

lab5

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1 An Investigation into the Frequency, Energy, and Entropy of Macrostates and Microstates

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```
In [1]: import numpy as np
import pandas as pd
from scipy.stats import norm
from matplotlib.ticker import MaxNLocator
import matplotlib.pyplot as plt
%matplotlib inline
```

1.1.1 1

How many microstates are possible?

```
In [2]: 2**18 #2 options for each of 18 spots
```

```
Out[2]: 262144
```

How many microstates are there with 9 “up” wiggle-eyes?

```
In [3]: def factorial (n):
    try:
        int(n)
        if n > 0:
            return n*factorial (n-1)
        else:
            return 1
    except:
        return 0
```

```
In [4]: factorial(18)/factorial(9)**2 #arrangements of 9 of each
```

```
Out[4]: 48620.0
```

How many microstates are there with all 18 wiggle-eyes “up”?

```
In [5]: factorial(18)/factorial(18) #arrangements of 18 of up
```

```
Out[5]: 1.0
```

1.1.2 2

How many macrostates are possible?

```
In [6]: print('The number \'up\' is an element of', np.arange(0,18+1), 'so there are', len(np.arange(0,18+1)))
```

```
The number 'up' is an element of [ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18] so there are 19
```

```
In [7]: ourdata = pd.read_csv('~/.Downloads/Entropy Lab Data - Spring 2018 - 1.csv')
```

```
ourdata = ourdata[5:] #first five rows were a repeat
ourdata.append({'1':1, '0':0, '1.1':1, '1.2':0, '1.3':1, '0.1':1, '1.4':1,
                '1.5':1, '1.6':0, '1.7':0, '1.8':1, '1.9':1, '1.10':1, '1.11':0,
                '1.12':0, '1.13':0, '0.2':1, '0.3':0}, ignore_index=True) #last row was cut off
```

```
Out[7]:
```

	1	0	1.1	1.2	1.3	0.1	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	\
0	0	1	0	1	0	0	1	0	0	0	1	0	0	1	0	
1	0	1	1	0	1	1	0	0	1	0	1	0	1	0	0	
2	0	0	1	1	0	1	0	0	1	0	1	1	1	1	1	
3	1	0	1	0	0	1	1	0	1	0	1	0	1	1	0	
4	0	0	1	0	1	1	0	0	0	0	1	0	0	1	0	
5	1	0	0	0	0	1	0	0	0	1	0	0	1	0	1	
6	0	1	0	1	1	1	0	0	1	0	1	0	0	1	0	
7	0	1	1	1	0	1	0	1	0	1	0	0	0	1	1	
8	1	0	1	0	0	0	1	1	1	0	0	1	0	0	0	
9	1	1	1	0	0	0	0	1	0	0	1	0	0	1	0	
10	1	1	1	0	0	0	1	0	0	0	1	1	0	1	0	
11	0	1	0	0	0	0	1	1	1	0	1	1	0	0	1	
12	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	
13	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	
14	1	0	0	1	0	1	1	0	0	0	0	1	0	1	0	
15	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	
16	1	1	1	0	0	1	1	0	1	0	1	1	0	1	1	
17	1	0	1	0	0	1	0	1	1	1	0	0	0	1	1	
18	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	
19	1	0	0	1	0	1	0	0	0	1	0	0	1	1	1	
20	1	0	1	1	1	1	0	1	1	0	1	0	0	1	0	
21	1	1	1	0	0	1	1	1	1	1	0	0	1	0	0	

22	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1
23	0	0	0	0	1	0	0	0	1	0	1	1	1	0	1
24	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1
25	1	1	1	1	1	1	0	0	0	0	1	0	0	1	1
26	0	1	0	0	0	0	0	1	1	0	0	1	1	0	0
27	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0
28	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
29	0	0	1	1	1	1	0	1	0	0	0	1	1	1	1
...
70	1	1	1	0	1	0	1	0	1	0	0	1	1	0	1
71	0	1	1	0	0	0	0	1	1	0	1	0	0	1	1
72	1	0	0	0	0	1	1	0	0	1	0	1	1	1	1
73	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0
74	1	0	0	1	0	0	1	1	0	1	0	1	0	0	0
75	0	1	0	1	1	1	1	0	0	0	1	0	1	0	1
76	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
77	1	0	0	0	0	0	0	0	1	1	1	1	1	0	0
78	1	0	0	1	1	1	0	0	1	0	0	0	1	1	1
79	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
80	0	1	0	0	1	0	0	0	0	0	0	0	1	0	1
81	1	0	1	0	1	1	1	1	0	0	0	1	0	0	0
82	1	0	0	0	0	0	1	1	0	1	0	0	1	1	0
83	1	1	1	0	0	1	0	0	0	1	0	1	1	1	0
84	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0
85	1	1	1	0	0	0	0	0	0	1	0	0	0	1	1
86	1	1	1	1	0	0	0	1	0	1	0	1	0	0	0
87	1	0	1	0	1	1	0	0	0	1	0	1	1	0	1
88	0	1	0	1	0	1	0	0	0	0	0	0	0	1	1
89	1	1	1	1	0	1	1	0	0	1	0	1	0	0	0
90	0	0	1	1	0	1	1	1	0	0	0	0	1	1	0
91	1	1	0	1	0	0	1	1	1	1	1	0	1	0	1
92	1	0	1	1	0	0	0	1	0	0	0	1	1	1	1
93	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0
94	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0
95	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1
96	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
97	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
98	1	0	1	0	1	1	1	1	0	0	1	1	1	0	0
99	1	0	1	0	1	1	1	1	0	0	1	1	1	0	0

	1.13	0.2	0.3
0	1	0	1
1	1	1	0
2	1	0	0
3	0	0	0
4	0	1	0
5	0	0	1
6	0	1	1

7	1	1	1
8	1	1	0
9	1	1	1
10	0	0	1
11	0	1	1
12	0	0	0
13	0	0	1
14	0	0	1
15	0	1	0
16	1	0	0
17	0	1	1
18	1	1	0
19	1	0	0
20	0	1	1
21	1	1	0
22	1	1	1
23	1	1	0
24	0	1	1
25	0	1	0
26	0	0	0
27	1	1	1
28	0	0	1
29	1	1	0
...
70	1	0	0
71	0	0	1
72	1	0	0
73	0	0	1
74	1	0	0
75	1	0	0
76	0	1	0
77	0	1	0
78	0	0	0
79	0	0	0
80	1	1	0
81	1	0	0
82	1	1	0
83	1	0	0
84	1	0	1
85	0	0	0
86	1	0	0
87	0	1	0
88	0	0	0
89	1	0	0
90	0	1	1
91	0	1	0
92	0	0	0
93	1	1	1

```

94     1     0     0
95     1     0     0
96     0     1     1
97     1     1     1
98     0     1     0
99     0     1     0

```

```
[100 rows x 18 columns]
```

Did your experiment “visit?” all of them?

```

In [8]: ourmacrostates = []
        for i, row in ourdata.iterrows():
            ourmacrostates.append(sum(row))

```

```
In [9]: set(ourmacrostates)
```

```
Out[9]: {3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16}
```

No, not all macrostates were visited.

1.1.3 3

Plot a histogram of your macrostates. You should also calculate the mean value n for your experiment.

```

In [10]: fig = plt.figure(figsize=(4,3))
          ax = fig.add_subplot(111)
          ax.hist(ourmacrostates)
          ax.xaxis.set_major_locator(MaxNLocator(integer=True))
          ax.yaxis.set_major_locator(MaxNLocator(integer=True))

```

