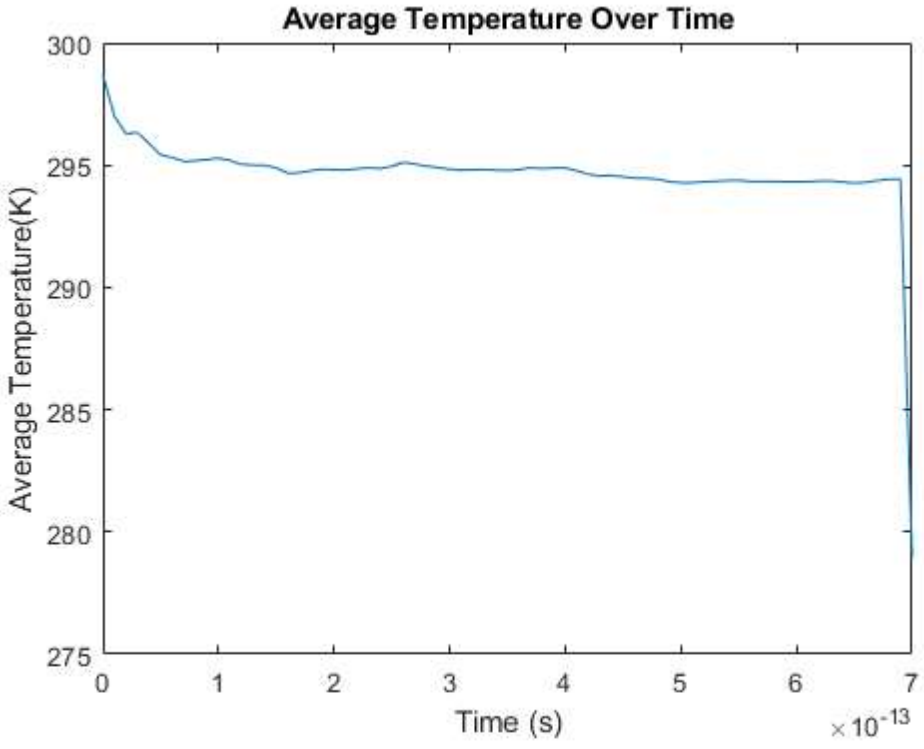

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

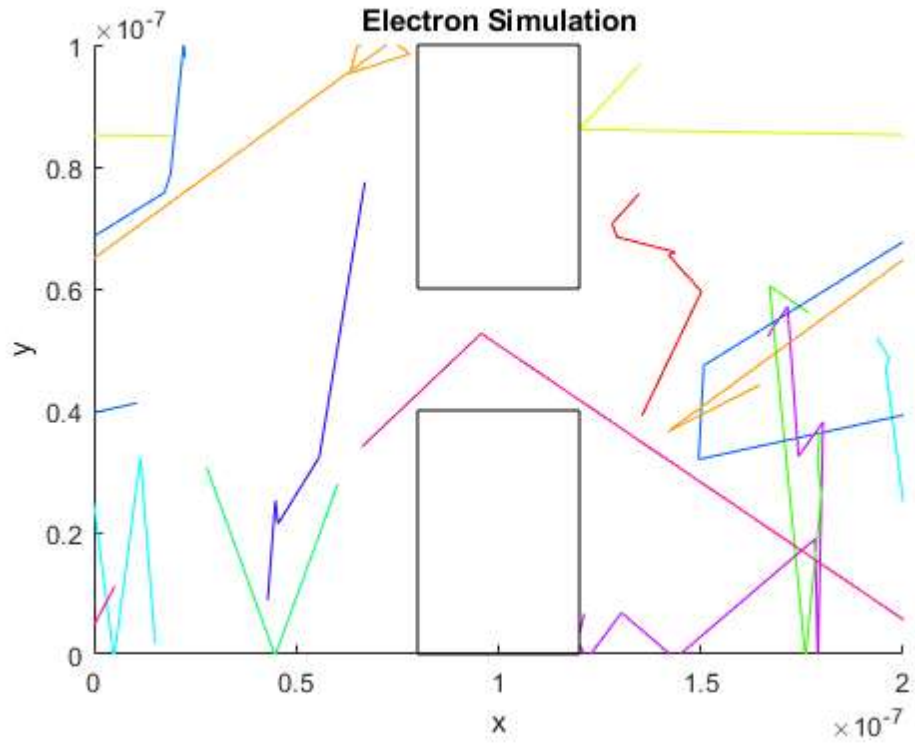

Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

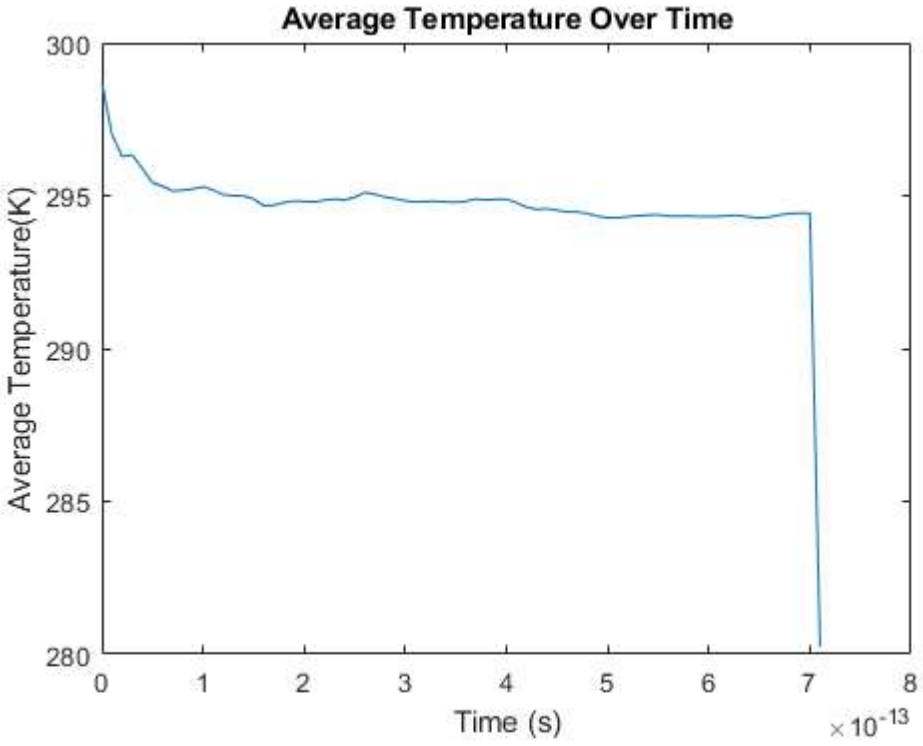

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

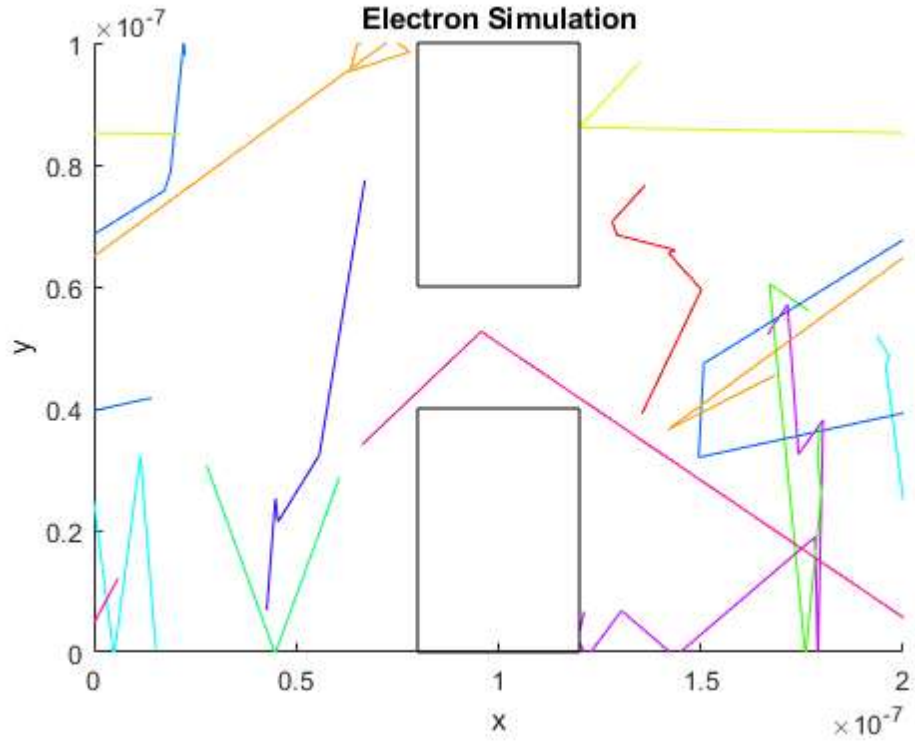

Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

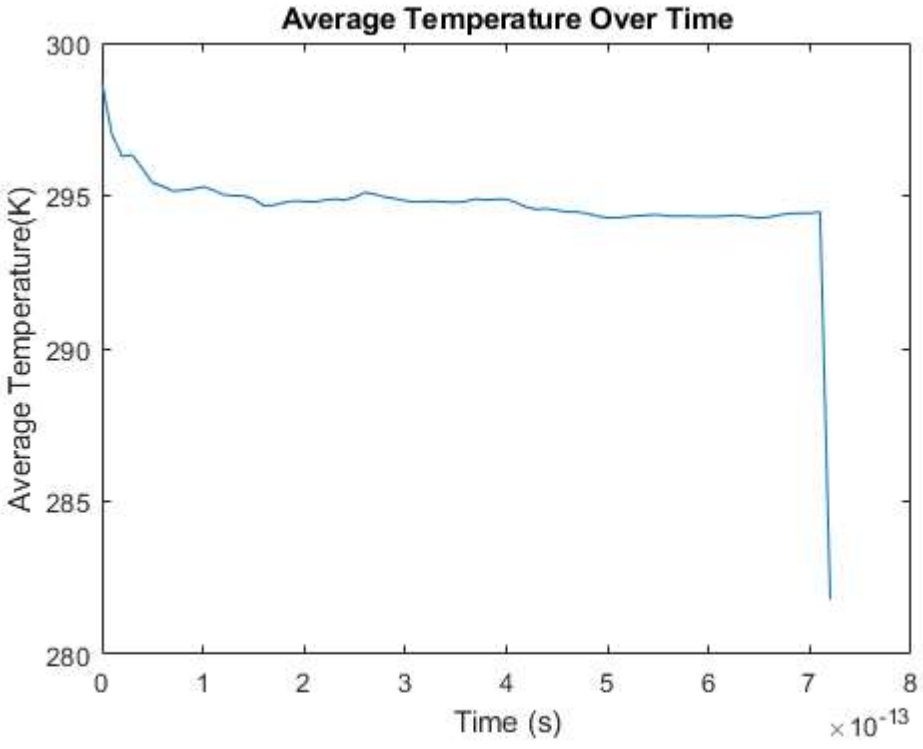

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

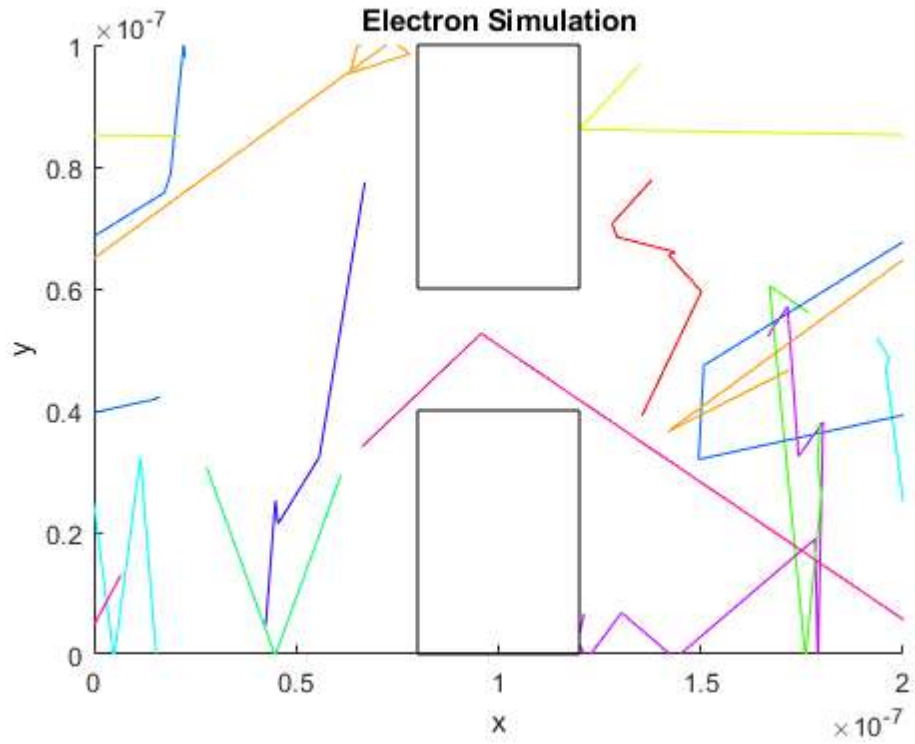

Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

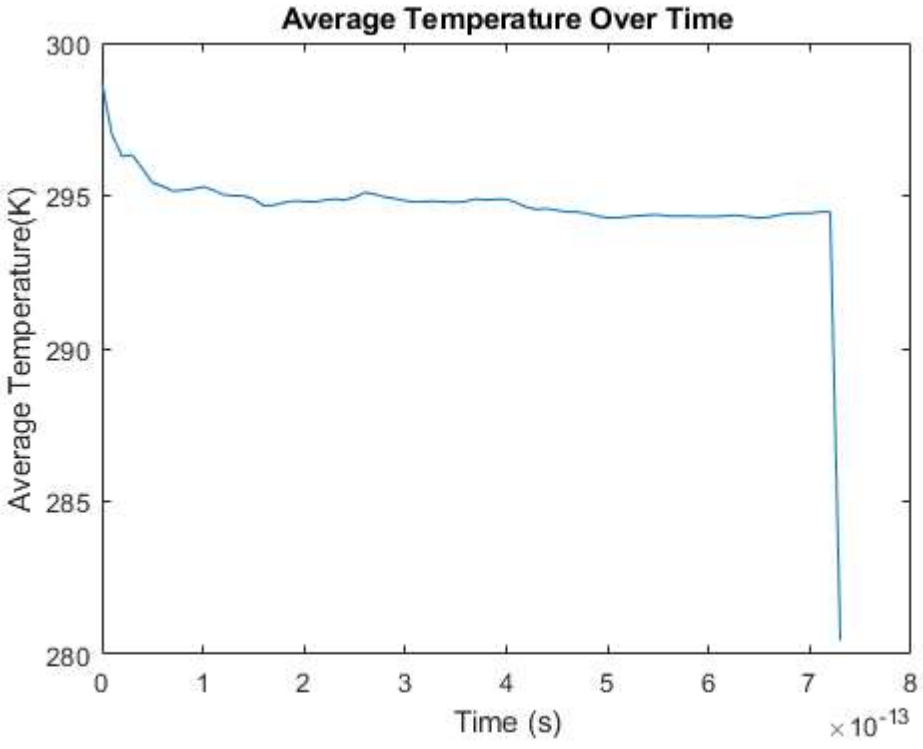

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

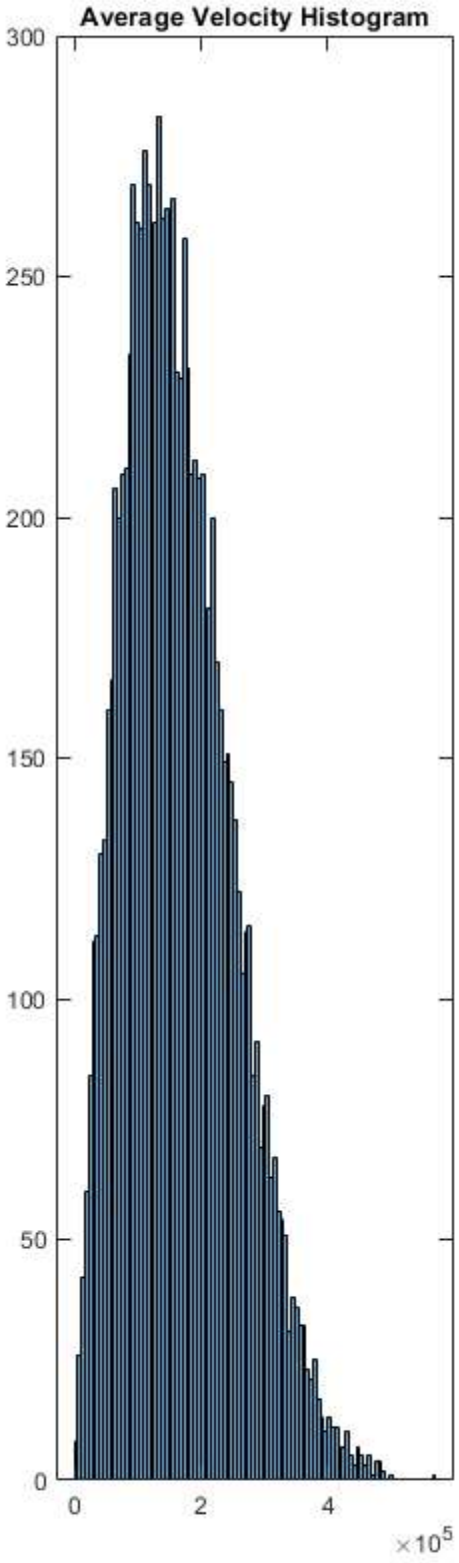

Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-13

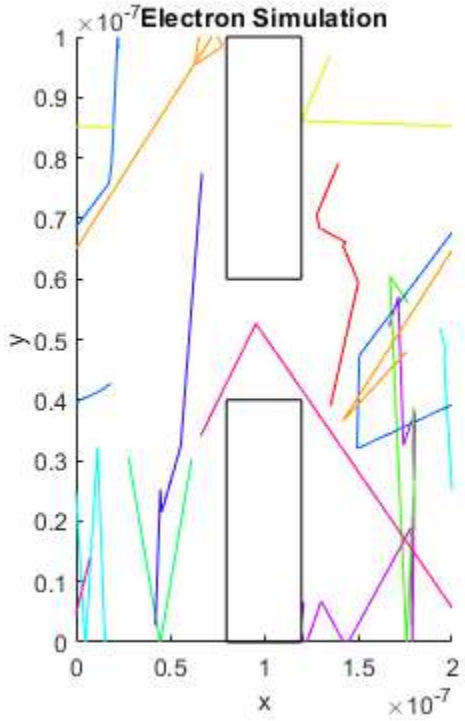

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

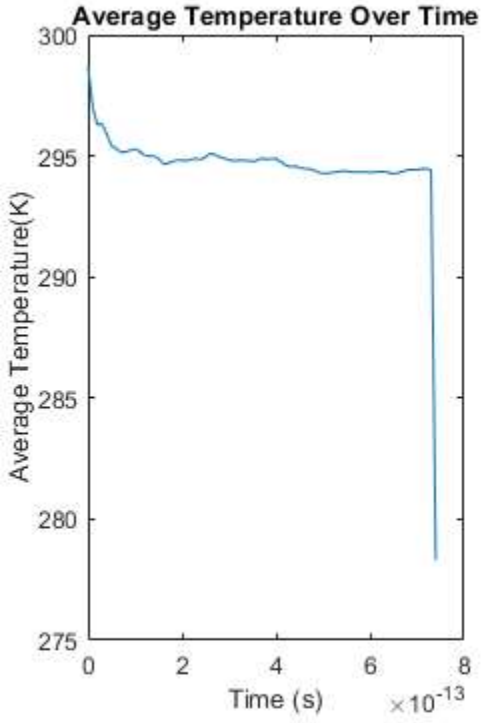

Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-13

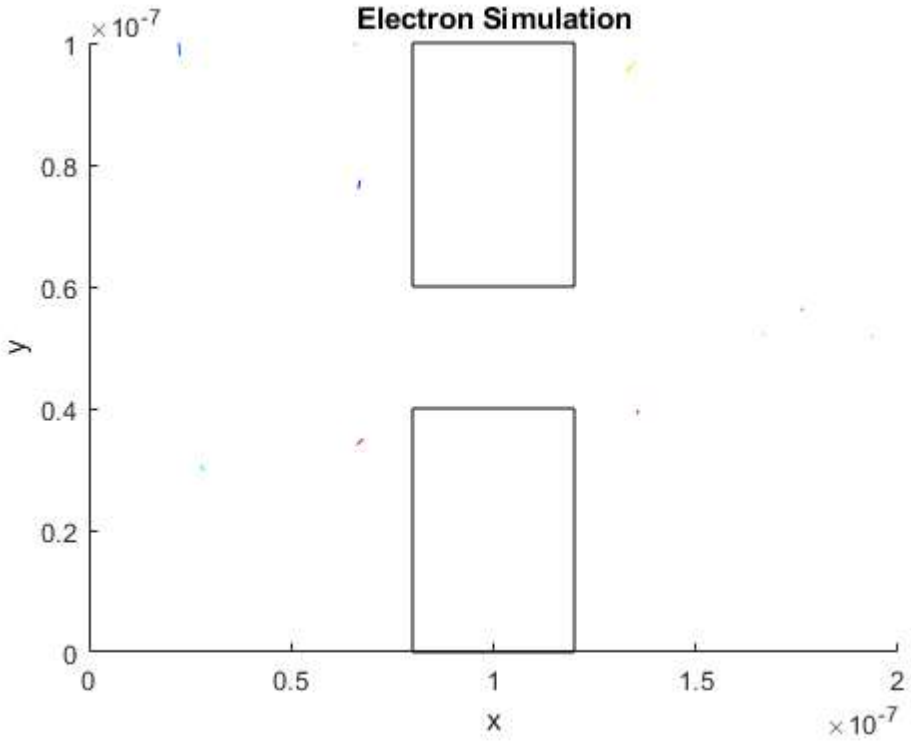


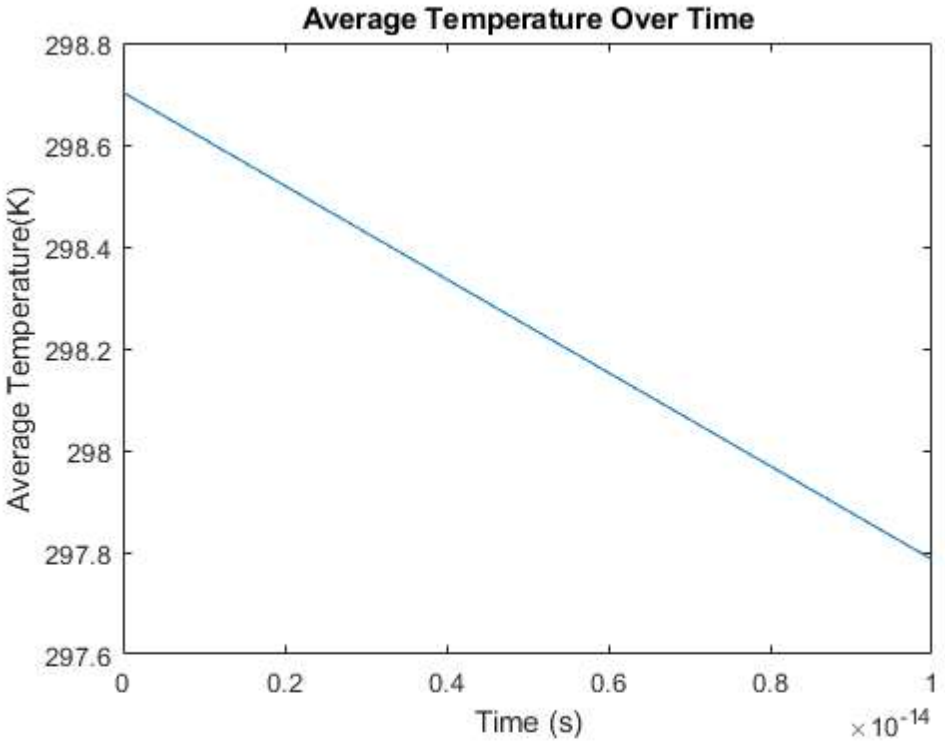


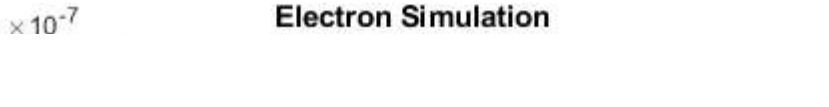


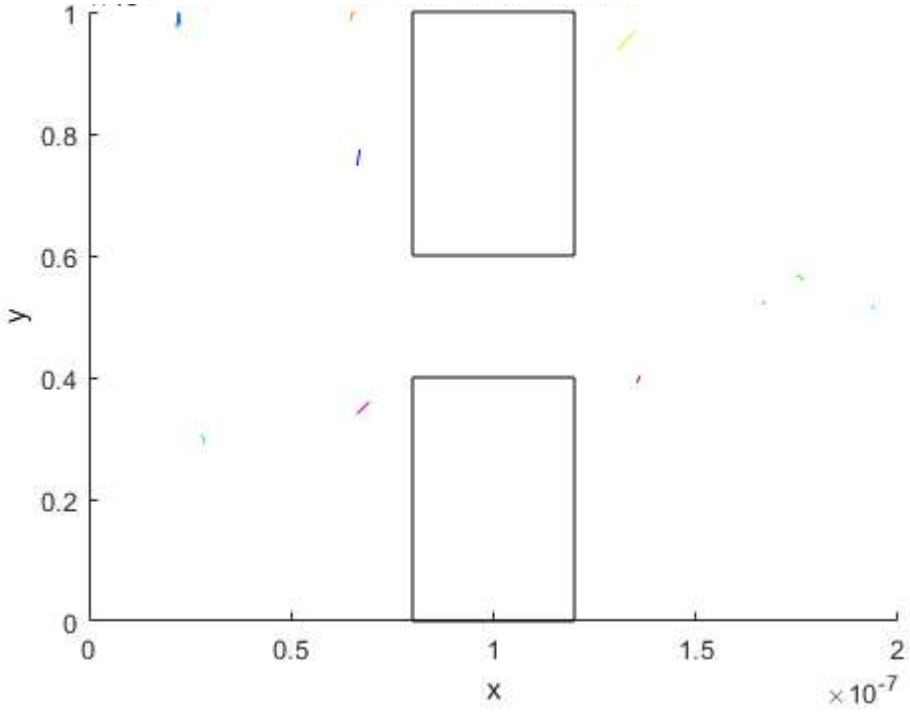
Then the average heat plot is updated.

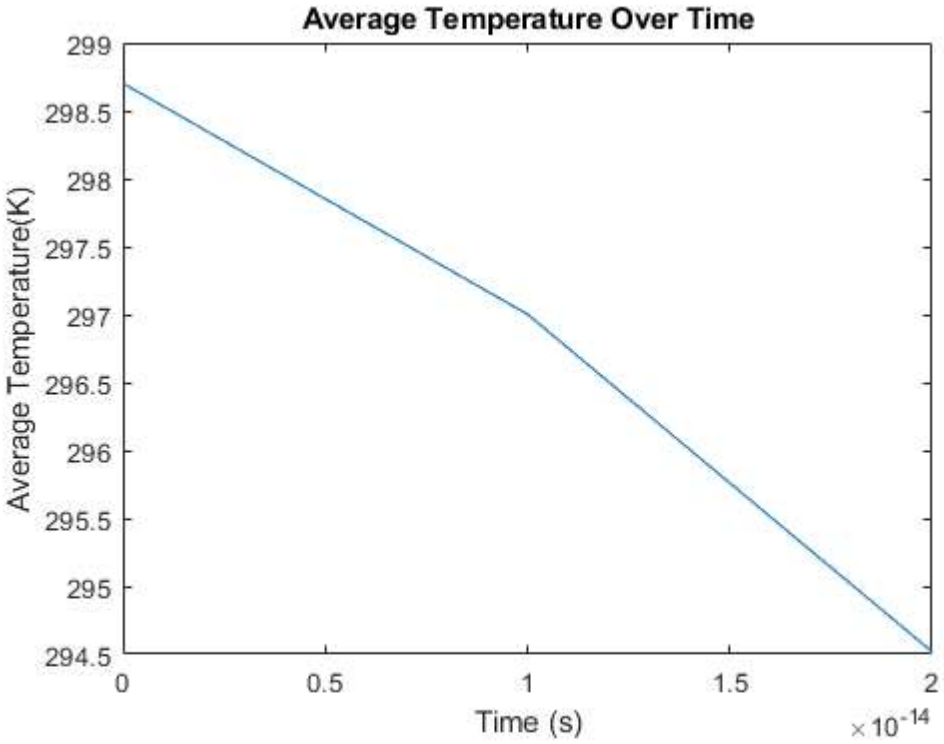
```
avev = sqrt(vy.*vy + vx.*vx);
avet = ((avev.*avev)*mn)/(2*kB);
asumavt = sum(avet)/NE;
sumavt = cat(1, sumavt, asumavt);
sumavt(i) = sum(sumavt)/length(sumavt);
subplot(2,1,2)
plot(time, sumavt);
xlabel('Time (s)')
ylabel('Average Temperature(K)')
title('Average Temperature Over Time');

ylt = y < 0;
ygt = y > h;

xlt = x < 0;
xgt = x > w;

y(ylt) = 0;
y(ygt) = h;
x(xlt) = w;
x(xgt) = 0;

vy(ylt) = -(vy(ylt));
vy(ygt) = -(vy(ygt));
```

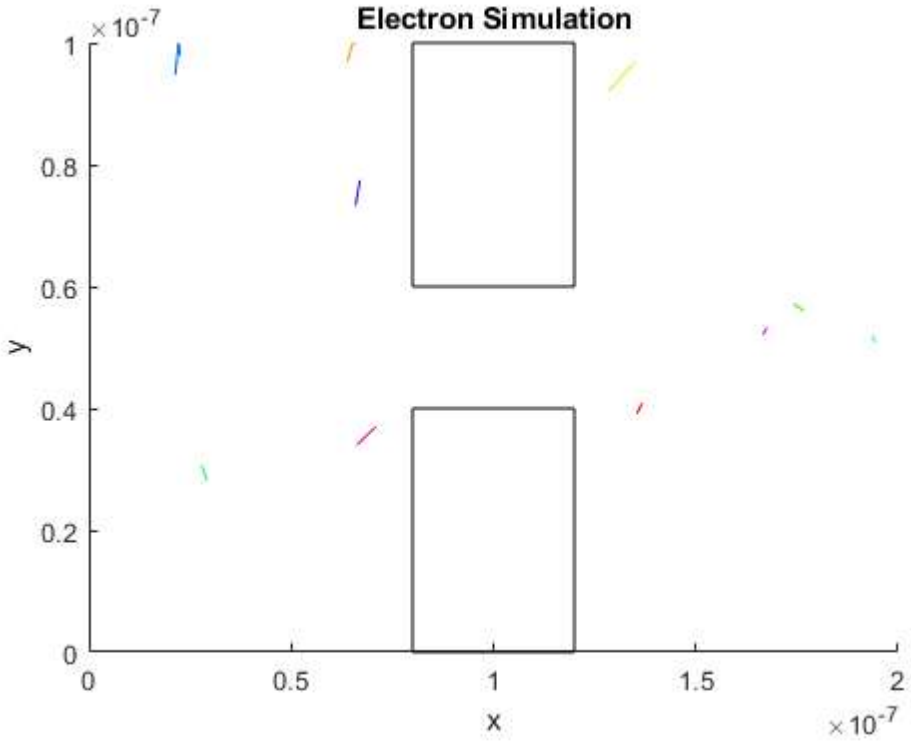

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

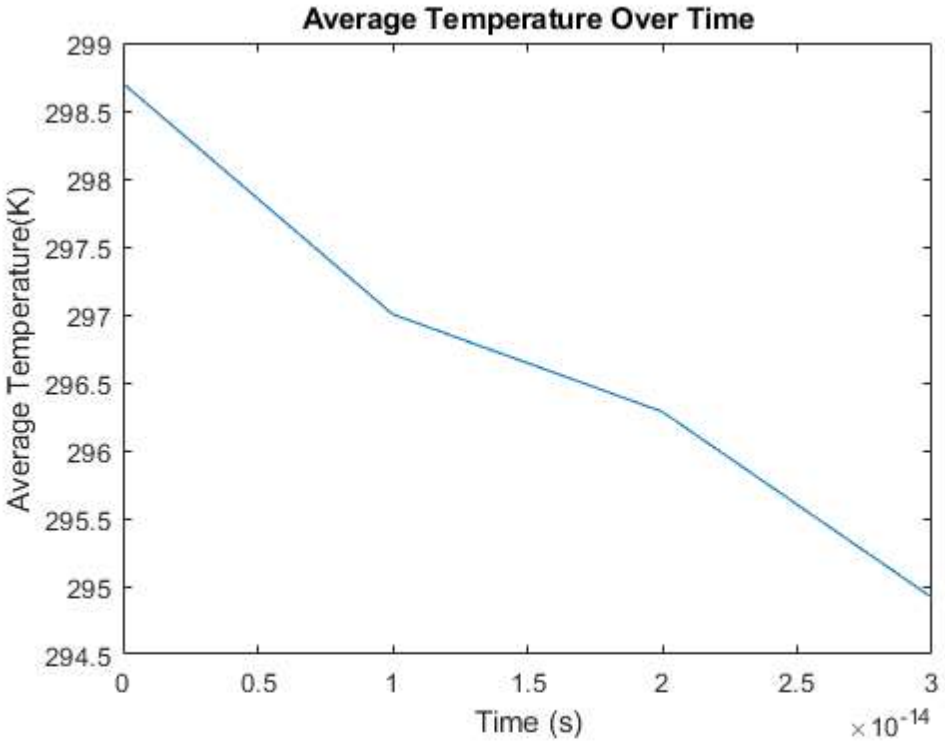

Average Temperature Over Time
298.8
298.6
298.4
298.2
298
297.8
297.6
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
Time (s)
×10^-14

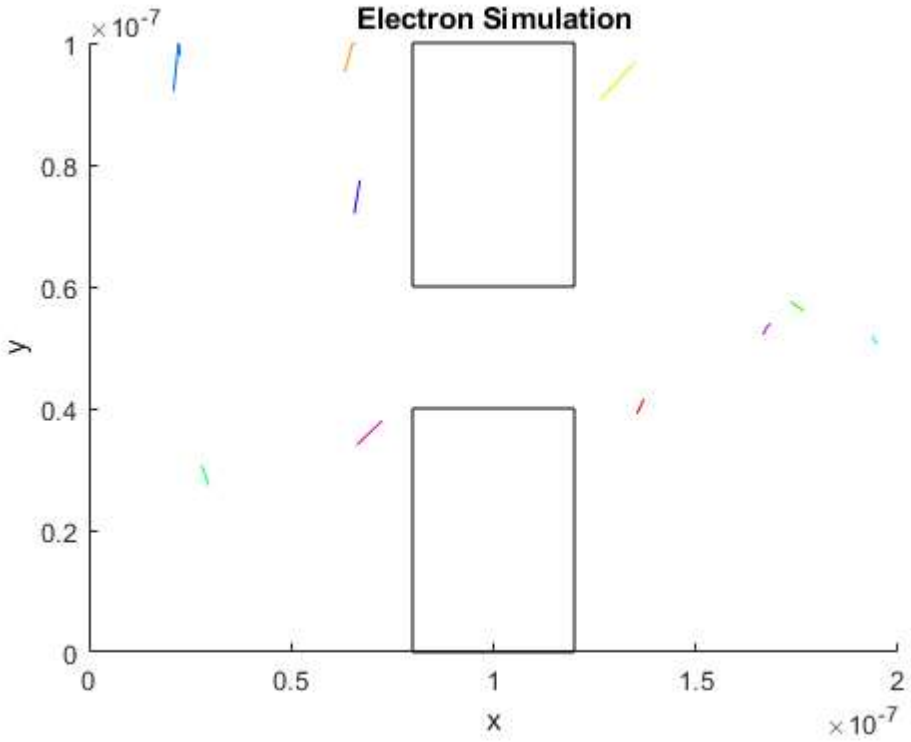

×10^-7
Electron Simulation

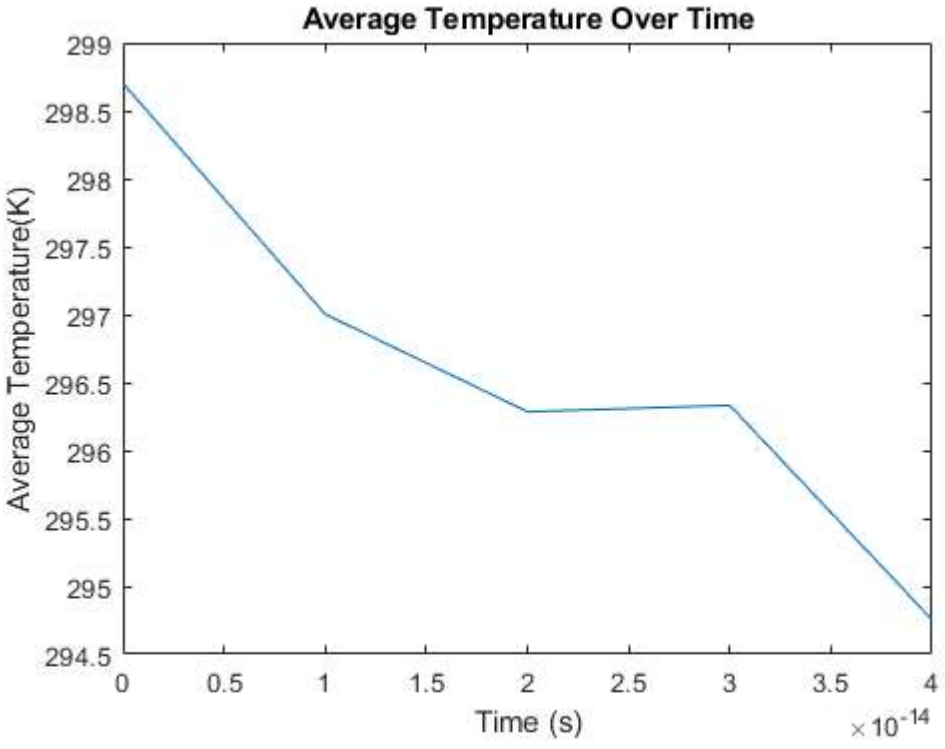

1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

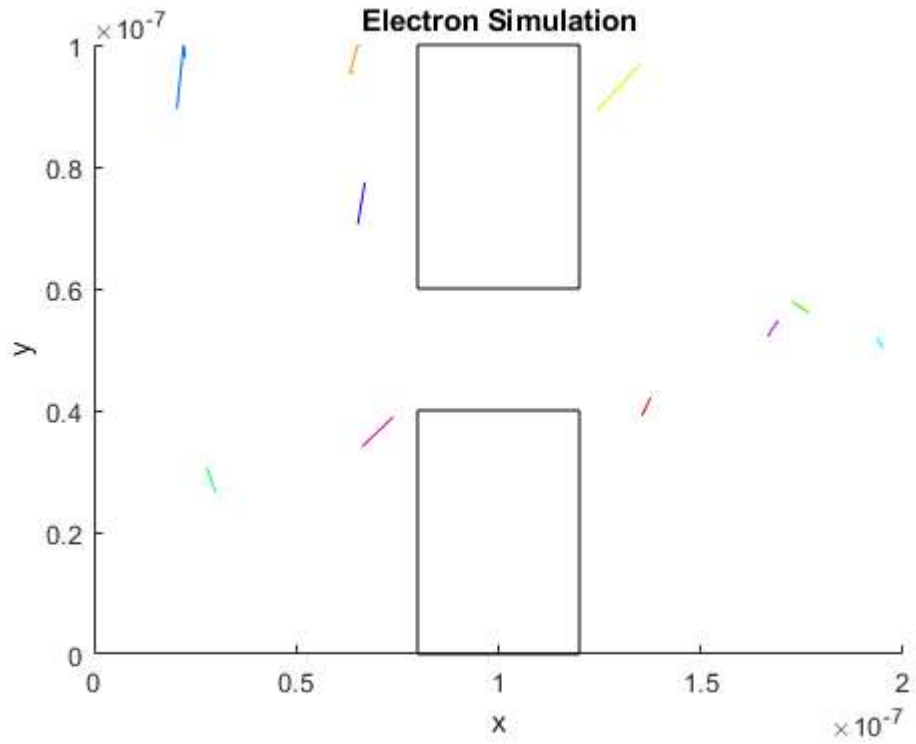

Average Temperature Over Time
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
Average Temperature(K)
0
0.5
1
1.5
2
Time (s)
×10^-14

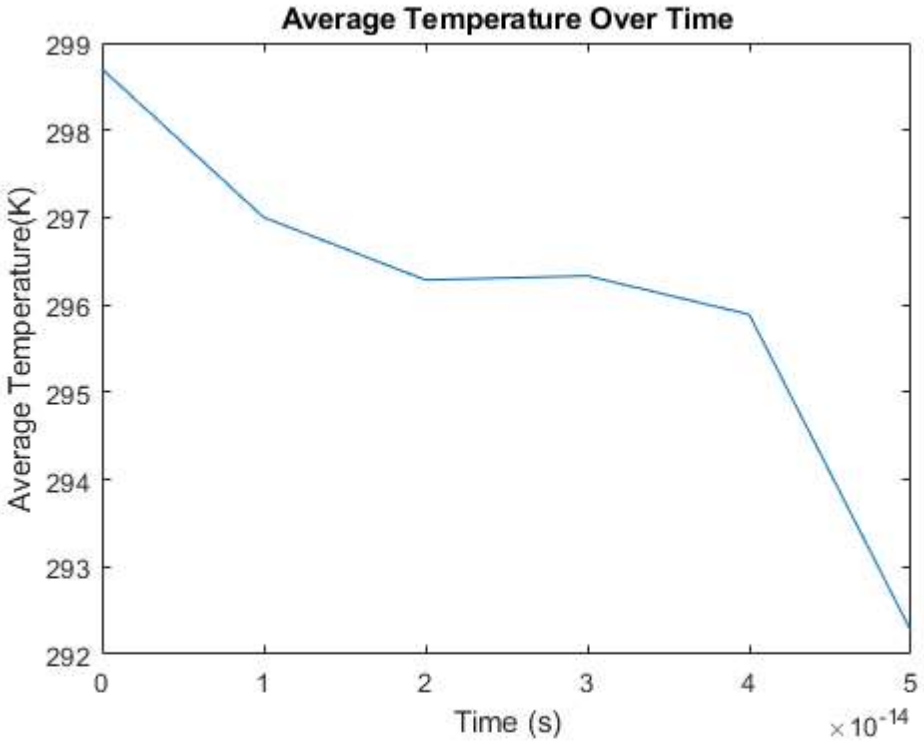

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

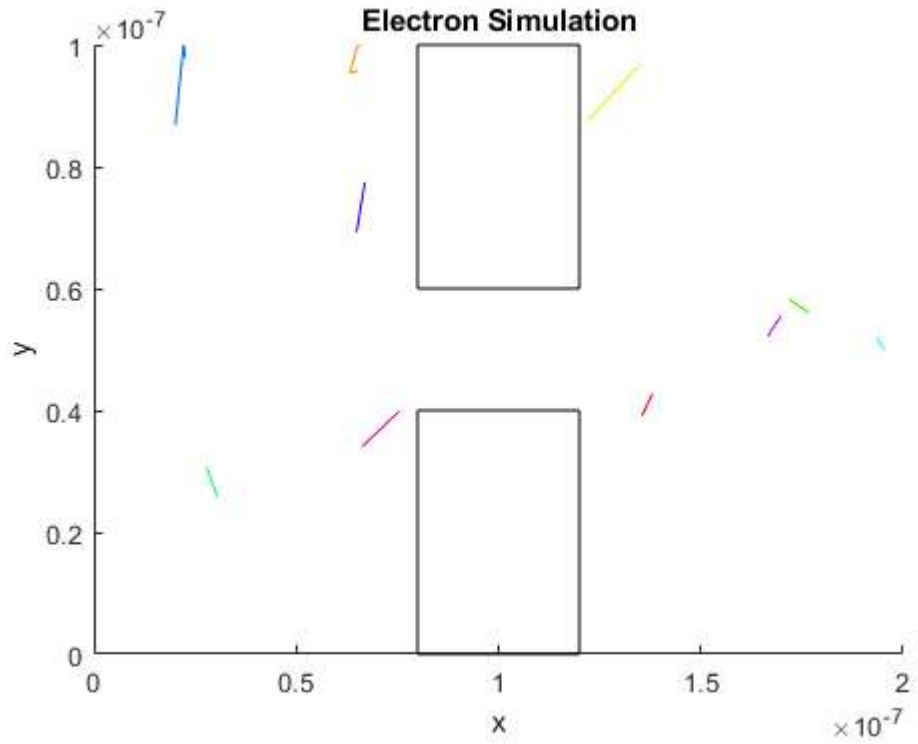

Average Temperature Over Time
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-14

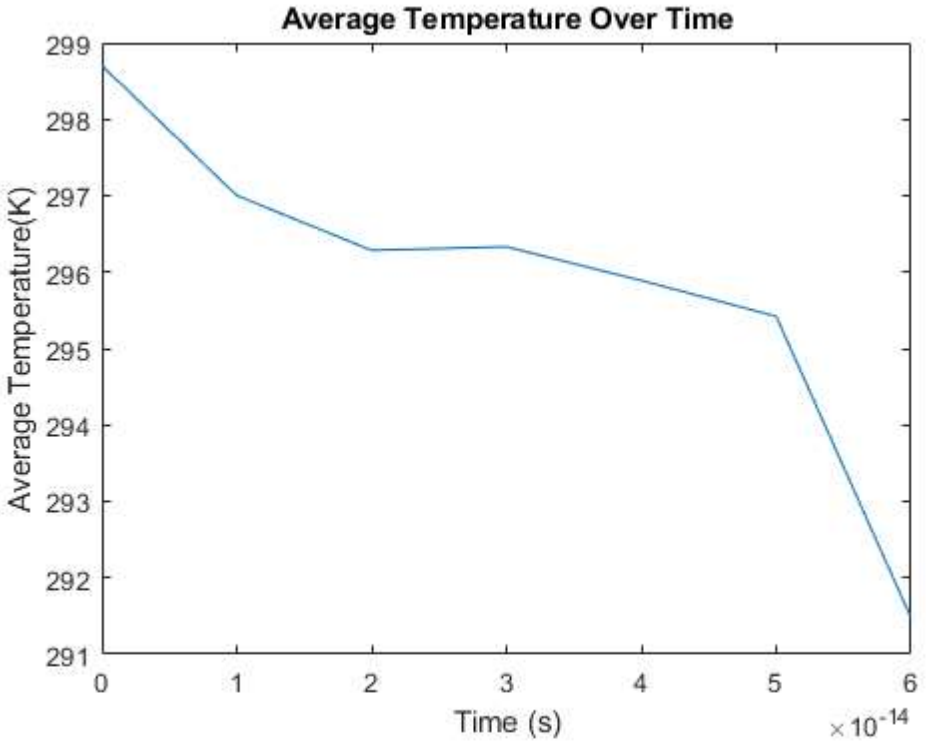

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

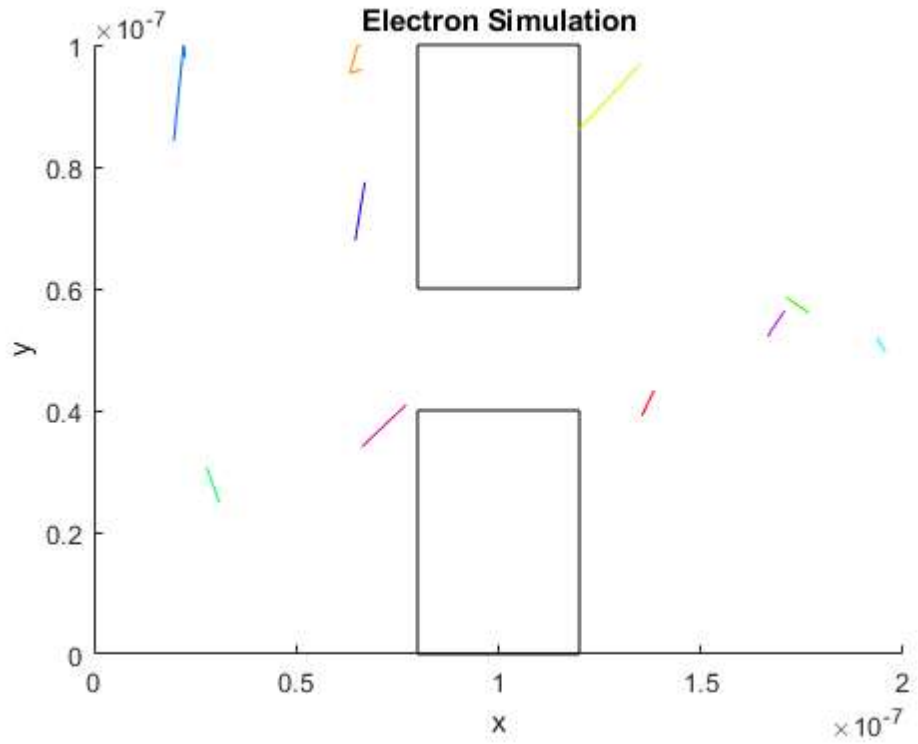

Average Temperature Over Time
Average Temperature(K)
299
298.5
298
297.5
297
296.5
296
295.5
295
294.5
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-14

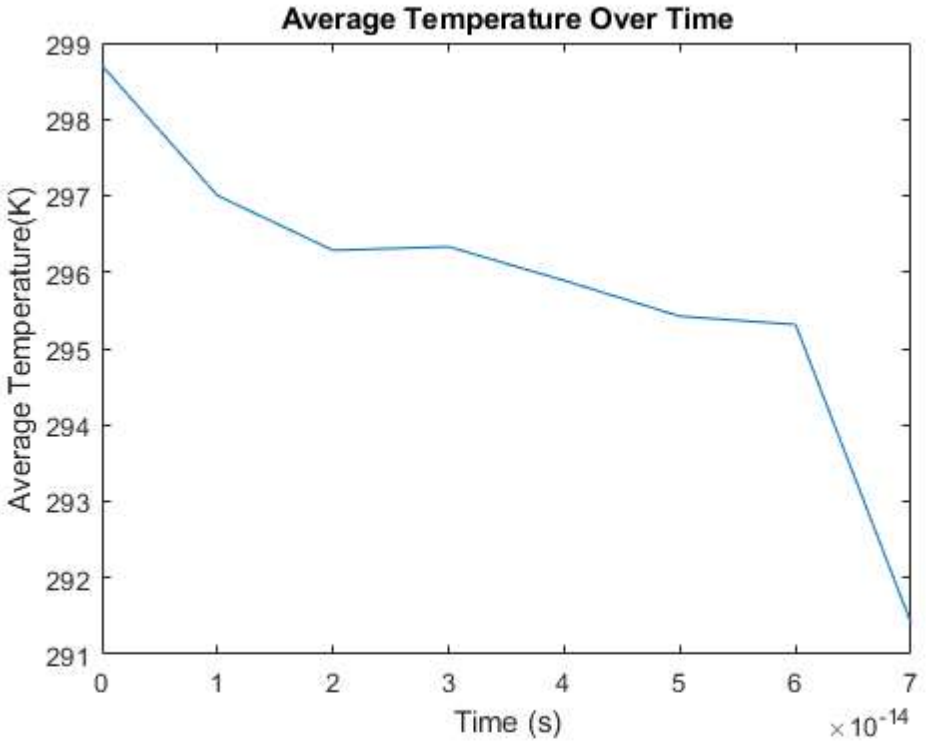

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

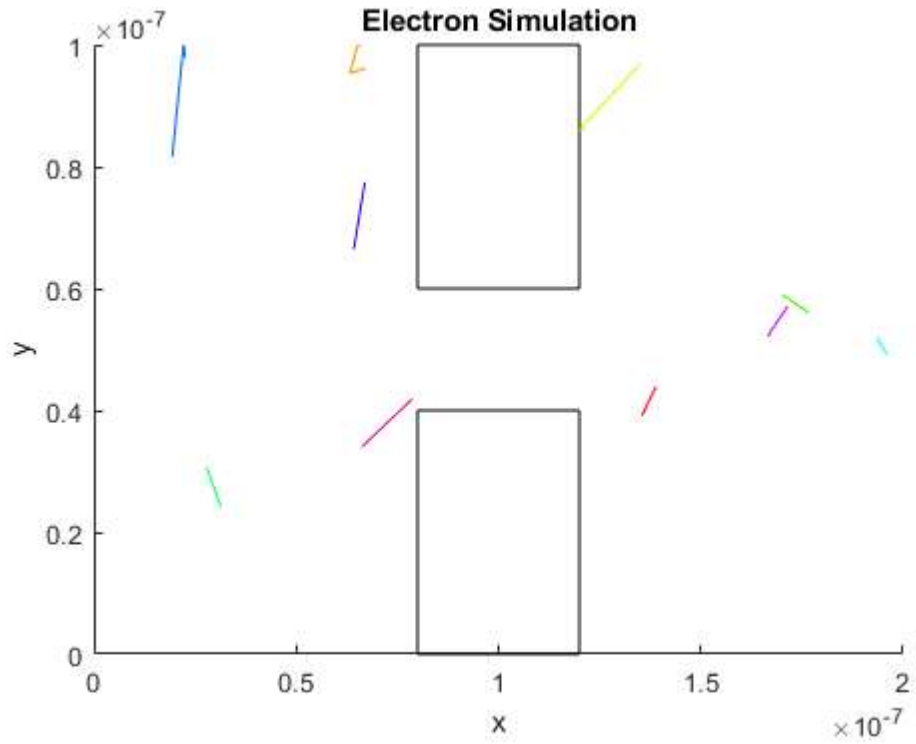

Average Temperature Over Time
299
298
297
296
295
294
293
292
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-14

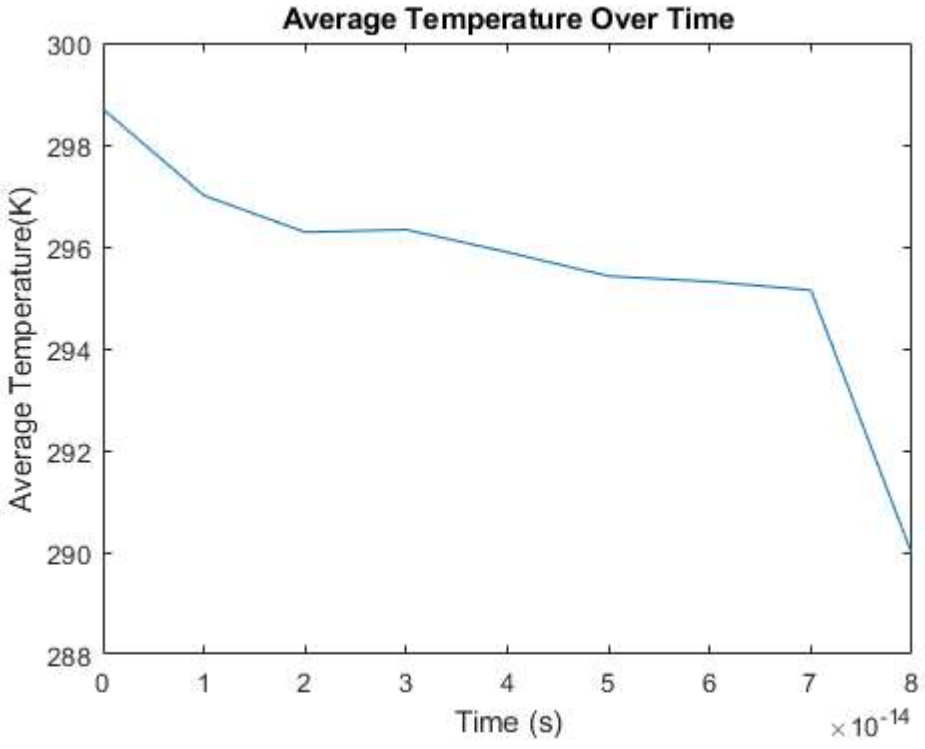

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

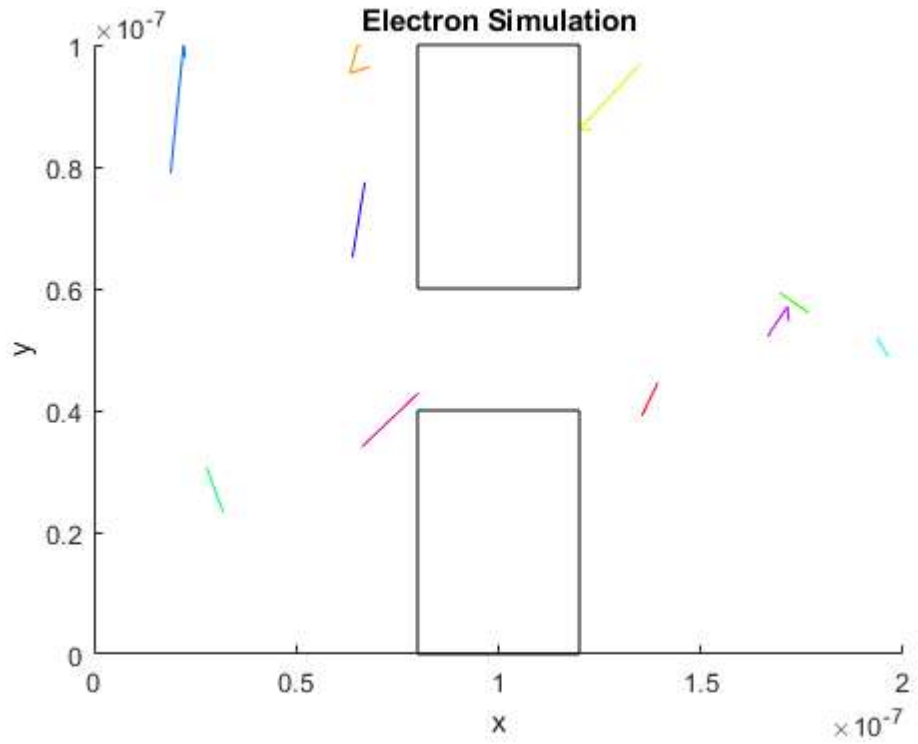

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
0
1
2
3
4
5
6
Time (s)
×10^-14

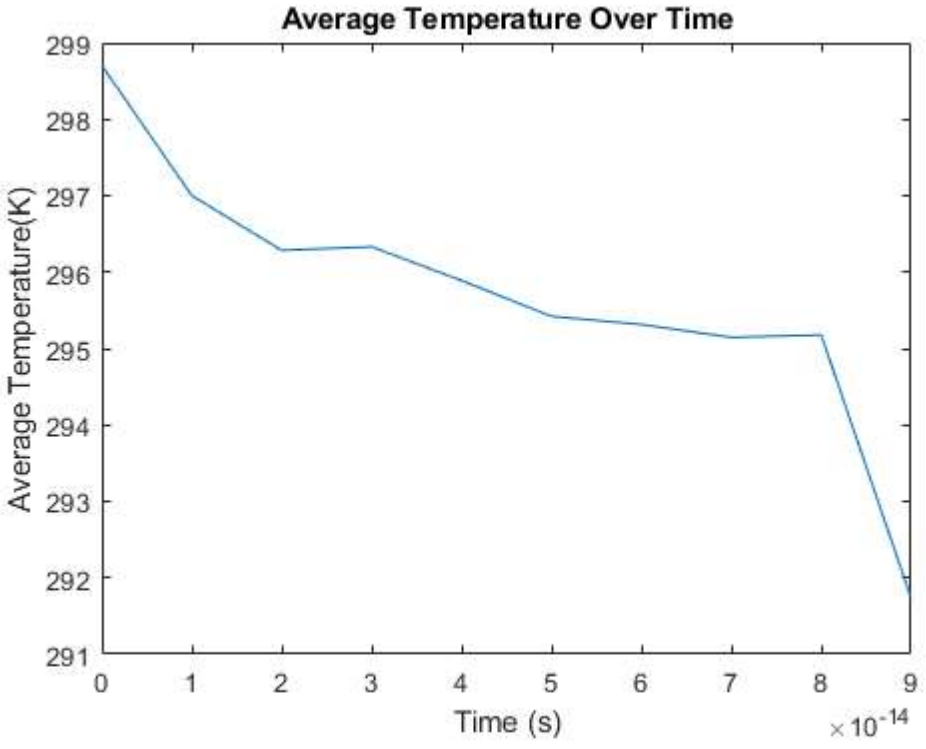

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

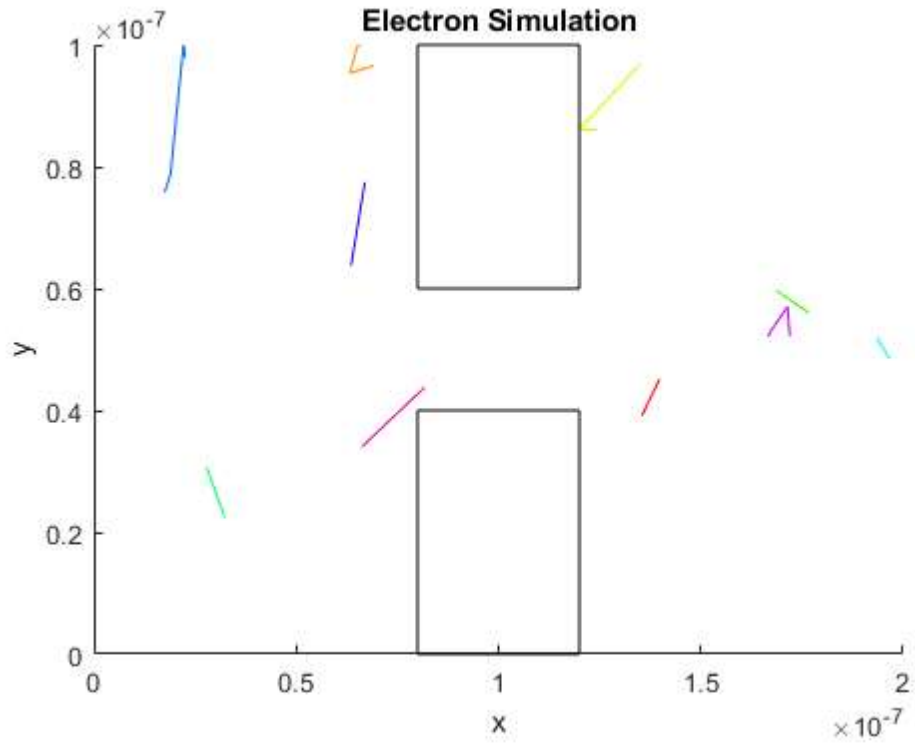

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
0
1
2
3
4
5
6
7
Time (s)
×10^-14

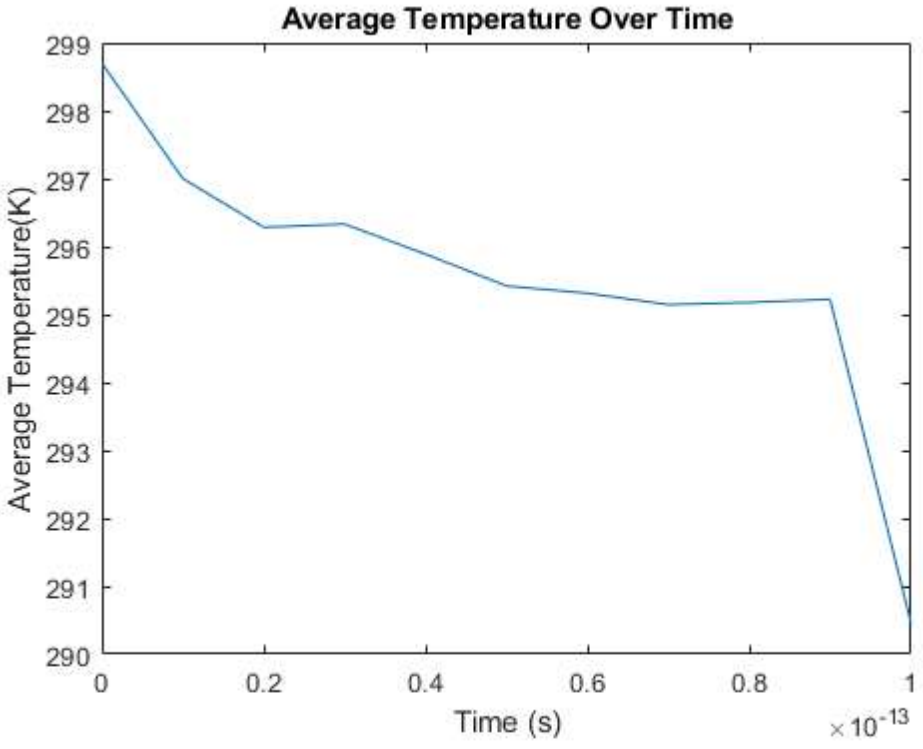

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

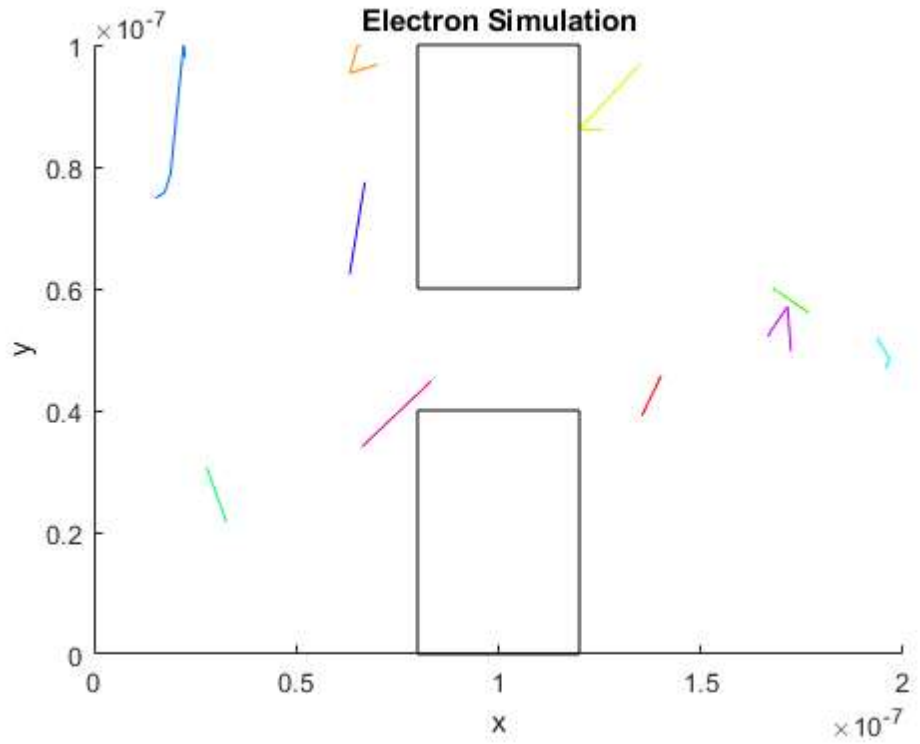

Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-14

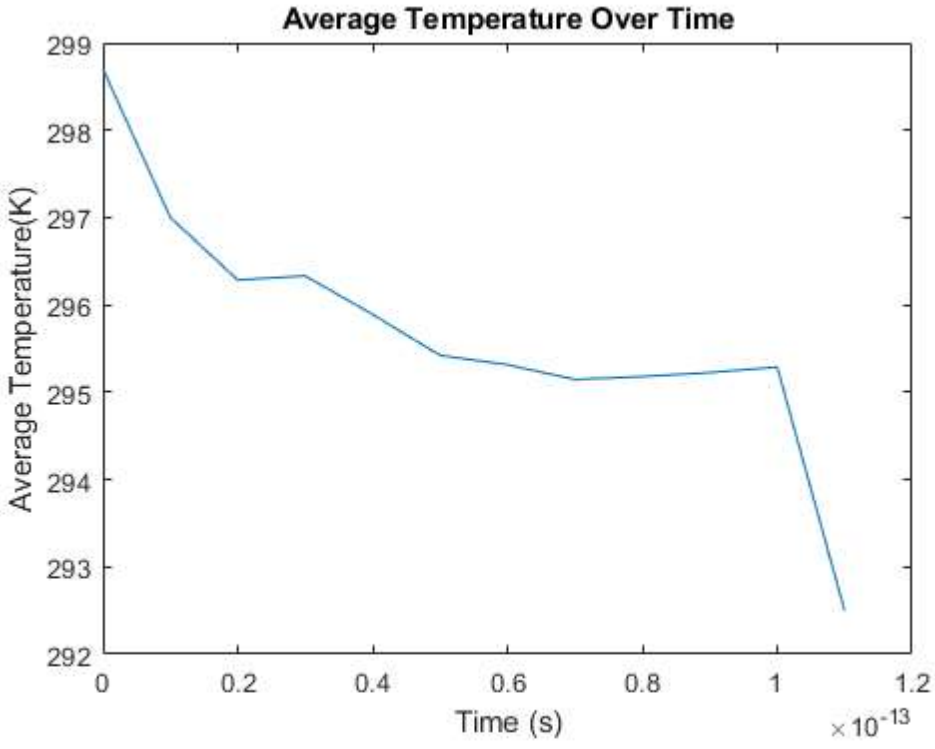

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

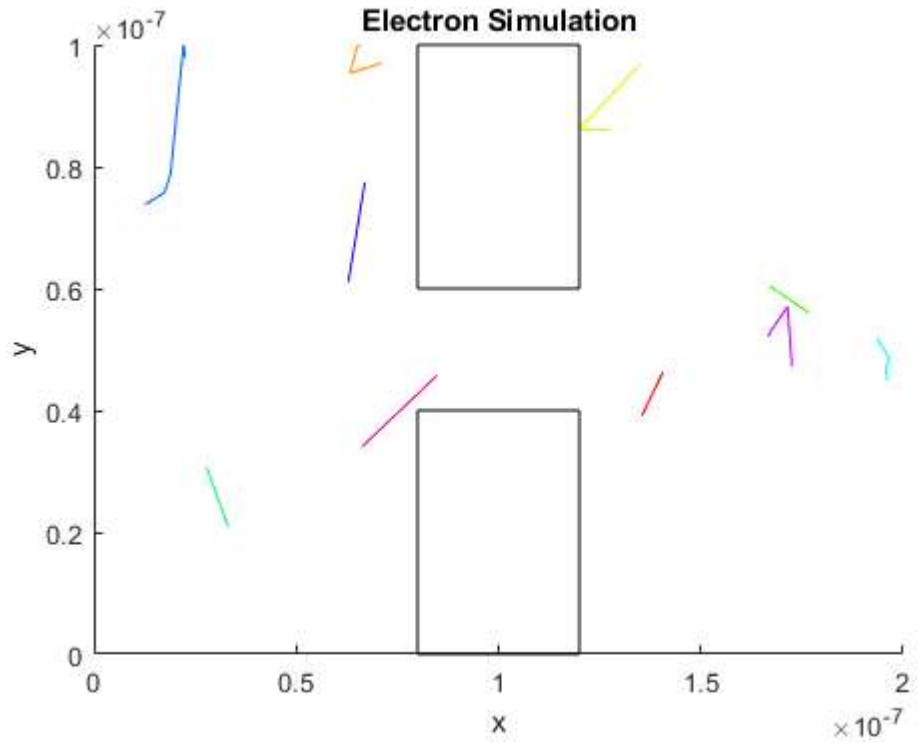

Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
0
1
2
3
4
5
6
7
8
9
Time (s)
×10^-14


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
290
0
0.2
0.4
0.6
0.8
1
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
297
296
295
294
293
292
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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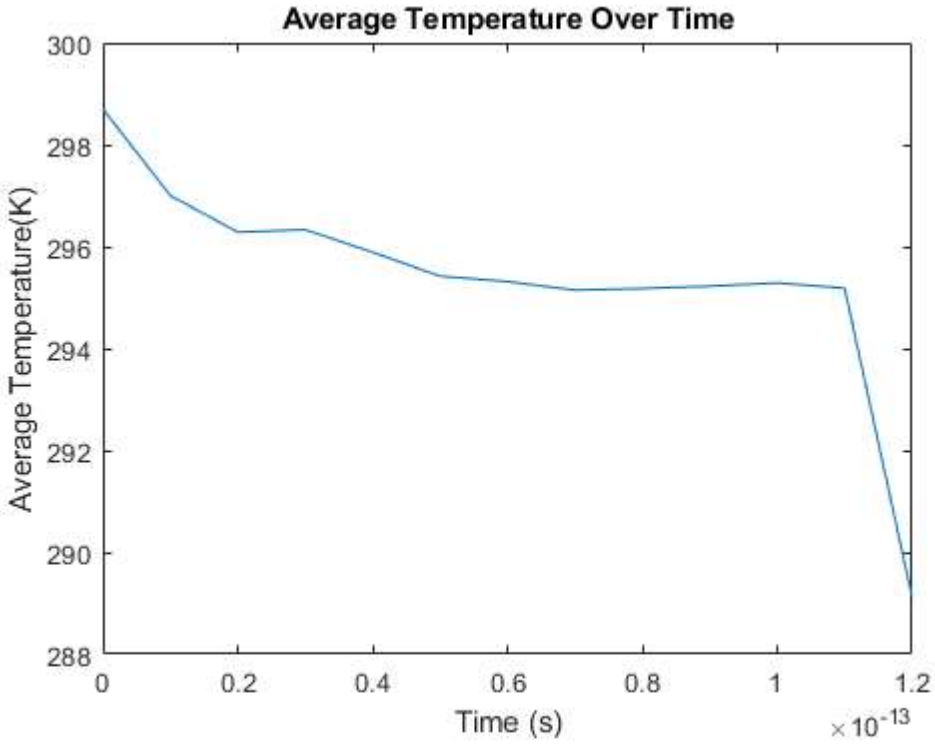
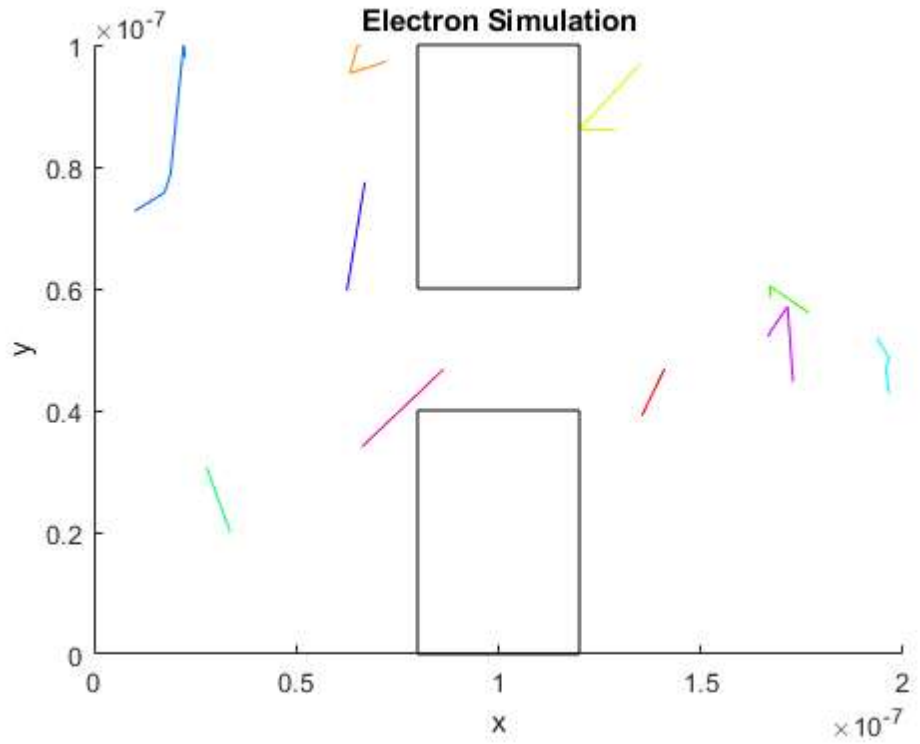
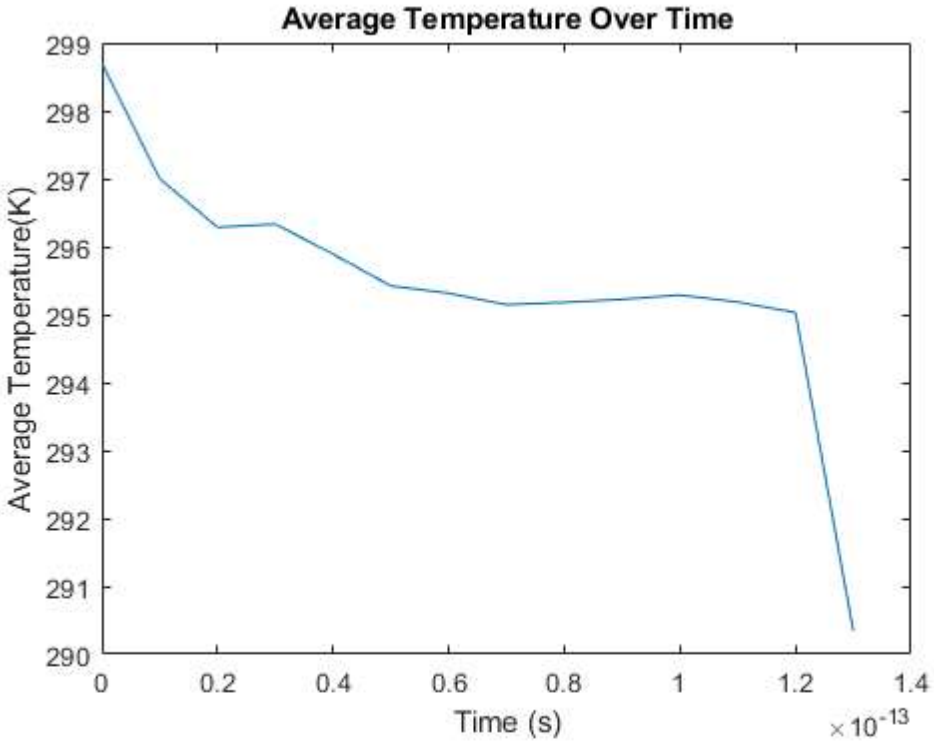
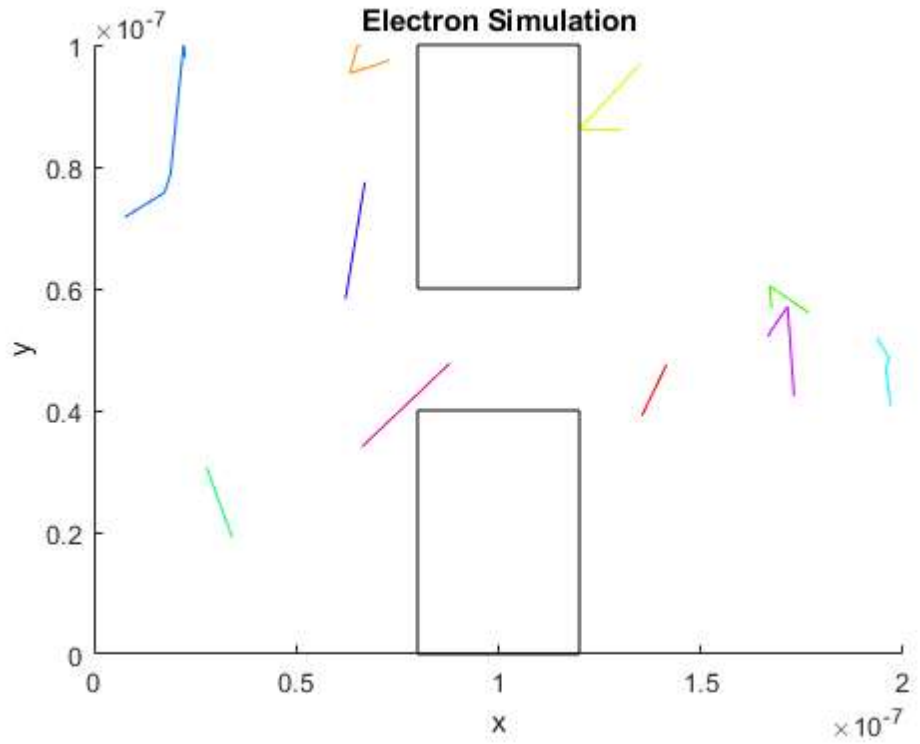
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
Average Temperature(K)
299
298
297
296
295
294
293
292
291
290
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Time (s)
×10^-13


Electron Simulation
×10^-7
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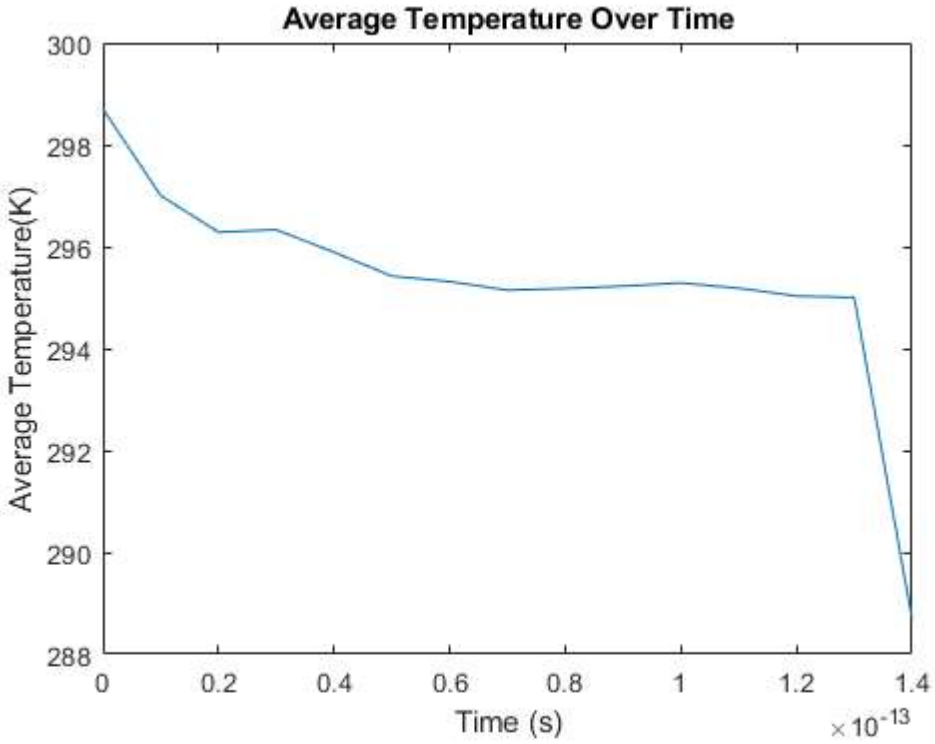
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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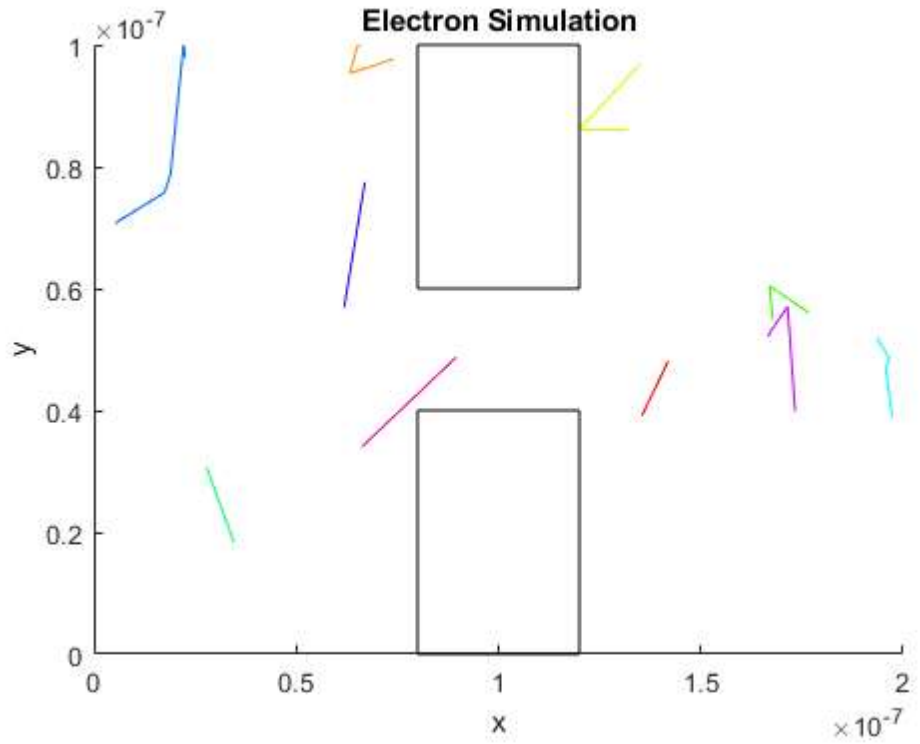
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Time (s)
×10^-13


Electron Simulation
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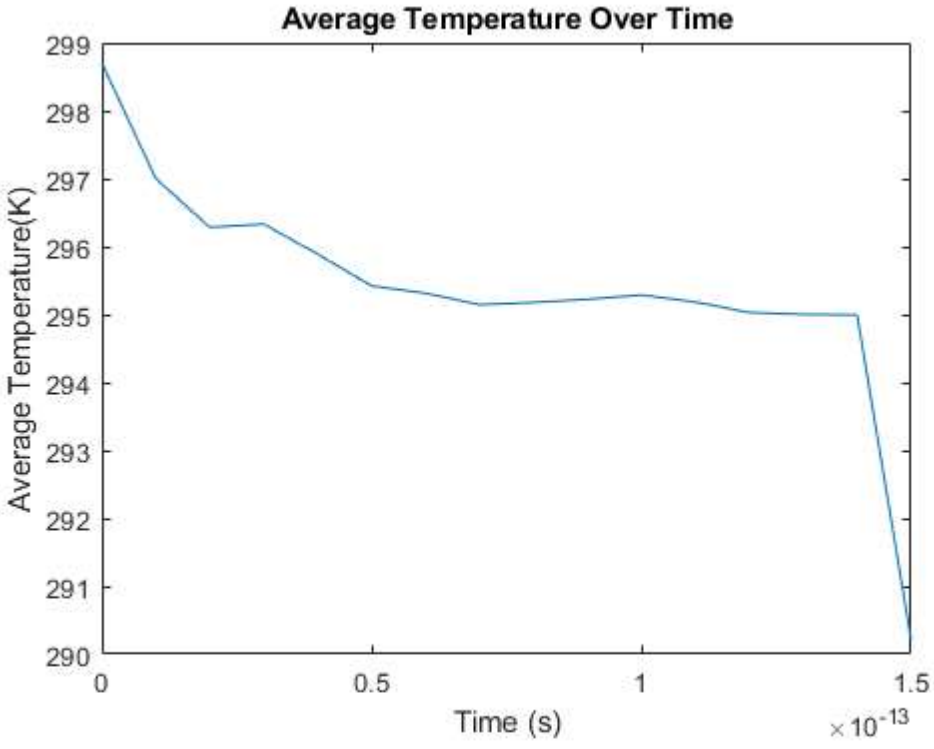
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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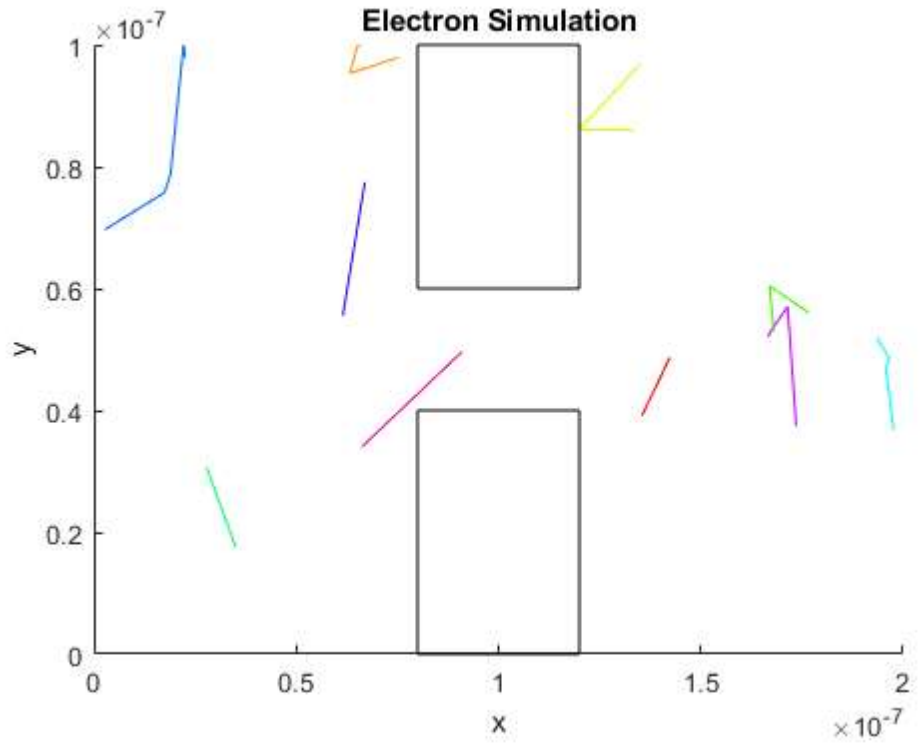
292
291
290
Average Temperature(K)
0
0.5
1
1.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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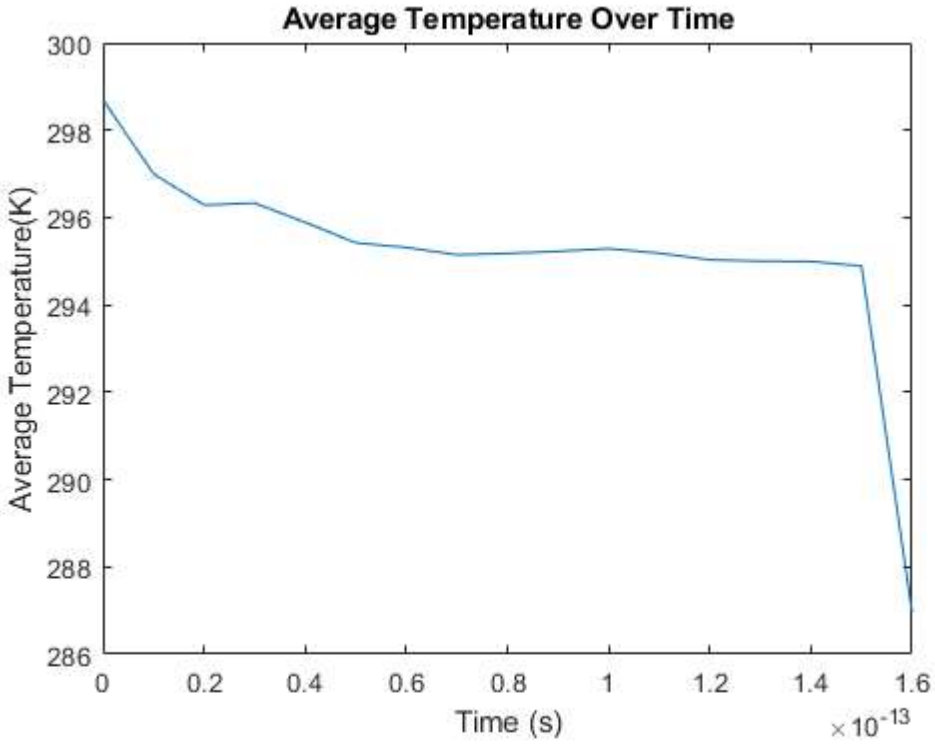
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
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Average Temperature(K)
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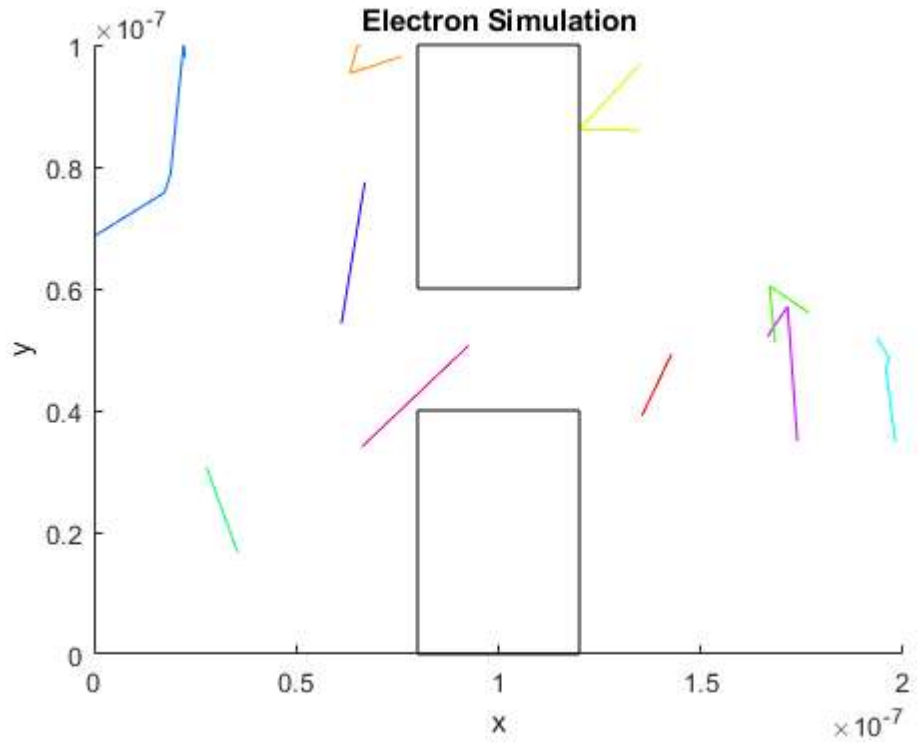
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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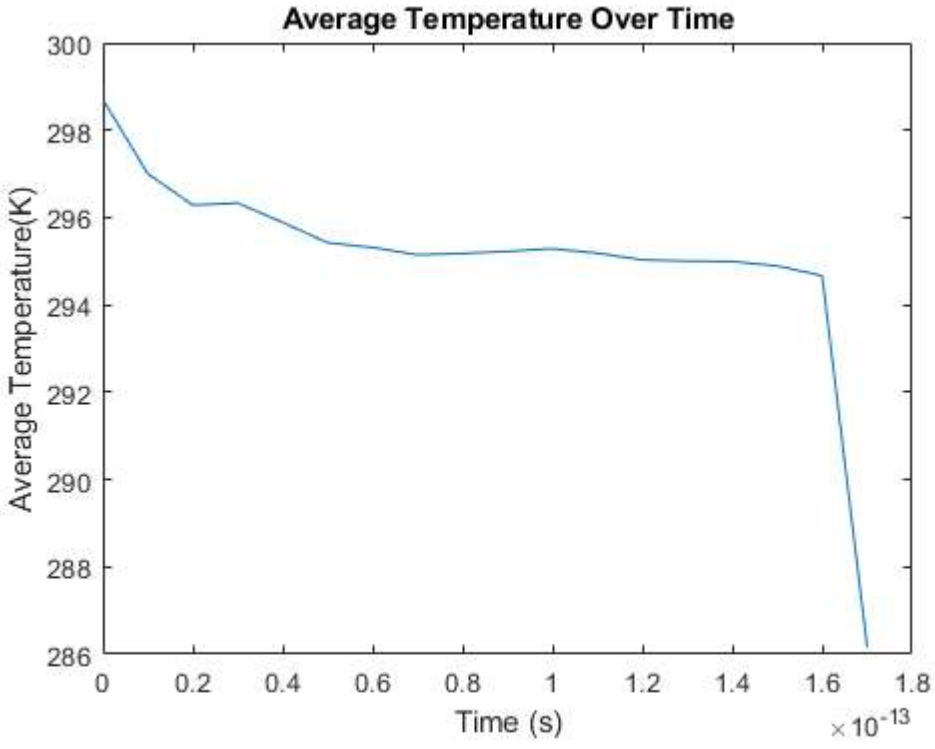
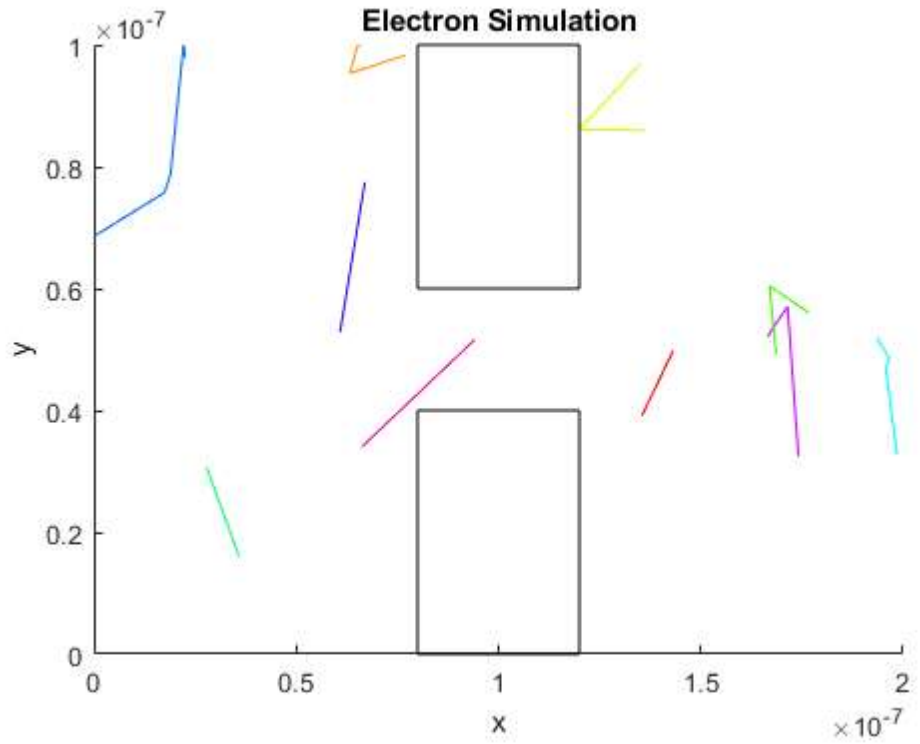
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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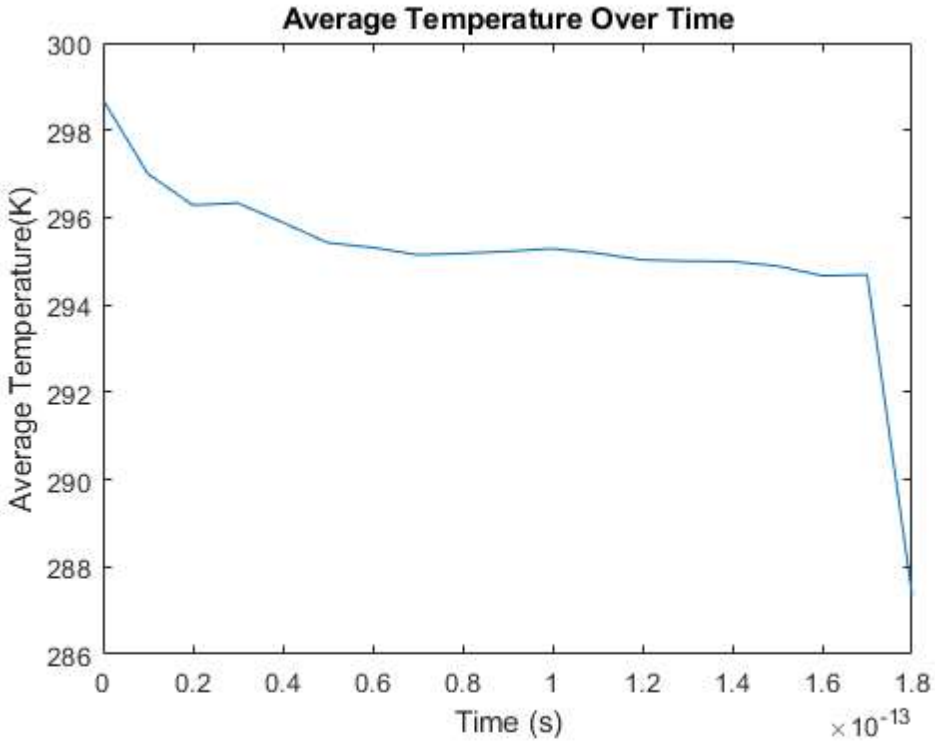
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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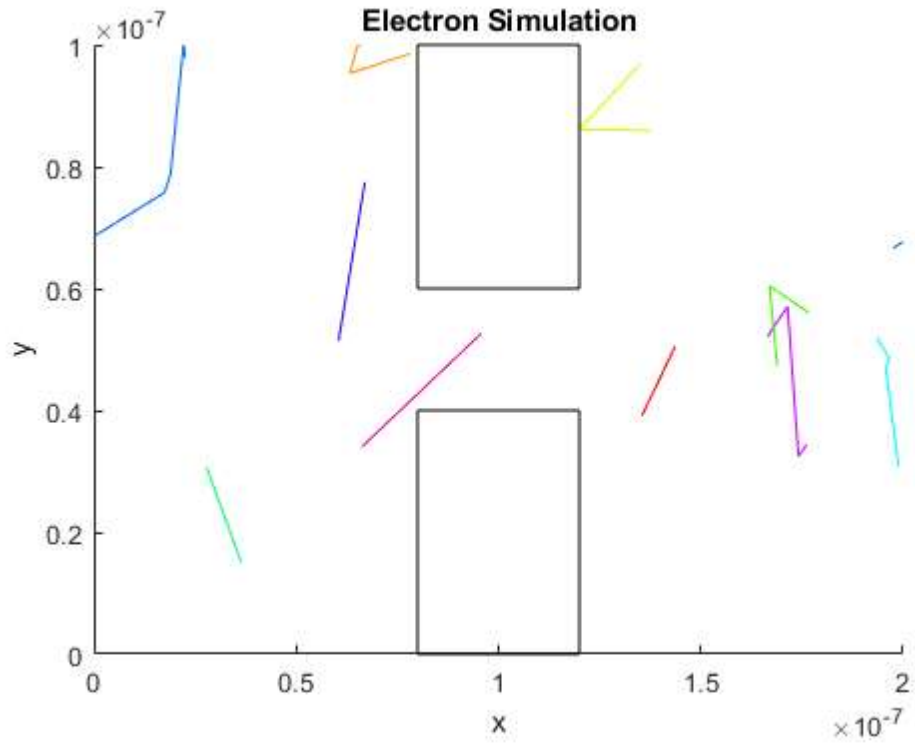
294
292
290
288
286
Average Temperature(K)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time (s)
×10^-13


Electron Simulation
×10^-7
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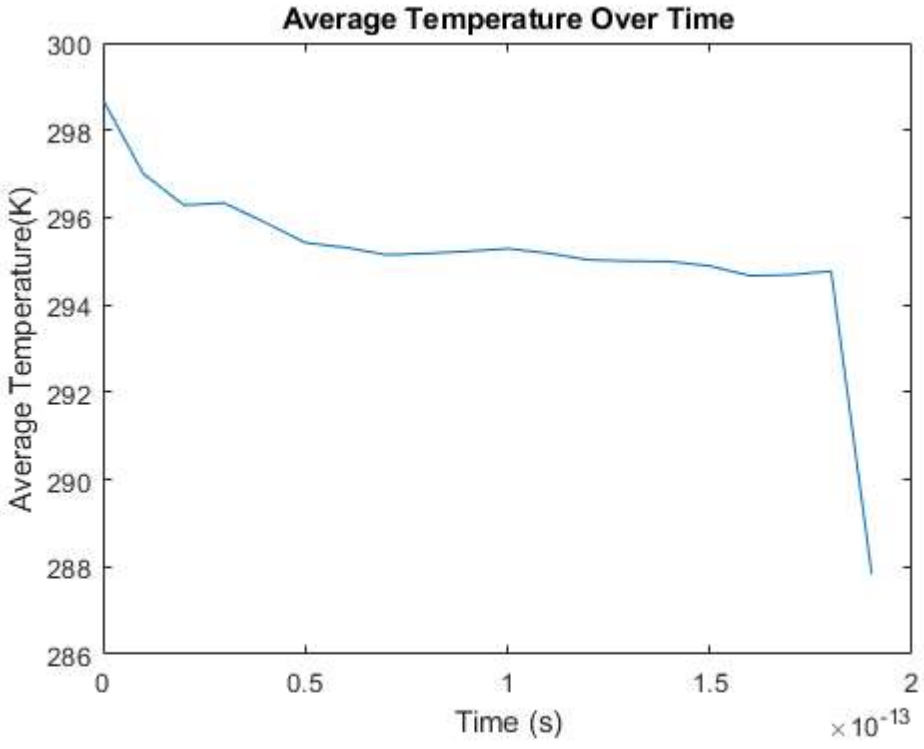
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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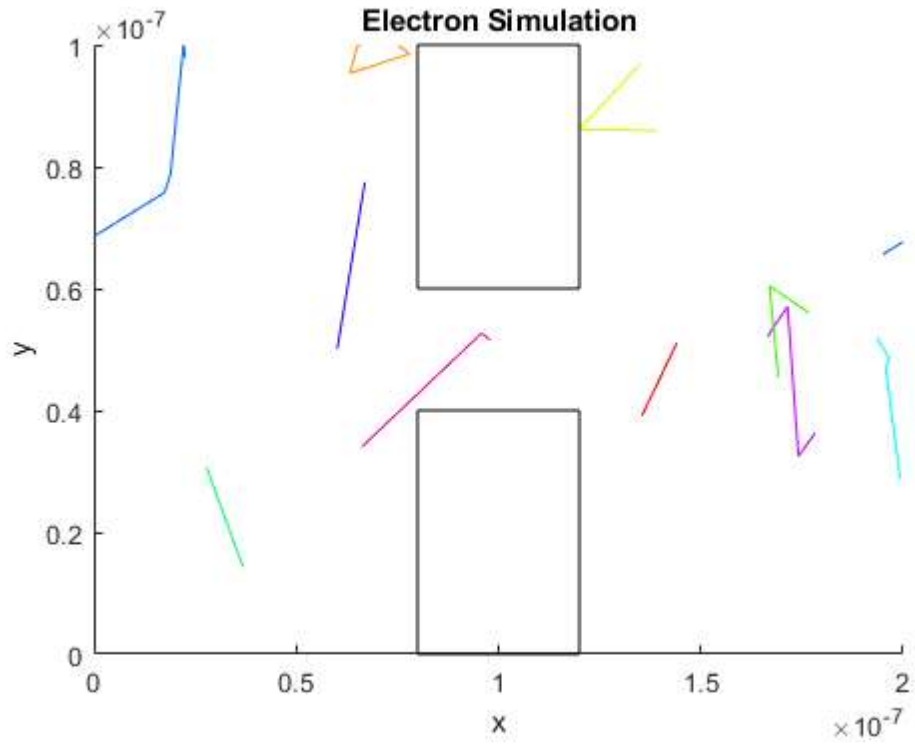
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
Time (s)
×10^-13


Electron Simulation
×10^-7
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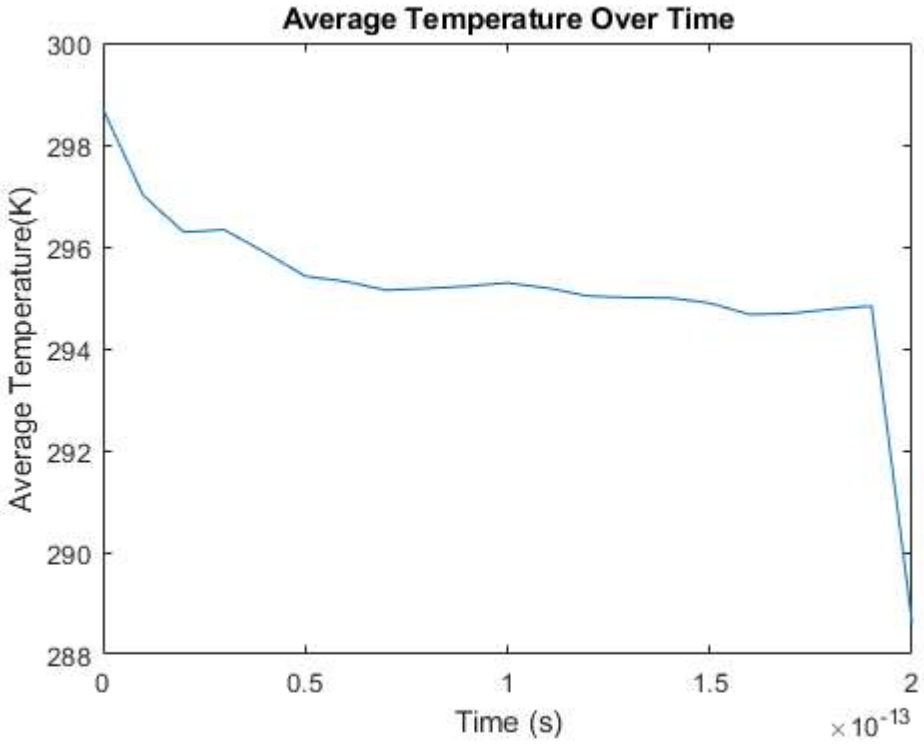
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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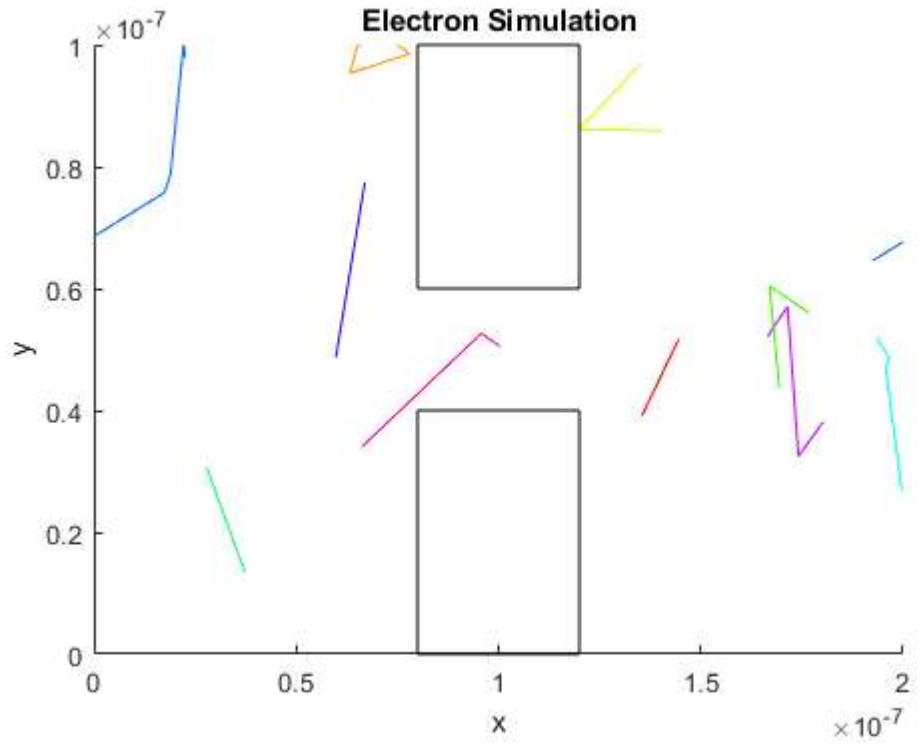
0.5
1
1.5
2
Time (s)
×10^-13


Electron Simulation
×10^-7
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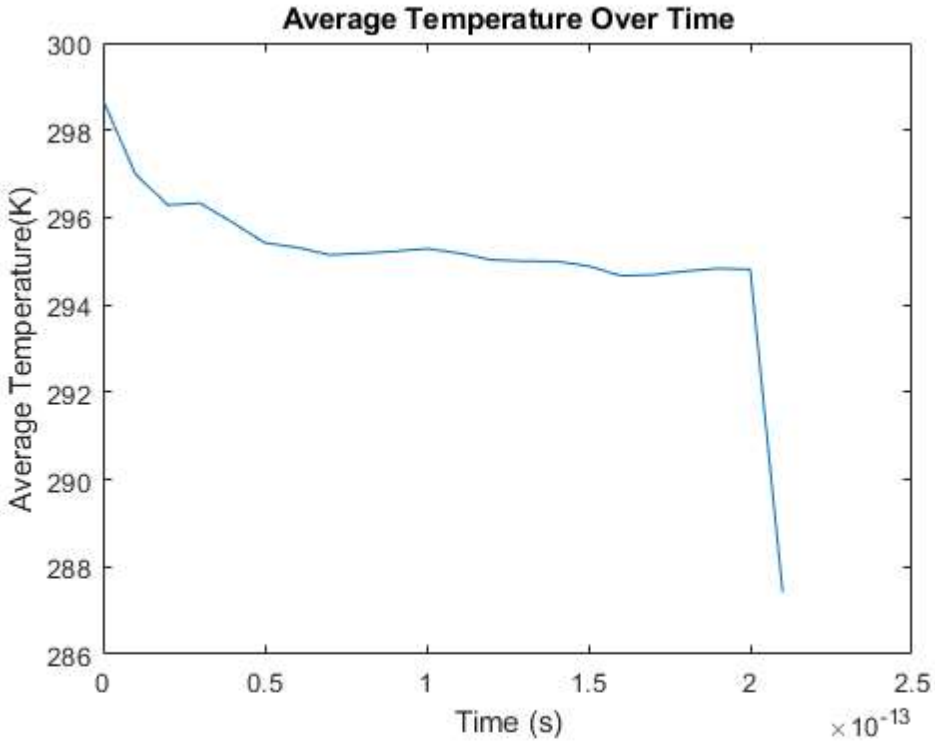
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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286
Average Temperature(K)
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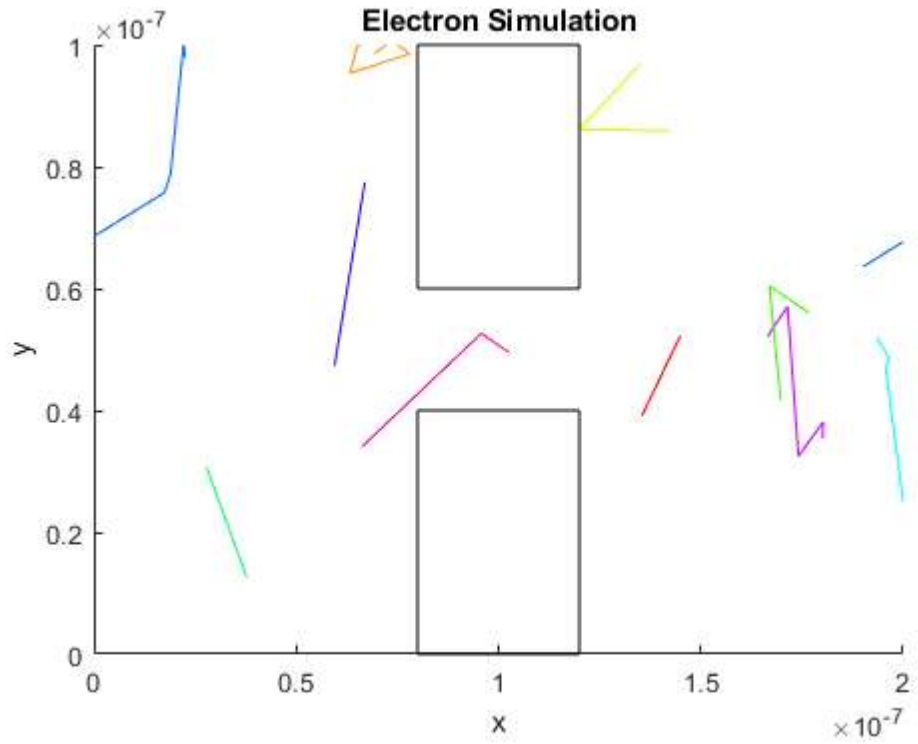
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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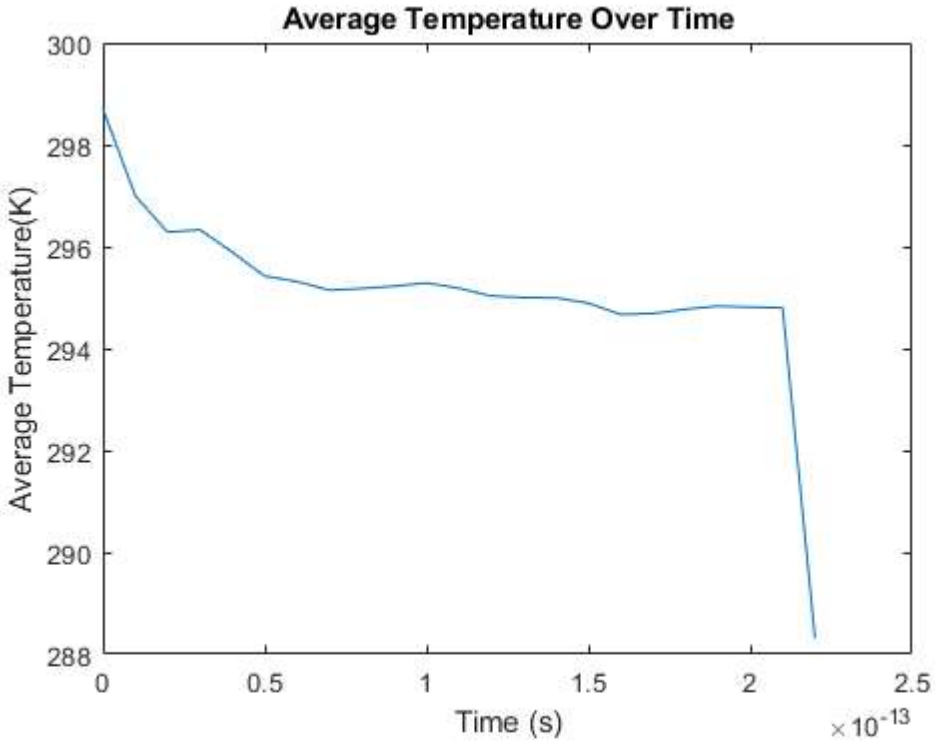
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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288
Average Temperature(K)
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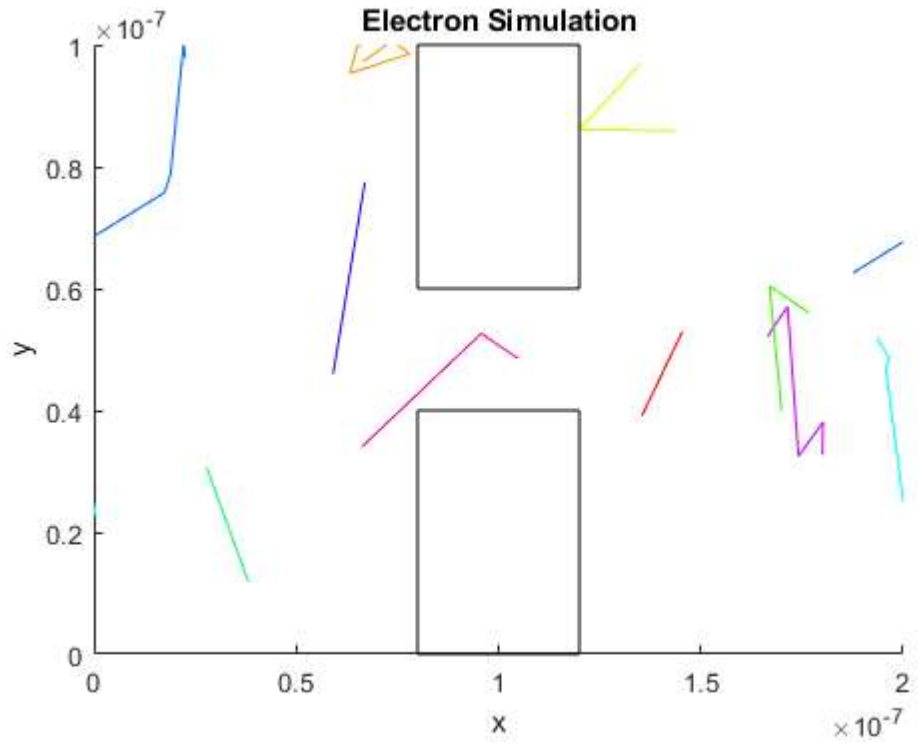
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
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0
y
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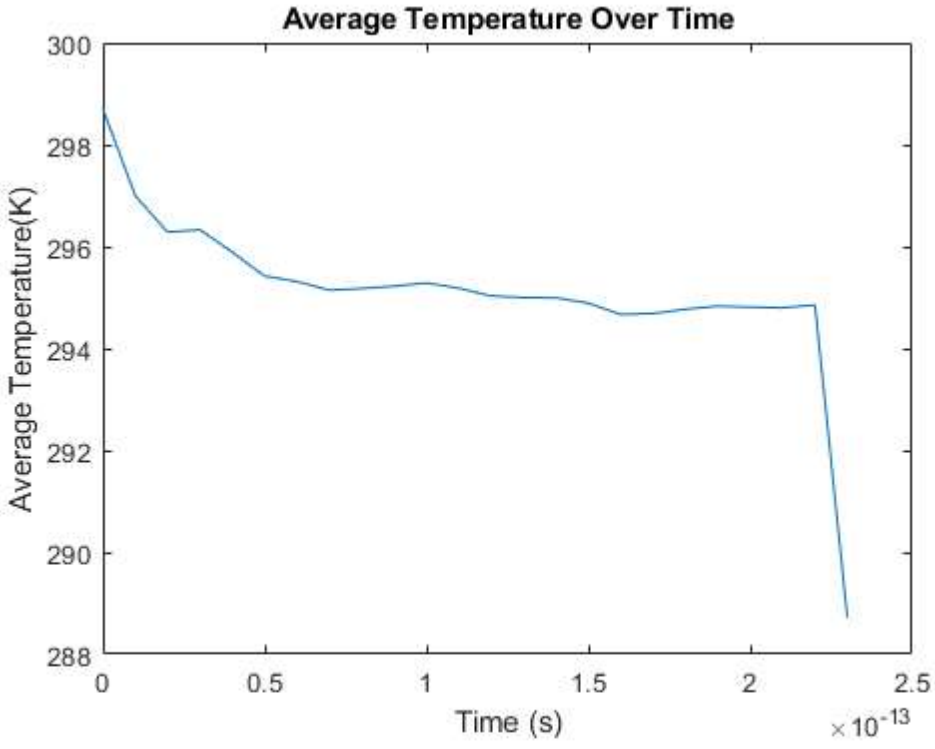
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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Average Temperature(K)
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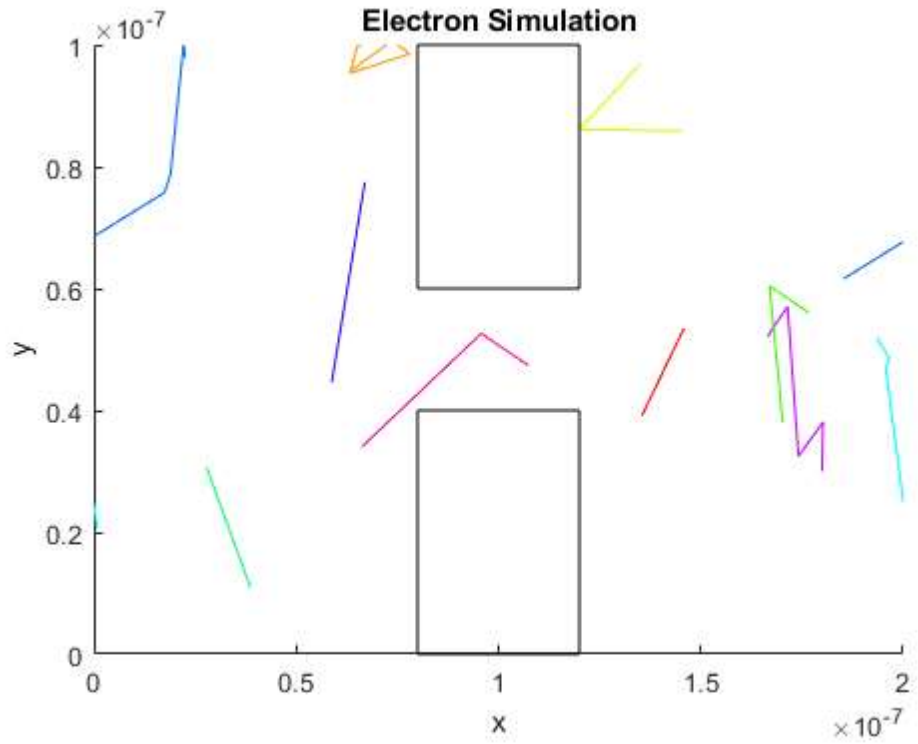
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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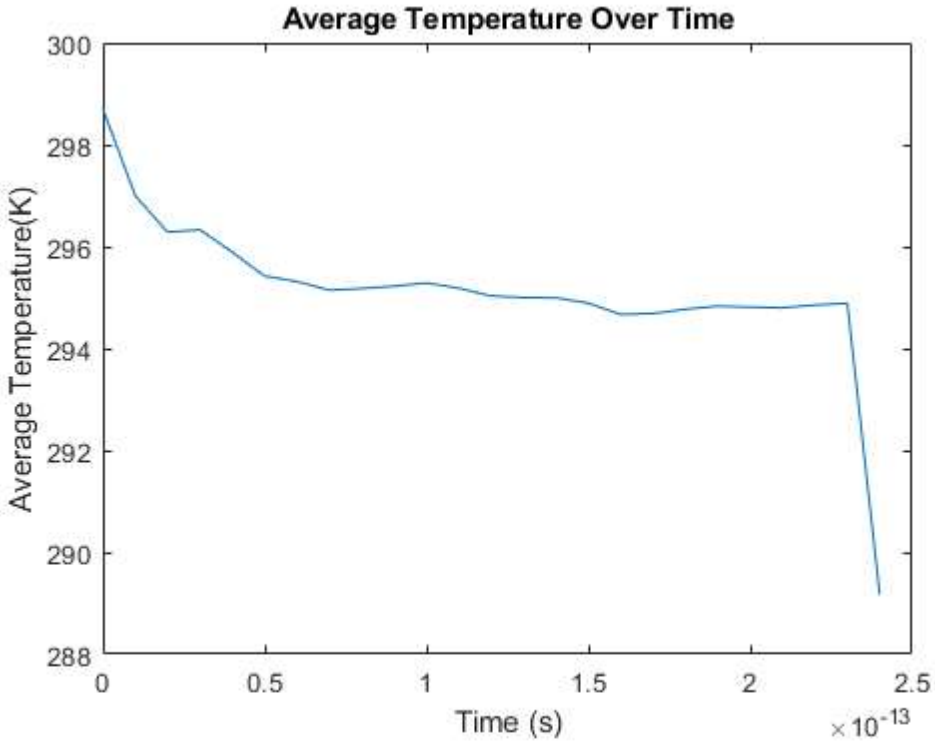
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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294
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290
288
Average Temperature(K)
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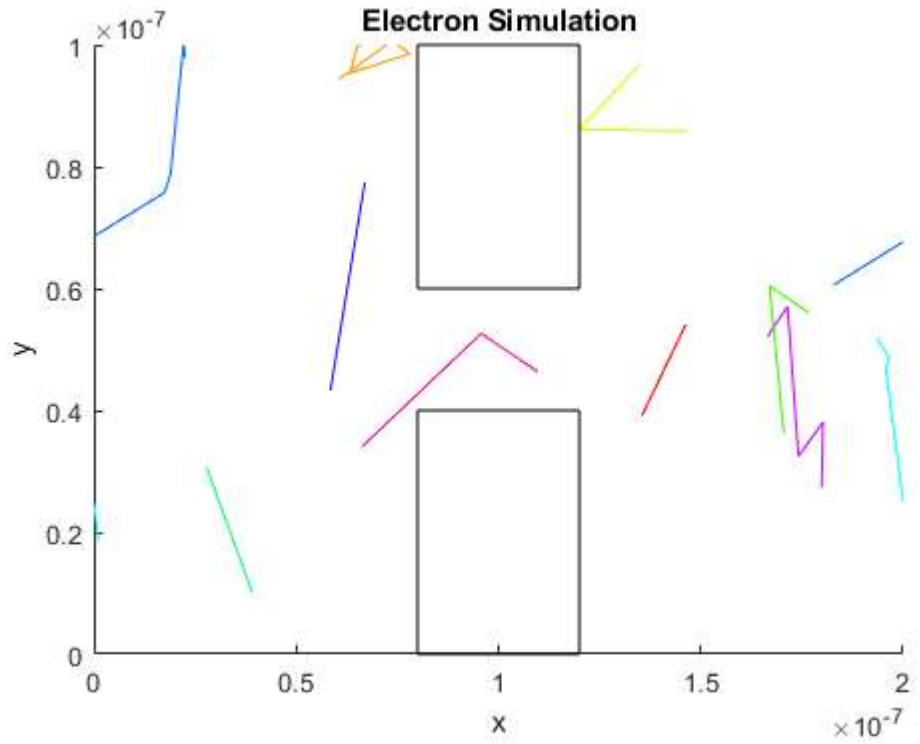
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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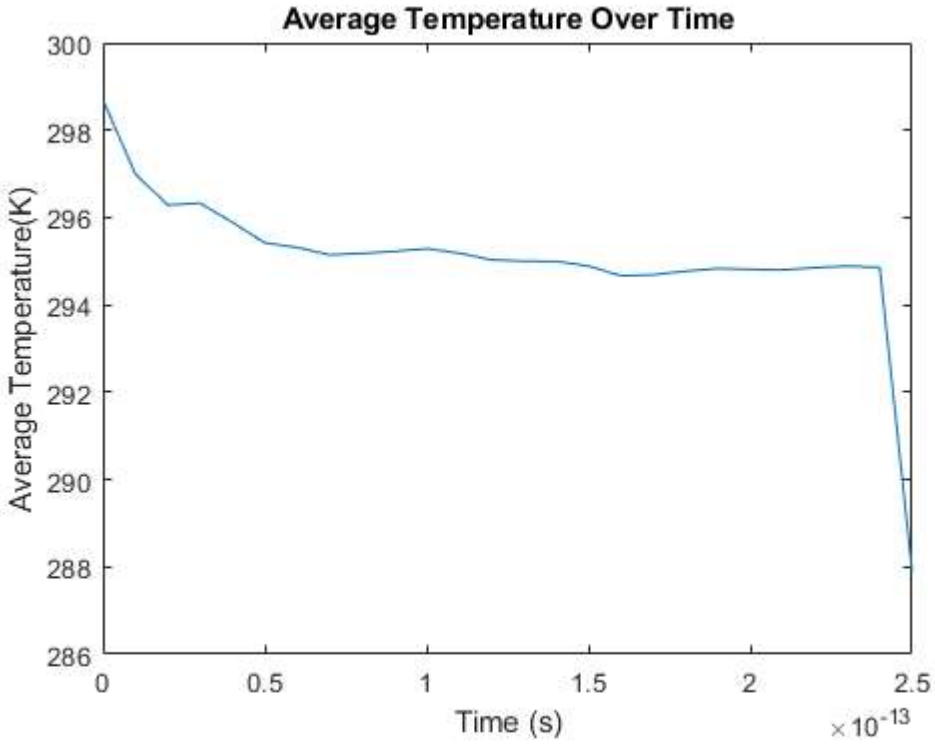
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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288
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Average Temperature(K)
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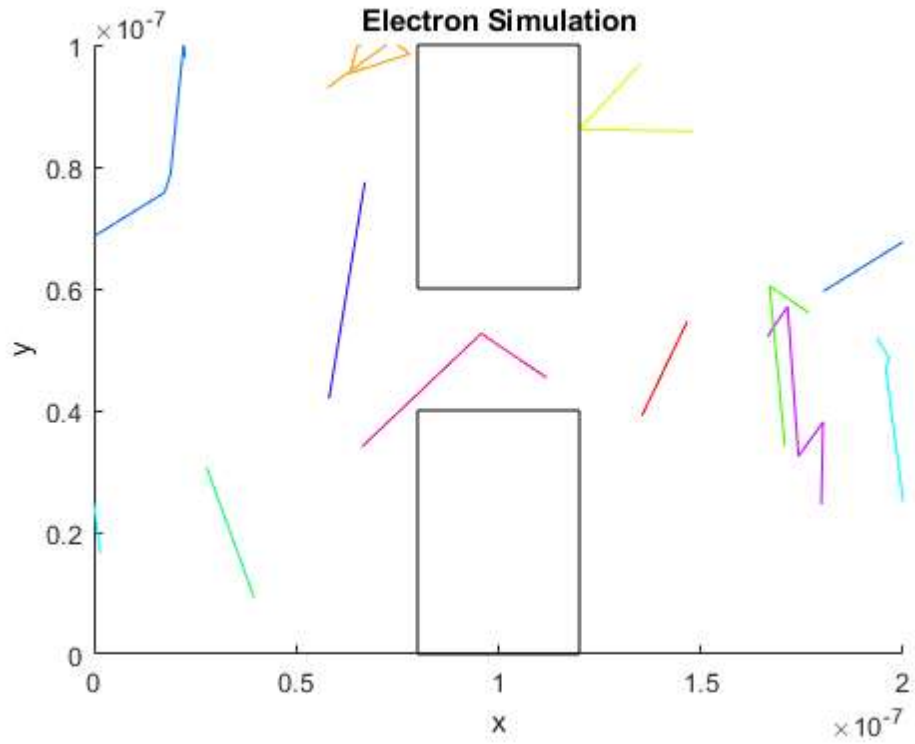
0.5
1
1.5
2
2.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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0.6
0.4
0.2
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y
0
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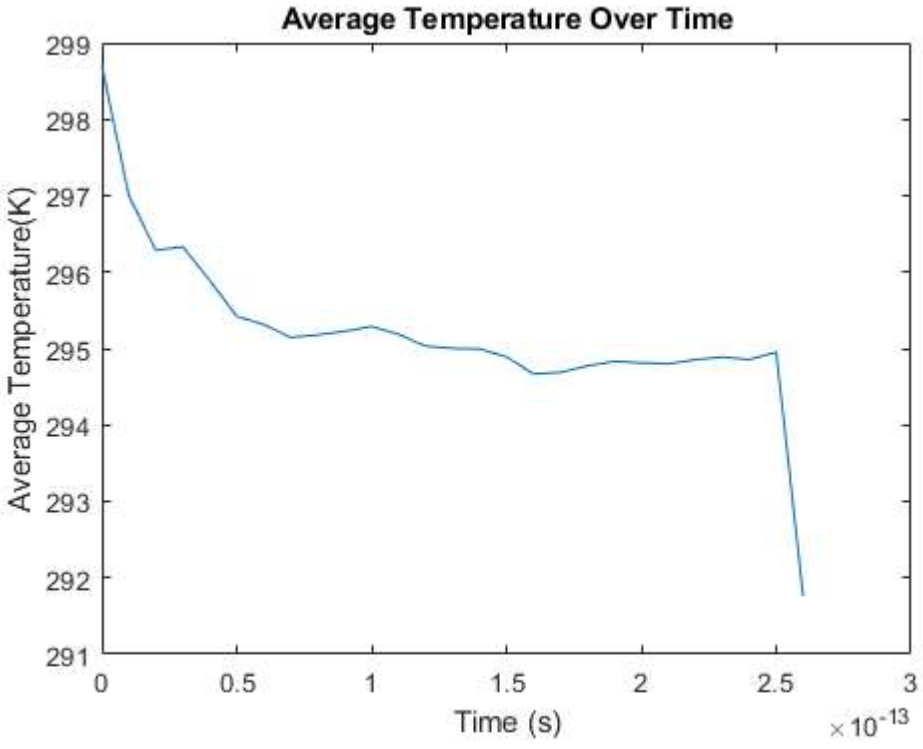
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
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Average Temperature(K)
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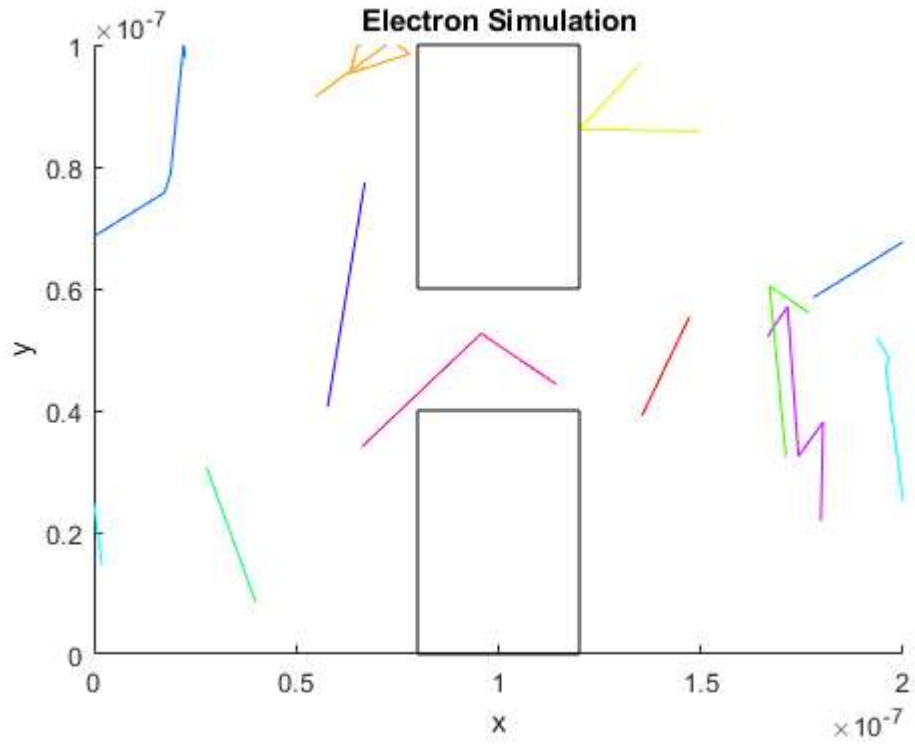
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
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0.6
0.4
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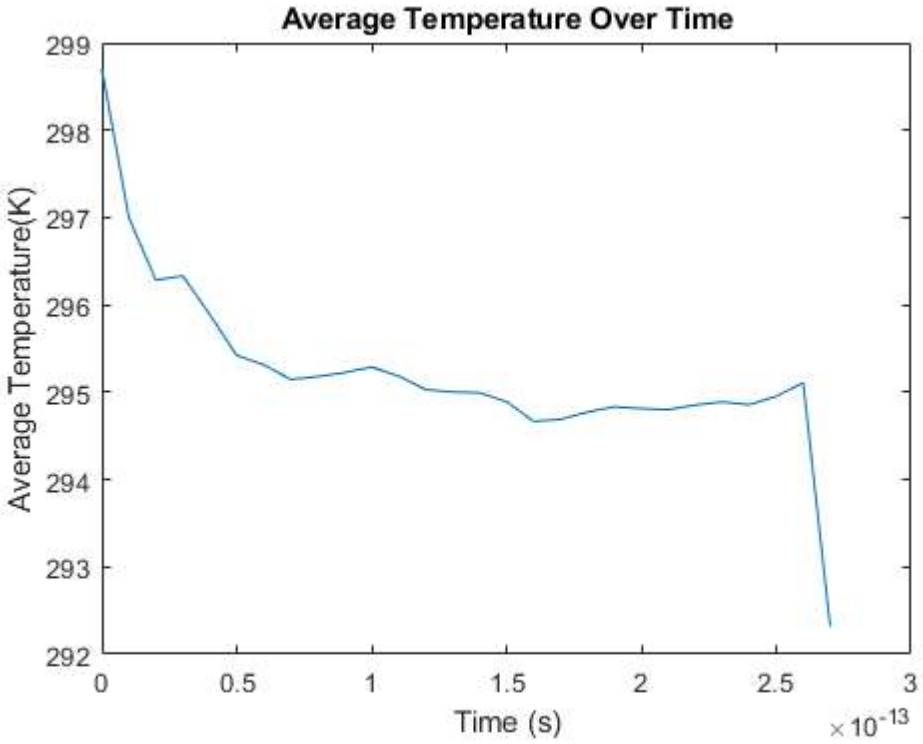
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
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Average Temperature(K)
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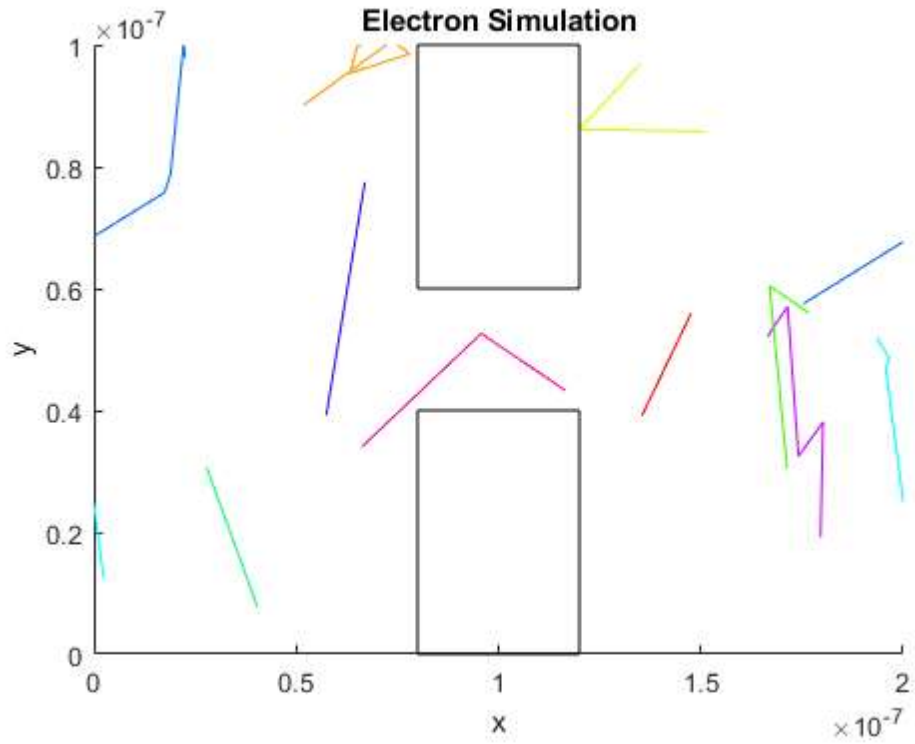
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
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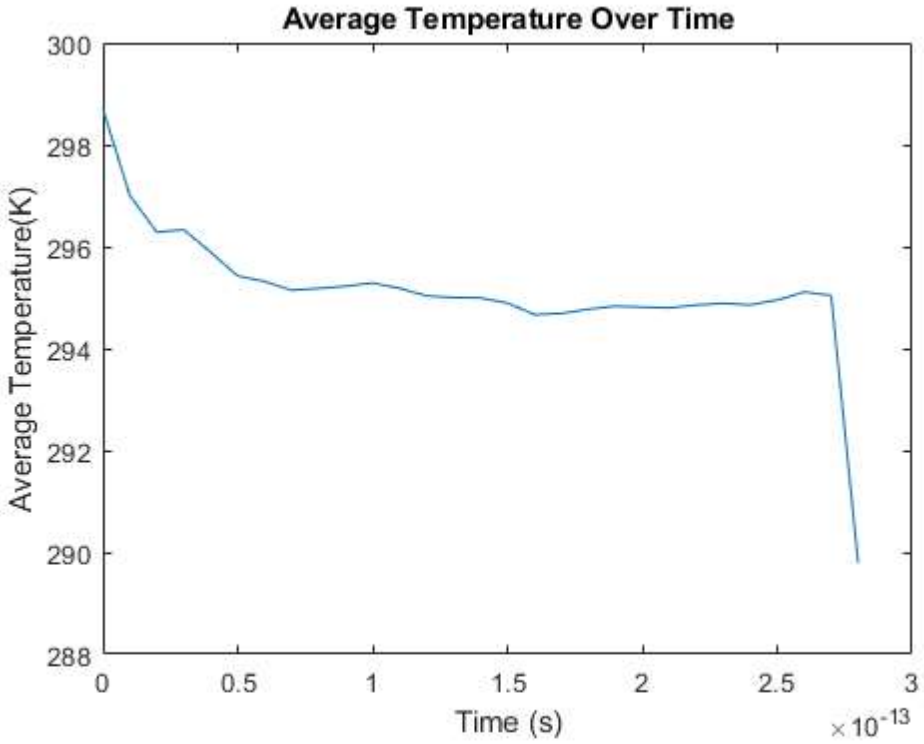
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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Average Temperature(K)
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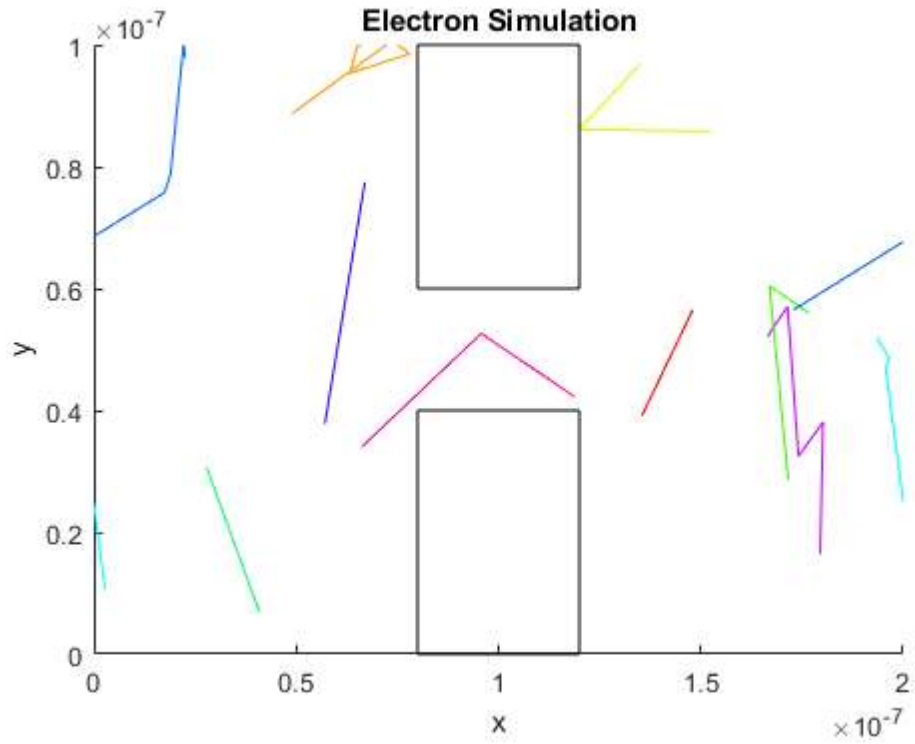
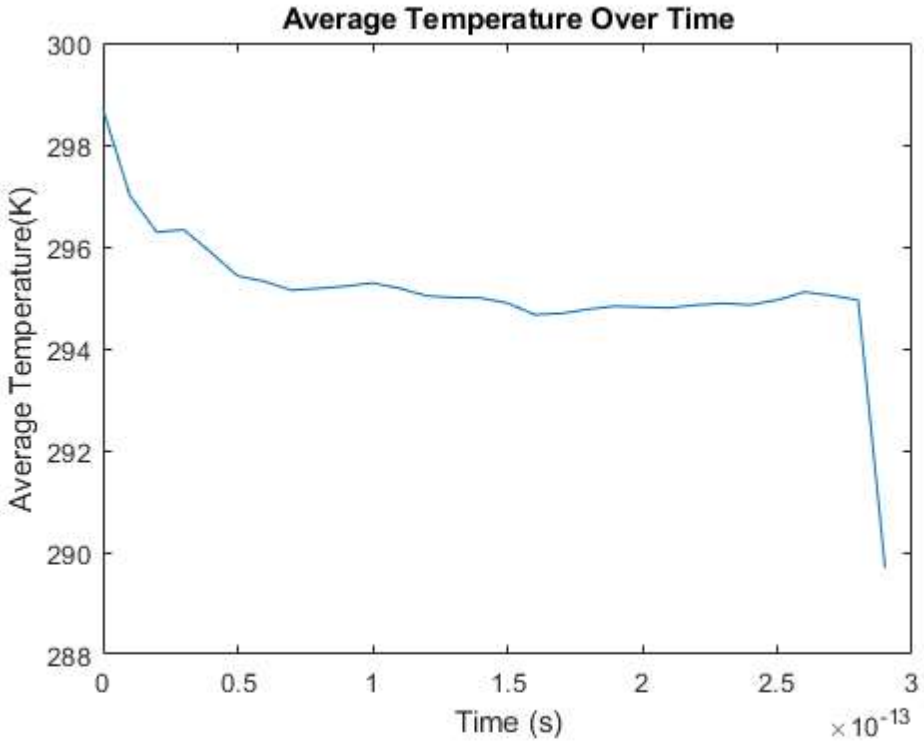
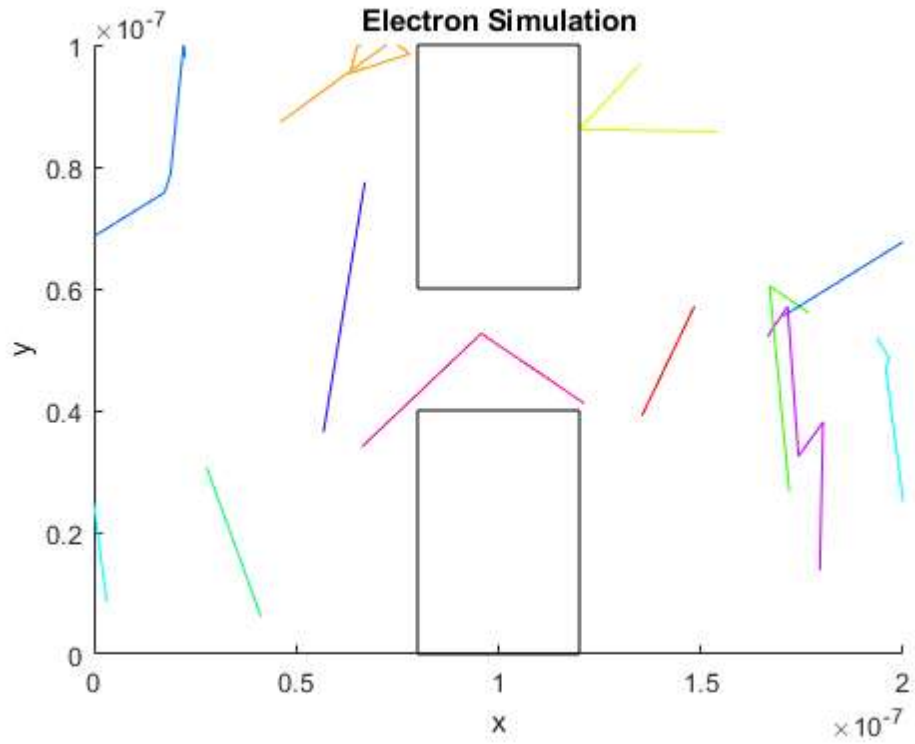
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
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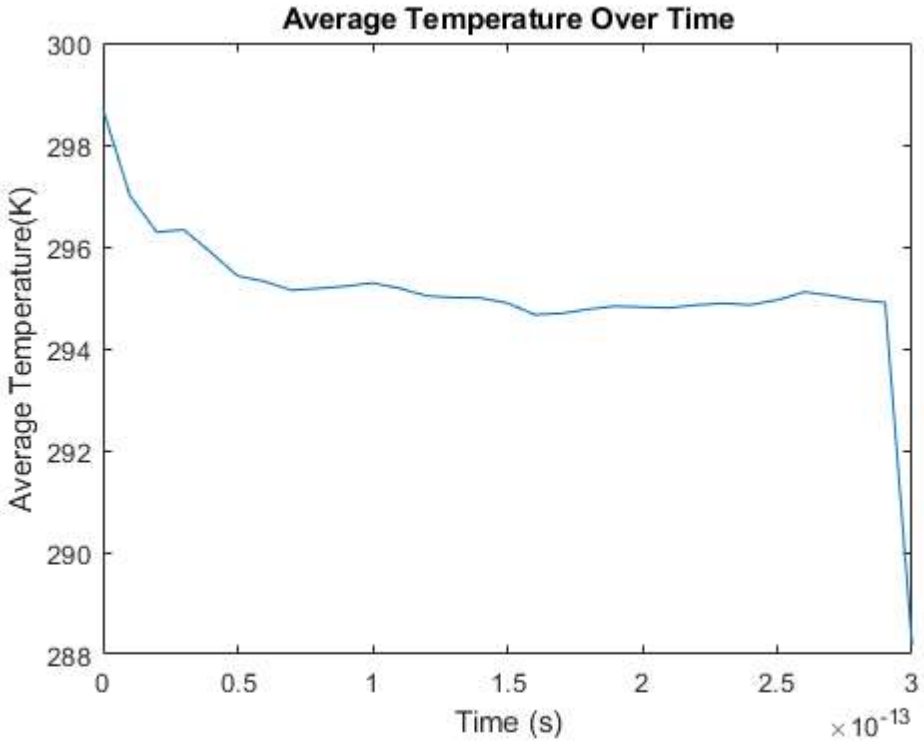
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
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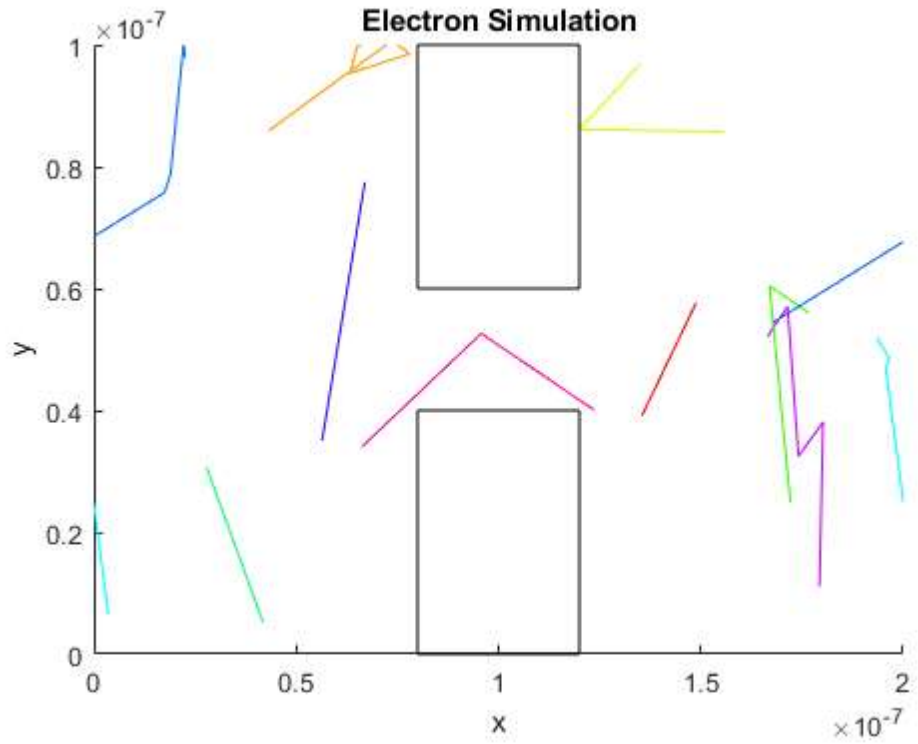
292
290
288
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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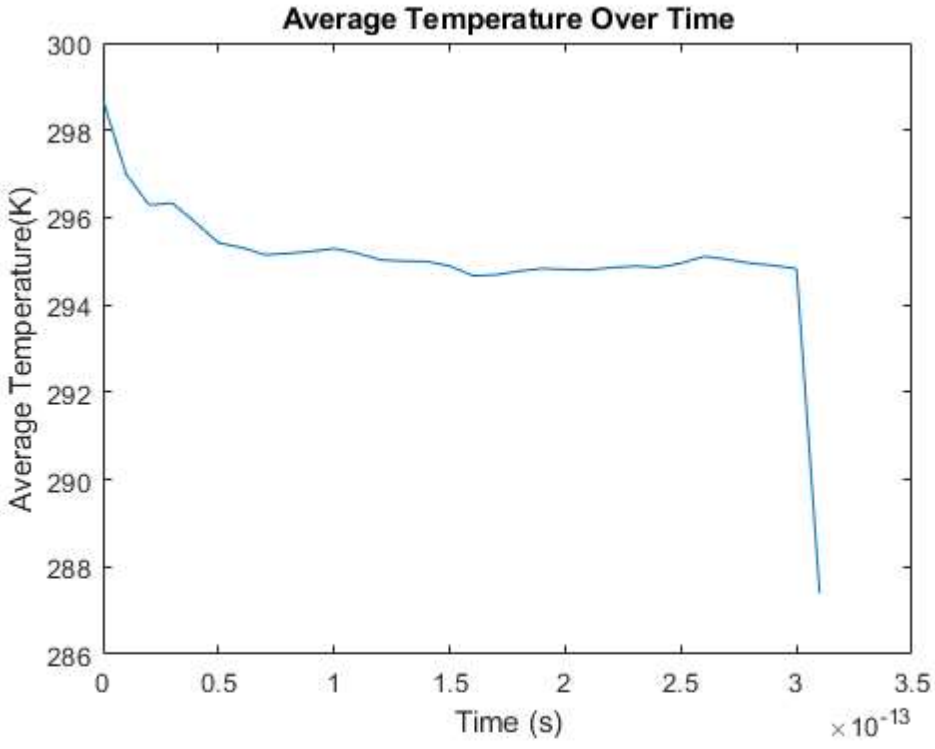
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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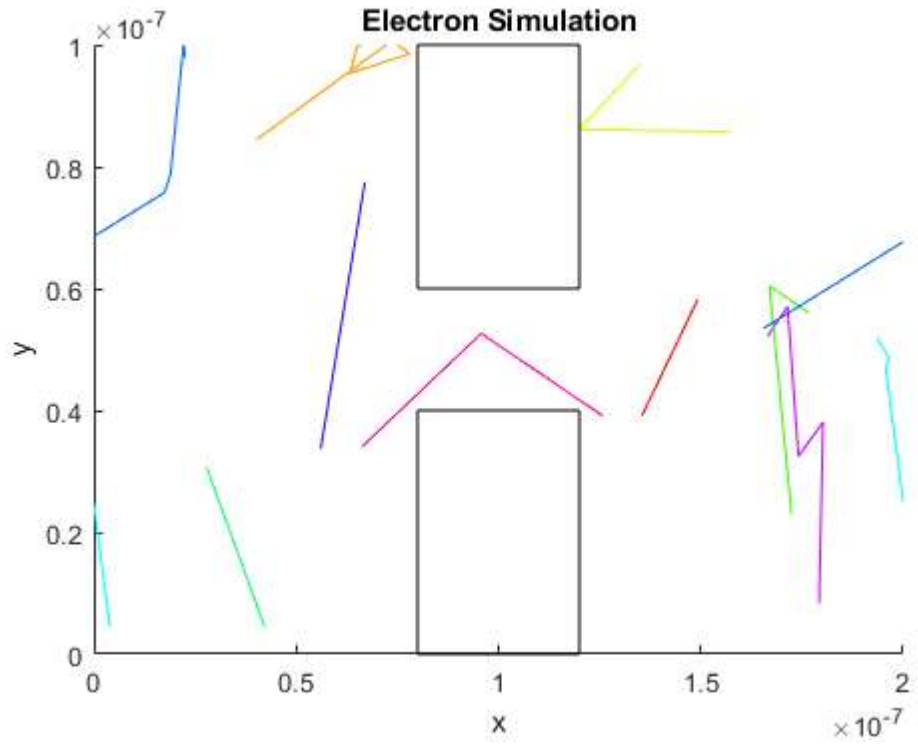
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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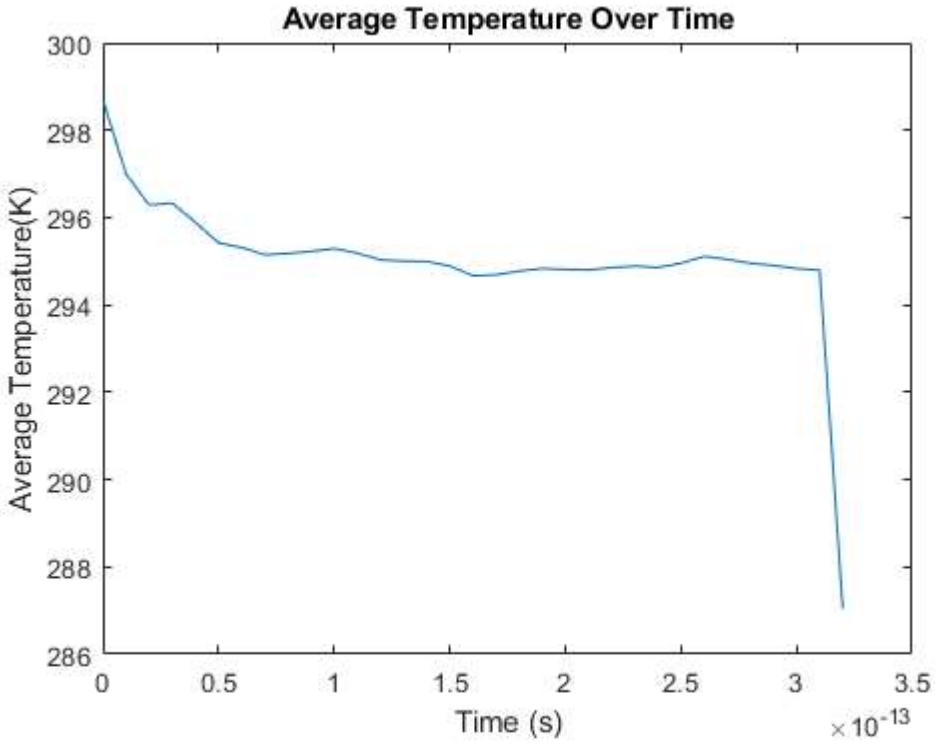
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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294
292
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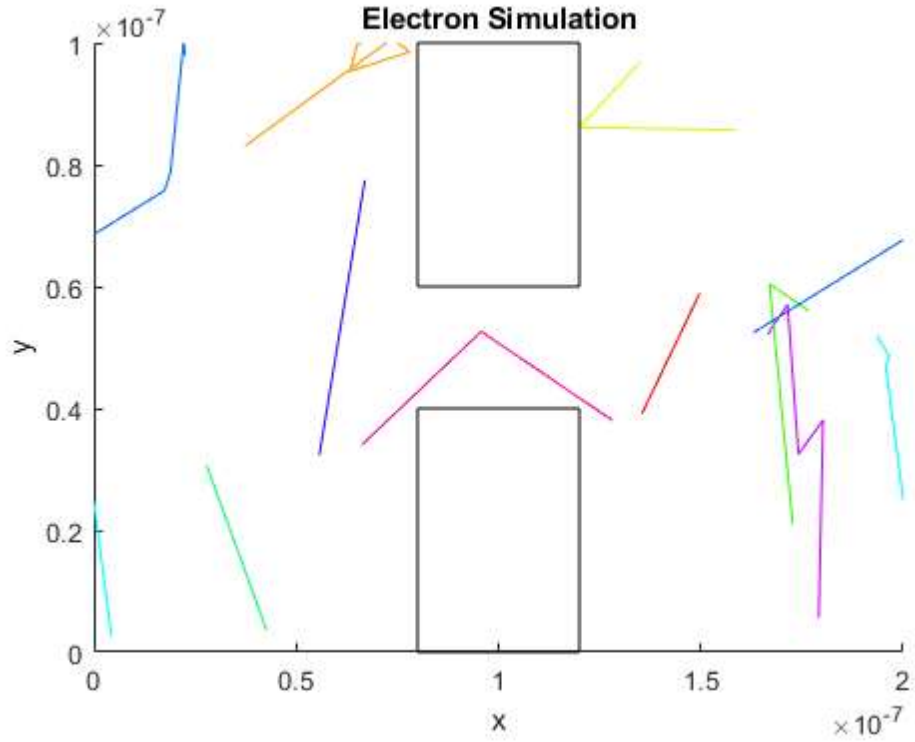
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
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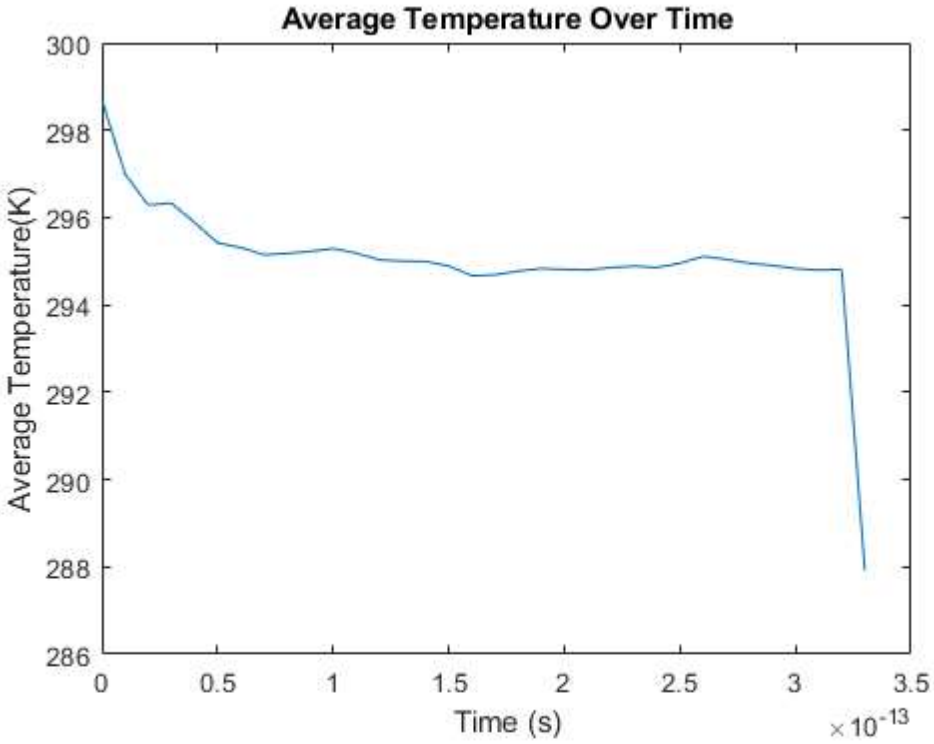
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
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294
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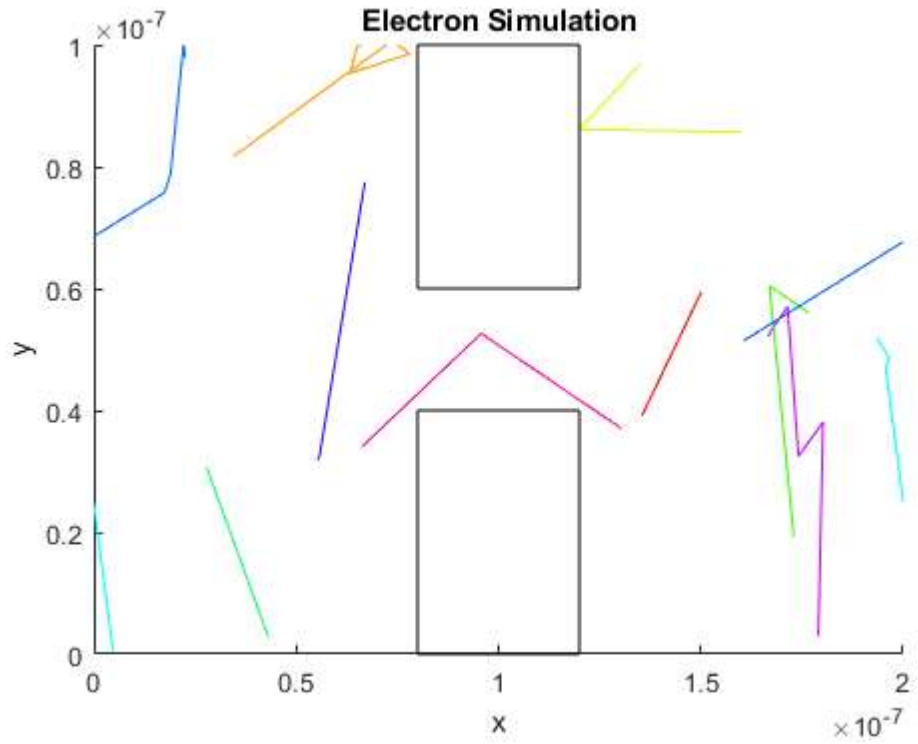
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
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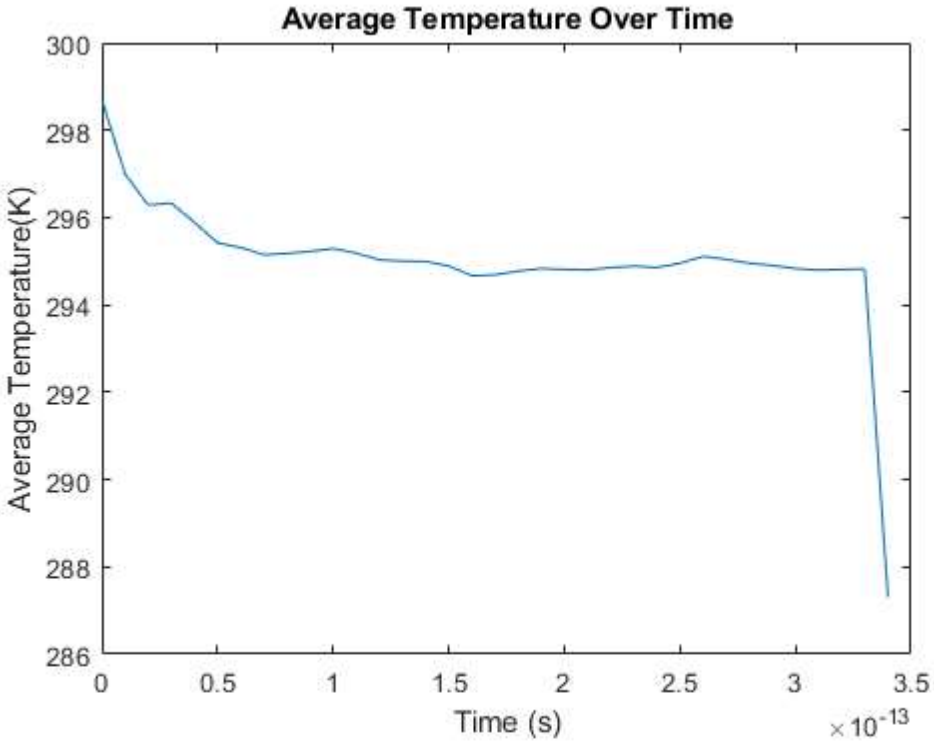
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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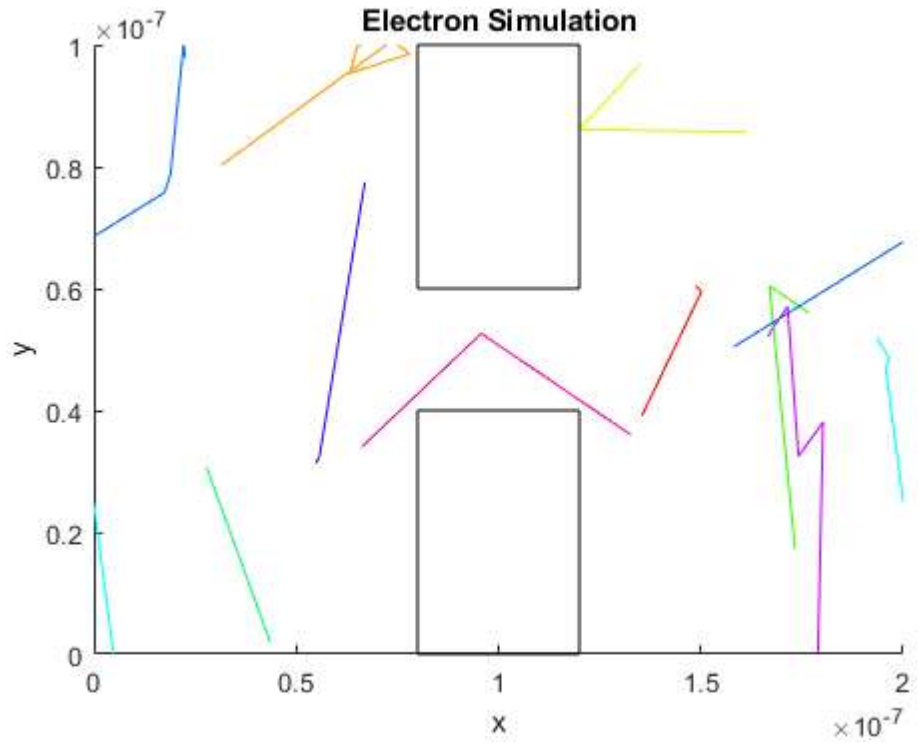
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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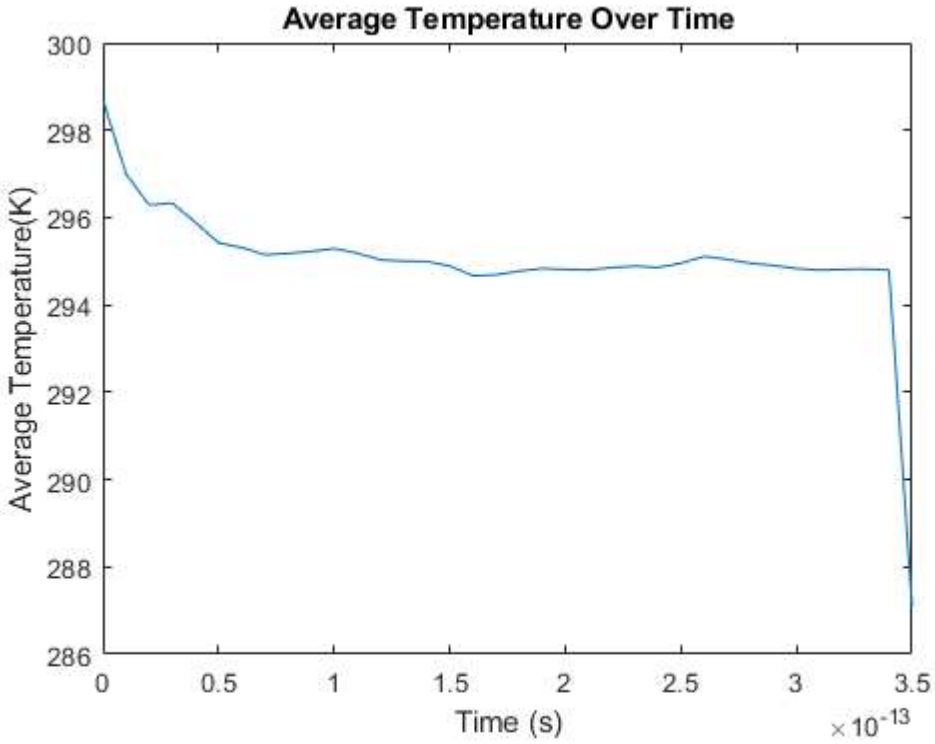
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
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292
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Average Temperature(K)
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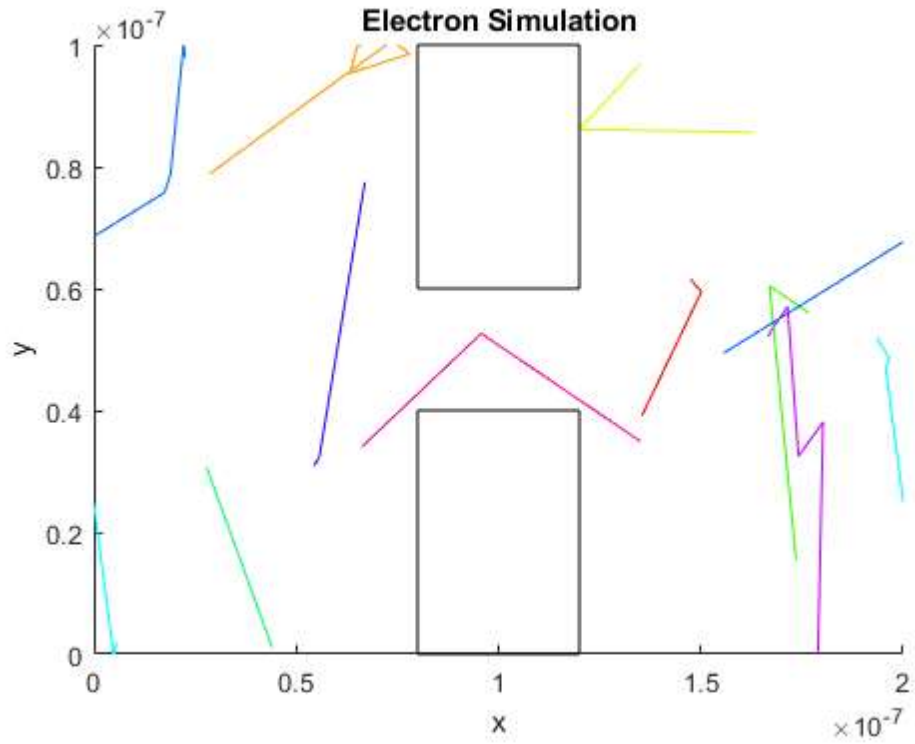
0.5
1
1.5
2
2.5
3
3.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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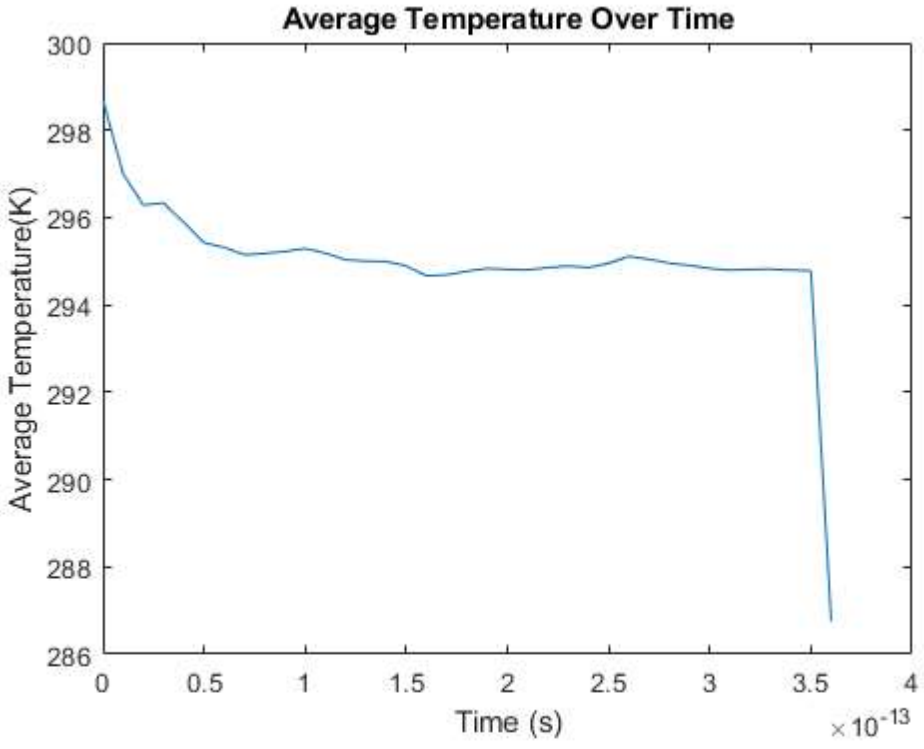
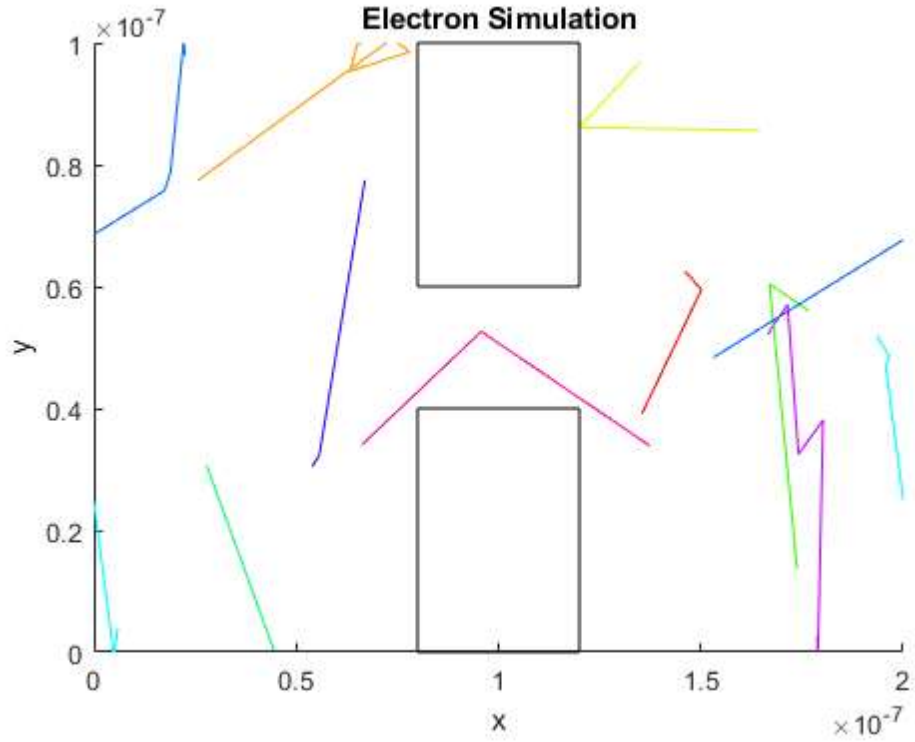
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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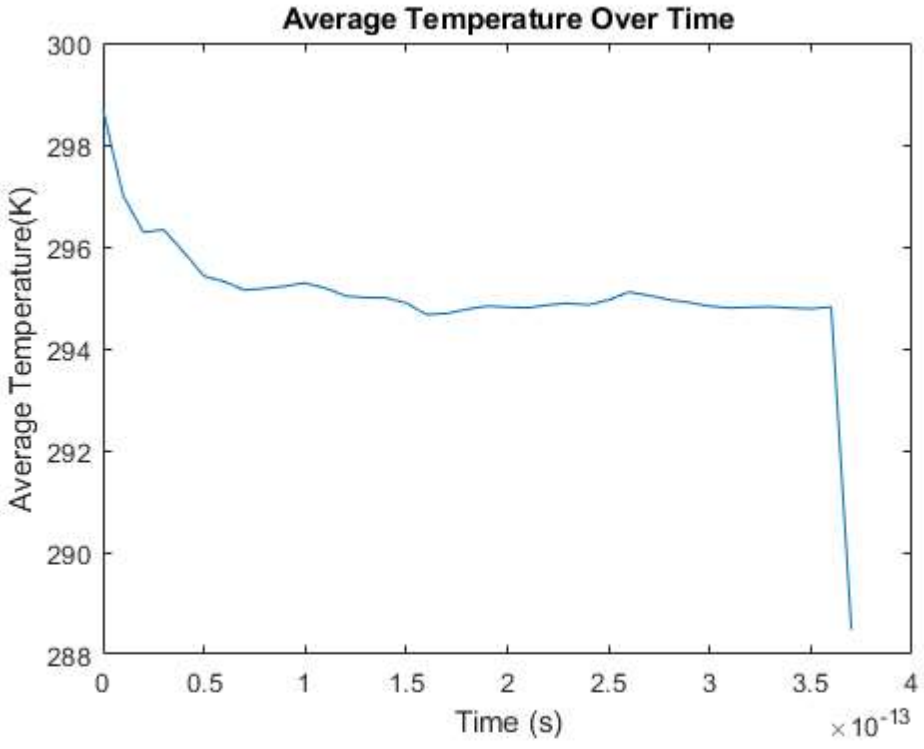
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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288
Average Temperature(K)
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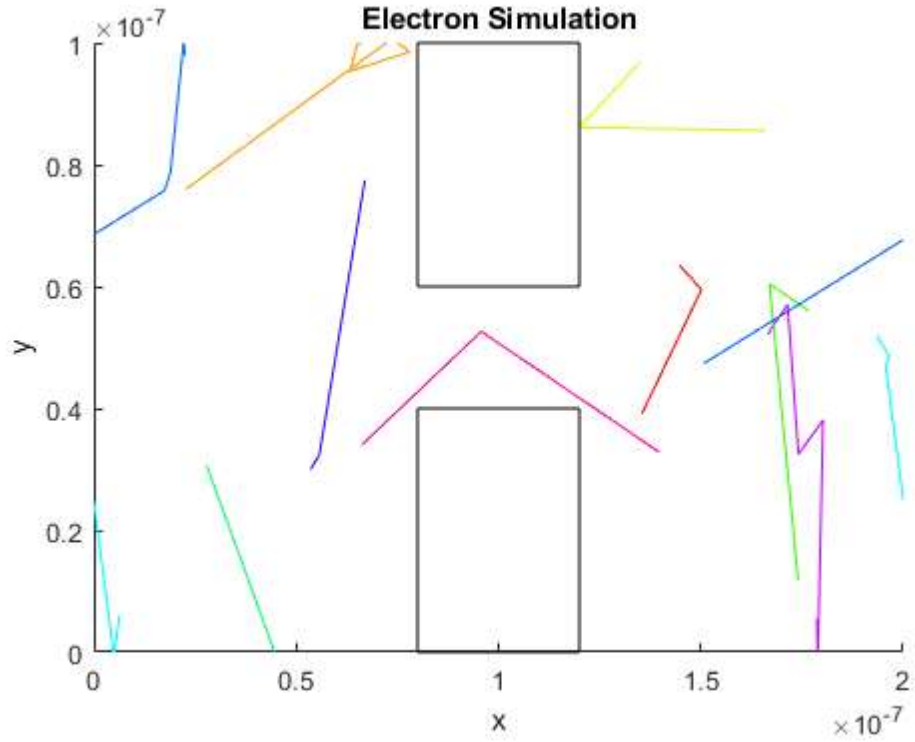
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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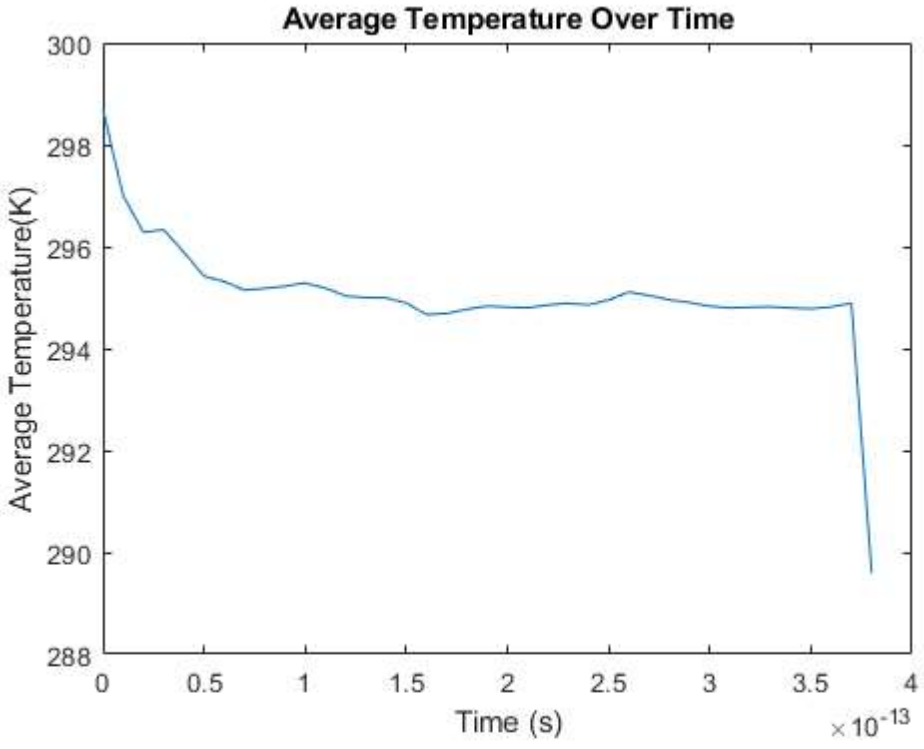
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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288
Average Temperature(K)
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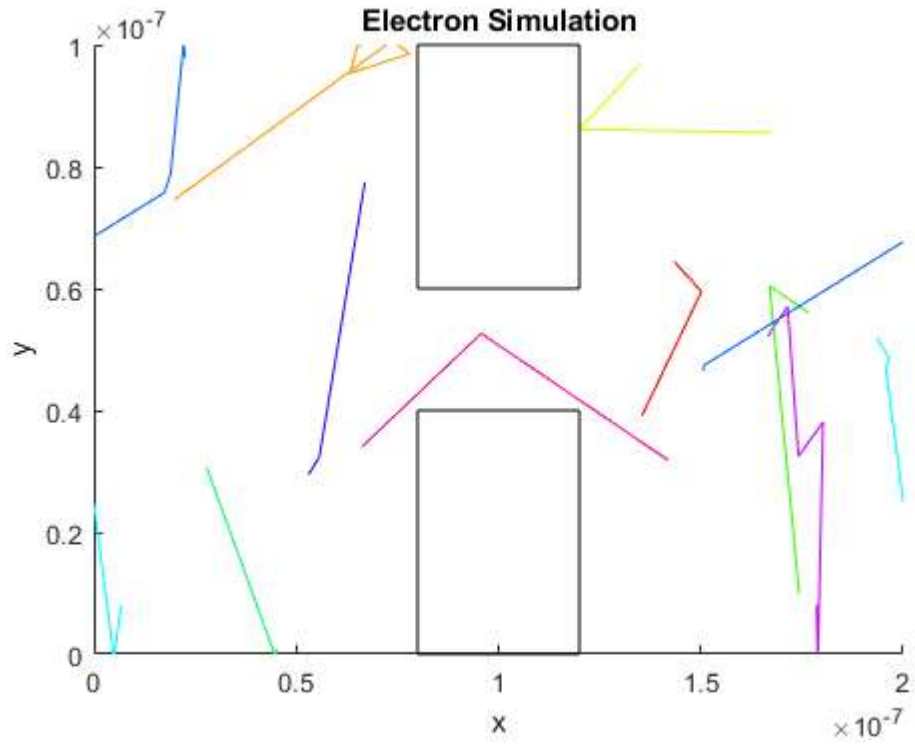
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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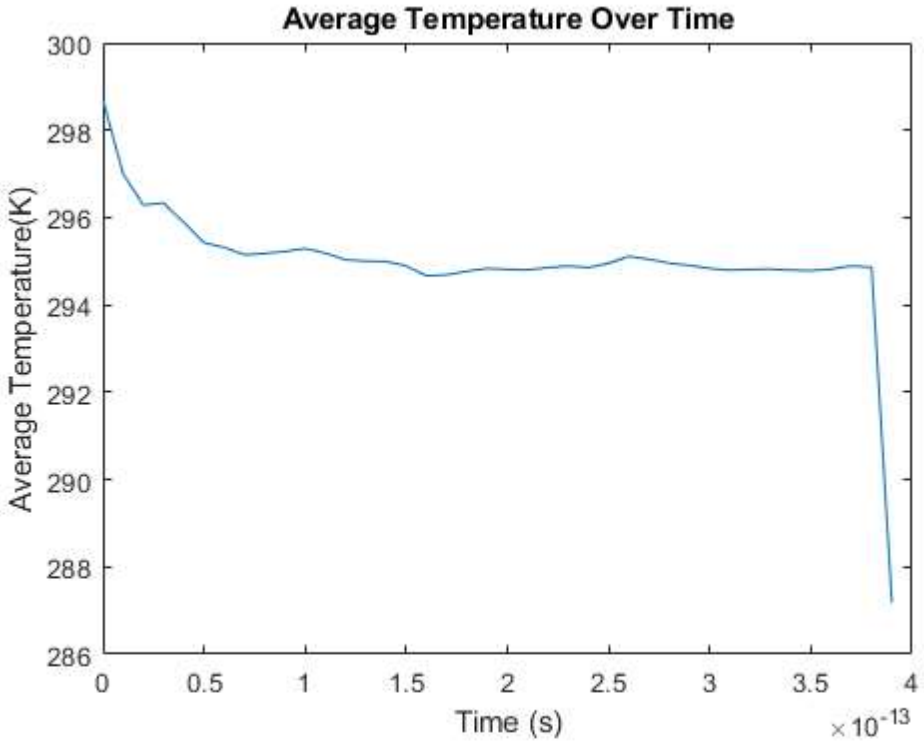
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
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Average Temperature(K)
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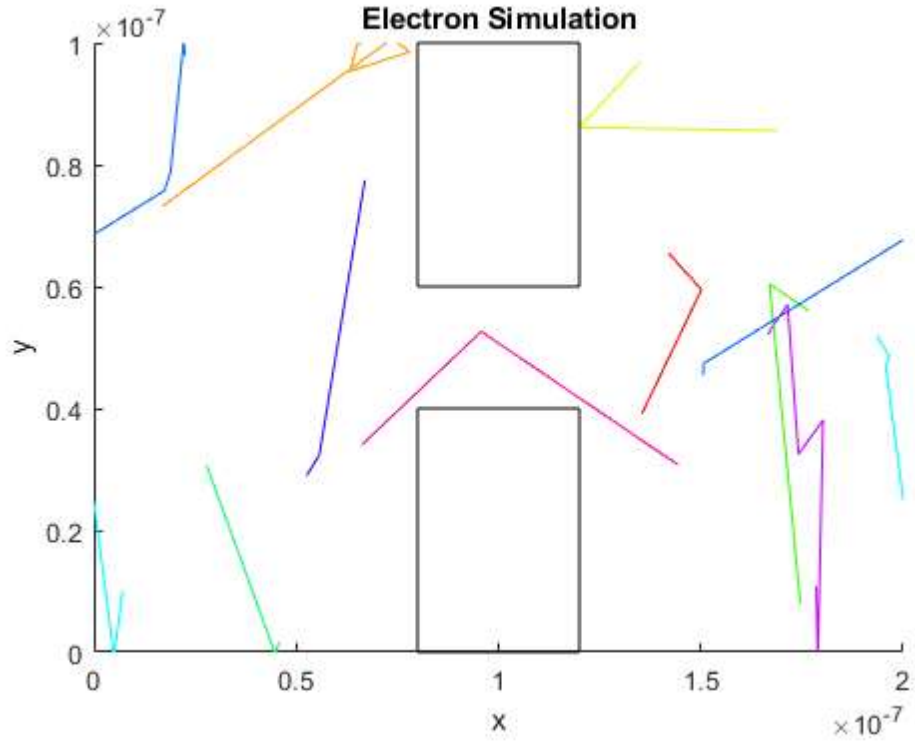
0.5
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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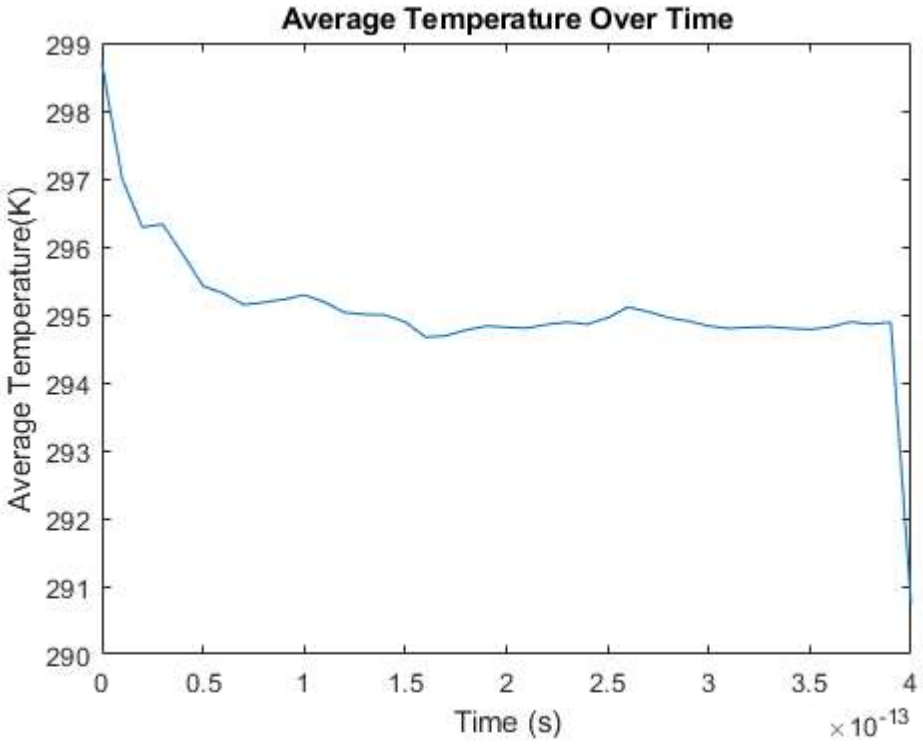
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
299
298
297
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295
294
293
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Average Temperature(K)
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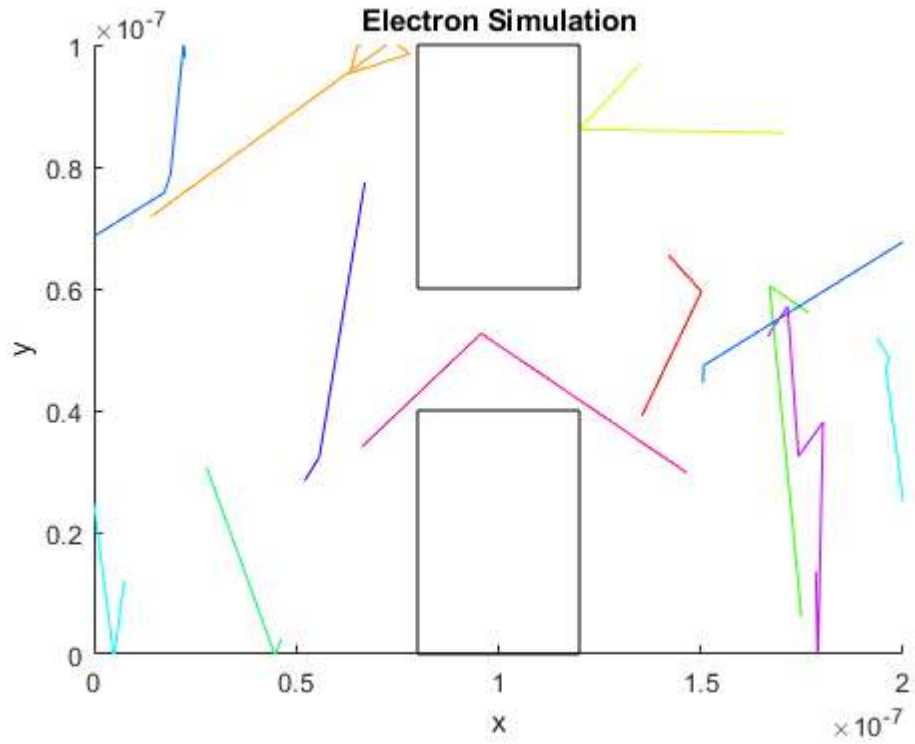
1
1.5
2
2.5
3
3.5
4
Time (s)
×10^-13


Electron Simulation
×10^-7
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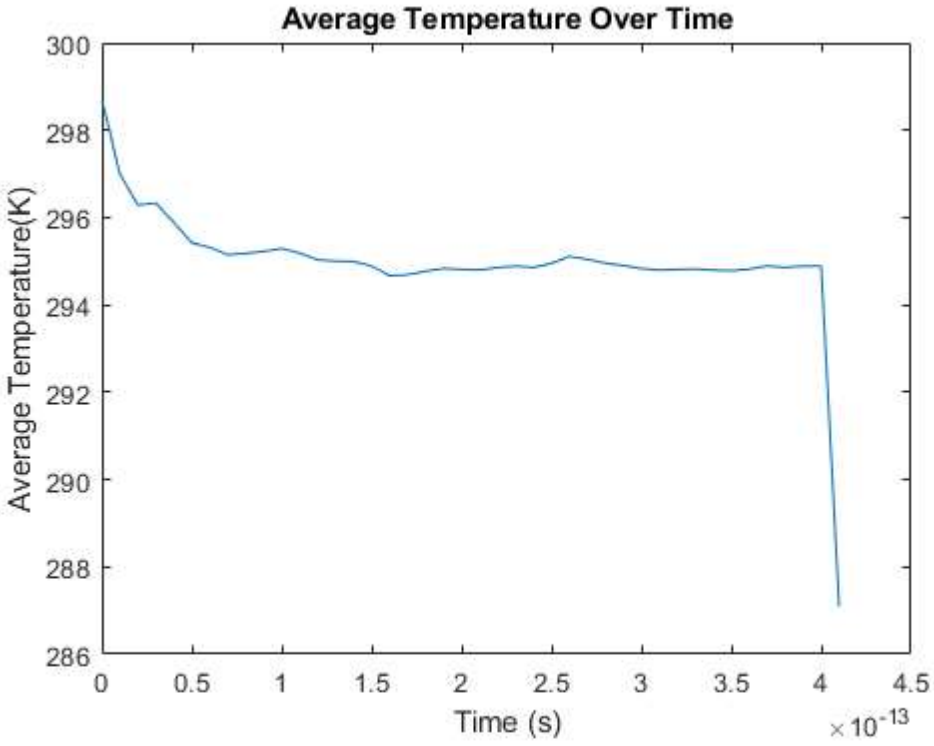
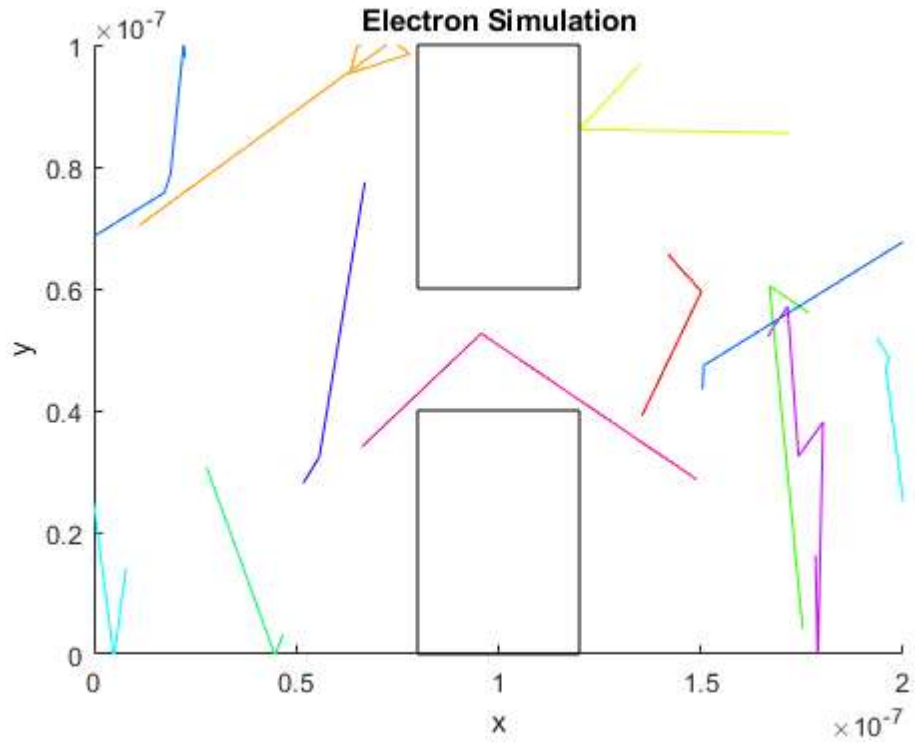
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
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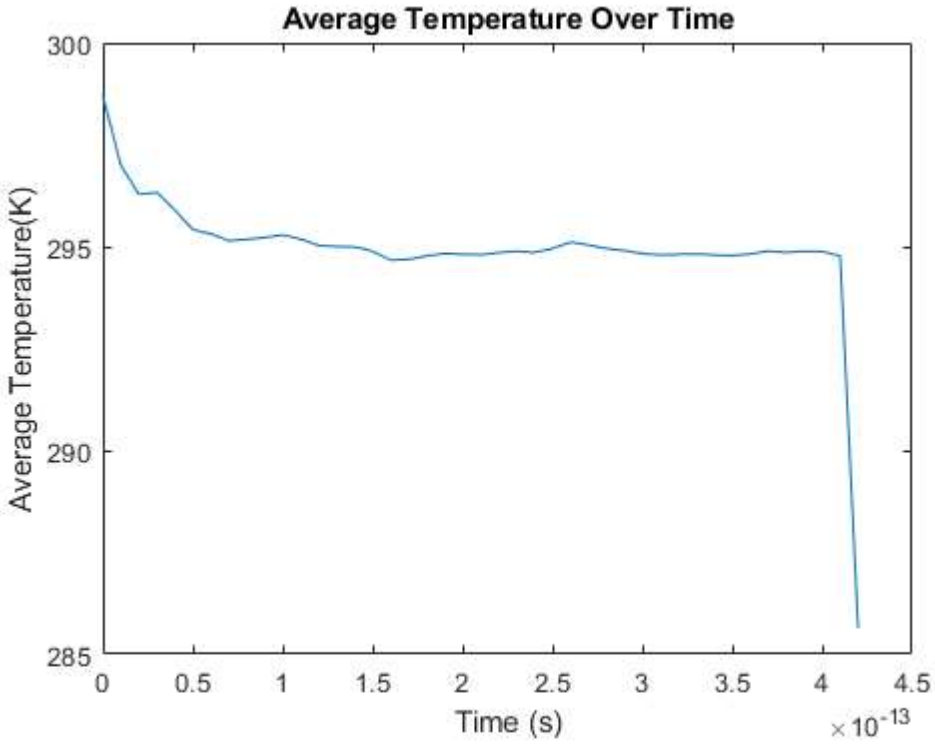
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
Average Temperature(K)
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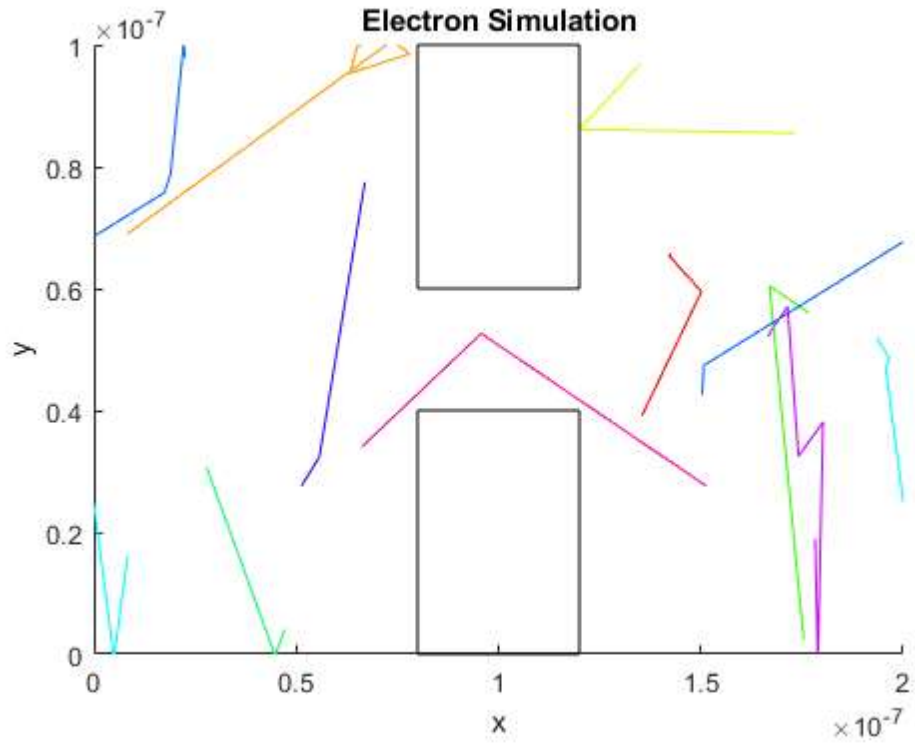
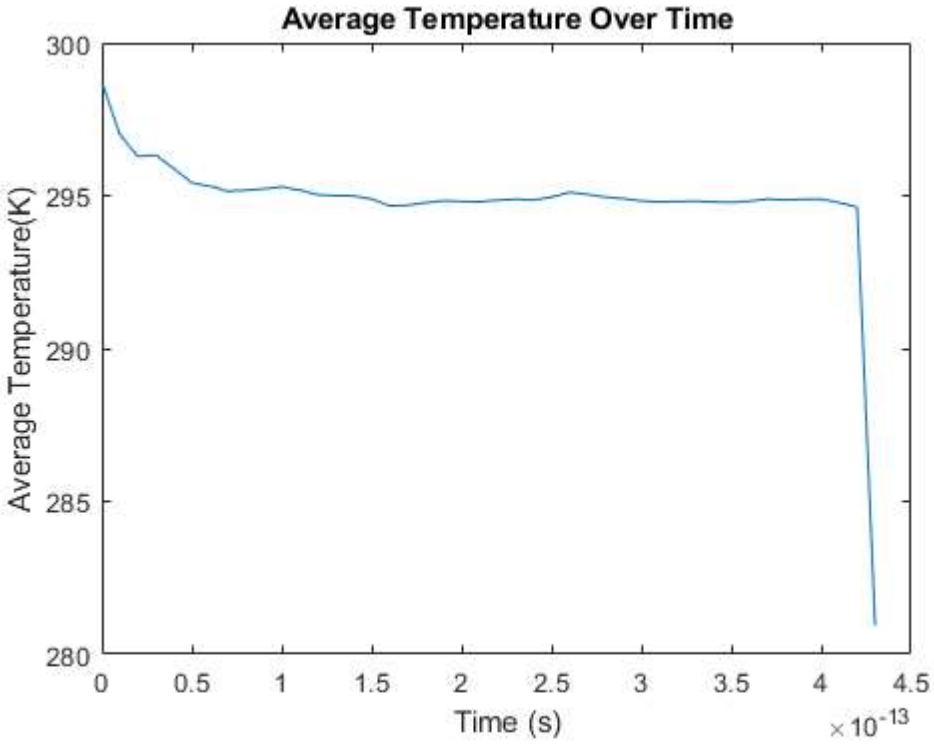
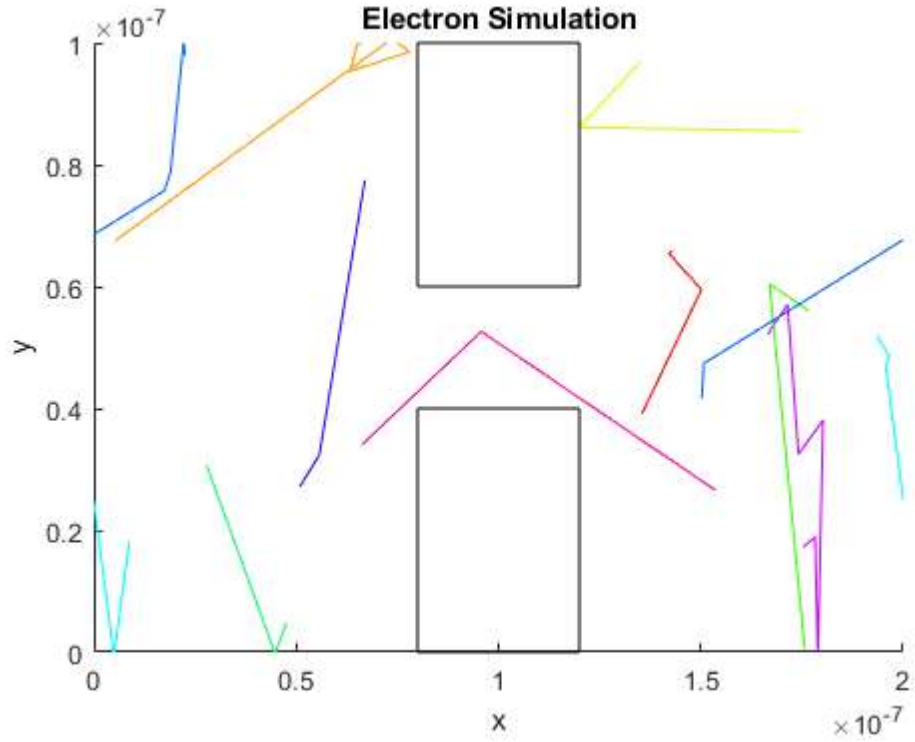
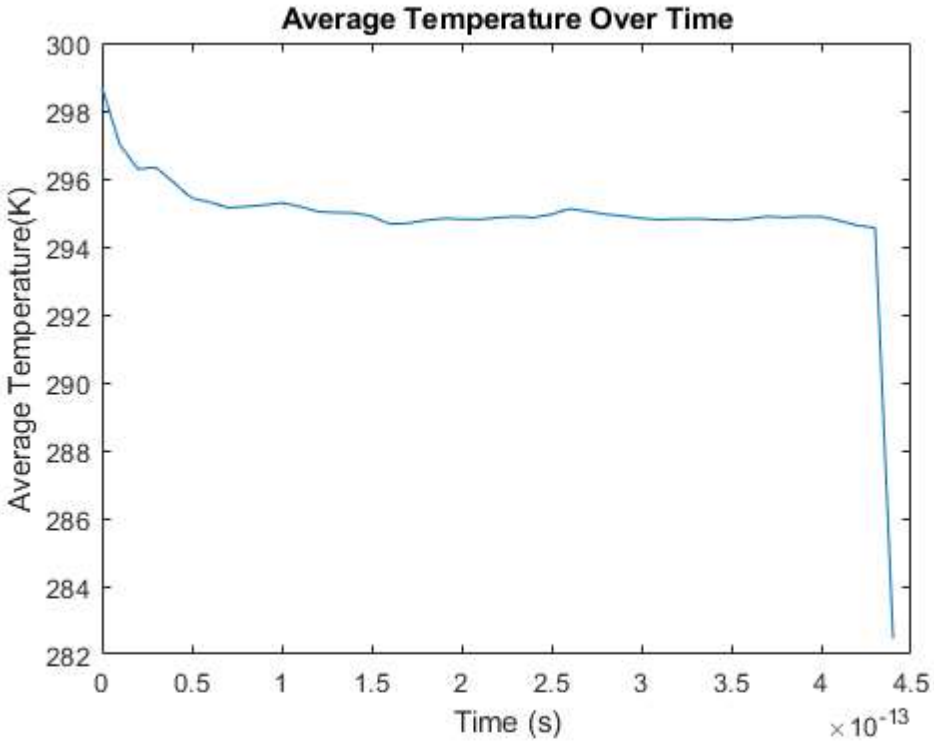
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
298
296
294
292
290
288
286
284
282
Average Temperature(K)
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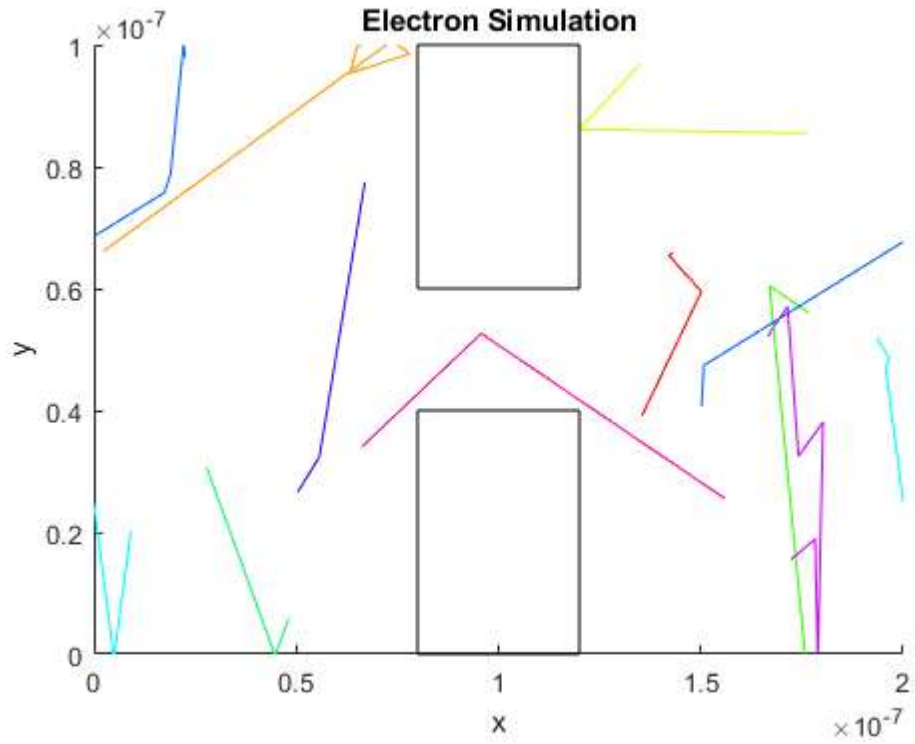
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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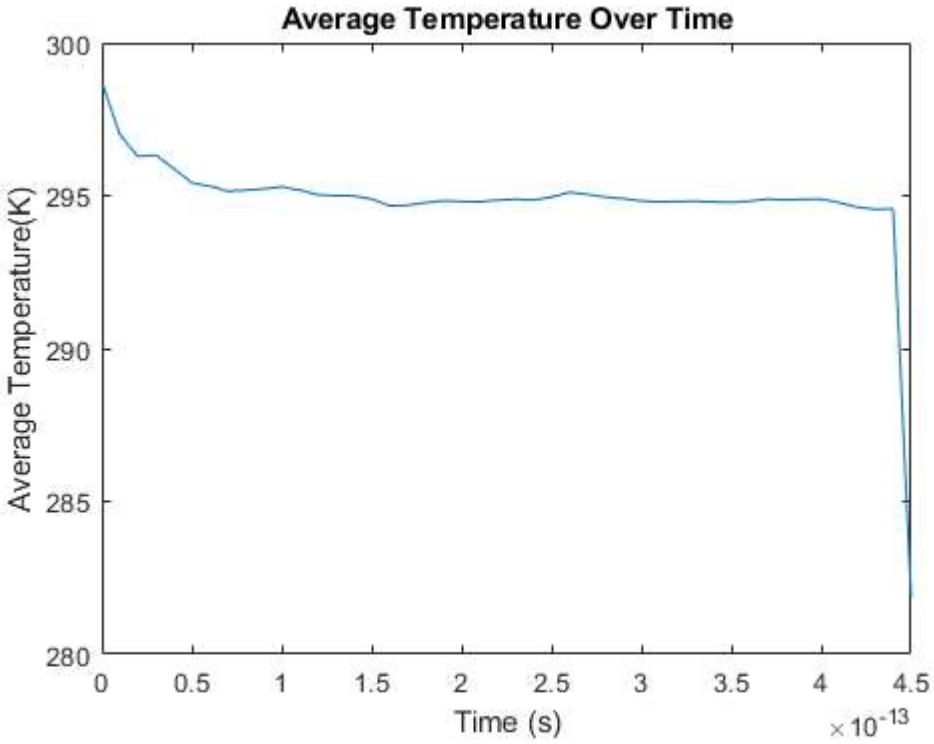
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
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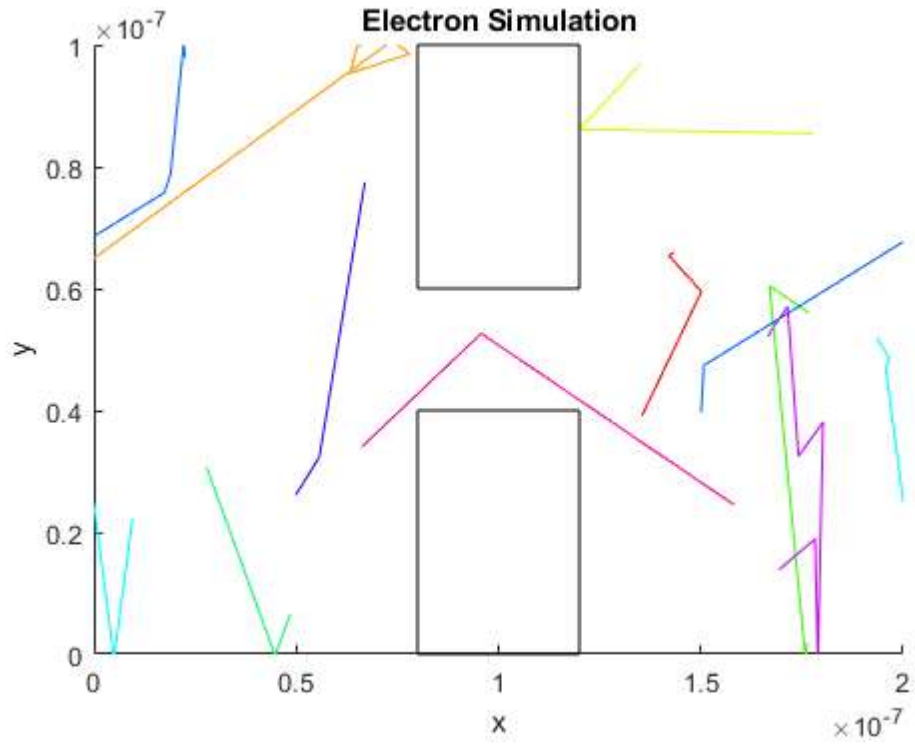
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)
×10^-13


Electron Simulation
×10^-7
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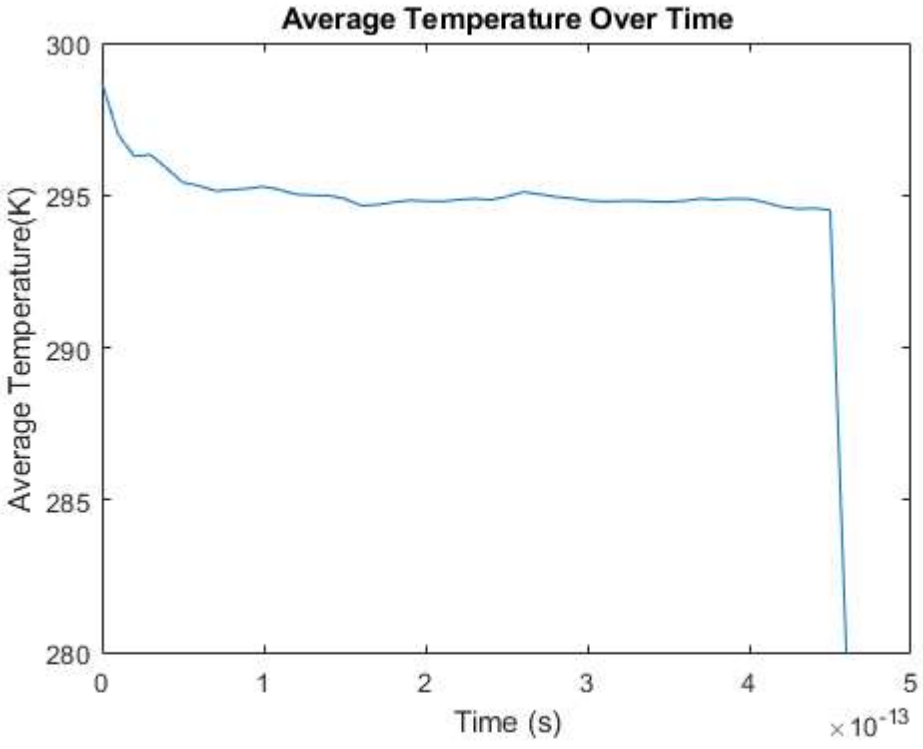
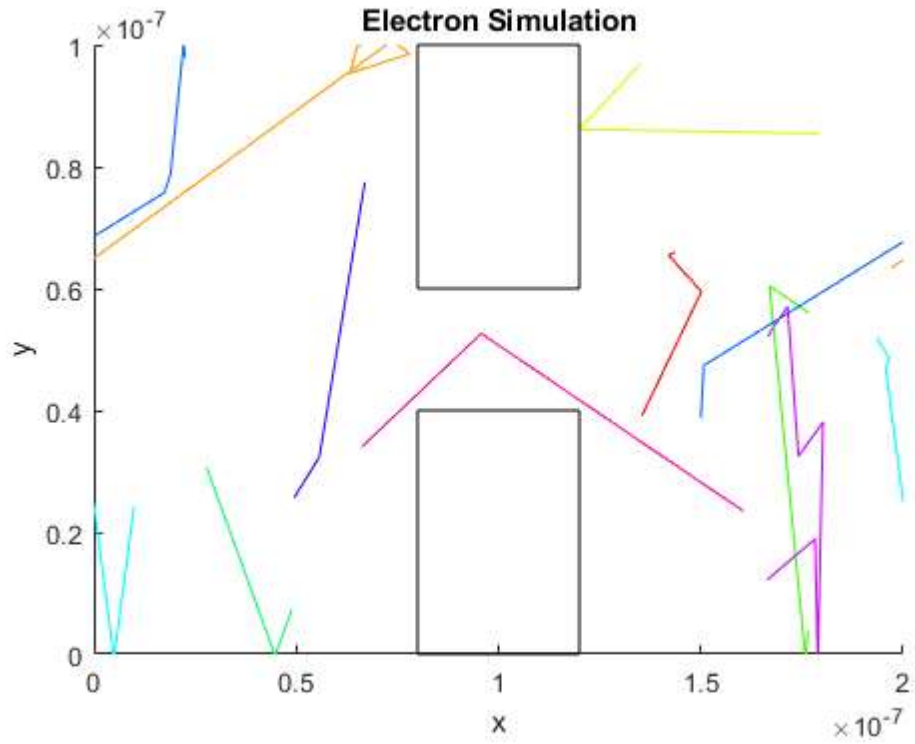
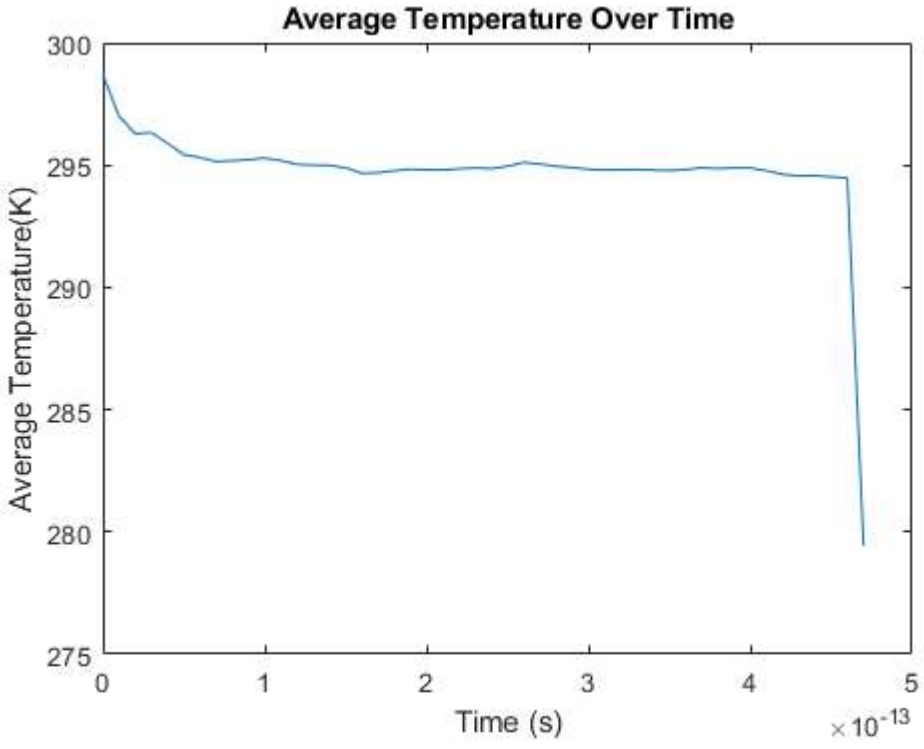
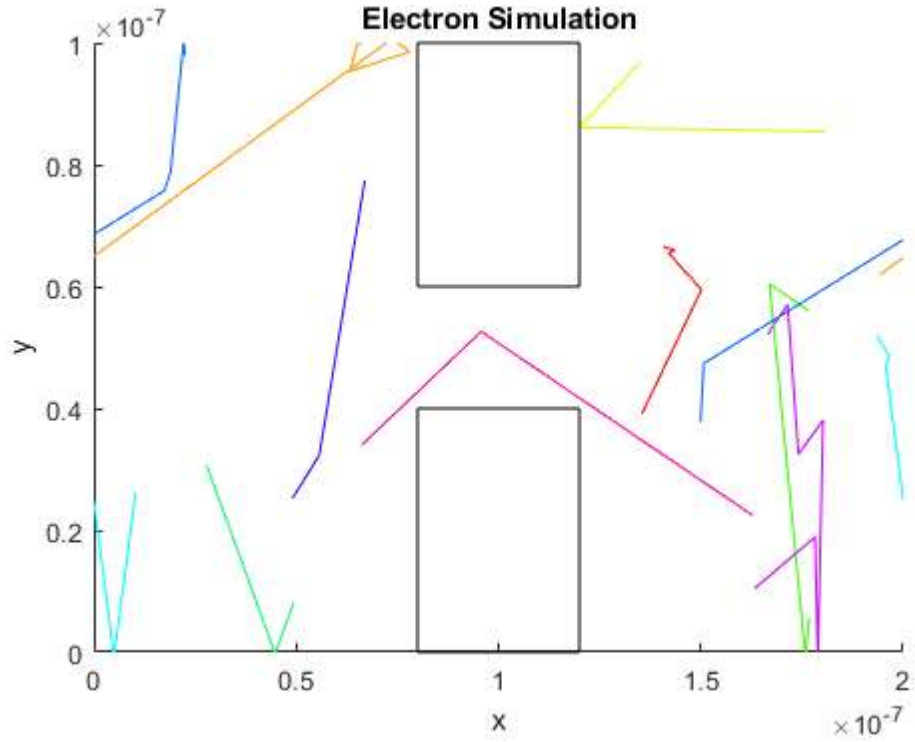
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
Time (s)
×10^-13


Electron Simulation
×10^-7
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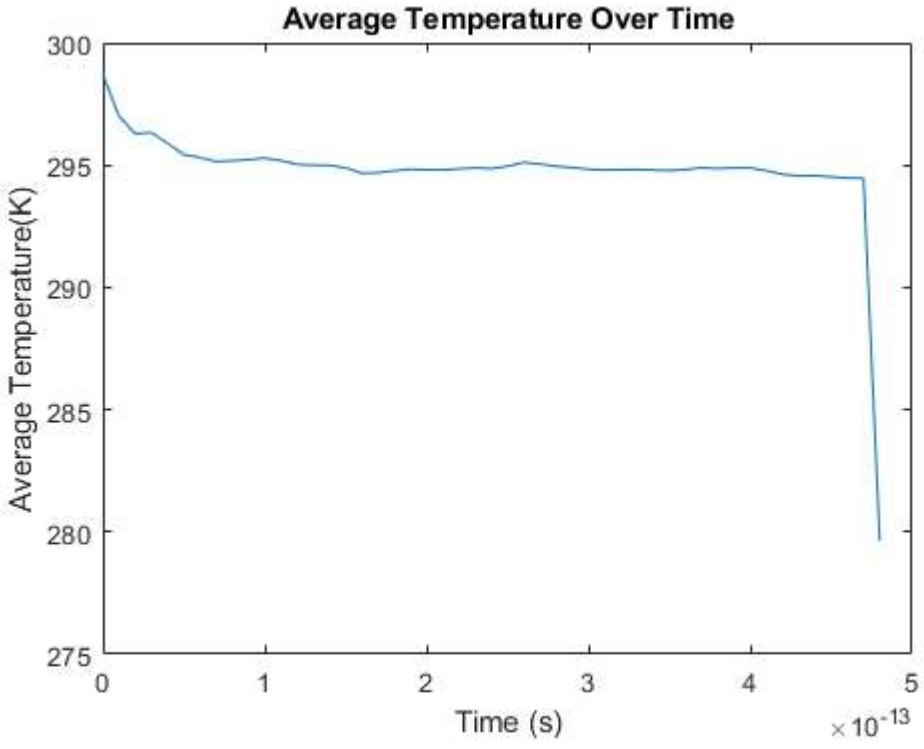
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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1
2
3
4
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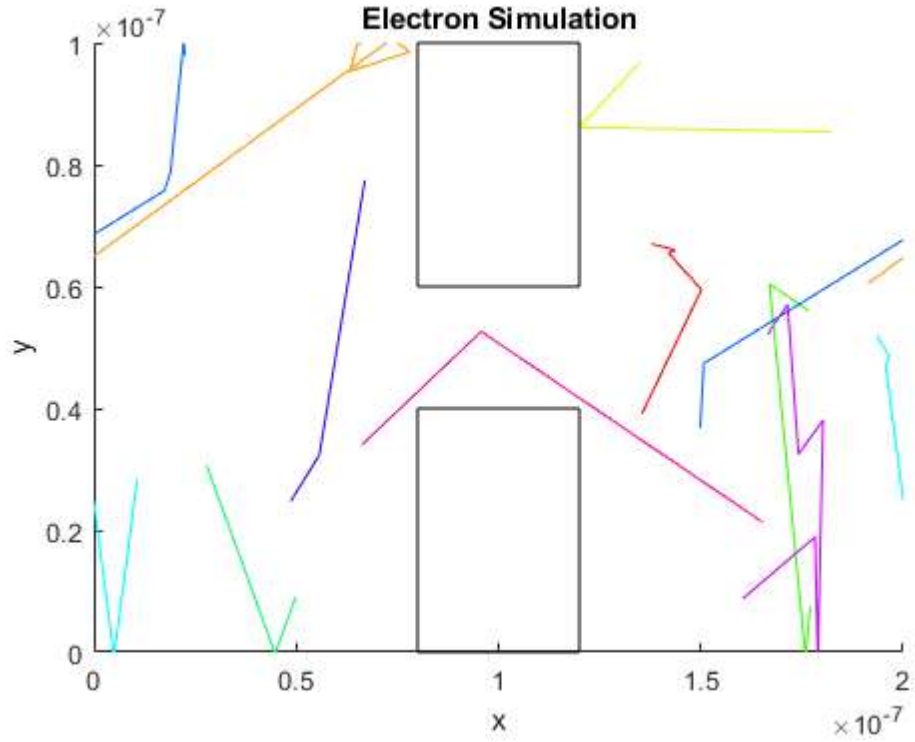
Time (s)
×10^-13


Electron Simulation
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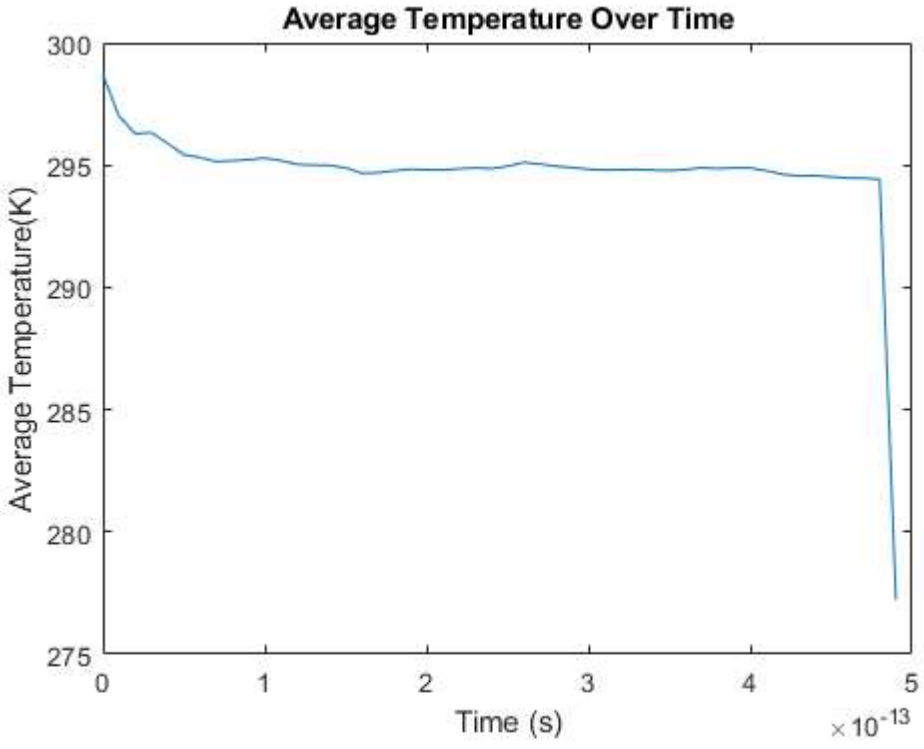
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7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Average Temperature(K)
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1
2
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4
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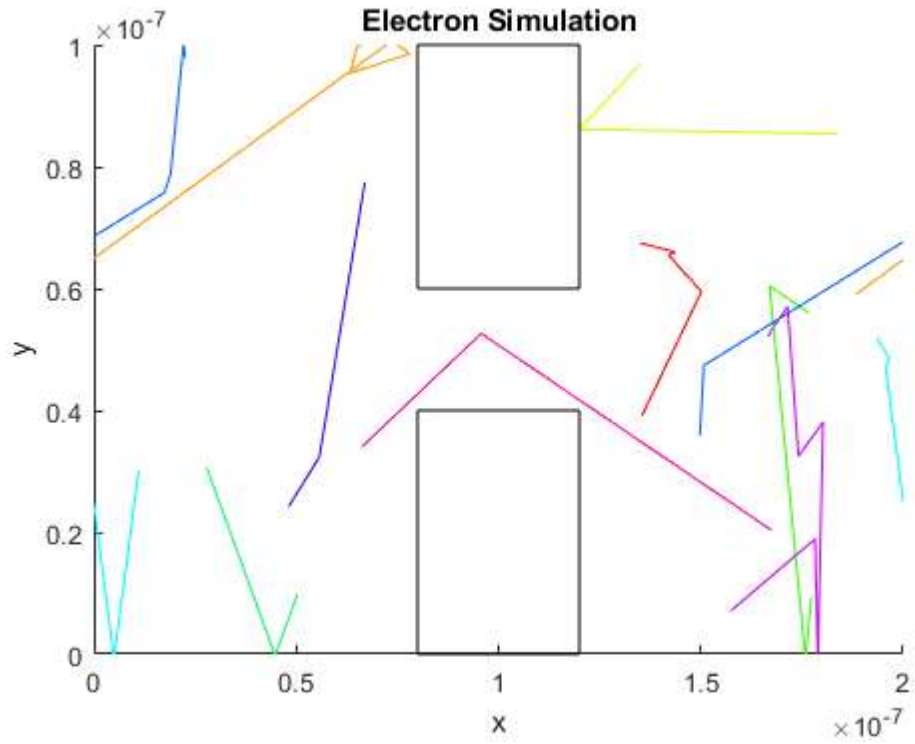
Time (s)
×10^-13


Electron Simulation
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0.2
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y
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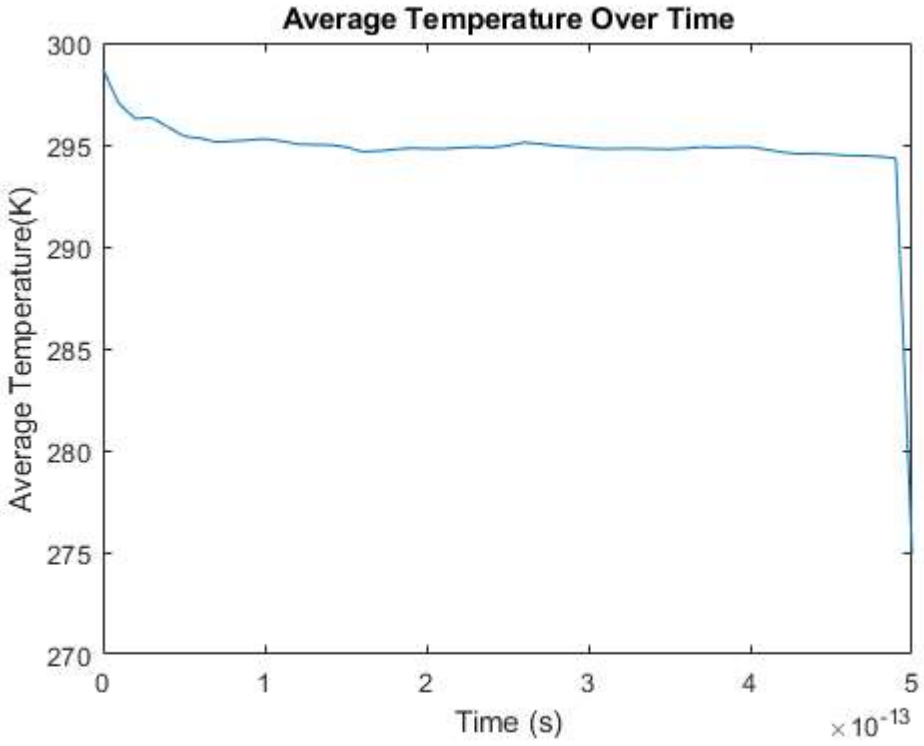
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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1
2
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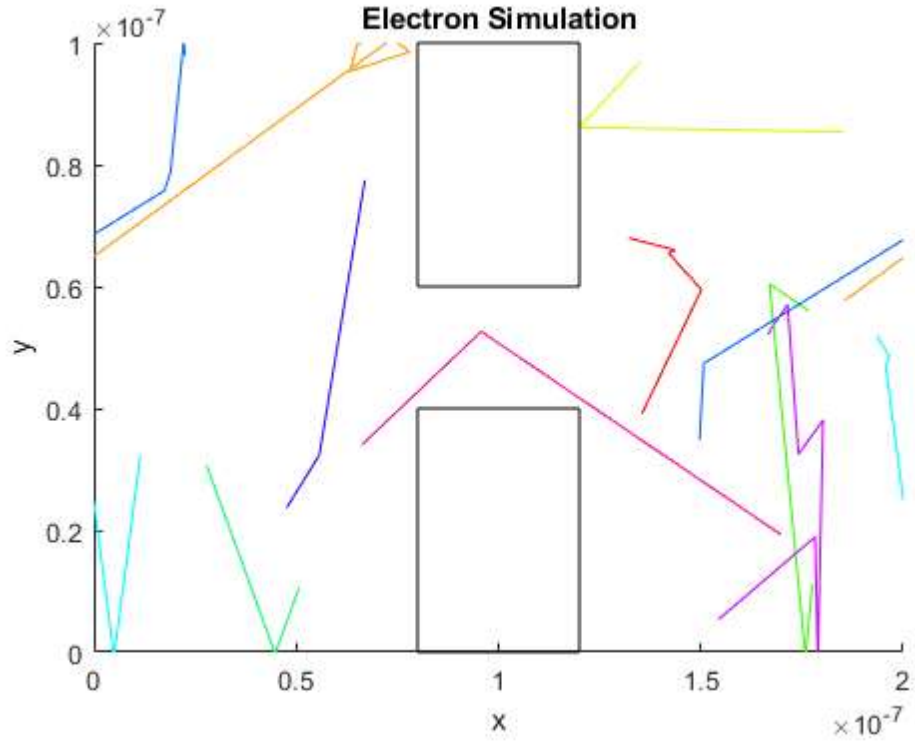
Time (s)
×10^-13


Electron Simulation
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y
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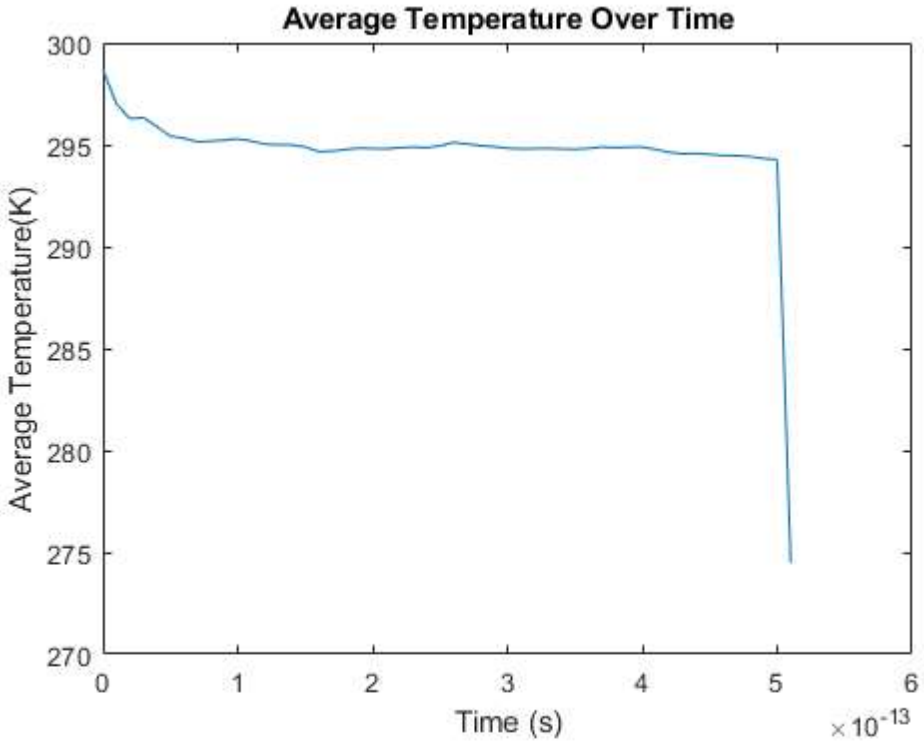
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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1
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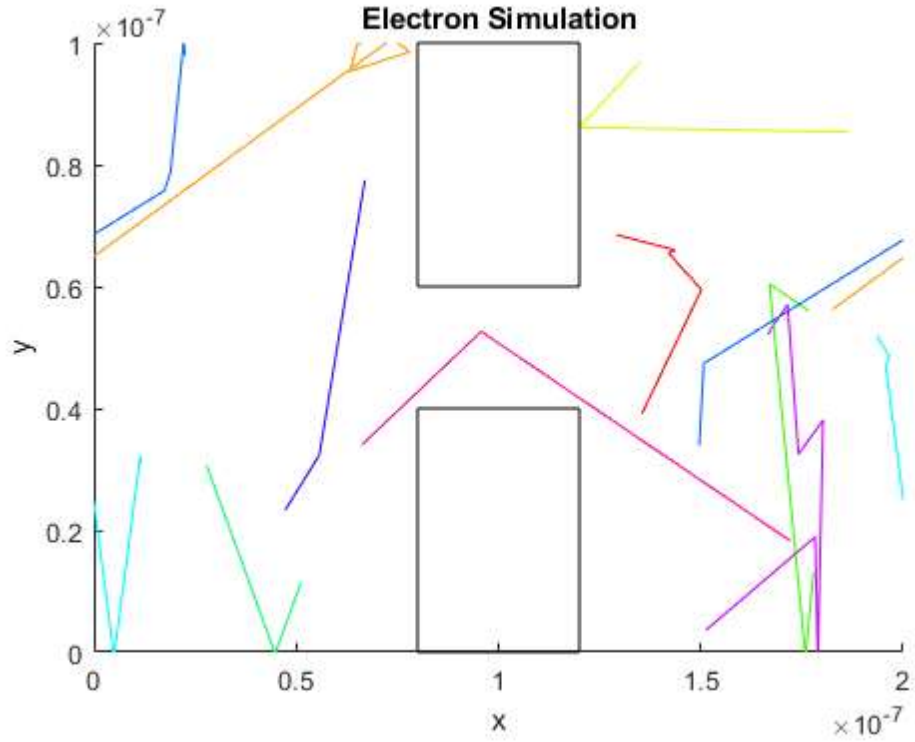
Time (s)
×10^-13


Electron Simulation
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0.2
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y
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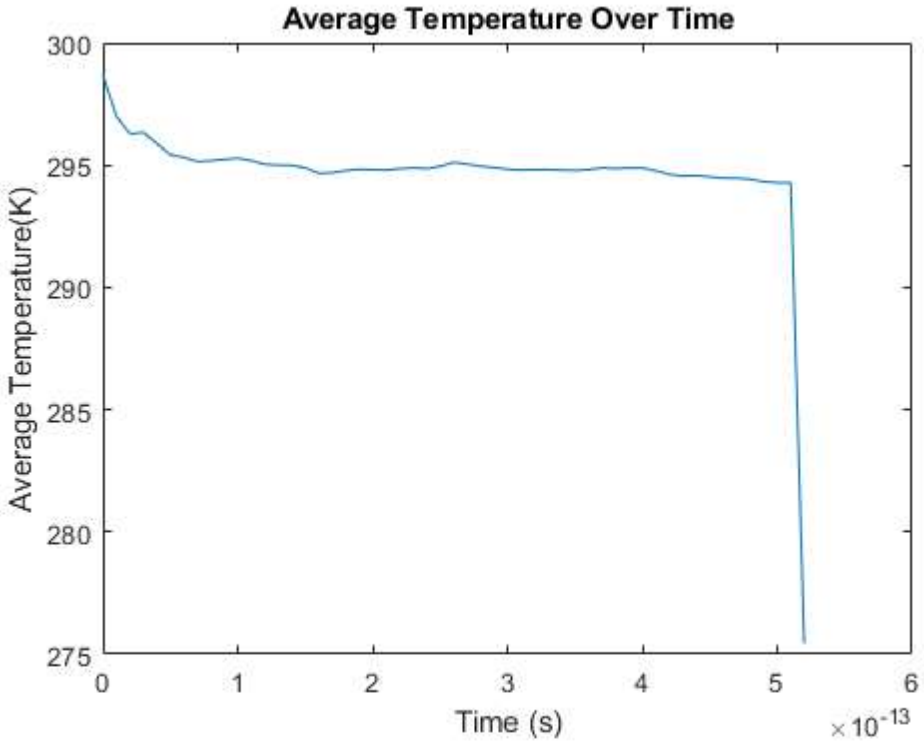
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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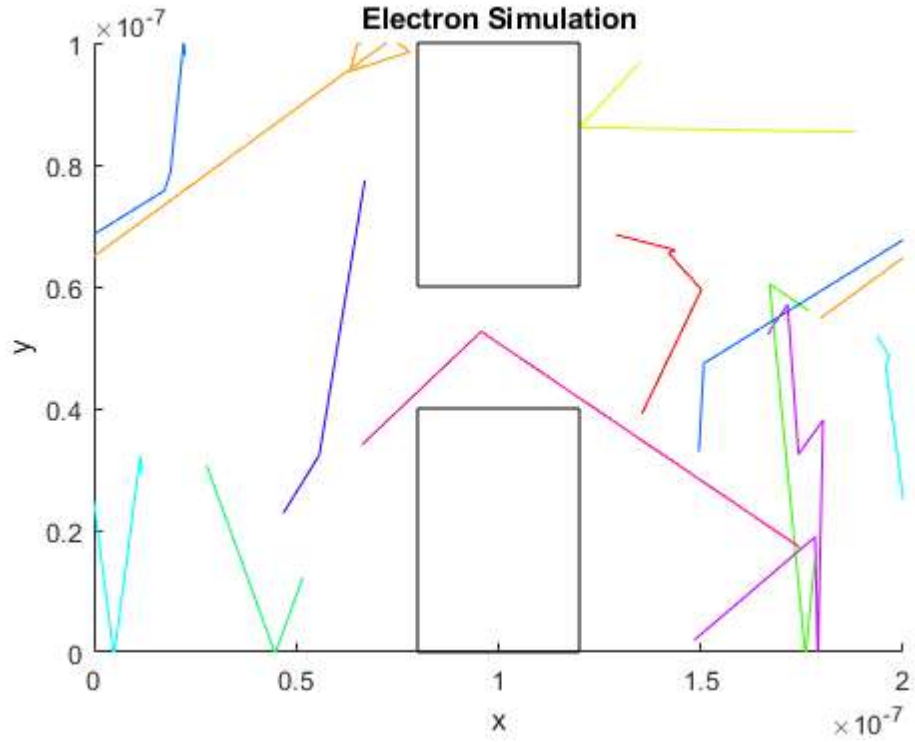
Time (s)
×10^-13


Electron Simulation
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0.2
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y
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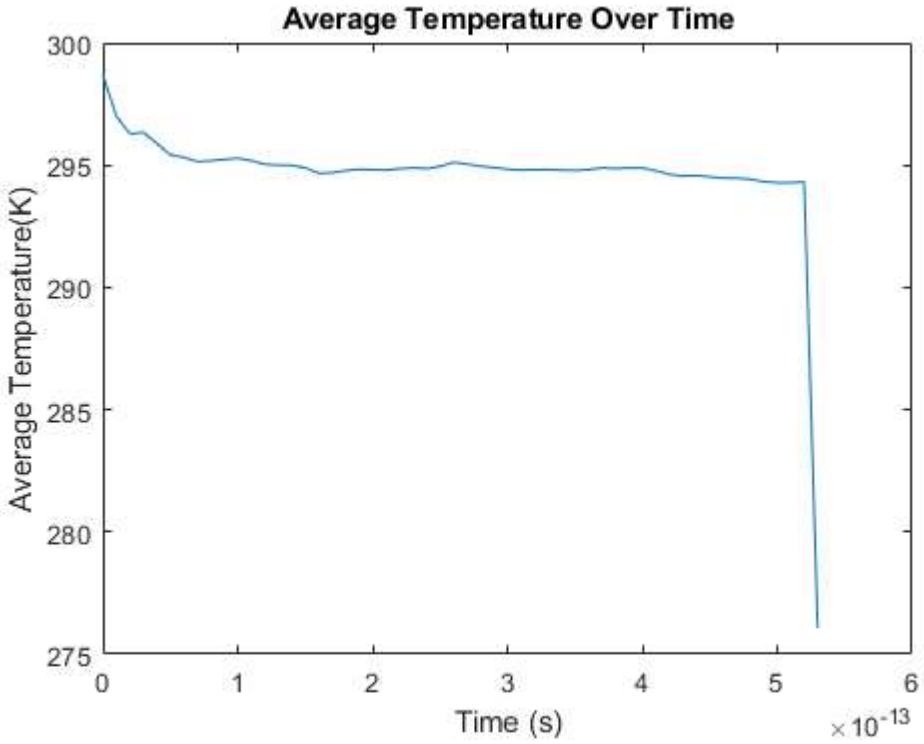
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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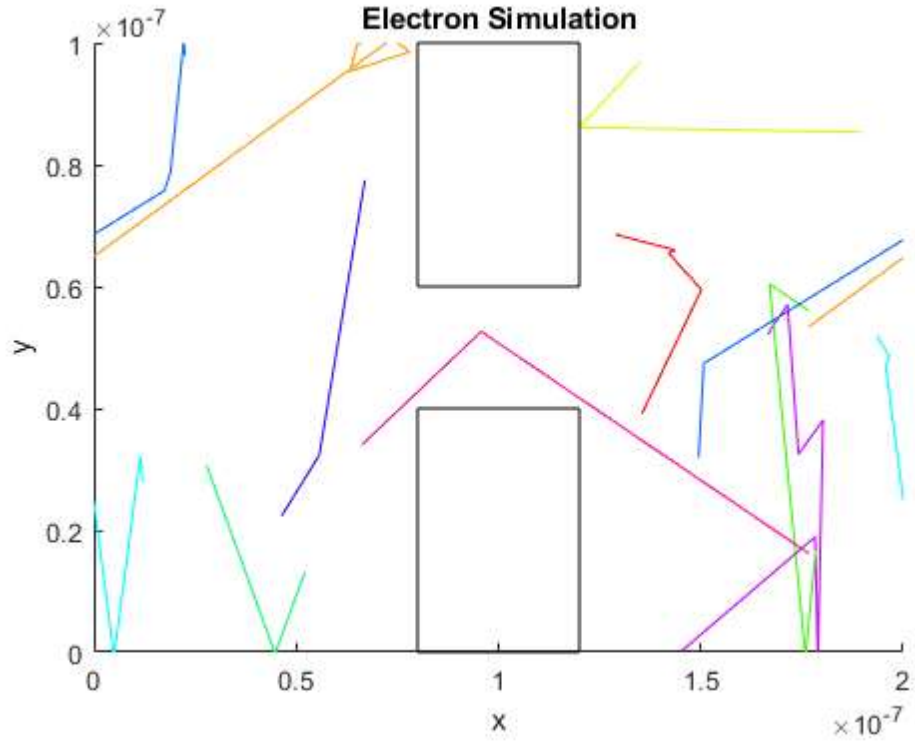
Time (s)
×10^-13


Electron Simulation
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y
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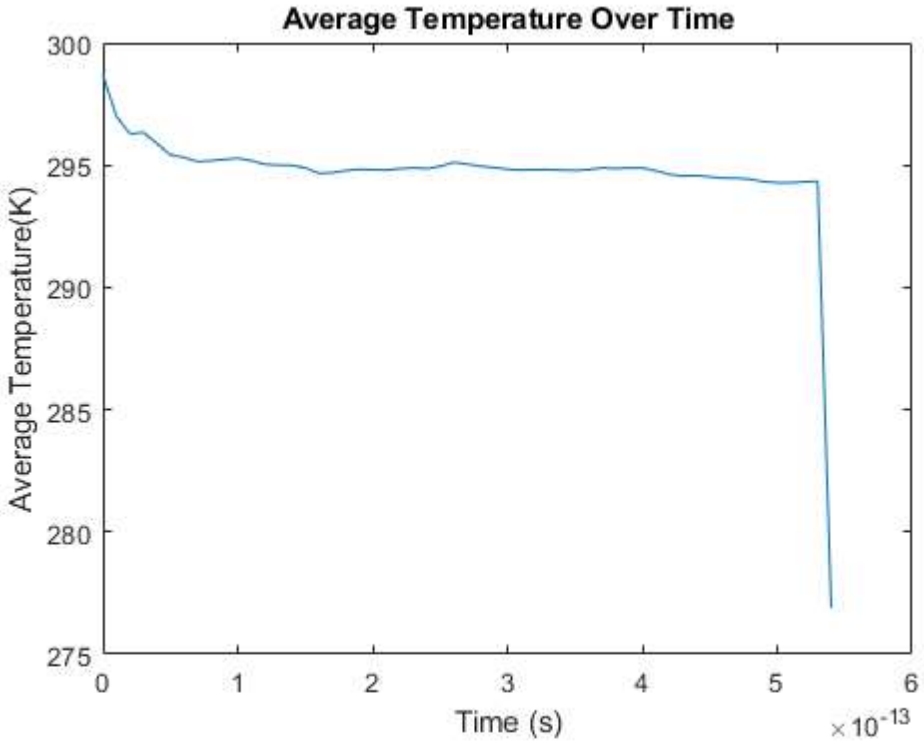
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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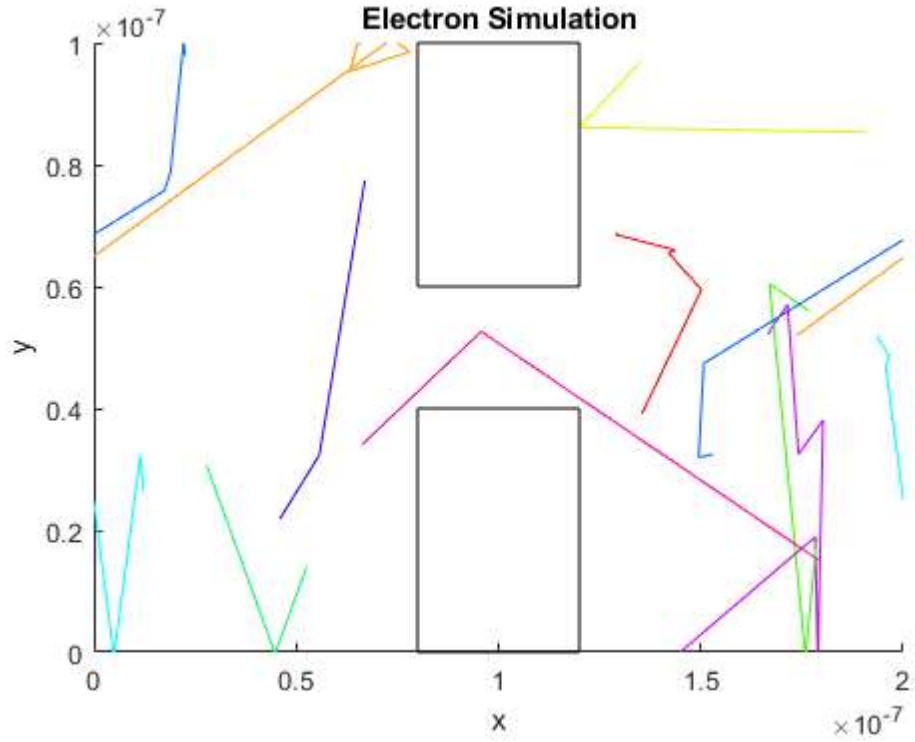
Time (s)
×10^-13


Electron Simulation
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y
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1
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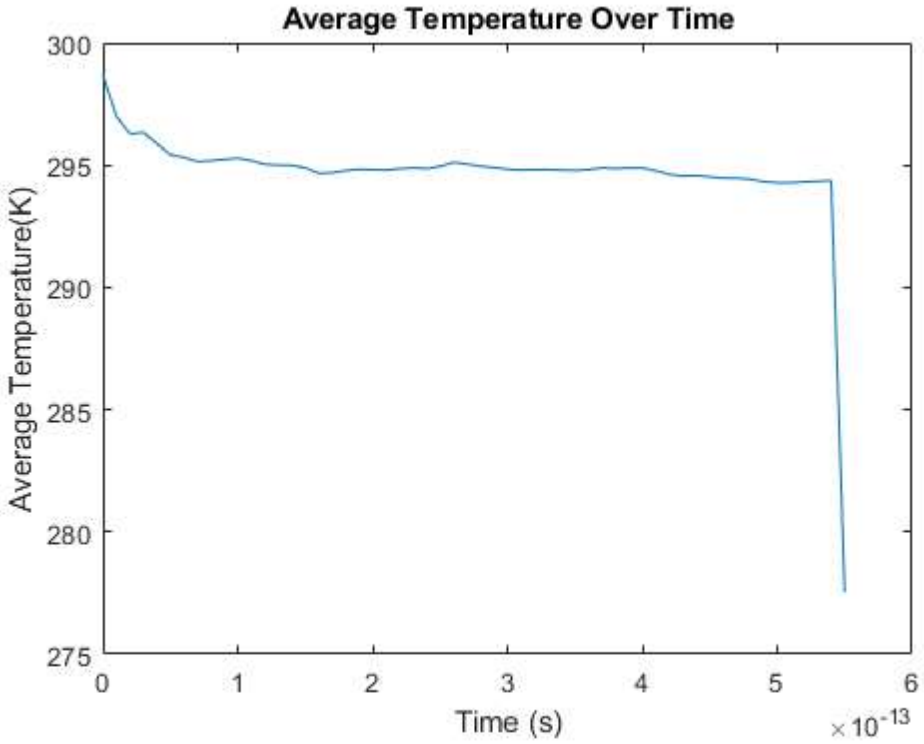
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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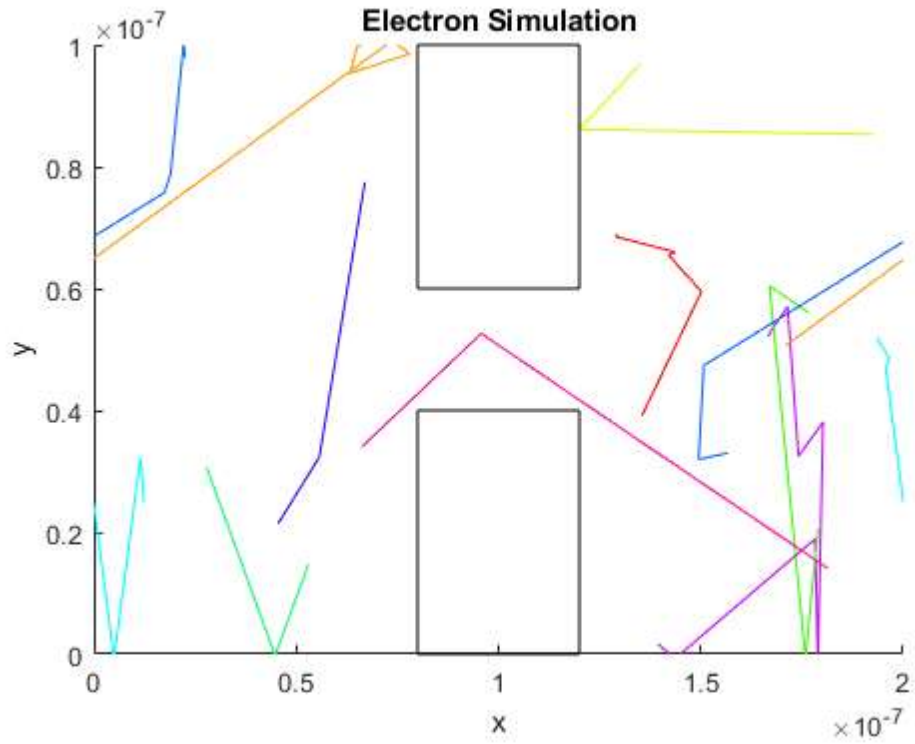
Time (s)
×10^-13


Electron Simulation
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y
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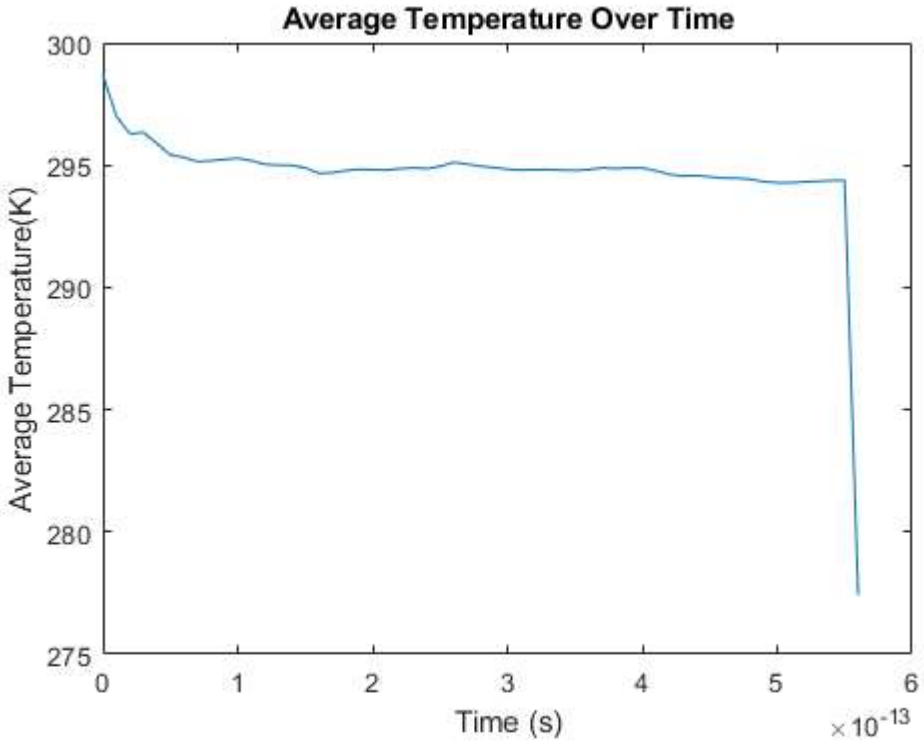
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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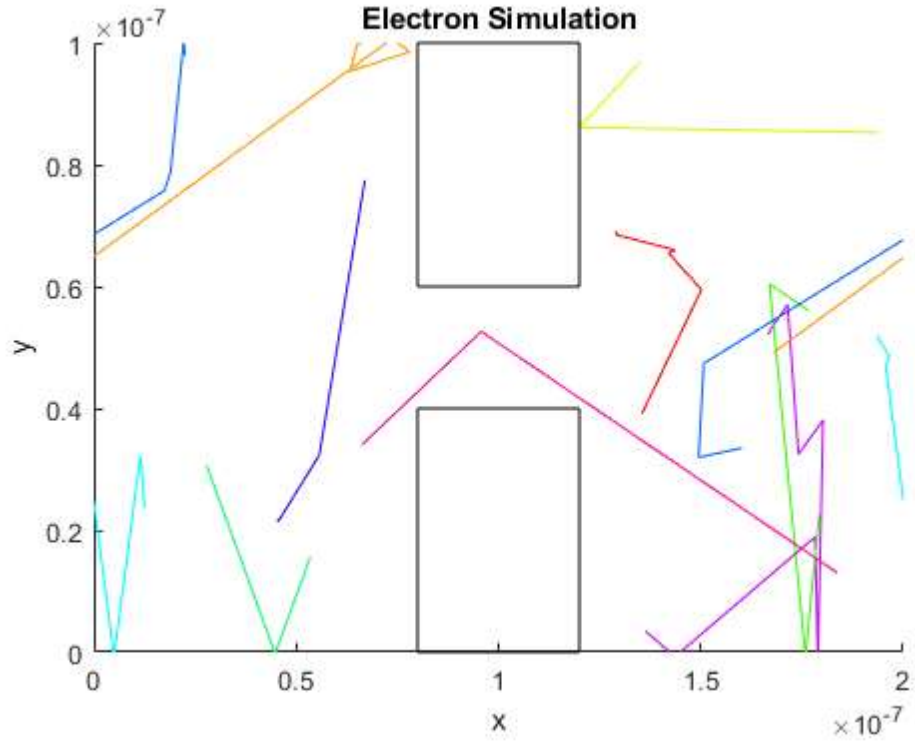
Time (s)
×10^-13


Electron Simulation
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y
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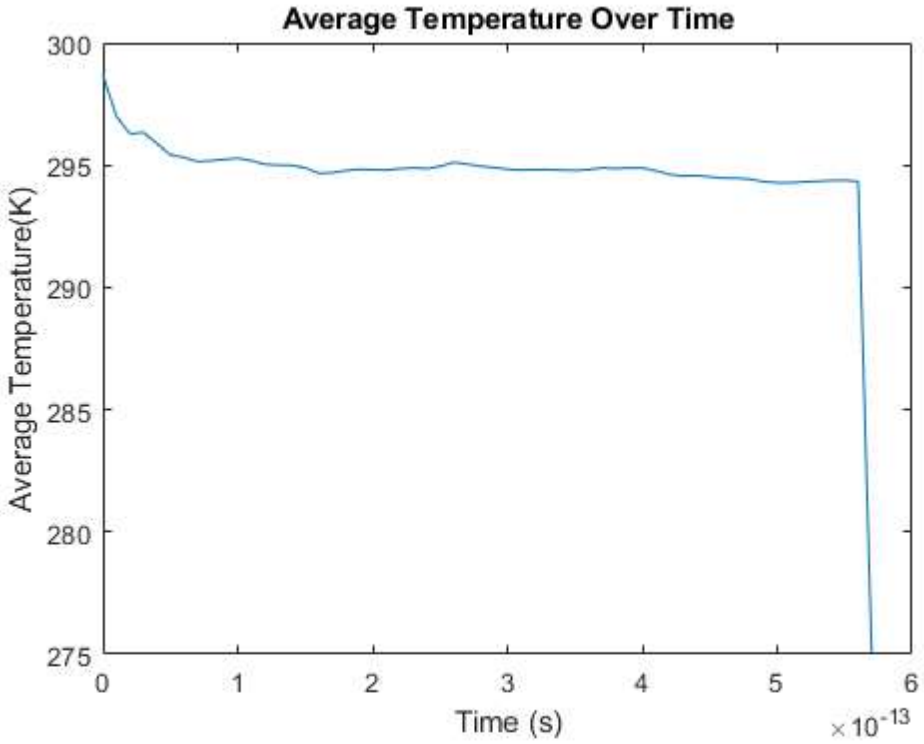
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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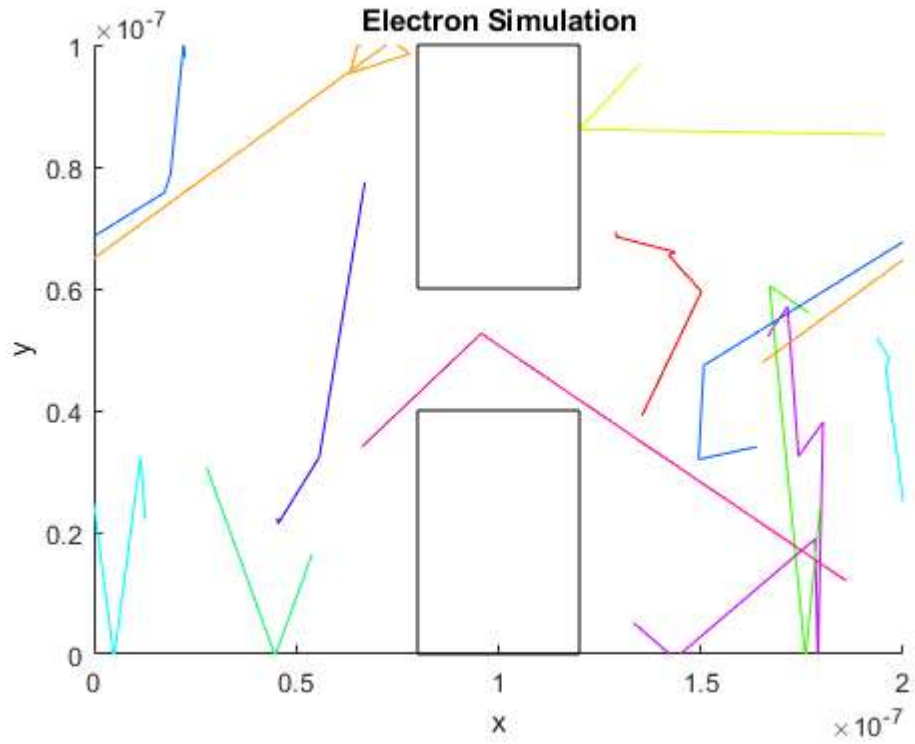
Time (s)
×10^-13


Electron Simulation
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y
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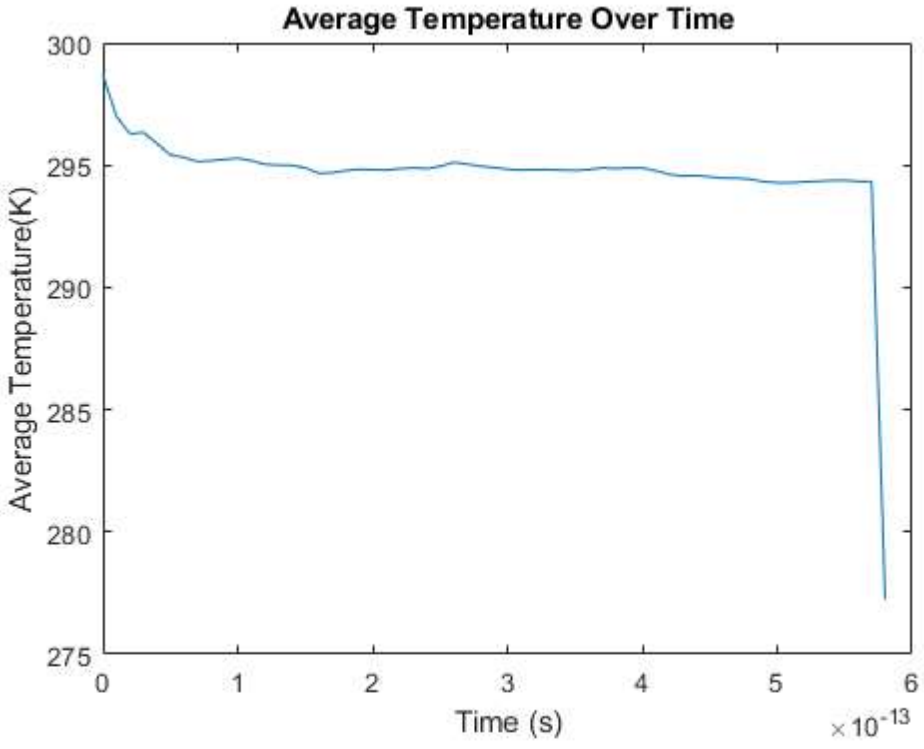
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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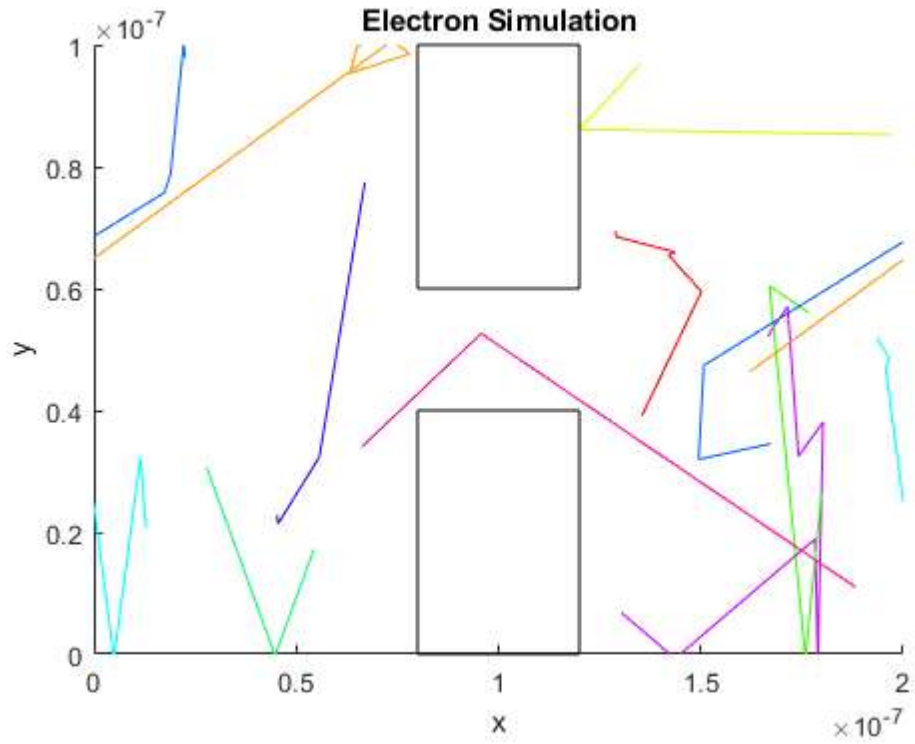
Time (s)
×10^-13


Electron Simulation
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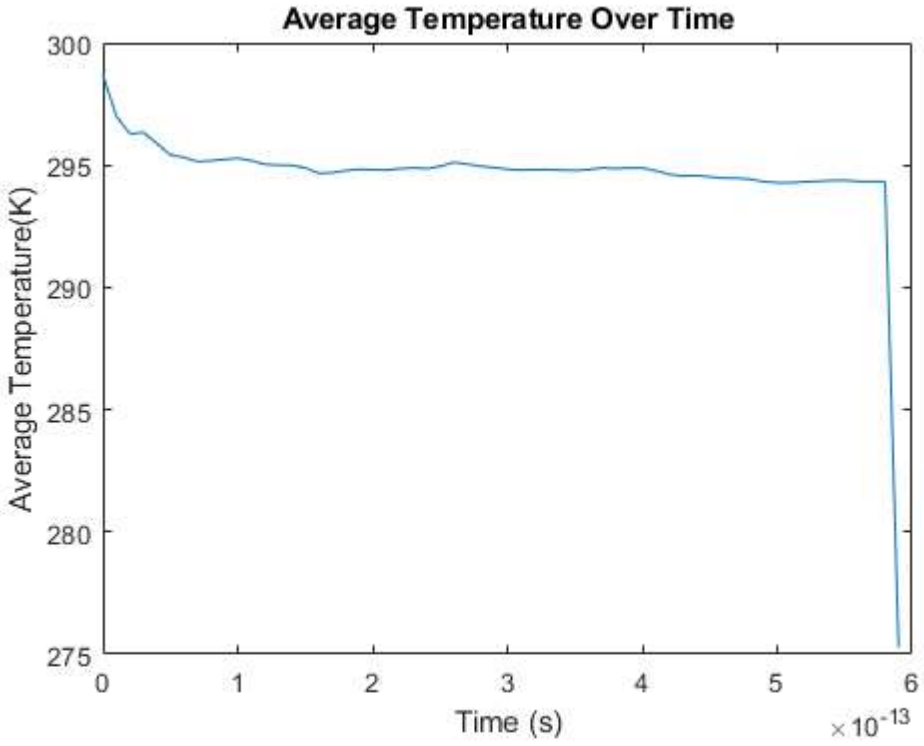
2
x
×10^-7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Average Temperature(K)
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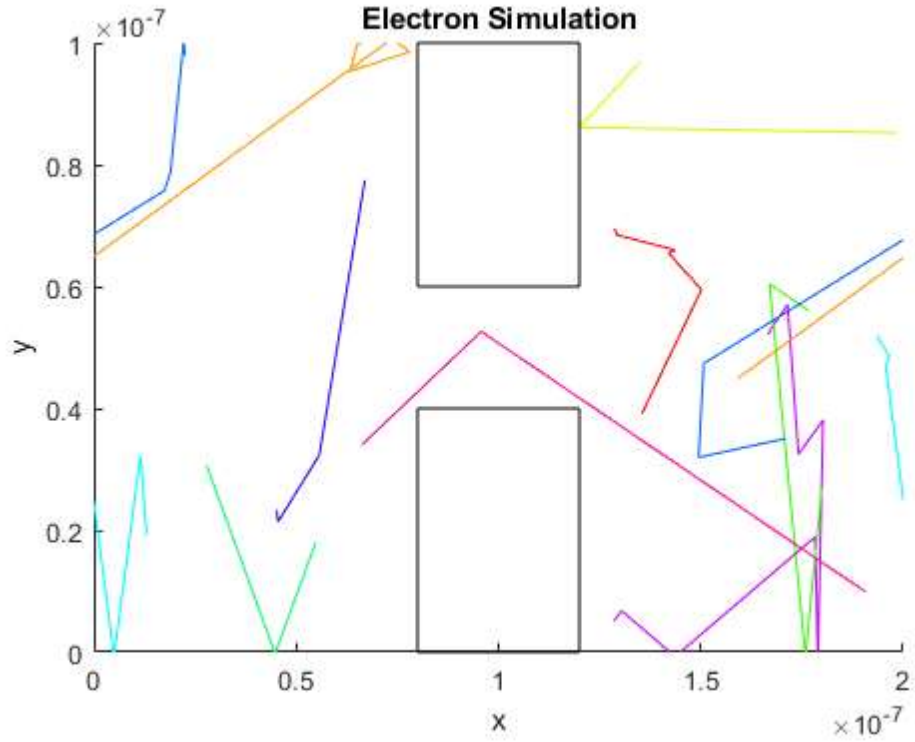
Time (s)
×10^-13


Electron Simulation
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y
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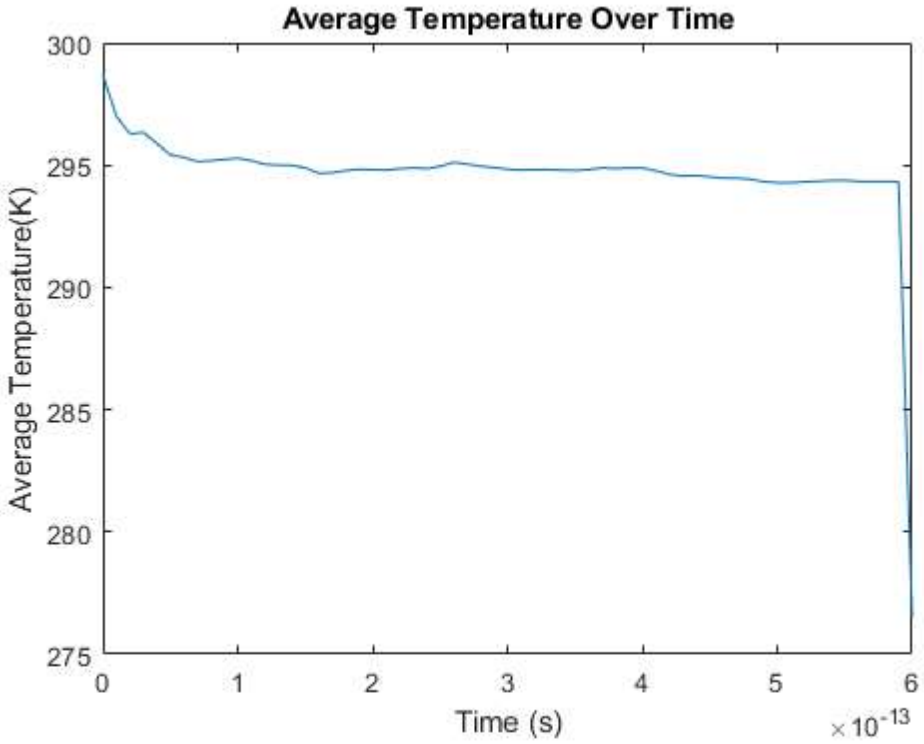
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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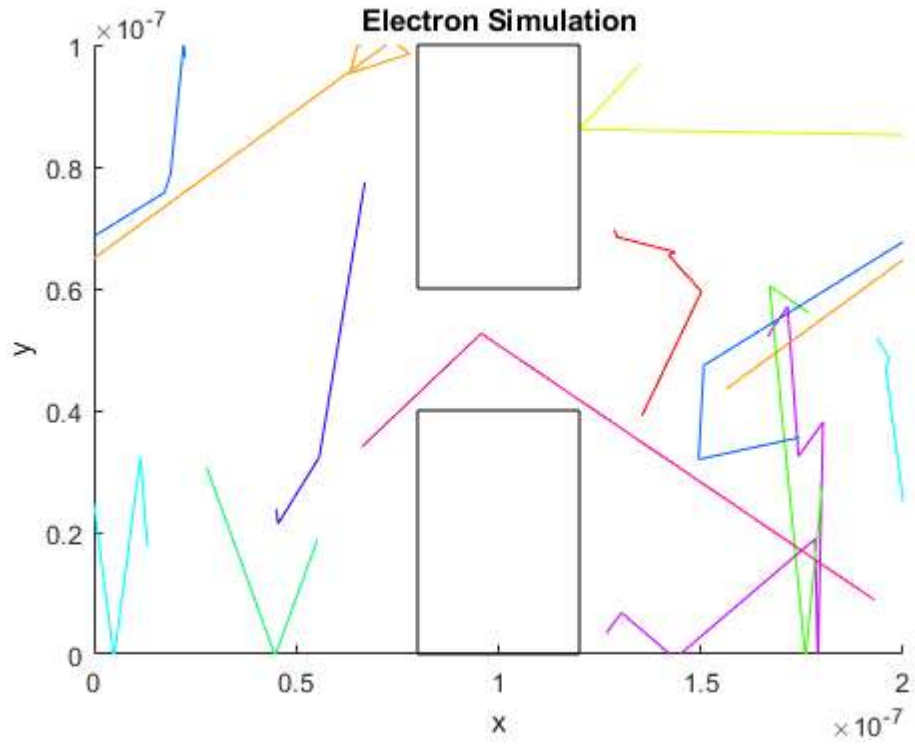
Time (s)
×10^-13


Electron Simulation
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y
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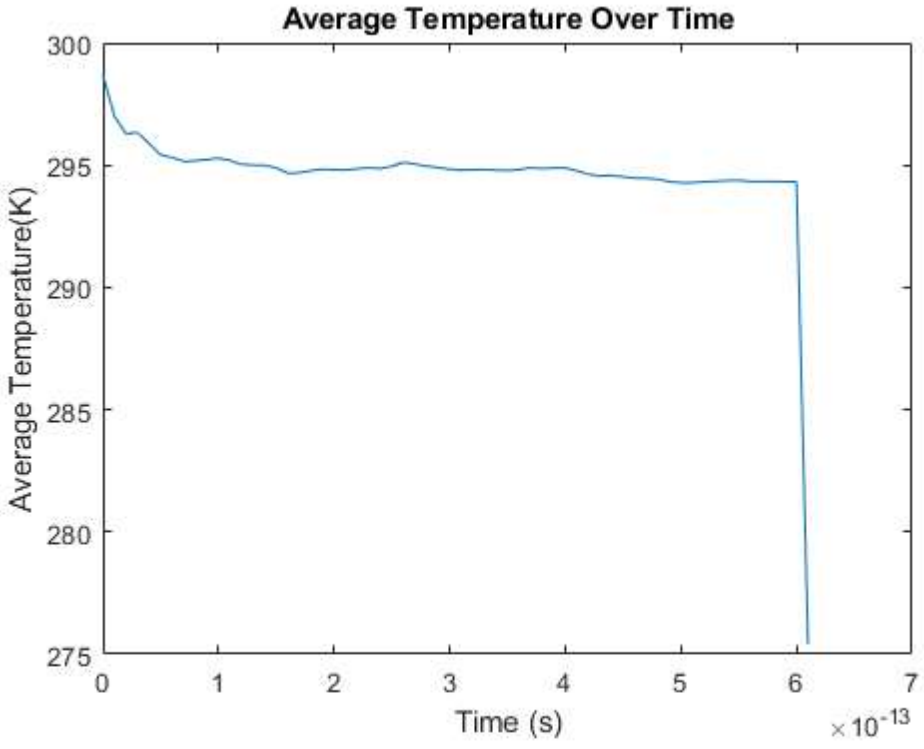
0.5
1
1.5
2
x
×10^-7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Average Temperature(K)
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6
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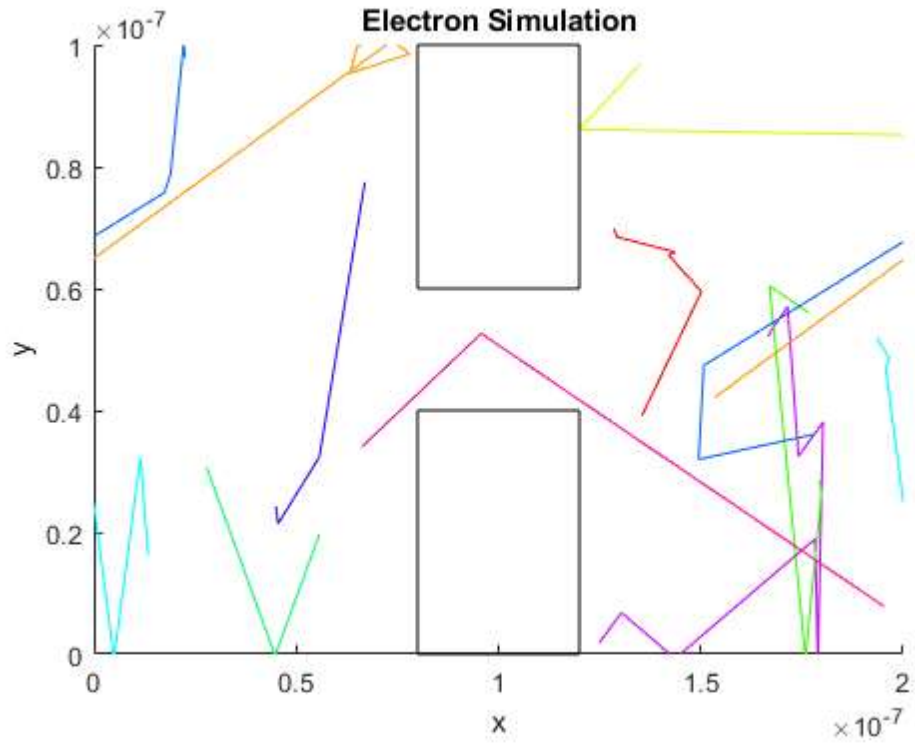
Time (s)
×10^-13


Electron Simulation
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y
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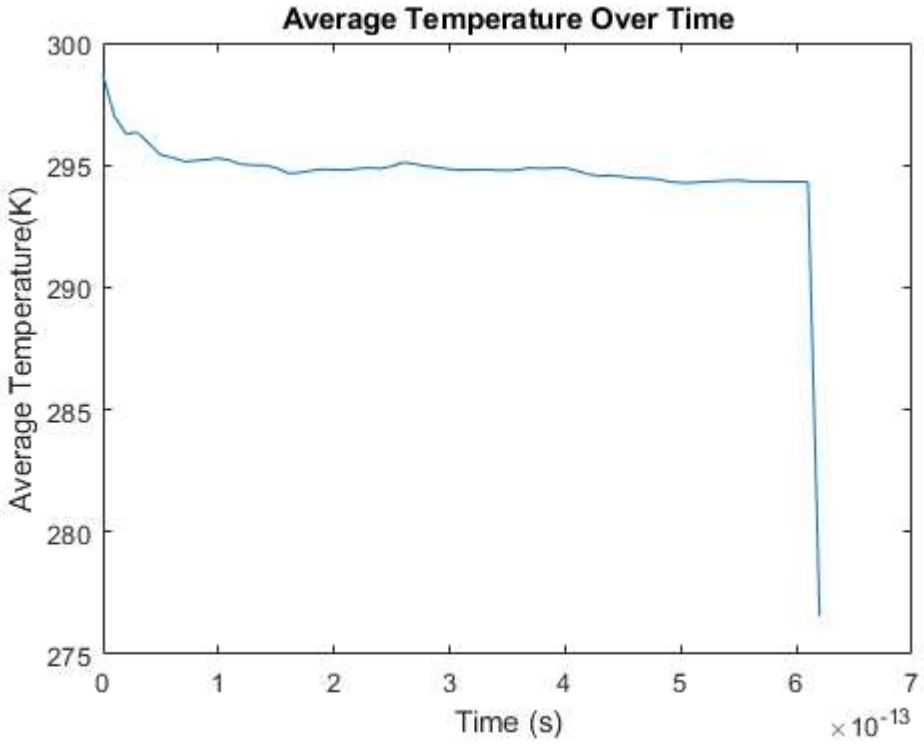
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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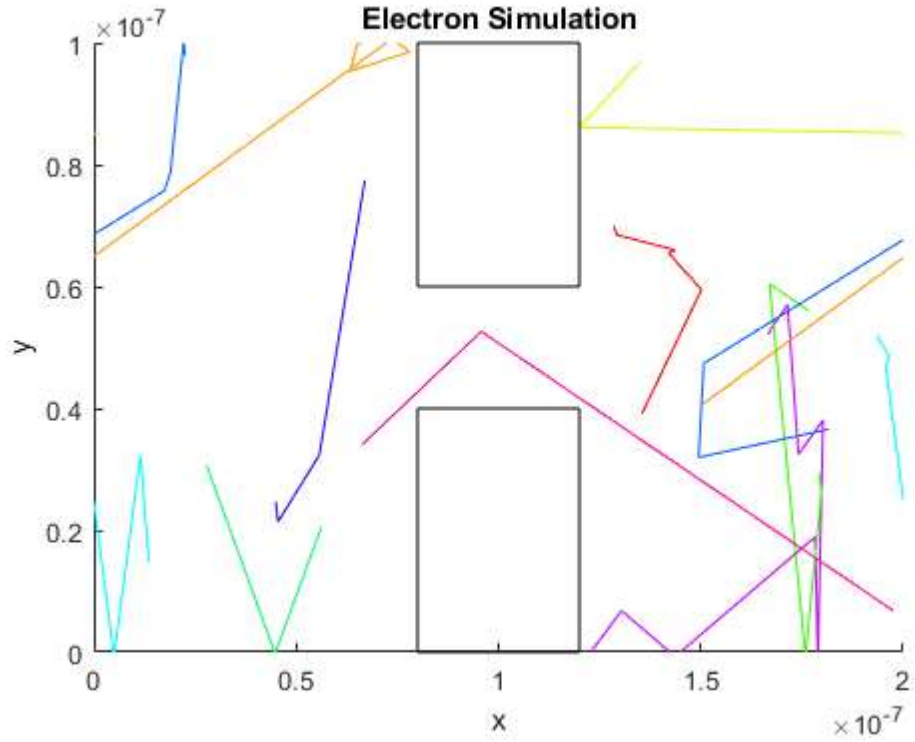
Time (s)
×10^-13


Electron Simulation
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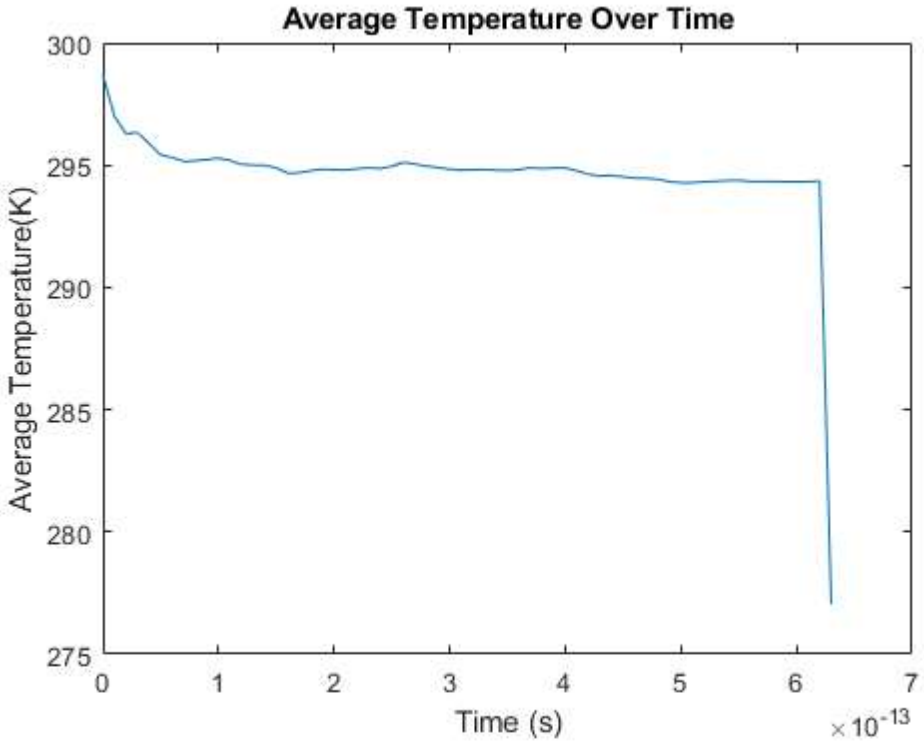
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Time (s)
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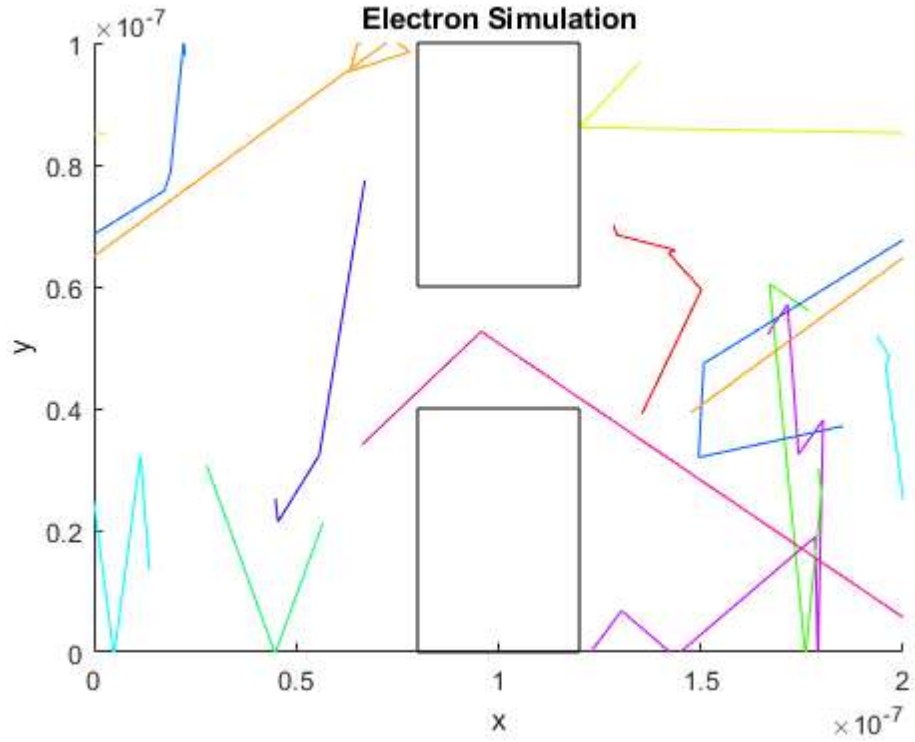
Electron Simulation
×10^-7
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y
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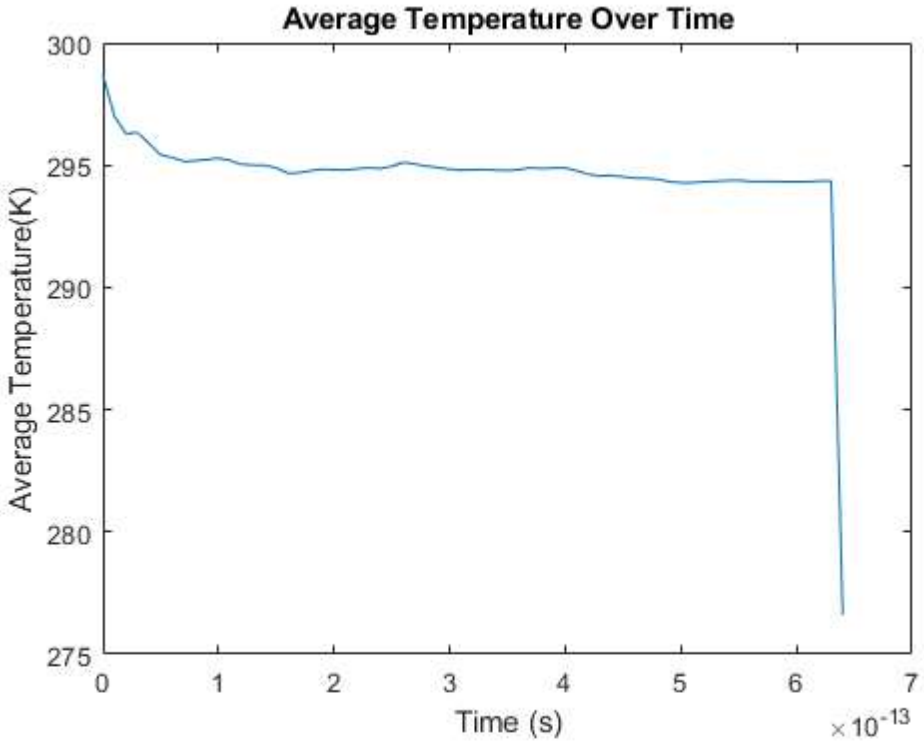
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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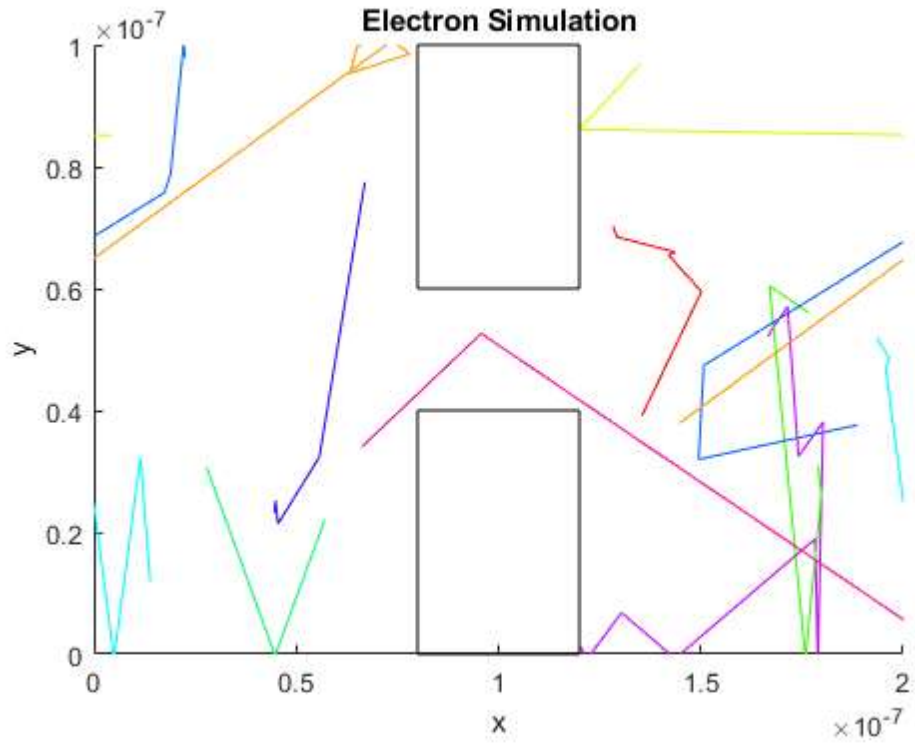
Time (s)
×10^-13


Electron Simulation
×10^-7
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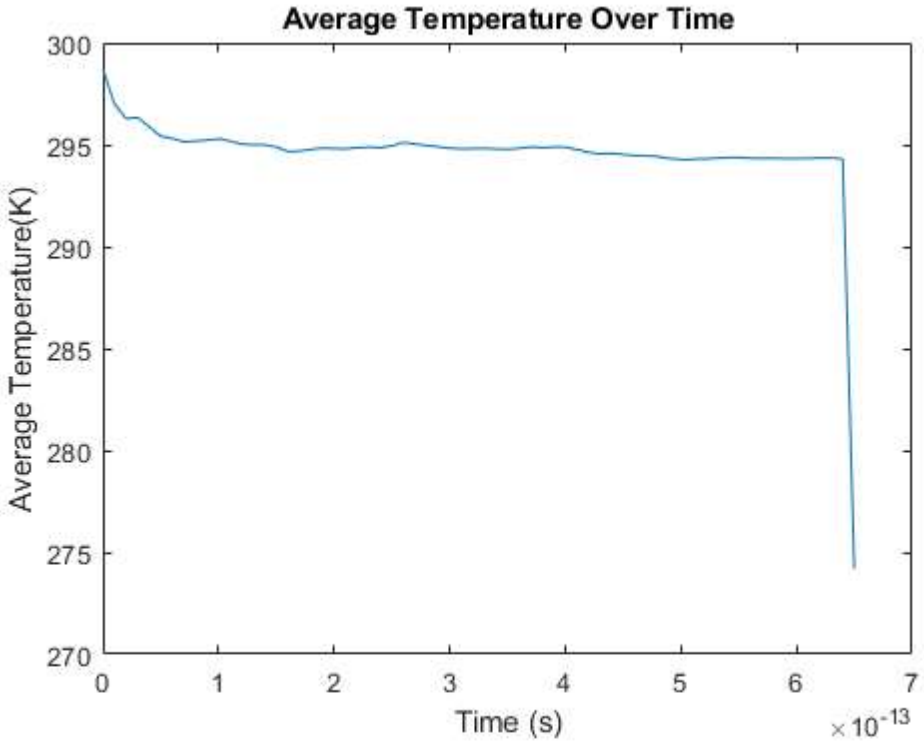
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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Average Temperature(K)
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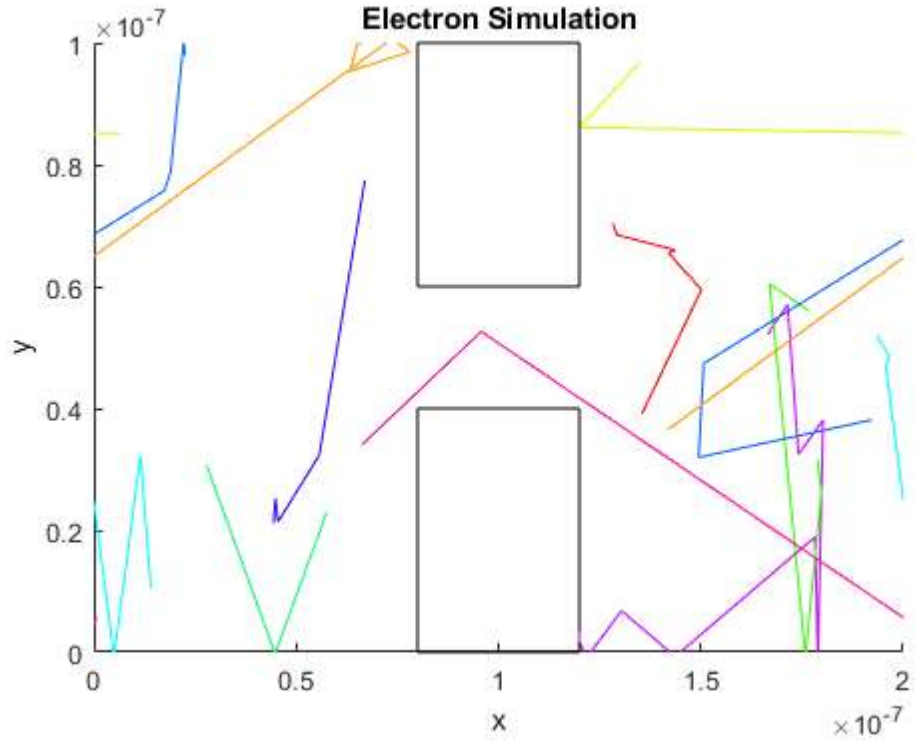
Time (s)
×10^-13


Electron Simulation
×10^-7
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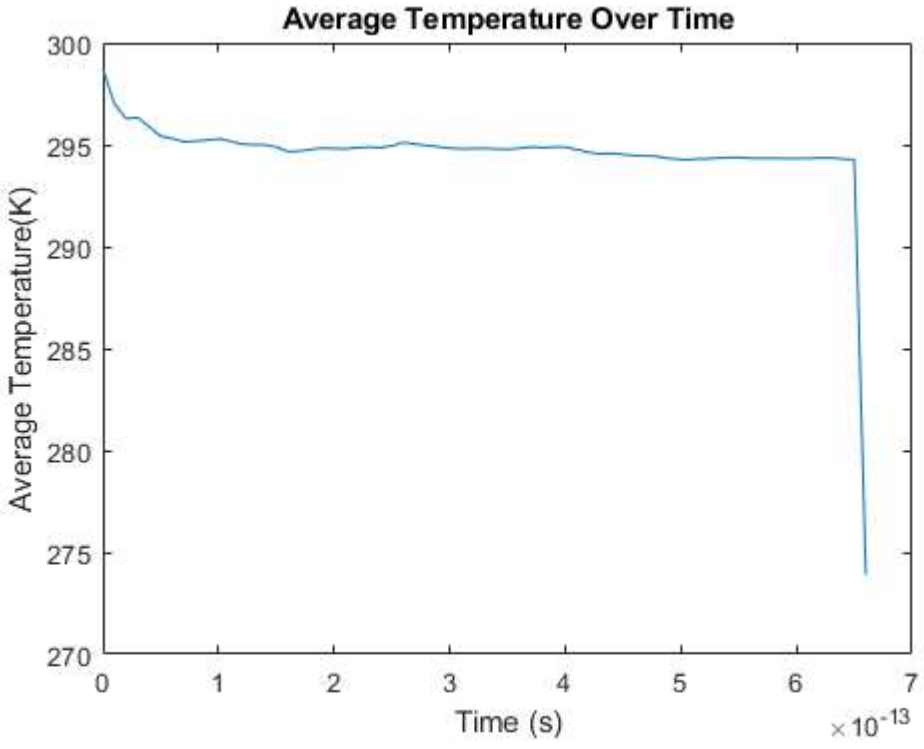
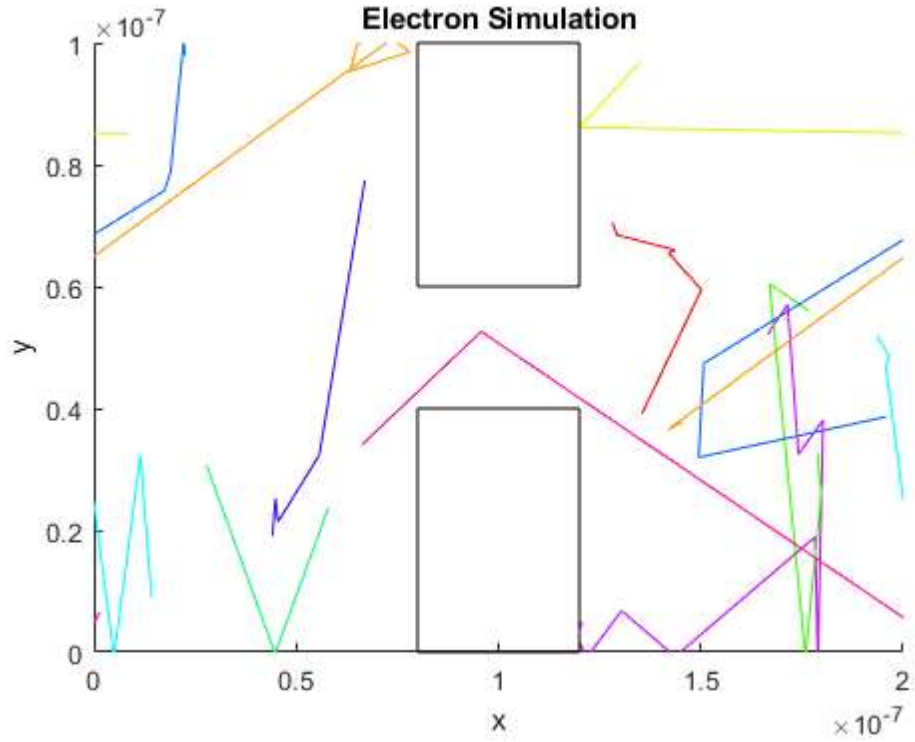
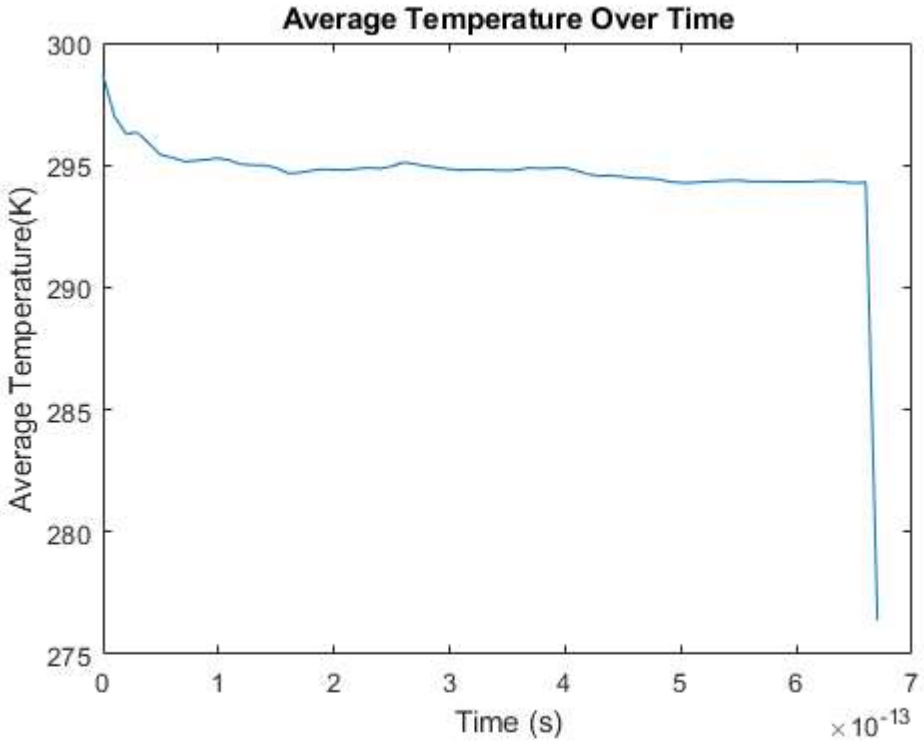
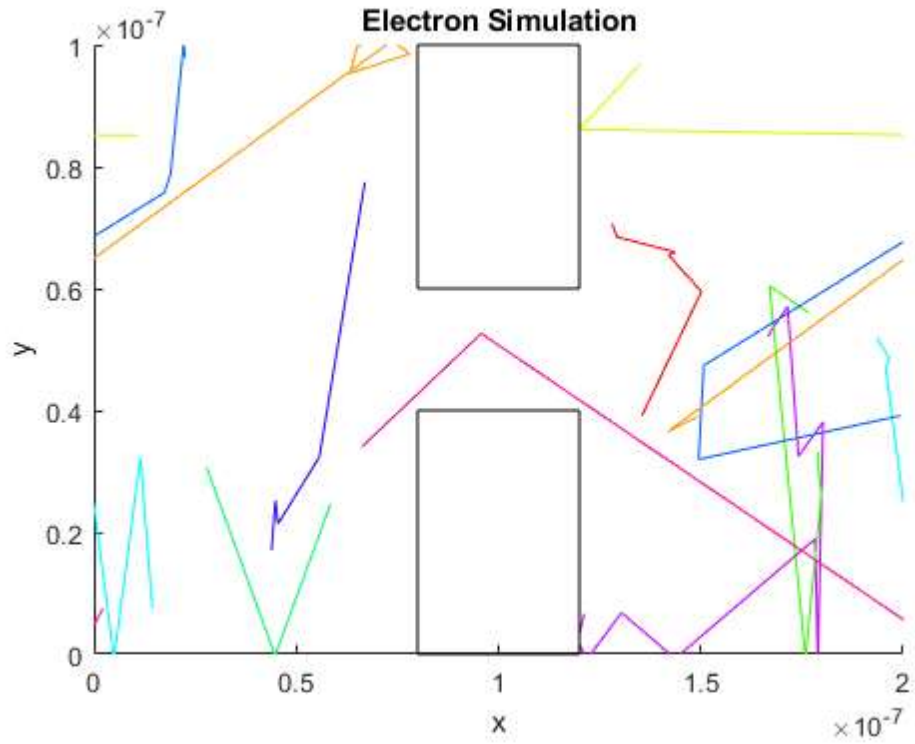
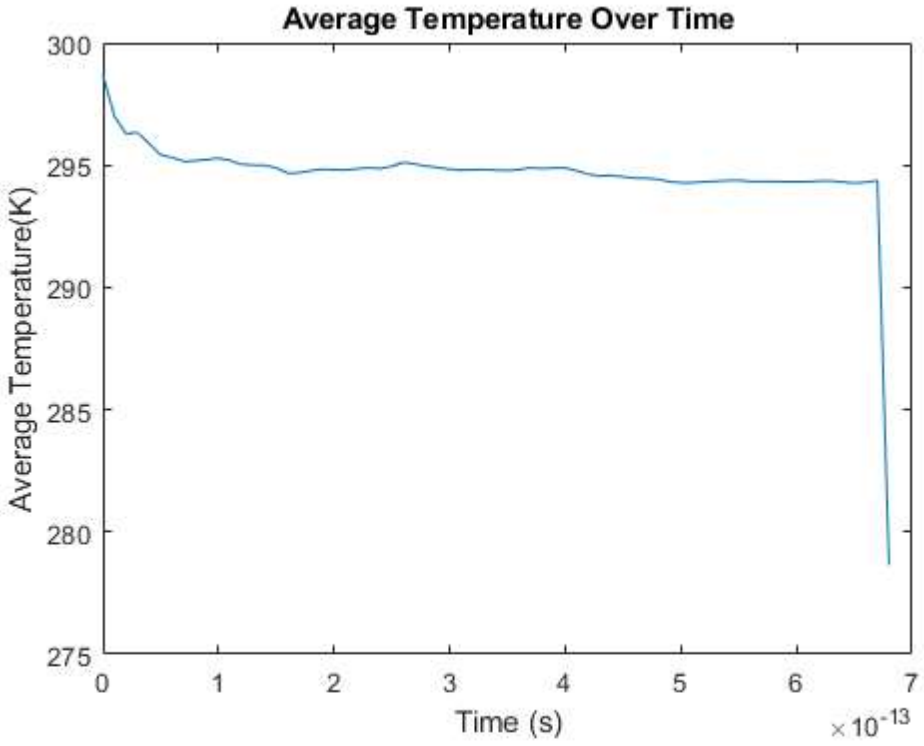
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

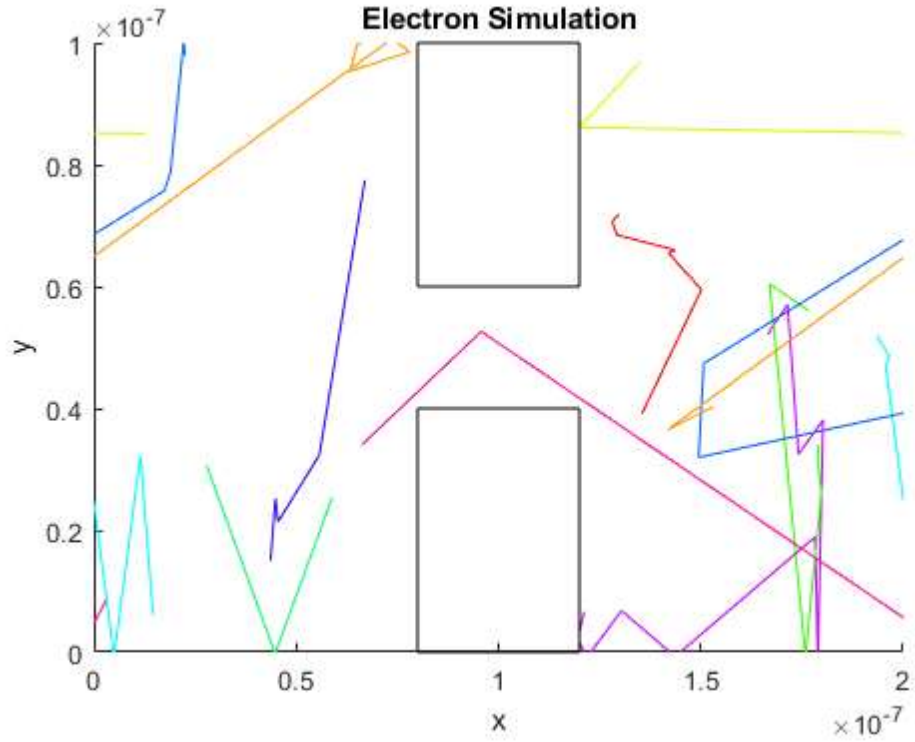

Average Temperature Over Time
300
295
290
285
280
275
270
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

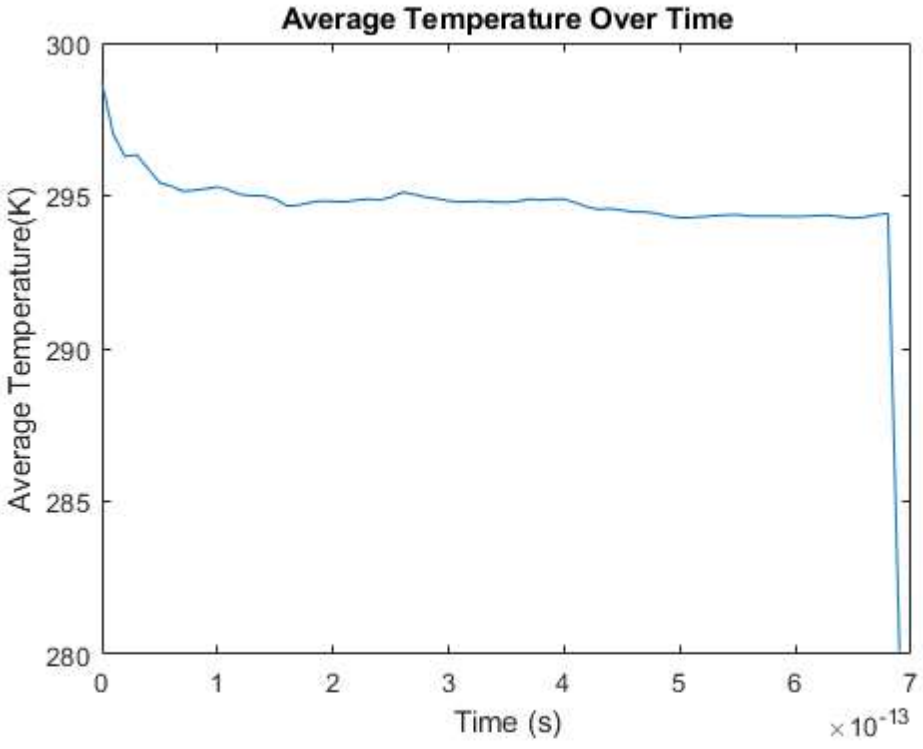

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

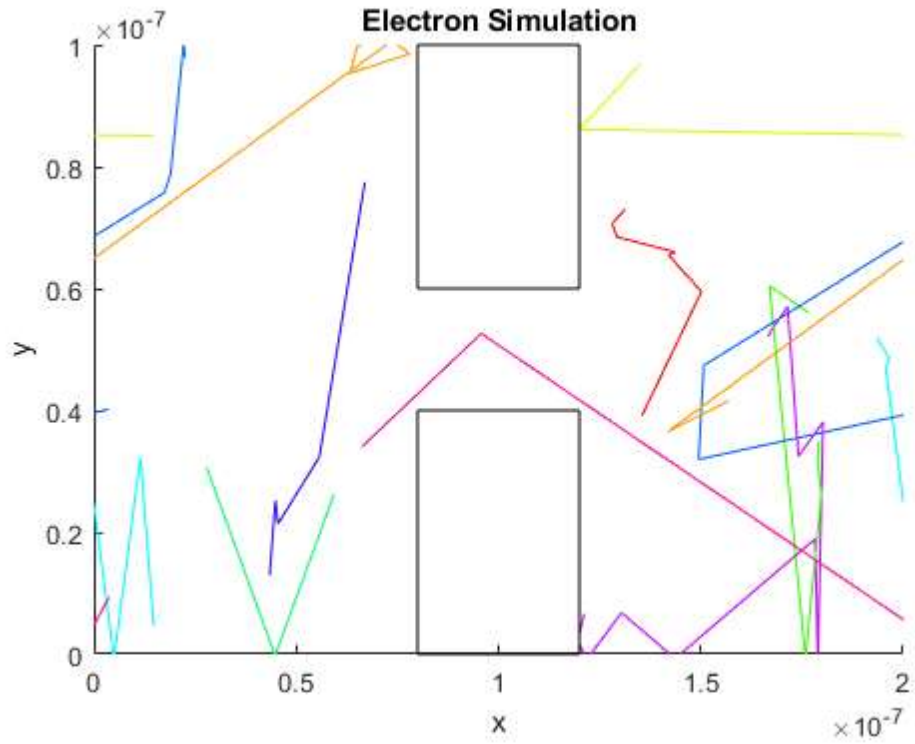

Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

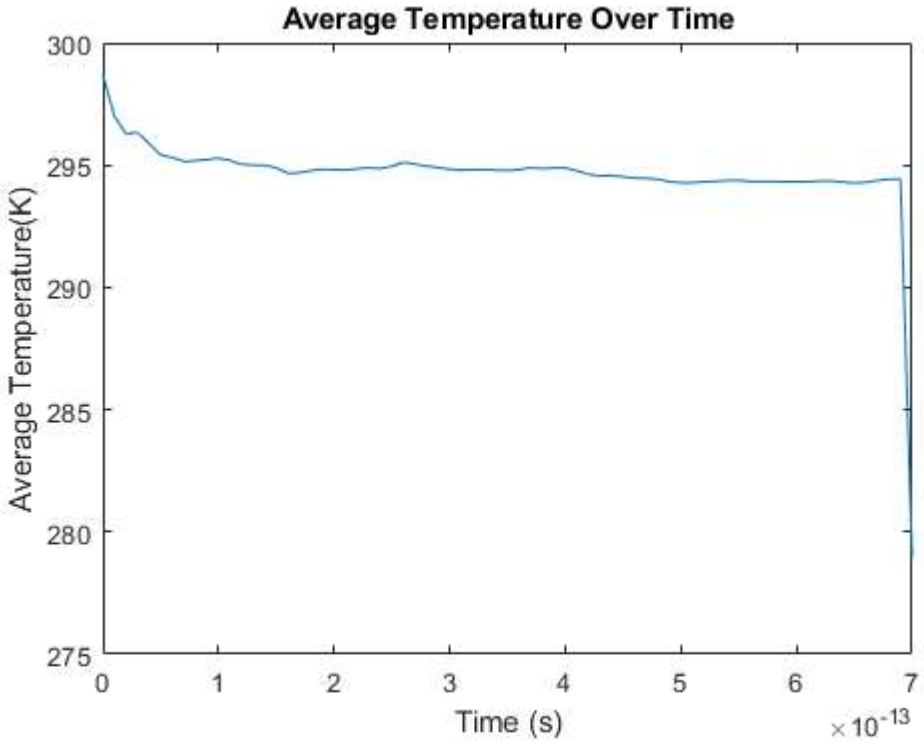

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

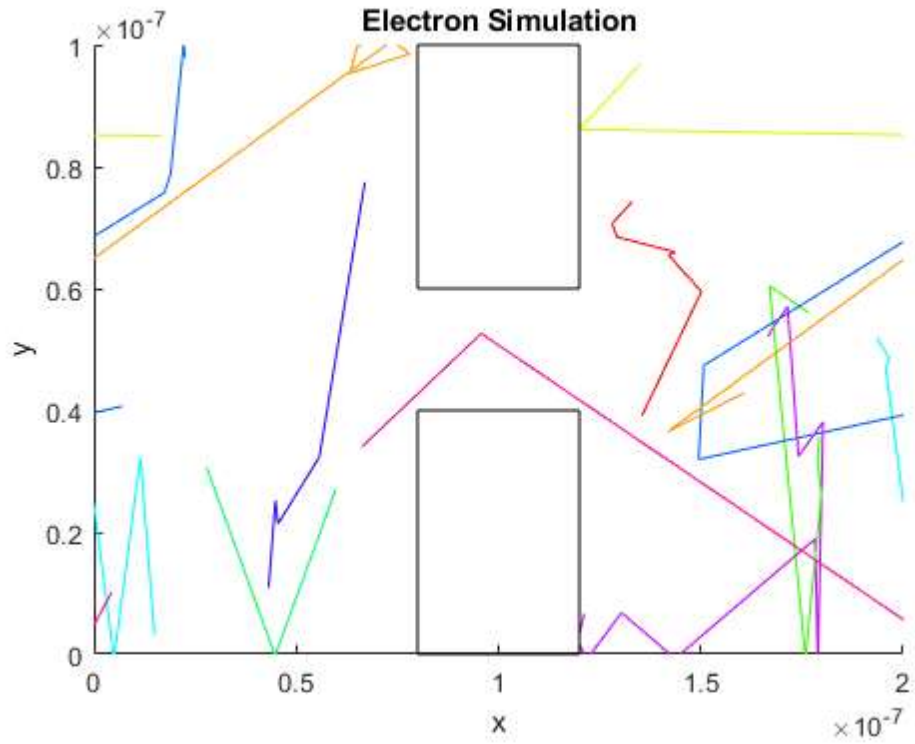

Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

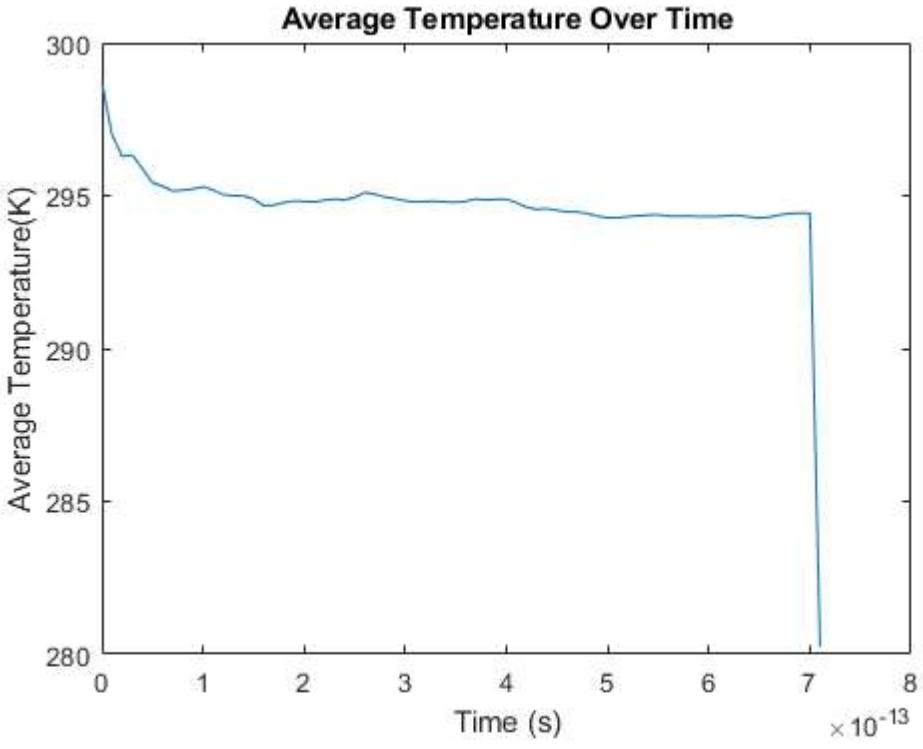

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

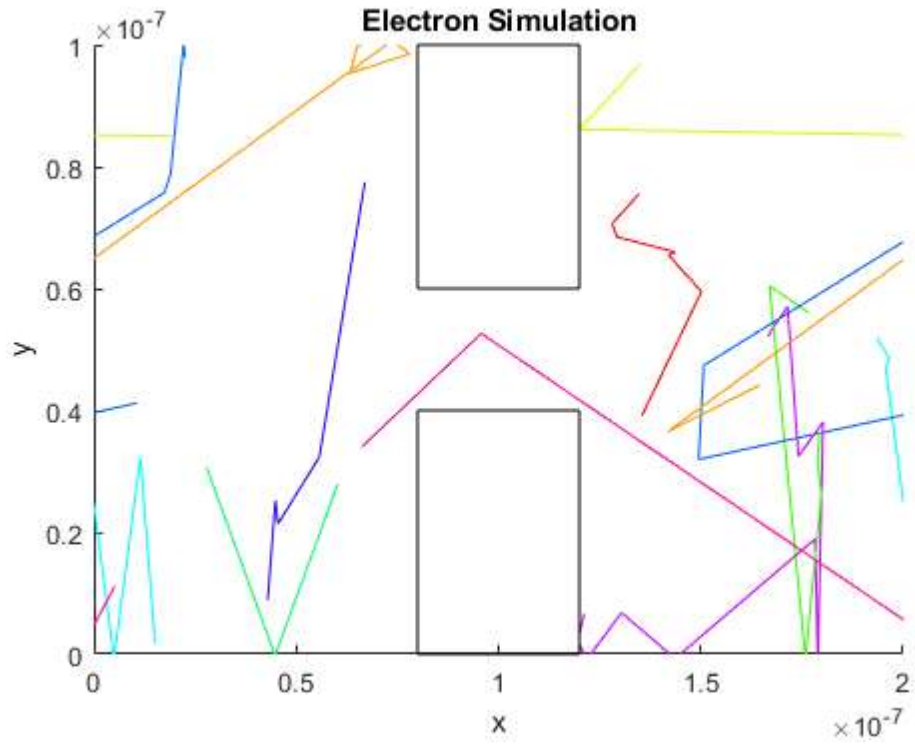

Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

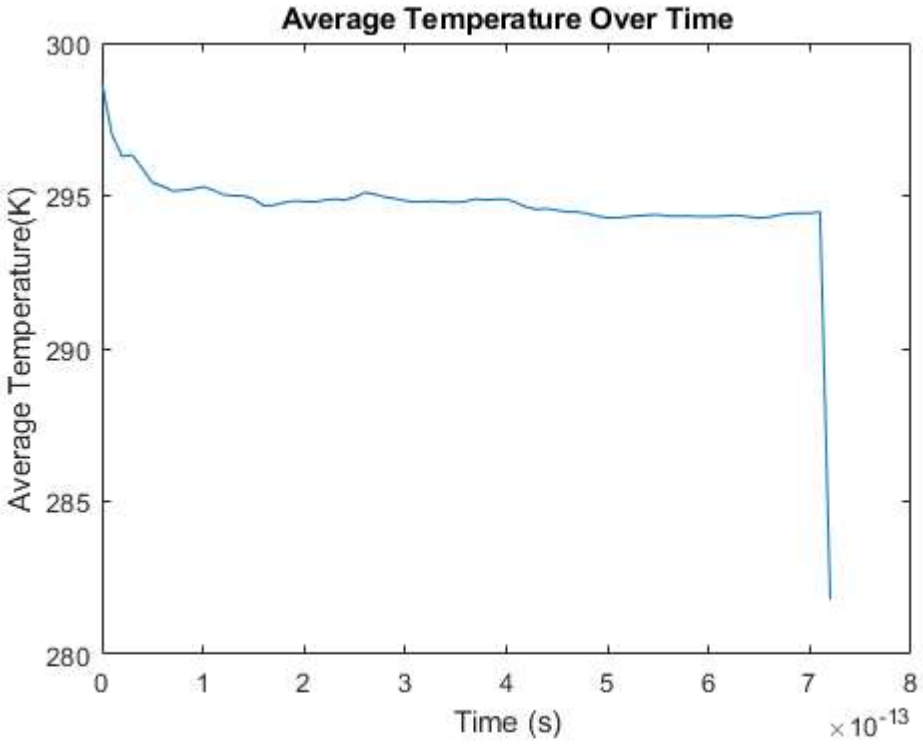

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7

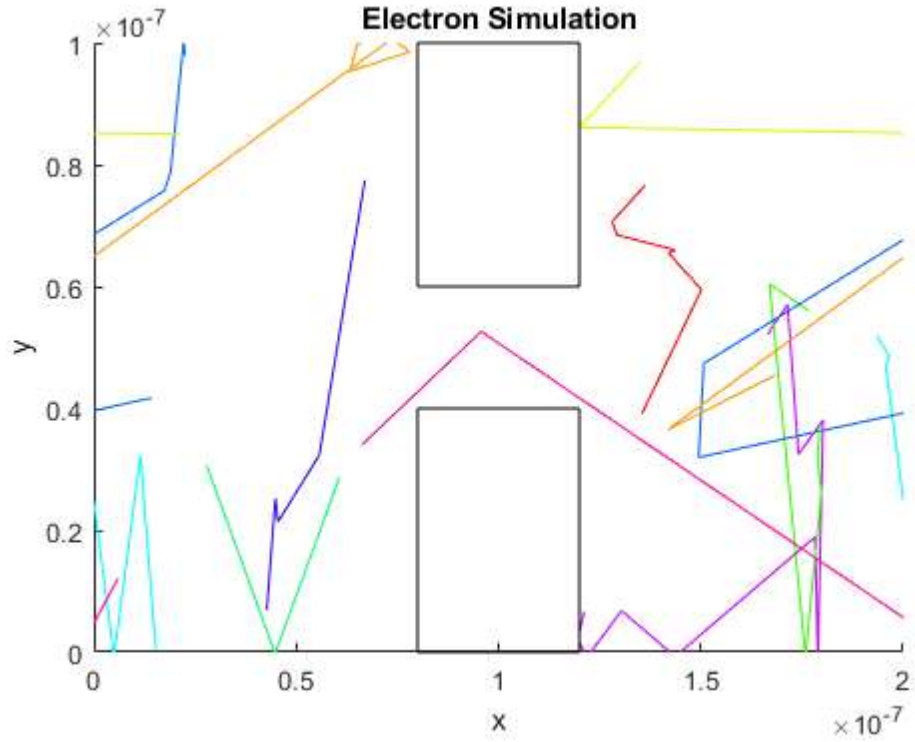

Average Temperature Over Time
300
295
290
285
280
275
Average Temperature(K)
0
1
2
3
4
5
6
7
Time (s)
×10^-13

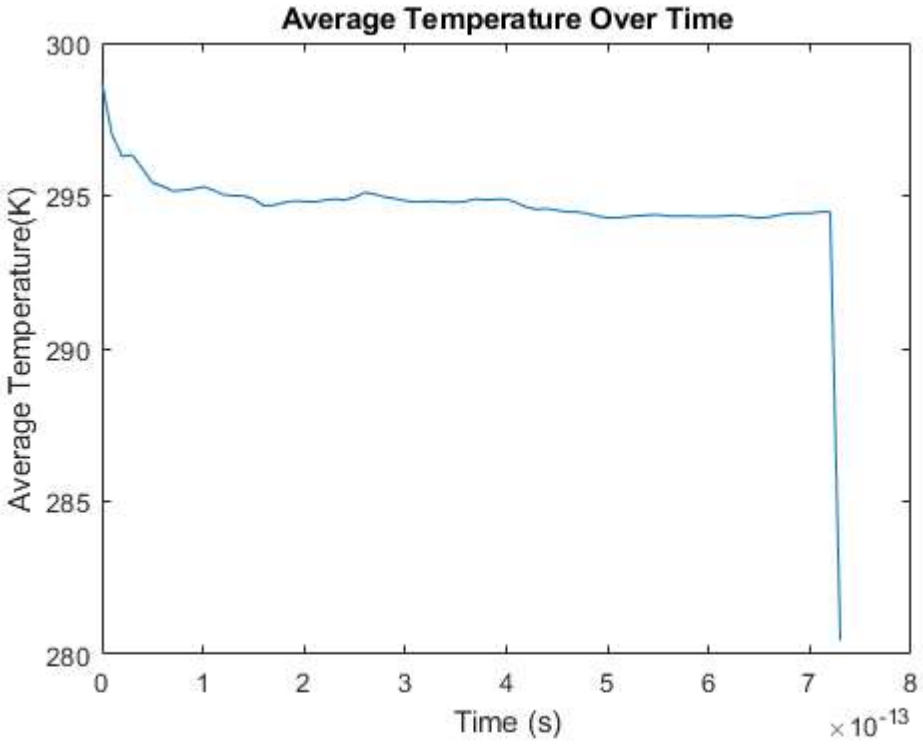

Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
290
285
280
Average Temperature(K)
0
1
2
3
4
5
6
7
8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
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280
Average Temperature(K)
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1
2
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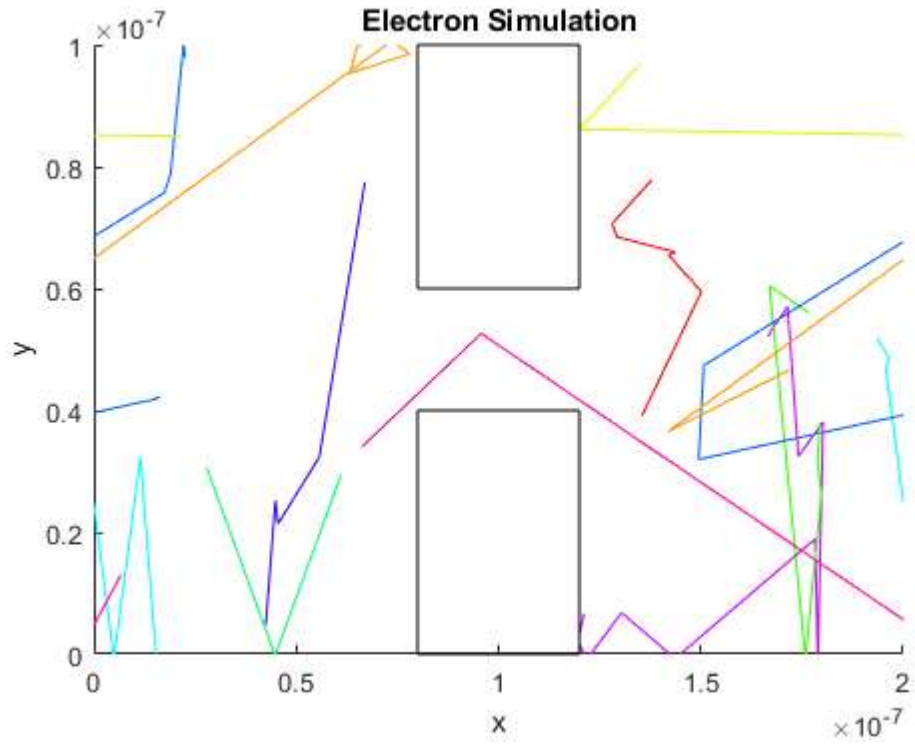
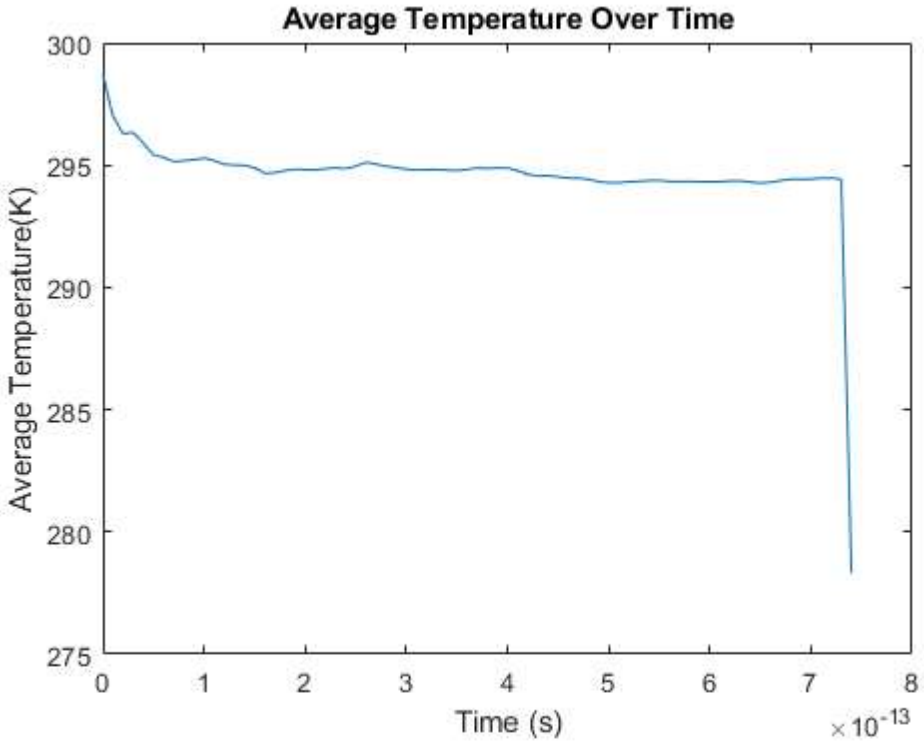
4
5
6
7
8
Time (s)
×10^-13


Electron Simulation
×10^-7
1
0.8
0.6
0.4
0.2
0
y
0
0.5
1
1.5
2
x
×10^-7


Average Temperature Over Time
300
295
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275
Average Temperature(K)
0
1
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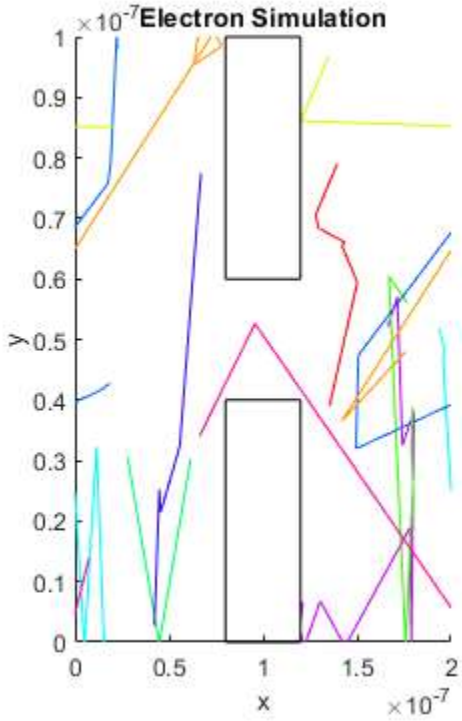
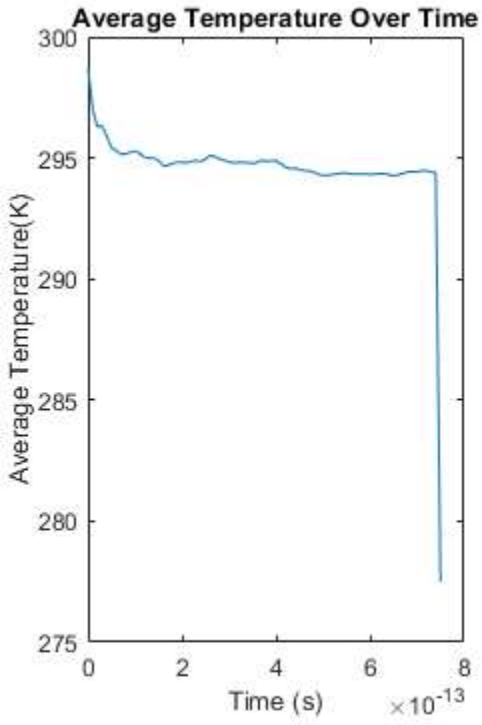
6
7
8
Time (s)
×10^-13





Next, the previous x and y values are updated with the current values of x and y.

```
    xp = x;
    yp = y;
```

Scattering is done, pscat is the probability to scatter, then scat represents the indices which must scatter.

```
    pscat = 1 - exp(-dt/tmn);
    scat = pscat > rand(NE, 1);

    scatlength = length(vx(scat));
```

Next, the velocities are scattered.

```
    if(scatlength>0)
        vx(scat) = 1*sqrt((kB*T)/mn)*randn(scatlength, 1);%velocity x and y
        vy(scat) = 1*sqrt((kB*T)/mn)*randn(scatlength, 1);
    end
```

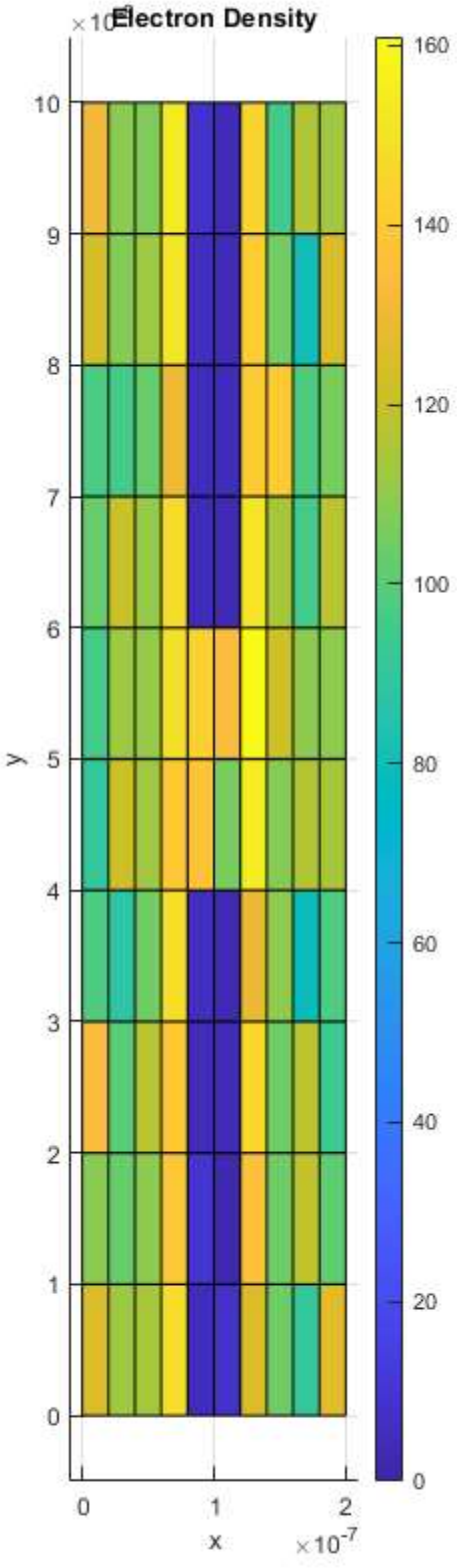
```
end
```

The electron spectral density is created through use of a histogram.

```
figure(3)
hist3([x, y], 'CDataMode','auto','FaceColor','interp');
title('Electron Density')
xlabel('x')
ylabel('y')
colorbar
view(2)
```

```
function traj(electrons, xp, x, yp, y, TrajColours, w, h)
```

```
    rectangle('position', [80e-9 60e-9 40e-9 40e-9])
    hold on
    rectangle('position', [80e-9 0e-9 40e-9 40e-9])
    hold on
    for k =1:length(electrons)
        x1 = xp(k);
        x2 = x(k);
        y1 = yp(k);
        y2 = y(k);
        colour = TrajColours;
        plot([x1 x2], [y1 y2], 'color', colour(k,:));
        axis([0 w 0 h])
        xlabel('x')
        ylabel('y')
        title(['Electron Simulation']);
    end
```



2. Discussion

The thermal velocity was found to be 1.870135757482418e+05m/s. The mean free path was found to be 3.740271514964836e-08m. From Figure 2 it is evident that over time the average temperature regresses toward 300K the given temperature. A solution

was not found to calculate the mean time between collisions, the mean free path, and a temperature map.

3. Conclusion

In conclusion, the assignment was mostly completed. A simulation of the behaviour of electrons under many different circumstances was designed.

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