Assignment_6

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EE2703: Applied Programming

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1 Abstract

This weeks assignment concerns with solving for the simulation of a tublelight, in 1-Dimension. We make certain simplifying assumptions that allow us to simulate easily.

2 Introduction

Consider electrons being emitted by the cathode with zero energy, and accelerate in this field. When they get beyond a threshold energy E_0, they can drive atoms to excited states. The relaxation of these atoms results in light emission. In our model, we will assume that the relaxation is immediate. The electron loses all its energy and the process starts again.

Those electrons reaching the anode are absorbed and lost. Each "time step", an average of N electrons are introduced at the cathode. The actual number of electrons is determined by finding the integer part of a random number that is "normally distributed" (Gaussian Distributed) with standard deviation of 2 and mean 10.

1. We are using Python 3, GCC for C
2. Underscore naming vs Camel Case
3. PEP 25 convention style.

3 Code Description

We have wrapped the entire simulation into a class called, *Simulate_tubelight*, which creates the universe, then vectors. The simulation steps (which is run sequentially in a loop) is described below:

1. All electrons are constrained between $0 < x < L$, anything out of range is set to $x = 0, u = 0$.
2. Displacement and Velocity are updated with time steps as: $dx_i = u_i\Delta t + \frac{a(\Delta t)}{2} = u_i + 0.5$.
3. Determine which particles have hit the anode, reinitiate them to $(x = 0, u = 0)$.
4. Find out which electrons are sufficiently energised, together with a probability of collision, determine the number of photons emmited at a particular position.
5. Assuming inelastic collision, set their velocities to zero, and random position.

6. Inject a randomly distributed number of electrons, with the given mean M and variance M_sig.
7. Compile a list of existing electrons into respective vectors.

The entire loop may be run iteratively using a class method.

```
In [404]: import numpy as np
          import matplotlib.pyplot as plt
```

```
In [407]: class Simulate_tubelight(object):
              '''Simulate a tubelight'''
              def __init__(self,n=100,M=5,nk=1000,u0=7,p=0.5,Msig=0.2):
                  self.create_universe(n,M,nk,u0,p,Msig)
                  self.create_vectors()

              def create_universe(self,n=100,M=5,nk=1000,u0=7,p=0.5,Msig=0.2):
                  self.n=n  # spatial grid size.
                  self.M=M    # number of electrons injected per turn.
                  self.nk=nk # number of turns to simulate.
                  self.u0=u0  # threshold velocity.
                  self.p=p # probability that ionization will occur
                  self.Msig=Msig

              def create_vectors(self):
                  dim=self.n*self.M
                  self.xx=np.zeros(dim) # Electron position
                  self.u=np.zeros(dim) # Electron velocity
                  self.dx=np.zeros(dim) # Displacement in current turn
                  self.I=[] # Intensity of emitted light,
                  self.X=[] # Electron position
                  self.V=[] # Electron velocity

              def loop(self):
                  # Find the electrons present in the chamber.
                  self.ii=np.where(self.xx>0)[0]

                  # Compute the displacement during this turn
                  self.dx[self.ii]=self.u[self.ii]+0.5

                  # Advance the electron position and velocity for the turn.
                  self.xx[self.ii]+=self.dx[self.ii]
                  self.u[self.ii]+=1

                  # Determine which particles have hit the anode
                  self.hit_anode=np.where(self.xx>self.n)[0]
                  self.xx[self.hit_anode]=0
                  self.u[self.hit_anode]=0
                  self.dx[self.hit_anode]=0
```

```
        # Find those electrons whose velocity is greater than or equal to the threshol
        self.kk=np.where(self.u>=self.u0)[0]
        # Of these, which electrons are ionized
        self.ll=np.where(np.random.rand(len(self.kk))<=self.p)[0]
        self.kl=self.kk[self.ll]

        # Reset the velocities of these electrons to zero (they suffered an inelastic
        self.u[self.kl]=0
        # The collision could have occurred at any point between the previous xi and t
        self.xx[self.kl]-=self.dx[self.kl]*np.random.rand()

        # Excited atoms at this location resulted in emission from that point.
        self.I.extend(self.xx[self.kl].tolist())

        # Inject M new electrons
        m= int(np.random.randn()*self.Msig+self.M)  # actual number of electrons injec
        # Add them to unused slots. Adding randomly
        self.slots_to_add_to=np.where(self.xx==0)[0]

        if len(self.slots_to_add_to)>=m:
            random_start=np.random.randint(len(self.slots_to_add_to))
            self.xx[self.slots_to_add_to[random_start:m+random_start]]=1
            self.u[self.slots_to_add_to[random_start-m:random_start]]=0
        else: # If no free slots
            self.xx[self.slots_to_add_to]=1
            self.u[self.slots_to_add_to]=0

        self.existing_electrons=np.where(self.xx>0)[0]
        self.X.extend(self.xx[self.existing_electrons].tolist())
        self.V.extend(self.u[self.existing_electrons].tolist())

    def run_loop(self):
        [self.loop() for i in range(self.nk)]

    def plot_intensity(self):
        plt.hist(self.I,bins=np.arange(1,100),ec='black',alpha=0.5)
        plt.title("Light Intensity Histogram ")
        plt.show()

    def plot_electron_density(self):
        plt.hist(self.X,bins=np.arange(1,100),ec='black',alpha=0.5)
        plt.title("Electron Density Histogram")
        plt.show()

    def plot_intensity_table(self):
        import pandas
        a,bins,c=plt.hist(self.I,bins=np.arange(1,100),ec='black',alpha=0.5)
```

```
            xpos=0.5*(bins[0:-1]+bins[1:])
            d={'Position':xpos,'Count':a}
            p=pandas.DataFrame(data=d)
            print(p)

        def plot_electron_phase_space(self):
            plt.plot(self.xx,self.u,'x')
            plt.title("Electron Phase Space")
            plt.xlabel("Position")
            plt.figsize=(15,10)
            plt.ylabel("Velocity")
            plt.show()
```

The probability distribution for the displacement after collision is not uniform in space despite being uniform in time. This can be corrected using:

$$x = \frac{at^2}{2}$$

(when u=0)

$$p_X(x) = p_T(t) * \frac{\partial t}{\partial x}$$

.

We also write a code block to utilise system arguments to alter various paramters. These are:

1. '-n', "–grid_size", help="Grid Size",default=100.
2. '-M','–no_of_electrons', help="Downscale ratio", default=5.
3. '-nk', '–turns', help="Number of iterations",default=500.
4. '-u0', '–threshold_velocity', help="Threshold Velocity for electron",default=500.
5. '-p', '–probability', help="Probability of collision",default=500.
6. '-Msig', '–variance', help="Variance of probability distribution".

```
In [397]: import argparse as ap

          if __name__=='__main__':
              parser = ap.ArgumentParser()
              parser.add_argument('-n', "--grid_size", help="Grid Size",default=100)
              parser.add_argument('-M','--no_of_electrons', help="Downscale ratio", default=5)
              parser.add_argument('-nk', '--turns', help="Number of iterations",default=500)
              parser.add_argument('-u0', '--threshold_velocity', help="Threshold Velocity for el
              parser.add_argument('-p', '--probability', help="Probability of collision",default
              parser.add_argument('-Msig', '--variance', help="Variance of probability distribut
              args = vars(parser.parse_args())
              n,M,nk,u0,p,Msig=(args.grid_size,args.no_of_electrons,args.turns,args.threshold_ve
                                args.probability,args.variance)
              a=Simulate_tubelight(n,M,nk,u0,p,Msig)
```

```
usage: ipykernel_launcher.py [-h] [-n GRID_SIZE] [-M NO_OF_ELECTRONS]
                             [-nk TURNS] [-u0 THRESHOLD_VELOCITY]
                             [-p PROBABILITY] [-Msig VARIANCE]
ipykernel_launcher.py: error: unrecognized arguments: -f /Users/Ankivarun/Library/Jupyter/runtim
```

```
An exception has occurred, use %tb to see the full traceback.


SystemExit: 2
```

```
/Users/Ankivarun/anaconda3/envs/tf_python3/lib/python3.6/site-packages/IPython/core/interactives
  warn("To exit: use 'exit', 'quit', or Ctrl-D.", stacklevel=1)
```

4 Simulation Results

We plot the results for the values of:

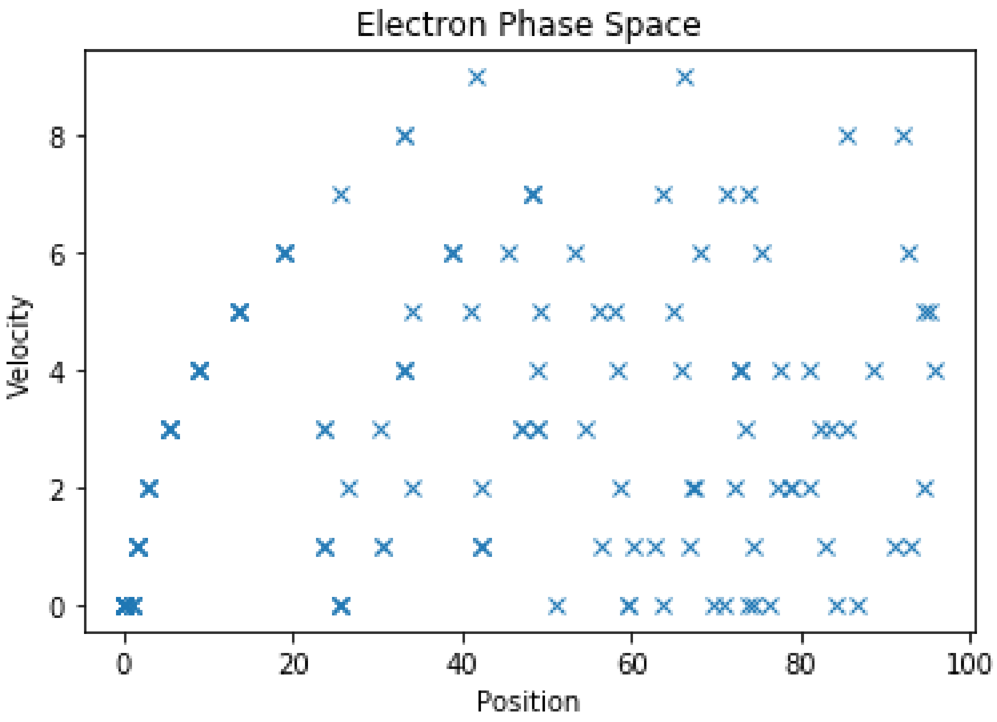
1. '-n', "–grid_size", help="Grid Size", = 100.
2. '-M','–no_of_electrons', help="Downscale ratio", = 5.
3. '-nk', '–turns', help="Number of iterations",= 500.
4. '-u0', '–threshold_velocity', help="Threshold Velocity for electron",= 500.
5. '-p', '–probability', help="Probability of collision", = 500.
6. '-Msig', '–variance', help="Variance of probability distribution".

The following plots are made:

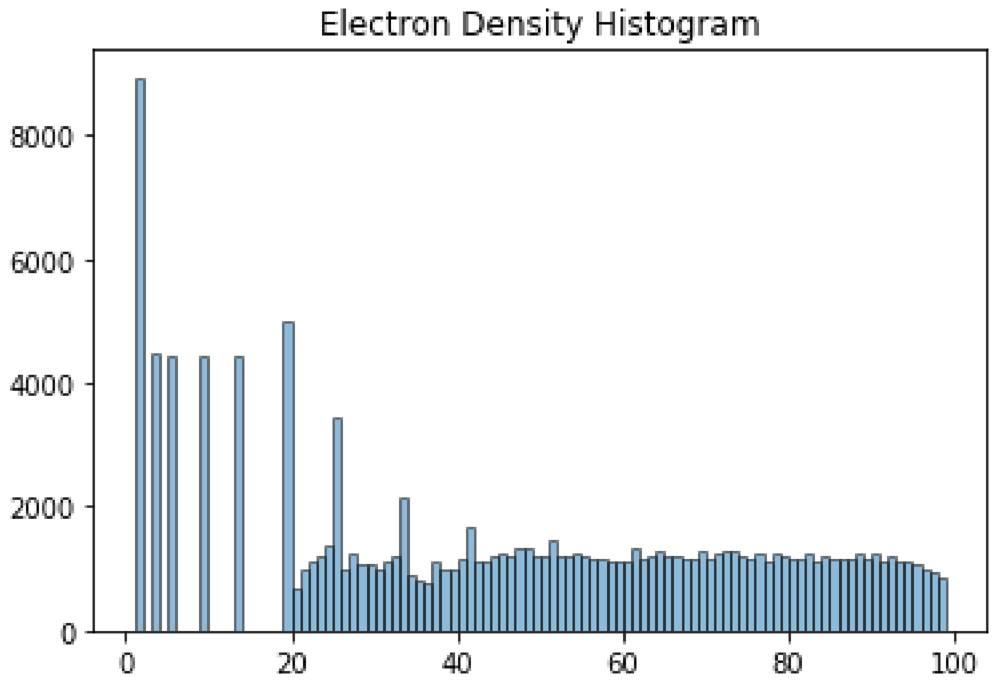
1. Electron Phase space plot (displacement - velocity)
2. Electron Density Histogram
3. Light Intensity Histogram
4. Intensity versus Displacement Table.

```
In [398]: a=Simulate_tubelight()
          a.run_loop()
```

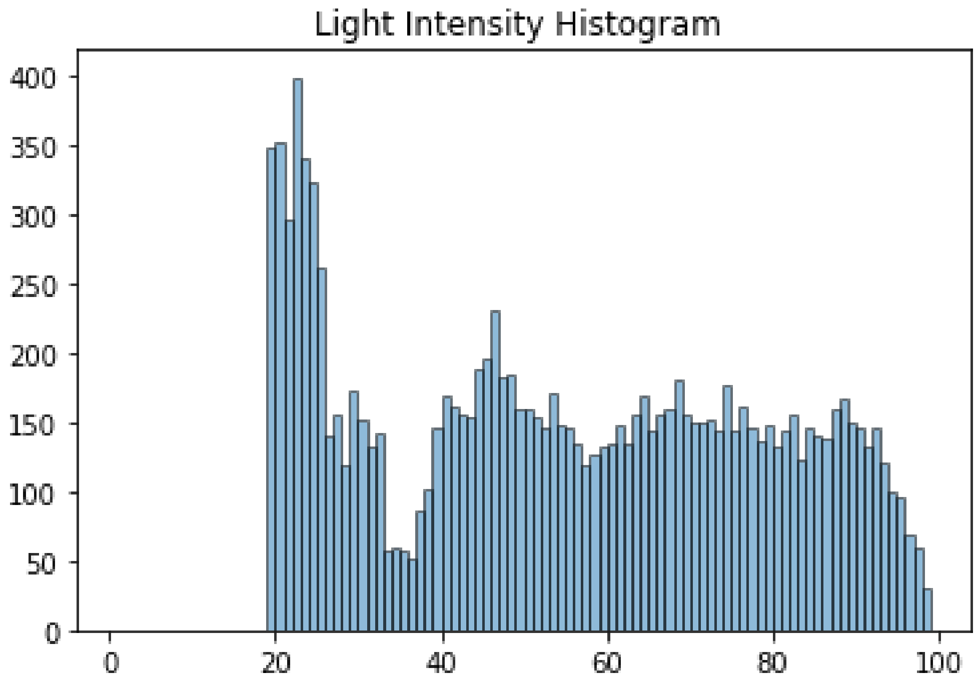
```
In [399]: a.plot_electron_phase_space()
```



```
In [400]: a.plot_electron_density()
```



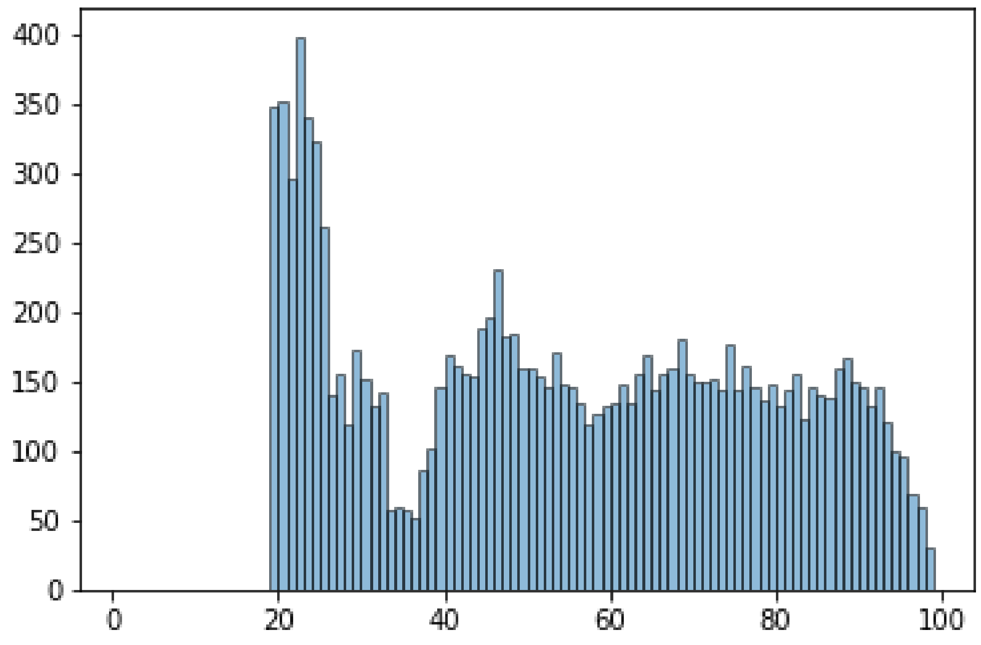
```
In [401]: a.plot_intensity()
```



```
In [402]: a.plot_intensity_table()
```

```
    Count  Position
0     0.0       1.5
1     0.0       2.5
2     0.0       3.5
3     0.0       4.5
4     0.0       5.5
5     0.0       6.5
6     0.0       7.5
7     0.0       8.5
8     0.0       9.5
9     0.0      10.5
10    0.0      11.5
11    0.0      12.5
12    0.0      13.5
13    0.0      14.5
14    0.0      15.5
15    0.0      16.5
16    0.0      17.5
17    0.0      18.5
18  348.0      19.5
19  352.0      20.5
```

```
20  295.0      21.5
21  398.0      22.5
22  340.0      23.5
23  322.0      24.5
24  261.0      25.5
25  139.0      26.5
26  156.0      27.5
27  118.0      28.5
28  172.0      29.5
29  152.0      30.5
..    ...       ...
68  156.0      69.5
69  150.0      70.5
70  150.0      71.5
71  152.0      72.5
72  144.0      73.5
73  176.0      74.5
74  144.0      75.5
75  161.0      76.5
76  145.0      77.5
77  136.0      78.5
78  147.0      79.5
79  133.0      80.5
80  144.0      81.5
81  155.0      82.5
82  123.0      83.5
83  146.0      84.5
84  140.0      85.5
85  138.0      86.5
86  159.0      87.5
87  166.0      88.5
88  149.0      89.5
89  146.0      90.5
90  133.0      91.5
91  145.0      92.5
92  121.0      93.5
93   99.0      94.5
94   95.0      95.5
95   68.0      96.5
96   60.0      97.5
97   30.0      98.5

[98 rows x 2 columns]
```



5 Inference and Discussion

Firstly, the intensity histogram reveals that the electrons donot cause excitation of atoms til they cross a particular threshold velocity, as dictated by the nature of the gas used. Secondly, this gives rise to a peak in intensity just after the first mean length. This is beaucse a majority of electrons collide with atoms at this distance. Further this, subsequent peaks do exist, but have larger spread and are less prominent. We observer around 2 dark bands in this intensity profile.

The electron phase plots show the constant acceleration all electrons initially undergo, and the subsequent random motion post collision. The phase plots are nearly uniformly distributed in the middle portion of the tubelight.

6 Altering Simulation Parameters

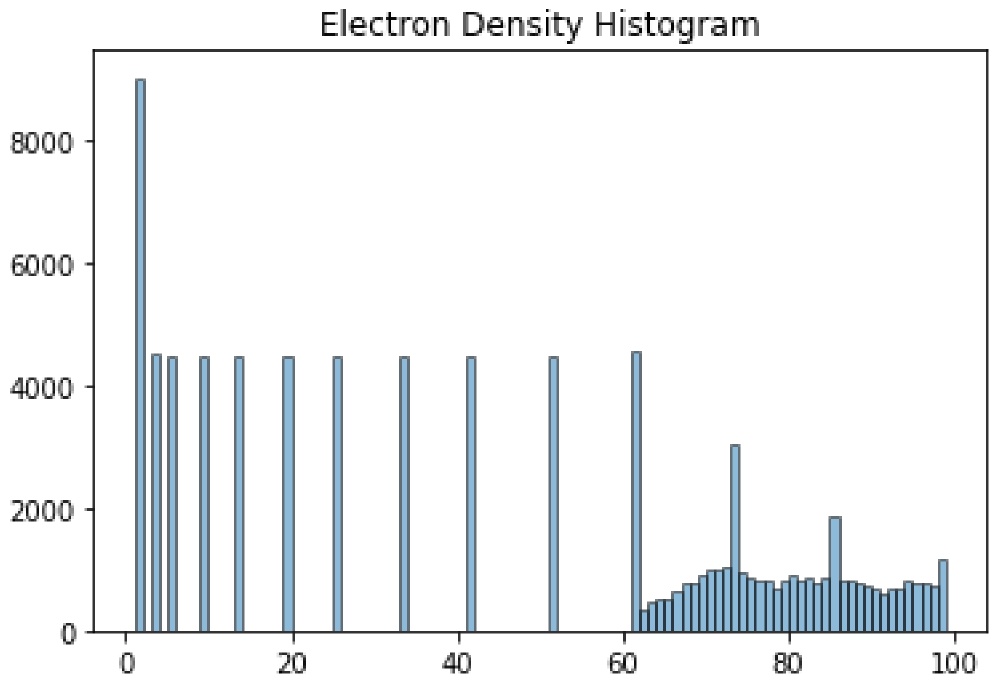
We try out the following set of parameters:

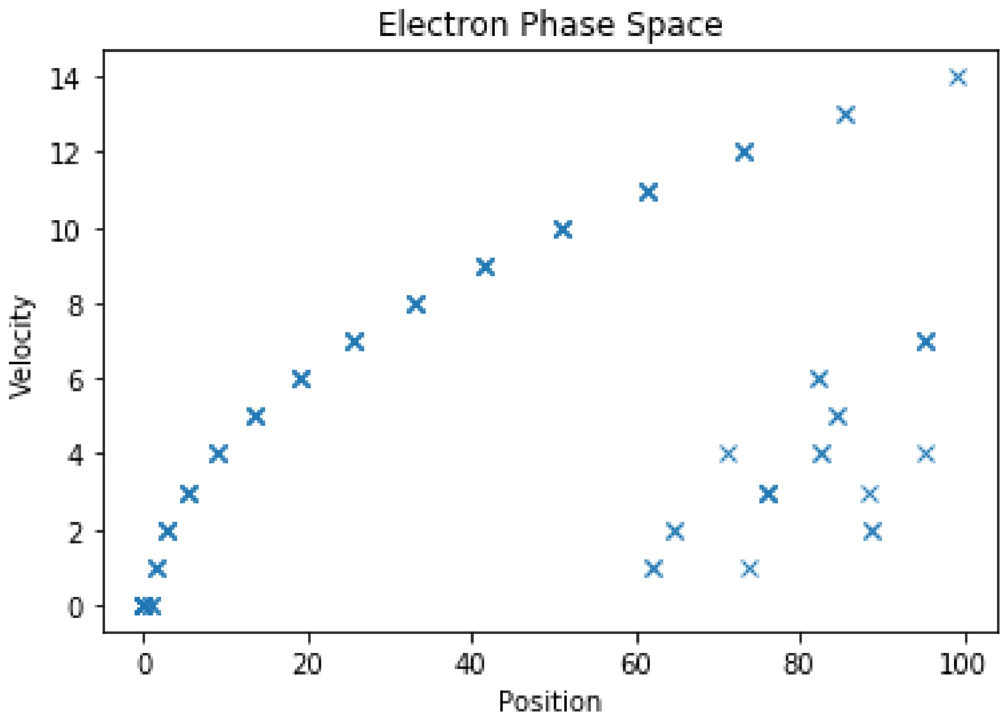
1. n=100, M = 5, nk =1000, u0=20, p=0.5,Msig=0.2 (larger threshold velocity).
2. n=100, M = 5, nk =1000, u0=7, p=0.1 ,Msig=0.2 (lower probabiltiy of collision).
3. n=100, M = 5, nk =1000, u0=7, p=0.1 ,Msig=4 (higher variance of randomness(normal variable)).

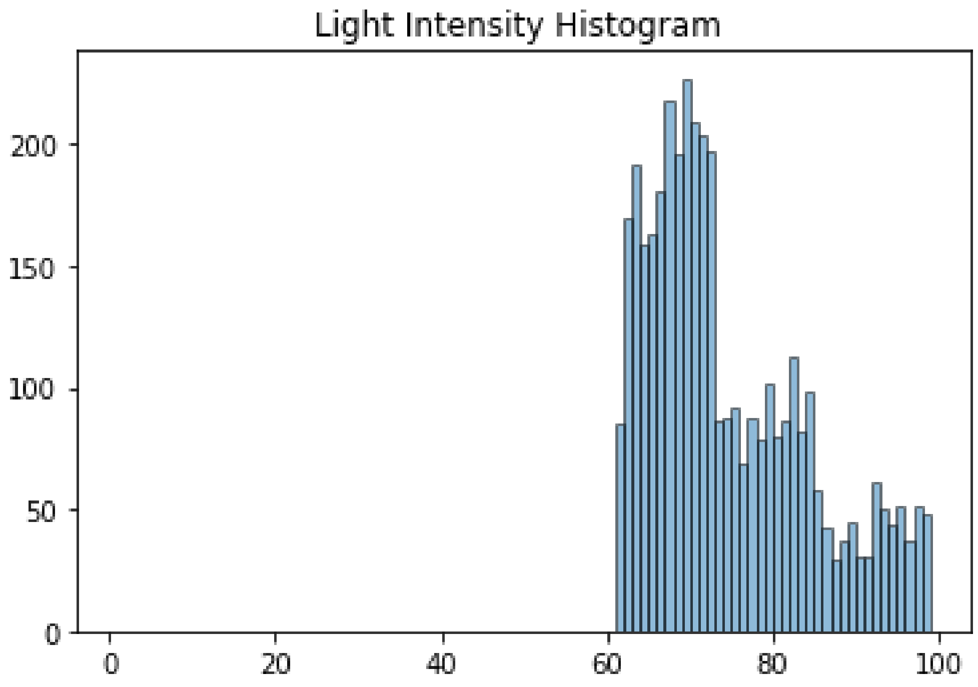
```
In [413]: List_of_params=[(100, 5, 1000,12,0.5,0.2 ),(100, 5, 1000,7,0.1,0.2 ),(100, 5, 1000,7,0

          for params,i in zip(List_of_params,range(len(List_of_params))):
              n,M,nk,u0,p,Msig=params
```

```
        print("\t Parameter Case \t",i+1)
        a=Simulate_tubelight(n,M,nk,u0,p,Msig)
        a.run_loop()
        a.plot_electron_density()
        a.plot_electron_phase_space()
        a.plot_intensity()
```

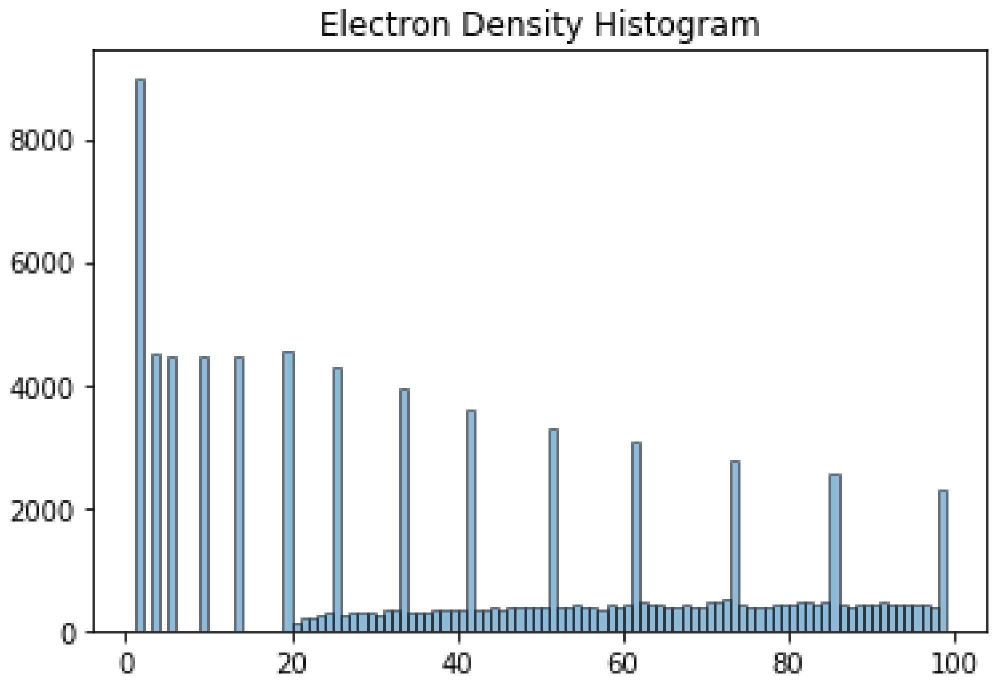
```
Parameter Case          1
```

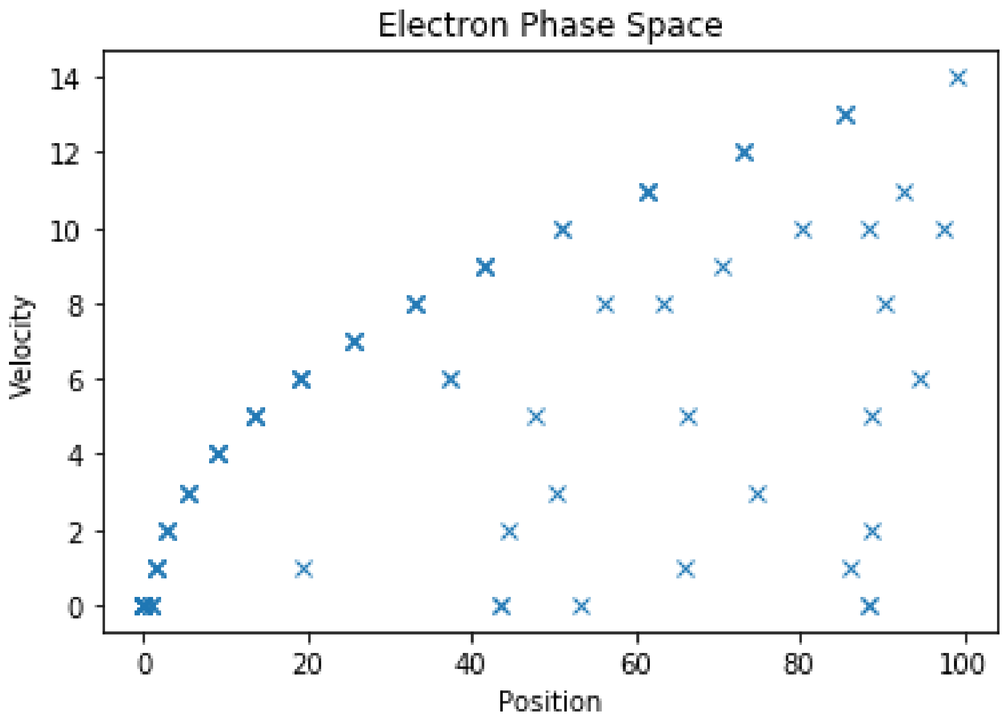


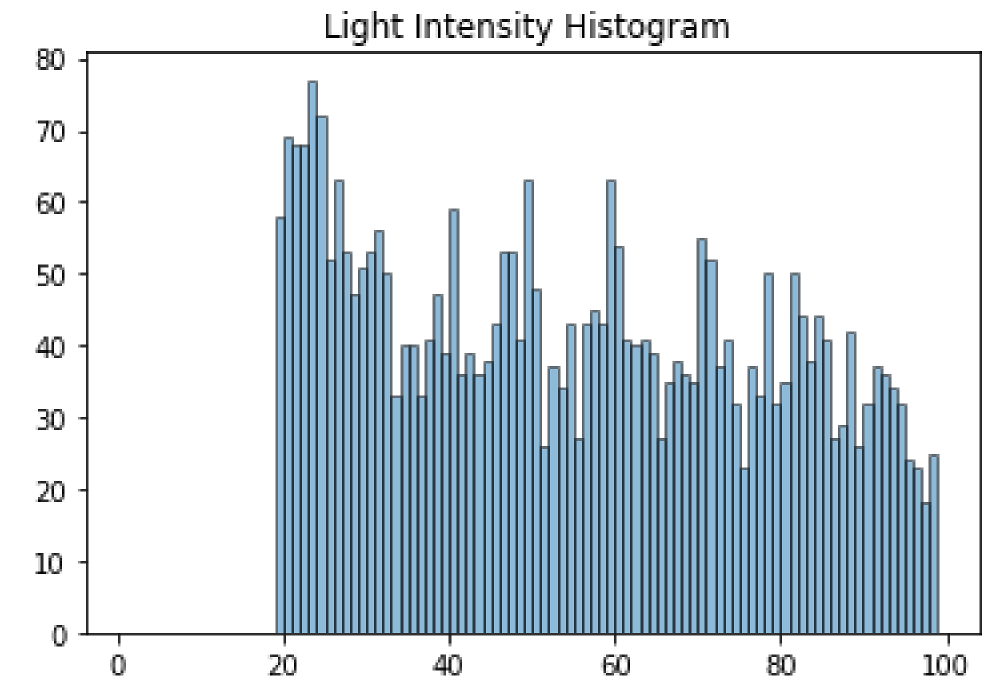

Electron Phase Space
Velocity
Position
0
2
4
6
8
10
12
14
0
20
40
60
80
100


Light Intensity Histogram
0
50
100
150
200
0
20
40
60
80
100

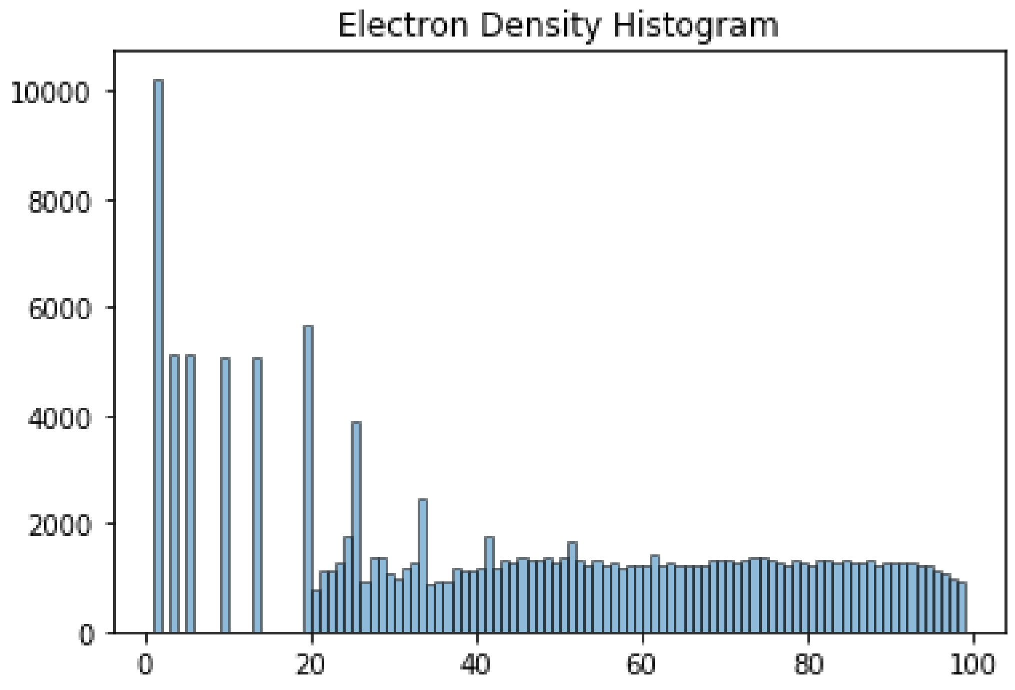
```
Parameter Case          2
```

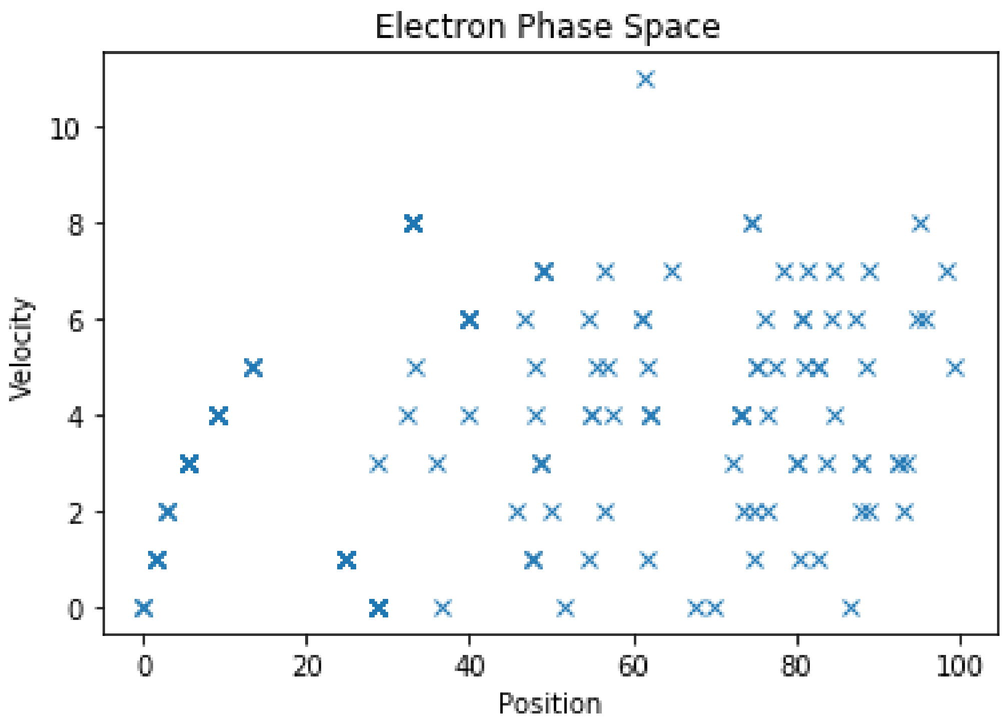


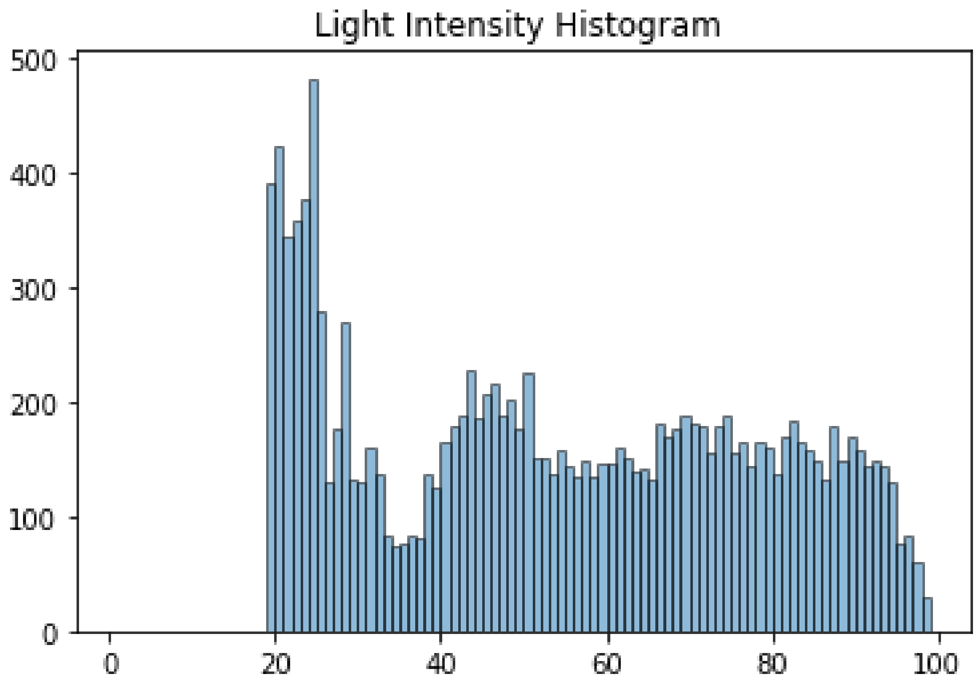




```
Parameter Case          3
```




Electron Phase Space
Velocity
Position
0
2
4
6
8
10
0
20
40
60
80
100


Light Intensity Histogram
0
100
200
300
400
500
0
20
40
60
80
100

6.0.1 Results of Altered Parameters

1. Gives us a longer distance until first peak. If we cross the length of the tubelight, we see no emmision. The acceleration region of the phase space too has increased.
2. Lowers the intensity of the first peak. However, there are now more local maxima's in the intensity histogram.
3. Increases the overall intensity of light, while lowering those of minimae.

6.1 Conclusion

This week's assignment covers using python to simulate models for various requirements. In this case,we utilsise it for simualting electron motion in a tubelight, and hence find out the illumination at different points. The existence of an initial peak, and those of dark patches. In the subsequent sections, we also went over the effect of changing various parameters including probability of collision, threshold velocities and standard deviation.